

GROUNDWATER HARPACTICOIDS (CRUSTACEA, COPEPODA: HARPACTICOIDA) IN THE KARST AREAS OF APUSENI MOUNTAINS (NORTHWESTERN ROMANIA)

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Abstract. Harpacticoid copepods – a diverse and abundant crustacean order in groundwater – have been studied in Romania since the early 20th century, mainly by the Swiss researcher P. A. Chappuis. The Apuseni Mountains in northwestern Romania are the most studied area, with 31 species and subspecies reported from all types of groundwater habitats, representing half of the species known at the country level. The Pădurea Craiului is the most investigated karst unit within the Apuseni, showing the highest number of records (122) and species (28), with the highest diversity of species found in the Crișul Repede and Crișul Negru river basins. Bihor-Vlădeasa is the second most studied area, with 18 species, including cold-stenotherm species like *Bryocamptus (Arcticocamptus) cuspidatus cuspidatus* and *Spelaocamptus spelaeus*. Only two endemic species have been identified in the Apuseni, *S. spelaeus* (in various groundwater habitats from both Pădurea Craiului and Bihor-Vlădeasa) and *Elaphoidella winkleri* (in a single cave within the Bihor-Vlădeasa unit). The dataset presented here extends over a period of more than 90 years allowing to evidence the historical research on this group of crustaceans in the Apuseni and to identify the future research directions to enhance the knowledge in groundwater of this emblematic karst region of Romania.

Key words: distribution, diversity, endemism, groundwater, Harpacticoida.

1. INTRODUCTION

Harpacticoids are copepods crustaceans residing in nearly all types of freshwater ecosystems, including groundwater (GALASSI, 2001; DUSSART AND DEFAYE, 2011; DANIELOPOL *et al.*, 2002; IANNELLA *et al.*, 2020). The initiation of harpacticoids studies started with the first described species *Canthocamptus (Canthocamptus) staphylinus staphylinus* (JURINE, 1820) from pond benthos in the surroundings of Geneva (Switzerland). Significant contribution to their knowledge was added from the early 19th century by several authors, including C. F. W. Claus (CLAUS, 1863) and O. Schmeil (SCHMEIL, 1893) in Germany, G. O. Sars (SARS, 1863) in Norway and A. Mrázek (MRÁZEK, 1893) in Czechia.

Investigations of groundwater harpacticoid was initiated with the description of *Elaphoidella elaphoides* (CHAPPUIS, 1924) from a cave in Serbia (CHAPPUIS, 1924). This was followed by extensive studies in European groundwater's, primarily France and the Balkans, by E. V. Borutzky (BORUTZKY, 1930, 1931, 1934, 1940, 1952, 1960), P. A. Chappuis (1922–1960) and R. Rouch (CHAPPUIS AND ROUCH, 1960; ROUCH, 1986). A major advance in the study of groundwater harpacticoids was made with the discovery of a new type of groundwater habitat by Chappuis and Karaman, the interstitial sediments of the hyporheic zone of rivers, thus further expanding the knowledge on subterranean species (CHAPPUIS, 1942). The first *World directory of Crustacea Copepoda of inland waters* has been compiled in 2002 by B. Dussart and D. Defaye and re-edited in 2006 and 2011. This work represents one of the most outstanding compilations on systematic, taxonomy and distribution of copepods including harpacticoids worldwide.

In recent decades, the advance on harpacticoids systematic and taxonomy knowledge has expanded exponentially. Worldwide, more than 1000 groundwater-dwelling species are currently known (ROUCH, 1986; GALASSI, 2001). Europe has a high concentration of harpacticoid species, hosting almost 40% (395 taxa) of the world recorded groundwater taxa (CERASOLI *et al.*, 2025).

In Romania, the study of harpacticoids dates back to 19th century. E. von Daday intensively worked in Transylvania (northwest Romania) (DADAY, 1882) and S. Jakubisiak in Dobrogea along the Romanian coast of the Black Sea (JAKUBISIAK, 1938). However, the most consistent and systematic works belong to Pierre-Alfred Chappuis. Based in Cluj-Napoca, he served as vice-director of the Emil Racoviţă Institute of Speleology (1922–1949) and found the first school of copepod taxonomy (CHAPPUIS, 1925, 1929, 1933; MOTĂŞ, 1963).

Chappuis was a pioneer in studying subterranean and groundwater copepods, describing a high number of harpacticoids known at the time, *i.e.*, 253 species and 14 genera. Chappuis was a key collaborator of Emil Racoviţă within the *Biospeologica* campaign – a collaborative research program dedicated to exploring and studying the cave fauna (RACOVIŢĂ, 1913; 1926). The biospeological campaigns covered the whole Romania; however, the most prospected area was the Apuseni karst. His work, including the description of several new species of harpacticoids, has been mainly published in a new journal, founded together with Emil Racoviţă: *Buletinul Societăţii de Ştiinţe din Cluj* (CHAPPUIS, 1924, 1925, 1928, 1929, 1930, 1932).

Following Pierre-Alfred Chappuis's work until his departure from Romania in 1949, the systematic study of Romanian groundwater harpacticoids declined. Romanian zoologist (e.g., L. Botoşăneanu, D. Zincenco, E. Şerban and C. Pleşa) continued the works on harpacticoids (CHAPPUIS AND ŞERBAN, 1953; DAMIAN AND BOTOŞĂNEANU, 1954, 1986; BOTEAN AND PLEŞA, 1964; PLEŞA *et al.*, 1968; ZINCENCO, 1971; PLEŞA *et al.*, 1996). A key effort to synthesize the harpacticoid research in Romania was the first catalogue of freshwater species, *Fauna*

Republicii Populare (Socialiste) Romania – Copepoda Harpacticoida (forme de apă dulce) by A. Damian-Georgescu (DAMIAN-GEORGESCU, 1970).

A second significant gap in harpacticoid studies extended thereafter for more than 40 years. The general absence of systematic and taxonomy of harpacticoids in this period can be partially ascribed to species identifications of this group of copepods. A more recent and renewed interest in the taxonomy of harpacticoids in Romania emerged in the 2000s, however mainly in the context of ecological cave studies (MELEG *et al.*, 2011, 2012; CÎMPEAN *et al.*, 2022; SAMBOR *et al.*, 2022). Moldovan *et al.* (2020) published the first comprehensive database of Romanian cave fauna, including a Red List and a list of “hotspot” and “coldspot” caves. The list includes also records on groundwater harpacticoids, providing crucial data for conservation efforts for cave species in Romania. The last checklist of Romanian harpacticoids was published in 2021 (IEPURE *et al.*, 2021), in which the older dataset was supplemented with new records.

We here aim to provide an overview on current knowledge of harpacticoid copepods from the Apuseni Mountains in Romania and compile a comprehensive list of species and subspecies, including old records and new findings. We also provide a tentative identification key of Canthocamptids species from this karst area.

2. MATERIAL AND METHODS

2.1. STUDY AREA

The Apuseni Mountains (10.750 km²) are the NW extensions of the Carpathian Mountains and are hosts to the most extensive karst landscape in Romania (PONTA AND ONAC, 2018). These mountains contain two main well-defined regions with karstifiable rocks: Bihor-Vlădeasa, located in central part of the Apuseni and Pădurea Craiului, in the northwest (ORĂȘEANU, 2020). Other small and isolated karst units are found in Codru-Moma, Gilău, Metaliferi, Meseș, Muntele Mare, Plopiș, Trascău and Zarand (ORĂȘEANU, 2020).

The aquifers of the Apuseni are discontinuous and highly fragmented (FEHER *et al.*, 2024; ORĂȘEANU, 2020, PONTA AND ONAC, 2018). They provide a wide variety of groundwater habitats through the large complex systems of caves and fissures network, and interstitial sediments of karstic rivers, making these mountains the biodiversity hotspot area for copepods of Romania (IEPURE *et al.*, 2016).

2.2. SPECIES LIST

The harpacticoid dataset lists 31 species and subspecies from 63 sites spanning the four of the ten units of the Apuseni Mountains (Fig. 1). The spatial extents covered by the data are 22.3219° E – 23.3281° E and 46.0482° N – 47.0222°.

