Subterranean Biology 9: 85-102, 2011
doi: 10.3897/subtbiol.9.2512

The groundwater oligochaetes (Annelida, Clitellata) of Slovenia

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ABSTRACT
Historical data on the biodiversity of oligochaetes inhabiting ground waters of Slovenia depicted a fauna of 25 species, 19 of which are stygobiotic. Over about the last 35 years, faunistic surveys carried out in Slovenian ground waters has enabled us to conduct extensive studies on the oligochaete fauna of this environment. Three primary sources of information have been integrated to summarize in this paper: a campaign in Slovenian caves conducted by Fabio Stoch, a large collection of groundwater fauna made available to us by Boris Sket, and samples collected during the European project PASCALIS. The data derived from the examination of this large amount of material has enabled us to broaden our knowledge of the oligochaete diversity of Slovenia, increasing the number of species to one hundred, and has allowed us to summarize the biological diversity in Slovenian waters to be a substantial percentage of the known diversity present elsewhere in Europe. Endemic, rare and new species constitute a remarkable proportion of the stygobiotic oligochaete fauna. Among these, species of the genera *Trichodrilus*, *Rhyacodrilus*, *Rhyacodriloides*, *Parvidrilus*, *Epirodrilus* and *Abyssidrilus* are some of the most noteworthy taxa because of their endemicity, range-size, rarity, habitat selection, and/or taxonomic isolation (including phylogenetic relictuality).

Key words: biodiversity, stygobiont, endemic, groundwater oligochaetes, Slovenia

INTRODUCTION

This study summarizes the results of an extensive survey of the groundwater oligochaete fauna of Slovenia, integrating all literature data available for the area. The classification adopted here follows the definition of the large taxon Naididae (see Erséus et al. 2008, 2010) – including the taxa in the former family Tubificidae and the recently erected subfamily Rhyacodriloidinae (Martin et al. 2010). The study of oligochaetes in Slovenia began in 1880 with the description of an enchytraeid from a cave (*Enchytraeus cavicola* Joseph, 1880), but the species was not considered valid thereafter (Michaelsen 1900). In 1941, Černosvitov reported *Haplotaxis gordioides* (Hartmann). Our knowledge increased with the contributions of Hrabě (1942, 1963, 1966, 1973) who described 10 new species, and those of Karaman (1974, 1976, 1983, 1987), who studied the Dinaric fauna and described six new Slovenian species. The first general synthesis on the fauna of Slovenia was in the "Catalogus Faunae Jugoslaviae", where Kerovec and Mršić (1981) listed all the oligochaete species known at that time; it was soon followed by the data compiled in "Stygofauna mundi" (Juget and Dumnicka 1986) and "Encyclopedia Biospeologica" (Dumnicka and Juberthie 1994) – each of which focused only on groundwater species. In their publications on the Slovenian fauna, Sket (1995, 1997, 1999) and Bole et al. (1993) presented data on oligochaete diversity. Recent publications, including those in which six species new to science were described, have further increased our knowledge of groundwater fauna (Martínez-Ansemil et al. 1997; Sambugar et al. 1999; Giani et al. 2001; Martin et al. 2010).

Data that has been examined and summarized in this paper was obtained from three geographical regions in Slovenia: the Centre, the South, and certain areas in the North-eastern part of the country. About 40% of the territory of Slovenia is a karst area. The karst is divided in three units: 1) the Alpine karst, situated in the North-western part of the country; 2) the Dinaric karst in Western and Southern Slovenia, consisting of three elongated parallel belts; and 3) the isolated patches of karst of the sub-Alpine and sub-Dinaric Slovenia (Sket et al. 1994). The Slovenian karst is a natural reservoir of underground waters inhabited by one of the richest and most endemic troglobiotic and stygobiotic fauna of the world (Sket

Received 7 June 2011; Accepted 19 September 2011

2010). Examples of the rich surface and underground Slovenian landscapes include: great cave systems with streams, lakes and percolating waters from rock crevices; subterranean rivers; sinking rivers born on the surface, flowing kilometers through the caves and giving birth to wide resurgences (like the Postojna-Planina Cave System, Sket and Velkovrh 1981a; Sket 2004); surface rivers (i.e.: Sava, Drava, Mura) with broad exposed gravelly river beds highly suitable for interstitial fauna (e.g. Sket and Velkovrh 1981c); and slightly thermal springs (Sket and Velkovrh 1981b). We had the opportunity to study the oligochaete fauna linked to many of these habitats. This contribution will summarize our knowledge, to date, of oligochaete communities inhabiting the freshwaters of Slovenia, and establish a basis for future research focusing on subterranean oligochaete fauna.

MATERIALS AND METHODS

Samples of oligochaetes from 261 localities were studied. Some of these samples were kindly provided by colleagues Boris Sket and Fabio Stoch. The studied material of the collection from the biology department of the Biotechnical faculty, University of Ljubljana (mainly collected by B. Sket and F. Velkovrh) is only a part of a large collection of approximately 400 samples from the Dinaric region, collected from caves, wells, springs, and interstitial areas over many years (1960s through 1990s). The study of this material is still in progress. The Fabio Stoch collection consists of 46 samples from Slovenian caves, all taken in the 1990s; our review of the specimens in these samples has been completed. In 2001, the European project PASCALIS (Protocols for the Assessment and Conservation of Aquatic Life in the Subsurface) was initiated to compliment our knowledge of groundwater biodiversity in Europe (Gibert 2001; Gibert and Culver 2009). Six European regions were studied, including the Slovenian 'Krim Massif' area by A. Brancelj and B. Sket. The Annelida were an integral part of that project, and results associated with the oligochaetes are presented here.

Samples were collected from different underground habitats such as pools, lakes and rivulets of caves, interstitial of rivers, springs, phreatic layer of wells. All sampled sites, with related localities, are listed in Appendix 1. In caves and springs, the fauna was sampled by sieving sediments through a hand net (100 μm mesh); in hyporheic areas, the Bou-Rouch pump or the Karaman-Chappuis method were used; wells were sampled by using a Cvetkov closing vertical net. Sampling strategy and used methods are explained in Malard et al., 2002. Samples were fixed in the field with 4% formaldehyde solution and sorted in the laboratory under a stereomicroscope; the collected specimens were stored in vials and preserved in 70% ethanol. Oligochaetes were mounted as whole specimens in glycerin on slides; mature specimens were stained with Mayer's Paracarmin, destained in 70% acid alcohol, at times dissected, dehydrated in ethanol, cleared in xylene and mounted in Canada Balsam on slides. Immature specimens were stored in 70% ethanol. The specimens were observed with a compound light microscope equipped with differential interference contrast optics. Oligochaetes were identified to the species level except for poorly preserved specimens or very scarce material (in these cases we often used 'cf' when referencing this material in the inventory). For practical purposes, throughout the text, we will refer to all of these as species taxa. All studied material discussed below has been deposited in the collections of the authors.

RESULTS

An updated checklist

Table 1 presents a list of aquatic oligochaete taxa presently known to occur in subterranean waters of Slovenia: 25 taxa are known to occur in this country based upon historical records published in the literature, and 78 are added as new records for the country based upon the results of this study. One hundred and three species taxa, thirty-nine genera and six families (Enchytraeidae, Haplotaxidae, Lumbricidae, Lumbriculidae, Naididae, Parvidrilidae) constitute the total number of oligochaetes currently known from Slovenian ground waters. This list represents in fact the majority of the oligochaete fauna known, collectively, from all freshwater habitats in this country; only 10 additional species could be added (Kerovec and Mršić 1981) if we were to also consider those occurring in epigean freshwaters: *Lumbriculus variegatus* Müller, 1774), *Limnodrilus udekemianus* Claparède, 1862, *Psammoryctides albicola* (Michaelsen, 1901), *Psammoryctides moravicus* (Hrabě, 1934), *Potamothrix heuscheri* (Bretscher, 1900), *Chaetogaster diaphanus* (Gruithuisen, 1828), *Uncinais uncinata* (Ørsted, 1842), *Nais simplex* Piguet, 1906, *Stylaria lacustris* (Linnaeus, 1767), and *Aulophorus furcatus* (Oken, 1815). The results of this present study increases the total number of stygobiotic species from 19 to 29. In addition, 15 other species could be considered as stygophiles *(Cernosvitoviella atrata, Haplotaxis gordioides, Marionina argentea, Pristina aequiseta, P. jenkinae, P. osborni, P. rosea, Rhyacodrilus coccineus, R. falciformis, Spirosperma velutinus, Stylodrilus brachystylus, S. heringianus, S. lemani, S. parvus, Trichodrilus strandi*) and one as crenophile *(Rhynchelmis tetratheca)*. During this study, several species identified as new to science are aligned with the following genera: *Fridericia, Abyssidrilus, Epirodrilus* and *Parvidrilus*.

Habitat and distributional information for stygobiotic species is presented below; taxonomical remarks have also been included for the most relevant species. Brief information for all species considered new to science is also presented, but limited to some anatomical and diagnostic features; complete descriptions for these new taxa will be completed and properly described in upcoming publications. The specific status of some specimens thought likely to represent undescribed taxa is uncertain due to the scarcity or the poor quality of the material; however, we will soon examine additional material in the collection provided by Boris Sket, perhaps allowing us to resolve some of the taxonomic and morphological issues with the material already examined.

