

Aquatic Microannelids (Oligochaeta and Aphanoneura) of Underground Waters of Southeastern New York

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ABSTRACT: We investigated the distribution of aquatic oligochaetes and *Aeolosoma* in the hyporheic zone and other underground habitats in southeastern New York. Twenty-four species of oligochaetes were found, exclusive of the Enchytraeidae, which could not be identified to species. Two of the species, *Rhyacodrilus* cf. *subterraneus* and *Chaetogaster* cf. *krasnopolskiae*, are reported for the first time from North America. Most of the oligochaetes found in underground waters are widespread in surface waters as well. Annual cycles of abundance and reproductive activity of five abundant taxa are described; these cycles are similar to those of the oligochaetes from lakes and streams.

INTRODUCTION

The underground waters of North America remain largely unexplored biologically, despite the economic importance of groundwaters, the ecologically significant connections between ground- and surface waters (*e.g.*, Hynes, 1983) and the demonstration by European zoologists that underground waters contain rich and often distinctive faunas (Delamare Deboutteville, 1960; Botosaneanu, 1986). Notable exceptions include ecological and evolutionary studies of the macroscopic animals of caves (Culver, 1982; Barr and Holsinger, 1985), investigations into the systematics of some of the larger invertebrates (*e.g.*, Holsinger, 1978; Herschler and Longley, 1986) and an increasing body of ecological works on the hyporheic macrobenthos of streams (Williams, 1984).

Reported here are some of the results of a survey of the invertebrate fauna of the shallow groundwaters of southeastern New York. The goals were to describe the composition of the invertebrate communities, the natural history of their dominant members and to make comparisons with invertebrate communities of ground- and surface waters elsewhere. Because of technical difficulties in sampling the fauna of underground waters, this study was limited to shallow groundwaters and zones of contact between underground and surface waters, such as gravel bars associated with streams, seeps and springs, rather than "deep" groundwater.

STUDY AREA

Most samples came from Dutchess or Ulster counties in southeastern New York. Single sites in nearby Litchfield County, Connecticut, and in Columbia County, New York, were visited. Most of the area is underlain by shales of Ordovician age. Consequently, most surface waters in the region are hard ($pH = \text{ca. } 8$; $Ca^{++} = 0.5$ to 1 meq/liter) and fertile. There are a few outcrops of limestone and, in Ulster County, a large exposure of a hard Silurian quartzite conglomerate that forms the Shawangunk Mountains. Waters on the Shawangunks are soft and acid ($pH = 4$ to 6 ; $Ca^{++} = 0.02$ to 0.2 meq/liter), in marked contrast to surrounding areas. The entire study area was glaciated.

Most samples were taken from gravel bars along or beneath streams (the hyporheic zone, habitat type L1 of Botosaneanu, 1986). These sites are fed largely by stream water, because the water temperature in such sites was typically only 1-3 C cooler than stream water during the summer and 1-2 C warmer than stream water during the winter. However, many of these sites receive lateral seepage from nearby slopes as well. Other samples were taken from seeps (habitat N, the hypotelminthorheic, of Botosa-

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neanu, 1986), wells and shallow phreatic waters (habitat K), lake psammon (habitat M) and springs (habitat S). A few samples were taken from small streams (habitat L3) running in the Ellenville Ice Caves, a series of crevices and cavities formed by breakage and mass-wasting of enormous pieces of the Shawangunk conglomerate.

Detailed studies were made at two sites: the East Branch of Wappinger Creek at the Cary Arboretum near Millbrook (41°47'N by 73°45'W) and the Coxing Kill near New Paltz (41°46'N by 74°12'W). The East Branch is a fourth-order, hardwater trout stream. Most samples came from a low-gradient (2.7 m/km) reach that runs through an open gallery forest. The sediments in this reach consist chiefly of sand, gravel and small stones derived from the local shale and formed into extensive alluvial bars. The Coxing Kill is a shaded, second-order, trout stream in the Shawangunk Mountains. The study reach drops steeply (32 m/km) over conglomerate bedrock and unconsolidated sediments derived from this conglomerate that range in size from sand to boulders. Despite the great differences between these two sites, the sediments sampled were similar (Table 1).