2.3. SPECIES LIST COMPILATION AND TAXONOMIC VALIDATION

The records of harpacticoid copepods included in the checklist (159) have been compiled from the published and grey literature (i.e., project reports, contracts), supplemented by new records of the authors (mentioned as *present data*). The taxonomic validation of the species uses the published literature (BORUTZKY, 1952; DUSSART, 1967, 1969; BOXSHALL AND HALSEY, 2004; WELLS 2007) and online resources of the Virtual Copepod Library (<https://www.marinespecies.org/copepoda/aphia.php?p=sources>).

We updated the generic allegations of species changed in the last decade and following the recent taxonomic revisions in accordance with the International Code of Zoological Nomenclature (ICZN 1999).

2.4. SPATIAL VALIDATION OF RECORDS AND DISTRIBUTION MAP

The geographical coordinates of records were validated as follows:

1. Browsing web resources (e.g., cave cadastres, technical project reports by research institutions, and websites of speleological clubs, www.speologie.org).
2. The coordinates of cave species refer to the cave entrance. For each sampling locality reported from the bibliography and old references, we add the corresponding geographic coordinates using Google Earth Pro software (WUTHRICH, 2006).
3. All sites were displayed in maps using the QGIS Pro software (version 3.22.8) (ROSAS-CHAVOYA *et al.*, 2022).

2.5. HABITATS SAMPLING DESCRIPTION FOR NEW RECORDS

The new samples cover groundwater habitats mainly from aquatic cave habitats, i.e., gours, temporary basins, percolation water from the vadose zone (including the epikarst), and interstitial sediments of subterranean rivers. The gours have been sampled by directly filtering the water through a 60 µm planktonic net or using a pipette. Percolating water from the vadose zone has been sampled cf. the protocol established by BRANCELJ (2006). The interstitial sediments of caves subterranean rivers have been sampled using the Karaman-Chappuis method (CHAPPUIS, 1942). All samples were preserved in ethanol. The specimens were dissected and determined using determination keys (DAMIAN-GEORGESCU, 1970; JANETZKY *et al.*, 1996).

3. RESULTS

Thirty-one species and subspecies of harpacticoids have been reported from 63 sites in the Apuseni Mountains (Fig. 1). The harpacticoids belong to two families, Canthocamptidae with nine genera, *i.e.* *Attheyella*, *Bryocamptus*,

Canthocamptus, *Ceuthonectes*, *Elaphoidella*, *Maraenobiotus*, *Moraria*, *Pesceus* and *Spelaeocamptus* and Parastenocarididae with only one genus, *Stammericaris* (Table 1).

About 63.12% of all records are from caves (n=101) and from the hyporheic zone of rivers (n=42). Springs (n=15) and wells provide the lowest number of species (Table 2). The majority of harpacticoids (n=20) are stygophiles and stygoxenes, whereas the stygobite species display a significantly lower number (n=11).

In the Apuseni the harpacticoids have been reported in different units, with the highest concentration found in the Pădurea Craiului (115 records, 28 species and subspecies) and Bihor-Vlădeasa units (34 records, 18 species and subspecies) (Table 1). The other regions within the Apuseni Mountains were less prospected and therefore exhibit fewer records of harpacticoids. Metaliferi in southeast has nine records and six taxa, and Meseş in the northwest displays only one record (Fig. 1)

The number of endemic species is very low with only two documented species, *Spelaeocamptus spelaeus* (Chappuis, 1925) and *Elaphoidella winkleri* (Chappuis, 1928).

Taxonomic classification and checklist of inventoried species from the Apuseni Mountains (NW Romania)

(in brackets the county of each locality; the numbers correspond to site locations in Fig. 1).

Class Maxillopoda Dahl, 1956 Subclass Copepoda Milne-Edwards, 1840 Order Harpacticoida Sars G. O., 1903 Fam. Canthocamptidae Brady, 1880

***Attheyella* (*Attheyella*) *crassa* (Sars G. O., 1863)**

Ecological status: stygoxene.

Records: Arieş spring (Alba) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (3); Bulzului spring (Alba) (CÎMPEAN *et al.*, 2022) (5); Tăuz spring (Alba) (CÎMPEAN *et al.* 2022) (21); hyporheic of Cărmăzanului Valley, (Bihor) (PLEŞA *et al.*, 1964) (30); Igrîţa Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (45); Meziad Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (47); hyporheic of Mişidului Valley near Moanei Cave (Bihor) (PLEŞA *et al.*, 1964) (50); hyporheic of Precup Valley (Bihor) (PLEŞA *et al.*, 1964) (57); Vadu Crişului Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (60); Găunoasă de la Ormindea Cave (Hunedoara) (CHAPPUIS, 1933) (25); de la Ruseşti Cave (Hunedoara) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (27).

Remarks: *Attheyella (A.) crassa* is an eurithermal species widely distributed in the Palearctic, in both Eurasia and North Africa. It was originally described as *Canthocamptus crassus* from Norway by SARS (1863) and later on found in other European countries, including Russia and Asia (Korea, Japan) (SÖNMEZ & KARAYTUG, 2019). There is a large variability observed between these distant populations that strongly indicates that *A. (A.) crassa* is a species complex composed of probably related taxa. In Romania, the species is widely distributed in a large array of groundwater habitats in the Apuseni, but also in the Southern Carpathians.

***Attheyella (Attheyella) wierzejskii crenophila* Damian-Georgescu, 1955**

Ecological status: stygophile

Records: Hyporheic of Cărmăzanului Valley (Bihor) (PLEŞA *et al.*, 1964) (30); Filii Valley (Bihor) (PLEŞA *et al.*, 1964) (43); Gura Apei spring (Bihor) (CÎMPEAN *et al.*, 2022) (16); Mişidului Valley, spring 2 (Bihor) (PLEŞA *et al.*, 1964) (51); Săichii Valley (Bihor) (PLEŞA *et al.*, 1964) (58).

Remarks: The type locality of this crenophilic species described by Damian-Georgescu (1955) are cold springs seeps of the Aries River in Bihor karst unit. The exact location of the type locality is nowadays difficult to find, since no other details of the positions are provided. The species was recently reported from cold springs (above 1500 m a.s.l.) in the Retezat Mountains (the southern Carpathian chain).

***Attheyella (Attheyella) wierzejskyi wierzejskyi* (Mrázek, 1893)**

Ecological status: stygophile

Records: Tăuz spring (Alba) (CÎMPEAN *et al.*, 2022) (21); Măgura Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (18); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (54).

Remarks: Species with preference for cold waters present in springs and caves in Romania.

***Bryocamptus (Arcticocamptus) cuspidatus cuspidatus* (Schmeil, 1893)**

Ecological status: stygophile

Records: Arieş spring (Alba) (DAMIAN-GEORGESCU, 1970) (3); Drăganului Valley (Cluj) (DAMIAN-GEORGESCU, 1970) (11).

Remarks: Coldwater-form with preferences for waterbodies harbouring mosses.

Bryocamptus (Bryocamptus) minutus minutus (Claus, 1863)

Ecological status: stygophile

Records: Copăceoasa Valley (Bihor) (PLEȘA *et al.*, 1964) (33); downstream from Moanei Cave (Bihor) (PLEȘA *et al.*, 1964) (42); hyporheic of Mișidului Valley, near Moanei Cave (Bihor) (PLEȘA *et al.*, 1964) (50); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (54).

Remarks: *Bryocamptus (B.) minutus minutus* the type species of the genus is a rather warm water taxon, found in eutrophic, oligotrophic and dystrophic waters.

Bryocamptus (Bryocamptus) vej dovskiyi minusculus (Willey, 1925)

Ecological status: stygophile

Records: Vadu Crișului Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (60); Rusești Cave (Hunedoara) (DAMIAN-GEORGESCU, 1970) (27).

Remarks: This taxon has been reported from North America (REID & WILLIAMSON, 2010), and in Romania it is likely a different species. It falls within the *Bryocamptus minutus* complex with an inner seta on leg 1 exopod segment 2 and a 3-segmented leg 1 endopod bearing an inner seta on segment 1.

Bryocamptus (Echinocamptus) dacicus (Chappuis, 1924)

Ecological status: stygobite

Records: de la Fântâna Roșie Cave (Bihor) (present data) (12); de sub Bulz Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (40); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (54); Vadu Crișului Cave (Bihor) (MELEG *et al.*, 2011) (60); Rusești Cave (Hunedoara) (CHAPPUIS, 1925, 1933) (27).