Table 1 - List of oligochaetes (Annelida, Clitellata) reported from ground waters in Slovenia. Original data are integrated with literature in an updated checklist of Slovenian groundwater oligochaetes. The new findings reported here are referred by the number of the locality adopted in Appendix 1. Species we consider to be stygobiotic are marked with an asterisk; the symbol ° indicates that the species is new to Science.

	Family	**Subfamily**	**Species**	**Reference**	**Present study**
1	Enchytraeidae		*Achaeta* sp.		6, 66, 101, 107, 180, 189, 192, 254
2			*Buchholzia* cf. *appendiculata* (Buchholz, 1862)		13, 18, 30, 31
3			*Buchholzia simplex* Nielsen & Christensen, 1963		25, 29, 36, 53, 82, 233
4			*Cernosvitoviella atrata* (Bretscher, 1903)		201
5			*Cernosvitoviella* cf. *palustris* Healy, 1979		77
6			*Cernosvitoviella* cf. *aggtelekiensis* Dozsa-Farkas, 1970		23
7			*Cognettia cognettii* (Issel, 1905)		14, 102
8			*Cognettia glandulosa* (Michaelsen, 1888)		27
9			*Cognettia sphagnetorum* (Vejdovský, 1878)		7, 12, 14, 19, 55, 60
10			*Enchytraeus buchholzi sensu lato*		7, 10, 16, 19, 31, 32, 35, 51, 59, 128, 129, 143, 144
11			*Enchytraeus cavicola* Joseph, 1880 species inquirenda	Joseph, 1880	
12			*Enchytraeus* cf. *bulbosus* Nielsen & Christensen, 1963		103
13			*Fridericia benti* Schmelz, 2002		55
14			*Fridericia discifera* Healy, 1975		37
15			*Fridericia galba* (Hoffmeister, 1843)		89
16			*Fridericia maculata* Issel, 1905		36
17			*Fridericia semisetosa* Dózsa-Farkas, 1970		25
18			*Fridericia striata* (Levinsen, 1884)		11
19			°*Fridericia* sp. 1		31
20			°*Fridericia* sp. 2		6
21			°*Fridericia* sp. 3		6
22			°*Fridericia* sp. 4		55
23			°*Fridericia* sp. 5		107
24			*Henlea perpusilla* Friend, 1911		6, 7, 21, 30, 31, 32, 36, 37, 60, 203
25			*Henlea ventriculosa* (d'Udekem, 1854)		7, 31, 32

	Family	Subfamily	Species	Reference	Present study
26			*Marionina argentea* (Michaelsen, 1889)		12, 34, 196
27			*Marionina* cf. *argentea* (Michaelsen, 1889)		57, 82
28			*Marionina* cf. *southerni* Černosvitov, 1937		58, 63, 77
29			*Marionina riparia* Bretscher, 1899		1, 3, 6, 7, 13, 19, 27, 28, 29, 30, 31, 32, 35, 37, 165, 187, 207, 249
30			*Marionina* sp. 1		31, 34
31			*Mesenchytraeus armatus* (Levinsen, 1884)		198
32	Haplotaxidae		**Delaya bureschi* (Michaelsen, 1925)	Hrabě, 1963	
33			*Haplotaxis gordioides* (Hartman, 1821)	Černosvitov, 1941	7, 4, 107, 156, 213, 250, 260
34	Lumbricidae		*Eiseniella tetraedra* (Savigny, 1826)		3, 5, 13, 33, 192, 200, 205, 234, 237
35	Lumbriculidae		**Guestphalinus wiardii* (Michaelsen, 1933)	Hrabě, 1973	
36			*Lumbriculus variegatus* (Mueller, 1774)		189
37			*Rhynchelmis limosella* Hoffmeister, 1843		45, 121, 184, 190, 191, 192, 207
38			*Rhynchelmis tetratheca* Michaelsen, 1920		39, 136, 137, 140, 142
39			*Stylodrilus* cf. *asiaticus* (Michaelsen, 1905)		119, 120
40			*Stylodrilus brachystylus* Hrabě, 1928		23, 206
41			*Stylodrilus heringianus* Claparède, 1862	Hrabě, 1973	3, 4, 6, 21, 114, 143, 147, 153, 184, 192, 195, 196, 197, 198, 202, 204, 206, 245, 249, 250
42			*Stylodrilus lemani* Grube, 1879	Hrabě, 1973	19
43			*Stylodrilus parvus* (Hrabě & Černosvitov, 1927)		118, 136, 137, 146
44			**Trichodrilus cernosvitovi* (Hrabě, 1937)		29, 90
45			**Trichodrilus leruthi* Hrabě, 1937		103
46			**Trichodrilus pragensis* Vejdovsky, 1875		3, 10, 12, 15, 23, 29, 121, 143, 148, 154
47			**Trichodrilus ptujensis* Hrabě, 1963	Hrabě, 1963	
48			**Trichodrilus sketi* Hrabě, 1963	Hrabě, 1963	
49			**Trichodrilus stammeri* Hrabě, 1937	Hrabě, 1937	
50			*Trichodrilus strandi* Hrabě, 1936	Karaman, 1987	1, 3, 4, 36, 115, 116, 117, 192, 193, 194, 191, 192
51			**Trichodrilus tacensis* Hrabě, 1963	Hrabě, 1963	

	Family	Subfamily	Species	Reference	Present study
52			**Trichodrilus tenuis* Hrabě, 1960		14, 99
53	Naididae	Naidinae	*Chaetogaster diastrophus* (Gruithuisen, 1828)		23, 75, 95, 113, 114, 119, 176, 197, 201, 241
54			*Chaetogaster langi* Bretscher, 1896		77, 239
55			*Nais alpina* Sperber, 1948		58, 74, 116, 151, 153, 154, 156, 166, 167, 196, 197, 199, 205
56			*Nais barbata* Mueller, 1774		34, 87
57			*Nais bretscheri* Michaelsen, 1899		14, 114, 119, 195, 197, 199, 200, 202, 203, 204, 224, 235, 240
58			*Nais communis* Piguet, 1906		27, 28, 29, 35, 77, 94, 95, 107, 135, 163, 186, 190, 191, 192, 198, 201, 202, 205, 231, 239, 241, 246
59			*Nais elinguis* Mueller, 1774		28, 29, 30, 32, 33, 116, 119, 133, 183, 231, 233
60			*Nais pardalis* Piguet, 1906		142, 146, 149, 152, 154, 197, 200, 241, 259
61			*Nais pseudobtusa* Piguet, 1906		35
62			*Nais stolci* Hrabě, 1981		155
63			*Nais variabilis* Piguet, 1906		29, 30, 32, 107, 116, 186, 205, 230, 232
64			*Opidonais serpentina* (Mueller, 1774)		35
65			*Vejdovskyella intermedia* (Bretscher, 1896)		55
66		Pristininae	*Pristina aequiseta* Bourne, 1891		29, 32, 34, 54, 189, 198, 200, 205, 206, 231, 241, 242, 247, 250, 253, 256, 257, 258, 259
67			*Pristina bilobata* (Bretscher, 1903)		163
68			*Pristina jenkinae* (Stephenson, 1932)		18, 24, 29, 30, 54, 57, 70, 76, 77, 105, 143, 196, 197, 198, 199, 200, 204, 221, 224, 225, 231, 232, 233, 234, 240, 243, 249, 253, 257, 259
69			*Pristina menoni* (Aiyer, 1929)		119
70			*Pristina osborni* (Walton, 1906)		195, 197
71			*Pristina rosea* (Piguet, 1906)		32, 151
72		Phallodrilinae	**Abyssidrilus* cf. *cuspis* (Erséus & Dumnicka, 1988)	Sambugar et al., 1999	
73			°**Abyssidrilus* sp.1		9
74			**Spiridion phreaticola* (Juget, 1987)		107, 147, 182, 205