MATERIALS AND METHODS

Several sampling methods were used, depending upon the characteristics of the habitat. Most of the samples were taken by the Karaman-Chappuis technique (Delamare Deboutteville, 1960); *e.g.*, by digging a shallow pit, allowing it to fill with water, then collecting and filtering the water that flows into the pit. The method is crude and useful only where groundwater lies close to the soil surface. Samples were also taken within 1 m of the soil surface with a Bou-Rouch pump (Bou, 1974), filtering the water through a 100- μ m mesh net. Our use of the Bou-Rouch pump was limited, because a preliminary comparison of the technique with the Karaman-Chappuis approach showed that samples taken by the latter method contained many more taxa than those taken by the pump. Samples of sediment were taken from springs and cave streams and washed onto a 100- μ m mesh sieve. A modified Cvetkov net (Danielopol, 1978) was used to sample wells.

All samples were refrigerated until they could be sorted, without preservation, under a stereoscopic microscope within a few days of collection. Microannelids were preserved in 70% alcohol and mounted on slides in CMC-9 (Master's Chemical Co., Des Plaines, Ill). Identifications and nomenclature follow Hiltunen and Klemm (1980) and Brinkhurst (1986). Voucher specimens have been deposited in the United States National Museum of Natural History (USNM lot numbers 102817 through 102837).

The work reported here consists of two parts: a broad, synoptic survey of sites throughout the Hudson valley and a more detailed set of samples taken throughout the year at two sites (the East Branch of Wappinger Creek and the Coxing Kill). At these sites monthly Karaman-Chappuis samples were taken from three or four gravel bars,

TABLE 1.—Characteristics of sediments from which Karaman-Chappuis samples were taken. Sediments were oven-dried at 60 C, dry-sieved and ignited at 500 C for 15 hr. Values are means \pm SE expressed as a percentage of the dry mass of the samples

Characteristic	East Branch (n = 16)	Coxing Kill (n = 10)
Loss on ignition	2.2 \pm 0.2	2.6 \pm 0.4
Particle size		
< 0.25 mm	4.7 \pm 0.85	5.5 \pm 1.4
0.25-1 mm	26 \pm 3.8	22 \pm 3.2
1-4 mm	26 \pm 2.2	28 \pm 2.1
4-16 mm	29 \pm 3.1	28 \pm 3.0
> 16 mm	15 \pm 3.3	16 \pm 4.8

0.5-2 m from the water's edge and 10-30 cm down in the gravel bar. Each sample consisted of ca. 3 liter of water filtered through a 100- μ m mesh net.

RESULTS

Microannelids typically constituted 15-40% of the invertebrates in our samples. The microannelid fauna of underground waters in southeastern New York is dominated by naidids, aeolosomatids and enchytraeids, with much smaller contributions by tubificids, lumbriculids and haplotaxids (Table 2). Because the taxonomy of North American aeolosomatids and enchytraeids is so poorly known, it was not possible to identify species in these families. At least three species of *Aeolosoma* and several enchytraeids were present in our samples. Most species collected from the four other families are ecologically eurytopic species commonly found in various surface-water habitats. Notable exceptions include *Haplotaxis*, a characteristic genus of underground habitats, and two species (*Rhyacodrilus* cf. *subterraneus* and *Chaetogaster* cf. *krasnopolskiae*) known previously only from subterranean waters of Europe.

We found two individuals of *Chaetogaster* cf. *krasnopolskiae* in gravel bars near the Fishkill Creek in the town of East Fishkill in Dutchess Co. The chaetae of this small worm (Fig. 1a, b) are distinctively unlike those of any North American species of the genus. The chaetae of segment II are 62-65 μ m long, in bundles of four, with the upper tooth slender and a little shorter than the lower. In other segments, the chaetae are in bundles of five or six, and the upper tooth is even more reduced than in segment II. Both of our specimens consist of two zooids, and have a total body length of 0.6-0.7 mm after preservation and slide-mounting. The only known species of *Chaetogaster* that may match our species is *C. krasnopolskiae*, reported from the sandy sediments of Rus-