Remarks: Reported in Romania exclusively from cave habitats (gours, percolating waters) this species was found recently found in percolating water of caves from Slovenia (CULVER *et al.*, 2009). The older mentions of the species in the Balkans are from lakes in the subalpine and alpine belts in Rila Mountains (Bulgaria) (BASAMAKOV, 1969).

Bryocamptus (Echinocamptus) echinatus (Mrázek, 1893)

Ecological status: stygophile

Records: Arieș spring (Alba) (DAMIAN-GEORGESCU, 1970) (3); Mișidului Valley (Bihor) (DAMIAN-GEORGESCU, 1970) (48); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (54); Firii Valley close to Humpleu Cave (Cluj) (DAMIAN-GEORGESCU, 1970) (13).

Remarks: Cold stenotherm species with robust body, present in Europe and Middle East (Iran) in a large array of freshwater habitats (i.e., the profundal zone of lakes, benthos of brooks, streams and rivers; springs, mosses, groundwater and in man-made city water pipes). Prefers alkaline and oxygenated waters.

Bryocamptus (Echinocamptus) hoferi (Van Douwe, 1908)

Ecological status: stygophile

Records: Downstream from Moanei Cave (Bihor) (PLEŞA *et al.*, 1964) (42); Filii Valley (Bihor) (PLEŞA *et al.*, 1964) (43); Moanei Cave (Bihor) (PLEŞA *et al.*, 1964) (54); Săichii Valley (Bihor) (PLEŞA *et al.*, 1964) (58).

Remarks: In Romania it is a widespread species in caves and hyporheic zones of rivers from the whole country. Reported from caves and springs in Europe, and more recently from meiobenthic habitats of the Maggiore Lake (Italy) (CIFONI *et al.*, 2022).

Bryocamptus (Rheocamptus) cfr. baikalensis Borutzky, 1931

Ecological status: stygobite

Records: Ciorăştii Valley (Bihor) (PLEŞA *et al.*, 1964) (31); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (54).

Remarks: Species described from the Baikal Lake (Russia) that together with the other 10 species described belong to *B. zschokkei* group (OKUNEVA & EVSTIGNEEVA, 2001).

Bryocamptus (Rheocamptus) bispinosus Borutzky, 1940

Ecological status: stygophile

Records: Downstream from Moanei Cave (Bihor) (PLEŞA *et al.*, 1964) (42).

Remarks: Species described by Borutzky, 1940 from caves in Russia.

Bryocamptus (Rheocamptus) pygmaeus pygmaeus (Sars G. O., 1863)

Ecological status: stygophile

Records: Hyporheic of Alunul Mic Valley (Bihor) (present data) (1); Cărmăzanului Valley (Bihor) (PLEŞA *et al.*, 1964) (30); Filii Valley (Bihor) (PLEŞA *et al.*, 1964) (43); Mişidului Valley, near Moanei Cave (Bihor) (PLEŞA *et al.*, 1964) (50); Mişidului Valley, downstream from Şesii Valley (Bihor) (PLEŞA *et al.*, 1964) (49); Precup Valley (Bihor) (PLEŞA *et al.*, 1964) (57); Săichii Valley (Bihor) (PLEŞA *et al.*, 1964) (58); Poicului Valley (Cluj) (DAMIAN-GEORGESCU, 1970) (23); Crişul Alb spring (Hunedoara) (DAMIAN-GEORGESCU, 1970) (7).

Remarks: Cosmopolitan eurytopic species with a broad ecological amplitude inhabiting both surface water bodies but also groundwater in Europe, North Africa and North America, except the tundra zone.

***Bryocamptus (Rheocamptus) spinulosus spinulosus* Borutzky, 1934**

Ecological status: stygophile

Records: Filii Valley (Bihor) (PLEȘA *et al.*, 1964) (43); Mișidului Valley, downstream from Șesii Valley (Bihor) (PLEȘA *et al.*, 1964) (49); Mișidului Valley, spring 5 (Bihor) (PLEȘA *et al.*, 1964) (52); Mișidului Valley, spring 7 (Bihor) (PLEȘA *et al.*, 1964) (53); Moanei Cave (Bihor) (MELEG *et al.*, 2011) (54); Vadu Crișului Cave (Bihor) (MELEG *et al.*, 2011) (60); Săichii Valley (Bihor) (PLEȘA *et al.*, 1964) (58).

Remarks: Morphologically the species is very close to *B. zschokkei* (Schmeil, 1893). In Romania the species is currently known only from the hyporheic zone of rivers, caves (percolating water) and springs in the Apuseni. In Europe, it has been reported from Slovakia, Czech Republic (STERBA 1968), mountain brooks and springs in the North Caucasus (BORUTZKY, 1952), Albania and Bulgaria (APOSTOLOV, 2004).

***Bryocamptus (Rheocamptus) typhlops* (Mrázek, 1894)**

Ecological status: stygophile

Records: de sub Corlată Cave (Alba) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1925) (24); Ghețarul de la Barsa Cave (Bihor) (present data) (14); cu Gheață de la Vârtop Cave (Alba) (present data) (15); Lucia Mare Cave (Alba) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1925) (26); Hyporheic of Alunul Mic Valley (Bihor) (present data) (1); Cărmăzanului Valley (Bihor) (PLEȘA *et al.*, 1964) (30); Ciorăștii Valley (Bihor) (PLEȘA *et al.*, 1964) (31); Crișului Repede Valley (Bihor) (DAMIAN-GEORGESCU, 1970) (34); de la Bălnaca Cave (Bihor) (DAMIAN-GEORGESCU, 1970; Chappuis, 1925) (38); Mișidului Valley (Bihor) (DAMIAN-GEORGESCU, 1970) (48); Pișolca Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (19); Ungurului Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (59); Vadu Crișului Cave (Bihor) (MELEG *et al.*, 2011) (60); 3707/68 Vizu I Cave (Bihor) (MELEG *et al.*, 2011) (62).

Remarks: The species belongs to the *pygmaeus-typhlops* group sensu Borutzky (1952), including taxa with 2 lateral spines on the last segment of P2-P4 exopods and a 1- (*typhlops*-group) or 2-segmented (*pygmaeus*-group) P4 endopod. In Romania, the species was found in various hyporheic zone and caves from the Apuseni, however in Europe is a widespread species present also in mosses, bogs and springs.

***Bryocamptus (Rheocamptus) zschokkei caucasicus* Borutzky, 1960**

Ecological status: stygophile

Records: Arieş spring (Alba) (DAMIAN-GEORGESCU, 1970) (3); Hyporheic of Alunul Mic Valley (Bihor) (present data) (2); Ciorăştii Valley (Bihor) (PLEŞA *et al.*, 1964) (31); Ciur Izbuca Cave (Bihor) (MELEG *et al.*, 2011) (32); cu Apă din Valea Leşului Cave (Bihor) (MELEG *et al.*, 2011) (37); de la Bălnaca Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (38); Doboş Cave (Bihor) (MELEG *et al.*, 2011) (41); Filii Valley (Bihor) (PLEŞA *et al.*, 1964) (43); Meziad Cave (Bihor) (MELEG *et al.*, 2011) (47); Mişidului Vlley, near Moanei Cave (Bihor) (PLEŞA *et al.*, 1964) (50); Mişidului Valley, spring 5 (Bihor) (PLEŞA *et al.*, 1964) (52); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (54); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59); Vadu Crişului Cave (Bihor) (MELEG *et al.*, 2011) (60).

Remarks: The species belongs to the *zschokkei* group, widespread and very common in the Holarctic. *B. z. zschokkei* was first described from Kutaisi caves in Georgia (BORUTZKY, 1960) and later on reported from springs in Korea (LEE AND CHANG, 2006) and Slovakia (NOVIKMEK *et al.*, 2007). In Romania, the species is mainly present in the Apuseni Mountains. A single report of the species from a cave in southern Carpathians needs to be confirmed (DAMIAN-GEORGESCU, 1964).