	Family	Subfamily	Species	Reference	Present study
75		Rhyacodrilinae	*Bothrioneurum vejdovskyanum*		35, 191
76			**Epirodrilus slovenicus* Karaman, 1976	Karaman, 1976	
77			°*Epirodrilus* sp.1		12
78			**Rhyacodrilus caudosetosus* Karaman, 1983	Karaman, 1983	
79			*Rhyacodrilus coccineus* (Vejdovsky, 1876)		41, 43
80			*Rhyacodrilus falciformis* Bretscher, 1901		8, 106, 187, 239
81			**Rhyacodrilus gasparoi* Martínez-Ansemil, Sambugar, Giani, 1997		3, 4, 91, 93, 105, 212
82			**Rhyacodrilus maculatus* Karaman, 1983	Karaman, 1983	
83			*Rhyacodrilus* cf. *maculatus*		177
84			**Rhyacodrilus omodeoi* Martínez-Ansemil, Sambugar, Giani, 1997	Martínez-Ansemil et al., 1997	36
85			**Rhyacodrilus sketi* Karaman, 1974	Karaman, 1974	
86			**Rhyacodrilus* cf. *sketi*		18
87			**Stochidrilus glandolosus* Martínez-Ansemil, Sambugar, Giani, 1997	Martínez-Ansemil, et al., 1997	
88		Rhyacodriloidinae	**Rhyacodriloides latinus* Martin, Martínez-Ansemil, Sambugar, 2010	Martin et al., 2010	29, 96, 107, 110, 120, 123, 168, 169
89		Tubificinae	*Aulodrilus pluriseta* (Piguet, 1906)		39, 100
90			**Haber zavreli* (Hrabě, 1942)		58, 63, 99, 100, 160, 208, 210
91			*Limnodrilus hoffmeisteri* Claparède, 1862		33, 35, 36, 39, 186
92			*Lophochaeta ignota* (Stolc, 1886)		206, 248, 250, 252, 254, 255, 259, 260
93			*Potamothrix hammoniensis* (Michaelsen, 1901)		3, 70, 87, 100, 101, 102, 137, 182, 186, 193, 199
94			**Potamothrix postojnae* Karaman, 1974	Karaman, 1974	
95			*Psammoryctides barbatus* (Grube, 1861)		3, 28, 41, 85, 186, 193, 198, 199, 206
96			**Psammoryctides hadzii* Karaman, 1974	Karaman, 1974	
97			**Sketodrilus flabellisetosus* (Hrabě, 1966) aumg. Karaman, 1976	Karaman, 1976	
98			*Spirosperma* ferox Eisen, 1879		142
99			*Spirosperma velutinus* (Grube, 1879)	Hrabě 1973	1, 4, 27, 39, 54, 55, 85, 193, 232, 236, 238
100			**Tubifex pesce*i (Dumnicka, 1980)	Martínez-Ansemil et al., 1997	
101			*Tubifex tubifex* (Mueller, 1774)		1, 19, 22, 24, 32, 35, 36

	Family	Subfamily	Species	Reference	Present study
102	Parvidrilidae		**Parvidrilus spelaeus* Martínez-Ansemil, Sambugar, Giani, 2002	Martínez-Ansemil, et al., 2002	92, 178, 182
103			°**Parvidrilus* spp.		23, 256
		: presence : absence			

* stygobiont species
° new species

Comments on stygobiotic species

1 - Haplotaxidae

Delaya bureschi. Known from the Slovenian caves Križna (Lož) and Mrzla (Planina) (Hrabě 1963). Transdinaric distribution from Slovenia to Bulgaria.

2 - Lumbriculidae

Guestphalinus wiardii. This species is known from the interstitial area of Vipava river, Dornberk (Nova Gorica) (Hrabě 1973). Very rare species; sporadic citations for localities in Europe (Slovenia, Germany).

Trichodrilus cernosvitovi. New to Slovenia, found in a spring and in hyporheic habitat. Rare species; sporadic citations for localities in Europe (Belgium, France, Romania, Italy).

Trichodrilus leruthi. New to Slovenia, found in a spring. Rare species; sporadic citations for localities in Europe (Belgium, France, Italy).

Trichodrilus pragensis. New to Slovenia, widespread, found in caves, springs, hyporheic habitats, and phreatic habitats. Rather common in Europe.

Trichodrilus ptujensis. Species described from wells in Ptuj (Maribor) and in Tacen (Ljubljana) (Hrabě 1963). Known only from the original localities (the type locality, however, was not stated in Hrabě's paper).

Trichodrilus sketi. Known only from the type locality: interstitial habitat of Sava river, near Ljubljana (Hrabě, 1963).

Trichodrilus stammeri. Species described from ground waters of Carso/Kras (Timavo river) (Hrabě 1937). Known only from the type locality.

Trichodrilus tacensis. This species was described from a well in Tacen (Ljubljana) (Hrabě 1936). Known only from the type locality.

Trichodrilus tenuis. New to Slovenia, found in two caves. Sporadic citations for localities in Europe (France, Germany, Spain).

3 - Naididae

3.1 Phallodrilinae

Spiridion phreaticola. New to Slovenia, found in springs and hyporheic habitats. Prior to this current study, *S. phreaticola* was only known from subterranean habitats in France (Juget 1984, 1987; Erséus et al. 1992; Sambugar et al. 1999; Giani et al. 2001; Route et al. 2004).

Abyssidrilus* cf. *cuspis. Some specimens, which differ from the typical diagnose of *A. cuspis*, were found in the cave Škocjanske (Sambugar et al. 1999).

3.2 Rhyacodrilinae

Epirodrilus slovenicus. Known from the type locality: cave Planinska (Karaman, 1976), and from a spring in Creta (Martin and Giani 1995).

Rhyacodrilus caudosetosus. Known only from the type locality: cave Planinska (Karaman, 1983).

Rhyacodrilus gasparoi. New to Slovenia, found in springs, phreatic habitats, and a cave. Previously known only from an Italian cave (Martínez-Ansemil et al. 1997), this species now appears to be more widespread in the Alpine Arc (unpublished data).

Rhyacodrilus maculatus. Known only from the type locality: cave Planinska (Karaman 1983). ***Rhyacodrilus omodeoi***. Described for the cave Križna (Martínez-Ansemil et al. 1997), it is first reported here from a spring. Endemic in Slovenia.

Rhyacodrilus sketi. Known only from the type locality: cave Planinska (Karaman 1974).

Stochidrilus glandulosus. Known only from the type locality: cave Viršnica (Martínez-Ansemil et al. 1997).

3.3 Rhyacodriloidinae

Rhyacodriloides latinus. Described from a cave in Italy, hyporheic habitats and a spring in Slovenia (Martin et al. 2010), we include here the additional records for springs, hyporheic habitats and phreatic habitats based upon specimens we have collected from Krim Massif and from the hyporheic areas of the Sava river.

3.4 Tubificinae

Haber zavreli. New to Slovenia, found in caves, a spring, and phreatic habitats. Rare species; sporadic citations for localities in Europe (Italy, Poland, Slovakia).

Potamothrix postojnae. Known only from the type locality: cave Planinska (Karaman 1974).

Psammoryctides hadzii. Known only from the type locality: cave Planinska (Karaman 1974).

Sketodrilus flabellisetosus. Originally described from specimens from a cave near the sources of the Timavo river (Monfalcone) in Italy (Hrabě 1966), this species was redescribed in 1976 by Karaman from specimens collected from the cave Planinska.

Tubifex pescei. Found in the cave Križna (Martínez-Ansemil et al. 1997), this species was previously known only from Italian wells (Dumnicka 1981; Dumnicka 1990).

4 - Parvidrilidae

Parvidrilus spelaeus. Described from caves of Italy and Slovenia (Martínez-Ansemil et al. 2002), it is now mentioned for springs in the Krim Massif.

TAXONOMICAL REMARKS

1 - Enchytraeidae

Cernosvitoviella cf. ***palustris***

Two specimens, site 77

Chaetae, size of male glands and shape and size of spermathecae are very similar to those observed in known specimens of *C. palustris*, although we have observed a conspicuous seminal vesicle in XI of these two specimens, which are absent or small in *C. palustris*. The spermathecal ectal pore has the form of a transverse slit, and the clitellum is girdle-shaped. Both traits are unknown in *C. palustris*.

Cernosvitoviella cf. ***aggtelekiensis***

Two specimens, site 23

Chaetae in our specimens are smaller (20-30 µm) than originally described (35 µm). Very similar is *C. parviseta,* distinguishable from *C. aggtelekiensis* only by smaller chaetae (15 µm). *C. aggtelekiensis* was originally described from caves; it has subsequently been recorded from epigeic habitats (e.g., Erséus et al., 2005).

Cognettia sphagnetorum

Twenty-two specimens, sites 7, 12, 14, 19, 55, 60

Specimens belong to two of the three forms distinguished in Schmelz and Collado (2010): one form has 2 chaetae in anterior lateral bundles and a regular set of pharyngeal glands, the other has 2 and 3 chaetae in anterior lateral bundles and irregular pharyngeal glands in VII and VIII, enlarged and with ventral lobes.

Fridericia sp. 1

One mature specimen, site 31

Body length ca. 18 mm, 57 segments, up to 6 chaetae per bundle. Clitellum girdle-shaped, dense rows. Seminal vesicle large, extending to septum 9/10. Sperm funnel pear-shaped, about as long as body diameter. Male glands large, oval, compact, 240 µm long, twice as long as wide or high, bursal slit longitudinal. Subneural glands in XIII – XV. Spermathecae with two irregularly shaped diverticula bent ectad, without subchamber; ectal gland small, if present at all (trait not fully confirmed due to poor preservation of specimen). The combination of traits in this single specimen is unique in the genus *Fridericia*; a more complete description of this taxon will be possible if additional specimens can be collected.