TABLE 2. — Number of individuals of microannelid species collected in the study area

Aeolosomatidae	
<i>Aeolosoma</i> spp.	1324
Enchytraeidae	1297
Lumbriculidae	
<i>Lumbriculus variegatus</i> (Müller)	37
<i>Stylogdrilus heringianus</i> Claparede	2
Haplotaxidae	
<i>Haplotaxis</i> cf. <i>gordiioides</i> (Hartmann)	1
Tubificidae	
<i>Rhyacodrilus coccineus</i> (Vejdovsky)	1
<i>R.</i> cf. <i>subterraneus</i> Hrabe	20
immature tubificids	30
Naididae	
<i>Chaetogaster diastrophus</i> (Gruithuisen)	312
<i>C.</i> cf. <i>krasnopolskiae</i> Lastockin	2
<i>Amphichaeta leydigi</i> Tauber	16
<i>Specaria josinae</i> (Vejdovsky)	1
<i>Pristina leydyi</i> Smith	27
<i>P. aequiseta</i> Bourne (morph <i>foreli</i>)	147
<i>Dero obtusa</i> d'Udekem	1
<i>Slavina appendiculata</i> (d'Udekem)	14
<i>Vejdovskyaella comata</i> (Vejdovsky)	2
<i>Nais simplex</i> Piguet	8
<i>N. bretscheri</i> Michaelsen	50
<i>N. elinguis</i> Müller	2
<i>N. communis</i> Piguet	82
<i>N. variabilis</i> Piguet	1
<i>Pristinella sima</i> (Marcus)	687
<i>P. jenkiniae</i> (Stephenson)	501

sian rivers (Lastockin, 1937; Fomenko, 1972). This species is said to be the only member of the genus that has chaetae with reduced upper teeth. Unfortunately, the original description (Lastockin, 1937) is very sketchy and includes no illustrations. The only illustration that we have seen is by Kasprzak (1981), which is reminiscent of, but not identical with, our Figure 1a, b. Until better descriptions are made of European and North American material, the taxonomic placement of our specimens must remain unclear.

Rhyacodrilus cf. *subterraneus* was found regularly, but in small numbers, in the gravel bars along the East Branch. The chaetae (Fig. 1c-f) are unlike those of any known North American species of *Rhyacodrilus*. The anterior dorsal bundles contain two or three pectinate chaetae and one (rarely two) hair chaeta. The hair chaetae are absent from bundles posterior to approximately segment X. The pectinate chaetae are 60-130 μm long with an upper tooth that is much longer than the lower. The hair chaetae are 120 μm long in segment II and only 160-185 μm long at most. Ventrally, bundles contain 3-5 bifurcate or slightly pectinate chaetae. None of our specimens had genital chaetae, so our animals cannot yet be positively identified with the European *R. subterraneus*, but the somatic chaetae match Hraeb's (1963) original description well. This species is known only from a few specimens collected from German springs (Hraeb, 1963) and the headwaters of the Tambre River in Spain (Martinez-Ansemil and Gianì, 1980). Among known North American species, this taxon most resembles *R. montana*, which has much longer and more numerous hair chaetae.

Identifications of the species of the *Nais communis/bretschleri/variabilis* group were not always certain. Posterior zooids of *N. bretscheri* sometimes lacked giant chaetae and pre-