***Bryocamptus (Rheocamptus) zschokkei tatrensis* (Minkiewicz, 1916)**

Ecological status: stygophile

Records: de la Bălnaca Cave (Bihor) (CHAPPUIS, 1933) (38); Meziad Cave (Bihor) (MELEG *et al.*, 2011; CHAPPUIS, 1933) (47); Moanei Cave (Bihor) (MELEG *et al.*, 2011; Chappuis, 1933) (54); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59); Vadu Crişului Cave (Bihor) (MELEG *et al.*, 2011; PLEŞA *et al.*, 1996; CHAPPUIS, 1933) (60); Vizu I Cave (Bihor) (MELEG *et al.*, 2011) (63); Vizu II Cave (Bihor) (CHAPPUIS, 1933) (63); nr. 1 din Valea Topliţei Cave (Bihor) (CHAPPUIS, 1933) (56); Avenul din Tătăroaia Cave (Bihor) (CHAPPUIS, 1933) (4); de la Pârâul Budu Cave (Bihor) (CHAPPUIS, 1933) (8); Izvorul Crişului Negru Cave (Bihor) (CHAPPUIS, 1933) (17); Ruseşti Cave (Hunedoara) (CHAPPUIS, 1933) (27).

Remarks: The species is currently known in Romania only from caves in the Apuseni. The species was originally described from few lakes from the northern part of the Tatra Mountains ranging from 1404–1724 m a.s.l. (MINKIEWICZ, 1916). According to PETKOVSKI (1972) this species could be synonym with *B. (R.) typhlops*.

***Bryocamptus (Rheocamptus) zschokkei zschokkei* (Schmeil, 1893)**

Ecological status: stygophile

Records: Tăuz spring (Alba) (CÎMPEAN *et al.*, 2022) (21); cu Apă de pe Valea Leşului Cave (Bihor) (CÎMPEAN *et al.*, 2022) (37); de la Bălnaca Cave

(Bihor) (DAMIAN-GEORGESCU, 1970) (38); Meziad Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (47); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59).

Remarks: Cosmopolitan cold-water stenothermal form, found in the littoral of alpine lakes, cold springs and brooks.

***Bryocamptus unisaetosus* Kiefer, 1930**

Ecological status: stygobite

Records: de sub Corlată Cave (Alba) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (24); din Sohodolul Chicerii Cave (Alba) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (10); Lucia Mare Cave (Alba) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (26); de la Bălnaca Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (38); de la Pârâul Budu Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (8); Moanei Cave (Bihor) (MELEG *et al.*, 2011) (54); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59); Vizu I Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (62); Vizu II Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (63).

Remarks: This is one of the two stygobite species of *Bryocamptus* of Romania, very close morphologically to *B. typhlops*. Some authors consider these species as synonyms (WELLS, 2007), however, without a proper description of males they are recognized as distinct taxa. In Romania, *B. unisaetosus* has restricted distribution to caves from the Apuseni and other two from the Southern Carpathians and Mehedinti plateau. *B. unisaetosus* is known mainly from Eastern European caves (Romania, Macedonia) and later on was reported from southern France and Italy (FERREIRA *et al.*, 2007).

***Bryocamptus* sp. 1**

Records: cu apă de pe Valea Leșului Cave (Bihor) (MELEG *et al.*, 2011) (37).

***Bryocamptus* sp. 2**

Records: cu apă de pe Valea Leșului Cave (Bihor) (MELEG *et al.*, 2011) (37), Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59).

***Bryocamptus* sp. 3**

Records: Ciur Izbuc Cave (Bihor) (MELEG *et al.*, 2011) (32).

***Canthocamptus* (*Canthocamptus*) *staphylinus staphylinus* (Jurine, 1820)**

Ecological status: stygoxene

Records: Mișidului Valley, near Moanei Cave (Bihor) (PLEȘA *et al.*, 1964) (50).

Remarks: Cosmopolitan cold-stenothermic species, good swimmer widespread in all types of surface waters (moist soils, preferring small water bodies

and oligohaline waters) and groundwater. It is widely distributed in the Palearctic, Nearctic, Neotropical, Oriental, Middle Eastern regions and is tolerant towards anthropogenic influences.

***Ceuthonectes serbicus* Chappuis, 1924**

Ecological status: stygobite

Records: Igrîţa Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1929; CHAPPUIS, 1933) (45).

Remarks: The genus currently includes 12 species, the majority being endemics. *C. serbicus* was described from a small cave in eastern Serbia (Morava). From all species of the genus, *C. serbicus* appears widely distributed in groundwater from Slovenia, Macedonia, Serbia, Romania and France.

***Elaphoidella phreatica* (Chappuis, 1925)**

Ecological status: stygobite

Records: Avenul din Tătăroaia Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (4); de la Pârâul Budu Cave (Bihor) (CHAPPUIS, 1933) (8).

Remarks: Described from distant localities across Romania (phreatic, wells and caves), currently the species is only known in the Apuseni from two caves in the Bihor-Vlădeasa unit. *E. phreatica* is one of the most widespread species of this genus in European groundwater (known from several localities in France, Italy, Slovenia, Croatia, Montenegro, Romania, Hungary, Germany, Czech Republic, Slovakia and Austria). The species shows a very high degree of variability, especially at the chaetotaxy of its swimming legs, but also a high ecological plasticity being found in a variety of habitats from the the unsaturated vadose zone (epikarst) to deep saturated unconsolidated aquifers, springs and the hyporheic zone of streams and rivers.

***Elaphoidella putealis* (Chappuis, 1925)**

Ecological status: stygobite

Records: Vadu Crişului Cave (Pădurea Craiului) (MELEG *et al.*, 2011) (60).

Remarks: Described from the tap water of Cluj town, the species was later on documented from one cave in the Pădurea Craiului unit. At country level, *E. putealis* shows a striking distribution, being known also from a cave in southwestern Romania (Banat region).

***Elaphoidella simplex* Chappuis, 1944**

Ecological status: stygobite

Records: Crişului Repede Valley (Bihor) (DAMIAN-GEORGESCU, 1970) (34); Someşului Valley (Cluj) (DAMIAN-GEORGESCU, 1970) (20).

Remarks: The species belongs to the *simplex*-group (APOSTOLOV, 1985, 1988) that includes species with 6 or 4/5 setae on the distal article of the exopodite of leg 4, respectively. In Romania, the species is restricted to Apuseni Mountains. In Europe, it is a widespread species.

***Elaphoidella winkleri* (Chappuis, 1928)**

Ecological status: stygobite

Records: de sus de la Corbești Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1929; CHAPPUIS, 1933) (9).

Remarks: The species is endemic and restricted to one cave in the Apuseni.

***Maraenobiotus carpathicus* Chappuis, 1928**

Ecological status: stygobite

Records: Ciur-Izbuc Cave (Bihor) (MELEG *et al.*, 2011) (32); cu Apă de la Remeți Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1929; CHAPPUIS, 1933) (36); cu apă din Valea Leșului Cave (Bihor) (MELEG *et al.*, 2011) (37); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59); Vadu Crișului Cave (Bihor) (MELEG *et al.*, 2011) (60).

Remarks: The species of *Maraenobiotus* usually live in cold waters, however in the Apuseni the species has been found in five caves, all from Pădurea Craiului. At country level the species has been reported from warm caves in southern Romania.

***Maraenobiotus vej dovskiy* Mrázek, 1893**

Ecological status: stygophile

Records: Meziad Cave (Bihor) (MELEG *et al.*, 2011) (47); Vadu Crișului Cave (Bihor) (MELEG *et al.*, 2011) (60).

Remarks: The species is restricted in Romania to Pădurea Craiului in the Apuseni, whereas in Europe the species is widely distributed and considered a post-glacial relict (HUSMAN, 1975).

***Moraria (Moraria) brevipes brevipes* (Sars G. O., 1863)**

Ecological status: stygoxene

Records: Vadu Crișului Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; PLEȘA *et al.*, 1996; CHAPPUIS, 1933) (60).

Remarks: Although widespread in European fresh and brackish waters, the species has only one record in the Apuseni.

Moraria (Moraria) poppei poppei (Mrázek, 1893)

Ecological status: stygoxene

Records: Crişului Repede Valley (Bihor) (DAMIAN-GEORGESCU, 1970) (34); Vadu Crişului Cave (Bihor) (MELEG *et al.*, 2011) (60).

