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Cernosvitoviella Species (Oligochaeta, Enchytraeidae) from Alpine Freshwaters

Elzbieta Dumnicka[1] and Angela Boggero[2*]

[1]Institute of Nature Conservation, Polish Academy of Sciences, Krakow, Poland

[2]CNR-Institute of Ecosystem Study (ISE), Largo Tonolli 50, Verbania Pallanza, Italy

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***For Correspondence**

Angela Boggero, CNR-Institute of Ecosystem Study (ISE), Largo Tonolli 50, Verbania Pallanza, Italy,
Tel: 00390323518300.

E-mail: a.boggero@ise.cnr.it

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ABSTRACT

The paper refers to the merge of data, based mainly on bibliography, but also on recent sampling campaign, on the genus *Cernosvitoviella* present in different freshwater habitat types of the Alps, but greatly overlooked. Three different States with their regions or cantons were involved, and a total amount of 15 species was found. Some notes on the ecological requirements and on the geographic distribution of all the species caught are provided to give a more sound grounding of their presence in different water-types at local level. In addition, during the monitoring campaign of the International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes, individuals of *Cernosvitoviella goodhui* Healy 1975 from one high altitude lake in Canton Ticino were found for the first time for Switzerland and here presented.

INTRODUCTION

The '90s, with the launch of several European programmes like AL:PE (1991-1994), MOLAR (1996-1998), EMERGE (2000-2002), CRENODAT (2004-2007) or International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters, 1994-present) as well as of trans-national (Interreg III A – Alcotra, 2005-2006) and national projects (HIGHEST, 2001-2004; SHARE-Stelvio, 2010-2013; Convention with ValGrande National Park, 2004-2005), marked the beginning of a deep exploration of the invertebrate fauna of Alpine water bodies.

These programmes allowed the collection of hundreds of macroinvertebrates' species with a special focus on a greater knowledge of the faunal diversity and a better understanding of its function in harsh environments, to promote the conservation of specific areas or freshwater habitats. The extensive dataset assembled, constituted to date the basis for interpreting the effects of water pollution (including acidification) or of climate changes on the invertebrate fauna composition in high altitude stagnant and running waters, including springs and caves. A huge amount of papers has been published on specific topics [1-6] and in the last years, the oligochaete fauna was analysed to state the important role it has in the structure and function of the community assemblage as a whole [7-12]. During these extended sampling periods, which have involved the entire Alpine range, beside common and ubiquitous species, some rare species were also found. Of remarkable interest, the genus *Cernosvitoviella* showed a strong presence in different types of waters (lakes, lake-tributaries, streams, springs and caves), even in Switzerland, where three out of four Alpine cantons exhibit some species. In 2007, during one of this sampling campaign, for the first time, individuals of *Cernosvitoviella goodhui* Healy 1975 were found in the Northern side of the Alps (Switzerland) together with other rare species from this genus. Moreover, the presence of two young *Cernosvitoviella* individuals was stated in springs of German Alps [14], but the identification of species was unsuccessful therefore these results are not taken into consideration in the present paper.

The main aim of the present paper is a) to take stock of the present situation and geographic distribution of the genus *Cernosvitoviella* in high altitude freshwaters, b) to describe the main morphological characteristics of the most frequently-occurring species as well as of a few rare species found over the Alps as a whole, and c) to describe their ecological preferences, actually not recorded in detail.

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Geographic Coverage and Water Types

Sampling sites are distributed along the Alps, covering an area comprised in the Alpine biogeographical region [15]. Three States were covered by enchytraeids species sampling, identification and description **(Figure 1** and **Table 1)**: France and Switzerland in the Northern side of the Alps, and, in the Southern side, Italy. In France, only the Provence-Alpes-Côte d'Azur region was considered, while in Switzerland three main cantons were explored (Vaud, Ticino and Grigioni). In Italy, five regions were extensively run: Piedmont, Aosta Valley, Lombardy, Trentino-Alto Adige and Veneto.

