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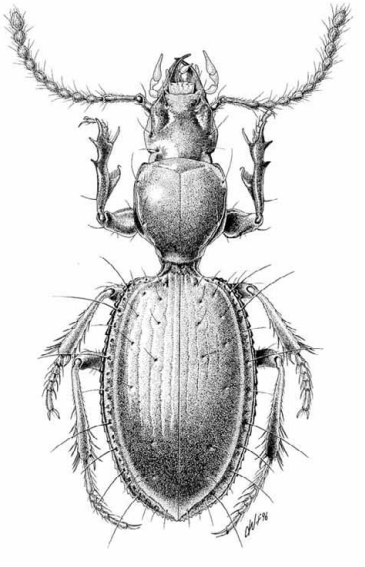
AN OVERVIEW OF THE CAVE AND INTERSTITIAL BIOTA OF CROATIA



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AN OVERVIEW OF THE CAVE AND INTERSTITIAL BIOTA OF CROATIA

Editor
SANJA GOTTSTEIN MATOČEC

HRVATSKI PRIRODOSLOVNI MUZEJ

CROATIAN NATURAL HISTORY MUSEUM

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AN OVERVIEW OF THE CAVE AND INTERSTITIAL BIOTA OF CROATIA

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The karst areas in Croatia, part of the Dinarides, have been defined biospeleologically as an area of high biodiversity in world terms, covering 26 thousand km^2 in all. In this monograph we give data about the biodiversity of subterranean habitats and their biota primarily from a taxonomic perspective with special attention being paid to regional diversity. The diversified geomorphology, hydrology and climate have resulted in a remarkable range of different underground habitats in Croatia, viz. inland and coastal caves, superficial and deep phreatic networks, interstitial – hyporheic substrates and other infiltration zones, etc. In Croatia more than 500 obligate subterranean species and subspecies are known from caves and interstitial habitats. The majority of subterranean species in Croatia are terrestrial biota. There are 299 troglobiont and 170 stygobiont taxa (species and subspecies) recorded. Most subterranean species have very restricted ranges, almost

70% of them endemic to Croatia. Cave fungi are poorly known. Among them there are several important parasitic troglobionts and troglophilic species on cave coleopterans and troglophilic moths in Croatian caves. Some saprotrophic species could be troglobiotic too but their taxonomic and/or ecological status must be clarified in future research. With a respect to the number of troglobionts, the five largest animal groups are Coleoptera, Pseudoscorpiones, Araneae, Gastropoda and Diplopoda. The beetles (Coleoptera) are predominant. More than 100 cavernicolous beetles (species and subspecies) are known in Croatia. Among stygobionts, the Crustacea predominate. At least half of species described are Crustacea. Among Crustacea, the orders Syncarida and Thermosbaenacea are exclusively stygobiotic. Numerically, among crustacean stygobiotic Amphipoda dominate in caves and Copepoda in interstitial habitats. The only known stygobiotic sponge *Eunapius subterraneus* Sket *et* Velikonja inhabits several caves in Croatia. Also, the only known stygobiotic clam *Congeria kusceri* Bole inhabits a series of caves in Croatia. Other important groups include hydrozoa, planarians (Temnocephalida and Tricladida), snails (Mollusca: Gastropoda) and the only European stygobiotic Chordata *Proteus anguinus* Laurenti. The high taxonomic diversity of the subterranean biota of Croatia can be attributed partly to the geographical heterogeneity and a rather unique combination of various geological and ecological phenomena.

Key words: subterranean biota, biospeleology, stygobionts, troglobionts, biodiversity, karst, cave, interstitial habitat, terrestrial habitat, groundwater, distribution, Croatia

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Krško područje Hrvatske ukupne površine 26 tisuća km^2, s dijelom dinarskog krša, biospeleološki je određeno kao područje velike biološke raznolikosti u svijetu. U ovoj monografiji podastiru se podaci o biološkoj raznolikosti podzemnih staništa i organizama primarno s taksonomskog aspekta i s posebnim osvrtom na regionalnu raznolikost. Geomorfološka, hidrološka i klimatološka raznolikost Hrvatske rezultirala je osobitim rasponom različitih podzemnih staništa, kao što su kontinentalne i priobalne špilje, mreža plitke i duboke freatičke zone, intersticij – hiporeička zona i drugi tipovi infiltracijskih zona, itd. Iz špilja i intersticijskih staništa Hrvatske poznato je preko 500 obveznih podzemnih vrsta i podvrsta. Većina podzemnih vrsta u Hrvatskoj su kopneni organizmi. Utvrđeno je 299 troglobionata i 170 stigobionata. Većina podzemnih vrsta ima vrlo ograničeno područje rasprostranjenosti, gotovo 70 % je endemno za Hrvatsku. Špiljske gljive su vrlo slabo poznate. Među njima je nekoliko troglobionata i troglofila koji su paraziti na špiljskim kornjašima i troglofilnim leptirima. Neke subtroglofilne vrste možda su također troglobiontske, no njihov taksonomski i/ili ekološki status morala bi razjasniti buduća istraživanja. U pogledu najveće brojnosti troglobionata, pet je velikih skupina životinja – Coleoptera, Pseudoscorpiones, Araneae, Gastropoda i Diplopoda. Kornjaši (Coleoptera) su najdominantniji. U Hrvatskoj je poznato više od 100 kavernikolnih kornjaša (vrsta i podvrsta). Među stigobiontima dominiraju raci. Gotovo polovica opisanih vrsta su iz skupine Crustacea. Među racima, skupina Syncarida i Thermosbaenacea su isključivi stigobionti. Brojčano gledano, među stigobiontskim racima skupina Amphipoda dominira u špiljama, a skupina Copepoda u intersticiju. Jedina do danas poznata stigobiontska spužva *Eunapius subterraneus* Sket *et* Velikonja nastanjuje nekoliko špilja u Hrvatskoj. Također jedini poznati stigobiontski školjkaš *Congeria kusceri* Bole nastanjuje niz špilja u Hrvatskoj. Ostale važne skupine su obrubnjaci, virnjaci (Temnocephalida i Tricladida), puževi (Gastropoda) i jedini poznati stigobiontski kralješnjak *Proteus anguinus* Laurenti. Velika taksonomska raznolikost podzemnih organizama Hrvatske pripisuje se djelomično geološkoj heterogenosti i posebno jedinstvenom spoju različitih geoloških i ekoloških pojava.

Ključne riječi: podzemni organizmi, biospeleologija, stigobionti, troglobionti, biološka raznolikost, krš, špilja, intersticijsko stanište, kopneno stanište, podzemna voda, rasprostranjenost, Hrvatska

PREFACE

An overview of the cave and interstitial biota of Croatia was assembled from available literature data, museum collections and from numerous notes made in various field researches of the present authors.

This Overview provides data on Croatian underground biodiversity and a taxonomic basis for further monographic publications of Underground Biota and extended activities, such as developing a Croatian Biospeleological Database (CBSD) and the preparation of The Atlas of Cave Fauna.

As previous review - Croatia - of similar subject matter published in the III Vol. of Encyclopaedia Biospeologica was printed in rather limited number of copies an effort was done to make an extended monograph more available to regional and international scientists, to applied scientists and society in general. The present Overview emerged as the result of this effort as a supplement enlarged and improved with many new data included (such as: additional records for some species, records on new species, Checklists, updated systematics and classification of the numerous groups of organisms, colour photographs etc.).

INTRODUCTION

According to CAMACHO (1992) and HOLSINGER (1994) we used the term troglobiont for terrestrial, cave-limited species and stygobiont for aquatic species, which by definition is a species generally restricted to hypogean waters: in caves and also in interstitial habitats. The term cavernicolous species (= cave-dwelling species) is used for some terrestrial species where more precise terms - troglobiont and troglophile were inapplicable because neither troglobiotic nor troglophilous status cannot be assigned for those species specifically. We expect for some species that are not limited only to the caves. Also, criteria that distinguish cavernicolous species are inexact in some cases and the real nature of many cavernicolous species is so far virtually unknown.

1. GENERALITIES

by SANJA GOTTSTEIN MATOČEC

Croatia, although a small country (56.610 km^2 of land surface), has a wide diversity of ecosystems and habitats that is reflected in richness of flora, mycoflora and fauna. Such an abundance is a result of the geographic characteristics of Croatia, as it is at the border of several biogeographic regions, various types of relief, geologic, pedologic, hydrologic and climatic types.

However, human beings have also had an influence on the diversity. According to the natural characteristics, one can divide Croatia into four regions: the Croatian lowlands, the Croatian highlands, the Mediterranean coast, and finally – the islands and the Adriatic Sea. The Croatian lowland is a flat area surrounded by rivers Sava,

Mura, Drava and Danube, and by the outer Panonian hills (54.4% of the land area). It consists of numerous regions; of them, Slavonija, the Zagreb region, Žumberak, Pokuplje, Kordun and Banovina are the most important from the biospeleological point of view. The Croatian Highlands is a part of the Dinarides, with its highest peak of Dinara (1,831 m). This region is a high karstic belt from mountain to foothill area, with »islands« of impenetrable rocks, karst valleys and river valleys (14% of the land area). A peculiarity of the region is the great geomorphologic diversity of the karst phenomena: caves, potholes, rocks, crevasses, canyons and dolines. It consists of the regions Gorski kotar and Lika. The Mediterranean coast and islands of Croatia make a narrow coastal belt with islands, separated from the inland with high mountains (31.6% of the land area). The Croatian coast is the most diverse coast of the Mediterranean with 1,200 islands and rocks across the 5,835 km of coastline. It has the following regions: Istra, Hrvatsko primorje with Kvarner and Dalmacija. The Adriatic Sea is a distinct unit well known for its biodiversity, including marine caves with deep water and relict fauna, and for the great depth of the Jabuka basin of the South Adriatic (RADOVIĆ, 1999).

2. KARST AND CAVES

2. 1. The Karst

by MLADEN KUHTA

In the development of a branch of science nothing is fortuitous; this includes the use of Croatian karst phenomena terms such as ponor, dolina, polje, jama, etc., in the international geological vocabulary. The karst relief covers a major part of the Croatian national territory. The systematic research of karst has a history of over two hundred years. This region, with its numerous, well-developed and diverse karst forms, both on the surface and underground, is unique in the world, a »locus typicus«. Furthermore, geological scientists from all over the world, when referring to the Dinaric karst refer to it as the »classical karst«.

The Croatian territory south of Karlovac, as well as the Dinaric karst belt that extends from Slovenia through Croatia to Albania is the region of the classical karst. The karst covers about 26.000 km^2 in Croatia, which is 46% of the national territory. The geology of the karst terrain is dominated by Mesozoic and Tertiary carbonate rocks (limestone and dolomite) and clastic Paleozoic-Triassic rocks and Cretaceous-Paleogene carbonate flysch rocks are subordinate.

According to recent analysis (HERAK, 1986; 1991), the Croatian Dinaric region consists of four paleo-dynamic and paleo-structural belts (Fig. 1). Carbonate rocks and karst phenomena are situated within the Adriaticum and the Dinaricum structural units. These are areas of former carbonate platforms, where carbonate deposition lasted during the whole of the Mesozoic and continued even later. The Epiadriaticum is of small spatial extent (tectonic reduction) and consists of basinal and marginal, predominately clastic sedimentary rocks. The Supradinaricum contains only sporadic occurrences of karst.

The geotectonic position is interpreted in the light of the mobilistic theory, i.e., of plate tectonics. The shaping of the Dinaric fabric was gradual, and caused by the movement of the Adriatic micro-plate and the deformation of the earth's crust in the marginal zone of the European plate (BIJU-DUVAL & MONTADERT, 1977; DEWEY, 1987; MOORES & TWISS, 1995). In the context of global geotectonic movements a subduction zone was formed and elements of the Epiadriaticum and the Adriaticum were subject to underthrust beneath the Dinaricum carbonate mass. This process began during the transition into the Paleogene and the convexial currents

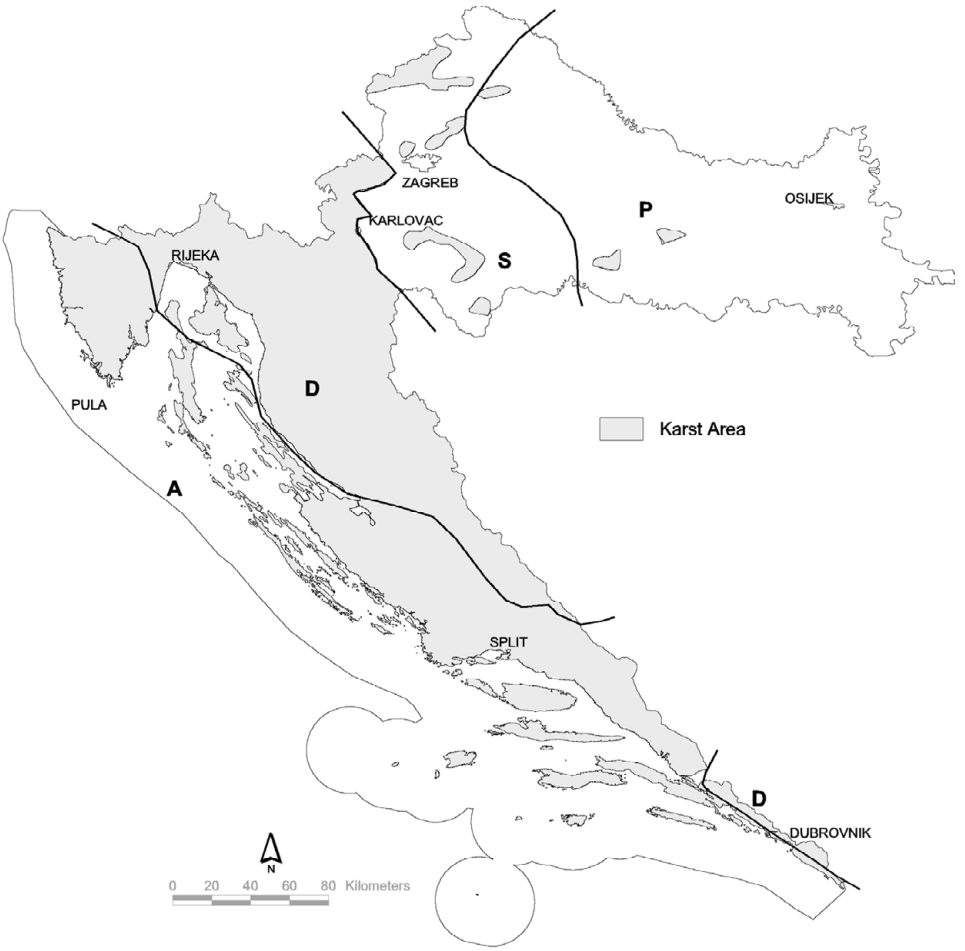


Fig. 1. Simplified general tectonic map of the Croatian part of the Dinarides with the distribution of karst. Key to symbols: A – Adriatic carbonate platform (Adriaticum), D – carbonate platform (Dinaricum), S – Eudynamic area (Supradinaricum), P – Geological structures of the Pannonian basin (basic data after HERAK 1986, RADOVIĆ 1999, modified by D. BUKOVEC, design by OIKON Ltd.).

caused intensive folding and the formation of nappe structures. As a consequence, the major part of the Croatian classical karst is manifested as a complex orogenic karst accumulation. The present structural-tectonic fabric was formed by neotectonic movements, characterised by radial tectonics, accompanied by further disruption of rock masses and the differential downthrow or uplift of individual blocks.

The hydrogeological relationships in the Dinarides are complex. The vast thickness of the carbonate deposits allows the karst aquifers to be open at depths. Rocks of lower permeability, the position of which depends on the structural-tectonic fabric of the terrain, sometimes act as lateral or partial barriers, of varying length and strike, and as such have a major influence on the groundwater dynamics. The principal retention zones are formed within the mountain massifs, and the groundwater drains towards their margins. The type of groundwater flow ranges from fast vertical percolation in the unsaturated zone, or turbulent flow through networks of subsurface channels or slow siphonal water movement in the deeper parts of the karst aquifers. The velocity of groundwater flow determined by numerous tracing tests ranges from several millimeters to tens of centimeters per second, with mean velocities of 4 cm/s. In the discharge/outflow zones typical karst springs with large yield occur. One of the largest of such outflows is the Ombla spring near Dubrovnik with a maximal yield of 154 m^3/s.

A large number of submarine springs (vrulja) exist in the coastal region. Their present position is the consequence of the change in the level of the Adriatic Sea; the sea level has risen approximately 100 m since the time of the Würm glacial period (ŠEGOTA, 1968). In addition to resulting in the submergence of springs and older speleological objects, the rise in the sea level has had an effect on specific relationships in coastal and island aquifers. One such phenomenon is the Vrana Lake on Cres Island. With a surface of 5 km^2, and a volume of 220 million m^3 of potable water of high quality and a depth of 60 m below the sea level, it is an unique karst phenomenon in the Dinarides (BIONDIĆ *et al.*, 1998).

The present karst relief is relatively young in a geological sense. Its development was favored as a consequence of the tectonic disruption of carbonate rocks, which is one of the major conditions contributing to the development of karstification. The karst regions in Croatia are a belt parallel to the coastline. The most prominent geomorpholohical and orographic feature of the region is the Dinarides with altitudes up to 1800 m (Mt Dinara, 1831 m). The vicinity of the sea and the mountains results in the formation of condensation and large quantities of rain, with an annual rainfall ranging from 1300 to 2000 mm (from 1600 mm on the coast to 3600 mm inland in Gorski kotar). The corrosive and erosional water action on the fractured carbonate bedrock has resulted in the formation of numerous surface and subsurface morphological phenomena.

On the surface, in addition to relatively unimportant forms such as karren and solution pans (kamenica) the most frequent are sinkholes and uvalas. In intensively karstified regions sinkhole density can be over 160 sinkholes per km^2 (ŠARIN & HRELIĆ, 1984), some of which are several hundred meters in diameter and more than 100 m deep. The largest morphological phenomena are the poljes (valleys). Fourteen major karst poljes with an area in excess of 10 km^2 are located in Croatia.

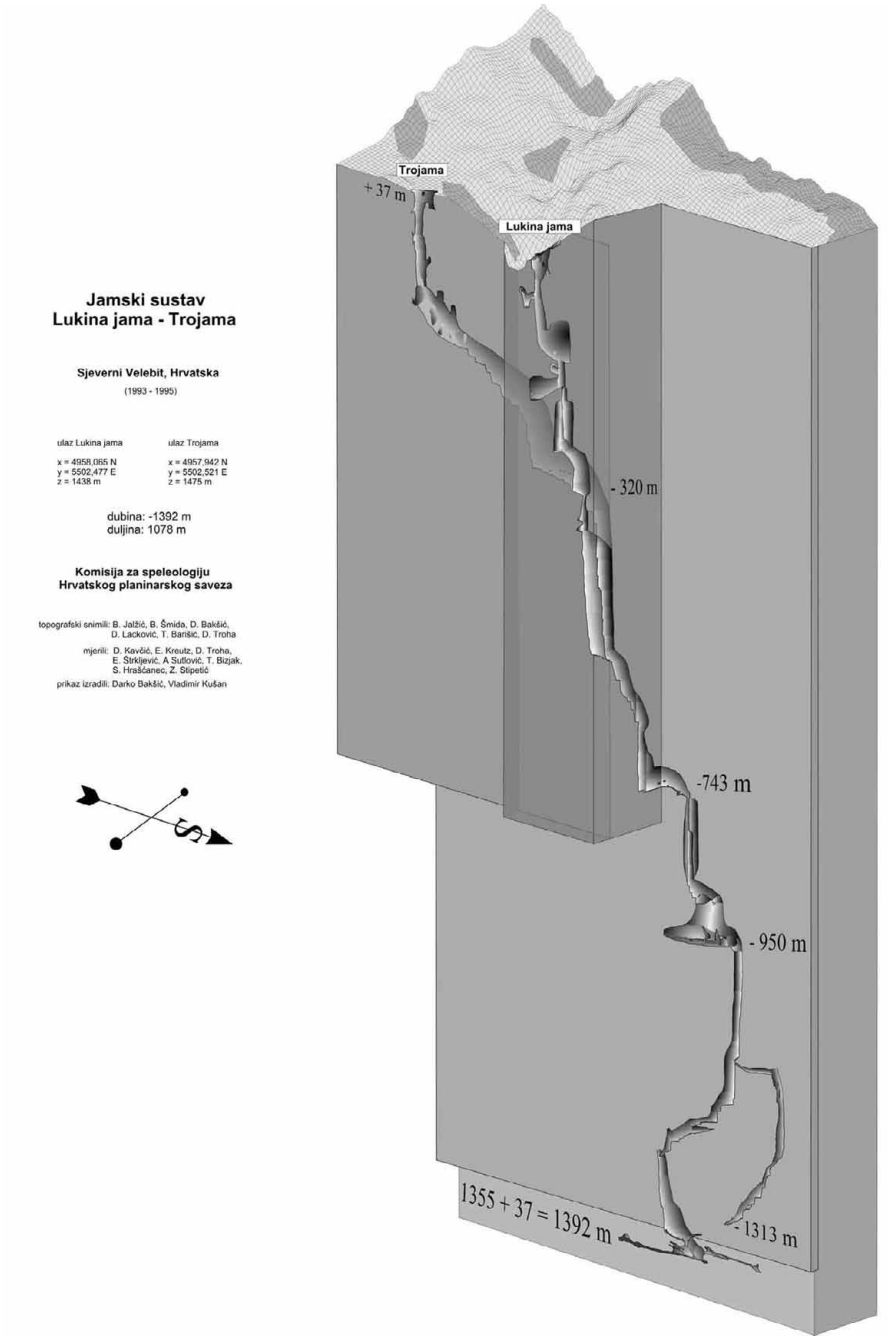


Fig. 2. The jama-system Lukina jama – Trojama (–1392 m) on Mt Velebit is among the deepest caves in the world (drawing by D. BAKŠIĆ & V. KUŠAN).

The largest polje is the Ličko polje with an area of 465 km^2. Due to the fast infiltration of meteoric water, the surface hydrography is poorly developed and the flow is confined to a few rivers. In contrast to this, large quantities of water are retained in the karst underground, which has formed a rich hydrographic network and numerous speleological phenomena. So far, about 7000 caves have been investigated. From a morphological point of view, jamas (potholes or pits) predominate, accounting for over 70%, while 30% of the morphological phenomena are horizontal caves. Although most of these explored speleological phenomena are dry features, water is permanently or periodically present in 1842 of them (GARAŠIĆ, 1991). The ponors play an important role within the karst, on such cave-ponor system, Đulin ponor-Medvedica, near Ogulin, with an explored length of 16,396 m, is also the longest cave in Croatia. Very deep jamas (potholes) have been found in the karst mountain region. The jama-system Lukina jama – Trojama (–1392 m) and Slovačka jama (–1301 m) on Mt Velebit are among the deepest speleological phenomena in the World (Figs. 2 & 29).

The karst regions, due to the lack of surface water and the small arable soil surfaces, and their failure to be incorporated into the transportation network, have always been sparsely populated. Today, in view of the increasing vulnerability of the natural environment, this seems to be an advantage. The karst region of Croatia in most part has been preserved. The developed relief of this region, its extension through various climatic zones ranging from the Mediterranean type to the mountain type, its high degree of natural preservation and finally the large number of speleological phenomena, make it an immensely interesting terrain for biospeleological research.

2. 2. Caves

by BRANKO JALŽIĆ and ROMAN OZIMEC

There are more than 7500 registered caves in Croatia, and it is estimated that at least twice as many exist. Annually, 50 to 100 new caves are discovered and explored. Such a large number of caves and potholes is a consequence of the characteristic karst fabric of the region. In the northern, continental part of Croatia only small areas of isolated karst are found, and the continuous karst zone lays to the south of Zagreb. The Croatian karst consists of high mountain ranges and mountain plateaus, but also of low, fluvial and shallow karst. Most of the caves are located in numerous mountains and many are still not adequately surveyed. The caves are developed in limestone and dolomite bedrock, or in combinations of both. Caves that have developed in marls, flysch and sandstone are very rare, but some are of importance in world terms. The cave of Piskovica in Istra is located within flysch deposits and is 1036 m long (Fig. 30) (JEKIĆ & KOVAČEVIĆ, 1988), and the Špilja cave near Šušnjari in Banovina province has developed in marl deposits (GARAŠIĆ & KOVAČEVIĆ, 1991).

Most of the caves developed as a result of the combined action of erosion and corrosion of waters percolating through tectonically predestinated bedrock. Along the Adriatic coast, abrasion widened these caves and today they are submerged be-

low the sea surface. Some of the more famous submarine caves are the cave Medova buža on the island of Rab and the submarine vertical cave Zmajevo uho near Rogoznica. Since some of the phenomena are located within the tidal zone they often produce sonorous effects and the local people call them *rikavica* (she that roars) (STRAŽIČIĆ, 1954). »Blue« caves are also frequent, such as the Modra špilja cave on the island of Biševo. Caves of volcanogenic origin have not been found in Croatia. Artificial caves derive from human activity during the construction of roads, military facilities and hydroelectric power plants (BOŽIČEVIĆ, 1984). During tunnel and quarry excavations numerous natural caves were discovered, previously inaccessible, and sometimes of immense dimensions (such as the Cavern in the Učka Tunnel, 1490 m long; the Cave in the Tounj quarry, 8487 m long (Fig. 27).

Historical cavities include mines, wells, subterranian quarries, catacombs, etc. A unique facility is the Roman water supply system on the island of Pag, from the first century AD (BOŽIĆ, 1987), as well as the smithsonite mine with several horizons from the 19th century, located in northwestern Croatia (Fig. 28) (OZIMEC, 1994).

The morphological and hydrological features of Croatian caves were described by GARAŠIĆ (1991).

The most frequent speleo-morphological phenomena are vertical caves – jamas – (70%), horizontal caves account for approximately 28% and there are about 2% of combined caves. In a morphological sense there are simple features (20%), knee type (40%), branching (30%), in several horizons (9%) and other system forms accounting for a share of less than 1%. Among them the rarest are traverses (the traverse Matešićeva-Popovačka cave in the Kordun province). Of all the described speleological features, 65.8% are dry, while 34.2% are hydrologicaly active. In accordance with their hydrologic function there are permanent (0,7%) springs, intermittent springs (3%), permanent ponors (5%) and intermittent ponors (5%), also there are estavellas (7.5%) and the most frequent (17%) percolating objects. All of these caves are situated either within the Black Sea drainage basin or the Adriatic Sea drainage basin.

A special group of subterranean habitats consists of submarine springs (vrulje), anchihaline caves, ice caves as well as chambers with elevated CO_2 concentrations. The submarine springs (vrulje) are located along the whole Adriatic coast, with the highest occurrence frequency in the Velebit and the Biokovo channels, and in the latter the largest submarine spring Vruja is located (ALFIREVIĆ, 1969). Most of them have small entrances, and some twenty have been explored so far. The study of submarine spring fauna dates to more recent times (PETRICIOLI *et al.*, 1994). Anchihaline objects also occur along the Adriatic coast at the area of contact between fresh and saline water. These were investigated from Istra to Dubrovnik, and they contain both marine and fresh water faunas, but also some endemic species (SKET, 1986a, b).

Features with elevated concentrations of CO_2 and SO_2 have been identified in Istra and on some Dalmatian islands. Recently in one such jama on the island Lastovo a new taxon from the family Pselaphidae (ordo Coleoptera) was discovered.

Ice caves in Croatia are found in large numbers. In the specific microclimatic conditions numerous caves contain permanent snow and ice. In these conditions

typical troglobiotic fauna is present, often with glacial relicts. Numerous toponyms exist for these phenomena: Sniježnica, Ledenica, Ledena špilja, etc.

Large caves and cave systems are found in the region of shallow karst (Kordun and the Ogulin plateau), as well as in the outer karst belt as terminal parts of fossil subsurface river channels (N and S Dalmacija).

The deepest potholes, up to as much as 1400 m, are found in the regions of the highest mountains especially in the Velebit and Biokovo massifs (Tab. 1). A unique phenomenon is Crveno jezero (the Red Lake) near Imotski, which probably developed as a consequence of the ceiling collapse of an underground cavern.

Thirty-one caves are protected by nature conservation legislation; 29 are classified as geomorphologic monuments of nature and two as palaeontological sites. Fourteen caves are open to the public (BOŽIĆ, 1999). The caves have been the subjects of archaeological and paleontological studies. In this context over 100 caves have been researched, including the site with the world's most abundant remnants of Neanderthal man (MALEZ, 1984), Hvar culture and many other finds (ČEČUK & DRECHSLER-BIŽIĆ, 1984).

Studies of inorganic environmental features of underground features in Croatia are rare and mostly deal with temperature and humidity measurements. In terms

Tab. 1. The list of the largest caves in Croatia.

Name	Region	Length & depth (m)
The longest caves		
1. The Đulin ponor – Medvedica system	Ogulin	16,396
2. The Panjkov ponor – Kršlje system	Rakovica, Kordun	12,385
3. The cave in the Tounj quarry	Tounj, Kordun	8,487
4. Veternica	Zagreb, Mt Medvednica	7,100
5. The Jopićeva špilja – Bent system	Brebornica, Kordun	6,590
6. Munižaba	Crnopac, Mt Velebit	3,700
7. The Vilinska špilja – Ombla system	Dubrovnik, Dalmacija	3,060
8. Gospodska špilja	Vrlika, Cetinska krajina	3,060
9. Donja Cerovačka špilja	Gračac, Lika	2,682
10. Slovačka jama	Mali kuk, Mt Velebit	2,414
The deepest caves		
1. The Lukina jama – Trojama system	Hajdučki kukovi, Mt Velebit	–1,392
2. Slovačka jama	Mali kuk, Mt Velebit	–1,301
3. Amfora	Mt Biokovo, Dalmacija	–790
4. Meduza	Rožanski kukovi, Mt Velebit	–707
5. Stara Škola	Mt Biokovo, Dalmacija	–576
6. Vilimova jama (A-2)	Mt Biokovo, Dalmacija	–572
7. Patkov gušt	Gornji kuk, Mt Velebit	–553
8. Ledena jama	Lomska duliba, Mt Velebit	–536
9. Ponor na Bunovcu	Bunovac, Mt Velebit	–534
10. Jama Olimp	Mt Velebit	–531

of temperature, speleological features can be classified as ice caves (ledenice) with temperatures below 1°C, high mountain objects at altitudes over 1000 m (1–5°C), continental (5–10°C), sub-Mediterranean (10–14°C), and Mediterranean (14 to 20°C). JALŽIĆ (1984) performed the first systematic studies of fauna and temperature dependence. The humidity in most caves ranges from 85 to 100%, and only in the Mediterranean region does it drop below 60%. Some features are characterized by air circulation, especially in the continental parts of Croatia and on the Velebit massif, which has led to the creation of toponyms for caves with air circulation (Vetternica cave, Puhaljka pothole).