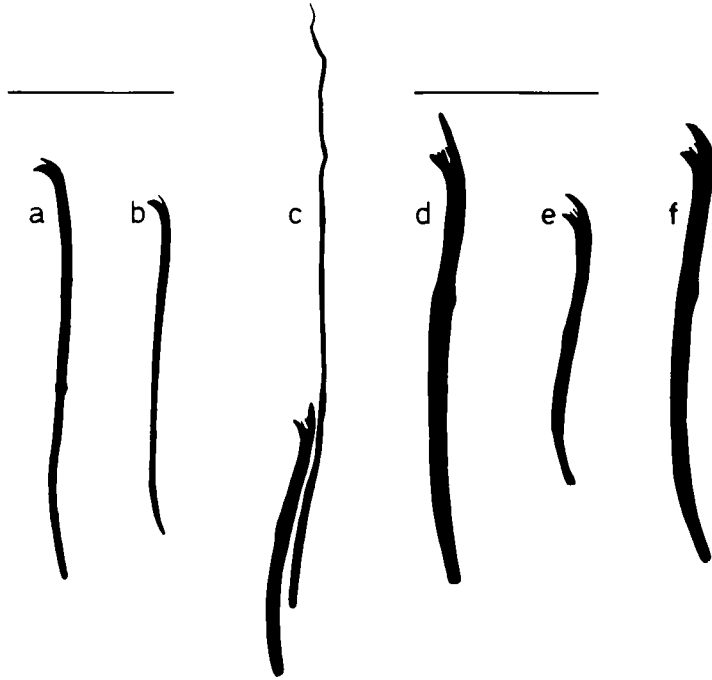


Fig. 1.—Camera lucida drawings of chaetae from *Chaetogaster* cf. *krasnopolskiae* (a,b) and *Rhyacodrilus* cf. *subterraneus* (c-f). (a) chaeta from segment II; (b) chaeta from segment IV; (c) dorsal bundle from segment II, (d) dorsal chaeta from segment VI; (e) ventral chaeta from segment II; (f) ventral chaeta from segment VI. Scale bar for (a) and (b) represents 25 μm ; scale for (c-f) represents 40 μm

sumably would have been identified as *N. communis* if separated from the parent zooid. Also, there may be two taxa in the study area that key out as *N. communis*.

The abundance of microannelids and the species composition of the community varied seasonally in our samples from the East Branch and Coxing Kill. At both sites, microannelids were least abundant during the winter (Fig. 2a). We do not know whether this minimum was due to a decrease in population size or movement of the population into neighboring habitats (*i.e.*, deep groundwater or the stream itself).

Various taxa of microannelids showed different seasonal patterns. The enchytraeids (Fig. 2b) were present throughout the year. There were no conspicuous seasonal peaks in abundance, and sexually mature animals (of different species?) were present throughout the year. *Aeolosoma* spp. were most abundant during the summer and nearly or completely absent through the winter (Fig. 2c). Mature animals were rare, but occurred in September and in May. *Chaetogaster diastrophus* (Fig. 2d) was present year-round in the East Branch, but had a marked peak in abundance in April. *Chaetogaster*