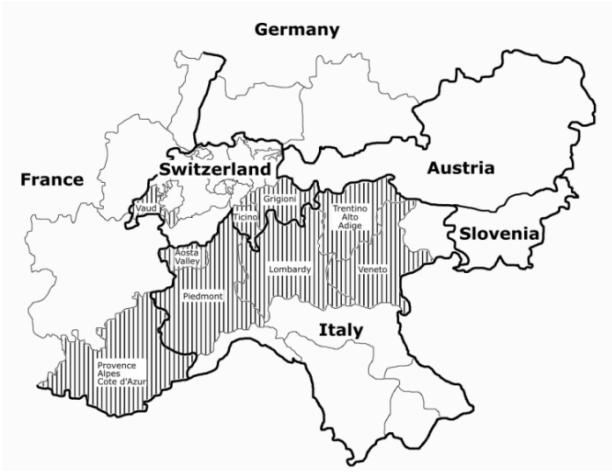

Figure 1. Sampling regions or cantons (striped areas) distributed along the Alps, and States to which they belong.

Table 1. List of sites where *Cernosvitoviella* species were found. Details are given on: Northern/Southern side of the Alps, type of water body, number of considered sites, main lithology of the sampled system, geographic boundary limits (altitude in m a.s.l., latitude and longitude as WGS84 DD) within which the species occur. Information incomplete in Trentino.

State/Region/Canton	Side (North/South)	Water body type	No. sites	Longitude range	Latitude range	Altitude range	Lithology
Italy							
Aosta Valley	S	lakes	1	6.86	45.77	1960	calcareous
Piedmont	S	lakes	8	8.07-8.49	46.00-46.32	1881-2441	siliceous
Lombardy	S	lake outlets	2	10.48-10.49	46.33-46.34	2386-2606	siliceous
Veneto	S	caves	2	12.87-12.89 (entrance of the area)	46.15-46.16 (entrance of the area)	-210/-460	calcareous
Veneto	S	springs	1	10.86-11.11	45.58-45.62	710-961	calcareous
Trentino	S	streams	12	10.65-10.71	46.41-46.44	1950-2703	siliceous
Trentino	S	springs	28	10.56-11.92	45.80-46.49	250-2314	calcareous/ siliceous
Alto Adige	S	springs	15	11.07-12.29	46.52-47.08	510-2530	calcareous/ siliceous
Switzerland							
Canton Ticino	S	lake inlets, outlets	8	8.49-8.77	46.18-46.47	1875-2128	siliceous
Canton Vaud	N	lakes	5	10.12-10.14	46.72-46.73	2551-2663	siliceous
Canton Grigioni	N	streams	6	9.86-9.90	46.43-46.49	1773-2009	siliceous
France							
Provence-Alpes-Côte d'Azur	N	hyporheos	8	6.59-7.59	44.08-44.39	475-1355	siliceous
Provence-Alpes-Côte d'Azur	N	springs	10	6.69-7.24	44.08-44.37	1211-2440	siliceous

Among the different States, six main habitat types were covered by the different sampling sites:

- Mountain lakes: lakes with surface areas greater than 1 ha - 0.01 km^2 and maximum depths, at mean water level, greater than 1 m, located close to the tree line;
- Ponds: still body of water smaller than a lake, which is between 1 m^2 and 20,000 m^2 in area;
- Streams: a small and narrow body of water that naturally flows in a channel or bed, as brooks, rivulets, small rivers comprising lake inlets and outlets;

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- Hyporheos: subsurface part of a stream bed, where a clear mix of shallow groundwater and surface water is present;
- Caves: natural open underground spaces, most commonly formed by the dissolution of soluble rocks, generally limestone;
- Springs: underground waters held in the soil and in pervious rocks and where water naturally flows out of the ground.

METHODS

The data set was created by collating different information managed by several research institutions and museums. The information on species presence at each site comes from published papers on national and international journals directly conducted by the first author, or by other researchers and their collaborators from 2001 to 2015. Moreover, it includes additional reports from universities and research institutions, as well as notes in technical reports like master thesis, books, and monographs. The data refer mainly to preserved specimens.

Species Distribution on the Alps

To date, 15 species belonging to the genus *Cernosvitoviella* were found in the Alpine water bodies. Their distribution among the States which border the Alps and among the different habitat types were reported in **Figure 2**. The highest number of species was recorded in the most widely studied Italian region (Trentino-Alto Adige) **(Table 2)**.

The list of species included two species new for science described from the Italian Alps (Trentino-Alto Adige) *C. tridentina* and *C. longiducta* [15,16], and probably one more new species (*Cernosvitoviella* sp. 1 group *parviseta*) was reported by Mezzanotte, Sambugar and Stoch et al. [11,17] from springs in the same region. Within the European species, *C. pusilla* described from the Canadian Arctic Archipelago [18], was also found.