3. BIOSPELEOLOGY

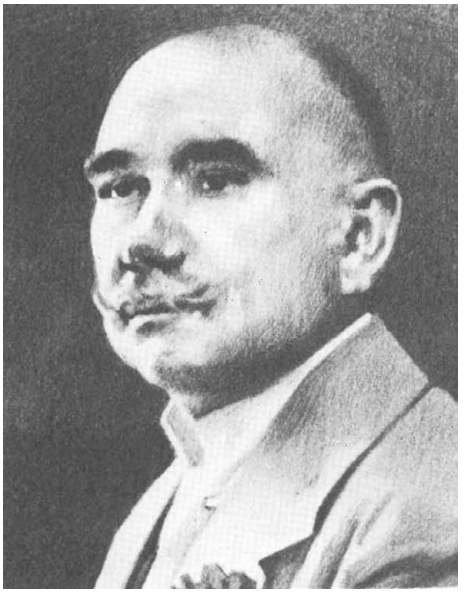
3.1. The history of biospeleology

by ROMAN OZIMEC and SANJA GOTTSTEIN MATOČEC

The first information regarding cave organisms in Croatia dates from the first half of 19th century. For that period, the typical methods were sampling and giving a short description of sample material. Numerous findings are marked by the name of region only, for example, »Dalmatia« – which makes it difficult today to judge whether they are members of Croatian fauna, because of changes in administrative regionalization and of frontiers. The troglomorphic snail *Lanzaia elephantota* (Muhlfeldt) (syn. *Turbo elephantota* Muhlfeldt) was described in 1824 as a marine organism of the Dalmatian coast. More than 100 years later it was discovered to be a member of the subterranean fauna (KUŠČER, 1933). The troglophilic cave cricket *Dolichopoda araneiformis* (Burmeister) (syn. *Phalangopsis araneiformis* Burmeister) was described in 1838, most probably, from a cave in the environs of Dubrovnik (KARAMAN, 1958). The olm *Proteus anguinus* Laurenti was found in Dalmacija by F. CARRARA from Split in 1840 (the source of Goručica River by Sinj). On the basis of this finding, plus a sample from an unnamed cave in the Neretva area, FITZINGER (1850) described the species *Hypochton carrarae* Fitzinger, which was later not recognised as being a separate species of *Proteus*.

During the second half of 19th century faunistic surveys led by numerous researchers began in Croatia. From material collected in Dalmacija by J. ERBER from Vienna, new species of cave beetles and spiders were described (MILLER, 1861a, b; KEYSERLING, 1862). In caves of Lika in 1862, the Slovene N. HOFFMAN defined the first accurate finding of troglomorphic beetles for Croatia (PRETNER, 1973). J. SAPETZA and J. STIEGLER from Karlovac collected in caves in the Pokuplje area and discovered new species of cave Coleoptera (MILLER, 1867; HAMPE, 1870). S. BRUSINA collected material in caves of Kordun and Lika, and noted the first sample of troglobiont snail in caves (HIRC, 1902), and the first cavernicolous millipedes. In the Lika region, on July 7th, 1879 the olm was found, for which BRUSINA (1880) defined a new taxonomic category, *Proteus croaticus* nom. nud. Faunistic research into phreatic waters in the environs of Zagreb (VEJDOVSKY, 1882), and various interstitial biotopes in other parts of Croatia (ŠOŠTARIĆ, 1888) were started. M. PADEWIETH of

S. Brusina

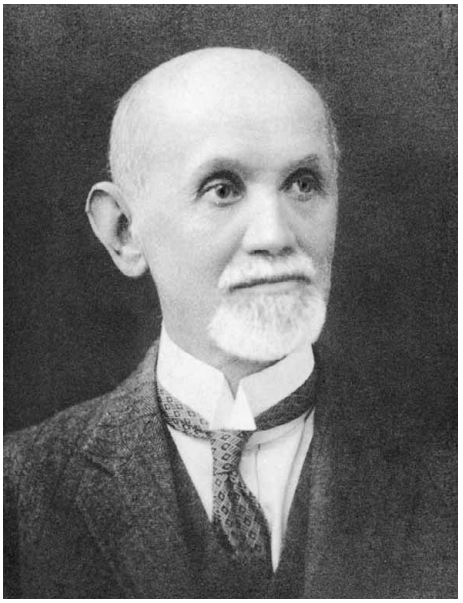


D. Hirc

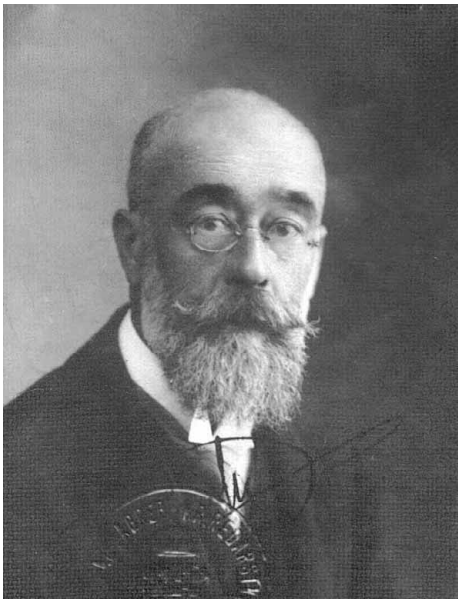
Senj collected beetles in Lika and the Mt Velebit region and described new taxa (PADEWIETH, 1891). Unfortunately, due to the commerce with cave organisms, he hid the locations or named and marked them wrongly, so his data are mostly not useful. Cave data, and descriptions of the flora and fauna of entrance zones can be found in numerous papers of D. HIRC (e. g. 1898, 1900). As well as by these researchers, cave fauna was collected by J. SCHLOSSER-KLEKOVSKI and F. ERJAVEC in continental parts of Croatia, by M. PAVEL in the Gorski kotar region, J. STUSSINER, A. STOSSICH, and A. VALLE in Istra, A. GOBANZ, E. REITTER, R. STURANY, L. BIRO and A. LANGHOFFER in the Mt Velebit and Lika region, and by I. NOVAK, N. DAMIN and A. GOBANZ in Dalmacija. The first systematic biospeleological study was performed by A. E. JURINAC who collected, in the period from 15th till 31st August, 1883 items of fauna in five caves in the Kordun region. The results are published in »*Prilog hrvatskoj fauni ogulinsko-slunjske okolice i pećina*« (JURINAC, 1887b). Among other findings, a new species of stygobiotic amphipod *Niphargus croaticus* (Jurinac) (syn. *Eriopis croatica* Jurinac) (Fig. 3) is described. This survey earned him a Ph.D. in Jena (JURINAC, 1888). He also surveyed the cave fauna in the surroundings of Krapina, including fauna in the wells of the Slavonija region (JURINAC, 1886, 1887a).

In the first half of the 20th century biospeleologic research became much more vigorous and thorough. In the period from 1902 to 1913, A. LANGHOFFER led surveys on the grandest scale to date. Rich animal material was collected from caves in Kordun, Gorski kotar, Lika and Zagreb and the surrounding regions. A review of cavernicolous taxa known up to that time and defined by numerous Croatian and foreign researchers was published in two parts under title »*Fauna cavernarum Croatiae*« (LANGHOFFER, 1912, 1915b). From 1912 to 1914 similar research was per-

formed in Dalmacija by U. GIROMETTA. A list of fauna collected in more than 50 caves in Central Dalmacija was published in two works, the latter, entitled »*Fauna cavernarum Dalmatiae*« (GIROMETTA, 1914) being more detailed. V. STILLER (1911–1918) in the paper »*Meine Höhlenexkursionen in Kroatischen Montangebiet*«, described fauna collected in eight caves in Lika, Gorski kotar and the region around Zagreb. D. POLJUGAN (1915) redescribed the species and described the male of the troglobiotic spider *Parastalita stygia* (Joseph) (syn. *Stalita gracilipes* Kulcz.) (Fig. 4). The fauna of water tanks and wells was surveyed by L. CAR (1901), and subterranean decapods were reviewed by K. BABIĆ (1922). In 1932 the Slovene malacologist L. KUŠČER (1933) conducted the first fairly large-scale research in subterranean molluscs in Croatia. Intensive biological research into interstitial underground waters was started in the 30s by S. KARAMAN who studied the topic till his death in 1959. Alongside F. VEJDOVSKY and P. A. CHAPPUIS he is considered to be the pioneer of research into interstitial underground waters. Mention should be made of Croatian cave fauna collectors: in Continental Croatia – I. HOCHETLINGER, M. ŠNAP, R. WEINGÄRTNER, V. SLABNIK, F. OPERMAN, B. KOSIĆ, E. RÖSSLER, PEUPELMANN, S. PLANČIĆ, J. POLJAK, Ž. KOVAČEVIĆ, E. PRETNER and V. REDENŠEK, in the Hrvatsko primorje region (Kvarner) – G. DEPOLI and A. GOIDANICH, and in Dalmacija – P. NOVAK, S. KARAMAN, Z. KARAMAN, P. MARDESIĆ, S. SVIRĆEV, K. MUSSAP and G. NONVEILLER. Of foreign researchers, a major contribution to knowledge about Croatian subterranean fauna was made by Czech biospeleologist K. ABSOLON who surveyed the Dinarides with breaks from 1901 to 1933, and Croatia from 1908 to 1922. In his collection named »*Biospeologica Balcanica*«, the most significant part was ob-



A. Langhofer



L. Car

tained in Croatia (PRETNER, 1976). As well as his own, material obtained by B. H. VRSALOVIĆ (island of Brač), L. WEIRATHER and U. GIROMETTA (Dalmacija), G. DEPOLI (Kvarner), and J. OBENBERGER, V. STILLER, R. MEUSEL and A. LANGHOFFER (Continental Croatia) was included in the collection (ABSOLON, 1916). As well as in numerous papers of his own, the majority of the material is described in a large number of publications by distinguished European specialists: M. BEZZI, S. J. SCHMITZ, J. KRATOCHVIL, J. LANG, M. BEIER, B. FOLKMANOVA, C. ATTEMS, J. KOMAREK, A. J. WAGNER, C. WILLMANN, etc. G. MÜLLER collected cave beetles in the Hrvatsko primorje region from Istra to Dalmacija up to World War II. He described numerous new taxa of beetles and pseudoscorpions, as well as of crustaceans (MÜLLER, 1931a, 1931b). At the beginning of the 20th century, in Southern Dalmacija V. APFELBECK researched into coleopterans. He had a job in Ludbreg (Croatia) before he got a position in the Sarajevo Museum. During 30s, the Czechs J. KRATOCHVIL and F. MILLER started to survey spiders in Dalmacija, while in 1935 and 1936 F. PAX described the fauna of two caves in Lim Channel, in Istra (PAX, 1937, 1938). R. FRANKENBERGER and V. BALTHASAR surveyed terrestrial isopods in Dalmacija, and also described isopods collected by J. KRATOCHVIL (FRANKENBERGER, 1938a, 1939). L. WEIRATHER in the period 1908 – 1938 visited about 500 caves, many of them in Croatia. The flora of cave entrances on the Kvarner islands was surveyed by A. HARAČIĆ and F. MORTON. As well as these researchers, in Istra, Hrvatsko primorje and the Kvarner islands there were also F. J. SCHMIDT, A. WINKLER, G. HORVATH, L. GYLEK, L. MADER, F. NETOLITZKY, H. KREKICH-STRASSOLDO, E. STOLFA, K. STRASSER, O. CHENDA, CIRKOVICH, G. RAVASINI, A. SCHATZMAYR, C. LONA, P. PARENZAN and H. SPRINGER. In Lika, the major researchers are: R. MEUSEL, F. TAX and A. WINKLER. The most vigorous biospeleologic research was carried out in Dalmacija, where subterranean fauna was collected by numerous coleopterologists, while specialists for other groups are less numerous (NONVEILLER, 1989). The best known scientists from all the groups were: G. PAGANETTI-HUMMLER, F. TAX, H. KRAUSS, K. A. PENECKE, O. WETTSTEIN, J. STAUDACHER,

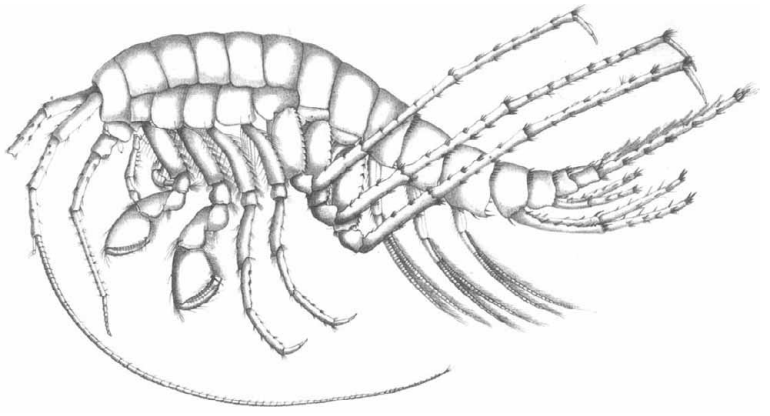
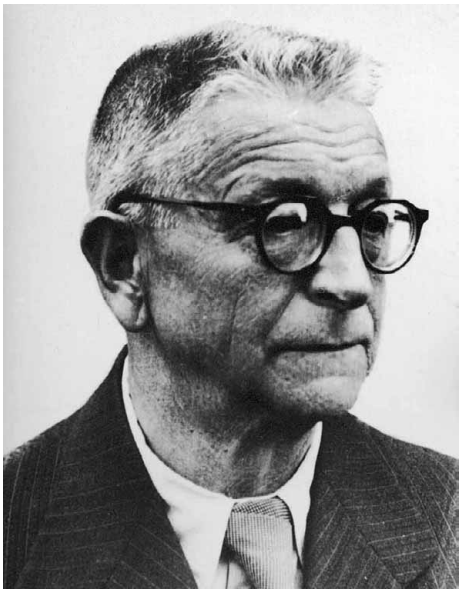


Fig. 3. Amphipoda, Niphargidae. *Niphargus croaticus* (Jurinac) (after JURINAC 1887a, modified).



K. Babić

P. Novak

C. MAYER, H. KREKICH-STRASSOLDO, A. SCHATZMAYR, M. GRABOWSKI, E. DOMBROWSKI, J. KLIMESCH, J. ROUBAL, F. BLÜHWEISS, A. HOFFMAN, A. WINNEGUTH, G. MESSA, F. HEIKERTINGER, P. CZERNY, A. WINKLER, J. MATCHA, F. NETOLITZKY, F. NEUMANN, E. KOHLMEYER, E. STOLFA and P. A. REMY.

In the second half of the 20th century specialist biospeleological research was conducted. After World War II, cave Coleoptera were surveyed by E. PRETNER from Postojna, but he also collected other cave material such as millipedes, pseudoscorpions, etc. Coleoptera were collected by V. REDENŠEK from Zagreb, while spiders were surveyed by F. NIKOLIĆ from Dubrovnik. In 1954, M. MEŠTROV started systematic research into the interstitial fauna in the Sava River valley and on Mt Medvednica (MEŠTROV, 1957, 1958, 1960a, b, 1961, 1962, 1964). He discovered and described a new type of underground habitat, the **hypotelminorheic zone** – »le biotope hypotelminorhéique« (Fig. 5), in Mt Risnjak and Mt Medvednica (MEŠTROV, 1962). Later, with his colleagues, he did intensive faunistic-ecologic research into interstitial waters next to the rivers of the Adriatic basin, and the rivers Sava and Drava. Studies of vertical and horizontal distribution and density of population depending on ecological factors, the mutual influence between a polluted river and its hyporheic zone, etc., were also carried out (MEŠTROV & LATTINGER-PENKO, 1981; MEŠTROV *et al.*, 1976, 1983). In the period from 1962 to 1967, and later, supported by SAZU (the Slovene Academy of Sciences and Arts) the Dinarides was surveyed systematically by Slovene bispeleologists, J. BOLE, B. DROVENIK, J. MATJAŠIČ, A. POLENEC, E. PRETNER, B. SKET, K. TARMAN, F. VELKOVRH, etc. Rich cavernicolous material was collected, only partially described (MATJAŠIČ & SKET, 1969). From 1961 to

1988 C. DEELEMAN–REINHOLD from the Netherlands did research into the spiders of the Dinarides. She surveyed about 400 caves in nearly 30 years of research. Beside description of numerous new taxa of cave spiders she described taxa from several

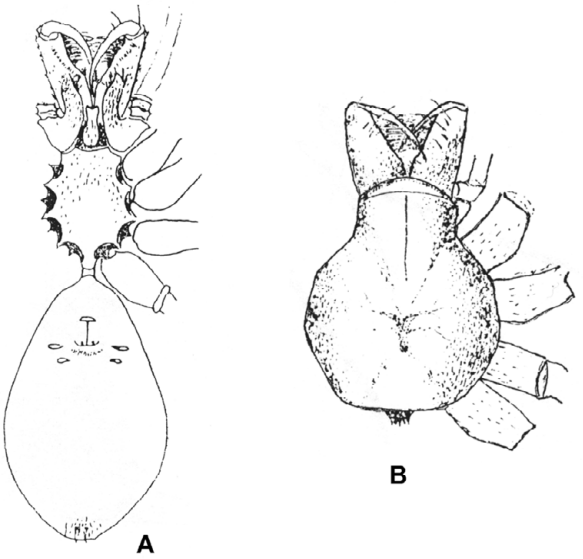


Fig. 4. Araneae, Dysderidae. *Parastalita stygia* (Joseph). Key: A – dorsal view, female; B – ventral view of cephalothorax, male (after POLJUGAN 1915, modified).

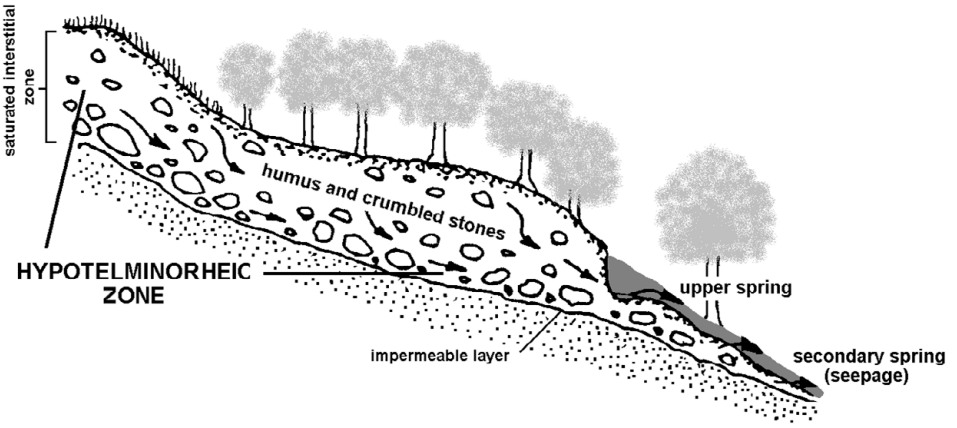
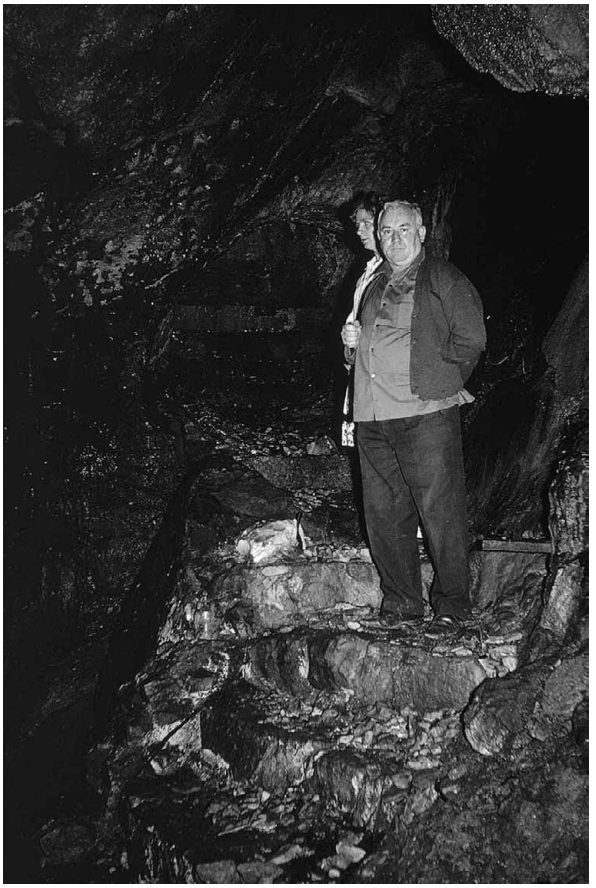


Fig. 5. Schematic presentation of the interstitial habitat – the hypotelminorheic zone in Mt Medvednica, in non-limestone rocks. Arrows indicate the direction of water flow (basic data after LATTINGER, 1988; MEŠTROV, 1962; modified and drawing by S. GOTTSTEIN MATOČEC).



F. Nikolić

other groups (e. g. isopods) (DEELEMAN-REINHOLD, 1965, 1971a, b, 1978, 1983, 1985, 1993). Arachnology research was carried out by J. KRATOCHVIL and F. MILLER until 1977. They produced a monograph on cave spiders of the Dysderidae family and a review of the cavernicolous spiders of the Dalmatian islands (KRATOCHVIL, 1970, 1978). Since the late 1960s, cave fauna in the whole of Croatia has been collected by the coleopterologist B. JALŽIĆ. Among his numerous works on the taxonomy and distribution of coleopterans he has contributed to the research into stygobiotic fauna (JALŽIĆ, 1984, 1993, 1998, 2001; JALŽIĆ & PRETNER, 1977). Since the end of the 70s, mostly in Dalmacija, cavernicolous fauna has been collected by the malacologist T. RAĐA. From work on material obtained from these two researchers, numerous new taxa of pseudoscorpions, millipedes, crustaceans and other groups have been described (ĆURČIĆ, 1988; G. KARAMAN, 1989a; MRŠIĆ, 1992; etc.). Faunistic and ecological research into interstitial subterranean waters and other underground water biotopes, focused on the taxonomy and ecology of aquatic isopods, has been done

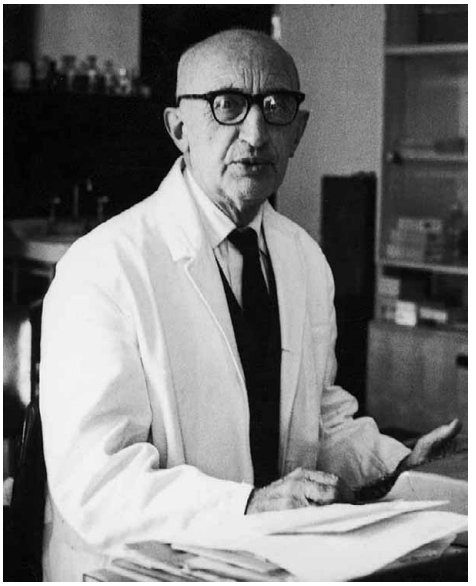
by R. LATTINGER (R. LATTINGER-PENKO, 1970, 1972a, b, 1979). Cavernicolous snail fauna has been surveyed by H. SCHÜTT and the Slovene malacologists J. BOLE, F. VELKOVRH, recently by R. SLAPNIK and the Croatian malacologist V. ŠTAMOL. The spiders of Dalmacija have been investigated by M. BRIGNOLI, and those in the Gorski kotar region by F. GASPARO. Crustacean fauna has been investigated by G. KARAMAN, B. SKET and F. STOCH, and recently by S. GOTTSTEIN MATOČEC. B. SKET has started research into anchihaline caves (SKET, 1981; 1986a, b, 1996). Millipede fauna was surveyed by N. MRŠIĆ, and the olm by B. SKET, T. RAĐA, T. KOVAČEVIĆ, B. JALŽIĆ and E. KLETEČKI. Bat fauna has been surveyed by B. ĐULIĆ, N. TVRTKOVIĆ and D. KOVAČIĆ. Recently, numerous young researchers have been dealing with subterranean fauna in Croatia, most of them having contributed to the preparation of the data for this paper. In 1996 the Croatian Biospeleological Society (Hrvatsko biospeleološko društvo) was founded; this unites biospeleologists of Croatia. And without co-operation from caving organisations from all around Croatia, contemporary biospeleological research of this kind would not have been possible. This was particularly obvious during the »Lukina jama 1993« and »Slovačka jama 1998/99« expeditions in which systematic faunistic and ecological research was carried out.

3.2. Biospeleological organisation in Croatia

by SANJA GOTTSTEIN MATOČEC

The Croatian Biospeleological Society is a non-governmental, non-profit organization, established in 1996 under direction of the Croatian Natural History Museum in Zagreb. It is so far the only society dealing with biospeleology in the country. Its

M. Meštrov



E. Pretner

R. Lattinger (behind) & V. Tavčar (in front)

efforts are focused on the research into underground biota and the registration of biospeleological activity in Croatia.

Additionally, the Society is concerned with the evaluation, conservation and protection of underground habitats and underground biota in Croatia, as well as with education related to all aspects of this topic. It is planned to achieve these objectives through various activities, lectures, workshops, multimedia events, co-operation with the other, related, organisations in both Croatia and foreign countries, publishing various popular, educational, and scientific articles and various promotional materials (BEDEK *et al.*, 2002; GOTTSTEIN MATOČEC *et al.*, 2001a, 2001b; OZIMEC, 2000, 2001, 2002). The members of the Society have formed a special biospeleological collection in the Croatian Natural History Museum in Zagreb in which they are endeavouring to collect all troglobiotic fauna typical of Croatian underground habitats with holotypes, paratypes, allotypes, etc. At present the CBSS has approximately 40 members, distributed around the country. Members include speleologists, research scientists, conservationists, students of biology and many others with an active interest in biospeleology and nature conservation.

B. Đulić

C. Deeleman-Reinhold

The CBSS organised in 1999 the 14th International Biospeleological Symposium in Makarska, with more than 100 participants from eighteen different countries (HOLCER & ŠAŠIĆ, 1999). The primary objective of this symposium was to bring together members of the international scientific community specializing in the study of all kinds of life in underground ecosystems.

Whenever appropriate, the CBSS makes its work known to the public by presenting the results of its own scientific programs and CBSS-sponsored projects (BEDEK *et al.*, 2002; OZIMEC & RUBINIĆ, 2001; OZIMEC & JALŽIĆ, 2002).

4. THE FLORA OF CAVE ENTRANCES

by SUZANA BUZJAK

The first speleobotanic observations in Croatia were published at the end of 19th and the beginning of 20th century (HIRC, 1898, 1900; GIROMETTA, 1914). At the beginning of the 20th century, A. HARAČIĆ described different types of species of *Asplenium hybridum* (Milde) Bange (f. *tipica*, f. *lobata*, f. *Reichardati*) found on the island of Lošinj (TOMAŽIČ, 1955). Surveys on the Kvarner islands were taken up by MORTON (1914, 1932), who studied the influence of light on cave plants, particularly on the species *Asplenium hybridum* (Milde) Bange (endemic in the Kvarner region). While doing research on the island of Rab, he discovered a new type of the species *Adiantum capillus veneris* L (f. *subintegrina* Morton *et* Paulin). Cave entrances were studied by S. HORVATIĆ (1939) from the phytocoenologic point of view.

In the mid-90s, systematic ecological and floristic research into cave entrances in Croatia was started (FIEDLER & BUZJAK, 1997, 1998; BUZJAK & VRBEK, 1999; VRBEK & FIEDLER, 2000; BUZJAK & VRBEK, 2001). Different parts of Dinarides have been included since then – the isolated karst of NW Croatia (Žumberak highlands, Samoborsko gorje, Mt Medvednica) and the classical Dinaric Karst of Gorski kotar, Mt Velebit, and islands of Krk, Rab, Cres and Lošinj. Floristic research is at present limited to the higher plants – Pteridophytes and Spermatophytes. The ecological factors measured are temperature and relative air humidity, as well as light intensity down to the lower limit of plant growth.

In surveys to date we have noted 318 species and subspecies of Spermatophytes and 27 species and subspecies of Pteridophytes. On Mt Medvednica there are 53, on the islands 131, and in Gorski kotar and the Velebit region 206 species and subspecies. Species found in all surveyed caves on Mt Medvednica are *Asplenium trichomanes* L. and *Mycelis muralis* (L.) Dumort. On all the islands, we have noted, in at least one cave, the species *Arum italicum* Miller, *Asplenium trichomanes* L. and *Parietaria judaica* L., while in Gorski kotar and Mt Velebit in all caves surveyed the species *Asplenium trichomanes-ramosum* L., *Cystopteris fragilis* (L.) Bernh. and *Veronica urticifolia* Jacq. were present.

The species *Asplenium scolopendrium* L., *Asplenium trichomanes* L., *Mercurialis perennis* L. and *Mycelis muralis* (L.) Dumort have been noted in the areas surveyed from inland to the islands of Croatia. Among all those recorded, the species *Asplenium scolopendrium* L., *Asplenium trichomanes-ramosum* L., *Aruncus dioicus* (Walter) Fernald and *Cystopteris fragilis* (L.) Bernh. grow to the greatest depths in vertical caves, while the species *Asplenium trichomanes* L. grows at the greatest length in horizontal caves.