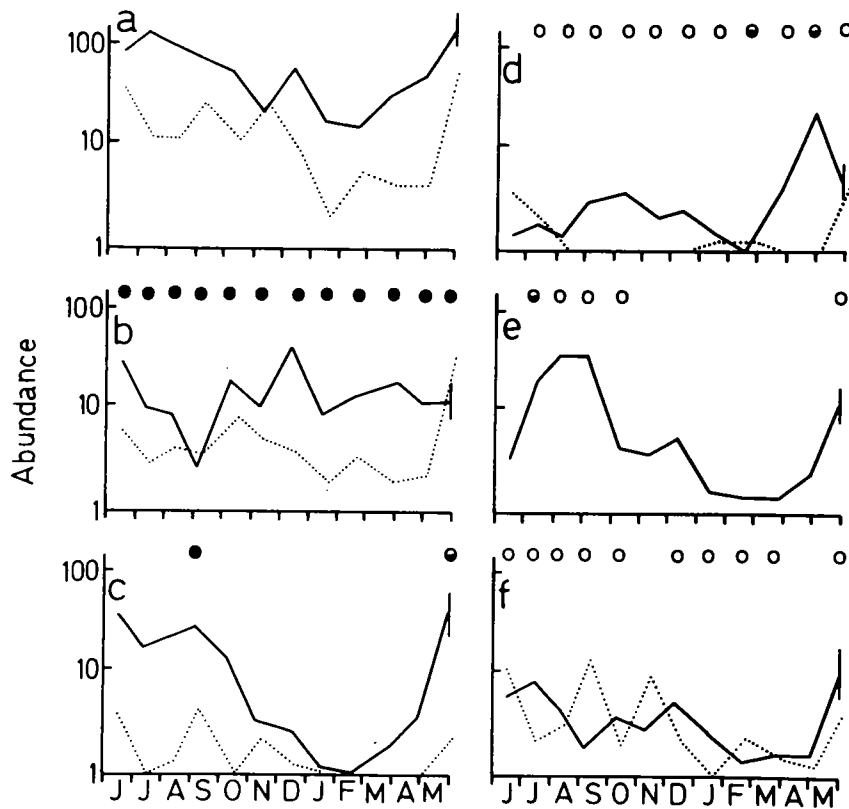


Fig. 2. — Annual cycles of abundance and reproductive activity of (a) all microannelids; (b) Enchytraeidae; (c) *Aeolosoma* spp.; (d) *Chaetogaster diastrophus*; (e) *Pristinella sima*; and (f) *Pristinella jenkinsae* in the East Branch of Wappinger Creek (—) and the Coxing Kill (.....). Abundance is expressed as the mean of $\ln(X + 1)$, where X is the number of individuals in a sample. The vertical bar plotted on the data point for the East Branch in May is the average standard error for each taxon. Months of reproductive activity are shown for paratomy (○), sexual reproduction (●) or both (◐).

diastrophus was too scarce at the Coxing Kill to exhibit any seasonal pattern in abundance. Sexually mature animals were found only in February and April, but individuals undergoing paratomy (asexual reproduction) were present year round. *Chaetogaster diastrophus* has been reported to feed on algae, with small invertebrates constituting a lesser portion of its diet (Streit, 1977; Frenzel, 1981; Strayer, 1985). Although our samples were taken 10-30 cm down in gravel bars 0.5-2 m from the water's edge, the *C. diastrophus* in our samples were feeding largely on diatoms. *Pristinella sima* (Fig. 2e) had a clear seasonal cycle at the East Branch, with peak densities and reproduction occurring in May through October. We never found *P. sima* at the Coxing Kill. *Pristinella jenkiniae* (Fig. 2f) was found year-round at both sites; wintertime densities were lower than those found during the summer. Paratomy occurred throughout the year.

DISCUSSION

As was the case in this study, the microannelid fauna of hyporheic and phreatic habitats typically is dominated by naids and enchytraeids (Table 3). Although naids often dominate the fauna in numbers of species and individuals, the naids in hyporheic and phreatic habitats almost always belong to species that are widespread in surface-water habitats, especially streams. In fact, not a single naidid is included in Juget and Dumnicka's (1986) list of characteristically subterranean freshwater oligochaetes. The only unusual naidid that we found in our study was *Chaetogaster* cf. *krasnopolskiae*, a poorly known but apparently ecologically specialized species which may eventually come to be classified as psammophilic or stygophilic.

The tubificids are important elements of the oligochaete community in some sites, constituting up to 50% of the species and individuals (e.g., Ladle, 1971; Schwank, 1982; Juget, 1984). At other sites, tubificids are rare or entirely absent (Botea, 1963; Tilzer, 1968; this study). There is no obvious environmental difference between these two classes of sites, but we suspect that differences in characteristics of the sediments (pore size, organic content) may be responsible. Although many of the tubificid species reported from underground waters are common eurytopic species, there are several species, most notably in the genus *Rhyacodrilus* (Juget, 1984; Juget and Dumnicka, 1986), that appear to be restricted to hyporheic and phreatic waters.

Other families (Lumbriculidae, Aeolosomatidae, Haplotaxidae, Lumbricidae, Dorydrilidae, Pomatodrilidae) are less speciose, but the lumbriculids and aeolosomatids sometimes are abundant. In addition, most of these families contain species that are more or less restricted to underground waters (Juget and Dumnicka, 1986). The microannelid fauna of hyporheic and phreatic waters is composed of common, ecologically widespread species mixed with a smaller number of species that are not often found in surface waters.

Detailed studies of the life histories of hyporheic and phreatic microannelids are lacking. However, features of the life histories of *Aeolosoma* spp. and naids in the East Branch and Coxing Kill (i.e., spring or summer peaks in density; sexual reproduction rare and seasonally restricted; Fig. 2) are similar to those reported for oligochaetes living in streams (Learner *et al.*, 1978; Loden, 1981). This observation further supports the notion that shallow groundwaters are inhabited by an ecologically undifferentiated group of oligochaete species.