Remarks: Restricted to the Pădurea Craiului unit in Romania, the species is widespread in European surface (mosses, benthic zone of rivers and brooks, ponds) and groundwaters, as well as in Northern Africa.

Pesceus schmeili schmeili (Mrázek, 1893)

Ecological status: stygophile

Records: de la Bălnaca Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1925; CHAPPUIS, 1933) (38); Moanei Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (54); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59); Vadu Crişului Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; PLEŞA *et al.*, 1996; CHAPPUIS, 1933) (60); Vizu I Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (62); Crişului Repede Valley, between Mişid Valley and Izbândiş Valley (Bihor) (BOTEA AND PLEŞA, 1968) (35); Zăpodie Cave (Bihor) (MOLDOVAN *et al.*, 2020) (22).

Remarks: The species is restricted in Romania to the Pădurea Craiului unit of the Apuseni, however it is reported from various caves and the hyporheic zone of rivers.

Spelaecamptus spelaeus (Chappuis, 1925)

Ecological status: stygobite

Records: cu Gheaţă de la Vârtop Cave (Bihor) (present data) (15); Bătrânelui Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011) (28); Ciur Izbuc Cave (Bihor) (MELEG *et al.*, 2011) (32); cu Apă din Valea Leşului Cave (Bihor) (MELEG *et al.*, 2011) (37); de la Pârâul Budu Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (8); Doboş Cave (Bihor) (MELEG *et al.*, 2011) (41); Gălăşeni Cave (Bihor) (MELEG *et al.*, 2011) (44); Igrîţa Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1925; CHAPPUIS, 1933) (45); Întorsuri Cave (Bihor) (MELEG *et al.*, 2011; CHAPPUIS, 1933) (46); Meziad Cave (Bihor) (MELEG *et al.*, 2011; CHAPPUIS, 1933) (47); Napiştileu Cave (Bihor) (MELEG *et al.*, 2011; CHAPPUIS, 1933) (55); Pişolca Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (19); Ungurului Cave (Bihor) (MELEG *et al.*, 2011) (59); Vadu Crişului Cave (Bihor) (DAMIAN-GEORGESCU, 1970; PLEŞA *et al.*, 1996; CHAPPUIS, 1933) (60); Vântului Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (61); Well in

Bratca (Bihor) (DAMIAN-GEORGESCU, 1970) (29); de la Bălnaca Cave (Bihor) (DAMIAN-GEORGESCU, 1970; CHAPPUIS, 1933) (38); de la Cubleş Cave (Bihor) (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; CHAPPUIS, 1933) (39).

Remarks: The species is restricted in Romania to the Apuseni Mountains; however, it shows a large ecological plasticity, having several populations in all groundwater habitats.

Class Maxillopoda Dahl, 1956
Subclass Copepoda Milne-Edwards, 1840
Order Harpacticoida Sars G. O., 1903
Fam. Parastenocarididae Chappuis, 1940

***Stammericaris phreatica* (Chappuis, 1936)**

Ecological status: stygobite

Records: Cetățile Ponorului Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (6); Întorsuri Cave (Bihor) (DAMIAN-GEORGESCU, 1970) (46).

Remarks: The species is reported from two caves in the Apuseni only, however, it is likely a new species. It was formerly described from a cave in Serbia (CHAPPUIS, 1936) and is considered endemic to Spain/France and Romania/Czech Republic, respectively (CHAPPUIS, 1936, 1937; ROUCH, 1986).

***Parastenocaris* sp. 1**

Records: Vadu Crișului Cave (Bihor) (MELEG *et al.*, 2011) (60).

***Parastenocaris* sp. 2**

Records: Ciur Izbuca Cave (Bihor) (MELEG *et al.*, 2011) (32).

***Parastenocaris* sp. 3**

Records: Meziad Cave (Bihor) (MELEG *et al.*, 2011) (47).

Identification key of Harpacticoid families

- A. P₁ or only the endopod is prehensile Fam. Canthocamptidae Brady, 1880
 B. P₁ is a swimming leg Fam. Parastenocarididae Chappuis, 1940

Identification key of Canthocamptidae harpacticoids from the Apuseni Mountains (*new species included)

There is no specific dichotomous key for all Canthocamptidae genera of the Apuseni Mountains, as the family is complex and taxonomic views are

evolving. However, identifying both females and males of Canthocamptidae generally involves examining the morphology of appendages like antennae, maxillipeds, the shape of the rostrum, and swimming legs (P1-P5), paying close attention to the number and arrangement of setae and spines, the segmentation of endopods and exopods, and the shape of the caudal rami.

Key for the identification of Canthocamptidae genera (females)

1. A. Genital segment with small chitinous shapes, either round or sack-shaped 2
B. Genital segment with big, round chitinous shapes 11
2. A. P₁ exopod with 3 articles 3
B. P₁ exopod with 2 articles, P₂–P₄ exopods with 3 articles, inner lobe of the basal article of P₅ with 4–5 setae..... *Maraenobiotus* Mrázek, 1893
3. A. Inner lobe of the basal article of P₅ well expressed 4
B. Inner lobe of the basal article of P₅ absent....*Spelaeocamptus* Chappuis, 1933
4. A. P₁–P₃ endopods with 3 articles, P₄ endopod with 2 articles 5
B. P₁–P₃ endopods with 2 articles, P₄ endopod with 1-2 articles 6
5. A. Furcal rami twice as long as wide, short copulatory duct
.....*Canthocamptus* Westwood, 1836
B. Furcal rami as long as wide, with very long copulatory duct
.....*Bryocamptus* (*Bryocamptus*) Chappuis, 1929
6. A. Posterior edge of each segment serrated 7
B. Posterior edge of each segment smooth 9
7. A. Second antenna with 2 articles*Pesceus* Özdikmen, 2008
B. Second antenna with 1 article..... 8
8. A. Inner lobe of the basal article of P₅ with 3–6 setae, distal article of P₅ with spines on the inner side *Attheyella* Brady, 1880
B. Inner lobe of the basal article of P₅ with 4 or less setae, distal article of P₅ without inner spines *Elaphoidella* Chappuis, 1928
9. A. Last article of P₁–P₄ exopods as long as the first two, 2nd article of P₁ exopod without inner seta, short copulatory duct
..... *Bryocamptus* (*Echinocamptus*) Chappuis, 1929
B. Last article of P₁–P₄ exopods shorter or equal to the first two together, 2nd article of P₁ exopod with inner seta, long deferent channel 10
10. A. P₁–P₂ exopods short, almost quadrate, with short spines and setae, egg sac with 1–2 eggs *Bryocamptus* (*Arcticocamptus*) Chappuis, 1929
B. P₁–P₂ exopods long and narrow, with long spines and setae, egg sac with numerous eggs *Bryocamptus* Chappuis, 1929
11. A. P₅ with 2 articles, second antenna with 2–4 setae, anal operculum rounded, triangular or quadrate, with or without *Moraria* Scott T. and Scott A., 1893
B. P₅ with 1 article, second antenna with 1–2 setae, anal operculum rounded, with fine setae *Ceuthonectes* Chappuis, 1924

Key for the identification of Canthocamptidae genera (males)