The floral characteristics, abundance and depth of plant growth depend upon several factors: the climatic features of area in which the caves are positioned, their microclimatic characteristics, cave entrance morphology and dimensions that influence light intensity. Due to a drop in light intensity, a fall in air temperature, and the increase of relative humidity, with depth the total number of plant species decreases. An important influence is played by the mostly thin soil layers, increased humidity and lower temperature.

5. CAVE FUNGI
Ascomycota, Basidiomycota and Anamorphic (Mitosporic) fungi
by NEVEN MATOČEC

5.1. Introduction

The cave fungi of Croatia are poorly known. In spite of the fact that the typical hyperkarst of the Dinarides dominates the western and southern parts of Croatia, covering almost half of the territory, only few mycological surveys have been done in the karst underground. Only two taxonomic groups of fungi have been surveyed – species from the orders *Laboulbeniales* and *Hypocreales* (both from the division

Ascomycota). All research so far performed on cave fungi belonging to *Laboulbeniales* in Croatia has been recorded in review articles by BÁNHEGYI (1960), STADELMANN & POELT (1962), HULDÉN (1985), and SANTAMARIA *et al.* (1991). Although laboulbenialean fungi are relatively well known in comparison with other groups, one can assume that the real number of species belonging to the group occurring in our caves can be even greater. Recently, a systematic survey of higher fungi in the Croatian underground has been started, resulting in the first paper on the genus *Cordyceps* (Fr.) Link (MATOČEC & OZIMEC, 2001). We plan surveys to cover other groups of fungi, particularly *Ascomycota*.

5.2. Major taxa with notes on cave biodiversity and ecology

In the following review some specific ecological characteristics of fungi, in relation to major taxa that differ in some important way, are given in brief. Each chapter gives an assessment of biodiversity at a generic level and notes on particular features of Croatian cave mycoflora.

At the end is a table with a list of taxonomic groups review followed by the Preliminary Checklist of species recognised so far in underground of Croatia, which must probably represent only a small part of the total cave mycoflora of the country. The »lower fungi,« so called, (*Chytridiomycota*, *Zygomycota* and taxa recently excluded from the kingdom of *Fungi*) are not included, neither are those genera of Anamorphic (Mitosporic) fungi (mostly *Ascomycota*) that do not have a teleomorph in the pleomorphic order *Hypocreales*.

Laboulbeniales

These fungi, both in and out of caves, infest arthropods, mostly coleopterans. It would seem that they are not true parasites as infested animals have all their life functions undisturbed, except in cases of extraordinarily massive infestation. These organisms are highly specialised, so most species can infest only one taxon or a few related host taxa. If their hosts are troglobionts, then the fungi are considered to be troglobiotic, too.

To date, six species of the group have been recorded in the cave mycoflora of Croatia. However, it can be assumed on the basis of the world-wide review work provided by BALAZUC (1998) that at least four more troglobiotic and troglophilic species may exist in Croatia. The author lists the European species of the genera *Arthrorhynchus* Kolen., *Laboulbenia* Mont. & C. P. Robin, *Rhachomyces* Thaxt. and *Symplectromyces* Thaxt., which infest troglobiotic and troglophilic insects species (mostly coleopterans) that have already been found in Croatian caves. Two species found in the karst underground of Croatia are possibly endemic in the Dinarides or the Alpine-Dinaric region: *Laboulbenia shanorii* Bánhegyi and *Rhachomyces hypogaeus* (Thaxt.). Endemism in these fungi can thus be expected whenever the hosts are endemic.

Hypocreales

There are few troglobiotic species; they belong to the entomopathogenic genera *Cordyceps* (Fr.) Link and *Torrubiella* Boud. However, the majority of the species be-

longing to *Hypocreales* are pleomorphic fungi, one species thus having at least two states in its life cycle: sexual i.e., teleomorphic and at least one non-sexual i.e., anamorphic (see chapter: Anamorphic ascomycetous fungi). In caves one can find a certain number of entomopathogenic anamorphic form species belonging to the form genera *Hirsutella* Pat., *Stilbella* Lindau and *Gibellula* Camara. Some other non-cavernicolous anamorphic form species of these genera have been shown to be only anamorphic states of species belonging to the pleomorphic genera *Cordyceps* and *Torrubiella*. We can assume that for these anamorphic form species either that we still do not know their teleomorphic states or that they have evolved (at least some of them) to such an extent as completely to lose their telemorphic state. Fungi of the group are highly specialised parasites on insects and spiders.

In the caves of Croatia two species of the genus *Cordyceps* have been identified to date. *Cordyceps riverae* Pacioni (Fig. 35) is found only in European cave habitats, thus being considered a troglobiont. Two hundred caves in Croatia have been surveyed systematically to date. In 69 of these caves, the only potential host recorded is the troglophilic species of the genus *Triphosa*, Lepidoptera; the fungus itself is recorded in only eight such caves (MATOČEC & OZIMEC, 2001). *Cordyceps sphingum* (Tul.) Sacc. is widespread in Europe and North America outside of cave habitats. The only record in Croatia is one from the cave Tučepska Vilenjača, Dalmacija (mscr.) and match with an underground record from Algeria (LAGARDE, 1913).

Other pleomorphic and teleomorphic Ascomycota

Of other groups of the division *Ascomycota* we can indicate several genera with some species that have been recorded in Croatian cave ecosystems (indeed some of them can be found there regularly): *Ciboria* Fuckel, *Dasyscyphella* Tranzschel, *Hymenoscyphus* Gray, *Lachnum* Retz., *Mollisia* (Fr.) P. Karst. (from *Helotiales*), *Peziza* Fr., *Tarzetta* (Cooke) Lambotte, (from *Pezizales*), *Hypoxylon* Bull., *Xylaria* Hill ex Schrank (from *Xylariales*), *Shanorella* Benjamin (from *Onygenales*). These are mostly lignicolous saprobionts that normally live out of caves and cannot be considered true cave fungi. On the other hand, among terricolous and coprophilous species (e.g. from the genera *Tarzetta* and *Shanorella*) troglobionts are possible, as in case of the terricolous species »*Lachnea*« *spelaea* Barbacovi so far known only from the caves of Italy.

Anamorphic (Mitosporic) Ascomycota

An important fact about the group is that the organism does not produce meiospores, in other words they have only a part of the life cycle that pleomorphic fungi have – a non-sexual state i.e. anamorphic, producing mitospores. In contrast, pleomorphic fungi (many Ascomycota and some Basidiomycota) produce two »generations«: (1) an anamorphic or non-sexual state – in which mitospores are produced (no recombination of genes occur) and (2) a teleomorphic or sexual state, sexual reproduction with gene recombination occuring in meiosporangia. There are usually many meiosporangia situated on (or in) complex fruit bodies (see chapter: *Hypocreales*). As less energy is needed to produce non-sexual structures than for sexual (more complex) pleomorphic fungi are regularly found in non-sexual states in periods of poor ecological conditions. Consequently, we can assume that many

cave fungi of this taxonomically artificial group lost their sexual state (teleomorph) in the process of adaptation to cave habitats. Members of the group are saprotrophic or entomopathogenic species.

We are dealing with those taxa from genera of the Anamorphic *Ascomycota* whose species (at least some of them) are only an anamorphic phase of pleomorphic *Hypocreales*. In connection with this group, SAMSON, EVANS & LATGÉ (1988) state that there are highly specialised troglobiotic species of the genera *Hirsutella* and *Stilbella*, parasites on coleopterans and dipterans, common in cave habitats of Europe. Although in Croatian caves there must be several species from the group, the survey recently started has resulted in the discovery of only one still unidentified species of the genus *Hirsutella*.

Basidiomycota

The majority of the species build large and fleshy fruit bodies on their mycelia (the mycelium is a true fungal body). A number of species, particularly of the orders *Agaricales* and *Aphyllophorales* s.l., are quite often found in cave ecosystems world wide. However, nearly all species of the group found in caves can live underground only if there is a sufficient input of a suitable substrate (wooden material mostly) and if the space is humid enough over a longer period of time. In normal conditions these species live out of the karst underground, but as they do not require light they can acclimate to cave conditions to certain degree. Mycorrhizal species can be found occasionally in caves (e.g. species of the genera *Scleroderma* Pers. and *Suillus* Gray have already been found in the Croatian underground), but exclusively in cave entrances within the range of the rhizosphere of trees, their symbiotic partners.

Tab. 2. An overview of mycodiversity known today in the subterranean karst of Croatia.

Groups	Number of species	Genera with species number in parentheses
Ascomycota	**19**	
Laboulbeniales	6	*Laboulbenia* (3), *Rhachomyces* (2), *Symplectromyces* (1)
Onygenales	1	*Shanorella* (1)
Hypocreales	2	*Cordyceps* (2)
Xylariales	2	*Hypoxylon* (1), *Xylaria* (1)
Helotiales	5	*Ciboria* (1), *Dasyscyphella* (1), *Hymenosyphus* (1), *Lachnum* (1), *Mollisia* (1)
Pezizales	2	*Peziza* (1), *Tarzetta* (1)
Basidiomycota	**6**	
Agaricales	5	*Coprinus* (1), *Hypholoma* (1), *Marasmius* (1), *Mycena* (1), *Suillus* (1)
Sclerodermatales	1	*Scleroderma* (1)
ANAMORPHIC FUNGI		
Hyphomycetes	1	*Hirsutella* (1)
Total	**25**	**21 genera**

The most frequently found *Basidiomycota* in the caves of Croatia are species of the genera: *Coprinus* Pers.: Fr., *Hypholoma* (Fr.) P. Kumm., *Marasmius* Fr. and *Mycena* (Pers.: Fr.) Roussel. These species are saprotrophic organisms – nearly all are lignicolous (cfr. DOBAT, 1973; PASSAUER, 1997). Many inspections made numbers of times in particular large caves in Croatia have shown that populations of certain species of *Coprinus*, which have colonised large woody remnants, are very stable as their fructifications were repeatedly found in the same place for a number of years. Thus, species of the genus *Coprinus* would seem, in comparison to other genera of the group, to be particularly well adapted to underground conditions.

5.3. Preliminary Checklist of troglobiotic fungi and fungi occuring both in and out of cave underground in Croatia

Laboulbenia Mont. *et* C. P. Robin

L. flagellata Peyritsch
– ectotrophic commensal on Tp *Laemosthenes cavicola*, Tp, ref: STADELMANN & POELT (1962).

L. shanorii Bánhegyi
– ectotrophic commensal on Tb *Neotrechus dalmatinus* and *N. suturalis*, Tb, ref: BÁNHEGYI (1960).

L. subterranea Thaxt.
– ectotrophic commensal on Tp *Anophtalmus dalmatinus*, Tp, ref: STADELMANN & POELT (1962).

Rhachomyces Thaxt.

R. hypogaeus (Thaxt.) Thaxt
– ectotrophic commensal on Tb *Typhlotrechus bilimeki*, Tb, ref: BÁNHEGYI (1960); BALAZUC (1970).

R. stipitatus Thaxt.
– ectotrophic commensal on Tp *Typhlotrechus velebiticus* and Ns *Duvalius reitteri*, Tp or Ns (populations dependent on host behavior i.e. on host species), ref: BÁNHEGYI (1960).

Symplectromyces Thaxt.

S. vulgaris (Thaxt.) Thaxt.
– ectotrophic commensal on Tp? *Quedius mesomelinus* var. *kraussi*, Tp?, ref: STADELMANN & POELT (1962).

Shanorella Benjamin

Shanorella sp.
– coprophilous saprotroph on *Mustella* sp. (and perhaps *Martes* sp.) dung so far only in caves, Tb?, ref: none; new for Croatia.

Cordyceps (Fr.) Link

C. riverae Pacioni
– parasite on Stp *Triphosa dubitata* and *T. sabaudiata*, Tb, ref: MATOČEC & OZIMEC (2001).

C. sphingum (Tul.) Sacc.
– parasite on Stp lepidopteran, Ns, ref: GOTTSTEIN MATOČEC *et al.* (2001).

Hypoxylon Bull.

Hypoxylon sp.
– saprotroph on woody remnants, Ns, ref: none; new for Croatian underground.

Xylaria Hill ex Schrank

X. cf. *arbuscula* Sacc.
– saprotroph on woody remnants, Ns, ref: none, new for Croatia.

Ciboria Fuckel

C. americana Durand aggr.
– saprotroph on woody remnants, Ns, ref: none; new for Croatian underground.

Dasyscyphella Tranzschel

D. nivea (Hedwig: Fr.) Raitviir
– saprotroph on woody remnants, Ns, ref: none, new for Croatian underground.

Hymenoscyphus Gray

Hymenoscyphus sp.
– saprotroph on woody remnants, Ns, ref: none; new for Croatian underground.

Lachnum Retz.

L. fasciculare Velen.
– saprotroph on woody remnants, Ns, ref: none; new for Croatia.

Mollisia (Fr.) P. Karst.

M. fusca (Pers. ex Mérat) P. Karst.
– saprotroph on woody remnants, Ns, ref: none; new for Croatia.

Peziza Fr.

P. succosella (Le Gal *et* Romagn.) Avizohar-Hershenzon *et* Nemlich
– terricolous in cave entrance, Ns, ref: none; new for Croatia.

Tarzetta (Cooke) Lambotte

Tarzetta sp.
– terricolous on cave floor, Tb?, ref: GOTTSTEIN MATOČEC *et al.* (2001).

Hirsutella Pat.

Hirsutella sp.
– parasite on Tb *Leptodirus hochenwarti* and *Parapropus sericeus*, Tb, ref: GOTTSTEIN MATOČEC *et al.* (2001).

Coprinus Pers.: Fr.

Coprinus sp.
– saprotroph on woody remnants, Ns, ref: GOTTSTEIN MATOČEC *et al.* (2001).

Hypholoma (Fr.) P. Kumm.

H. fasciculare (Huds.: Fr.) P. Kumm.
– saprotroph on woody remnants, Ns, ref: none; new for Croatian underground.

Marasmius Fr.

Marasmius sp.
– saprotroph on woody remnants, Ns, ref: none; new for Croatian underground.

Mycena (Pers.: Fr.) Roussel

Mycena sp.
– saprotroph on woody remnants, Ns, ref: GOTTSTEIN MATOČEC *et al.* (2001).

Scleroderma Pers.

Scleroderma sp.
– mycorrhizal, symbiont of *Carpinus betulus*, in cave entrance area, Ns, ref: GOTTSTEIN MATOČEC *et al.* (2001).

Suillus Gray

Suillus sp.
– mycorrhizal, symbiont of *Pinus halepensis*, in cave entrance area, Ns, ref: none; new for Croatian underground.

Key:

Ns – not strictly cave organisms, i.e. living both in and out of cave underground
Stp – subtroglophilous
Tp – troglophilous
Tb – troglobiotic

6. HYPOGEAN FAUNA

6.1. Hypogean aquatic fauna

INVERTEBRATES

Porifera by TATJANA BAKRAN-PETRICIOLI

Species of the most abundant class of sponges – Demospongia – inhabit different biotopes: from the shallow marine littoral zone to very deep parts of the hadal zone in the sea, as well as different types of freshwater biotopes on the continents. Although species of marine sponges represent an important part of marine cave fauna (VACELET, 1994), freshwater species (which belong to the family Spongillidae) are very rare inhabitants of inland caves.

In the Dinarides, some surface freshwater species, which cannot be considered real troglobionts, have been found in caves. An example from Croatia is *Ephydatia fluviatilis* (Linné) from a cave near Metković in southern Dalmacija (VAN SOEST & VELIKONJA, 1986).

The only known troglobiont sponge was described by SKET & VELIKONJA (1986) from the surroundings of Ogulin in Croatia. It is the species *Eunapius subterraneus* Sket *et* Velikonja, with two subspecies: *E. s. subterraneus* Sket & Velikonja from Tounjčica cave and Mikašinovića pećina (Zala cave) (Fig. 32), and *E. s. mollisparspanis* Sket *et* Velikonja from Rudnica spring. This sponge is very soft, with large and prominent oscula and long, spinulose spicules (mean length above 300 ìm). Gemmules are scarce and with atypically developed coats (partial reduction). The described populations live in total darkness and over a quite stable temperature (range throughout the year: 7.2 °C – 11 °C); they have never been found in surface waters.

Hydrozoa by SANJA GOTTSTEIN MATOČEC

Several specimens of the epigean hydroid *Hydra vulgaris* Pallas were found by MEŠTROV (1960) in the interstitial waters of the Sava River valley.

Velkovrhia enigmatica Matjašič & Sket

The first work dealing with the cave hydroid *Velkovrhia enigmatica* in Croatia was published by VELIKONJA (1986). This is the only stygobiotic representative of the Hydrozoa (and probably of Cnidaria) in cave fresh waters; it is grouped within the subclass Athecatae, family Bougainvilliidae (MATJAŠIČ & SKET, 1971; KUŠTOR, 1977). Its distribution area extends from central Slovenia and western Croatia to Hercegovina. In Croatia *V. enigmatica* is found on stones in small underground pools in Tounjčica Cave (Kordun region). Here it lives together with the stygobiotic freshwater sponge *Eunapius subterraneus subterraneus* Sket *et* Velikonja (VELIKONJA, 1986).

Turbellaria

- Temnocephalidea by SANJA GOTTSTEIN MATOČEC

All subterranean Temnocephalidea in Croatia belong to the Scutariellidae family. Most of them live as epizootic and ectoparasitic species on cave shrimps of the genus *Troglocaris*. The only species that lives exclusively on amphipod shrimps is the species *Stygodyticola hadzii* Matjašič, so far noted on some *Niphargus* species in caves near Ogulin (MATJAŠIČ, 1958b, 1959, 1980).

Five species of four genera have been recorded in subterranean Croatian fauna, belonging to two subfamilies: Bubalocerinae and Scutariellinae. However, as the group is poorly surveyed the number is expected to be higher. Species noted in Croatia are found in caves and springs of the environs of Ogulin, in Lika and in caves around the source of the Cetina. We assume that in Croatian fauna one should also be able to find the species *Scutariella stammeri* Matjašič (Subfam. Scutariellinae), which lives on *T. anophthalmus* (Kollar) and probably on *Spelaeocaris pretneri* Matjašič. In Croatia, the species *Troglocaridicola istriana* Matjašič and *T. vilkae*

Matjašič can also be expected to be found, as they live on *T. anophthalmus* in the Istrian region in Slovenia. Due to the connection between the underground waters of southern and south-eastern Herzegovina and Southern Croatia, after the discovery of *Spelaeocaris pretneri* in the area, we also expect to find the species *Troglocaridicola spelaeocaridis* Matjašič.

It is expected that many new species will be found. To support this claim, we will mention that on *Spelaeocaris pretneri*, a specimen that most likely belongs to a new species of the genus *Troglocaridicola* (MATJAŠIČ, 1990, 1994) has been found. *Spelaeocaris pretneri*, poorly researched in Croatia, derives from a cave next to the source of the Cetina River (Dalmacija).

Tab. 3. List of Temnocephalidea in Croatian underground.

Family and subfamilies	Species
Scutariellidae	
Bubalocerinae	*Bubalocerus sketi* Matjašič
	B. undulatus Matjašič
Scutariellinae	*Stygodyticola hadzii* Matjašič
	Subtelsonia perianalis Matjašič
	Troglocaridicola capreolaria Matjašič

• Tricladida by ROMAN OZIMEC

The first work dealing with subterranean Tricladida in Croatia was published by KOMAREK (1919), based on material collected by K. ABSOLON in Dalmacija and J. LANGHOFFER in Kordun. In the paper, one new species of the genus *Dendrocoelum* found in the Đulin ponor-Medvedica cave system (Kordun) are described. *Dendrocoelum subterraneum* Komarek shows a greater degree of adaptation to subterranean life conditions and it is endemic to the Croatian underground. In a karstic spring close to the village of Cernik Primorski (Rijeka) the subterranean species *Dendrocoelum plesiophthalmum* de Beauchamp has been found. From a pothole on Mt Mosor (Central Dalmacija) the species *Dugesia absoloni* (Komarek) has been described. This endemic species has developed troglobiotic features.

Unfortunately, for all the species described for Croatia, new specimens, after description, have not been noted, and thus their taxonomic and ecological status is in question. Recently, stygobiotic specimens of the genus *Dendrocoelum* have been collected in south-western Croatia (Žumberak).

Tab. 4. List of troglomorphic Tricladida in Croatia.

Families	Species
Dendrocoelidae	*Dendrocoelum plesiophthalmum* de Beauchamp
	D. subterraneum Komarek
Dugesiidae	*Dugesia absoloni* (Komarek)

Mollusca

• Gastropoda by TONĆI RAĐA

Subterranean aquatic gastropods inhabit all underground biotopes from interstitial to anchihaline waters. In comparison with terrestrial subterranean gastropods aquatic snails are more numerous. The first record of an underground aquatic species dates from 1824 – the snail *Lanzaia elephantota* (Mühlfeldt) (syn. *Turbo elephantotus* Mühlfeldt, *Lanzaia brusinai* Kuščer, *L. zrnovnicae* Bole *et* Velkovrh, nom. nud.) was found in the marine sediment of the Žrnovnica River near Split (VON MÜHLFELDT, 1824). Since this accidental discovery, 29 endemic and stygobiotic species and subspecies have been discovered and described. An extraordinary contribution to discoveries and knowledge of subterranean aquatic snails in the Croatian karst was made by the Slovene malacologists J. BOLE (BOLE, 1961a, 1992; BOLE & VELKOVRH, 1986, 1987), L. KUŠČER (1933) and F. VELKOVRH (1970, 1971), and the German malacologist H. SCHÜTT (1960, 1961a, b, c, 1963, 1968, 1970, 1972, 1975, 2000).

Subterranean aquatic snails of the Croatian karst, as a part of the European subterranean aquatic gastropod fauna, differ in respect of their biodiversity and a narrow range of distribution. Many of the species live in inaccessible underground water flows, being known by their shells only, which is inadequate for the determination of an appropriate taxonomic position.

It is necessary to make some reference to the relict species »*Orygoceras« sketi* Bole *et* Velkovrh, nom. nud. with only one specimen caught in a well near Varaždin (NW Croatia). The species is the only living representative in Europe of the genus *Orygoceras*, numerous in the Tertiary.

Intensive biospeleological research recently done in Croatia, particularly on the Adriatic islands, has enabled the collection of underground material resulting in the discovery of new species, the description of which is not complete.

• Bivalvia by BRANKO JALŽIĆ

Congeria kusceri Bole

The first record in Croatia of this only cave freshwater bivalvia was noted by the Slovene malacologist Ljudevit Kuščer in the spring of Stinjevac near Vrgorac in Dalmacija, in the year 1934 (BOLE, 1962; BOLE & VELKOVRH, 1986).

In the karst areas, 8 spots out of 11 are discovered in the catchment basin of the Neretva (Dalmacija) (JALŽIĆ, 1998). During 1999 there were two new discoveries in the northern part of Mt Velebit, far away from the previous discoveries (OZIMEC, 1999b) (Fig. 7). The temperature range of the species is from +4 °C to +19 °C (Fig. 37).

Polychaeta by BRANKO JALŽIĆ

Marifugia cavatica Absolon *et* Hrabě

The first specimen was discovered by the Czech caver K. ABSOLON in 1913 at the source of the Trebišnjica in Popovo Polje, Bosnia and Herzegovina. In Croatia, the first discoveries were made by L. KUŠČER around towns Ogulin, Split, Vrgorac and Metković (STAMMER, 1935). In following years, the species was observed in numer-

Tab. 5. List of stygobiotic species and subspecies of Gastropoda in Croatia. E = Croatian endemic taxon, L = taxon has its *locus typicus* in Croatia.

Orders and families	Species and subspecies	E	L
Archaeogastropoda			
Neritidae	*Neritaea subterrelicta* Schütt	+	+
Mesogastropoda			
Orientalinidae	*Belgrandia torifera* Schütt	+	+
	Belgrandiella croatica (Hirc)	–	+
	Belgrandiella krupensis Radoman	+	+
	Belgrandiella pageti Schütt	–	+
	Bithyospeum absoloni (A. J. Wagner)	–	–
	Bithyospeum (Iglica) elongatum (Kuščer)	+	+
	Bithyospeum (I.) langhofferi (A. J. Wagner)	–	+
	Bithyospeum (Rhaphica) bagliviaeformis (Schütt)	–	+
	Cilgia dalmatica (Schütt)	+	+
	Costellina turrita Kuščer	+	+
	Dalmatella miljackae Bole *et* Velkovrh	+	+
	Dalmatella sketi Velkovrh	+	+
	Erythropomatiana erythropomatia (Hauffen)	–	–
	Hadziella anti Schütt	–	+
	Hadziella ephippiostoma Kuščer	–	–
	Hadziella rudnicae Bole	+	+
	Hadziella sketi Bole	–	+
	Hadziella thermalis Bole	–	–
	Hauffenia edlaueri (Schütt)	–	+
	Hauffenia jadertina Kuščer	+	+
	Hauffenia media Bole	–	+
	Hauffenia plana Bole	–	–
	Hauffenia sinjana (Kuščer)	+	+
	Hauffenia tovunica Radoman	+	+
	Istriana mirnae Velkovrh	–	+
	Lanzaia elephantota Mühlfeldt	+	+
	Lanzaia kotlusae Bole	+	+
	Lanzaia kusceri Karaman	+	+
	Lanzaia kvarnerica Bole *et* Velkovrh	+	+
	Lanzaia latecostata Schütt	–	+
	Lanzaia rudnicae Bole	+	+
	Lanzaia skradinensis Bole	+	+
	Lanzaia vjetrenicae Kuščer	–	–
	Marstoniopsis croatica Schütt	–	–
	Orientalina troglobia (Bole)	–	–
	»Orygoceras« sketi Bole *et* Velkovrh nom. nud.	+	+
	Plagigeyria edlaueri Schütt	–	+

	Plagigeyeria klemmi Schütt	+	+
	Plagigeyeria minor (Schütt)	–	+
	Plagigeyeria nitida angelovi Schütt	+	+
	Plagigeyeria robusta asculpa Schütt	–	–
	Plagigeyeria robusta robusta (Schütt)	–	–
	*Paladilhiopsis illustris Sc*hütt	+	+
	Paladilhiopsis pretneri Bole *et* Velkovrh	+	+
	Paladilhiopsis solida Kuščer	–	–
	Sadleriana cavernosa Radoman	+	+
	Saxurinator brandti Schütt	+	+
	Saxurinator labiatus Schütt	+	+
	Saxurinator microbeliscus Schütt	+	+
	Saxurinator sketi (Bole)	+	+
Basommatophora			
Acroloxidae	*Acroloxus vruljae* Bole *et* Velkovrh	+	+

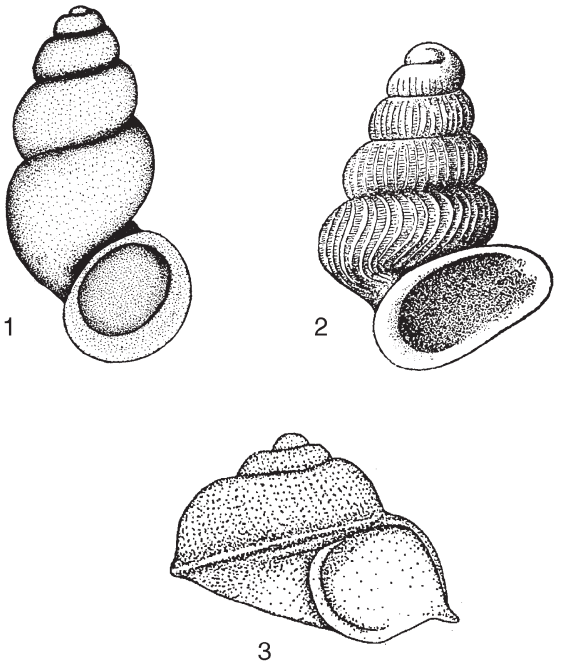


Fig. 6. Some aquatic gastropods from Croatian underground. 1– *Istriana mirnae* Velkovrh – inhabits interstitial habitats in Istra (after VELKOVRH, 1971); 2 – *Lanzaia elephantota* Mühlfeldt – inhabits subterranean waters next to the seashore of Dalmacija (after BOLE & VELKOVRH, 1986); 3 – *Dalmatella sketi* Velkovrh – endemic genus and species from Dalmatian groundwater (after VELKOVRH, 1970).

ous places in the Dinarides (SKET, 1970). In Croatia, *Marifugia cavatica* inhabits the waters of many caves from Istra to southern Dalmacija. The species is not noted in the region of Žumberak and the Samobor Highlands or in the area of isolated karst NW and E from Zagreb. In Slovenia and the northern parts of Croatia and Bosnia the colonies are less dense than those in Southern Croatia and Herzegovina. The temperature range of the species is from +4 °C to +19 °C.

Oligochaeta by MLADEN KEROVEC

No systematic research of underground oligochaetes in Croatia has been done. The data we know derive from the results of complex ecological surveys of interstitial underground waters.