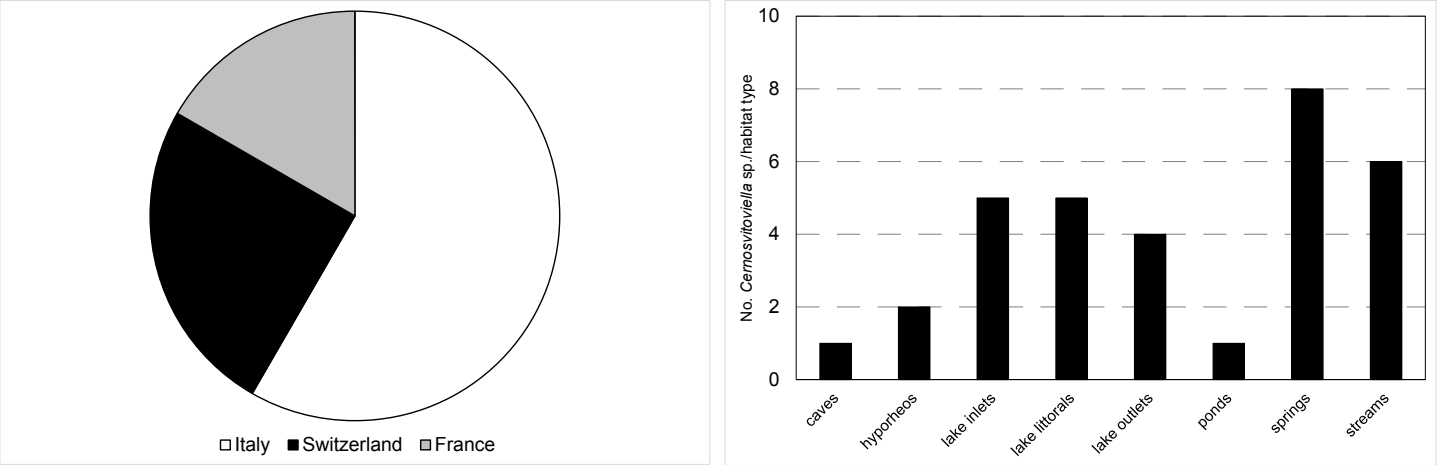

Figure 2. Different distribution of *Cernosvitoviella* species among States (left), and habitat types (right).

Table 2. List of *Cernosvitoviella* species found in different regions (Italy and France), cantons (Switzerland), and habitats of the Alps with the respective bibliographic references.

State/Region Canton	Species List	Habitat Type	References
Italy			
Aosta Valley	*C. tridentina*	lake outlet	[1]
Piedmont	*C. ampullax*	lake littoral, inlet & outlet	[3,7]
	C. atrata	lake littoral, inlet & outlet, streams	
	C. microtheca	lake inlet	
Lombardy	*C. atrata*	lake outlet	[36]
	C. longiducta	lake inlet	
	C. omodeoi	lake inlet	
	C. minor	lake inlet	
Veneto	*Cernosvitoviella* sp.	springs	[10,53,57]
	C. atrata	springs	
	C. minor	caves	
Trentino-Alto Adige	*C. aggtelekiensis*	springs	[9,11,16,17,24]
	C. ampullax	streams	
	C. atrata	springs, streams	
	C. goodhui	springs	
	C. longiducta	streams, lake littoral	
	C. minor	springs	

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	C. omodeoi	streams	
	C. palustris	springs	
	C. cf. *parviseta*	springs	
	C. pusilla	springs	
	C. tatrensis	springs	
	C. tridentina	streams	
Switzerland			
Canton Ticino	*C. ampullax*	lake littoral	[12]
	C. atrata	lake littoral, lake outlet	
	C. goodhui	lake littoral	
	C. microtheca	lake littoral	
	C. immota	lake outlet	
Canton Grigioni	*C. atrata*	streams	[31]
	C. carpatica	streams	
Canton Vaud	*C.* cf. *immota*	ponds	[8]
France			
Provence-Alpes-Côte d'Azur	*C. minor*	springs	[44]
	C. cf. *minor*	springs	
	C. cf. *parviseta*	hyporheos, springs	
	C. tatrensis	springs	
	C. cf. *tridentina*	hyporheos	

Taxonomy and ecology of species

Cernosvitoviella aggtelekiensis [19]

Detailed species description can be found in Ref [19]. According to Schmelz and Collado [20] length of setae exceeds 30 µm.