1. A. P₃ endopod with 3 articles and apophysis on the 2nd article 2
 B. P₃ endopod with 2 articles and apophysis on the last article 11
2. A. P₁ exopod with 3 articles 3
 B. P₁ exopod with 2 articles, P₂-P₄ exopods with 3 articles, inner lobe of basal article of P₅ with 4–5 setae *Maraenobiotus* Mrázek, 1893
3. A. Inner lobe of the basal article of P₅ well expressed 4
 B. Inner lobe of the basal article of P₅ absent *Spelaecamptus* Chappuis, 1933
4. A. P₁-P₃ endopods with 3 articles, P₄ endopod with 2 articles 5
 B. P₁-P₃ endopods with 2 articles, P₄ endopod with 1–2 articles 6
5. A. Furcal rami twice as long as wide, last article of P₂ endopod with chitinous thickening on the middle of the outer side, very short apophysis of the 2nd article of P₃ endopod *Canthocamptus* Westwood, 1836
 B. Furcal rami as long as wide, last article of P₂ endopod with apical chitinous thickening, very long apophysis of the 2nd article of P₃ endopod.
 *Bryocamptus (Bryocamptus)* Chappuis, 1929
6. A. Posterior edge of each segment serrated 7
 B. Posterior edge of each segment smooth 9
7. A. Second antenna with 2 articles *Pesceus* Özdikmen, 2008
 B. Second antenna with 1 article 8
8. A. Inner lobe of the basal article of P₅ with at least 1 seta
 *Attheyella* Brady, 1880
 B. Inner lobe of the basal article of P₅ without spines or setae
 *Elaphoidella* Chappuis, 1928
9. A. Last article of P₁-P₄ exopods as long as the first two together, 2nd article of P₁ exopod without inner seta *Bryocamptus (Echinocamptus)* Chappuis, 1929
 B. Last article of P₁-P₄ exopods shorter or equal to the first two together, 2nd article of P₁ exopod with inner hair 10
10. A. P₁-P₂ exopods short, almost square, with short spines and hairs, short apophysis of P₃ endopod *Bryocamptus (Arcticocamptus)* Chappuis, 1929
 B. P₁-P₂ exopods long and narrow, with long spines and hairs, long apophysis of P₃ endopod (more than twice as long as the last article) *Bryocamptus* (other subgenera) Chappuis, 1929
11. A. P₅ with 2 articles, second antenna with 2–4 setae, anal operculum rounded, triangular or quadrate, with or without denticle
 *Moraria* Scott T. and Scott A., 1893
 B. P₅ with 1 article, second antenna with 1-2 hairs, anal operculum rounded, with fine setae *Ceuthonectes* Chappuis, 1924

**Key identification for Canthocamptidae harpacticoids
from the Apuseni Mountains (Based on the identification key
of Damian Georgescu, 1970)**

In the following, we provide keys identification for the Canthocamptids genera *Attheyella*, *Bryocamptus*, *Elaphoidella*, *Maraenobiotus* and *Moraria*

***Attheyella* Brady, 1880**

1. A. Inner side of furcal rami smooth, without chitinous appendix. First antenna with 8 articles (female) *Attheyella (Attheyella) crassa* (Sars G. O., 1863)
- B. Inner side of furcal rami with chitinous appendix. First antenna with 7–8 articles (female) 2
2. A. Outer apical thorns of P₂–P₄ endopods terminal articles normal *Attheyella (Attheyella) wierzejskii wierzejskii* (Mrázek, 1893)
- B. Outer apical thorns of P₂–P₄ endopods terminal articles short and very thick *Attheyella (Attheyella) wierzejskii crenophila* Damian, 1955

***Bryocamptus* Chappuis, 1929**

Bryocamptus includes four subgenera, *Bryocamptus (Arcticocamptus)* Chappuis, 1929; *Bryocamptus (Rheocamptus)* Borutzky, 1952; *Bryocamptus (Bryocamptus)* Chappuis, 1929 and *Bryocamptus (Echinocamptus)* Chappuis, 1929. The subgenus *Bryocamptus (Arcticocamptus)* Chappuis, 1929 include only one species *Bryocamptus (Arcticocamptus) cuspidatus cuspidatus* (Schmeil, 1893). In the following, we provide key identifications for subgenera and for the species of the last three subgenera.

1. A. P₁–P₂ exopods short, almost square, with short spines and hairs, short apophysis of P₃ endopod *Bryocamptus (Arcticocamptus)* Chappuis, 1929
- B. P₁–P₂ exopods long and narrow, with long spines and hairs, long apophysis of P₃ endopod (more than twice as long as the last article) 2
2. A. P₁ endopod with 3 articles 3
- B. P₁ endopod with 2 articles
..... *Bryocamptus (Rheocamptus)* Borutzky, 1952
or *Bryocamptus unisaetosus* Kiefer, 1930
3. A. P₂–P₃ endopods with 3 articles, P₄ endopod with 2 articles
..... *Bryocamptus (Bryocamptus)* Chappuis, 1929
- B. P₂–P₄ endopods with 2 articles
..... *Bryocamptus (Echinocamptus)* Chappuis, 1929

**Key for the identification of species from the subgenus *Bryocamptus*
(*Rheocamptus*) Borutzky, 1952**

1. A. P₄ endopod with 1 article 2
 B. P₄ endopod with 2 articles 4
2. A. Furcal rami without outer apical seta, armature formula of the terminal article of P₂–P₄ exopods 1, 2, 3; 1, 2, 2; 1, 3, 2.....
 *Bryocamptus unisaetosus* Kiefer, 1930
 B. Furcal rami with outer apical seta 3
3. A. Armature formula of the last article of P₂–P₄ exopods is 1, 2, 2; 1, 2, 2; 2, 2, 2, anal operculum with 3 large denticles ... *Bryocamptus (R.) typhlops* (Mrázek, 1894)
 B. Anal operculum with 2 large denticles
 *Bryocamptus (R.) bispinosus* Borutzky, 1940*
4. A. Anal operculum with several denticles (7–16), terminal article of P₂ endopod with 4 appendages, first article of P₄ endopod without armature, armature formula of the terminal article of P₂–P₄ exopods is 1, 2, 2; 2, 2, 2; 2, 2, 2
 *Bryocamptus (R.) pygmaeus pygmaeus* (Sars G. O., 1863)
 B. Anal operculum with 7 or less denticles, terminal article of P₂ endopod with 5 appendages, first article of P₄ endopod with armature, armature formula of the terminal article of P₂–P₄ exopods 1, 2, 3; 2, 2, 3; 2, 2, 3 5
5. A. First article of the P₂–P₃ endopods with 2 inner setae, posterior edge of abdominal segments slightly denticulate
 *Bryocamptus (R.) zschokkei zschokkei* (Schmeil 1893)
 B. First article of P₂–P₃ endopods with 1 inner seta, posterior edge of abdominal segments smooth 6
6. A. Inner lobe of the basal article of P₅ with 5 setae (female)
 *Bryocamptus (R.) zschokkei tatrensis* (Minkiewicz, 1916)*
 B. Inner lobe of the basal article of P₅ with 6 setae 7
7. A. Anal operculum with 4 large denticles
 *Bryocamptus (R.) spinulosus spinulosus* Borutzky, 1934*
 B. Long aesthetasc, surpasses the end of the first antenna (female), furcal rami with variable apical inner setae and 1 spine next to the outer setae, inner lobe of the basal article of P₅ with 6 setae (female), anal operculum with numerous long spines (male)
 *Bryocamptus (R.) zschokkei caucasicus* Borutzky, 1960
 C. Short aesthetasc, reaches the antepenultimate article of the first antenna (female), furcal rami with equal inner setae, inner lobe of the basal article of P₅ with 6 setae (female), anal operculum with 3 denticles
 *Bryocamptus (R.) baikalensis* Borutzky, 1931

**Key to the species of the subgenus *Bryocamptus* (*Bryocamptus*)
Chappuis, 1929**

1. A. Furcal rami with well-developed outer apical seta and reduced inner apical seta *Bryocamptus* (*B.*) *minutus minutus* (Claus, 1863)
 B. Furcal rami with well developed median apical seta, small apical inner seta and without outer apical seta *Bryocamptus* (*B.*) *vejdovskyi minusculus* (Willey, 1925)

**Key to the species of the subgenus *Bryocamptus* (*Echinocamptus*)
Chappuis, 1929**

1. A. Anal operculum with numerous setae
 *Bryocamptus* (*E.*) *dacicus* (Chappuis, 1924)
 B. Anal operculum with several spines 2
 2. A. Aesthetasc surpasses the end of the first antenna.....
 *Bryocamptus* (*E.*) *hoferi* (Van Douwe, 1908)*
 B. Aesthetasc does not surpass the end of the first antenna *Bryocamptus* (*E.*) *echinatus* (Mrázek, 1893)

***Elaphoidella* Chappuis, 1928**

1. A. Posterior edge of segments denticulate
 *Elaphoidella winkleri* (Chappuis, 1928)
 B. Posterior edge of segments smooth 2
 2. A. First article of P₂–P₄ endopods without armature
 *Elaphoidella phreatica* (Chappuis, 1925)
 B. First article of P₂–P₄ endopods with one seta in inner apical angle 3
 3. A. Last article of P₄ exopod with 5 appendages, last article of P₃ endopod with 4 appendages *Elaphoidella simplex* Chappuis, 1944
 B. Last article of P₄ exopod with 6 appendages, last article of P₃ endopod with 3 appendages *Elaphoidella putealis* (Chappuis, 1925)