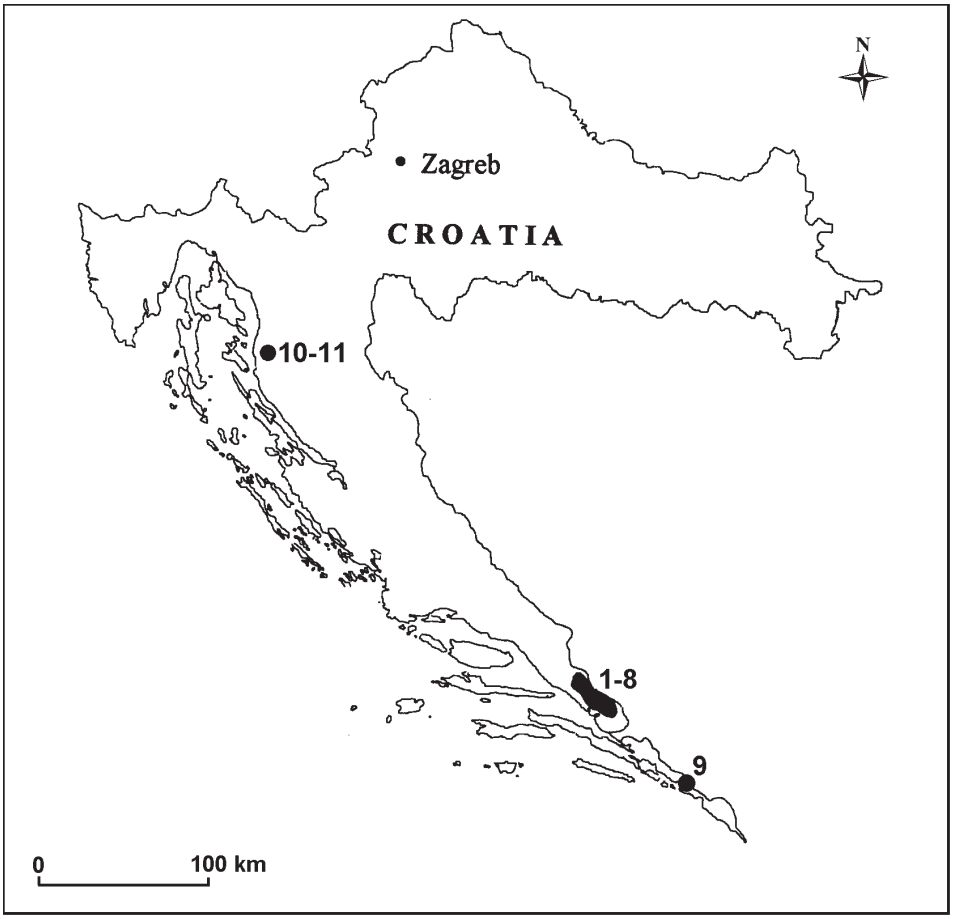


Fig. 7. Distribution of *Congeria kusceri* Bole in Croatia. 1–8 = eight spots in the catchment basin of the Neretva River (Dalmacija); 9 = one spot in the catchment basin of the Ombla river (Dalmacija); 10–11 = two spots in the northern part of Mt Velebit.

The first record of oligochaetes in underground waters in Croatia was published by CAR (1928), describing the species *Haplotaxis gordioides* Car found near Pakrac and in 1927 in a well in Zagreb area. Later, MEŠTROV (1960a) as a part of complex faunal and ecological research undertaken in underground interstitial waters (hyporheic and phreatic zones) of the Sava valley, recorded 9 species of oligochaetes of the families Aeolosomatidae, Naididae, Enchytraeidae, Tubificidae, Lumbriculidae and Haplotaxidae. Twenty years later, in similar, long-term (several years) research, in nearly the same area close to the Sava (MEŠTROV *et al.*, 1983), more species of oligochaetes from families Tubificidae and Naididae were found. In yet another long-term survey, of streams at Mt Medvednica close to Zagreb (LATTINGER, 1988), 17 mostly stygoxenic species of oligochaetes were found. HRABĚ (1973) mentions 14 species of Oligochaeta from more than 10 different spots (springs and caves) in the Karst region of Croatia. In two springs in central Istra, KEROVEC (1981) recorded several species of oligochaetes of the families Lumbriculidae, Tubificidae and Naididae.

Among oligochaetes in Croatia there are very few that are stygobiotic. Members of this group are of the family Lumbriculidae, genus *Trichodrilus* Claparède (interstital waters along the Sava River) and *Bythonomus sulci* Hrabě (the springs of Miljacka-Knin and Butina-Vrgorac).

Similarly, only three species: *Haplotaxis gordioides* (Hartmann) (Haplotaxidae), *Rhynchelmis limosella* (Hoffmeister) (Lumbriculidae) and *Aeolosoma quaternarium* (Ehrenberg) (Aeolosomatidae) belong to the group of stygophiles. They are found in interstitial waters along the Sava River and along the streams on the Mt Medvednica, and also in one spring on the island of Rab and in another – the Nele close to the Cetina River.

In interstitial underground waters and springs many stygoxenic species of oligochaetes are regularly found. These species are from surface waters, such as*: Lumbriculus* Grube, *Stylodrilus* Claparède (Lumbriculidae), *Limnodrilus* Claparède, *Potamothrix* Vejdovsky *et* Mrazek, *Psammoryctides* Hrabě, *Rhyacodrilus* Bretscher, *Spirosperma* Eisen (*Peloscolex* Leidy), *Tubifex* Lamarck (Tubificidae), *Chaetogaster* von Baer, *Dero* Oken, *Homochaeta* Bretscher, *Nais* Müller, *Ophidonais* Gervais, *Paranais* Czerniavsky, *Pristina* Ehrenberg (Naididae), and more species from the family Enchytraeidae.

A record of the species *Thalassodrilus modricensis* Hrabě (Tubificidae) in a brackish spring near Maslenica (Zadar) should be mentioned. This is the *locus typicus* of the only endemic aquatic Oligochaeta in Croatia.

Hirudinea by MLADEN KEROVEC

Of more than 600 leeches known world-wide only a few are stygophilous or stygobiotic species. In Croatia there are 17 species, of which the only stygophilic species is *Dina krasensis* (Sket) (Family Erpobdellidae) found in the Istria and Lika regions and in the vicinity of Bakar and Novi Vinodolski (SKET, 1968). Up to date, the only one stygobiont leech found in Dalmacija, is *Dina absoloni* Johansson, known also from other parts of SE Dinarides – Hercegovina and Montenegro (SKET, 1968; 1999). A very large troglomorphic *Dina* sp. occurs near Ogulin in the NW part of

Croatia (SKET *et al.*, 2001). During biospeleological research of Northern Velebit (the Lukina jama Speleological Expedition 1994) a new stygobiotic leech *Croatobranchus mestrovi* Kerovec, Kučinić *et* Jalžić (Family Erpobdellidae) was found, 1320 m deep in the pothole Lukina jama, which is one of the deepest caves in the world (KEROVEC *et al.*, 1999; SKET *et al.*, 2001) (Fig. 45). Several other species have been found occasionally in caves: *Hemiclepsis marginata* (O. F. Müller), *Glossiphonia complanata* (Linné), *Dina lineata* (O. F. Müller), *Erpobdella octoculata* (Linné) and *Erpobdella testacea* (Savigny) (SKET, 1986).

Crustacea

• Copepoda by IVANČICA TERNJEJ

The fauna of subterranean copepods (Copepoda) in Croatia is poorly known. Most of the known species are described by a Macedonian specialist PETKOVSKI (1954, 1955, 1959, 1961, 1978). The subterranean fauna of microcrustaceans is surveyed by SKET (1986a, 1988, 1994b, 1996) from Slovenia and MEŠTROV (1960a) from Zagreb University. No subterranean Cladocera species has been discovered in Croatia.

Out of 112 known species and subspecies of copepods in Croatia, roughly one third (40) are seasonal or permanent inhabitants of the underground. They are found in freshwater habitats: springs, sources, interstitial waters, waters in caves, but brackish water habitats too, such as the interstitium next to the sea shore or anchihaline caves. Brackish habitats close to the sea are inhabited by marine species, such as *Halicyclops* A. M. Norman and *Cyclopina* Claus of Cyclopoida, plus *Schizopera* Sars and *Delamarella* Chappuis of Harpacticoida. Most of the subterranean species are of the order Harpacticoida (20), Cyclopoida (19), while the order Calanoida is represented by two species, *Troglodiaptomus sketi* Petkovski and *Stygodiaptomus petkovskii* Brancelj. All endemic species of the order Harpacticoida belong to the genera *Morariopsis* Borutzky, *Elaphoidella* Chappuis and *Parastenocaris* Kessler. Only six species out of all subterranean members of Harpacticoida, Ameiridae and Canthocamptidae live in freshwater habitats. The rest inhabit freshwater and brackish habitats and interstitia by the sea. The most widespread underground species from Cyclopoida are from *Acanthocyclops* (Kiefer) and *Diacyclops* (Kiefer). *Acanthocyclops gordani* Petkovski and *Diacyclops antrincola* Kiefer in habit springs, caves and interstitial waters of the Dinarides, but some taxa are found in interstitial waters outside karst areas, for example the endemic species *Acanthocyclops petkovskii* Pesce *et* R. Lattinger (PESCE & LATTINGER, 1985). Other species of these genera are found only occasionally in subterranean habitats: *Acanthocyclops vernalis* (Fischer), *Diacyclops bicuspidatus* (Claus) and *Diacyclops crassicaudis* (Sars). More stygophilic species are from the genera *Halicyclops* A. M. Norman, *Eucyclops* Claus, *Macrocyclops* Claus, *Paracyclops* Claus, *Tropocyclops* Kiefer, *Thermocyclops* Kiefer, *Cyclops* O. F. Müller and *Mesocyclops* Kiefer.

• Ostracoda by SANJA GOTTSTEIN MATOČEC

Subterranean ostracods are mentioned in articles by Croatian scientists and researchers of underground waters only from the point of view of their abundance. The first taxonomic data are found in a description of a species in Hvar (DANIELOPOL,

1969). This is an article that has been used as foundation for research into ostracods in the interstitial subterranean habitats of the Sava River valley (Opatovinski sprud). During research in the 90s, the systematic, adaptive morphology, biogeography and ecology of ostracods in the Sava valley were compared to those of similar habitats in other parts of Europe (DANIELOPOL *et al.*, 1994; ROGULJ & DANIELOPOL, 1993; ROGULJ *et al.*, 1993, 1994). Subterranean representatives of the group are little known in Croatia in spite of fact that their presence is noted in various types of underground habitats.

In underground waters of the island of Hvar (well water) an endemic species of the family Candonidae (Order Podocopida) – *Mixtacandona hvarensis* Danielopol has been described (DANIELOPOL, 1969). The coastal caves of Istra are inhabited by the species *Sphaeromicola sphaeromidicola* Hubault (Family Entocytheridae).

Coastal underground waters are populated by some surface species such as *Cypria lacustris* G. O. Sars (SKET, 1986a). In shallow interstitial underground waters (hyporheic zone) but also in surface waters by the Sava River at Zagreb, *Fabaeformiscandona wegelini* (Petkovski) (Candonidae) has been found. The former species has less developed troglomorphic characteristics than the more specialised endemic *Mixtacandona lattingerae* Rogulj *et* Danielopol (Family Cyprididae), which is found in the deeper interstitial underground waters of the Sava valley (ROGULJ & DANIELOPOL, 1993; ROGULJ *et al.*, 1993, 1994).

• Syncarida by SANJA GOTTSTEIN MATOČEC

The taxonomic characteristics and ecology of the group in the interstitial waters of the Sava valley were surveyed by MEŠTROV (1957, 1958, 1960a).

Two stygobiotic species are recognised in Croatia (MEŠTROV, 1957, 1960a), *Bathynella natans* Vejdovsky of the family Bathynellidae and *Parabathynella stygia* Chappuis of the family Parabathynellidae. Both species live in underground (phreatic) waters of the Sava River valley.

• Isopoda by SANJA GOTTSTEIN MATOČEC

S. KARAMAN was one of the most significant researchers of underground aquatic isopods in Croatia at the beginning and in the middle of the 20th century. His research was done in the interstitial waters of non karstic parts in NW Croatia and in wells and springs in the Dinarides. He described several new taxa (S. KARAMAN, 1952b, 1954, 1955). An important contribution to the knowledge of the families Asellidae and Sphaeromatidae both in Mediterranean and continental parts of Croatia was made by C. DEELEMAN-REINHOLD (1965, 1971). MEŠTROV described new taxa of the aquatic isopod *Protelsonia hungarica thermalis* (Meštrov). It inhabits the underground water of the Sava valley and of the foothills of Mt Medvednica (MEŠTROV, 1960b, 1961). In the 70s, intensive ecological research was conducted on the subterranean thermophilic endemic relict shrimp *Protelsonia* (LATTINGER-PENKO, 1970a, b, 1972). Since the 60s, SKET has systematically researched aquatic isopods in the Dinarides and other areas. He has described numerous new taxa, and the spatial distribution and ecological characteristics of biota, etc. (SKET, 1959, 1964, 1965a, b, c, 1967a, 1994a, b).

In Croatia, 30 taxa of aquatic isopods (freshwater and brackish species) have been recorded, and of these 24 taxa (species and subspecies) are stygobionts of five families: Asellidae, Cirolanidae, Microparasellidae, Sphaeromatidae and Stenasellidae.

Most of the stygobiotic taxa are distributed in the Dinarides, the region known for the biggest number of endemic species. Stygobiotic representatives of Asellidae and Sphaeromatidae are widely distributed in the Dinarides. Members of *Proasellus* Dudich (Asellidae) are found in interstitial waters and springs from the interior, continental, to the coastal and Adriatic parts of Croatia including some of islands. The family Sphaeromatidae, of all the aquatic isopods, has the biggest number of endemic taxa (6) in Croatia. The endemic species *Monolistra pretneri* Sket inhabits karstic springs and caves that have running water and lives in a biocoenosis with the biggest underground aquatic isopod in Croatia – *Sphaeromides virei mediodalmatina* Sket, yet another Croatian endemic subspecies. The species *Monolistra* (*Microlistra*) *sketi* Deeleman-Reinhold is also an endemic sphaeromatid isopod found in Croatia (Fig. 8). In the interstitial waters of Zagreb and surroundings, two relict taxa of

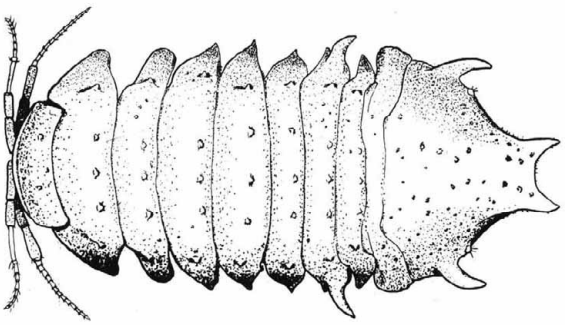


Fig. 8. Isopoda, Sphaeromatidae. *Monolistra* (*Microlistra*) *sketi* Deeleman-Reinhold – endemic isopod in Croatia from the Lika region (after DEELEMAN-REINHOLD 1971, modified).

Stenasellidae: *Balkanostenasellus skopljensis croaticus* S. Karaman and *Protelsonia hungarica thermalis* (Meštrov) have been found.

Subterranean aquatic isopods are recorded in various types of habitats such as underground and surface springs, submarine springs, flysch springs, thermal springs, underground water and water flows, and interstitial waters – phreatic, hyporheic and hypotelminorheic. The interstitial habitats are almost exclusively characterized by the genus *Microcharon* (Karaman). The coastal springs and caves of the Adriatic are populated by stygophilic species of the genus *Jaera* Leach, which may exhibit a slight troglomorphy.

• Amphipoda by SANJA GOTTSTEIN MATOČEC

The first important research into amphipods in Croatia dates from the middle of the 19th century (GRUBE, 1864, 1866). By the end of the 19th century, JURINAC described a new species of the subterranean amphipod *Niphargus croaticus* (Jurinac),

Tab. 6. Subterranean isopods of fresh and brackish water in Croatia with notes on endemics.

Families	Genera	Total species	Number of endemic species
Asellidae	*Asellus* E.L. Geoffroy	1	
	Proasellus Dudich	6	1
Cirolanidae	*Sphaeromides* Dollphus	1	
Janiridae	*Jaera* Leach	2	
Microparasellidae	*Microcharon* (Karaman)	2	
Sphaeromatidae	*Monolistra* Gerstaecker	7	2
Stenasellidae	*Balkanostenasellus* Cvetkov	1	
	Protelsonia Méhely	1	
Total number of species		21	3

found in Kordun area (JURINAC, 1887a, b). At the beginning of the 20th century a Czech scientist, SCHÄFERNA, while researching in Dalmacija, found a new species of subterranean amphipod on the island of Mljet, many years later described by STRAŠKRABA (1959) as *Niphargus miljeticus* Straškraba (Fig. 39). SCHÄFERNA (1922) has given wide review of amphipods found in the Balkan region, including the area of today's Croatia.

From the beginning till the middle of the 20th century S. KARAMAN was one of the most fruitful researchers into subterranean fauna of amphipods in Croatia. He described a remarkable number of new taxa, particularly in the caves and springs of the Dubrovnik area and the Adriatic psammolittoral (S. KARAMAN, 1931, 1932, 1935, 1950, 1952b, 1953a, b, 1960). SCHELLENBERG, from the Natural History Museum in Berlin, described new taxa in Istra, an important contribution to the knowledge of amphipods in Croatia (SCHELLENBERG, 1933a, b).

In the 60s and until the end of the 80s MEŠTROV, LATTINGER and colleagues from Zagreb University researched interstitial Amphipods, particularly in the Sava valley and the foothills of Mt Medvednica (LATTINGER, 1988, 1989; MEŠTROV, 1960a, 1961; MEŠTROV *et al.*, 1983, 1986).

The spatial distribution, ecology and taxonomy of subterranean amphipods of coastal anchihaline caves is the same as in other types of brackish habitats investigated by RUFFO & KRAPP-SCHICKEL (1969) and SKET (1969, 1977, 1986a, b).

The contribution to science involving research into the subterranean amphipod fauna of Croatia was made by B. SKET from Ljubljana University (Slovenia) and G. KARAMAN from Podgorica University (Montenegro). Both scientists have described many new taxa based on samples taken in Croatia (G. KARAMAN, 1962, 1978, 1983, 1984, 1985, 1988a, b, c, 1989a, b, 1991; G. KARAMAN & SKET, 1989; 1990a, b; SKET, 1959, 1971). Recently, subterranean amphipods in all parts of Croatia have been investigated by GOTTSTEIN MATOČEC (GOTTSTEIN *et al.*, 1998, 1999, 2000; GOTTSTEIN MATOČEC *et al.*, 2002).

Amphipods are an important part of the aquatic subterranean fauna in nearly the whole area of Croatia. 64 troglomorphic species and subspecies of eight families and one group (Bogidiellidae, Crangonyctidae, Gammaridae, Hadziidae, Melitidae, Niphargidae, Typhlogammaridae, Salentinellidae, Pseudoniphargid-group) have been recognised to date; they are found in underground marine, brackish and freshwater habitats. The best represented is the family Niphargidae, if one considers the total number of taxa and endemic species or subspecies. Nineteen out of 52 taxa (species and subspecies) of the genus *Niphargus* Schiödte are endemic in Croatia. There are 46 stygobionts and six stygophiles. The family Gammaridae is composed of only one stigobiotic genus, *Accubogammarus* G. Karaman, two slightlytroglomorphic species, *Rhipidogammarus karamani* Stock, and *Rhipidogammarus rhipidiophorus* (Catta), and some epigean taxa from the genera *Echinogammarus* Stebbing and *Fontogammarus* S. Karaman recorded from wells and karstic springs. Some epigean species such as *Gammarus balcanicus* Dobreanu *et* Manolache, and *Echinogammarus thoni* (Schäferna) are found very sporadically in caves of Dalmacija, but never represented there by stable populations (SKET, 1994b). Amphipods are represented in all types of subterranean habitats such as: interstitial, including hyporheic, hypotelminorheic, phreatic, deep cracks, anchihaline caves, different types of sediments in littoral and sublittoral marine zone. Some stygobiotic taxa are specific for particular biotopes, like *Hadzia fragilis* S. Karaman, *Pseudoniphargus adriaticus* (S. Karaman) and *Salentinella angelieri* Dellamare Debouteville *et* Ruffo mostly recorded near the coast in brackish underground water. The genus *Bogidiella* Hertzog is found in interstitial underground waters of the inland region and near the coast.

Some taxa of *Niphargus* inhabit specific epigean biotopes such as stony and grown-over brooks, karstic springs, forest ditches with fallen leaves and eutrophic pools: *Niphargus elegans zagrebensis* S. Karaman, *N. hrabei* S. Karaman, *N. ilidzensis dalmatinus* Schäferna, *N. krameri* Schellenberg, *N. tauri jurinaci* S. Karaman, *N. tauri medvednicae* Karaman and *N. valachicus* (Dobreanu *et* Manolache). The taxa of the

Tab. 7. Stygobiotic and stygophilic amphipods of fresh and brackish water in Croatia with notes on endemics.

Families	Genera	Total species	Number of endemic species
Bogidiellidae	*Bogidiella* Hertzog	4	1
Crangonyctidae	*Synurella* Wrzesniowski	1	
Gammaridae	*Accubogammarus* G. Karaman	1	
Hadziidae	*Hadzia* S. Karaman	1	
Melitidae	*Melita* Leach	2	
Niphargidae	*Niphargus* Schiödte	52	19
Pseudoniphargid-group	*Pseudoniphargus* Chevreux	1	
Salentinellidae	*Salentinella* Ruffo	1	
Typhlogammaridae	*Typhlogammarus* (Schäferna)	1	
Total number of species		64	20

genus *Niphargus* mentioned here are only eyeless. When some of subterranean species are found in superficial biotopes, for example reservoirs, it could be a sign that there is a spring at the bottom of such habitats (the Ponikve reservoir, island of Krk).

Populations of *Synurella ambulans* (Müller) are widely represented in Croatia. They are common inhabitants of interstitial waters next to streams, eutrophic waters next to flooding rivers, together with the species *Niphargus valachicus. Synurella ambulans* is also noted at the bottom of deep lakes (the lake Vransko jezero, island of Cres – at a depth of 50 to 70 m).

• Thermosbaenacea by SANJA GOTTSTEIN MATOČEC

The first representative of the group in Croatia was described by S. KARAMAN (1953b). When surveying underground habitats in coastal areas near Dubrovnik, he discovered a new shrimp species in an anchihaline cave in Cavtat and named it *Monodella halophila* S. Karaman.

The coastal anchihaline caves of South Dalmacija are inhabited by *Monodella halophila*. The species is noted in habitats with high saline characteristics (up to about 30‰) in Croatia, differently than its close relatives in Greece and the northern coast of Italy, where they may be found in freshwater habitats (SKET, 1986a).

• Decapoda by SANJA GOTTSTEIN MATOČEC

In the first half of the 20th century, subterranean decapods were investigated by BABIĆ (1922) and G. MÜLLER (1931b). BABIĆ (1922) described the new taxon *Troglocaris anophthalmus intermedia* Babić (syn. *Troglocaris schmidti intermedia* Babić) in the Kordun region, NW Dinarides. G. MÜLLER intensively explored subterranean fauna in the coastal areas of Croatia. Taxonomic research of subterranean decapods in Croatia in comparison to fauna in Bosna and Herzegovina was carried out by MATJAŠIČ (1958a). Distribution pattern and taxonomical research on the genus *Troglocaris* Dormitzer and *Spelaeocaris* Matjašič has recently been started by GOTTSTEIN (GOTTSTEIN *et al.*, 1997, 1999).

In Croatia, the recorded subterranean decapods are the freshwater shrimps *Troglocaris* (Natantia, Atyidae) and they are the characteristic inhabitants of hypogean freshwaters in the Dinarides. *Troglocaris* is spread from the coast (anchihaline caves and wells) to caves far into the continental part on the very northern edge of the Dinarides. It lives in biocenosis with *Proteus* and isopods *Monolistra* Gerstaecker, plus the epigean shrimp *Palaemonetes antennarius* (H. Milne Edwards) (GOTTSTEIN MATOČEC & KEROVEC, 2002).

The shrimp family Atyidae is represented by four stygobionts in Croatia. *Troglocaris anophthalmus anophthalmus* (Kollar) occupies subterranean waters in Istra, while *Troglocaris anophthalmus intermedia* Babić is restricted to the hypogean waters of the Kordun region (W Croatia). The specimens of *Troglocaris* found in the coastal region of Croatia (Dalmacija) could constitute a new taxon. Of the family Atyidae, in southern Croatia, a subterranean shrimp *Spelaeocaris pretneri* Matjašič has been noted (Fig. 9), previously known in Bosnia and Herzegovina and Montenegro. It can be found in

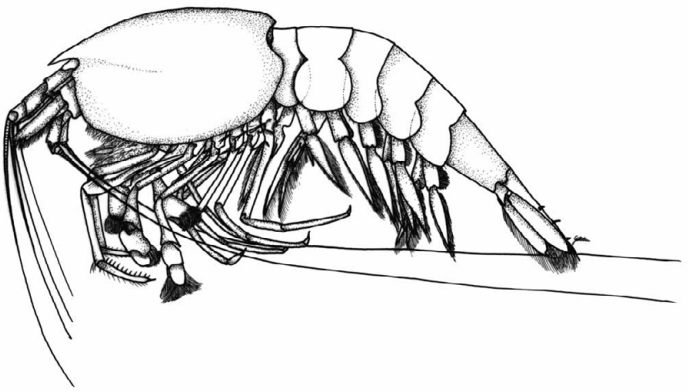


Fig. 9. Decapoda, Atyidae. *Spelaeocaris pretneri* Matjašič; adult male (27 mm) from a man-made cavern in the Cetina valley (drawing by S. GOTTSTEIN MATOČEC).

springs and man-made caverns containing water originating from South Herzegovina (GOTTSTEIN *et al.*, 1999).

In a submarine cave next to the island of Levrnaka in the Kornati archipelago SKET found a new species of a marine shrimp *Salmoneus sketi* Fransen (Natantia, Alpheidae) (FRANSEN, 1991).

Spring-caves, cave sources and sinkholes may be inhabited with epigean species of the family Astacidae: *Astacus astacus* (Linnaeus), *Austropotamobius torrentium* (Schrank) and *Austropotamobius pallipes italicus* (Faxon).

Hydracarina by ROMAN OZIMEC

During research of interstices of the surroundings of Zagreb the water mite fauna has been described. From the group Hydrachnellae in the interstitial waters of the Zagreb environs a stygophilic species *Partnunia angusta* (Koenike) has been found, among stygoxenic members of families Sperchonidae and Labertiidae (LATTINGER, 1988).

Diptera by SANJA GOTTSTEIN MATOČEC and ROMAN OZIMEC

In the interstitial waters of the environs of Zagreb close to the Sava River, and in the interstitial waters of the rivers Drava (NW Croatia), Neretva (S Croatia) and Rječina (Rijeka surroundings) huge number of taxa from the Chironomidae have been recorded. More than 20 taxa of chironomid larvae have been found in the hyporheic. The more abundant populations are of those species which endure greater fluctuations of temperature and of dissolved oxygen and carbon dioxide. The majority of them feed on detritus or are predators. They prefer stony-gravelly or gravelly-sandy river-bed with detritus (MEŠTROV & LATINGER-PENKO, 1977/78; MEŠTROV & TAVČAR, 1972; TAVČAR & MEŠTROV, 1970). Lately, material has been collected occasionally and has not been researched.

VERTEBRATES

Pisces and lampreys by NIKOLA TVRTKOVIĆ and MARIJANA FRANIČEVIĆ

There are no stygobiotic species of fishes and lampreys in Croatia, but some endemic stygoxene taxa do exist. The oldest data about the underground life of Dinaric karst freshwater fish (»Gobize« Raguseis = *Phoxinellus ghetaldii*) in the cave systems in the Ragusa (Dubrovnik) area and Popovo polje (Herzegovina) are in letters from Jakov Sorkočević to Ulisse Aldrovandi in 1584 (GRMEK & BALABANIĆ, 2000). The first scientific descriptions of stygophilic taxa were given by HECKEL (1843), HECKEL & KNER (1858) and STEINDACHNER (1882, 1886), and later by M. KARAMAN (1972). Their taxonomic positions are still under revision (MRAKOVČIĆ *et al.*, 1996; KOTTELAT, 1997; BOGUTSKAYA & ZUPANČIČ, 1999; ZUPANČIČ & BOGUTSKAYA, 2000). The most common in the subterranean waters of the Adriatic basin and the Croatian karst part of the Danube drainage basin are the Cyprinidae: *Aulopyge hugelii* (Heckel), *Leuciscus polylepis* (Steindachner), *L. svallize* (Heckel *et* Kner), *L. turskyi* (Heckel), *Phoxinellus adspersus* (Heckel), *P. croaticus* Steindachner, *P. ghetaldii* Steindacher and *P. fontinalis* M. Karaman. One gobiid, *Knipowitschia croatica* (Mrakovčić *et al.*), and the Po Brook Lamprey *Lethenteron zanandreai* (Holčik *et* Mrakovčić) probably spend only part of their life cycle in the subterranean waters near Vrgorac (Dalmacija).

Some scarce observations concerning the interesting stygophilic ecology of *Phoxinellus* species are to be found in TRGOVČEVIĆ (1905) and SPANDL (1926), but some other authors have concluded that the Po brook lamprey (HOLČIK & MRAKOVČIĆ, 1997) and other endemic fish (VUKOVIĆ & IVANOVIĆ, 1971; MRAKOVČIĆ *et al.*, 1996) probably live underground during summer, and in some cases in winter too. Their presence in the surface streams, and their return to the groundwater (via the karstic springs, and thus deliberately, and not the result of being passively sucked in via the swallow holes) are probably conditioned by the water regime, water temperature and the availability of food. They stay in the groundwater for up to several months, as long as half a year. In most cases they spawn in surface waters, but some species probably spawn underground. All of them are on the Red Data List (POVŽ *et al.*, 1990; MRAKOVČIĆ *et al.*, 1995; TVRTKOVIĆ, 2001). Threats are water supply operations, pollution, dam construction and the introduction of new predators.

Amphibia by EDUARD KLETEČKI, BRANKO JALŽIĆ and TONĆI RAĐA

Olm (*Proteus anguinus* Laurenti)

The olm is an endemic stygobiont of Slovenia, the Trieste region in Italy, Croatia and Bosnia and Herzegovina. It inhabits subterranean waters of the Dinarides. In KLETEČKI *et al.* (1996), 47 records of distribution within Croatia are listed. Since then, ten more records have been obtained (Tab. 8), as shown on the map of distribution (Fig. 10). Nine of them are new data (Tab. 8, no. 1), while one is an old record by HIRC (1905) and mentioned in SKET (1997).

