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New records of rare Bdelloidea and Monogononta Rotifers in gravel streams

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With 7 figures in the text

Abstract: Rare rotifer species have been newly found in two different gravel streams (Oberer Seebach, Austria; and Afon Mynach, North Wales, Great Britain). The taxonomy and habitat distribution is revised, and confirmed for: *Philodinavus paradoxus* (Murray), *Henoceros falcatus* (Milne), *Microcodides chlaena* (Gosse), *Proalinopsis caudatus* (Collins), *Dicranophorus difflugiarum* (Penard), *Wigrella depressa* Wiszniewski and *Myersinella tetraglena* (Wiszniewski). *H. falcatus* is the first European record outside Great Britain, and it was found for the first time seventy-eight years after it was described. Similarly, *W. depressa* and *M. tetraglena* were found after fifty-eight years. The presence of Rotifera in the hyporheos, and video observations of their feeding behaviour are also discussed.

Introduction

A number of studies have confirmed that lotic ecosystems seem to have a high species richness of Rotifera. In one large scale study, Donner (1970) gave a list of 154 species found in submerged mosses and other biotopes of the River Salzach (Austria) and he later found 195 species within the River Danube and its tributaries (Donner 1972). Braioni & Gottardi (1979) found 48 species in the interstitial (0–40 cm) of the River Adige (Italy), and Schwank (1985) found a similar number in the stream Breitenbach in Germany. Zullini & Ricci (1980) reported an assemblage of 18 species of Bdelloidea in a small Italian stream, and Schmid-Araya (1993 a), working in a 100 m stretch of mountain gravel stream gave a preliminary list of 69 Rotifera species (42 Monogononta and 27 Bdelloidea).

Large rivers can sustain both planktonic and benthic species of Rotifera. But, the extreme species richness of the latter group in running waters gener-

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ally may be due to the habitat heterogeneity which has many refugia such as pools, riffles, debris dams, mosses and in gravel streams the hyporheic interstitial where many species can proliferate. There is also great spatio-temporal fluctuation of algal species, and particularly the organic matter with associated biofilm at the surface, and the hyporheos may contribute to a heterogeneous food source for rotifers inhabiting lotic systems.

There have been few recent publications dealing with taxonomic aspects of benthic Rotifera in running waters. This is probably due to the methodological problems involved when studying smaller organisms in samples which usually contain large amounts of organic particles, and are time-consuming to process. Moreover, examination of Bdelloidea at the species level may be hindered by the fact that it is essential that taxonomic identification is conducted on living specimens.

The present study examines new records of rare Bdelloidea and Monogononta from two gravel streams (in Austria and Great Britain) found when processing samples aimed at understanding the Rotifera community structure and their dispersal. The taxonomy, habitat use and feeding behaviour of these species is discussed.

Materials and methods

The specimens were collected with different sampling procedures. *Philodinavus paradoxus, Henoceros falcatus* and *Proalinopsis caudatus* were collected in the stream Oberer Seebach, lower Austria (47° 51′ N, 5° 04′ E) while performing drift experiments between August and December 1994. The drift samplers were positioned on the sediment surface and maintained there for 4 minutes. The samplers have an opening of 0.065 m^2 and a 2 m long net of 40 µm mesh. The samplers (SIEGL 1993) are equipped with a current meter which permits determination of the exact volume of water filtered during a period of time.

Microcodides chlaena was collected in the stream Afon Mynach, Gwynedd, North Wales, Great Britain (52° 57′ N, 3° 38′ W National Grid: SH909407) using stand pipe traps, details of which are described elsewhere (SCHMID-ARAYA 1993 b). *Dicranophorus difflugiarum, Wigrella depressa,* and *Myersinella tetraglena* were collected from the sediments using either stand pipe traps or surber samplers in the gravel stream Oberer Seebach.

All samples were examined live as suggested for interstitial fauna by RUTTNER-KOLISKO (1971). The rotifers were observed under a dissecting stereomicroscope, and later transferred to an Olympus BH-2 microscope equipped with a JVC videocamera connected to a JVC videorecorder. All animals were recorded without coverslips, but dissection of the trophi and later examination of Monogononta rotifers was done on specimens compressed by coverslips with 5 % KOH solution.