Fridericia sp. 2

One mature specimen, site 6

Body length ca. 7.5 mm, 41 segments, up to 4 chaetae per bundle. Clitellum absent dorsally, present ventrally. Seminal vesicle large, 2 segments. Male glandular bulb small, length 45-50 µm, with a median incision. Subneural gland in XIII and perhaps also in XIV. Ectal duct of spermatheca short, ampulla with two sessile, thin-walled diverticula of ca. 35 µm diameter; ectal gland not ascertained. Only one Chinese species of *Fridericia* (*F. unisetosa* Xie et al. 2000) has a clitellum that appears similar to the clitellum observed in this *Fridericia* sp. 2 specimen: absent dorsally, but present ventrally. However, *F. unisetosa* lacks lateral chaetae and has ventrally only 1 chaeta per bundle. Although several morphological characteristics were not clearly observable in our specimen, the peculiar chaetal pattern will certainly allow re-identification and formal description should additional specimens be collected.

Fridericia sp. 3

One mature specimen, site 6

49 segments, up to 4 chaetae per bundle. Body wall thin (10-15 µm), septa 5/6 – 9/10 thickened. Clitellum girdle, flat, cells absent anteriorly of bursal slits, cell pattern reticulate. Seminal vesicle one complete segment, sperm heads at least 70 µm long. Sperm funnel c. 2x as long as wide, barrel-shaped, collar slightly wider than funnel body, separated by a constriction. Spermatheca with small ectal gland, 2 small diverticula with subchamber oriented towards the ampulla, and separate attachments to oesophagus.

In consideration of the spermatheca (2 diverticula with subchamber), the species belongs to the *F. perrieri*-group as established in Schmelz (2003: 185, 265f., 296, 312, 341f.), but differs from it in the presence of spermathecal ectal glands.

***Fridericia* sp. 4**

One submature specimen, site 55

Body length c. 12 mm, 53 segments, up to 5 chaetae per bundle. Body wall thick (20-30 µm), cuticle c. 2 µm thick; septa 7/8 to 9/10 thickened. Clitellum girdle-shaped, cells in indefinite rows. Seminal vesicle large, 2 segments. Sperm heads ca. 45 µm long. Sperm funnel tapering distad, collar as wide as funnel body. Male gland small, bursal slits T-shaped. Spermathecae with ectal glands, 2 diverticula each and separate attachments to oesophagus. Ectal duct widening proximad, ampulla much widened distally, almost as long as ectal duct. Diverticula oriented towards ampulla or ear-shaped, outline irregular, lumen smaller than ampullar lumen.

This species is a part of the *F. aurita*–species complex as established in Schmelz (2003, p. 112f.). It is also similar to *F. humicola* Bretscher 1900, especially regarding the overall shape of the spermatheca, but in our specimen the spermathecae are smaller, the proximal widening of the ectal duct is much less pronounced (comp. Schmelz 2003, Fig. 39A), and sperm heads are shorter (80 µm in *F. humicola*).

***Fridericia* sp. 5**

One specimen, site107

Chaetae absent laterally, ventrally 2 chaetae per bundle. Cuticle thick. Spermatheca without diverticula. Ampulla large, globular. The combination of traits is unique in *Fridericia*; a more complete description of this taxon will be possible if additional specimens can be collected.

Marionina* cf. *argentea

Six specimens, sites 57, 82

Specimens identifiable as *M. argentea* on behalf of body size, chaetal pattern, coelomocyte texture and size of the male reproductive apparatus, have a clitellum that is only laterally developed, i.e. absent ventrally and dorsally. Since in *M. argentea* the clitellum is dorsally present (Schmelz and Collado 2010), this is perhaps a new species.

Marionina* cf. *southerni

Four specimens, all submature, sites 58, 63, 77

Most traits agree with the diagnosis of *M. southerni*. Noteworthy are chaetal pattern, size of seminal vesicle and male gland, coelomocyte texture. The latter is surprisingly conserved, probably as a result of the use of creosote as dehydrating medium. The spermathecal ampulla lacks the typical ring of sessile diverticula, but these may develop only in fully mature specimens (Schmelz, unpublished observations). Inner traits were not seen in all specimens. With 5 mm body length and 25 segments, specimens are in the lower size and segment range of the species. *M. southerni* is the only *Marionina* species with *argentea*-like chaetal pattern (i.e. bisetose, chaetae lacking only in II laterally) and large seminal vesicles and male glands. Our records suggest that viable populations of this brackish water species live independently of marine coastal pools.

***Marionina* sp. 1**

Four immature specimens, sites 31, 34

Body length 1 mm, segment number 11-22. Shorter specimens with elongate pygidium. Chaetae 2 in all bundles, sharply pointed, with minute distal bend, anteriorly ca. 30 µm long and < 2 µm thick, posteriorly up to 38 µm long and > 2 µm thick. Body wall c.5 µm thick, cuticle almost 1 µm thick. Preclitellar nephridia at 6/7 and 7/8. Coelomocytes small, diameter c. 6-10 µm. This species is unidentifiable but cannot be assigned to any of the species listed here.

Enchytraeus cavicola **Joseph, 1880 - species inquirenda**

The first subterranean record of an enchytraeid in Slovenia was by Joseph (1880), who erected the new species *Enchytraeus cavicola*. The species was never recorded again and type material has not been found. Michaelsen (1900) and Nielsen and Christensen (1959) considered *E. cavicola* as “species dubia”. The original description of this taxon is insufficient to recognize genus or species. The combination of traits described is not found in any of the known enchytraeid species, but we suggest that traits may have been erroneously observed by Joseph. For example, he describes the female pores as large lateral clefts, which seems more inspired by an erroneous figure in Vejdovský (1879, Pl. 5 Fig. 9) than by actual observation. Resampling of the type locality (cave Potiskavec in Dolenjsko) may lead to revalidation of the species. It should be noted that Joseph was the author of a number of fictitious cave species (Brancelj and Sket 1990).

2 - Lumbriculidae

Stylodrilus* cf. *asiaticus

Two mature and four immature specimens, sites 119, 120

In the hyporheic areas of Želimeljščica river very few specimens belonging to *Stylodrilus* genus were found. They share characters with *Stylodrilus asiaticus*: simple chaetae in the anterior segments, replaced by bifid chetae with reduced distal tooth in the following segments, atria pear-shaped, penes undistinguishable, spermathecae with short ducts and large ampullae. They appear to be morphologically close to *Stylodrilus asiaticus,* but the scarcity of mature specimens does not allow a more precise characterization of this material.

3 - Naididae

***Abyssidrilus* sp.1**

Five mature specimens, site 9

This taxon is a new species of *Abyssidrilus,* with spermathecae in the segment XII. It is similar to *A. cuspis*, from which it differs by the preclitellar chaetae, the position of the spermathecal pores, the shape of the spermathecal ampullae, the absence or very short penial chaetae, and the absence of posterior prostate glands. The specimens from Italy (cave Romana, Trieste) and Slovenia (cave Škocjanske), previously named by Sambugar et al. (1999) as *Abyssidrilus* cf. *cuspis,* seem to belong to this species.

Epirodrilus sp. 1

Two mature and fourteen immature specimens, site 12.

These specimens of *Epirodrilus* sp. 1 likely represent a new species, close to *Epirodrilus slovenicus*. In comparison with the latter, this taxon mainly differs by shorter atria, the anterior position of spermathecal pores, and the shape of chaetae in preclitellar dorsal bundles.

Haber zavreli

Many mature specimens, sites 58, 63, 99, 100, 160, 208, 210

A re-evaluation of the specimens in our collection (sites 58, 63), previously assigned to *H. monfalconensis* (Sambugar et al. 1999), and subsequent comparison of those specimens with new material collected during the PASCALIS project in Krim Massif, has led us to assign all of these specimens found in Slovenia to *H. zavreli.* The spermathecal pores are lateral rather than in line with the ventral chaetae, as defined by Hrabě (1965) for *H. monfalconensis* when described it as a subspecies of *Tubifex speciosus* Hrabě, 1931.

Rhyacodrilus cf. ***maculatus***

One mature and one immature specimens, site 177

Specimens determined as *Rhyacodrilus* cf. *maculatus* were found in a spring; the scarcity of material does not allow a more precise determination of this material.

Rhyacodrilus cf. ***sketi***

Two mature and three immature specimens, site 18

To date, *Rhyacodrilus sketi* has only been reported from the type locality: cave Planinska (Karaman 1974). In 1983, Karaman examined new material of the same cave, concluding from his observations that vasa deferentia enter atria subapically. The presence of a single penial chaeta per bundle – and especially the presence of a single and compact prostate gland attached to each atrium – are two characters that clearly differentiate *R. sketi* from all other known rhyacodrilines. Specimens examined by us also have just a single penial chaeta per bundle and a single compact prostate gland per atrium, yet the prostate gland is attached to the anterior side of the atrium (apical in *R. sketi*), together with the vas deferens entrance. All other anatomical characters of our specimens – including the shape and number of the somatic chaetae – strongly suggest an affinity with the taxon described in the original diagnosis of *R. sketi*. The atrial wall of our specimens is composed of a thick granular ectal part and a thin, not granular ental part. Unfortunately, Karaman (1974), in his original description of *R. sketi*, did not describe the structure of its atrial wall. Unfortunately, the type material of *R. sketi* is unavailable; thus, new material from the type locality is needed to resolve the taxonomical status of our material. Noting the presence of compact prostates and single penial chaetae in *R. sketi*, Brinkhurst and Wetzel, 1984 queried the inclusion of *R. sketi* in the Rhyacodrilinae; however, the presence of coelomocytes of rhyacodriline type, and the broad attachment of prostates to atria – in all of our specimens – supports the inclusion of this species in this naidid subfamily.