Seventy two years passed from the first scientific description of the olm (LAURENTI, 1768) to the first record of the species in the Croatian karst region. The first specimen was found in 1840 in the spring of Goručica near Sinj. FITZINGER (1850) wrote

Tab. 8. The list of the localities of *Proteus*. * = Certain findings; √ = Collected and preserved; □ = Most probably erroneous data; + = Collected and released; ▯ = Observed; ? = This sign was used in the table when the exact date of observing or collecting of the animals was not known; Collections: BD-FSE – Biological Department of Faculty of Science and Education, Split.

	UTM	List of localities	Date of collecting or observing	Collection, author or observer
1.	WL35	Ozaljska pećina cave, Ozalj □	?	(HIRC, 1905) (SKET, 1997)
2.	WL10	Rupećica spring, village Ivanci near village Zagorje, Ogulin *	1983: August or September (+)	JALŽIĆ, B. (information given by local people – collected and released 2 specimens)
3.	WL10	Zagorska peć cave, the spring of the Zagorska Mrežnica *	1999: January 2 (▯)	JALŽIĆ, B.
4.	WK09	Komarčeva cave I and II near Crno vrelo, Drežnica *	1999: August 17–18 (▯)	DOWAGNE, A. M.
5.	WJ87	Miljacka III cave (N. P. »Krka«), Šibenik *	1999: October 24 (▯)	JALŽIĆ, B.
6.	WJ87	Miljacka V cave (N. P. »Krka«), Šibenik *	1999: October 18 (▯)	LACKOVIĆ, D.
7.	WJ75	Pothole near Torak lake, Čikola river, (N.P. »Krka«), Šibenik *	1998: April 27 (▯)	JALŽIĆ, B.
8.	XJ43	Periodical spring in Vedrine village near Trilj *	1997: January 13 (√)	RAĐA, T. and RAĐA, B., BD FSE
9.	XH98	Kokorići village near Vrgorac *	1998: January (▯)	PERVAN, M. (KAPOVIĆ, 1998)
10.	XH98	In the spring near Čulića jama (Dropulića jama) pothole, Lukavac village near Vrgorac *	1999: January 14 (+)	ŠALINOVIĆ, N (inf. AJDUKOVIĆ)

about this finding, describing the olm as a new species *Hypochthon carrarae*. FITZINGER (1850), in the same article, quoted also the finding of the *Hypochthon carrarae* in the valley of the Neretva River and described other species of olm from the whole range of distribution recognised in that time. Later investigations denied the validity of this and other species of olm that he described (they were not recognised neither as subspecies – MERTENS & MÜLLER, 1940; MERTENS & WERMUTH, 1960; GRILLITSH & TIEDEMANN, 1994). With new methods of morphologic and genetic research, two new subspecies of olm are defined. One of them is in Slovenia (SKET & ARNTZEN, 1994), the other in Istra, Croatia (SKET, in preparation).

After the finding of the olm in the spring Goručica, written about by many authors (for example, PAGANETTI-HUMMLER, 1902; LANGHOFFER, 1912; 1915a), as well as Fitzinger, whose findings have been repeated several times with more specimens (e. g., BRUSINA, 1908), data about the finding of olm started to come from other localities from all around the karst region of Croatia. Many authors wrote about the findings, but even more of them made reviews of already known findings. The last

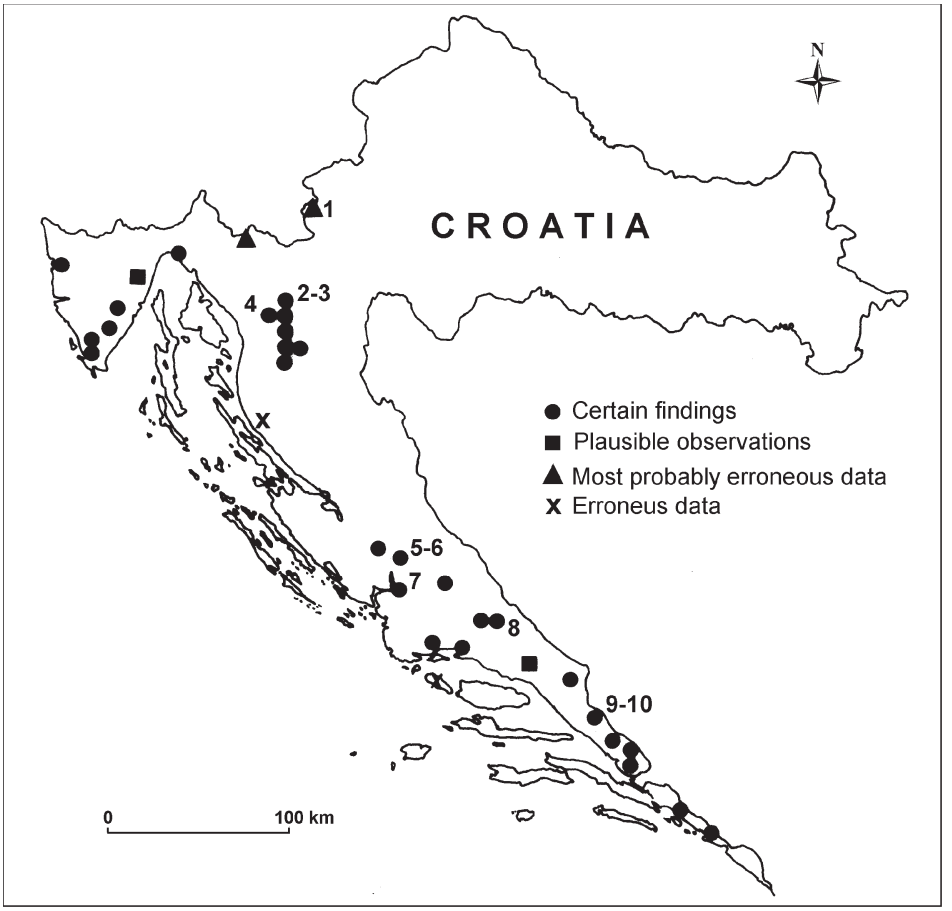


Fig. 10. The map of *Proteus* finding places in Croatia (the finding places mentioned in Tab. 8 are marked with numbers).

reviews were given by SKET (1997) and DURAND (1998). More intensive surveys of the Croatian underground are leading to a constant increase in the number of finding places.

6.2. Hypogean terrestrial fauna

INVERTEBRATES

Mollusca

• Gastropoda by VESNA ŠTAMOL

So far there has been no systematic research into terrestrial malacofauna in Croatian caves. The knowledge obtained in the 19th and the first half of 20th centuries is a result of random collecting activity during (bio)speleological surveys or during sys-

tematic research into surface fauna in some parts of Croatia. Successful collectors from that period (the 19th and first half of the 20th C.) were a Czech entomologist and biospeleologist K. ABSOLON, the Austrian coleopterologist G. PAGANETTI-HUMMLER and another Austrian, the herpetologist and orthopterologist F. WERNER. Many of taxa they collected were new species or subspecies, described by experienced malacologists of the time – R. STURANY (1901, 1908) and A. J. WAGNER (1914). Only few Croatians collected cave malacofauna at that time (A. E. JURINAC, M. ŠNAP, D. HIRC, A. LANGHOFFER), most of them not malacologists. This may be a reason why, judging from the quantity of their malacological cave material and the general abundance of cave fauna in the malacological collections of the Croatian Natural History Museum (ŠTAMOL, 1998), they have collected so few snails. However, one of them has to be pointed out – the entomologist A. LANGHOFFER (1912, 1915a, 1915b) who was the first to make lists of cave fauna, mostly of NW Croatia, including snails. The only malacologist of the time, who intensively researched (collected and scientifically analised) cave malacofauna in the region of ex-Yugoslavia including Croatia, was the Slovene L. KUŠČER. As a result, new taxa were found and ranges were better defined (KUŠČER, 1925, 1932, 1933).

In the second half of the 20th century most collectors of cave terrestrial snails were malacologists. The most important were the Slovenes J. BOLE and F. VELKOVRH, the Pole A. RIEDEL, the German P. SUBAI, the Hungarian A. SZIGETHY, and the Croat T. RAĐA. Their researches are highly focused on a particular systematic group, and thus the published results are in their areas of interest (BOLE, 1961b, 1974, 1975; PINTÉR & RIEDEL, 1973; PINTÉR & SZIGETHY, 1973; RAĐA, 1984; RIEDEL, 1960, 1996; RIEDEL & RAĐA 1983; RIEDEL & SUBAI, 1993; ŠTAMOL *et al.*, 1999b). The rest of the collected material is placed in private or institutional malacological collections and only partially described (MAASSEN, 1989; ŠTAMOL, 1997; ŠTAMOL *et al.*, 1999a). Hence the knowledge of terrestrial cave malacofauna of Croatia does not coincide with the quality of collected material and the intensity of collecting activities. Unfortunately, the archived material is not adequate for a proper description of Croatian cave terrestrial malacofauna due to lack, as mentioned previously, of systematic research.

It is difficult to define the exact number of troglobiotic taxa of terrestrial gastropods, due to different definitions of the term »troglobiont«, due to inadequate knowledge of morphology and biology of taxa and because of non-defined taxonomic status. If we accept the status of the species and subspecies of the genus *Zospeum* after BOLE (1974), later partly reviewed by SLAPNIK (1994), one can assume that in Croatia 19 troglobiotic species of terrestrial snails exist (or 24 species including taxa with an uncertain troglobiotic status, see Tab. 9). According data published in the Encyclopaedia Biospeologica (JUBERTHIE & DECU, 1994), the number of troglobiotic species in Croatia is the biggest among European countries and accounts for one fourth of the assumed 80 terrestrial, troglobiotic and troglophilic snail species worldwide (BERNASCONI & RIEDEL, 1994). Some troglobiotic species are represented in Croatia with one subspecies: *Zospeum spelaeum schmidti* (Frauenfeld), *Z. alpestre likanum* Bole, *Gyralina candida candida* (A. J. Wagner). One troglobiotic species in Croatia even has two subspecies: *Spelaeoconcha paganettii* Sturany with subspecies *S. p. paganettii* and *S. p. polymorpha* A. J. Wagner (MAASSEN, 1989). We should

Tab. 9. List of troglobiotic species and subspecies of Gastropoda in Croatia. ? – question mark in front of taxon name means that the troglobiotic status of the taxon is not well defined; E = Croatian endemic taxon, L = taxon has its *locus typicus* in Croatia; **Zospeum exiguum* is a species that can live for a longer period in water and thus some authors place this member of the genus *Zospeum* in the list of aquatic snails.

Orders and families	Species or subspecies	E	L
Architaenioglossa			
Cyclophoridae	*Pholeoteras euthrix* Sturany	–	–
Aciculidae	*Platyla elisabethae* (Pintér *et* Szigethy)	+	+
Pulmonata			
Carychiidae	*Zospeum spelaeum schmidti* (Frauenfeld)	–	–
	Zospeum alpestre likanum Bole	+	+
	Zospeum kusceri A. J. Wagner	–	–
	Zospeum subobesum Bole	–	+
	Zospeum isselianum Pollonera	–	–
	Zospeum pretneri Bole	+	+
	Zospeum amoenum (Fraunenfeld)	–	–
	**Zospeum exiguum* Kuščer	–	–
Argnidae	*Agardhiella formosa* (L. Pfeiffer)	–	–
Pupilloidea incertae saedis	*Spelaeoconcha paganettii paganettii* Sturany	+	+
	Spelaeoconcha paganettii polymorpha A. J. Wagner	+	+
Ferussaciidae	? *Cecilioides acicula jeskalovicensis* A. J. Wagner	+	+
	Cecilioides spelaea A. J. Wagner	–	–
Pristilomatidae	? *Vitrea subaii* Pintér *et* Riedel	+	+
	? *Vitrea zilchi* Pintér	+	+
	Gyralina cyrcumlineata (L. Pfeiffer)	–	–
	Gyralina candida candida (A. J. Wagner in Wohlberedt)	–	–
	Gyralina mljetica (Pintér *et* Riedel)	+	+
	? *Oxychilus perspectivus sinjanus* (A. J. Wagner)	+	+
Milacidae	? *Tandonia cavicola* (Simroth)	–	+
Zonitidae	*Meledella werneri* Sturany	+	+
	Troglaegopis mosorensis (Kuščer)	+	+
	Aegopis spelaeus A. J. Wagner	–	–

mention subspecies found only once, only in caves. However, their troglobiotic status is questionable, and they are not members of troglobiotic species: *Oxychilus perspectivus sinjanus* (A. J. Wagner) and *Cecilioides acicula jeskalovicensis* A. J. Wagner. The most numerous troglobiotic representatives are members of the family Carychiidae, genus *Zospeum* (8 taxa).

All mentioned troglobiotic taxa have limited ranges of distribution. They are found either in Croatia, or in most cases in Croatia and only one or a few surrounding countries. Twelve taxa (7 species and 5 subspecies) are endemic to Croatia. The most interesting are two monotypic endemic Croatian genera of very narrow ranges – the genus *Meledella* and its species *M. werneri* Sturany (Fig. 36), to

date found only on the island of Mljet (ŠTAMOL, 1997) and the genus *Troglaegopis*, species *T. mosorensis* (Kuščer) found at Mts Svilaja and Mosor (RIEDEL & RAĐA, 1983; RAĐA, 1984). These snails, including the troglobiotic species *Aegopis spelaeus* A. J. Wagner, endemic to Croatia and Herzegovina, are the biggest cavernicolous members of the family Zonitidae and the biggest terrestrial cave snails at all (ŠTAMOL *et al.*, 1999b). Two members of the Acteophila, *Zospeum alpestre likanum* and *Z. pretneri* Bole have a narrow range; they are found in caves in the Gračac area (BOLE, 1974). A monotypic genus *Spelaeoconcha* with the species *S. paganettii* Sturany is of a wider range. This is the first described troglobiotic species of cave terrestrial gastropod in Croatia, and its *locus typicus* is on the island of Korčula.

Troglophilic taxa of terrestrial snails are far more numerous than troglobiotic taxa. Members of the genus *Oxychilus* Fitzinger dominate as they are the most common Stylommatophora in caves (RIEDEL, 1996). Commonly found in caves are members of the genera: *Acicula* W. Hartmann, *Platyla* Moquin-Tandon, *Renea* Nevill, *Hypnophila* with *H. pupaeformis* (Cantraine), *Agardhiella* P. Hesse, *Gittenbergia* with *G. sororcula* (Benoit), *Discus* Fitzinger, *Hohenwartiana* with *H. hohenwartii* (Rossmässler), *Vitrea* Fitzinger, *Aegopis* Fitzinger, *Cecilioides* A. Férussac, *Chilostoma* Fitzinger, etc. For many of them, the troglophilic or trogloxene status is not defined.

Crustacea

• Isopoda by JANA BEDEK and SANJA GOTTSTEIN MATOČEC

The earliest records concerning subterranean terrestrial isopods in Croatia are from the 19th century. The most detailed surveys were done by K. VERHOEFF, H. STROUHAL, Z. FRANKENBERGER, A. VANDEL and A. KESSELYAK. The German zoologist K. VERHOEFF was the first systematically to collect terrestrial isopods, during his travels in 1894 and 1897. He described numerous subterranean endemic species and genera of the Dinarides (VERHOEFF, 1930, 1931b, 1938). The Viennese zoologists STURANY, REBEL, PAGANETTI-HUMLER and others collected terrestrial isopods on their excursions, too. The collected material is described in several articles by H. STROUHAL (1938, 1939a, b, c, d, 1940), who worked on the terrestrial isopods of the Balkans. The well-known researcher of cave fauna, K. ABSOLON, from Brno, worked in the Croatian karst during a 40-year-long-period (1900 – 1940). This comprehensive material was partially described by H. STROUHAL in the monograph »Biospeologica balcanica«. J. KRATOCHVIL collected terrestrial isopods when he researched the cave fauna of spiders, and the material is described by Z. FRANKENBERGER, and the results published in numerous articles (FRANKENBERGER, 1937, 1938a, b, 1939, 1940; FRANKENBERGER & STROUHAL, 1940). The French zoologist P. REMY, a specialist in aquatic isopods, visited Croatia several times between the two world wars, making an interesting collection of terrestrial isopods, later described by A. VANDEL (1946). In Istria, terrestrial isopods are described as new taxa in several works by A. KESSELYAK (1930) and A. ARCANGELI (1931–32, 1937–38). In the period from 1953 to 1960 A. BUTUROVIĆ (1955a, b, c) described many new terrestrial isopod species in coastal parts of Croatia, including the islands. In the 80s and 90s intensive research was carried out by F. POTOČNIK (1993).

In the fauna of Croatia, a total of 35 cavernicolous species (51 species and subspecies) of terrestrial isopods of four families, and 16 genera have recently been recorded (POTOČNIK, 1993; BEDEK, 2001). Most of the terrestrial cave isopods (20 taxa – species and subspecies) are endemic to Croatia, with the biggest number being recorded on the Dalmatian islands (9 taxa).

The most represented family in the Croatian underground is Trichoniscidae with 10 genera. The majority of the taxa from the genus *Androniscus* are endemic to Istra and Hrvatsko Primorje (Kvarner). Most of the endemic taxa are very rare and endangered. Nine taxa of the genus *Alpioniscus* inhabit the underground of Croatia. Out of them, 5 taxa are noted only on type localities – *locus typicus*, mostly islands of Southern Dalmacija, such as Brač, Hvar and Korčula. An exception is the cavernicolous species *Alpioniscus christiani* Potočnik, known only from the type locality outside of Southern Dalmacija – Vitezićeva pećina next to Omišalj (the island of Krk). Of *Aegonethes*, in Dalmacija, the trans-adriatic cavernicolous species *Aegonethes cervinus* (Verhoeff) is widespread, and is known from several potholes on the island of Mljet, Korčula, Vis and the surroundings of Cavtat. *Aegonethes antilocarpa* Frankenberger is noted in several potholes of the islands of Vis and Korčula only. *Titanethes* with 3 species that inhabit the underground of Croatia is one of the typical representatives of the subterranean fauna of the Dinarides. Due to its considerable hygrophilic characteristics, it lives in trickles and small pools in caves. *Stylohylea*, *Trichoniscus*, *Troglocyphoniscus*, *Cyphopleon* and *Cyphoniscellus* are represented in sub-

Tab. 10. Subterranean terrestrial isopods in Croatia with notes on endemics.

Families	Genera	Number of species	Number of endemic species
Armadillidiidae	*Troglarmadillidium* Verhoeff	2	1
	Echinarmadillidium Verhoeff	1	0
	Cyphodillidium Verhoeff	1	1
	Armadillidium Brandt	1	1
Oniscidae	*Strouhaloniscus* Arcangeli	3	3
Porcellionidae	*Porcellio* Latreille	1	0
Trichoniscidae	*Androniscus* Verhoeff	4	1
	Aegonethes Frankenberger	2	1
	Alpioniscus Racovitza	9	5
	Titanethes Schiödte	3	0
	Stylohylea Verhoeff	1	0
	Trichoniscus Brandt	1	0
	Haplophthalmus Schöbl	3	0
	Troglocyphoniscus Strouhal	1	1
	Cyphopleon Frankenberger	1	1
	Cyphoniscellus Verhoeff	1	0
Total	16 genera	35	15

terranean fauna with one taxon each. Members of the genus *Haplophthalmus* are found in caves only occasionally and are epiedaphic to euedaphic species.

Of the Oniscidae, the endemic troglophilic species *Strouhaloniscus dalmaticus* (Strouhal, 1937) is found only in Dalmacija (M. KARAMAN, 1966). However, it is not known whether it is a truly carvenicolous species. The two other species of the genus *Strouhaloniscus* are endemic to the Adriatic islands: *S. meledensis* (Strouhal) (the cave Jama Ostaševica, island of Mljet) and *S. stentai* (Arcangeli) (the cave Jama Činjandra and the cave near village Murvica, island of Brač) (ARCANGELI, 1926). *Chaetophiloscia* is also represented in the underground.

The third family with troglobiotic taxa in Croatia is Armadillidiidae with the endemic species *Troglarmadillidium* (*Typhlarmadillidium*) *kratochvili* (Frankenberger) from the island of Korčula, and the endemic genus *Cyphodillidium* from the island of Mljet (Fig. 38) and *Armadillidium dalmaticum* (Strouhal) found in caves (potholes) in Dalmacija. The troglophilic genus *Echinarmadillidium* is also represented underground (STROUHAL, 1934).

Of Porcellionidae, the troglophilic species *Porcellio longicornis* Stein is found in Croatian caves.

Many hygrophilic species can be found among carvenicolous terrestrial isopods. As there are a considerable number of endogeic taxa in caves, it is difficult to define them as truly troglobiotic species and subspecies.

Arachnida by ROMAN OZIMEC

Arachnids are one of the most diverse groups of animals in the subterranean habitats of Croatia. Most of them are predators, and therefore the number of specimens in a particular area is smaller than the number of specimens of other groups. On the other hand, numerous relict and endemic species of arachnids are found in Croatia.

Almost all cavernicolous forms are endemic in the Dinarides. Arachnids constitute the most numerous endemic taxa among all animal groups (almost 100 taxa are endemic for Croatia). Biodiversity is the biggest in the Mediterranean and Submeditteranean zone, particularly in the underground of Mt Velebit, Mt Biokovo and

Tab. 11. Arachnid orders with cavernicolous species listed according to number of cavernicolous taxa in Croatia. (No. indicates number of cavernicolous taxa.)

Orders	Number of genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Pseudoscorpiones	8	60	40
Araneae	27	66	35
Opiliones	13	23	13
Acari	15	22	7
Palpigradida	1	1	1
TOTAL	64	172	96

Southern Dalmacija (the Dubrovnik area). Due to the long period of adaptation to cavernicolous habitats, many of the species have expressive troglomorphic traits with total eye reduction, depigmentation and extraordinarily long extremities.

Spiders and pseudoscorpions are the better researched groups, the opiliones less, while mites and palpigrades are poorly known. Of the order Scorpiones, no cavernicolous taxon has yet been found, but depigmented forms of the taxa *Euscorpius carpathicus* (L.) and *E. italicus* (Herbst) that survive in cave conditions are common (HADŽI, 1964).

The number of taxa known to date in Croatia of the class arachnids is not definitive. It is very likely that the total number will increase after the description of recently collected specimens of the group throughout Croatia.

– Palpigradida by ROMAN OZIMEC

Only one specimen of cavernicolous palpigrades (Palpigradida) from the family Eukoeneniidae, described as the new subspecies *Eukoenia spelaea hauseri* Condé, has been found, in a cave in the Lika region. Records of other cavernicolous palpigrades of the genus *Eukoenenia, E. austriaca* (Hansen) and *E. remyi* Condé are found near the Croatian borders thus implying that these species also live within the Croatian karst. Recently, cavernicolous palpigrades have been collected in South Istra (the environs of Pula), North Istra (Mt Ćićarija), in the Paklenica National Park (Mt South Velebit) and in the Biokovo Natural Park (Mt Biokovo).

– Araneae by ROMAN OZIMEC

The first cavernicolous spider in Croatia, *Hadites tegenarioides* was described a long time ago by KEYSERLING (1862). Papers describing cave species, mostly of the family *Dysderidae*, genus *Stalita* Schiodte (THORELL, 1870; CHYZER & KULCZYNSKI, 1897) followed. At the beginning of the 20th century KULCZYNSKI (1914), DI CAPORIACCO (1927), REIMOSER (1929) described new cavernicolous taxa. Based on material collected from caves in Kordun the male of the species *Parastalita stygia* (Joseph) was described (POLJUGAN, 1915). GIROMETTA (1929) listed for the fauna of a cave in Central Dalmacija the species *Stalita giromettai* nom. nud. Based on material collected by P. PARENZAN in south Istra, a new species from the genus *Theridion* Walckenauer was described (TROSSARELLI, 1931).

Research into subterranean spiders reached a peak in the 30s in the numerous works of the Czech biospeleologists K. ABSOLON, J. KRATOCHVIL and F. MILLER. Cavernicolous spiders of the family *Dysderidae*, and the genera *Histopona* Thorell, *Sulcia* Kratochvil, *Barusia* Kratochvil, *Stygopholcus* Kratochvil, *Tegenaria* Latreille and *Troglohyphanthes* Joseph (ABSOLON & KRATOCHVIL, 1932, 1933; KRATOCHVIL, 1938b, c, 1940, 1948; KRATOCHVIL & MILLER, 1939, 1940) were described and surveyed. New species of genera *Asthenargus* Simon *et* Fage, *Amaurobius* C. L. Koch and *Meta* C. L. Koch were described, and the first list of cavernicolous spiders of the region (MILLER, 1938; KRATOCHVIL, 1934, 1942) was made. After the Second World War, J. KRATOCHVIL and F. MILLER continued surveying subterranean spiders, accompanied by F. NIKOLIĆ from Croatia, A. POLENEC from Slovenia, C. DEELEMAN-REINHOLD from the Netherlands and M. BRIGNOLI from Italy. The family *Dysderidae* (KRATOCHVIL,

1970; DEELEMAN – REINHOLD, 1971b, 1993), the genera *Lepthyphantes* Menge, *Troglohyphantes* Joseph and *Histopona* Thorell (F. MILLER, 1978; C. DEELEMAN – REINHOLD, 1978, 1983, 1985) were surveyed. Moreover, the distribution range and evolution of subterranean spiders (NIKOLIĆ, 1961), including cavernicolous spiders of the Dalmatian coast and islands (KRATOCHVIL, 1978; BRIGNOLI, 1971, 1978) were investigated.

A list of the spider fauna of this part of Europe, including cavernicolous forms, was published by F. NIKOLIĆ with the help of A. POLENEC (NIKOLIĆ & POLENEC, 1981); apart from this, the cavernicolous fauna of Croatia was included in a review of world cavernicolous spider fauna (RIBERA & JUBERTHIE, 1994). Lately, Croatian cave spiders have been investigated by F. GASPARO, R. OZIMEC and others.

Spiders are the richest group of Arachnids in the caves of Croatia, speaking in terms of the diversity. At the moment, more than 60 cavernicolous taxa are recognised, of 11 families and 27 genera and more than 50% of them are endemic to Croatia.

Amaurobiidae. *Amaurobius kratochvili* Miller is an endemic taxon of the central Dalmatian islands of Brač and Hvar. *Titanocoeca flavimana* Koch has been found in a South Istrian cave.

Dysderidae. Among the best adapted to cave conditions are some members of Dysderidae, which is represented in the Croatian underground by five genera: *Stalita* Schiodte, *Parastalita* Absolon *et* Kratochvil, *Mesostalita* Deeleman-Reinhold, *Folkia* Kratochvil and *Stalagtia* Kratochvil (Fig. 40). In addition to the numerous species there are six endemic species: *Stalita pretneri* C. L. Deeleman-Reinhold, from Mt Velebit, *Mesostalita comottii* (Gasparo), from Mt Biokovo, *Folkia haasi* (Reimoser) from the island of Korčula, *Folkia inermis* (Absolon *et* Kratochvil) and *F. subcupressa* Deeleman-Reinhold of Southern Dalmacija and *Folkia boudewijni* Deeleman-Reinhold, of the surroundings of Split. The status of *Stalita spinosissima* Kulczynsky described from a cave from the Gorski Kotar region is still under question.

Leptonetidae. Five species from the genera *Sulcia* Kratochvil and *Barusia* Kratochvil, are represented. All of them are endemic taxa of the Dalmatian islands: Hvar, Brač, Korčula and Mljet.

Pholcidae. Representatives of a troglophilic species *Pholcus phalangioides* (Fuesslin) have been found, as well as the species *Stygopholcus absoloni* (Kulczynski), which is better adapted to cave conditions.

Theridiidae are represented by the troglophilic species *Plocamis cavernicola* Kulczynski described from the Kvarner region and *Theridion parenzani* Trossarelli described from a cave in south Istra.

Nesticidae are represented by two troglophilic species of the genus *Nesticus* – *N. cellulans cellulans* (Clerck) and *N. speluncarum* Pavesi. The last one is better adapted to cave conditions than previous one.

Linyphiidae. In the subterranean habitats of Croatia, the best represented family is Linyphiidae. Besides the troglophilic and lucifugous species of the genera *Asthenargus* Simon *et* Fage, *Porrhomma* Simon, *Centromerus* Dahl and *Lepthyphantes* Menge, there are 14 taxa of the genus *Troglohyphantes*, most of them completely adapted to

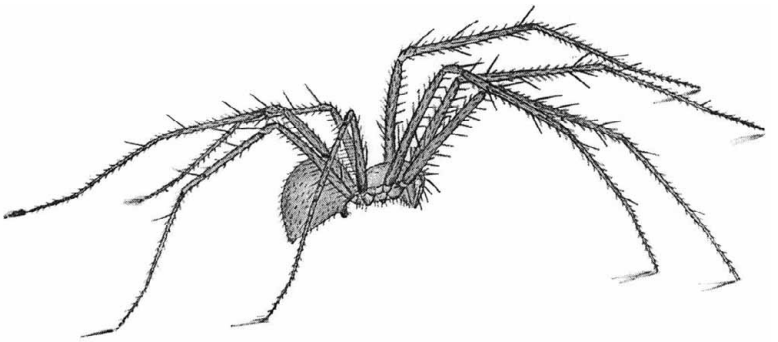


Fig. 11. Araneae, Linyphiidae. *Typhlonyphia reimoseri* Kratochvil, an endemic cave spider from the island of Korčula (after KRATOCHVIL 1935, modified).

carvernicolous conditions (*T. brignolii* Deeleman-Reinhold, *T. dinaricus* Kratochvil, *T. giromettai* Kulczynski, *T. kordunlikanensis* Deeleman-Reinhold, *T. liburnicus* Caporiacco, *T. roberti* Deeleman-Reinhold, *T. strandi* Absolon *et* Kratochvil, etc.) and all are endemic in Croatia. The genus *Typhlonyphia* Kratochvil was described from the island of Korčula based on a troglobiotic, endemic and relict species *T. reimoseri* Kratochvil, a supposed representative of the pre-tertiary fauna (Fig. 11). Recently, the species has been found on Mt Biokovo.