Results

Philodinavus paradoxus (MURRAY 1905) (Fig. 1 a, b, c)

The body is stout with a smooth surface. It is wider at the level of the mastax and at the posterior part of the trunk, giving the appearance of a worm-like animal. There are no traces of wheel-discs, and the corona is reduced to a trilobed field of short cilia around the mouth-opening. The rostrum has two segments, with two lamellae and is relatively short. The antenna is two-segmented, with the proximal segment longer than the distal. There is no eyespot. The foot has three segments, with two spurs and two pairs of toes, the dorsal pair smaller than the ventral pair (Fig. 1 b). The spurs have often been reported as variable in shape (BARTOS 1951, VOIGT 1957, DONNER 1965). The trophi are very close to the mouth opening. In contrast to other bdelloids, the unci, with 3–4 large teeth, move a lot and do not seem to be rigidly united (Fig. 1 c). Manubria, fulcrum and rami are variously structured (VOIGT 1957). The species is oviparous. The egg observed in specimens from the Oberer Seebach has a kidney-shape, with a hyaline zone in the ventral part (Fig. 1 a). According to DONNER (1965) the body can be partially or totally orange-red coloured (carotene grains). This carotene pigment is assumed to be relevant when

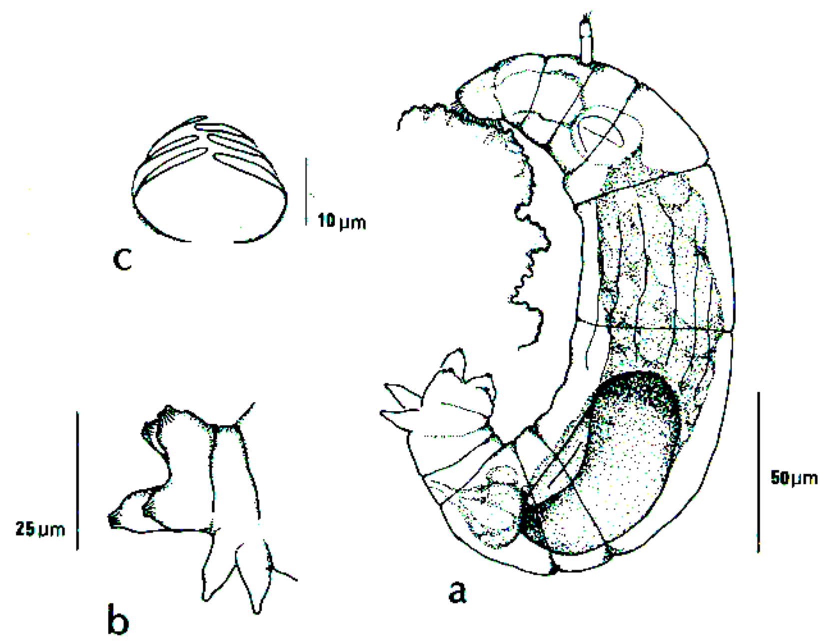

Fig. 1. *Philodinavus paradoxus* (MURRAY, 1905). a) Lateral view of an individual exploring an organic particle. b) Spurs and toes. c) Trophi.

the animals awake from anabiosis, and when they lay their eggs (BARTOS 1951).

This species has been recorded on the shore of the River Danube among *Fontinalis* sp. moss and at temperatures between 8 to 11.5 °C (DONNER 1972). The same author, in a earlier publication DONNER (1964), remarked the presence of this species only in running water ecosystems in Poland (PAWLOWSKI 1958) and Hungary (VARGA 1951). In the Oberer Seebach it was found in August and December 1994 at temperatures between 7 and 11 °C on drift samples at the surface of the stream (densities between 0.3 to 0.4 ind. $litre^{-1}$). Nevertheless, it is plausible that the temperature range of the species might be wider than expected. PAX & WULFERT (1942) reported the species in a thermal spring at 22.2 °C. Another habitat where it has been found is the hyporheos down to 40 cm depth, in March 1992 (SCHMID-ARAYA 1993 a).

Total length: up to 310 µm, antenna: 13–14 µm; egg length: 64 µm; trophi length: 19 µm width: 23 µm, spurs: 12 µm, dorsal toes: 9 µm, ventral toes 12 µm.