4 - Parvidrilidae

Parvidrilus spp.

A single specimen clearly belonging to *Parvidrilus* genus was found in the phreatic of the Podlipščica valley (site 256). The atria and spermatheca of this single undescribed specimen are in XII (different from that observed in *P. spelaeus*, in which the atria are in XII and spermathecae are in XIII). The atria in this undescribed specimen are very large and globular, occupying the whole segment. In the cave Pajsarjeva jama (site 23), a unique specimen that was found is characterized by very long atria reaching 13/14, with a thin wall and full of spermatozoids. Spermatheca is not seen due to the poor preservation of the specimen. Unfortunately, the scarcity of material thus far collected has prevented us from fully describing these two taxa that we consider new to Science.

DISCUSSION

At present, 103 species of oligochaetes have been identified from subterranean waters in Slovenia. The oligochaete assemblage can be organized around two components. The first component includes ubiquitous species – predominantly present in surface habitats – with wide geographical distribution and ecological tolerance (great dispersal power), and without habitat partition, e.g., *Nais communis, Potamothrix hammoniensis, Psammoryctides barbatus*. The second component includes 44 species (29 stygobionts and 15 stygophiles), some of them are new to science or for the first time registered for Slovenia (e.g. *Spiridion phreaticola, Trichodrilus leruthi, Trichodrilus cernosvitovi*). Many of these are strictly endemic, while others are linked to a peculiar habitat (e.g. *Trichodrilus ptujensis* to phreatic waters).

Naididae, Enchytraeidae and Lumbriculidae are the richest and most diverse families in Slovenian groundwaters, similar to the fauna present in other subterranean areas of Southern Europe (Giani et al. 2001, Sambugar et al. 2008, Achurra and Rodríguez 2010).

The family Naididae comprises 49 species here: *Nais* Müller (9), *Rhyacodrilus* Bretscher (9) and *Pristina* Ehrenberg (6) are the most diverse genera. *Nais* is a generalist and cosmopolitan genus, living in all epigean waterbodies and frequently in subterranean habitats of Italy (PASCALIS project: Lessinian mountains) and Spain (PASCALIS project: Cordillera Cantábrica) (Sambugar et al. 2009; Stoch et al. 2009; Martin et al. 2009; Achurra and Rodríguez 2010). *Rhyacodrilus* is a large genus consisting of 44 species, of which 17 are subterranean (4 stygophilic and 13 stygobiotic) (Creuzé des Châtelliers et al. 2009). Of the 9 species belonging to *Rhyacodrilus* found in Slovenia, 5 are stygobiotic (4 of them strictly endemic) and 2 stygophilic. The genus *Pristina*, with many stygophilic species, is also well represented, and, to some extent, illustrates the connections between subterranean and surface environments (Lafont and Vivier 2006). *Tubifex pescei* is the only stygobiotic species of the cosmopolitan genus *Tubifex*; the expansion of its biogeographic range to Slovenia suggests a wide distribution of this species in South European ground waters. *Epirodrilus slovenicus*, *Potamothrix postojnae*, and *Psammoryctdes hadzii* are the only stygobiotic species in their respective genera. *Haber* Holmquist*, Sketodrilus* Karaman, and *Stochidrilus* Martínez-Ansemil, Sambugar and Giani are genera inhabiting exclusively subterranean habitats. *Sketodrilus* and *Stochidrilus* are monospecific, and *Stochidrilus* is endemic in Slovenia.

Enchytraeidae is the second most diverse family, with 31 species identified. The most diverse genera include *Fridericia* Michaelsen (11 species) and *Marionina* Michaelsen (5 species). There may be stygobiotic species among the unidentified *Cernosvitoviella* and *Marionina* specimens discussed herein, but the new species of *Fridericia*, each represented by one specimen only, likely are surface taxa that are incidentals in the hyporheic community. The enchytraeid fauna of Slovenia is practically unknown; many as-yet undescribed species are likely to be discovered, especially of *Fridericia*, a genus dominant in both species and specimen numbers in calcareous (i.e., pH-neutral) soils, but thus far poorly represented in our collections (25 specimens altogether). It seems that up to now there is no confirmed case of a truly stygobiotic enchytraeid species. Creuzé des Châtelliers et al. (2009) list 12 stygobiotic enchytraeid species (i.e., those originally described from subterranean habitats). However, these species either (1) have records from surface soils, or (2) they have been synonymized with a known epigean species, or (3) they have been considered doubtful because of insufficient original description, or (4) they were recorded from sites where information on the surrounding epigeic enchytraeid fauna is limited or absent. Hypogean and epigean enchytraeid fauna were studied in parallel in Austria (Bauer 1996) and Hungary (Dózsa-Farkas 1990, Zicsi 1999); in each of these studies, species identified from subterranean habitats also were noted as occurring in surrounding surface soils, representing mostly very common and not rare species. Many enchytraeids live either in soils or at the soil/freshwater interface proper, known as a "critical transition zone" (Bardgett et al. 2001). This explains their repeated and species-rich occurrence in subterranean habitats, whereas the restriction of enchytraeid species to these habitats still awaits demonstration.

Concerning the Lumbriculidae, the third family in diversity (17 species), *Trichodrilus* Claparède and *Stylodrilus* Claparède are the richest genera with 9 and 5 species, respectively. *Trichodrilus* reaches a high rate of endemism. The diversification and radiative evolution in Slovenian ground waters by some large genera like *Trichodrilus* and *Rhyacodrilus* – with many stygobiotic species with narrow distribution pattern – could be in relation with the condition of subterranean environment characterized by stable temperatures, as judging by the overall distribution of these genera in freshwaters.

The 29 stygobiotic species now known to occur in Slovenia represent nearly 1/3 of all stygobiotic freshwater oligochaete species known in the world (104: Creuzé des Châtelliers et al. 2009) –strongly suggesting that Slovenia is a hotspot of biodiversity for freshwaters, and particularly for subterranean taxa (Culver and Sket 2000). If we compare the oligochaete microdrile biodiversity of Slovenia with that present in bordering Italy (the larger Venetian region, Eastern Alps), it appears that its richness is quite similar (103 species in Slovenia, 108 in Italy); however, the number of stygobiont oligochaetes in Slovenia (29) is twice that present in Italy (14). Even if the stygobiotic biodiversity of Italy has been underestimated (our unpublished data show that about eight other undescribed species live in this country), Slovenian data remain quite remarkable. Note that the surface of Slovenia is only 20, 273 km^2. In his opening lecture of the 20th International Conference on Subterranean Biology [ICSB] (Postojna, 2010), Boris Sket highlighted Slovenia as a biodiversity hotspot, reporting 240 stygobiotic species among all aquatic fauna present in the county. He also focused specifically on the Postojna-Planina Cave System – emphasizing the importance of research in this unique system and the number of faunal discoveries (Sket 2010).

The diversity of oligochaetes now known to be present in this geographic unit strengthens its importance, especially since several species seem to be strictly endemic to this area, e.g., *Psammoryctides hadzii, Potamothrix postojnae, Rhyacodrilus caudasetosus, Rhyacodrilus maculatus,* and *Rhyacodrilus sketi*. Several other species are highly localized in distribution, known to be present in a single cave, e.g., the dubious *Enchytraeus cavicola* (Potiskavec), *Stochidrilus glandulosus* (Viršnica), *Abyssidrilus* sp.1 (Jama 4101), and *Epirodrilus* sp.1 (Kevderc). Moreover *Trichodrilus sketi* was collected only in the interstitial of Sava river, *Trichodrilus tacensis* in a well in Tacen (at the same river), *Trichodrilus stammeri* in Timavo river: all these species are probably linked to isolated patches of karst. Of the total fauna known to occur in the Krim Massif, 55 species (more than half of the whole subterranean oligochaete diversity) were found in a relatively small karst area. Taking into account the high rate of endemicity of Slovenian stygofauna, an intensively sampled unit can depict a representative survey of a large region. In fact, the Krim Massif is a marginal karst area ca 10 km south of Ljubljana; samples were taken in numerous sites along three small streams traversing an approximately 35 x 10 km (i.e. 350 km^2) area.

Many species recorded here are new to Slovenia, which expands their geographical range known so far: *Tubifex pescei, Trichodrilus cernosvitovi, Trichodrilus leruthi, Trichodrilus pragensis, Stylodrilus brachystylus, Stylodrilus parvus, Rhynchelmis tetratheca* and *Spiridion phreaticola*. *Rhyacodrilus omodeoi*, endemic to Slovenia, enlarges its range inside the country; *Rhyacodrilus gasparoi* displays a wide occurrence in many habitats of Slovenia, and also in the Italian Alpine arc (unpublished data). However the disjunct distribution of many of these species, and of others (i.e., *Epirodrilus slovenicus* – known only from Slovenia and Greece), emphasizes our limited knowledge of subterranean fauna present in many countries, and of cryptic species.