Mycriphantidae are represented by two troglophilic and lucifugous species *Diplocephalus cristatus* (Blackwell) and *Porrhomma pygmaeum* (Blackwell), found in the continental part of Croatia.

Metidae are represented by troglophilic members of the genus *Meta* (*M. menardi* Latreille, *M. merianae* Scopoli), regularly found in cave entrances. *Meta bourneti* Simon is found only in one cave in Dubrovnik. *Meta milleri* Kratochvil, is an endemic taxon of Dalmacija (surroundings of Sinj).

Agelaenidae are represented by cavernicolous taxa of the genera *Histopona* Thorell and *Tegenaria* Latreille, some of them being endemic. *Histopona bidens* Absolon *et* Kratochvil is endemic to the island of Mljet, while *H. egonpretneri* is endemic to Mt South Velebit, and has been described from a cave in Paklenica NP. The troglophilic *Tegenaria decolorata* Kratochvil *et* Miller is endemic to the island of Krk. The endemic genus *Hadites*, species *H. tegenarioides* Keyserling, is widespread in the underground of the island of Hvar.

Of the family **Salticidae**, the lucifugous species *Roeweriella balcanica* Kratochvil, is found in the Slavonia region.

The distribution range and evolution of subterranean spiders have been the topic of several researches (NIKOLIĆ, 1961; DELTSHEV, 1978). Thus, from a zoogeographic point of view, Croatia extends over the Dinaric province, including all three zones: northern, central and southern, in which there are members of the pre-Tertiary fauna (*Pholcus* Walckenauer, *Typhlonyphia* Kratochvil), pre-Mesogeic (*Meta*, without *M. milleri* Kratochvil), Mesogeic (*Lepthyphanthes* Menge, *Troglohyphanthes* Joseph, *Histopona* Thorell), Egeious (*Sulcia* Kratochvil, a part of genus *Nesticus* Thorell),

Tab. 12. Cavernicolous spiders in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Amaurobidae	*Amaurobius* C. L. Koch	1	1
	Titanocoeca Thorell	1	
Dysderidae	*Folkia* Kratochvil	4	4
	Mesostalita Deeleman-Reinhold	1	
	Parastalita Absolon *et* Kratochvil	1	
	Stalagtia Kratochvil	1	
	Stalita Schiodte	5	3
Leptonetidae	*Barusia* Kratochvil	3	3
	Sulcia Kratochvil	2	2
Pholcidae	*Pholcus* Walckenauer	1	
	Stygopholcus Kratochvil	1	
Theridiidae	*Plocamis* Simon	1	
	Theridion Walckenauer	1	1
Nesticidae	*Nesticus* Thorell	2	
Linyphiidae	*Asthenargus* Simon *et* Fage	1	1
	Centromerus Dahl	1	
	Drapetisca Menge	1	
	Lepthyphantes Menge	5	2
	Troglohyphantes Joseph	14	11
	Typhlonyphia Kratochvil	2	2
Micryphantidae	*Diplocephalus* Bertkau	1	
	Porrhomma Simon	1	
Araneidae	*Meta* C. L. Koch	4	1
Agelenidae	*Hadites* Keyserling	1	1
	Histopona Thorell	6	2
	Tegenaria Latreille	3	1
Salticidae	*Roeweriella* Kratochvil	1	
TOTAL	27 genera	66	35

Hercinous (members of the family Dysderidae, *Hadites* Keyserling), Tirenidous (*Barusia* Kratochvil), Dinaric (a part of genus *Nesticus* Thorell) and western Balkan endemic fauna (*Centromerus* Dahl, *Porrhomma* Simon, *Stygopholcus* Kratochvil).

Recently, numerous findings of likely new taxa have been noted, from Istra to southern Dalmacija, including the Kordun area; therefore we can expect an increase in the recognised number of the cavernicolous spiders of Croatia.

– Pseudoscorpiones by ROMAN OZIMEC

The first findings of cavernicolous pseudoscorpions date from the year 1879 (leg. E. REITTER), from a cave in Lika, and from the year 1895 (leg. STURANY), most likely from the cave Špilja Šupljara above Lake Kaluđerovac, one of the Plitvice Lakes in Lika. In period from the beginning of 20th century, to the First World War interest in

cave fauna grew, so we know findings of pseudoscorpions collected in different parts of Croatia by V. STILLER, S. PLANČIĆ, J. POLJAK, I. HOCHETLINGER, A. LANGHOFFER, R. MEUSEL and K. ABSOLON. From 1918 to 1939, between the two world wars, cave pseudoscorpions were collected by S. KARAMAN, L. BIRO, L. MADER, M. PADEWIETH, K. STRASSER, G. MÜLLER, J. STAUDACHER and K. ABSOLON.

Only in 1928 the scientific research into the collected material started, with the description of the first Croatian endemic species – *Neobisium speluncarium* (Beier). The discovery was followed by numerous papers (BEIER, 1928, 1931; ROEWER, 1931; MÜLLER, 1931a; HADŽI, 1930, 1933), which increased the knowledge of Croatian cave pseudoscorpions.

The keystone work for the recognition of the richness of cave pseudoscorpion fauna in this part of Europe was provided by the Viennese arachnologist M. BEIER in a preliminary paper (BEIER, 1938), and in the monograph »*Die Höhlenpseudoscorpione der Balkanhalbinsel*« (BEIER, 1939).

As previously mentioned, the majority of the material collected to date, like most of the material from collection »*Biospeleologica balcanica*«, was researched and collected by K. ABSOLON and his colleagues during their thirty-year-long research into the Dinaric karst. In Croatian fauna, 22 new taxa that have troglophilic and troglobiotic features were described. After the Second World War, cave pseudoscorpions were collected by many Slovene biospeleologists, particularly in the period from 1962 to 1967 (MATJAŠIČ & SKET, 1969). Material collected from 128 caves has been surveyed by the arachnologist J. Hadži from Ljubljana, but the results are not published. A part of the mentioned material was researched into later by ĆURČIĆ (1987). Extensive material collected by Croatian biospeleologists is described by ĆURČIĆ (1988) in the monograph »*Cave-dwelling Pseudoscorpions of the dinaric karst*«. In the monograph ten species new to science are described and all are endemic in the Croatian karst underground. Endemic and relict genera are the topic of another work (ĆURČIĆ & DIMITRIJEVIĆ, 1984). Recently, pseudoscorpions have been collected by numerous young researchers all around Croatia, and the material has mostly been described (OZIMEC, 1999a).

Pseudoscorpions represent an important and taxonomically rich segment of the subterranean biocenosis in Croatia. At the moment, 92 taxa of pseudoscorpions are recorded in the Croatian fauna, 60 taxa (65%) proven to be cavernicolous. Almost 45% (40 taxa) are endemic to Croatia. In general, this group shows visible precavernicolous features, which eased survival and penetration into caves, while surface siblings were extinct long time ago.

Of the family **Chthoniidae** there are numerous representatives of the genus *Chthonius* L. Koch and two species of an endemic genus *Microchthonius* (*M. karamani* Hadži, *M. rogatus* Beier), widespread in the area of central Dalmacija. Recently, both species from the genus *Troglochthonius* have been found in Croatia, *T. mirabilis* Beier in the surroundings of Dubrovnik and *T. doratodactylus* Helversen in central Istra.

From the family **Neobisiidae**, the most common are the genera *Neobisium* J. C. Chamberlin (with an endemic subgenus *Pennobisium* Ćurčić) and *Roncus* L. Koch, with numerous species. Two endemic genera are noted, too: *Protoneobisium* Ćurčić,

at Mt Biokovo in central Dalmacija and *Insulocreagris* Ćurčić from the Dalmatian island of Vis. These endemic and relict genera are represented by only one species each (*Protoneobisium biocovense* (Müller) and *Insulocreagris reginae* Ćurčić), and are, very likely, the relicts of pre-Tertiary fauna (ĆURČIĆ, 1984). All cavernicolous forms are endemic in the Dinarides, and as many as 29 taxa have been found in Croatia alone. Gigantism is common, so in comparison with epigean species cavernicolous forms are much bigger – among the biggest in the world. The best examples are *Protoneobisium biocovense*, *Neobisium peruni* Ćurčić, and *N. maderi* Beier, endemic taxa of Mt Biokovo (Fig. 41).

For some species, we know that they are widespread in most areas of the Croatian karst (*Neobisium stygium* Beier, *N. spelaeum* Schiödte), and the vast majority are found only in one or a few caves, in a small number or even as only one specimen (*Chthonius radjai* Ćurčić, *C. jalzici* Ćurčić, *C. trebinjensis* Beier, *C. abnormis* Beier, *C. dalmatinus* Hadži, *C. simplex* Beier, *C. absoloni* Beier, *Neobisium speluncarium* (Beier), *N. staudacheri* Hadži, *N. caecum* Beier, *N. usudi* Ćurčić, *N. simargli* Ćurčić, *Roncus trojanicus* Ćurčić, *R. podaga* Ćurčić, *R. pripegala* Ćurčić, etc.). Revision is necessary in the case of some species: *Chthonius raridentatus* Hadži, *Neobisium stygium* Beier, *N. letheum* Beier, *N. gentile* Beier, *Roncus vulcanius* Beier, for which numerous subspecies are described.

Recently, in the Kordun and Žumberak region several, probably new, taxa have been found. At the same time, cavernicolous representatives of the family **Chernetidae**, most probably from the genus *Lamprochernes* Tömösvary, have been found on the islands of Hvar, Mljet and Lastovo.

– Opiliones by ROMAN OZIMEC

The first records of opilionids in Croatian caves were noted at the end of the 19th century in the Zagreb area (JURINAC, 1886). The first true cavernicolous form *Peltonychia troglodytes* (Roewer) (syn. *Absolonia troglodytes* Roewer) was found in 1913 by K. ABSOLON in a cave in the surroundings of Dubrovnik. During the 30s, rich cave material was investigated and as many as four taxa endemic to Dalmacija

Tab. 13. Cavernicolous pseudoscorpions in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Cthonidae	*Chthonius* L. Koch	17	8
	Microchthonius Hadži	2	2
	Troglochthonius Beier	2	
Neobisidae	*Insulocreagris* Ćurčić	1	1
	Protoneobisium Ćurčić	1	1
	Neobisium J. C. Chamberlin	30	23
	Roncus L. Koch	6	5
Cheliferidae	*Lamprochernes* Tömösvary	1	
TOTAL	8 genera	60	40

of the genus *Siro* were described (ABSOLON & KRATOCHVIL, 1932; KRATOCHVIL, 1937, 1940b). On the island of Hvar, the endemic troglobiotic species of the genus *Lola* (KRATOCHVIL, 1938a) was described. A review of cavernicolous opiliones of Dalmacija (KRATOCHVIL, 1946) followed. The most complete list of opiliones in this part of Europe, including cave forms, was published in the 70s (HADŽI, 1973). Today, we know 9 troglobiotic species and subspecies, with one endemic genus and more than 20 cavernicolous forms.

The **Sironidae** are represented in caves of Croatia by as many as five species of the genus *Siro*. Beside the edaphic and troglophilic species *S. duricorius* (Joseph), there are four endemic species in central and southern Dalmacija: *S. minutus* Kratochvil, *S. silhavyi* Kratochvil, *S. teyrovskyi* Kratochvil and *S. noctiphilus* Kratochvil. Due to the insufficient knowledge of the ecology of these species, it is not clear if they are edaphic or troglobiotic forms.

Phalangodidae. An endemic genus and species *Lola insularis* Kratochvil was found on the island of Hvar (Fig. 12). Although the species was collected in a cave of small dimensions it shows expresive troglomorphic features.

Travuniidae in Croatia are represented by two members of the endemic troglobiotic species of the genus *Travunia. T. anophthalma* Absolon *et* Kratochvil is found in the Dubrovnik area, while *T. jandai* Kratochvil (Fig. 44) is an endemic taxon of the island of Mljet. *Peltonychia troglodytes* (Roewer) is described from a cave in the Dubrovnik area.

Trogulidae of the genus *Trogulus* are found quite often in caves of Dalmacija, but their troglophilic status is under question. *Dicranolasoma verhoeffi* Dahl, is a troglophilic element on the Dalmatian islands.

Nemastomatidae. Several troglophilic forms are represented, particularly *Nemastoma insulare* Roewer and *Mitostoma olgae kratochvili* (Silhavy), endemic taxa of the central Dalmatian islands.

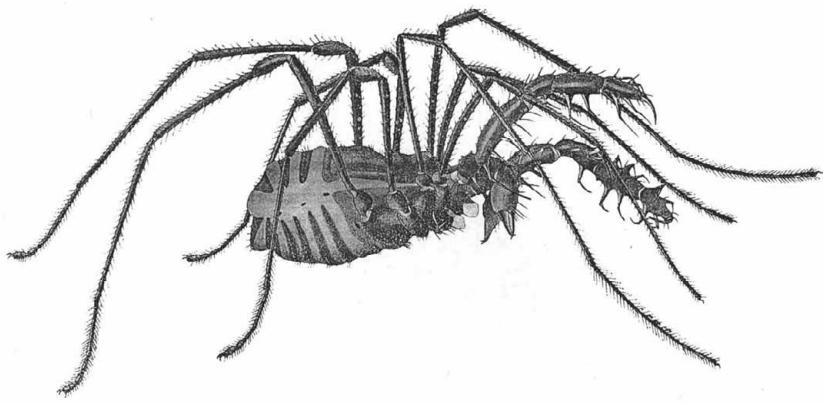


Fig. 12. Opiliones Phalangodidae. *Lola insularis* Kratochvil, an endemic genus and species – troglobiotic opilionid from the island of Hvar (Dalmacija) (after KRATOCHVIL, 1938a, modified).

Ischyropsalidae are represented by the common troglophilic species *Ischyropsalis muellneri* Hamann in the inland region.

Phalangiidae. *Nelima troglodytes* Roewer was the first cavernicolous opilion found in Croatia. For a long time it was believed that the species is a troglobiont, only recently having been found outside caves (RAMBLA & JUBERTHIE, 1994). A troglophilic element in the fauna is represented by *Leiobunum rotundum* Latreille, common in cave entrances. Of Gyantinae, sometimes in great number, one can find the troglophilic species *Amilenus aurantiacus* (Simon), while from the Phalangiinae there are numerous troglophile species of the genera *Platybunus* Koch and *Opilio* Herbst, some of them endemic: *P. kratochvili* Hadži, *P. spinosissimus* Hadži and *O. cavernarum* Roewer. During the surveys in Slovačka jama (–1.301 m) a very likely new troglobiotic species was spotted.

– Acarina by ROMAN OZIMEC

The first cavernicolous mite mentioned in Croatia was the species *Ixodes vespertilionis* (Koch), found in Dalmacija and the Zagreb area (GIROMETTA, 1914; LANGHOFFER, 1915b). Rich material was collected and investigated from a cave in the Lim Channel area in Istra (PAX, 1938). A most important contribution to the research was the material collected by K. ABSOLON before the Second World War in the Dinarides. The material was investigated by C. WILLMANN (1940a, 1940b), firstly in the form of short papers, and finally, as a monograph »*Die Acari der Höhlen der Balkanhalbinsel*« (WILLMANN, 1941). After the Second World War, the mite fauna of a cave in the Dubrovnik area, and also the evolution of carvernicolous mites (TARAMAN, 1958, 1969) were investigated.

Tab. 14. Cavernicolous opilionids in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Sironidae	*Siro* Latreille	5	4
Phalangodidae	*Lola* Kratochvil	1	1
Travuniidae	*Travunia* Absolon et Kratochvil	2	1
	Peltonychia Absolon et Kratochvil	1	1
Trogulidae	*Dicranolasma* Sörensen	1	
Nemastomatidae	*Nemastoma* C. L. Koch	2	2
	Mitostoma Roewer	2	1
Ischyropsalidae	*Ischyropsalis* C. L. Koch	1	
Phalangiidae	*Liobunum* C. L. Koch	1	
	Amilenus Martens	1	
	Nelima Roewer	1	
	Opilio Herbst	3	1
	Platybunus C. L. Koch	2	2
TOTAL	13 genera	23	13

Although the fauna of subterranean mites has been poorly surveyed, nine troglobiotic species and subspecies are recorded, among them an endemic genus, *Spelaeothrombium* Willmann, and numerous troglophilic forms. The hidden treasure that waits for discovery can be glimpsed from a discovery from the Šipun Cave of the Dubrovnik area, where as many as nine taxa of mites were discovered, three of them troglobiotic.

Parasitidae. Troglophilic species of the genus *Eugamasus (E. remberti* Oudemans and *E. loricatus* (Wankel)) have been noted. Of *Pergamasus*, in Dalmacija one can find the species *P. crassipes longicornis* Berlese and *P. barbarus* Berlese, while the species *P. meledensis* Willmann is an endemic taxon of the island of Mljet and probably eutroglobiont.

Rhodacaridae. Of *Euryparasitus*, in Istra and Dalmacija one can find the species *Euryparasitus emarginatus* (Koch).

Macrochelidae. A guanophilic species *Macrocheles penicilliger* Berlese, was found in the Kordun area, while from **Haemogamasidae** there is a pholeophilic species *Haemogamasus nidi* Michaelsen, known from Istra.

Ixodidae are represented by the species *Ixodes vespertilionis* (Koch), which is a parasite on the bats *Rhinolophus* spp.

Labidostomidae. *Nicoletiella absoloni absoloni* Willmann, is found in the Split area and is, most probably, a true troglobiont.

Rhagidiidae are represented by a troglobiont *Rhagidia dalmatina* Willmann, with its subspecies *gigantea* Willmann, 1941, and also by the troglobiotic species *R. longipes* Traghardh, recently recorded in the Žumberak area.

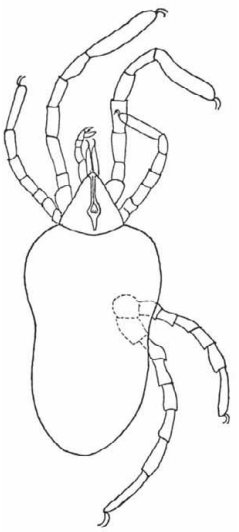


Fig. 13. Acarina, Trombidiidae. *Spelaeothrombium caecum* Willman – a troglobiotic endemic of South Dalmacija (after WILLMAN, 1940a, modified).

Tab. 15. Cavernicolous Acarina in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Parasitidae	*Eugamasus* Absolon	2	
	Pergamasus Berlese	3	1
Rhodacaridae	*Euryparasitus* Oudemans	1	
Macrochelidae	*Macrocheles* Latreille	1	
Haemogamasidae	*Haemogamasus* Berlese	1	
Ixodidae	*Ixodes* Latreille	1	
Labidostomidae	*Nicoletiella* Canestrini *et* Fanzago	1	1
Rhagididae	*Rhagidia* Thorell	3	1
Eupodidae	*Linopodes* C. L. Koch	1	
Ereynetidae	*Riccardoella* Thorell	1	
Trombidiidae	*Trombella* Berlese	1	1
	Spelaeothrombium Willmann	2	2
Belbidae	*Belba* Heyden	2	1
Galumnidae	*Pergalumna* Grandjean	1	
	Allogalumna Grandjean	1	
TOTAL	15 genera	22	7

Eupodidae are represented by the troglophilic species *Linopodes motatorius* (L.), and **Ereynetidae** by the species *Riccardoella oudemansi* Sig Thor, found on the island of Mljet, where it is a parasite on an endemic troglophilic snail *Meledella werneri* Sturany.

Trombidiidae are represented with few species well adapted to subterranean conditions. In Dubrovnik, one can find a troglobiotic species *Trombella bulbifera* Willmann, and an endemic genus *Spelaeothrombium* with *Spelaeothrombium caecum* Willmann, and subspecies *grandis* Willmann (Fig. 13). Both species are supposed to represent relict Tertiary fauna (TARAMAN, 1969).

Belbidae. In the Istra region an endemic and troglophile species *Belba longipes* Willmann, was found, while in the Dubrovnik region there is also the endemic taxon *B. gratiosa* Willmann, of troglomorphic form.

Galumnidae. On the island of Mljet there is a troglophilic species *Pergalumna altera* (Oudemans), while in the Dubrovnik area *Allogalumna longiplumus* (Berlese) is found.

Myriapoda by ROMAN OZIMEC

In caves of Croatia more than 300 taxa of Myriapods have been found (ATTEMS, 1959). Millipedes (Diplopoda) are dominant, while centipedes (Chilopoda) and Symphyla are less numerous. So far, there are no findings of Pauropoda. At the moment more than 50 cavernicolous taxa with 27 endemics have been estimated.

Tab. 16. Myriapod suborders with cavernicolous species listed according to the number of cavernicolous taxa in Croatia.

Orders	Number of Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Symphyla	1	1	
Chilopoda	4	9	2
Diplopoda	19	42	25
TOTAL	24	52	27

The outstanding richness of taxa found in Croatia, and also in the surrounding countries within the Dinarides, implies the possibilities of new findings. Recent discoveries of troglomorphic centipedes and symphyla give credence to this claim.

– Symphyla

Of the subclass Symphyla**,** a troglophile, *Scutigerella immaculata* Newport, from the family Scutigerellidae, was found in a cave of the Dubrovnik area. Recently, an undetermined taxon in Žumberak was found, and also an extremly troglomorphic specimen (over 50 antennae articles) in a cave of the Gorski Kotar region.

– Chilopoda

The first specimen of cavernicolous chilopod *Lithobius stygius* Latzel, was collected in beginning of the 20th century in caves of the Pokuplje area (LANGHOFFER, 1912). Soon afterwards, the species was found in the Lika and Gorski Kotar regions (LANGHOFFER, 1915b; KOVAČEVIĆ, 1918). In research into the material collected by the Czech biospelologist K. ABSOLON, many specimens of centipedes were found in Croatian caves (ATTEMS, 1959). In research of the chilopod material collected by Slovene biospeleologists new data are obtained (MATIĆ & DARABANTU, 1968). Recently, cave centipedes were surveyed by R. OZIMEC and I. KOS, who found new true troglobiotic species.

So far, in Croatia, about ten new taxa of centipedes have been found that show some cavernicolous features.

Cryptopidae. Two endemic taxa of the genus *Cryptops*, *C. croaticus* Verhoeff and *C. illyricus* Verhoeff have troglophilic features.

Geophilidae. Probably due to their edaphic character, the Geophilidae are frequently found in the underground. *Thracophilus monoporus* Attems is endemic in Southern Dalmacija and Herzegovina, and has only been found in caves to date.

Lithobiidae, including the genera *Eupolybothrus* Verhoeff and *Lithobius* Leach, are the best represented in the Croatian underground. As well as *Lithobius stygius* Latzel, which has troglobiotic features, there is also the troglophilic species *L. erytrocephalus erytrocephalus* Koch.

The male of the troglobiotic *Eupolybothrus obrovensis* Verhoeff has been recently collected in a pothole on Mt Ćićarija, while also troglophilic are *Eupolybothrus leostygis*

Tab. 17. Cavernicolous chilopods in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Cryptopidae	*Cryptops* Leach	2	2
Geophilidae	*Thracophilus* Verhoeff	1	
Lithobidae	*Lithobius* Leach	2	
	Eupolybothrus Verhoeff	4	
TOTAL	4 genera	9	2

(Verhoeff), *E. herzegowinensis* (Verhoeff) and the recently found in the caves of Mt Biokovo, *E. stygis* Folkmanova.

Eutroglobiotic forms have not been noted in Croatia until recent surveys. Specimens of centipedes that show big evidence of adaptation to subterranean conditions (total eye regression, long limbs, antennae up to 100 segments) have been found in Žumberak, Istra and Dalmacija. The description of them is not yet complete. Findings of troglobiotic centiped species of the genus *Lithobius* Leach and subgenus *Troglolithobius* Verhoeff, known from Herzegovina, are expected to be found in the Dubrovnik area (KOS, 1996).

– Diplopoda

The first data regarding cavernicolous millipedes of Croatia were published in the work »*Die Myriopoden der Österreichisch-Ungarischen Monarchie*«, by R. LATZEL, in 1880 in Vienna. He described the *Brachydesmus inferus* Latzel found in a pothole in Lika, and also the *Dischizopetalum illyricum troglobium* (Latzel) (syn. *Lysiopetalum illyricum troglobium* Latzel) from a cave on the island of Ugljan. Researches into millipedes were continued by Austrian scientists C. ATTEMS and K. W. VERHOEFF, including descriptions of new cavernicolous taxa (ATTEMS, 1898; VERHOEFF, 1897; 1929–1933). Numerous records from Croatian caves, particularly of *Brachydesmus* were noted in the beginning of the 20th century (KOVAČEVIĆ, 1918). In the thirties, cavernicolous material was collected by K. ABSOLON and J. LANG, and also by K. STRASSER (ABSOLON & LANG, 1933; LANG, 1938; STRASSER, 1933, 1935, 1938).

After the Second World War a detailed study was published, including the results of research into the collection made by K. ABSOLON (ATTEMS, 1959). By examination of material collected in caves in Lika, a new species of the genus *Haasia* Bollman and an endemic genus, *Egonpretneria* Strasser (STRASSER, 1966), were found. The most complete review of millipede fauna including cavernicolous forms was printed in the early 70s, but new records were added promptly (STRASSER, 1971a, b). The distribution range of cave millipedes has been investigated by I. TABACARU (1969). New species and ranges of Polydesmidae and Attemsiidae, plus the genus *Xestoiulus* Verhoeff, and the millipede fauna of Mt Biokovo, were identified by a survey based on material collected by Croatian biospeleologists (MRŠIĆ, 1986, 1987a, b, c, d). Based on material collected by B. JALŽIĆ, in the ice caves of Mt

Biokovo, a new family Biokoviellidae, including the species *Biokoviella mauriesi* Mršić (Fig. 14), has been described.

At the moment 177 taxa of diplopods have been registered in Croatia (MRŠIĆ, 1994), of them more than 40 cavernicolous taxa from 19 genera and 10 families are recorded. Here is one endemic family, 3 genera, 2 subgenera and 25 endemic taxa.

Glomeridae. Troglophilic species *Glomeris pulchra* Koch, is widespread across the Adriatic coast.

Glomeridellidae are represented with a troglobiont species *Typhloglomeris coeca* Verhoeff, in Dalmacija, and *Typhloglomeris fiumarana* Verhoeff, endemic species in Hrvatsko primorje (Kvarner).

Schizopetalidae. In Dalmacija, the biggest European millipedes, of the troglophilic genus *Apfelbeckia*, are very common. Among the three species, *Apfelbeckia hessei* Verhoeff is a Dalmatian endemic species. The enigmatic genus and species *Karlabsolonia mirabilis* Attems is likely to belong to *Apfelbeckia* and it is endemic of Mt Kozjak (STRASSER, 1971a). *Acanthopetalum carinatum* (Brandt) is troglophilic in Dalmacija. From the island of Brač, the endemic genus *Antropetalum* with the troglophilic species *A. brazzanum* Attems is known.

Attemisiidae are represented with *Attemsia* and *Schubartia*. Among the two troglobiotic species *A. coniuncta* Strasser, of Gorski kotar and *A. likana* (Strasser) of Lika there are the troglophilic species *Attemsia falcifera* Verhoeff, endemic species in Hrvatsko primorje and *Schubartia lohmanderi* Verhoeff, described from Slovenia and found in the cave of Veternica near Zagreb.

Craspedosomatidae are represented by the cavernicolous species, *Dyocerasoma biokovense* Mršić, endemic to Mt Biokovo and *D. insulanum* Attems, endemic taxon from the island of Brač.

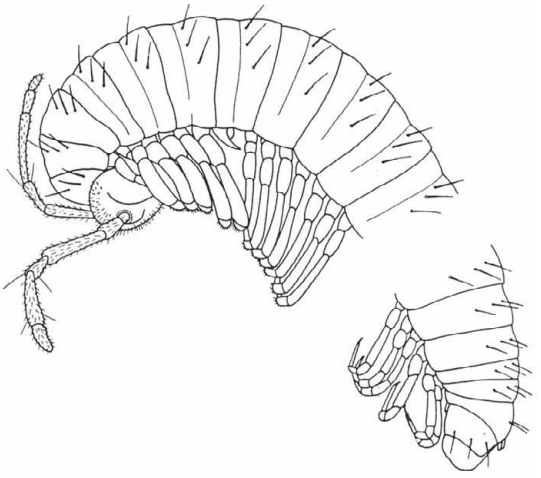


Fig. 14. Diplopoda Biokoviellidae. *Biokoviella mauriesi* Mršić, endemic genus and species from Mt Biokovo (Dalmacija) (after MRŠIĆ, 1992, modified).

Anthogonidae are endemic to the Western Balkans. In Croatia, they are represented by the troglobiotic species of the genus *Haasia* with three endemic species. In Lika, the endemic subgenus *Likasoma* consists of two species: *Haasia stenopodium* (Strasser), and *H. likanum* (Strasser). There is another endemic genus from Lika named *Egonpretneria* with *E. brachychaeta* Strasser. In Dalmacija, the troglobiotic species of the genus *Macrochaetosoma*, with *M. troglomontanum* Absolon *et* Lang (Fig. 43), including numerous subspecies, is found. *M. t. biokovense* Mršić is endemic to Mt Biokovo.

From Mt Biokovo an endemic family **Biokoviellidae** has been described, based on the troglobiotic species *Biokoviella mauriesi* Mršić. Some authors include this endemic genus into Anthogonidae (MAURIES, 1994).

Polydesmidae are the commonest diplopods in Croatian caves. On debris, even deep in caves, one can find numerous species of *Polydesmus* (the most common is the troglophilic *Polydesmus complanatus illyricus* Verhoeff). Members of *Brachydesmus* are the most common millipedes in caves and they are widespread through Croatia. Of 10 cavernicolous taxa there are five endemic (*Brachydesmus inferus inferus* Latzel, *B. inferus velebiticus* Mršić, *B. likanus* Strasser, *B. croaticus* Strasser, *B. spinosus spinosus* Attems). The endemic subgenus *Troglobrachydesmus* is represented by the troglobiotic species *T. absoloni* Attems, from the island of Brač.