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TABLE 3. — Composition of the microannelid fauna, expressed as the number of species per family, from various sites, not including caves. Family abbreviations: Nai = Naididae, Enc = Enchytraeidae, Tub = Tubificidae, Lum = Lumbriculidae, Aeo = Acolosomatidae, Hap = Haplotaxidae, Lmb = Lumbricidae, Dor = Dorytrilidae and Pom = Pomatodrilidae. ND = family present at site, but species not determined. Data from Juget (1984) and Schwank (1982) exclude rare species

Site	Habitat	Nai	Enc	Tub	Lum	Aeo	Hap	Lmb	Dor	Pom	Source
Southeastern New York	hyporheic	14	ND	2	2	≥ 3	1	0	0	0	this study
Harz, West Germany	hyporheic	10	6	2	3	3	1	1	0	0	Heitkamp <i>et al.</i> , 1985
Rhone Valley, France	shallow hyporheic	6	5	6	2	≥ 2	0	0	1	1	Juget, 1984
"	deep hyporheic	5	4	4	1	≥ 2	0	0	1	0	"
"	shallow phreatic	2	3	3	2	0	0	0	0	0	"
"	deep phreatic	1	3	3	0	≥ 2	0	0	1	0	"
Upper Hesse, West Germany	hyporheic	6	6	5	1	3	1	1	0	0	Schwank, 1982
River Oberwater, England	hyporheic	10	ND	7	2	0	0	1	0	0	Ladle, 1971
Alpine streams, Austria	hyporheic	4	ND	0	2	2	1	0	1	0	Tilzer, 1968
Romania	hyporheic	11	11	1	4	1	1	1	0	0	Botea, 1963