C. aggtelekiensis is closely related to *C. goodhui*, described by Healy [21], what suggesting Schmelz and Collado [20] to synonymize the species described later, but some anatomical features allow their separation. Point one, the transition from the spermathecal duct to the ampulla is gentle in *C. aggtelekiensis* and abrupt in *C. goodhui*. Point two, the ampulla is small and oval in *C. aggtelekiensis* whereas it is bigger and cylindrical in *C. goodhui*. Point three, the swollen part of the sperm duct involves at least ½ of its length in *C. aggtelekiensis*, but only ¼ of its length in *C. goodhui*. Moreover, these species differ in origin of dorsal blood vessels. Some specific characters separating these species were well illustrated by Timm [22]. For the first time, both species were found in Italian springs of Trentino-Alto Adige [11]. *C. aggtelekiensis* appears to prefer cold water habitats: it is known from cave waters in Hungary, and it was recently found in a spring in Italy [11].

Cernosvitoviella ampullax [23]

For an in-depth description of the species see Ref [23].

According to Fauna Europaea (http://www.fauna-eu.org/) this species is known from Northern Europe (Norway and Sweden) only, but it was lately found also in a few locations in the Swiss (Canton Ticino) and Italian Alps (Trentino-Alto Adige and Piedmont) [7,12,24].

The species was described from pit soil, found in soil humus with acid pH (3.2-5.9) and variable water content [23,25], but it is known also from slightly acidic running waters of Sweden [26] as well as from freshwaters (lakes and streams) of the Italian and Swiss Alps [7,12,24]. In the western Alps it seemed to prefer mildly stream- and lake-waters (pH values between 5.6 and 6.3, with an exception of pH=7.2 where a few individuals were found). Data are not available for the eastern Alps.

Up to now this species was exclusively recorded from cold or cool regions. It is typical of high latitudes in Europe (e.g., Scandinavia), but can be found also at high altitudes in Southern Europe (e.g., the Alps).

Cernosvitoviella atrata [27]

The most common species of the genus *Cernosvitoviella*, having Holarctic distribution (Fauna Europaea). Data are lacking for The Netherlands, Belgium, Luxembourg and Northern Ireland only. Known from many Alpine regions of Italy and Switzerland **(Table 2)**, it was not found in Alpes-Côte d'Azur (France). Probably this is a species complex [20]. Known from various terrestrial and aquatic habitats covering a wide range of ecological characteristics such as pH, conductivity and others [20,28].

Cernosvitoviella carpatica [29]

The species has three pairs of pharyngeal glands, unusual feature in this genus. Sometimes the secondary glands situated in the segments V and VI are small and hard to see, but the third pair, located in segment VII is well visible thereby distinguishing even juvenile specimens of this species from other *Cernosvitoviella* species.

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It is known from Ukraine and Poland where it was found mainly in mountain and sub-mountain regions [30]. A few findings covered also the lowland areas [28]. In addition, it was reported in Denmark [29], Slovakia and in the Swiss Alps (Canton Grigioni) [31].

The species was found mainly in aquatic habitats, but it is also known from marshes and bogs [28]. Only in Denmark it was found in damp soil [29]. It seems to be common in Carpathians Mts, where it was found in many locations. The findings outside Carpathians are rare.

Cernosvitoviella goodhui [21]

The shape of the setae is typical. In the studied specimens, their length reaches 62 µm in the anterior segments and 68 µm in the posterior ones. Primary pharyngeal glands are united dorsally, the secondary glands are stout, almost globular. The lymphocytes are not numerous, spindle-shaped, filled with granules (except both narrow ends). The sperm funnel is cylindrical, 2-2.5x as long as wide, with a distinct collar. The vas deferens is about 3x longer than the sperm funnel with a swollen ectal end. The swollen part of duct is not long - at most ¼ of its length. The male pore is densely surrounded by elongated gland cells. The spermathecal ampulla is cylindrical, tapered abruptly towards the narrow ectal duct. The spermathecal duct is at most 2x longer than the ampulla with an ectal part thickened and covered by small glands.