Macrosternodesmidae are represented with an endemic troglobiotic species *Verhoeffodesmus fragilipes* Strasser, found in Istra.

Iulidae. The richest number of diplopod species in Croatia shows the Iulidae, and some of them are cavernicolous. The endemic troglophilic species *Xestoiulus dalmaticus* Mršić is known from Mt Biokovo, and of *Typhloiulus,* troglobiotic species *T. insularis* Strasser, an endemic species of the island of Cres, plus troglobionts *T. illyricus* Verhoeff and *T. lobifer* Attems, the latter being an endemic taxon of the island of Brač. Common in caves is the troglophilic *Pachiulus varius* (Fabricius). The genus *Chersoiulus* is represented by two troglobiotic species, *Chersoiulus ciliatus* Strasser (Fig. 42), an endemic species of the island of Cres and *C. sphinx* Strasser from the Rijeka area and the island of Krk.

Insecta

• Apterygota by ROMAN OZIMEC

The first record of apterygotes in a Croatian cave is the trogloxene species *Machilis polypoda* Linne (Thysanura), found in a cave in the Zagreb area (JURINAC, 1886). The first carvernicolous species was collected by L. BIRO in 1893, in a cave of the Lika region (STACH, 1934a). At the beginning of the 20th century the first cavernicolous types of apterygotes were noted (LANGHOFFER, 1915b). A new contribution to the knowledge of cavernicolous apterigote genera *Onychiurus* Gervais and *Oncopodura* Carl *et* Lebedinsky in particular was made by J. STACH (1929, 1934b). The rich material collected in the Western Balkans was investigated by K. ABSOLON and M. KSENEMANN (1932, 1942). A cave in Istra was surveyed (PAX, 1938) as well. The topics of research were the cavernicolous Diplura with the description of an endemic species *Plusiocampa (Stygiocampa) dalmatica* Conde (CONDE, 1947, 1959), in addition

Tab. 18. Cavernicolous diplopods in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Glomeridellidae	*Typhloglomeris* Verhoeff	2	1
Glomeridae	*Glomeris* Latreille	1	
Schizopetalidae	*Apfelbeckia* Verhoeff	5	2
	Acanthopetalum Verhoeff	1	
	Antropetalum Attems	1	1
Attemisiidae	*Attemsia* Verhoeff	3	3
	Schubartia Verhoeff	1	
Craspedosomatidae	*Dyocerasoma* Verhoeff	2	2
Anthogonidae	*Haasia* Bollman	3	3
	Egonpretneria Strasser	1	1
	Macrochaetosoma Absolon et Lang	2	1
Biokoviellidae	*Biokoviella* Mršić	1	1
Polydesmidae	*Polydesmus* Latreille	1	
	Brachydesmus Heller	10	6
Macrosternodesmidae	*Verhoeffodesmus* Strasser	1	1
Iulidae	*Xestoiulus* Verhoeff	1	
	Typhloiulus Latzel	3	2
	Pachiulus Berlese	1	
	Chersoiulus Strasser	2	1
TOTAL	19 genera	42	25

Tab. 19. Apterygot orders with cavernicolous species listed according to the number of cavernicolous taxa in Croatia.

Order	Number of genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Collembola	7	13	2
Diplura	4	6	1
TOTAL	11	19	3

to the Japyginae in Dalmacija (SILVESTRI, 1929; PAGES, 1953). Material from the interstitial waters of the Zagreb area was surveyed by M. MEŠTROV (1960a). Recently, numerous and very interesting materials have been collected.

– Collembola by ROMAN OZIMEC

Onychiuridae. Troglobiotic species of the genus *Onychiurus* are recorded. *O. giganteus* Absolon, is found in the continental Croatia; *O. stillicidii* (Schiodte) in Istra, while *O. paucituberculatus* Stach, is an endemic species of Lika.

Entomobryidae are represented with cavernicolous species of genera *Pseudosinella* Schäffer and *Heteromurus* (*Heteromurus margaritarius* Vankel, *Heteromurus nitidus* (Templeton)) widespread in Mediterranean. Species *Pseudosinella heteromurina* (Stach), inhabits Adriatic islands, while *Pseudosinella alba* (Packard), is found in the continental part.

Orchesellidae. Troglobiont members of *Verhoeffiella (V. longicornis* (Absolon), *V. cavicola* Absolon) are described from the Dalmacija – Herzegovina border and probably inhabit caves in the Dubrovnik area.

Tomoceridae are represented with two troglobiotic species of the genera *Tomocerus* Nicolet and *Tritomurus* Frauenfeld. Species of genus *Tomocerus* are found in continental part of Croatia, while *Tritomurus scutellatus* Frauenfeld, is widespread in Gorski kotar and Kordun.

Paronellidae are represented with a troglobiotic species of the genus *Troglopedetes*. *Troglopedetes pallidus pallidus* Absolon, that is described in Istra and spread till Dalmacija, while *Troglopedetes pallidus distincta* Absolon & Ksenemann (Fig. 15), is endemic for the central Dalmatian island of Brač.

Oncopoduridae. Genus *Oncopodura* with species *O. jugoslavica* Absolon *et* Ksenemann is described in areas of Southern Dalmacija and Herzegovina and *O. cavernarum* Stach is recorded in Istra. In the interstitial waters of Zagreb surroundings stygophile *Folsomia fimateria* (Tullberg, 1872) is found.

– Diplura by ROMAN OZIMEC

Campodeidae. The most troglomorphic are the members of the subgenus *Plusiocampa* (*Stygiocampa*). Recorded troglobiotic species are *Plusiocampa* (*Stygiocampa*) *nivea* Joseph, widespread in karstic parts of continental Croatia (Pokuplje, Kordun, Gorski kotar, Lika); *Plusiocampa (Stygiocampa*) *remyi* Conde, found in two caves near Dubrovnik; and *Plusiocampa (Stygiocampa*) *dalmatica* Conde, which is endemic to Dalmacija. Troglophile species of the genus *Campodea* are recorded in Kordun and Dalmacija (LANGHOFFER, 1915b).

Japygidae are represented by the mostly endogeous species of *Japyx* and *Metajapyx*, which are occasionally found in caves. A specimen of *Japyx* was noted in

Tab. 20. Cavernicolous Colembolla in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Onychiuridae	*Onychiurus* Gervais	3	1
Entomobrydae	*Pseudosinella* Schäffer	2	
	Heteromurus Wankel	2	
Tomoceridae	*Tomocerus* Nicolet	1	
	Tritomurus Frauenfeld	1	
Paronellidae	*Troglopedetes* Absolon	2	1
Oncopoduridae	*Oncopodura* Carl *et* Lebedinsky	2	
TOTAL	7 genera	13	2

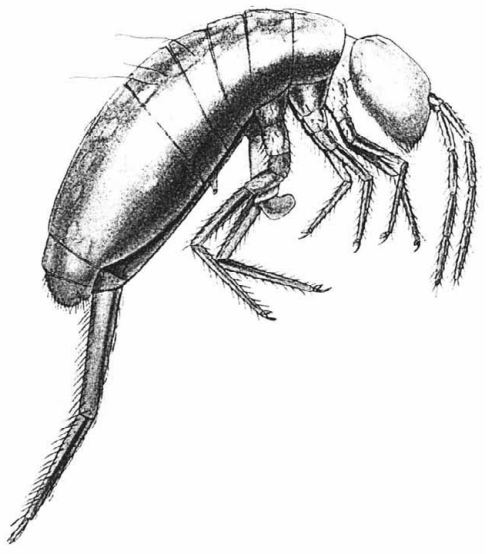


Fig. 15. Collembola Paronellidae. *Troglopedes pallidus distincta* Absolon *et* Ksenemann; endemic subspecies from the Island of Brač (after ABSOLON & KSENEMANN, 1942, modified).

Dalmacija as early as 1913 (GIROMETTA, 1914), most probably of Dalmatian taxa (*Japyx dalmaticus, Japyx validior). Metajapyx braueri* Verhoeff, has been recorded in Istra.

• Pterygota

– Orthoptera by ROMAN OZIMEC

In 1838 the cavernicolous species *Dolichopoda araneiformis* (Burmeister) (syn. *Phalangopsis araneiformis* Burmeister (Fig. 16) was described from material collected in the Dubrovnik area. Additional data of orthopterans in caves of Hrvatsko primorje and Dalmacija are found in works from the end of the 19th and the beginning of the 20th centuries (BRUNNER, 1882; PADEWIETH, 1900; KARNY, 1907, 1930). The first pa-

Tab. 21. Cavernicolous Diplura in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Campodeidae	*Plusiocampa* Silvestri	3	1
	Campodea Westwood	1	
Japygidae	*Japyx* Haliday	1	
	Metajapyx Silvestri	1	
TOTAL	4 genera	6	1

per that deals exclusively with cavernicolous taxa was published in the late 50s (Z. KARAMAN, 1958). At the same time varieties of the species *Troglophilus neglectus* Krauss (MARAN, 1958) were described. Only in the 70s was the species *Troglophilus brevicauda* Chopard found in Croatia, and the wider range of the distribution of some taxa was defined (US, 1970, 1979). Recently, the group was surveyed by R. OZIMEC and extensive material has been collected from more than 200 caves.

In Croatia, five troglophilic taxa of three genera and two families have been recorded. Although they are not true troglobionts they are found in great number, particularly in cave entrances.

Rhaphidophoridae. In Mediterranean Croatia the genus *Dolichopoda* with species *D. araneiformis* (Burmeister) is found. It is a Western Mediterranean endemic species with the range from Dalmacija to Greece. Of *Troglophilus*, one can find three species: *T. cavicola* (Kollar), *T. brevicauda* Chopard and *T. neglectus* Krauss. *Troglophilus cavicola* is widespread in continental Croatia and in Istra, while records referring to Dalmacija are probably of a new taxon. *Troglophilus brevicauda* is a related to *T. cavicola* and it is found in the Kordun and Žumberak areas, while *Troglophilus neglectus* is wide-

Tab. 22. Cavernicolous Orthoptera in Croatia.

Families	Genera	Number of cavernicolous species and subspecies
Rhaphodiphoridae	*Dolichopoda* Bolivar	1
	Troglophilus Krauss	3
Gryllidae	*Gryllomorpha* Fieber	1
TOTAL	3	5

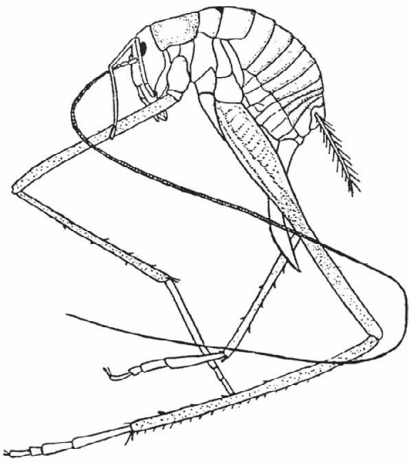


Fig. 16. Orthoptera. *Dolychopoda araneiformis* (Burmeister) from Močiljska Cave (Southern Dalmacija) (after Z. KARAMAN, 1958, modified).

spread throughout the whole of Croatia. For the latter species, a new subgenus *Paratroglophilus* (Z. Karaman) was proposed, where specimens from Croatia are members of its typical subspecies *P. neglectus* (MARAN, 1958).

Gryllidae. In the caves of Istra, Hrvatsko primorje and Dalmacija, there are occasionally findings of the species *Gryllomorpha dalmatina* (Ocskay). Most common are findings of larvae in winter months, while adult specimens are rare.

– Lepidoptera and Trichoptera by MLADEN KUČINIĆ

The fauna of moths (Lepidoptera) and caddis flies (Trichoptera) is represented by a small number of species in cave fauna. Data referring to this small part of our fauna are to be found in a few papers from the first half of the 20th century (GIROMETTA, 1914; LANGHOFFER, 1912, 1915b; RADOVANOVIĆ, 1935; WETTSTEIN, 1914). At the beginning of the 90s, supported by the Croatian Natural History Museum and the Faculty of Science in Zagreb, a systematic collection of moths and caddis flies in caves of Croatia was restarted. The aim of these surveys has been to define the fauna characteristics and range of distribution for the troglophiles of Croatia. During the ten year field work, more than 200 caves have been investigated. In 80 of them, the species of Trichoptera and Lepidoptera have been recorded. This research, and also the results obtained from a study of the literature and entomological collections of caddis flies and moths in the Croatian Natural History Museum in Zagreb have been the basis for several scientific papers and conference reports (KUČINIĆ, 1990, 1991, 1995; KUČINIĆ & ILIĆ, 1992/93; KUČINIĆ *et al.*, 1999).

Lepidoptera

In the troglophilic fauna of Croatia 11 species of Lepidoptera are recorded: *Hypena obsitalis* (Hübner), *H. palpalis* (Hübner), *Scoliopteryx libatrix* (Linnaeus), *Pyrois effussa* (Boisduval), *Apopestes spectrum* (Esper), *Mormo maura* L. (fam. Noctuidae), *Triphosa dubitata* (Linnaeus) and *T. sabaudiata* (Duponchel) (fam. Geometridae), *Agonopteryx atomella* (Denis *et* Schiffermüller) (fam. Oecophoridae), *Monopis obviella* (Denis *et* Schiffermüller) (= *M. feruginella* Hübner), *Alucita* sp. (Alucitidae).

Abundant data about troglophilic moth species are recorded in the caves located in the Croatian central mountain area (Kordun, Gorski Kotar, Lika) and Dalmacija (Mediterranean). The most common troglophilic species are the Noctuidae *Scoliopteryx libatrix* L. and the Geometridae *Triphosa dubitata* L. *Agonopteryx atomella* D. *et* S. (Oecophoridae) have been recorded in the Zaziđana pećina cave in Dalmacija (KUČINIĆ, 1991) alone. The biggest number of specimens in a cave has been noted for *Triphosa dubitata* L. in the Vrelo cave in Fužine (Gorski kotar), more than 1000 specimens being observed. Moths are found in different parts of different caves; once, a few metres from the entrance, another time even 150 m distant (KUČINIĆ, 1990; KUČINIĆ *et al.*, 1999).

Trichoptera

Nine species of Trichoptera have been noted: *Stenophylax vibex* Curtis, *S. permistus* McLachlan, *S. mucronatus* McLachlan, *Micropterna testacea* (Gmelin), *Micropterna sequax* McLachlan, *M. nycterobia* McLachlan, *M. lateralis* (Stephens) (fam. Limnephilidae), *Wormaldia occipitalis* Pictet, *Wormaldia subnigra* McLachlan (Philopotamidae) (KUČINIĆ *et al.*, 1999).

The most common species are: *Stenophylax permistus* McL., *Micropterna sequax* McL. and *M. nycterobia* McL. Other species are observed in only one cave each. They are mostly found in the summer months: June, July, August, and September, occasionally even in copulation (KUČINIĆ *et al.*, 1999).

A record from the literature about the finding of the species *Wormaldia subnigra* McL. in the Đulin ponor-Medvedica cave system (Croatian central mountain area) by LANGHOFFER (1912) needs to be revised, as it is possibly a misidentification, or an accidental finding of the species, most likely in the entrance of the system. The species *Micropterna testacea* Gmel. has, to the present, been noted in only two potholes in the mountains: Velebit (pothole Klementa V) and Biokovo (pothole Kraj stare ledenice) (KUČINIĆ & ILIĆ, 1992/93). These are the first records of the caddis fly in Croatian fauna.

A very interesting record is of *Wormaldia occipitalis* Pic. in the cave system Matešićeva-Popovačka špilja in Kordun (KUČINIĆ *et al.*, 1999). The specific ecological and geomorphologic features of the system (in fact a trough cave), have enabled the species *W. occipitalis* Pic. to close its life cycle within the cave. The species can be found in most parts of the cave, but a significant number of specimens are noted 500 to 600 m from one of the entrances. Part of population recorded in the cave is of significant size with at least several hundreds of specimens. A particular number have been observed while copulating. This is the first record of *W. occipitalis* Pic. in a cave in Croatia.

In subsequent surveys, a more detailed definition of the distribution range of known species we can expect to find a number of species of the orders Trichoptera and Lepidoptera in Croatian troglophile fauna, which have not yet been recorded.

– Coleoptera by BRANKO JALŽIĆ

The first discoveries of coleoptera were made in 1862 in Lika and were the beginnings of biospeleology in Croatia. Since then, more than 100 coleopterologists and cavers have collected and studied the fauna of underground coleopterans in Croatia. During the 19th century, most work was done by F. DOBIAŠ, I. NOVAK, E. REITTER, J. ERBER, J. SAPETZA and J. STIEGLER.

In the first half of the 20th century (before the Second World War) the most significant discoveries of new genera and species were made by V. STILLER, I. HOCHETLINGER, A. LANGHOFFER, J. MÜLLER, P. NOVAK, U. GIROMETTA, G. DEPOLI and E. WEIRATHER. After the year 1950, interest in research of cave fauna took off again. V. REDENŠEK, E. PRETNER and C. DELEEMAN worked on this matter at that time. Since 1970, valuable discoveries have been made by B. JALŽIĆ, T. RAĐA, and, lately, R. OZIMEC.

The first list of caves and potholes of Croatia, including the list of cave fauna of the Leptodirinae was made by a well known French coleopteran scientist R. JEANNEL (1911). A year later, A. LANGHOFFER published a list of caves with a systematic list of cave fauna (LANGHOFFER, 1912, 1915b). A list of cave ground beetles (Trechinae) was published by J. MÜLLER (1913) and ŠTEINER (1913).

Many discoveries of coleopterans are noted by R. JEANNEL in his classical monographs (JEANNEL, 1924, 1926-1928). In his book, P. NOVAK (1952) mentioned many caves and discoveries of cave beetles. E. PRETNER (1973) published the most de-

Tab. 23. List of cavernicolous coleopteran taxa in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species	Number of endemic species
Carabidae	**9 genera**	**36**	13
Scaritinae	*Spelaeodytes* Miller	1	0
Sphodrinae	*Laemostenus* Bonelli	3	0
Trechinae	*Anophthalmus* Sturm	9	1
	Biokovoaphaenopsis Jalžić	1	1
	Croatotrechus Casale *et* Jalžić	1	1
	Duvalius Delarouzée	13	6
	Lovricia Pretner	1	1
	Neotrechus Muller	5	2
	Typhlotrechus Muller	2	1
Cholevidae	30 genera	47	23
Leptodirinae	*Anisoscapha* J. Müller	2	1
	Antroherpon Reitter	2	0
	Aphaobius Abeille de Perrin	1	0
	Astagobius Reitter	2	1
	Bathyscia Schiödte	1	0
	Bathyscidius Jeannel	1	1
	Bathyscimorphus Jeannel	2	0
	Bathysciola Jeannel	1	0
	Bathysciotes Jeannel	1	0
	Blatochaeta Reitter	1	0
	Croatodirus Casale *et al.*	1	1
	Dalmatiola Jeannel	1	1
	Haplotropidius Müller	3	2
	Hoffmannella J. Müller	1	1
	Leptodirus Schmidt	1	0
	Leptomeson Apfelbeck	1	0
	Oryotus Miller	1	0
	Parapropus Ganglbauer	2	0
	Phaneropella Casale *et al.*	1	0
	Phleuonella Jeannel	2	1
	Prospelaeobates Giachino *et* Etonti	1	1
	Radziella Casale *et* Jalžić	1	1
	Redensekia Karaman	1	1
	Roubaliella Jeannel	1	1
	Spelaetes Apfelbeck	1	1
	Spelaeobates Müller	6	6
	Spelaeodromus Reitter	1	1
	Speonesiotes Jeannel	6	3
	Speoplanes Müller	1	1
	Zariquieyella Jeannel	1	1

Pselaphidae	7 genera	14 species	11
	Paramaurops Jeannel	1	
	Troglamaurops Ganglbauer	2	2
	Pauperobythus Nonveiller *et al.*	1	1
	Tychobythinus Ganglbauer	2	1
	Bryaxis Leach	2	1
	Machaerites Miller	5	5
	Thaumastocephalus Poggi *et al.*	1	1
Curculionidae	2 genera	3 species	1
	Otiorrhynchus Germar	1	1
	Troglorrhynchus Schmidt	2	0
Total	48 genera	100 species	35

tailed list of caves and coleopterans found in them. The results are reviewed later by JALŽIĆ & PRETNER (1977).

The Croatian karst is inhabited by a huge number of coleopteran genera and troglobiotic and troglophilic coleopteran species. Such a biodiversity is due to the number of underground habitats and the geographic characteristics of Croatia. Subterranean coleopterans are mostly Leptodirinae and Trechinae. Pselaphidae and Curculionidae are less represented, as far as we know today.

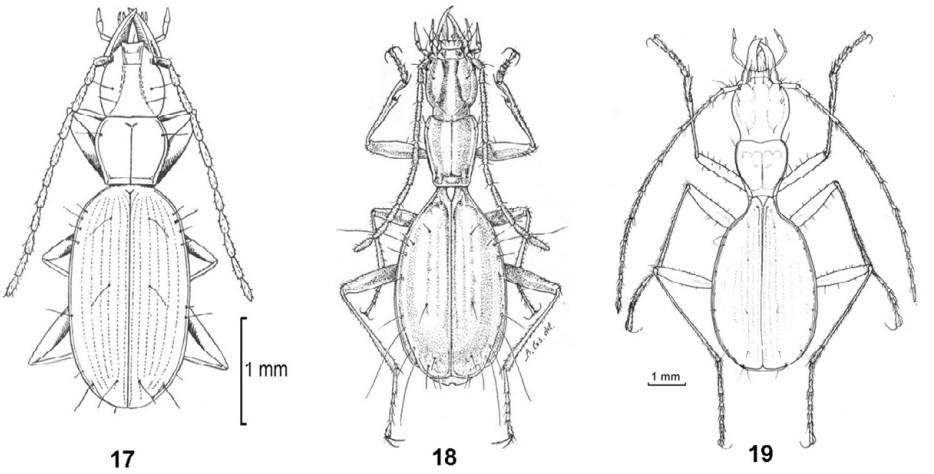
Trechinae. Seven genera are found in Croatia: *Anophthalmus* Sturm (9 species), *Croatotrechus* Casale *et* Jalžić (1 sp.), *Biokovoaphaenopsis* Jalžić (1 sp.), *Duvalius* Delarouzée (13 species), *Lovricia* Pretner (1 sp.), *Neotrechus* Muller (5 sp.) and *Typhlotrechus* Muller (2 sp.) (Fig. 17), and the higher taxonomic status for them is still not defined. Endemic genera of Croatia are *Croatotrechus* Casale *et* Jalžić (Fig. 18), *Biokovoaphaenopsis* Jalžić (Fig. 19) and *Lovricia* Pretner.

Sphodrinae are represented in the underground by species of the genus *Laemostenus* Bonelli (3 species).

Scaritinae are represented by one species of *Spelaeodytes* Miller (Fig. 20).

Leptodirinae has numerous genera in the underground of Croatia (29 genera): *Anisoscapha* J. Müller (2 sp.), *Antroherpon* Reitter (2 sp.), *Aphaobius* Abeille de Perrin (1 sp.), *Astagobius* Reitter (2 sp.), *Bathyscia* Schiödte (1 sp.), *Bathyscidius* Jeannel (1 sp.), *Bathysciola* Jeannel (1 sp.), *Bathyscimorphus* Jeannel (2 sp.), *Bathysciotes* Jeannel (1 sp.), *Blattochaeta* Reitter (1 sp.), *Croatodirus* Casale *et al.* (1 sp.), *Dalmatiola* Jeannel (1 sp.), *Haplotropidius* Müller (3 sp.), *Hoffmannella* J. Müller (1 sp.), *Leptodirus* Schmidt (1 sp.), *Oryotus* Miller (1 sp.), *Parapropus* Ganglbauer (2 sp.), *Phaneropella* Casale *et al.* (1 sp.), *Pholeuonella* Jeannel (2 sp.), *Prospelaeobates* Giachino *et* Etonti (1 sp.), *Radziella* Casale *et* Jalžić (1 sp.), *Redensekia* Karaman (1 sp.), *Roubaliella* Jeannel (1 sp.), *Spelaeobates* Müller (6 sp.), *Spelaeodromus* Reitter (1 sp.), *Spelaetes* Apfelbeck (1 sp.), *Speonesiotes* Jeannel (6 sp.), *Speoplanes* Müller (1 sp.) and *Zariquieyella* Jeannel (1 sp.).

In recent surveys of deep caves and systems of Northern Velebit, Istra and the Gorski Kotar region new genera have been found (survey in progress) – members of the tribe *Antroherponineae*. In the Žumberak highlands, a new taxon of genus *Leptodirus* has been found.



Figs. 17–19. Coleoptera Carabidae. 17 = *Typhlotrechus velebiticus velebiticus* (Ganglbauer) (after PRETNER, 1973, modified); 18 = *Croatotrechus tvrtkovici* Casale *et* Jalžić (after CASALE & JALŽIĆ, 1999, modified); 19 = *Biokovoaphenopsis radici* Jalžić (after JALŽIĆ, 1993, modified).

Endemic genera of Croatia are: *Anisoscapha*, *Redensekia*, *Zariquieyella*, *Hoffmannella*, *Dalmatiola*, *Roubaliella*, *Spelaetes*, *Spelaeodromus*, *Speoplanes*, *Radziella*, *Spelaeobates* and *Croatodirus* (Figs. 21–24).

Pselaphidae. In the underground of Croatia the following 7 genera are represented: *Paramaurops* Jeannel (1 sp.), *Troglamaurops* Ganglbauer (2 sp.), *Pauperobythus*

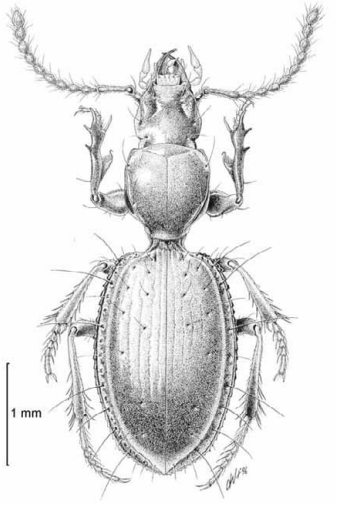


Fig. 20. Coleoptera Scaritinae. *Spelaeodytes mirabilis* Miller (after CASALE *et al.*, 1998, modified).

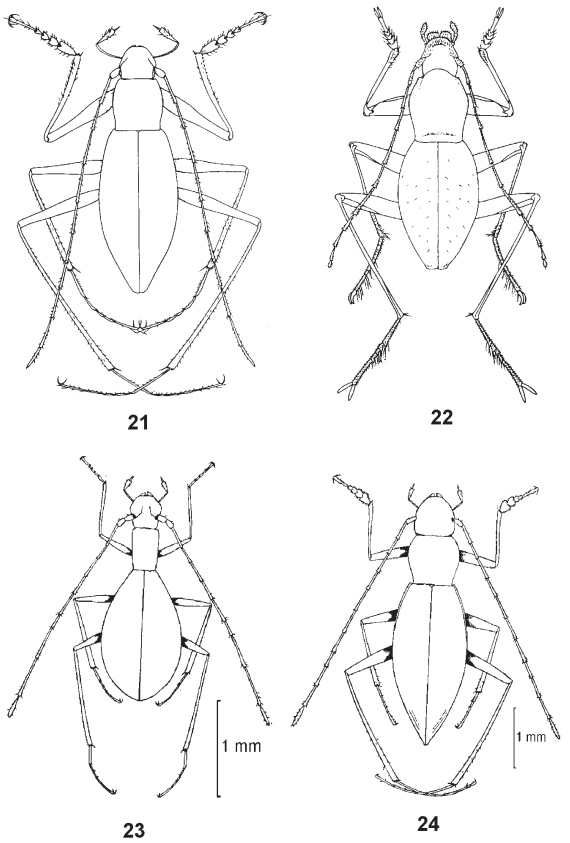
Nonveiller *et al.* (1 sp.), *Tychobythinus* Ganglbauer (2 sp.), *Bryaxis* Leach (2 sp.), *Machaerites* Miller (5 sp.) and *Thaumastocephalus* Poggi *et al.* (1 sp.). Endemic tribe of Croatia is Thaumastocephalini Poggi *et al.* From tribe Bythinini Raffray endemic genus for Croatia is *Pauperobythus* Nonveiller *et al.*

Curculionidae. In subterranean habitats are represented by *Otiorrhynchus* Germar (1 sp.) and *Troglorrhynchus* Schmidt (2 sp.).

In recent years, in coastal regions and islands, new species are found. An important discovery is a new taxon from the surroundings of Split (Dalmacija), which is a member of a new tribe (*in press*).

– Diptera by ROMAN OZIMEC

From a cave in the Dubrovnik area the species *Lamposoma cavaticum* (Becker) was described. The first male of a cavernicolous species *Scoliocentra troglodytes* (Loew)



Figs. 21–24. Coleoptera Cholevidae. 21 = *Speoplanes giganteus* J. Miller (after PRETNER, 1973, modified); 22 = *Radziella styx* Casale *et* Jalžić (CASALE & JALŽIĆ 1988, modified); 23 = *Spelaeobates peneckei* J. Miller (after PRETNER, 1973, modified); 24 = *Spelaeodromus pluto* (Reitter) (after PRETNER, 1973, modified).