LITERATURE CITED

- BARR, T.C. AND J.R. HOLSINGER. 1985. Speciation in cave faunas. *Annu. Rev. Ecol. Syst.*, **16**:313-337.
- BOTEÁ, F. 1963. Contributions to the study of *Oligochaeta* found in the phreatic water. *Rev. Biol.*, **8**:335-343.
- BOTOSANEANU, L. (ED.). 1986. *Stygofauna mundi*. E.J. Brill, Leiden. 740 p.
- BOU, C. 1974. Les methodes de récolte dans les eaux souterraines interstitielles. *Ann. Spéleol.*, **29**:611-619.
- BRINKHURST, R.O. 1986. Guide to the freshwater aquatic microdrile oligochaetes of North America. *Can. Spec. Publ. Fish. Aquat. Sci.*, **84**:259 p.
- CULVER, D.C. 1982. *Cave life*. Harvard University Press, Cambridge. 189 p.
- DANIELOPOL, D.L. 1978. Introduction to groundwater ecology. Limnologisches Institut Österreichische Akademie der Wissenschaften, Vienna. 50 p.
- DELAMARE DEBOUTTEVILLE, C. 1960. *Biologie des eaux souterraines littorales et continentales*. Hermann, Paris. 740 p.
- FOMENKO, N.V. 1972. Ecological groups of Oligochaeta worms in the Dnieper basin, p. 105-118. In: G.M. Belyaev, G.G. Vinberg, N.S. Gaevskaya, V.I. Zhadin, L.A. Zenkevich, N.I. Kashkin, O.G. Reznichenko and A.P. Shcherbakov (eds.). *Aquatic Oligochaeta worms: Taxonomy, ecology and faunistic studies in the USSR*. Nauka Publishers, Moscow. English translation published in 1980 by Amerind Publishing Co., New Delhi.
- FRENZEL, P. 1981. Untersuchungen zur Ökologie der Naididae des Bodensees. Die Nische von *Chaetogaster* und *Amphichaeta*. *Arch. Hydrobiol.*, **91**:45-55.
- HEITKAMP, U., D. LESSMANN AND C. PIEHL. 1985. Makrobenthos-, Moos- und Interstitialfauna des Mittelgebirgsbachsystems der Sieber im Harz (Süd-Niedersachsen). *Arch. Hydrobiol. Suppl.*, **70**:279-364.
- HERSCHLER, R. AND G. LONGLEY. 1986. Phreatic hydrobiids (Gastropoda: Prosobranchia) from the Edwards (Balcones Fault Zone) Aquifer, south-central Texas. *Malacologia*, **27**:127-172.
- HILTUNEN, J.K. AND D.J. KLEMM. 1980. A guide to the Naididae (Annelida: Clitellata: Oligochaeta) of North America. EPA Environ. Mon. Supp. Lab., Cincinnati. 48 p.
- HOLSINGER, J.R. 1978. Systematics of the subterranean amphipod genus *Stygobromus* (Crangonyctidae), Part II: species of the eastern United States. *Smithson. Contrib. Zool.*, **266**:144 p.
- HRABE, S. 1963. *Rhyacodrilus subterraneus* n. sp., eine neue Tubificiden-Art aus den Brunnen in der Umgebung von Leipzig. *Zool. Anz.*, **170**:249-252.
- HYNES, H.B.N. 1983. Groundwater and stream ecology. *Hydrobiologia*, **100**:93-99.
- JUGET, J. 1984. Oligochaeta of the epigeal and underground fauna of the alluvial plain of the French upper Rhône (biotypological trial). *Ibid.*, **115**:175-182.
- AND E. DUMNICKA. 1986. Oligochaeta (incl. Aphanoneura) des eaux souterraines continentales, p. 234-244. In: L. Botosaneanu (ed.). *Stygofauna mundi*. E.J. Brill, Leiden.
- KASPRZAK, K. 1981. Skapozzczety Wodne, I. Rodziny: Aeolosomatidae, Pomatodrilidae, Naididae, Tubificidae, Dorydrilidae, Lumbriculidae, Haplotaxidae, Glossoscolecidae, Branchiobdellidae. Polska Akademia Nauk, Warsaw. 226 p.
- LADLE, M. 1971. Studies on the biology of oligochaetes from the phreatic water of an exposed gravel bed. *Int. J. Speleol.*, **3**:311-316.
- LASTOCKIN, D.A. 1937. New species of *Oligochaeta limnicola* in the European part of the USSR. *C. R. (Dokl.) Acad. Sci. USSR*, **17**:233-235.
- LEARNER, M.A., G. LOCHHEAD AND B.D. HUGHES. 1978. A review of the biology of British Naididae (Oligochaeta) with emphasis on the lotic environment. *Freshwater Biol.*, **8**:357-375.
- LODEN, M.S. 1981. Reproductive ecology of Naididae (Oligochaeta). *Hydrobiologia*, **83**:115-123.
- MARTINEZ-ANSEMIL, E. AND N. GIANI. 1980. Premieres données sur les oligochètes aquatiques de la péninsule Iberique. *Ann. Limnol.*, **16**:43-54.
- SCHWANK, P. 1982. Turbellarien, Oligochaeten und Archianneliden des Breitenbachs und anderer oberhessischer Mittelgebirgsbäche. III. Die Taxozönosen der Turbellarien und Oligochaeten in Fließgewässern—eine synökologische Gliederung. *Arch. Hydrobiol. Suppl.*, **62**:191-253.
- STRAYER, D. 1985. The benthic micrometazoans of Mirror Lake, New Hampshire. *Ibid.*, **72**:287-426.

- STREIT, B. 1977. Morphological relationships and feeding habits of two species of *Chaetogaster*, *Ch. limnai* and *Ch. diastrophus*. *Ibid.*, 48:424-437.
- TILZER, M. 1968. Zur Ökologie und Besiedlung des hochalpinen hyporheischen Interstitials im Arlberggebiet (Österreich). *Arch. Hydrobiol.*, 65:253-308.
- WILLIAMS, D.D. 1984. The hyporheic zone as a habitat for aquatic insects and associated arthropods, p. 430-455. *In*: V. H. Resh and D.M. Rosenberg (eds.). The ecology of aquatic insects. Praeger, New York. 625 p.

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