Fauna Europea reported its presence in France, Great Britain, Ireland, and Sweden, while it is given as doubtful in Italy by Rota [32], who found some significant discrepancies between the studied specimens and the typical representatives of this species, hypothesizing that they do not represent the same species. Found for the first time in Switzerland in mountain lakes of Canton Ticino [12], it was also stated in springs of Trentino-Alto Adige [11].

Like many enchytraeids, this species is semi-aquatic, and able to survive dry periods. It prefers moist and wet soils, bogs and moorlands but it was also found at the edge of fresh and slightly brackish waters [25,33] as well as in springs and along the littoral of Alpine lakes with very low chloride content (below 0.11 mg L^{-1}), pH in the range of 6.24-6.73, and low conductivity values (below 12 µS cm^{-1}).

Cernosvitoviella immota [34]

According to Fauna Europaea it is widely distributed in Europe and known also from North Africa and the Nearctic region. In Switzerland the specimens identified as *C. cf. immota* were found in the Canton Vaud by Oertli et al. in 2008 [8], but the features distinguishing the studied specimens from the original species were not reported. Typical representatives of this species were found in the outlet of Lake Starlarèsc da Sgiof (Canton Ticino) [12].

The species is common in marshes, bogs and water bodies situated along the marine coasts from Spitzbergen to France [20], usually characterized by brackish and strongly mineralized waters. It was also found in tundra soil and in sub-mountain rivers in Poland [34]. Finding of this species in Alpine rivers and ponds with low conductivity allowed reasonably to suppose a high ecological adaptability of this species or the existence of two sister species having different ecological requirements.

Cernosvitoviella longiducta [16]

This species is characterized by a very long sperm duct justifying the species name (12-15x longer than the sperm funnel and coiled in XI and XII segments). Its final part is swollen and surrounded by small glands. Cylindrical sperm funnel small, only slightly longer than wide. Spermatheca with short, stout ectal duct and oval or saclike ampulla. Coelomocytes (spherical and oval) usually not numerous but sometimes abundant in the posterior part of the body.

Species known from the River Noce Bianco and the littoral of Lake Lungo (2535-2705 m a.s.l.) (Trentino-Alto Adige) [16] and from lake inlets and outlets of Lombardy [36]. In running waters mature specimens were found mainly in October, whereas it was possible to catch them only in August along the lake littoral.

Cernosvitoviella microtheca [33]

It was described by Rota and Healy in 1999 [33], and synonimized with *C. atrata* by Schmelz and Collado in 2010 [20], but important anatomical structure of genital organs differed between the two species [7].

Up to now known from Sweden [26,33] as shown by Fauna Europea, but recently found also in the Italian (Piedmont) and Swiss (Canton Ticino) Alpine lake-littorals [7,12]. The species probably has a wider distribution because Nielsen and Christensen [29] noted some specimens very similar to *C. microtheca* in terrestrial environments in Denmark.

The species was found in swamps and along the lake-shores, in ponds and slightly brackish bay [33] as well as in small Swedish rivers including their riparian zone [26]. It is also known from Italian Alpine lakes [7,12]. All the findings derived from cool climatic zones. In the Alps, this species inhabits waters with a relatively low conductivity values (10-50 µS cm^{-1}) and slightly acidic or almost neutral pH values (range: 6.04-7.47).

Cernosvitoviella minor [37]

Detailed description published by Dózsa-Farkas in 1990 [37].

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According to Fauna Europaea the species is known from Hungary and Sweden, but it was also found in Czech Republik [38].

Known from various terrestrial and aquatic habitats, such as sphagnum bogs [37], forests' soil, parks [25] and meadows [38]. Known also from streams and lake shores, swamps, including slightly brackish ones [25,33]. It was found in Italy in lake inlets and outlets of Lombardy [36], in several springs in Trentino-Alto Adige [11], and in cave waters of Veneto [10].

Cernosvitoviella omodeoi [32]

This species is easily recognized by the shape of the spermatheca, which has a long, cylindrical ampulla and a short ectal duct, about 4x shorter and distinctly narrower than the ampulla. The spermatozoa are concentrated in the slightly widened ental part of the ampulla; when the ampulla is empty, the widened part is not visible. The sperm funnel is barrel-shaped with a distinct collar, 4-5x shorter than the sperm duct, which consists of two parts of equal length: the narrow part is situated near the sperm funnel and the wide part near the ectal orifice.