***Maraenobiotus* Mrázek, 1893**

1. A. Last article of P₁ endopod with 1 seta and 1 spine
 *Maraenobiotus vejdovskyi* Mrázek, 1893*
 B. Last article of P₁ endopod with 3 apical setae
 *Maraenobiotus carpathicus* Chappuis, 1928

Moraria, Scott T. and Scott A., 1893

1. A. Last article of P₃–P₄ endopods with 3 setae
 *Moraria (M.) brevipes brevipes* (Sars G.O., 1862)
 B. Last article of P₃–P₄ endopods with 4 setae
 *Moraria (M.) poppei poppei* (Mrázek, 1893)

4. DISCUSSIONS

The Apuseni Mountains in Romania are a significant hotspot of subterranean biodiversity, particularly for groundwater species (Table 1, Fig. 1). The region hosts 31 species and subspecies of harpacticoids, most of them belonging to Holarctic genera (e.g., *Bryocamptus*, *Canthocamptus*, *Ceuthonectes*, *Moraria*, and *Pesceus*), which have small-scale distributions (DAMIAN-GEORGESCU, 1970; MELEG *et al.*, 2011; IEPURE *et al.*, 2016, 2021; NITZU *et al.*, 2016; MOLDOVAN *et al.*, 2020; and data therein).

Previous studies have shown that historical (e.g., geological history and hydrological features) and contemporary (e.g., rainfall and temperature patterns) factors influence the distribution of stygobitic (obligate groundwater dwelling) copepods (IEPURE *et al.*, 2016).

The heterogeneity of habitats in the Apuseni Mountains, with highly fragmented karst aquifers, enables the isolation of populations and speciation at local scales. Genera, such as *Bryocamptus* are particularly diverse in these mountains, with more than 15 species. Percolating waters in caves are the preferred living space for harpacticoids. They support rich and diverse communities of harpacticoids, formed by a mixture of stygobite and non-stygobite species (MOLDOVAN *et al.*, 2007; MELEG *et al.*, 2011, 2012). The most common stygobites include species like *Bryocamptus (Echinocamptus) dacicus*, *Elaphoidella putealis*, and *Spelaeocamptus spelaeus* whereas the most common non-stygobites are *Bryocamptus (Rheocamptus) typhlops*, *B. (R.) zschokkei caucasicus*, *B. (R.) zschokkei tatrensis* and *Attheyella (Attheyella) crassa*.

The Apuseni receives a high amount of rainfall (more than 1,350 mm per year), which influences the underground water flow and nutrient transport within the karst system. This, together with the potential preservation of forests in deep valley during the last glacial period (GRINDEAN *et al.*, 2015) could have resulted in caves acting as refuges for harpacticoids during glacial periods, (IEPURE *et al.*, 2016), especially for cold-adapted species in caves from Bihor unit (*see below*).

Despite strong evidence from other groundwater crustaceans, specific molecular studies on Romanian harpacticoids are currently missing. The diversification especially within stygobite lineages within this group may be higher than previously known, similar to patterns seen for harpacticoids from other European classical karst areas (GALASSI, 2001; CICCIO *et al.*, 2021; CERASOLI *et al.*, 2024).

Several harpacticoid species in the Apuseni might be new to science as an ongoing study debates about the taxonomic status of several taxa (FIERS *et al.*, 2008), particularly within the family Canthocamptidae. The most frequently found cave-dwelling stygobite endemic to the Apuseni, *Spelaeocamptus spelaeus*, is likely a cryptic species, as it has been found in diverse cave habitats across different hydrographic basins (FIERS *et al.*, 2008). Further research, especially molecular studies, is needed to provide more clarity on several population's status taxonomy and if this species has a more restricted distribution or a preference for specific cave habitats than is currently documented (MELEG *et al.*, 2011).

The Pădurea Craiului Mountains have a high diversity of harpacticoids (over 90% of the 28 harpacticoid species) (Table 2, Fig. 1). Here, the highest diversification appears within *Bryocamptus* (with 12 species) that shows wide distribution across the main hydrographic basins Crişul Repede (Mişid Valley) and Crişul Negru (Vida Valley) (Fig. 1). Several caves in the area are hotspots of biodiversity: Bătrânului – Vadu Crişului Cave System (with 14 species and subspecies), Moanei Cave (13), Ungurului Cave (8) and Bălnaca Cave (7) (Fig. 1) (IEPURE *et al.*, 2021; *data therein*).

Notably, this unit is characterised by an extensive low altitude (500–600 m a.s.l.) karst, varied climate (mild and humid at low altitudes and cold and humid at greater elevations) and *Fagus* dominated forests (BURESCU, 2009; PONTA AND ONAC, 2018). These characteristics create a mosaic of habitats with different underground ecological conditions that may contribute significantly to shape the species richness at both local and regional scales (MELEG *et al.*, 2011; IEPURE *et al.*, 2015).

The harpacticoids diversity in Pădurea Craiului could also reflect the exhaustive systematic works within this karst unit, especially in caves. An extensive historical record of species, which has been gathered from 72.32% of the records from the entire Apuseni, was supplemented by monitoring studies conducted over a long period and at small scales (PLEŞA *et al.*, 1964; BOTEAN AND PLEŞA, 1968; MOLDOVAN *et al.*, 2007; MELEG *et al.*, 2011, 2012). (Fig. 2) This broad spatially extensive data collection and intense sampling effort provided a wide-ranging picture of harpacticoids biodiversity in this karst unit and increases the likelihood of finding a greater number of species. Last, a proper identification of species distribution within a cave, combined with a fine scale tuning mainly within the unsaturated zone, leads to a more accurate representation of species richness by capturing rarer or less conspicuous species enabling also to define the taxon's ecological niches (MELEG *et al.*, 2011).

The second unit of the Apuseni rich in harpacticoids is Bihor-Vlădeasa, with 18 taxa reported so far (Table 2). Here, the higher ratio of species/records number is 0.52, compared to 0.24 in Pădurea Craiului, suggesting that sampling efforts in this unit have been more efficient or have captured a uniform distribution of species relative to the total number of records. This may also indicate that the full

extent of harpacticoid diversity has yet to be fully documented in Bihor karst unit. Here the most diverse genera are *Bryocamptus* (nine species) and *Elaphoidella* (three species) (Table 2).

Bihor-Vlădeasa unit is characterised by higher altitudes (1000–1200 m a.s.l.) and a cold humid climate with low annual average temperature (ca. 6.25°C) (Ponta and Onac, 2018). Here, the most particular feature is the presence of ice and cold caves, in which the species diversity is low but with cold-adapted taxa (Iepure, 2018). The most known cold-caves hosting harpacticoids are Ghețarul de la Vârtop Ice Cave (*Bryocamptus thyphlops*, *Speleocamptus spelaesus*) and Ghețarul de la Barsa (*B. thyphlops*) (SAMBOR *et al.*, 2022; *data herein*).

The endemicity in Bihor is similarly low as in Padurea Craiului. The only endemic species are *S. spelaesus*, widely distributed across the Apuseni (and potentially cryptic) and *Elaphoidella winkleri*, known from a single cave in the Sighiștel Valley.

The other karst units of the Apuseni exhibit a very low number of records and species. Harpacticoids are reported only from Metaliferi and Meseș with six and one species reported, respectively (Fig. 1, Table 3). A very poor sampling in these areas likely prevents an accurate estimate of the true diversity of groundwater harpacticoids of these areas.