Geographical distribution: Cosmopolitan? Austria (DONNER 1964, 1970, 1972; SCHMID-ARAYA 1993 a), Czech Republic (BARTOS 1951, 1959), Germany (PAX & WULFERT 1942, VOIGT 1957), Hungary (VARGA 1951), Poland (MADALINSKI 1961), Rumania (RUDESCU 1960), New Zealand (according to VARGA 1951).

Henoceros falcatus (MILNE 1916) (Fig. 2 a, b, c)

This species has not been found and recorded in the literature since it was first described by MILNE (1916). This author mentioned that the species is small and of a pale glaucous colour. The corona is inconspicuous and reduced to thin discs. The rostrum is well developed with strong cilia (Fig. 2 a, b). On the ventral side of the post-rostral segment there is a double arrangement of thin discs which project slightly right and left. The dorsal antenna is short compared to that of *P. paradoxus*. There is no eye-spot. The egg has an oval shape. The foot is stout, and it has a clear characteristic feature at the posterior end: four great sickle-shaped toes and one large spur (Fig. 2 a, c). In living specimens, each toe can move independently of the others. The structure of the trophi differs from that in the other member of the same family (Philodinavidae). It has a simple and symmetric design. Rami, unci and manubria are long and narrow. There are two separate rami on the outer sides of which rest the unci, which are hinged to the two manubria shown at their sides. MILNE's description reports that the fulcrum is cut into two symmetrical and minute rods lying between the ends of the unci and rami. However, REMANE (1929–1933) redescribed these rods as basal-apophyses or subunci. MILNE (1916) also mentioned the presence of a plate with fine striae between the rami and manubria

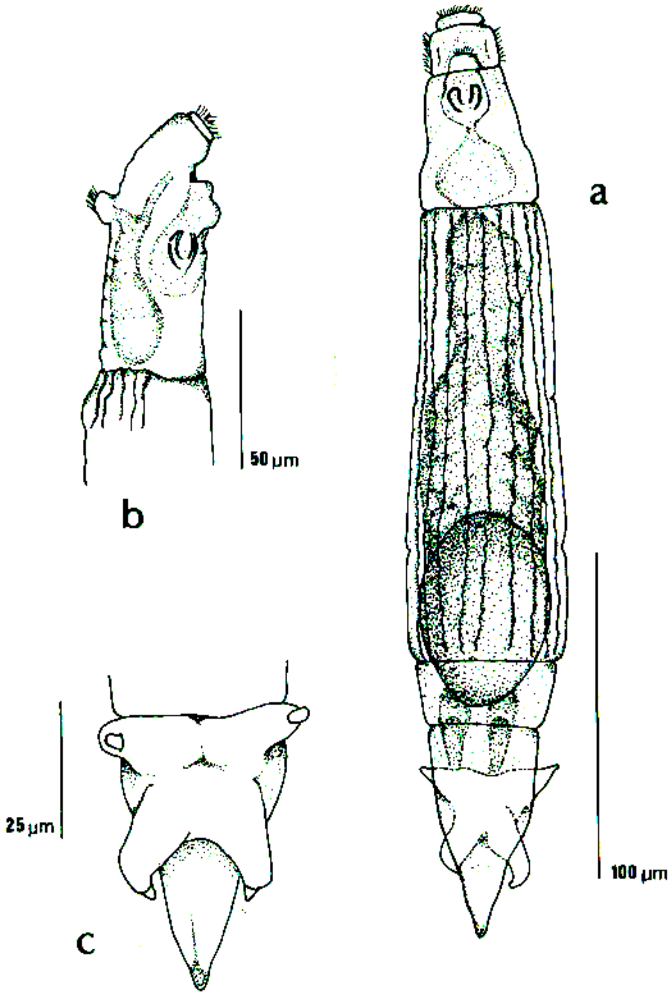

Fig. 2. *Henoceros falcatus* (MILNE, 1916). a) Dorsal view. b) Lateral view of the anterior part of the body. c) Ventral view of the spur and toes.

indicating a link to *Philodina* trophi. However, these observations cannot be confirmed with light microscopy. Further description awaits scanning microscope analyses.

The habitat of *H. falcatus* seems to be streams and rivers as both MILNE's and my findings demonstrate.