The species was described from litter and humus (pH 3.9-5.8) of chestnut wood in Tuscany (Central Italy) [35]. It was found for the first time outside locus typicus in kreno-rhitral part of streams (50 m below the source) at altitudes of 2703 m a.s.l. in Trentino-Alto Adige [24] and in lake inlets and outlets of Lombardy at altitudes ranging between 2386 and 2606 m a.s.l. [36].

Cernosvitoviella palustris [39]

Species described in the same year from Irish bogs and marshes [37] as well as from Pyrenean streams in Spain and France [40], found later in Portugal [41].

Species known from almost exclusively aquatic habitats, common in Southern European groundwaters [42], found also in springs of Trentino-Alto Adige (Italy) by Mezzanotte and Sambugar [17].

Cernosvitoviella parviseta [43]

The most characteristic feature of this species is the length of the setae: they are very short 15–22 µm, whereas in similar species (*C. aggtelekiensis* and *C. goodhui*) the setae are distinctly longer 35-42 µm in *C. aggtelekiensis* [20] and 52–58 µm in *C. goodhui* found in Lake Muino.

The species was described from cave waters in the Tatra Mts (Poland) [43], and found later in other types of Polish subterranean waters [30]. Recently, it was stated in Italian springs of Trentino-Alto Adige [11,17] and probably in springs and hyporheic waters in Provence-Alpes-Côte d'Azur (France) [44]. In the last mentioned locality, the length of setae is slightly longer (20–30 µm) than in the original description. The differences of setal length in various populations of this species could be the effect of different life conditions, according to the comments made on *C. tatrensis* populations living in streams and lakes in Polish mountains [30]. The species is exclusive of aquatic environments, it was found almost solely in various types of subterranean waters and springs. Probably, it is a stygobiontic species, preferring cold water bodies.

Cernosvitoviella pusilla [18]

Described shortly by Nurminen [18] from oligotrophic Lake Char in the Arctic Canadian archipelago. Stated for the first time in Norway according to the BOLD Systems (http://www.boldsystems.org/).

In the Italian Alps its finding was confirmed in two out of 110 springs studied by Stoch et al. [11] in Trentino-Alto Adige.

Cernosvitoviella tatrensis [45]

The species is characterized by an ectal duct of the spermatheca shorter than the ampulla, but with the same width. In fully mature specimens, the sperms are concentrated in two places in the ampulla: near its end and near the ectal duct, or sometimes in the ental part of the ampulla, only.

The species is known from Poland and Slovakia [44] as well as from Czech Republic [46], but recently it was found in Trentino-Alto Adige (Italy) as well as in Provence-Alpes-Côte d'Azur (France) [44]. The species is only known from the mountains (Tatra Mts, Śnieżnik Massive in Sudety Mts) and the sub-mountain areas (Raba River - Carpathians effluent of Vistula) where it inhabits various aquatic habitat types, including subterranean waters. Along the littoral of high-mountain lakes of the Tatra Mts it constituted an important part of the oligochaete community [7].

Cernosvitoviella tridentina [15]

The species has small seminal vesicles confined to XI segment and spermathecae with rounded ampulla and a long ectal duct (about 4x longer than the ampulla) without glands at the ectal orifice. Found for the first time in Italy in Trentino-Alto Adige [15], it was stated later in Aosta Valley [1] and probably in Provence-Alpes-Côte d'Azur [44]. In the last mentioned locality, only one specimen was found. In general, it conforms to the original description, with the exception of the length of the ectal duct of spermatheca, which is only 1.5x longer than the ampulla (4x longer in species diagnosis).

To date, *C. tridentina* is known only from Italian Alpine running waters of Trentino-Alto Adige from which the name derives.

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DISCUSSION

It is generally known that enchytraeids species identification is by far one of the most complex among worms because they need to be observed alive and frequently this is not possible, mainly when high altitude stations are considered, and external and internal characters must be observed. Enchytreids are therefore rarely studied and their presence is frequently underestimated.

The genus *Cernosvitoviella* is made up of small worms with slender sigmoid chaetae with nodulus [29]. The species from this genus are known mainly from Europe, but some of them are also described or found in Northern Asia and North America, so the genus has a Holarctic distribution. The genus is rich in species, and new ones are still described [47]. In some cases, only the molecular approaches enabled taxonomists to confirm or reject species identity [20], therefore the true number of species is so far not known exactly.