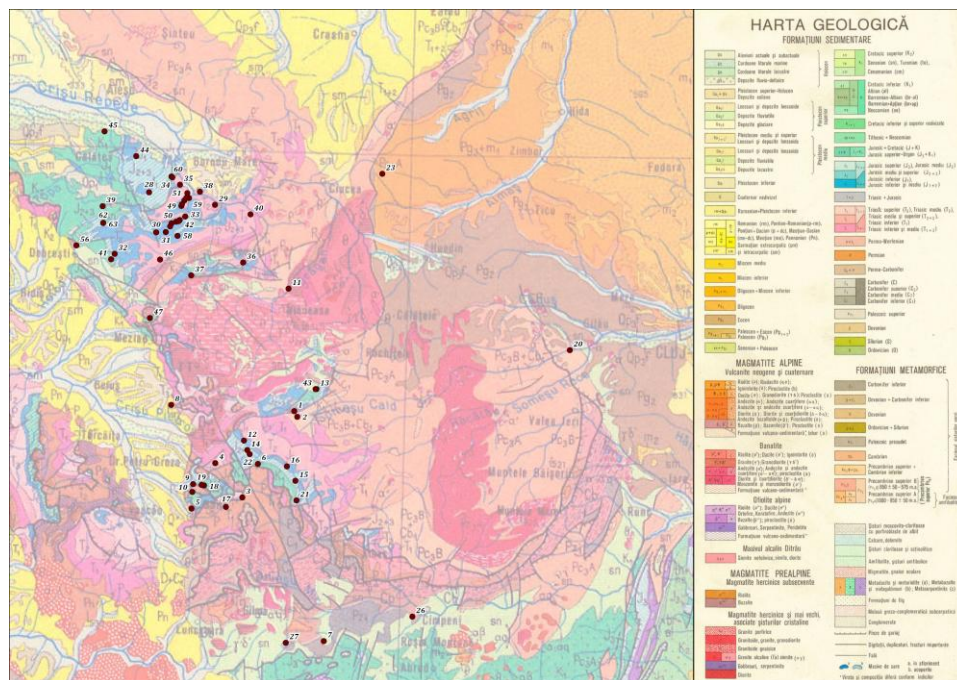


Figure 1. The distributions of groundwater harpacticoids in the Apuseni Mountains (northwest Romania) (the numbers correspond to site locations from the taxonomic classification and checklist of inventoried species from the Apuseni Mountains).

5. CONCLUSIONS

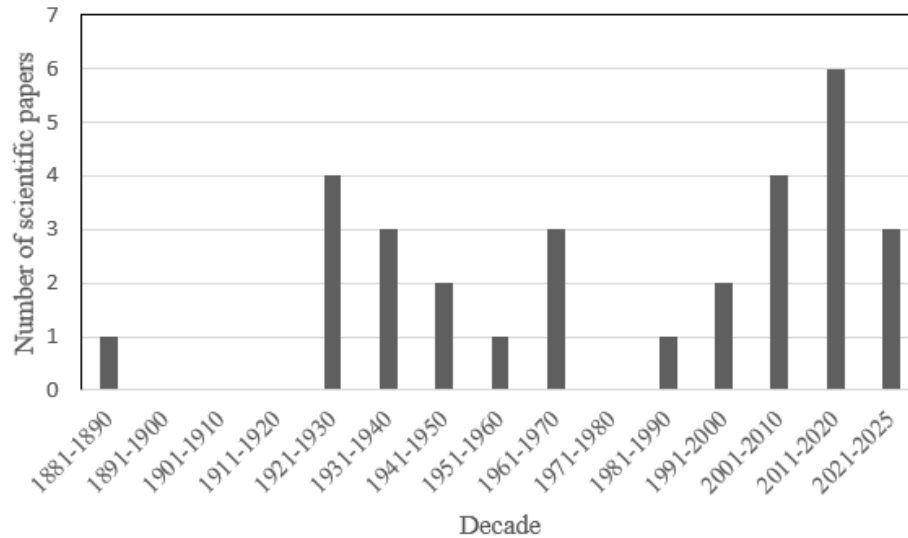


Figure 2. The number of harpacticoid-related papers published in Romania in every decade since 1881.

The present overview provides an updated taxonomy and distribution of groundwater harpacticoid copepods from the Apuseni Mountains in northwest Romania. The dataset presented here extends over a period of more than 90 years allowing to evidence the historical research on this group of crustaceans in the Apuseni and to identify the future research directions to enhance the knowledge in groundwater of this emblematic karst region of Romania.

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Table 1

Number of records (NR), species (NS) and endemic species (NE) for every present genus, in the Pădurea Craiului (PC) and Bihor-Vlădeasa (BV) karst units

No. crt.	Genera	NR		NS		NE	
		PC	BV	PC	BV	PC	BV
1	<i>Attheyella</i> Brady, 1880	11	6	3	3	0	0
2	<i>Bryocamptus</i> Chappuis, 1929	71	19	14	9	0	0
3	<i>Canthocamptus</i> Westwood, 1836	1	0	1	0	0	0
4	<i>Ceuthonectes</i> Chappuis, 1924	1	0	1	0	0	0
5	<i>Elaphoidella</i> Chappuis, 1929	3	4	2	3	0	1
6	<i>Maraenobiotus</i> Mrázek, 1893	7	0	2	0	0	0
7	<i>Moraria</i> Scott T. & Scott A., 1893	3	0	2	0	0	0
8	<i>Pesceus</i> Özdikmen, 2008	6	1	1	1	0	0
9	<i>Spelaeocamptus</i> Chappuis, 1933	15	3	1	1	1	1
10	<i>Stammericaris</i> Jakobi, 1972	1	1	1	1	0	0

Table 2

Number of records for each species in all groundwater habitat types from the Apuseni Mountains: caves (C), springs (S), hyporheic zones (H) and wells (W), with remarks on the ecological status (ES)

No. crt.	Taxon	C	S	H	W	ES
1	<i>Attheyella (A.) crassa</i>	5	3	3	0	stygophile
2	<i>Attheyella (A.) wierzejskii crenophila</i>	0	2	3	0	stygophile
3	<i>Attheyella (A.) wierzejskyi wierzejskyi</i>	2	1	0	0	stygophile
4	<i>Bryocamptus (A.) cuspidatus cuspidatus</i>	0	1	1	0	stygophile
5	<i>Bryocamptus (B.) minutus minutus</i>	1	0	3	0	stygophile
6	<i>Bryocamptus (B.) vej dovskiyi minusculus</i>	2	0	0	0	stygophile
7	<i>Bryocamptus (E.) dacicus</i>	5	0	0	0	stygobite
8	<i>Bryocamptus (E.) echinatus</i>	1	1	2	0	stygophile
9	<i>Bryocamptus (E.) hoferi</i>	0	0	4	0	stygophile
10	<i>Bryocamptus (R.) baikalensis</i>	1	0	1	0	stygobite
11	<i>Bryocamptus (R.) bispinosus</i>	0	0	1	0	stygophile (?)
12	<i>Bryocamptus (R.) pygmaeus pygmaeus</i>	0	1	8	0	stygophile
13	<i>Bryocamptus (R.) spinulosus spinulosus</i>	2	2	3	0	stygophile
14	<i>Bryocamptus (R.) typhlops</i>	9	0	5	0	stygophile
15	<i>Bryocamptus (R.) zschokkei caucasicus</i>	8	2	4	0	stygophile
16	<i>Bryocamptus (R.) zschokkei tatrensis</i>	12	0	0	0	stygophile
17	<i>Bryocamptus (R.) zschokkei zschokkei</i>	4	1	0	0	stygophile
18	<i>Bryocamptus unisaetosus</i>	9	0	0	0	stygobite
19	<i>Canthocamptus (C.) staphylinus staphylinus</i>	0	0	1	0	stygoxene
20	<i>Ceuthonectes serbicus</i>	1	0	0	0	stygobite

No. crt.	Taxon	C	S	H	W	ES
21	<i>Elaphoidella phreatica</i>	2	0	0	0	stygobite
22	<i>Elaphoidella putealis</i>	2	0	0	0	stygobite
23	<i>Elaphoidella simplex</i>	0	0	2	0	stygobite
24	<i>Elaphoidella winkleri</i>	1	0	0	0	stygobite
25	<i>Maraenobiotus carpathicus</i>	5	0	0	0	stygobite
26	<i>Maraenobiotus vej dovskyi</i>	2	0	0	0	stygophile
27	<i>Moraria (M.) brevipes brevipes</i>	1	0	0	0	stygophile
28	<i>Moraria (M.) poppei poppei</i>	1	0	1	0	stygoxene
29	<i>Pesceus schmeili schmeili</i>	6	0	1	0	stygophile
30	<i>Spelaecamptus spelaeus</i>	17	0	0	1	stygobite
31	<i>Stammericaris phreatica</i>	2	0	0	0	stygobite