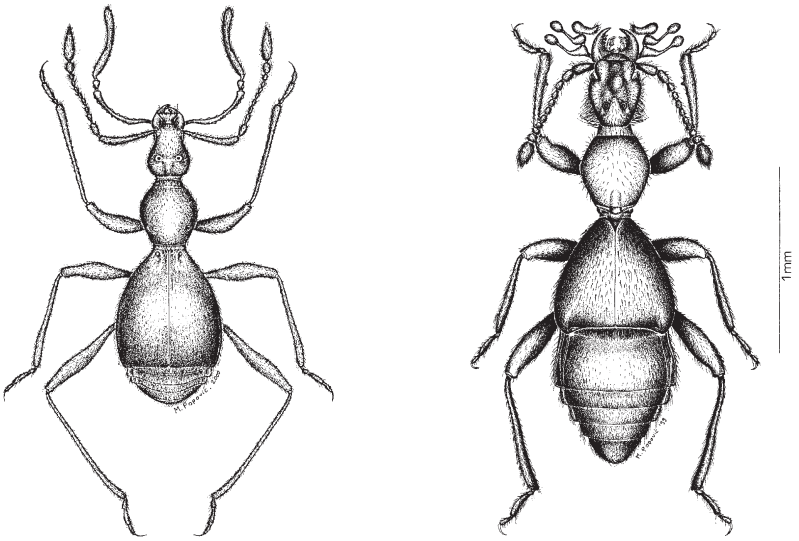


Fig. 25. Coleoptera Pselaphidae. Left: *Pauperobythus globuliventris* Nonveiller, Pavičević & Ozimec (after NONVEILLER *et al.*, 2002). Right: T*haumastocephalus folliculipalpus* Poggi *et al.* (after POGGI *et al.*, 2001) from endemic tribe to Croatia Thaumastocephalini.

(syn. *Gymnonus troglodytes* Loew) was sampled in 1890 from a cave in Lika (RÖDER, 1897; LANGHOFFER, 1912). In material collected by the Czech biospeleologists K. ABSOLON and J. KRATOCHVIL, new carvernicolous taxa were defined (BEZZI, 1914; SCHMITZ, 1919). Larvae of dipterans, from the same collection, were investigated by VIMMER (1920/21). From a cave on the island of Korčula the species *Bradysia dalmatina* (Lengersdorf) (syn. *Neosciara dalmatina* Lengersdorf), and from a cave in Istra the trogloxenic species *Conicera sensilipes* (Schmitz) were described. At the same time, abundant material was collected (24 spp.) (PAX, 1937, 1938).

In the fauna of dipterans collected in caves, representatives of guanophilic and humiphilic fauna are dominant, while true cavernicolous forms are rare. However, in the Dinarides one can find troglobiotic forms, too.

Phrynidae. From Southern Dalmacija the cavernicoulous *Bradysia dalmatina* (Lengersdorf) was described.

Mycetophilidae. From Kordun to Dalmacija troglophilic flies of this family are recorded. Identified species are *Speolepta leptogaster* (Winnertz) and *Macrocera fasciata* Meigen; their larvae in the marginal part of the distribution range develop in caves (MATILE, 1994).

Limoniidae. Numerous trogloxenic species of the family Limoniidae are found in caves. The most common is *Limonia nubeculosa* (Meigen).

Trichoceridae are represented with a facultative guanophilic *Trichocera maculipennis* Meigen, while the **Empididae** represented by the trogloxenic species *Atalanta penicissima* (Becker) and the troglophilic *Lamposoma cavatica* Becker, an endemic species of the Dubrovnik area.

Tab. 24. Cavernicolous Diptera in Croatia with notes on their endemism.

Families	Genera	Number of cavernicolous species and subspecies	Number of endemic species and subspecies
Phrynidae	*Bradysia* Winnertz	1	1
Mycetophilidae	*Speolepta* Edwards	1	
	Macrocera Meigen	1	
Empididae	*Lamposoma* Becker	1	1
Heleomyzidae	*Scoliocentra* Loew	1	
	Thelida Meigen	1	
TOTAL	6	6	2

Phoridae. Here are trogloxene, facultative guanophilic members of *Triphleba* (*T. aptina* (Schiner), *T. antricola* (Schmitz)) and *Megasella* (*M. pleuralis* (Wood), *M. rufipes* (Meigen)).

Heleomyzidae are represented by a troglobiotic species *Scoliocentra troglodytes* Loew, endemic in the Dinarides, and also the troglophilic species *Thelida atricornis* Meigen from Istra and Dalmacija.

Nycteribiidae. All around Croatia, records of the genus *Nycteribia* sp. are known, which are parasites on bats.

Sphaeroceridae. The troglobiotic species *Crumomyia absoloni* (Bezzi) and *Crumomyia parentela parentela* Seguy, are found in Hercegovina on the very border with Dalmacija and most likely they can be found around Dubrovnik.

– Hymenoptera by ROMAN OZIMEC

The fauna of Hymenoptera in Croatia has not been systematically surveyed. Of the Ichneumonidae in the Kordun area, a subtroglophilic species *Diphyus quadripunctatus* (Müller) (LANGHOFFER, 1915b) is found. In the caves of Istra, specimens of the genus *Apanteles* (Braconidae) and the ants *Pheidole pallidula* (Pax) (Formicidae) have been recorded.

VERTEBRATES

Aves by JELENA KRALJ

Among the birds of Croatia, only two species are cave breeders: the Alpine Chough (*Pyrrhocorax graculus* L.) and the Rock Dove (*Columba livia* Gmelin). The Alpine Chough has a range of distribution within the mountains of the oromediterranean region. The biggest populations in the Dinarides are on Mt Dinara and Mt Biokovo (RUCNER & RUCNER, 1993). Total population of Alpine Chough is assumed to be 3–5.000 pairs. They nest in colonies in potholes, even at a depth of more than 10 metres (CRAMP & PERRINS, 1994).

The Rock Dove more often nests on cliffs, but numerous colonies do nest in caves and potholes. The total number of birds breeding in Croatia is estimated to

from 15 to 20,000 pairs. The Rock Dove can be found in the whole of the Karst area, but most often in the coastal parts and on the islands. Its presence in caves is reflected in cave names (toponyms), many caves in Lika, Istra, Kvarner and Dalmacija being named after the Rock Dove – for example, Golublja jama (Dove pothole), Golubinka, Golubara or Golubnjača.

Mammalia by NIKOLA TVRTKOVIĆ

Until the middle of the 20th century the marine caves on the Adriatic coast and islands were used by the Mediterranean Monk Seal (*Monachus monachus* – Phocidae) as shelters and for rearing their young as well (BRUNO, 1976). The Monk Seal does not breed in the area nowadays, and records of its appearance are less frequent.

In the caves and potholes of the Croatian Dinaric karst, mammals of the bat group (Chiroptera), rodents (Rodentia) and carnivores (Carnivora) stay in caves for a part of the year or only for a part of the day.

The Long-fingered Bat (*Myotis capaccinii*) and Schreiber's Bat (*Miniopterus schreibersi*) are typical trogloxenes, exiting their underground habitat only when searching for food and while migrating from summer to winter habitats and vice versa.

In the caves and potholes of Croatia some other species of bats often breed and raise their young too: *Myotis blythi*, *M. emarginatus*, *M. myotis*, *Rhinolophus euryale*, and *R. ferrumequinum.*

Apart from these, more than 10 other bat species are noted in subterranean habitats. Many bats enter caves and potholes to mate or to shelter while on migration, or to winter. So far, the ecology of bats in the Croatian karst underground has been investigated by B. ĐULIĆ (1959, 1961, 1963, 1969).

Tab. 25. List of mammals – visitors and occasional visitors to caves.

Orders and families	Species
Chiroptera	
Rhinolophidae	*Rhinolophus euryale* Blasius
	Rhinolophus ferrumequinum (Schreber)
Vespertilionidae	*Miniopterus schreibersi* (Kuhl)
	Myotis blythi (Tomes)
	Myotis capaccinii (Bonaparte)
	Myotis emarginatus (Geoffroy)
	Myotis myotis (Borkhausen)
Rodentia	
Muridae	*Chionomys nivalis* (Martins)
	Dinaromys bogdanovi (Martino)
	Apodemus mystacinus (Danford *et* Alston)
Myoxidae	*Myoxus glis* (Linnaeus)
Carnivora	
Mustelidae	*Martes foina* (Erxleben)
Phocidae	*Monachus monachus* (Hermann)

Apart from bats, the best-known mammal in the Dinaric karst underground is the Fat Dormouse (*Myoxus glis*) which regularly uses particular shelters called »pušine« for hibernation. In a single such shelter several hundred specimens can spend the winter. The most adapted to the subterranean karstic habitats are the Tertiary relict Martino's Vole (= the Balkan Snow Vole) – *Dinaromys bogdanovi* (TVRTKOVIĆ, 1976; 1985; PETROV & TODOROVIĆ, 1982). A certain level of troglophilia has been noted in the case of the Rock Mouse *Apodemus mystacinus* (MIRIĆ, 1966) and the Snow Vole *Chionomys nivalis* (KRYŠTUFEK & KOVAČIĆ, 1989).

Common predators on bats and rodents in caves are the Stone Marten (*Martes foina*), and, less frequently, other mustelids.

7. FAUNA OF MARINE AND ANCHIHALINE CAVES

7.1. Marine caves

by TATJANA BAKRAN-PETRICIOLI and PETAR KRUŽIĆ

Due to its limestone character and diversity of karstic relief, the eastern coast of the Adriatic Sea is rich with marine caves, holes, passages, descending caves and potholes. All these phenomena were formed under subaeral conditions during periods of lowered sea level. During last 18000 years the sea level of the Adriatic Sea has risen approximately 120 meters and many karstic phenomena, once coastal, are now under the sea. Along the Croatian coast there are up to a hundred marine caves known but it is estimated that there must be many more not discovered yet. Now, the speleothems in such objects are subjected to biocorrosion and bioerosion by marine organisms which live on/in them (Fig. 31).

The first biological research into submarine caves in Croatia was started some forty years ago by RIEDL – in the book »*Biologie der Meereshöhlen*« (1966) he published results obtained during research and mapping of some submarine caves located along the Croatian coast and islands. LEGAC & LEGAC (1979) did faunistic research of submarine caves along the islands of Rab and Grgur, with the focus on photo-documentation. Recently, ARKO-PIJEVAC *et al.* (2001) undertook biocenological research into marine caves round the island of Krk.

In the classical bionomic classification (PÉRÈS & PICARD, 1964) two biocoenoses occupy the Mediterranean (as well as Adriatic) marine caves: b. of semi-dark caves and b. of dark caves. The biocoenosis of semi-dark caves is located in the first portion of the cave while the biocoenosis of dark caves is located deeper in the cave, where there is no light penetration at all.

Dense and diverse fauna, in which sponges usually dominate, characterises the biocoenosis of semi-dark caves. Sponges are associated with cnidarians (scleractinians, hydroids, anthozoans, octocorals), bryozoans, serpulids and ascidians. This biocoenosis is very similar to the coralligenous biocoenosis, which usually develops in the circalittoral zone on the hard substrata in the Adriatic. The main difference is that there are very few or no algae in the caves. This is the reason that only a few species can be defined as cavernicolous, such as: hard coral *Ceratotrochus magnaghii*

Cecchini, 1914, fish species *Oligopus ater* Risso, 1810 or *Gammogobius steinitzi*, Bath, 1971, rare species found in a submarine cave near Vrbnik, on the island of Krk (KOVAČIĆ, 1999). In the submarine pothole near the island of Levrnaka in the Kornati Archipelago, a new species of alpheid shrimp *Salmoneus sketi* Fransen, 1991 was found (FRANSEN, 1991).

Very common species of sponges that are found in the biocoenosis of semi-dark caves as well as in the circalittoral zone of the Adriatic, are e.g.: *Agelas oroides* (Schmidt), *Aplysina cavernicola* (Vacelet), *Spirastrella cunctatrix* Schmidt, *Oscarella lobularis* (Schmidt), *Petrosia ficiformis* Poiret, *Reniera sarai* Pulitzer. Among corals, besides the already mentioned species *Ceratotrochus magnaghii* Cecchini, the following are common: *Leptopsammia pruvoti* Lacaze-Duthiers, *Hoplangia durothrix* Gosse, *Phyllangia mouchezii* (Lacaze-Duthiers), *Caryophyllia inornata* (Duncan), *Madracis pharensis* (Heller), *Parazoanthus axinellae* Schmidt, as well as the endangered species *Corallium rubrum* (Linnaeus). Polychaete species of the families Serpulidae and Sabellidae are also very common. Decapods such as *Stenopus spinosus* Risso, *Plesionika narval* (Fabricius) and *Lysmata seticaudata* (Risso), the bryozoan species *Myriapora truncata* (Pallas) and genus *Sertella*, fish of the families Gobiidae (especially species like *Corcyrogobius liechtensteini* (Kolombatović), *Gammogobius steinitzi* Bath and *Thorogobius ephippiatus* (Lowe) (ARKO-PIJEVAC *et al.*, 2001)) as well as the species *Apogon imberbis* (Linnaeus) are also common inhabitants of the biocoenosis of semi-dark caves.

Not much is known about the biocoenosis of dark caves in the Adriatic Sea. In this biocoenosis in the Mediterranean as a whole the main groups of animals are sponges, serpulids and bryozoans. Foraminifera, brachiopods and scleractinians are also present. Dark caves can be considered as a prolongation of the deep aphotic system in the littoral zone (POULIQUEN, 1971, 1972; HARMELIN *et al.*, 1985).

Recently, deep sea organisms were discovered in the dark part of shallow descending submarine cave near Marseille in France (VACELET *et al.*, 1994). Due to the geomorphology, after the autumn's turnover of the whole water column, colder deep seawater can enter such caves and potholes and remain there for a long period of time. Thus the ecological conditions in such habitats are similar to those in the Mediterranean bathyal/abyssal zone (constant temperature, lack of light and limited food resources), which makes possible the colonization of the cave by deep sea organisms. It is suggested that such events of successful colonisation are quite rare (HARMELIN, 1997). The finding of bathyal organisms in the shallow littoral zone, at only 20 m of depth, has enabled scientists to study them *in situ* and in the laboratory (VACELET *et al.*, 1994; VACELET & BOURY-ESNAULT, 1995; VACELET & BOURY-ESNAULT, 1996). In the cave a population of tiny bathyal carnivorous demosponges *Asbestopluma hypogea* Vacelet *et* Boury-Esnault, was found as well as a population of the bathyal hexactinellid sponge *Oopsacas minuta* Topsent. This little hexactinellid sponge, as well as in the »cold« marine cave near Marseille, has also been found in deep parts of the Mediterranean Sea.

As some marine caves and potholes along the Croatian coast also have a descending character, and cold winter water can be trapped inside them, recently same bathyal organisms (like in France) were found. Thus in the cold marine part

of the Živa Voda pothole on the island of Hvar, at depths between 15 and 25 m, RAĐA (2000) discovered a dense population of the small hexactinellid sponge *Oopsacas minuta* (Fig. 33). Also, PETRICIOLI & BAKRAN-PETRICIOLI (personal data, in preparation) in 2000 found, on the southwestern part of Dugi Otok island, in narrow pothole on 24 m of depth, a dense population of carnivorous sponge *Asbestopluma hypogea* (Fig. 34). Besides bathyal sponges, in such descending caves and potholes other deep sea organisms like brachiopods were found, which confirms that cold sea water is present in them throughout the year.

The biology of marine caves in Croatia is still not very well known so there is a big need for its proper scientific research and evaluation as well as for the inventarisation and protection of such habitats – especially because they are endangered by human activities in the littoral zone (pollution, recreational diving, etc.).

7.2. Anchihaline caves

by SANJA GOTTSTEIN MATOČEC

The first data of subterranean brackish water fauna of the Adriatic coast were provided by S. KARAMAN (1950, 1952b, c, 1953a, b). Taxonomic problems of Amphipods in coastal subterranean waters were published by G. KARAMAN (1967, 1973, 1984). The first complex ecological research into coastal subterranean waters was carried out by RIEDL and OZRETIĆ (RIEDL, 1966; RIEDL & OZRETIĆ, 1969). Very inter-

Tab. 26. The number of stygobiotic and troglobiotic animals (species and subspecies) so far known in Croatia.

Groups of stygobionts	Number of species and subspecies	Groups of troglobionts	Number of species and subspecies
Porifera	2	Gastropoda	22
Hydrozoa	1	Araneae	45
Turbellaria	8	Pseudoscorpiones	53
Gastropoda	52	Opiliones	8
Bivalvia	1	Acarina	6
Polychaeta	1	Palpigrada	1
Oligochaeta	5	Isopoda	16
Hirudinea	2	Chilopoda	3
Crustacea		Diplopoda	23
Copepoda	10	Collembola	10
Ostracoda	2	Diplura	3
Syncarida	2	Coleoptera	106
Isopoda	24	Diptera	3
Amphipoda	54		
Decapoda	4		
Thermosbaenacea	1		
Amphibia	1		
TOTAL	170		299

esting faunistic data obtained during research into anchihaline cave waters of the Adriatic were provided by SKET (1969). In the 80s he continued with very intensive faunistic and ecological research into anchihaline caves and the coastal springs of the Adriatic coast (KARAMAN & SKET, 1990b; SKET, 1986a, b).

The best known and surveyed anchihaline cave in terms of faunistic research is the cave Šipun in Cavtat (Southern Dalmacija) with its little brackish pond. The Kornati Archipelago (Dalmacija) is rich in anchihaline caves and potholes, but also in marine springs with a specific subterranean fauna.

Widely distributed and characteristic anchihaline species of coastal caves, marine springs and sources of Croatia belong to the Crustaceans: *Acanthocyclops gordani* Petkovski, *Diacyclops antrincola* Kiefer (Copepoda); *Monodella halophila* S. Karaman (Thermosbaenacea); *Niphargus hebereri* Schellenberg, *Niphargus salonitanus* S. Karaman, *Pseudoniphargus adriaticus* (S. Karaman), *Hadzia fragilis* S. Karaman, *Salentinella angelieri balcanica* (S. Karaman), *Rhipidogammarus karamani* Stock (Amphipoda). Beside the previously mentioned, we should mention species of Crustacea that have a narrower range of distribution: *Bogidiella dalmatina* S. Karaman, *Niphargus pectencoronatae* G. Karaman *et* Sket, *Melita valesi* S. Karaman, *Melita bulla* G. Karaman (Amphipoda), etc.

As well as by Crustaceans, subterranean anchihaline waters are inhabited or visited by other groups such as foraminiferans (*Amonia beccarii* (L.)), gastropods (*Saxurinator sketi* (Bole)), polychaetes (*Nerilla marginalis* Tilzer), ophiurids (*Amphipholis squamata* (Della Chiaje), chaetognathes, etc. (SKET, 1986a, b).

8. PROTECTION OF KARST AND CAVES BIOTA

by SANJA GOTTSTEIN MATOČEC

In Croatia all underground fauna and their habitats are included in the CROATIAN LEGISLATION OF ENVIRONMENTAL PROTECTION (1995) and it is illegal to take any underground organism from the wild without license. The underground fauna protection act has been included in regulations to prevent organism collecting and pollution of the habitats. Numerous species are known only from type locality or from a very limited underground area. Thus, some caves need special conservation due to their high endemic character and the biodiversity of the biota. Consequently, most of the future efforts on the conservation of karst and cave biota should be aimed on endemism and biodiversity.

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PLATE I.

Fig. 26. Subterranean landscape from the cave Matešićeva-Popovačka špilja (Kordun region) showing widespread speleothem deposits (photo: R. OZIMEC).

Fig. 27. Subterranean landscape from the Cave in the Tounj quarry (Kordun region) showing the big subterranean »lake« (photo: R. OZIMEC).

PLATE II.

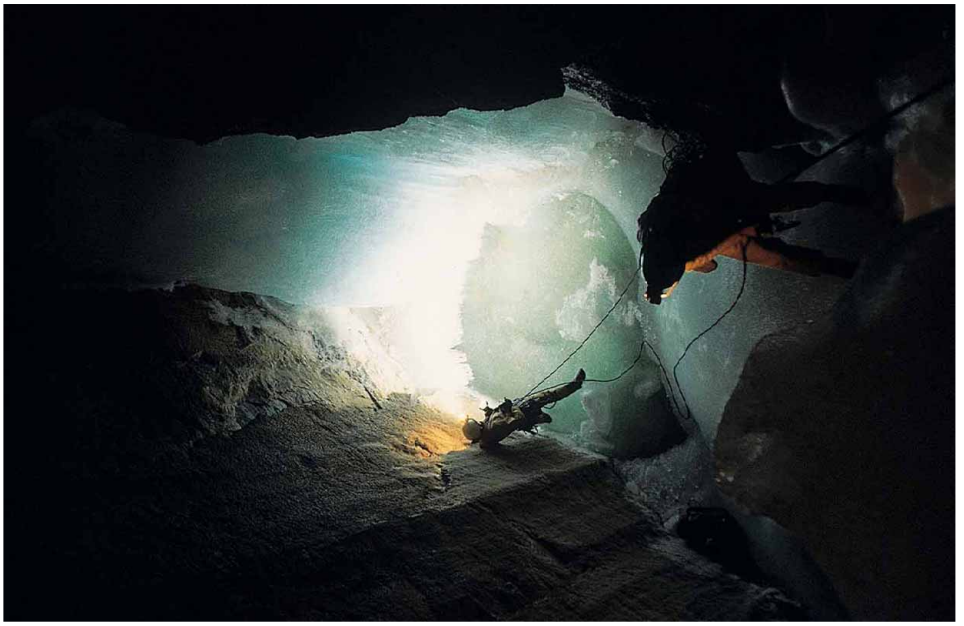

Fig. 29. Frozen part of Lukina jama pothole at 70 m of depth. Hajdučki kukovi, N Velebit (photo: B. JALŽIĆ).

Fig. 28. Smithsonite mine Kraševski zviri near Varaždin city, NW Croatia (photo: Z. GREGURIĆ).

PLATE III.

Fig. 30. Piskovica cave near Cerovlje in Istra – cave in flysch (photo: G. POLIĆ).

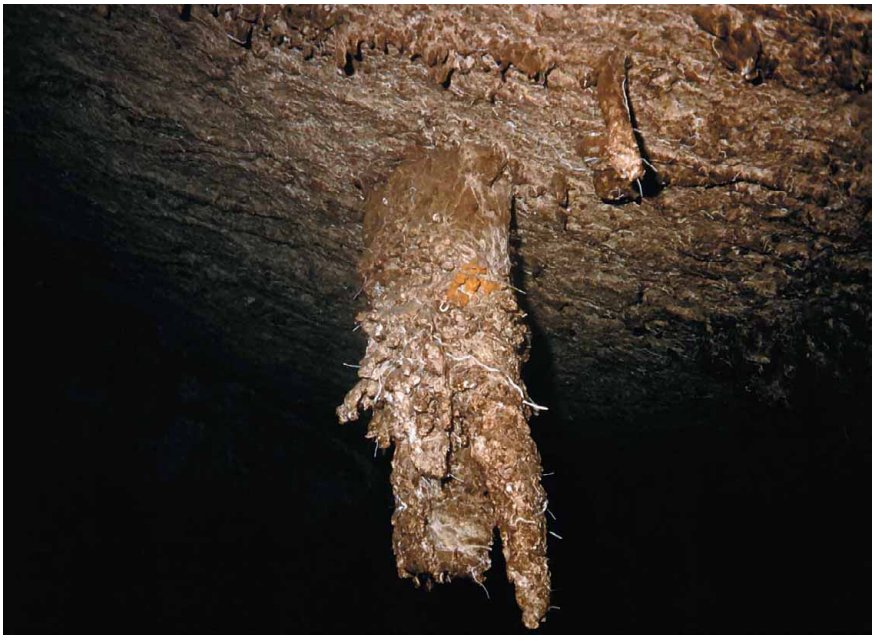

Fig. 31. Speleothems inside the marine cave on the southwestern part of Dugi Otok island, covered with marine organisms (photo: P. KRUŽIĆ).

PLATE IV.

Fig. 32. The only up to date known stygobiont sponge *Eunapius subterraneus*, Sket *et* Velikonja (photo: B. JALŽIĆ).

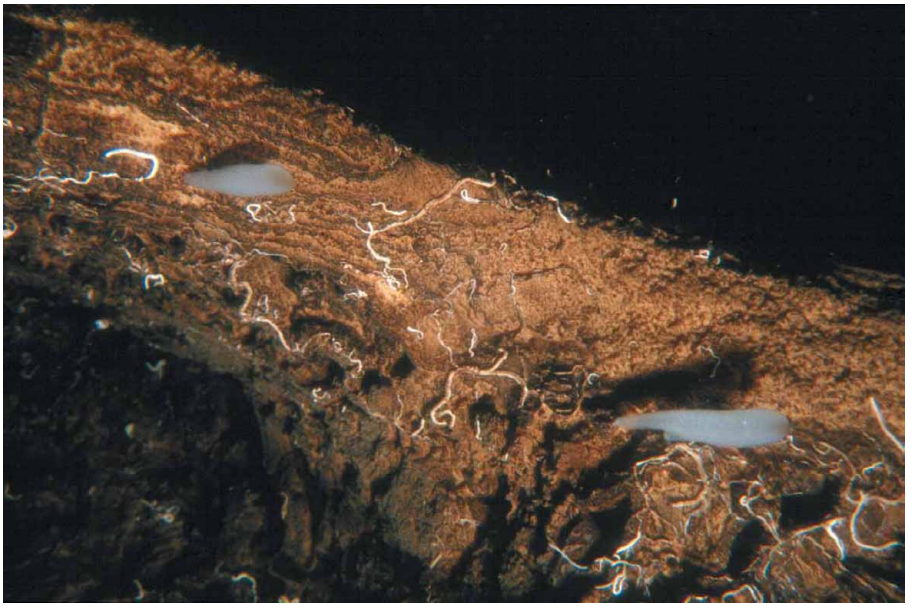

Fig. 33. Population of a bathyal hexactinellid sponge *Oopsacas minuta* Topsent on 25 m of depth in marine cave Živa Voda on the island Hvar (sponges are up to 2 cm long; photo: B. JALŽIĆ).

PLATE V.

Fig. 34. Bathyal carnivorous sponge *Asbestopluma hypogea* Vacelet *et* Bouri-Esnault on 24 m of depth, in »cold« marine pothole in the area of Natural Park »Telašćica« (Dugi Otok island) (sponge is only 10 mm high; photo: D. PETRICIOLI).

Fig. 35. Fungal troglobiotic species *Cordyceps riverae* Pacioni (*Hypocreales*, *Ascomycota*), troglomorph in the living state (photo: N. MATOČEC).

PLATE VI.

Fig. 36. Endemic troglophilic species *Meledella werneri* Sturany (Pulmonata, Zonitidae) Ostaševica cave, the island of Mljet (photo: R. OZIMEC).

Fig. 37. The only known stygobiotic clam *Congeria kusceri* Bole (Bivalvia, Dreissenidae). Pothole in Predolac, Metković (photo: D. PELIĆ).

PLATE VII.

Fig. 38. Endemic cavernicolous species *Cyphodillidium absoloni* (Strouhal) (Isopoda, Oniscida, Armadillidiidae). Cave in Soline, the island of Mljet (photo: R. OZIMEC).

Fig. 39. Endemic Croatian species *Niphargus miljeticus* Straškraba (Amphipoda, Niphargidae). Ostaševica cave, the island of Mljet (photo: R. OZIMEC).

PLATE VIII.

Fig. 40. *Stalagtia hercegovinensis* (Nosek) (Araneae, Dysderidae) from the cave Tučepska Vilenjača, Biokovo Mountain (Dalmacija) (photo: R. OZIMEC).

Fig. 41. *Neobisium maderi* Beier (Pseudoscorpiones, Neobisidae) – endemic species from the cave Tučepska Vilenjača, Biokovo Mountain (Dalmacija) (photo: R. OZIMEC).

PLATE IX.

Fig. 42. *Chersoiulus ciliatus* Strasser (Diplopoda, Iulidae), endemic species of the island of Cres (photo: R. OZIMEC).

Fig. 43. Troglobiotic species *Macrochaetosoma troglomontanum* Absolon *et* Lang (Diplopoda, Anthogonidae) (photo: R. OZIMEC).

PLATE X.

Fig. 45. Stygobiotic leech *Croatobranchus mestrovi* Kerovec, Kučinić *et* Jalžić (Hirudinea, Erpobdellidae), the pothole Lukina jama, Mt Velebit (photo: B. JALŽIĆ).

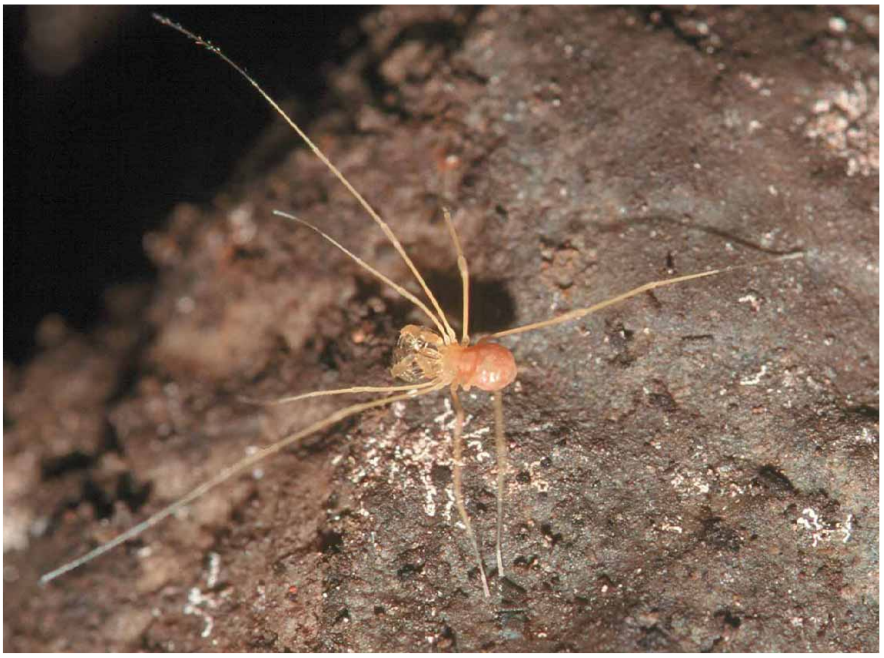

Fig. 44. *Travunia jandai* Kratochvil (Opiliones, Travunidae), endemic species of the island of Mljet. Cave in Soline, the island of Mljet (photo: R. OZIMEC).

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