For some taxa, as in the case of genus *Rhyacodriloides* Chekanovskaya, a disjunct distribution allows us to assume that some species are relicts – descendants of an old fauna that long ago became extinct in the surrounding areas, yet persist in environments that can be considered refugia (Martin et al. 2010).

Historical factors explain the biodiversity patterns of Phallodrilinae, pointing to the marine origin of part of the subterranean fauna: seven genera of Phallodrilinae are presently known in continental subterranean waters in the world (Sambugar et al. 1999, Pinder et al. 2006, Stoch et al. 2009, Rodríguez and Achurra 2010); among the 32 genera in this subfamily, two are present in Slovenia: *Abyssidrilus* Erséus (with one probably new species), and *Spiridion* Knöllner.

The stygobiotic family Parvidrilidae, Holarctic in distribution, presently includes two species, *P. strayeri* (North America – one location: Hendrick Mill Branch, Blount County, Alabama, USA [Erséus, 1999]) and *P. spelaeus* (Europe – 12 locations in Italy and Slovenia [see also Martínez-Ansemil et al. 2002]); however, six new species are currently in the process of being described (Martínez-Ansemil et al. in prep.). This family is represented in Slovenia by *P. spelaeus* and likely two additional (as-yet undescribed) species, thus increasing the diversity of the genus and suggesting a wider biogeographic range of the family in European groundwaters.

The patchwork of endemicity, the species regional differences and the biodiversity patterns displayed by the Slovenian fauna reflect the long and complex history of the Slovenian Karst, and suggest that the relative distribution of species may be the consequence of different histories, life conditions and patch partitioning, only partially explicable as our knowledge of groundwater biodiversity is still far from being complete.

ACKNOWLEDGEMENTS

We owe many thanks to Fabio Stoch, Boris Sket and Anton Brancelj for placing at our disposal the oligochaete material and for their invaluable suggestions to the early draft. We are also greatly indebted to our colleague Mark J. Wetzel for suggestions, constructive criticism, and language editing, and to Marina Cobolli, our journal editor. This contribution was partly supported by the PASCALIS Project funded by the E.U. Commission (contract no. EVK2-CT-2001-00121).

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APPENDIX 1

List of the sites of studied samples.

Data reported for each site are as follows: site number in the catalogue, name of the site; municipality (larger town); WGS84 decimal degrees coordinates; year of collection; sampling habitat.

The sampling habitats are abbreviated as follows: C= Cave; S= Spring; W= Well; H= Hyporheic, Bou-Rouch method; H, K.C.= Hyporheic, Karaman-Chappuis method; P= Phreatic.

From 1 to 41 samples are of the Ljubljana University collection (by B. Sket and F. Velkovrh); from 42 to 87 of Fabio Stoch collection; from 88 to 261 of PASCALIS project (in Biology department, University of Ljubljana, and National Institute of Biology, Ljubljana; all collected in 2002).

1. Anže 9; Brestanica (Krško); 15.51962222; 45.99015556; 1976; S.
2. Belinca; Sežana; 13.91351713; 45.72346414; 1978; C.
3. Bistra; Bistra (Vrhnika); 14.33310623; 45.94603575; 1977-1980-1989; S.
4. Bizjakova jama; Studena (Kostanjevica); 15.43382204; 45.83901632; 1998; C.
5. Bučerca 18; Kremen (Krško); 15.51390278; 45.98025556; 1976; S.
6. Hrastje; E Ljubljana; 14.63712446; 45.97160774; 1975; W.
7. S W of Bogatinsko sedlo (ca 1700 m a.s.l.); Komna; 13.73229722; 46.28157778; 1985; S.
8. Jama v Kamnolomu; Suha pri Šentjurju; 15.39389413; 46.14407739; 1979; C.
9. Jama 4101; Brje (Sežana); 13.8622; 45.77765556; 1979; C.
10. Jama II v Repoluskovih pečinah; Šentilj (Maribor); 15.61543042; 46.67950307 . 1978; C.
11. Jelendol ; Kočevje; 76239444; 45.67097778; 1974; S.
12. Kevderc; Todraž (Gorenja vas); 14.16141389; 46.08620278; 1975-1977; C.
13. Kovaceva 1; Šmartno (Ljubljana); 14.55538333; 46.07772778; 1998; W.
14. Krapljetova jama; KŠ 484 (Štajerska); 14.95860241; 46.285114991977; C.
15. Krapljetova; Radizelj (Maribor); 14.95860241; 46.28511499; 1977; C.
16. Vrtojba. Krožna 18; Vrtojba (Nova Gorica); 13.63122778; 45.91126667; 1977; W.
17. Kuperče; Maribor; 15.68054444; 46.54677222; 1977; S.
18. Loke 7; Nova Gorica; 13.71086667; 45.95856667; 1977; S.
19. Mejame; Kačiče (Divača); 13.98765624; 45.65148211; 1992; C.
20. Novokrajska jama; Novokračine (Jelšane); 14.30155106; 45.49109181; 1978; C.
21. Vrtojba. Operkarniška 43; Vrtojba (N. Gorica); 13.64497778; 45.91625278; 1977; S.
22. Osp 6; Osp (Koper); 13.85860; 45.5705; 1977; W.
23. Pajsarjeva jama; Podlipa (Vrhnika); 14.26574747; 45.99765285; 1998; C.
24. Potočnik; Polzela; 15.0708; 46.2814; 1977; C.
25. Potok; Mirtoviči (Brod na Kolpi); 14.76945; 45.51073056; 1979; S. confluence of Želimeljščica; Zelimlje (Ljubljana); 14.57211944; 45.91711944; 1976; S.
26. Rov; Grič Grad (Podčertrtek); 14.55535804; 46.0483949; 1978-1979; C.
27. Sava river; Litija; 14.83184722; 46.05880556; 1965; H K.C.
28. Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978-1987-1998; H.
29. Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978; H K.C.
30. Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978; H K.C.; C levi breg.
31. Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978; H K.C.; C otok.
32. Sava river; Jarški prod; 14.55059444; 46.081525; 1987; H.
33. Sava river; upstream Ježica (Ljubljana); 14.52072222; 45.09406389; 1987; H.
34. Sotla; Vonarje (Rogaška Slatina); 15.62689167; 46.17444444; 1979; H.
35. Spring near Želimeljščica; Želimlje (Ljubljana); 14.57211944; 45.91711944; 1976; S.
36. Studenec; Fužine (Ljubljana); 14.55535804; 46.0483949; 1998; S.
37. Sveto; Banjska planota; 13.68993889; 46.03633056; 1976-1977; W.
38. Verd 121; Vrhnika (Ljubljana); 14.30084444; 45.95181389; 1977; S.
39. Želimeljščica; Želimlje - Turjak; 14.59013611; 45.89666944; 1976; H.
40. Zaloka S; Male Lipljene (Grosuplje); 14.95860241; 46.28511499; 1982; S.
41. Boltaceva jama; Trojica; Domžale; 14.68622; 46.12461; 1992; C.
42. Ciganska jama pri Predgrižah; Crni Vrh; Idrija; 14.07017; 45.93738; 1993; C.
43. Hudournik; Turjak; Ljubljana; 14.59512; 45.89158; 1993; C.
44. Planinska jama; Kacja vas; Postojna; 14.24566; 45.8199; 1993; C.
45. Zelške jame; Rakov Škocjan; Cerknica; 14.30349; 45.79066; 1993; C.
46. Lipiška jama; Gropada; Sežana; 13.88277; 45.68371; 1993; C.
47. Lukova jama pri Zdihovem; Škrilj; Kocevje; 14.89423; 45.52556; 1993; C.
48. Štefakova pecina; Materija; Sežana; 14.00743; 45.57937; 1993; C.
49. Raciška pecina; Racice; Ilirska Bistrica; 14.15023; 45.50336; 1993; C.
50. Mackovica; Laze; Logatec; 14.27066; 45.85893; 1993; C.
51. Krempljak; Materija; Sežana; 13.99529; 45.57259; 1993; C.
52. Križna jama; Blocice; Cerknica; 14.46727; 45.7452; 1993; C.