The genus *Cernosvitoviella* comprises truly aquatic species [11], however many species are found in semi-aquatic habitats such as marshes, bogs or saturated soils. Based on published data, it seems that the aquatic habitats show a much higher species richness than soils. In Italy, where the terrestrial enchytraeid fauna was widely studied by Rota [32,48], only three species from this genus were found. Very often, *C. atrata* is exclusively found during the sampling campaigns of soil enchytraeid fauna [49,50,51]. In high mountain water bodies new species are found and described, not only in the Alps, but also in the Pyrenees [52].

In the Alps the highest number of *Cernosvitoviella* species was found in springs (eight species, considering also the species codified as cf.). Springs are usually quite small and unique habitats, regarded as transitional bodies between terrestrial and aquatic habitats, and between ground- and surface waters, showing rather constant temperatures and chemical composition, and forming therefore biodiverse complexes highlighting the presence of stygobiontic species confined there and probably typical of the nearby groundwater habitat. Despite the presence of representatives of the genus *Cernosvitoviella* in many springs, actually they are almost absent in this habitat in Veneto (Italy), as stated by Latella et al. [53].

Seven species were found in running waters (in its broadest meaning: streams, lake inlets and outlets), but only two of them were given as exclusive of this habitat type (*C. carpatica* and *C. tridentina*). *Cernosvitoviella*'s species composition of lake littorals was similar to that obtained for running waters, so the species found were common to both environments, justifying the high influence of lake-inlets as resupply habitats for high altitude lake-littorals. One particular issue is *C. atrata* found in all habitats, except cave waters.

The genus comprises species with different ecological requirements and in Alpine freshwaters representatives of at least three groups were stated. The most interesting group comprises those species which were exclusively known from the high mountains and/or from the arctic regions, as well as from the subterranean waters. All these types of waters were characterized by low temperatures for at least part of the year (even 8-9 months in the Alps). In the Alps this group was represented by: *C. aggtelekiensis*, *C. tridentina*, *C. longiducta*, *C. parviseta*, *C. tatrensis*, *C. ampullax* and *C. pusilla*. Notwithstanding this, *C. tatrensis* was found even in lowland Estonian streams [54], but the site of interest has a temporary character for most of the year, especially during summer. In this period, the riverbed is completely dry, but groundwater still remains justifying the relatively low water temperatures highlighted (Timm pers. comm.). The hydro-chemistry seemed to be less important for the distribution of the species, because they were found in waters showing various conductivity and pH values. In any case, they were not found in brackish waters.

The second group comprises those species which were usually found in brackish waters such as: *C. goodhui*, *C. immota*, and *C. microtheca*. Their presence in the Alps is difficult to explain. Probably, in small ponds or along the lake littorals with fluctuating water level the strong summer evaporation resulted in a higher solute content, similar to the one experienced by brackish waters. The other explanation taken into account is the existence of identical morpho-species having different ecological requirements. The ecological requirements of *C. omodeoi*, known from two quite different sites in Italy were not exactly known.

The third and last group included the common and widely distributed species such as: *C. atrata*, *C. carpatica*, *C. minor* and *C. palustris*. They were usually found in varied habitats.

The genus reproduces only sexually and most of the species found in the Alps probably become mature only once per year (in late summer or autumn), when specimens with developed genital organs were observed. According to Dózsa-Farkas [55], this type of reproduction (named type 2) is characteristic of cold stenothermic species.

As we said before, many species of Enchytraeidae could survive in longstanding ice-covered habitats [56]. At least some *Cernosvitoviella* species inhabiting longstanding frozen habitats seemed to belong to the third and widely distributed group.

CONCLUSIONS

Our presumption is that, after the last Ice Age (c. 110000 - c. 11700 years ago), Alpine waters were recolonized by macroinvertebrates, so currently the Alps are thought to have been an effective refuge for relict cold stenothermic species. In

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such a scenario, *Cernosvitoviella* could be considered as an example of boreo-alpine taxon with a wide distribution in Northern Europe and with populations in the Southern European mountains like the Alps, the Pyrenees, the Tatras where it could survive to very low temperatures and dry periods for long times.

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