53. Stobe; Petrova vas; Crnomelj; 15.17065; 45.60421; 1993; C.
54. Viršnica; Racna; Grosuplje; 14.70549; 45.90392; 1995; C.
55. Dolenjska jama; Dolenje; Ilirska Bistrica; 14.26103; 45.50267; 1995; C.
56. Ponikevska Draga; Avber; Sežana; 13.86258; 45.78983; 1994; C.
57. Kompoljska jama; Kompolje; Grosuplje; 14.73094; 45.7995; 1993; C.
58. Jama pod gradom Luknja; Precna; Novo mesto; 15.09978; 45.81841; 1994; C.
59. Marnena jama; Dolenje; Ilirska Bistrica; 14.26044; 45.50205; 1994; C.
60. Miškotova jama v Lokah; Ocizla; Sežana; 13.89452; 45.59344; 1994; C.
61. Jezerina; Gradišce; Sežana; 14.07897; 45.55201; 1994; C.
62. Podpeška jama; Videm-Dobrepolje; Grosuplje; 14.68632; 45.83927; 1994; C.
63. Polina pec; Hrušica; Ilirska Bistrica; 14.09475; 45.51799; 1994; C.
64. Široka jama; Hoticna; Sežana; 14.01819; 45.57432; 1994; C.
65. Stubica; Belcji Vrh; Crnomelj; 15.23952; 45.52083; 1994; C.
66. Tatrca; Kompolje; Grosuplje; 14.74736; 45.79179; 1994; C.
67. Trnska jama; Trnje; Postojna; 14.24168; 45.70537; 1994; C.
68. Vodna jama; Željne; Kocevje; 14.87422; 45.66142; 1994; C.
69. Željnske Jame; Željne; Kocevje; 14.88489; 45.65428; 1994; C.
70. Škocjanske jame; Naklo; Sežana; 13.99396; 45.66499; 1994; C.
71. Dimnice; Slivje; Sežana; 14.04022; 45.56362; 1996; C.
72. Košanski spodmol; Košana; Postojna; 14.13189; 45.69608; 1994; C.
73. Kostanjeviška jama; Oštrc; Krško; 15.43423; 45.83798; 1996; C.
74. Pajsarjeva jama; Podlipa; Vrhnika; 14.26575; 45.99765; 1996-98; C.
75. Zgornja Klevevška jama; Zbure; Novo mesto; 15.23328; 45.90667; 1996; C.
76. Spodnja Klevevška jama; Zbure; Novo mesto; 15.23341; 45.90671; 1996; C.
77. Bruhalnik za Javornikovo žago; Stavca vas; Novo mesto; 14.96248; 45.80829; 1996; C.
78. Dolga jama pri Koblarjih; Koblarji; Kocevje; 14.83005; 45.7122; 1994; C.
79. Jazbina pri Podturnu; Podturn; Novo mesto; 15.03633; 45.74696; 1998; C.
80. Blažev spodmol; Ocizla; Sežana; 13.89521; 45.59251; 1998; C.
81. Jezerina; Gradišce; Sežana; 14.07897; 45.55201; 1998; C.
82. Turkova jama; Petkovec; Logatec; 14.2139; 45.9695; 1998; C.
83. Jama pod Rdeco skalo; Strmec; Tolmin; 13.64394; 46.43348; 1998; C.
84. Jama pod gradom Luknja; Precna; Novo mesto; 15.09978; 45.81841; 1998; C.
85. Polina pec; Hrušica; Ilirska Bistrica; 14.09475; 45.51799; 1998; C.
86. Divaška jama; Divaca; Sežana; 13.95077; 45.67522; 1998; C.
87. PASCALIS PROJECT SITES
88. KRI001/A1; Jama pri Bajdincu; 14.61143; 45.88282; C.
89. KRI002/A1; Kolarjev graben 1; 14.57226; 45.90176; S.
90. KRI003/A1; S. Klančarci; 14.53757; 45.88971; S.
91. KRI004/A1; Kolarjev graben 2; 14.56968; 45.90175; S.
92. KRI005/A1; S. pri Žumerju; 14.59652; 45.8879; S.
93. KRI006/A1; S. Povšečka; 14.59301; 45.88294; S.
94. KRI007/A1; S. pri Bajdincu; 14.61459; 45.88279; S.
95. KRI009/A1; S. Dobra voda; 14.55615; 45.90237; S.
96. KRI010/A1; S. Pod mostom; 14.61489; 45.88504; S.
97. KRI011/A1; S. Močilo (desni); 14.55515; 45.90664; S.
98. KRI012/A1; S. pri Suši; 14.55867; 45.90958; S.
99. KRI013/A2; Vodni kevder; 14.61463; 45.88526; C.
100. KRI014/A2; Hudournik; 14.59488; 45.89167; S.
101. KRI015/A2; S. črna voda; 14.59035; 45.8944; S.
102. KRI016/A2; S. pod Turjaškim gradom; 14.60174; 45.87847; S.
103. KRI017/A2; S. v Želimljah; 14.57438; 45.91931; S.
104. KRI019/A2; S. pod Janezom; 14.57366; 45.93033; S.
105. KRI020/A2; S. Dremavščice; 14.56805; 45.94695; S.
106. KRI022/A2; S. pri Karčonu; 14.55856; 45.94534; S.
107. KRI023/A2; S. v Dragi I; 14.55011; 45.93317; S.
108. KRI024/A2; S. v Igu; 14.52834; 45.95422; S.
109. KRI025/A3; Želimeljščica-hypo1; 14.6048; 45.87149; H.
110. KRI026/A3; Želimeljščica-hypo2; 14.59576; 45.8844; H.
111. KRI027/A3; Želimeljščica-hypo3; 14.59327; 45.89171; H.
112. KRI028/A3; Želimeljščica-hypo4; 14.59391; 45.89172; H.
113. KRI029/A3; Želimeljščica-hypo5; 14.58709; 45.89956; H.
114. KRI030/A3; Želimeljščica-hypo6; 14.58514; 45.90226; H.
115. KRI031/A3; Želimeljščica-hypo7; 14.58187; 45.90899; H.
116. KRI032/A3; Želimeljščica-hypo8; 14.57791; 45.92157; H.
117. KRI033/A3; Želimeljščica-hypo9; 14.56753; 45.93053; H.
118. KRI034/A3; Želimeljščica-hypo10; 14.57301; 45.93055; H.
119. KRI035/A3; Želimeljščica-hypo11; 14.56295; 45.93951; H.
120. KRI036/A3; Želimeljščica-hypo12; 14.5614; 45.94444; H.
121. KRI037/A4; Želimeljščica-phreat1; 14.6048; 45.87149; P.
122. KRI039/A4; Želimeljščica-phreat3; 14.59327; 45.89171; P.
123. KRI043/A4; Želimeljščica-phreat7; 14.58187; 45.90899; P.
124. KRI044/A4; Želimeljščica-phreat8; 14.57791;

45.92157; P.
125. KRI046/A4; Želimeljščica-phreat10; 14.57301; 45.93055; P.
126. KRI047/A4; Želimeljščica-phreat11; 14.56295; 45.93951; P.
127. KRI048/A4; Želimeljščica-phreat12; 14.5614; 45.94444; P.
128. KRI051/B1; Velika Pasica; 14.49289; 45.9188; C.
129. KRI052/B1; Kevderc pri Planinci; 14.45311; 45.95186; C.
130. KRI055/B1; S. Pod vrhom; 14.47641; 45.92161; S.
131. KRI056/B1; S. pri lovski koči; 14.47527; 45.90608; S.
132. KRI057/B1; S. črni potok; 14.48336; 45.90117; S.
133. KRI058/B1; S. pri Benku; 14.48311; 45.89352; S.
134. KRI059/B1; S. Korito; 14.50923; 45.85248; S.
135. KRI060/B1; S. Gabrovica; 14.51523; 45.90378; S.
136. KRI061/B2; barsko okno ob Ižanki; 14.52593; 45.9722; S.
137. KRI062/B2; S. in Podkraj; 14.46772; 45.97229; S.
138. KRI063/B2; S. Vogli; 14.48706; 45.93819; S.
139. KRI064/B2; S. nad Strahomerskim ribnikom; 14.48853; 45.93471; S.
140. KRI065/B2; S. Z od Virje; 14.44271; 45.97296; S.
141. KRI066/B2; S. at Podpeško jezero; 14.43796; 45.96461; S.
142. KRI067/B2; S. between Jezero village and stone-quarry; 14.42886; 45.97132; S.
143. KRI068/B2; S. at Podpeško jezero; 14.43312; 45.96459; S.
144. KRI069/B2; S. in Ponikve I; 14.3856; 45.95462; S.
145. KRI070/B2; S. in Ponikve II; 14.3787; 45.96001; S.
146. KRI071/B2; S. Roček; 14.43514; 45.95636; S.
147. KRI072/B2; S. at Resnik; 14.47556; 45.97783; S.
148. KRI073/B3; Iška-hypo1; 14.49238; 45.90189; H.
149. KRI074/B3; Iška-hypo2; 14.49298; 45.90594; H.
150. KRI075/B3; Iška-hypo3; 14.49778; 45.91046; H.
151. KRI076/B3; Iška-hypo4; 14.5013; 45.91272; H.
152. KRI077/B3; Iška-hypo5; 14.50894; 45.92346; H.
153. KRI078/B3; Iška-hypo6; 14.51733; 45.92894; H.
154. KRI079/B3; Iška-hypo7; 14.51588; 45.93629; H.
155. KRI080/B3; Iška-hypo8; 14.5066; 45.93974; H.
156. KRI081/B3; Iška-hypo9; 14.50172; 45.94098; H.
157. KRI082/B3; Iška-hypo10; 14.49055; 45.94044; H.
158. KRI083/B3; Iška-hypo11; 14.48503; 45.95691; H.
159. KRI084/B3; Iška-hypo12; 14.4796; 45.9695; H.
160. KRI085/B4; Iška-phreat1; 14.49238; 45.90189; P.
161. KRI086/B4; Iška-phreat2; 14.49298; 45.90594; P.
162. KRI087/B4; Iška-phreat3; 14.49778; 45.91046; P.
163. KRI088/B4; Iška-phreat4; 14.5013; 45.91272; P.
164. KRI089/B4; Iška-phreat5; 14.50894; 45.92346; P.
165. KRI090/B4; Iška-phreat6; 14.51733; 45.92894; P.
166. KRI091/B4; Iška-phreat7; 14.51588; 45.93629; P.
167. KRI092/B4; Iška-phreat8; 14.5066; 45.93974; P.
168. KRI093/B4; Iška-phreat9; 14.50172; 45.94098; P.
169. KRI094/B4; Iška-phreat10; 14.49055; 45.94044; P.
170. KRI095/B4; Iška-phreat11; 14.48503; 45.95691; P.
171. KRI096/B4; Iška-phreat12; 14.4796; 45.9695; P.
172. KRI097/C1; S. pri Jelenska jama; 14.35532; 45.91806; S.
173. KRI098/C1; Jerinovec; 14.29341; 45.91951; C.
174. KRI099/C1; S. nad jamo (Jamovka); 14.35849; 45.90903; S.
175. KRI100/C1; S. nad železniškim predorom; 14.36568; 45.91116; S.
176. KRI101/C1; S. Kalašca; 14.42391; 45.93463; S.
177. KRI102/C1; S. Izber; 14.40665; 45.90575; S.
178. KRI103/C1; S. Šumik; 14.40802; 45.89789; S.
179. KRI104/C1; S. nad cesto Borovnica; 14.36474; 45.90913; S.
180. KRI105/C1; S. Malence 1; 14.3515; 45.91153; S.
181. KRI106/C1; S. Malence 2; 14.36474; 45.90913; S.
182. KRI107/C1; S. Malence 3; 14.3515; 45.91153; S.
183. KRI108/C1; S. Malence 4; 14.35312; 45.91086; S.
184. KRI109/C2; S. Trebina; 14.35537; 45.91155; S.
185. KRI110/C2; S. pri Ribiču; 14.31428; 45.95083; S.
186. KRI111/C2; S. v Dolu; 14.33372; 45.94426; S.
187. KRI112/C2; S. Breg pri Borovnici; 14.33603; 45.9391; S.
188. KRI113/C2; S. nad Ohonico; 14.34871; 45.92995; S.
189. KRI114/C2; S. nad železniškim predorom; 14.36377; 45.93769; S.
190. KRI115/C2; S. at Bistra castle; 14.37352; 45.90153; S.
191. KRI116/C2; S. pod Šivčevim hribom; 14.36568; 45.91116; S.
192. KRI117/C2; S. pod Sv. Jožefom; 14.337; 45.94062; S.
193. KRI118/C2; S. v Podkamniku; 14.38796; 45.96571; S.
194. KRI119/C2; S. pred odcepom za Preserje; 14.40994; 45.96042; S.
195. KRI120/C2; S. v Podpei; 14.41055; 45.96403; C.
196. KRI121/C3; Borovniščica-hypo1; 14.37278; 45.89088; H.
197. KRI122/C3; Borovniščica-hypo2; 14.37916; 45.89639; H.
198. KRI123/C3; Borovniščica-hypo3; 14.3803; 45.90164; H.
199. KRI124/C3; Borovniščica-hypo4; 14.37711; 45.90563; H.
200. KRI125/C3; Borovniščica-hypo5; 14.37312; 45.9085; H.
201. KRI126/C3; Borovniščica-hypo6; 14.37537; 45.90896; H.
202. KRI127/C3; Borovniščica-hypo7; 14.38121; 45.90562; H.
203. KRI128/C3; Borovniščica-hypo8; 14.38573; 45.9021; H.
204. KRI129/C3; Borovniščica-hypo9; 14.38883; 45.89293; H.
205. KRI130/C3; Borovniščica-hypo10; 14.3906; 45.88676; H.
206. KRI131/C3; Borovniščica-hypo11; 14.36719; 45.92061; H.
207. KRI132/C3; Borovniščica-hypo12; 14.35994; 45.93407; H.
208. KRI133/C4; Borovniščica-phreat1; 14.37278; 45.89088; P.
209. KRI134/C4; Borovniščica-phreat2; 14.37916; 45.89639; P.
210. KRI135/C4; Borovniščica-phreat3; 14.3803; 45.90164; P.

211. KRI136/C4; Borovniščica-phreat4; 14.37711; 45.90563; P.
212. KRI137/C4; Borovniščica-phreat5; 14.37312; 45.9085; P.
213. KRI138/C4; Borovniščica-phreat6; 14.37537; 45.90896; P.
214. KRI139/C4; Borovniščica-phreat7; 14.38121; 45.90562; P.
215. KRI140/C4; Borovniščica-phreat8; 14.38573; 45.9021; P.
216. KRI141/C4; Borovniščica-phreat9; 14.38883; 45.89293; P.
217. KRI142/C4; Borovniščica-phreat10; 14.3906; 45.88676; P.
218. KRI143/C4; Borovniščica-phreat11; 14.36719; 45.92061; P.
219. KRI144/C4; Borovniščica-phreat12; 14.35994; 45.93407; P.
220. KRI145/D1; Pajsarjeva jama; 14.2656; 45.99775; C.
221. KRI146/D1; S. pri Jama v Kobilji dolini; 14.32199; 46.00762; S.
222. KRI147/D1; S. pod Špico; 14.24624; 45.97656; S.
223. KRI149/D1; S. pri Moravcu; 14.28146; 45.99712; S.
224. KRI150/D1; S. v Hleviški graben; 14.20878; 46.00263; S.
225. KRI151/D1; S. v Celarjih; 14.23562; 46.01252; S.
226. KRI152/D1; S. nad V. Ligojno; 14.30177; 45.99851; S.
227. KRI155/D1; Korita 1; 14.25629; 45.97303; S.
228. KRI156/D1; izvir ob cesti V.Ligojna-Horjul; 14.29176; 45.99934; S.
229. KRI157/D2; Pajsarjeva jama; 14.2656; 45.99775; S.
230. KRI158/D2; Jama v Kobilji dolini; 14.32089; 46.0078; S.
231. KRI160/D2; S. pod V. Ligojno; 14.29861; 45.99354; S.
232. KRI161/D2; S. pri Ogrinu; 14.29442; 45.99261; S.
233. KRI162/D2; S. pri Merlaku; 14.28956; 45.99461; S.
234. KRI163/D2; S. pri Koprivcu; 14.32685; 46.00563; S.
235. KRI164/D2; S. pri Pajsarju; 14.26502; 45.99625; S.
236. KRI165/D2; S. Moravc; 14.28146; 45.99703; S.
237. KRI166/D2; Veliki Močilnik; 14.29201; 45.95414; S.
238. KRI167/D2; Malo okence; 14.29561; 45.94988; S.
239. KRI169/D3; Podlipščica-hypo1; 14.22037; 46.00451; H.
240. KRI170/D3; Podlipščica-hypo2; 14.21479; 46.01174; H.
241. KRI171/D3; Podlipščica-hypo3; 14.23239; 45.9989; H.
242. KRI172/D3; Podlipščica-hypo4; 14.23864; 45.99667; H.
243. KRI173/D3; Podlipščica-hypo5; 14.25013; 45.98604; H.
244. KRI174/D3; Podlipščica-hypo6; 14.25899; 45.98567; H.
245. KRI175/D3; Podlipščica-hypo7; 14.25018; 45.99286; H.
246. KRI176/D3; Podlipščica-hypo8; 14.26258; 45.99009; H.
247. KRI177/D3; Podlipščica-hypo9; 14.27442; 45.98951; H.
248. KRI178/D3; Podlipščica-hypo10; 14.28441; 45.98938; H.
249. KRI179/D3; Podlipščica-hypo11; 14.28893; 45.98903; H.
250. KRI180/D3; Podlipščica-hypo12; 14.29483; 45.98618; H.
251. KRI181/D4; Podlipščica-phreat1; 14.22037; 46.00451; P.
252. KRI183/D4; Podlipščica-phreat3; 14.23239; 45.9989; P.
253. KRI184/D4; Podlipščica-phreat4; 14.23864; 45.99667; P.
254. KRI185/D4; Podlipščica-phreat5; 14.25013; 45.98604; P.
255. KRI186/D4; Podlipščica-phreat6; 14.25899; 45.98567; P.
256. KRI187/D4; Podlipščica-phreat7; 14.25018; 45.99286; P.
257. KRI188/D4; Podlipščica-phreat8; 14.26258; 45.99009; P.
258. KRI189/D4; Podlipščica-phreat9; 14.27442; 45.98951; P.
259. KRI190/D4; Podlipščica-phreat10; 14.28441; 45.98938; P.
260. KRI191/D4; Podlipščica-phreat11; 14.28893; 45.98903; P.
261. KRI192/D4; Podlipščica-phreat12; 14.29483; 45.98618; P.