Total length: 285 µm, dorsal antenna: 5 µm; egg length: 60 µm; trophi length: 13–14 µm, toes: 18–20 µm.

Geographical distribution: Austria (first record), Britain (?), South Africa (MILNE 1916).

Microcodides chlaena (Gosse 1886) (Fig. 3a, b, c, d)

Female: The body is cone-shaped, and dorsally asymmetric (Fig. 3b). The lorica is thin and flexible (Beauchamp & Pourriot 1961). The dorsal lorica has parallel longitudinal ridges and ribs (Fig. 3a, b) and at the posterior end there are the lateral antennae with relatively clear setae projecting outside the body. The eye-spot is pigmented. The foot has two toes of different lengths, one of which can be slightly bent. The trophi are malleate, and the unci have eight parallel teeth (Fig. 3c, d).

The habitats where this species has been observed are: ponds, mosses, moors, among sphagnum. The specimen of this study was found at a depth of 0–10 cm in the hyporheos of the gravel stream Afon Mynach (Gwynedd,

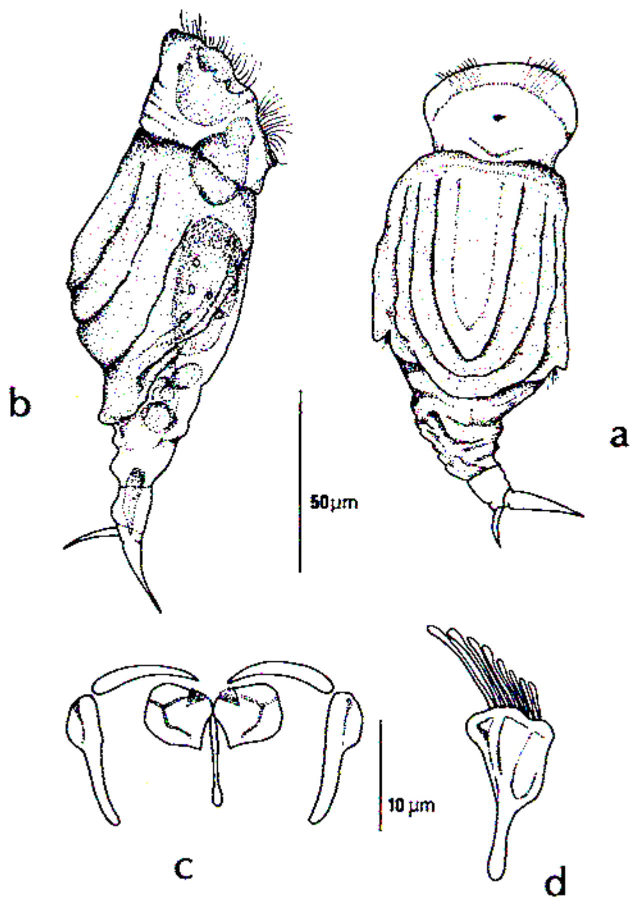

Fig. 3. *Microcodides chlaena* (Gosse, 1886). a) Dorsal view. b) Lateral view. c) Trophi. d) Lateral of manubrium and uncus.

North Wales) with a pH of 5.0. KOSTE (1978) reports *M. chlaena* f. *mobilis* (RODEWALD 1940), probably a juvenile of *M. chlaena*.

Total length: 165 µm, toes: 15 and 23 µm, trophi length: 15 µm, fulcrum: 8 µm, manubria: 13 µm, unci: 10 µm.

Geographical distribution: Czech Republic (BARTOS 1959), France (BEAUCHAMP & POURRIOT 1961), Germany (WULFERT 1940), Great Britain (GALLIFORD 1947?), Russia (KUTIKOVA 1970).

Proalinopsis caudatus (COLLINS 1872) (Fig. 4 a, b, c)

Female: The body is fusiform, slender, and extremely transparent (Fig. 4 a, b). Dorsally the body is humped. The neck is nearly the same width as the head, long and slender. A pale red eye-spot is present. The foot is spindle-shaped with two segments, the proximal larger than the distal, and with a knob-like dorsal projection bearing a slight long, deflexed seta (setigerous papilla sensu HARRING & MYERS 1922). The toes are moderately long, lanceolate, acutely pointed and slightly curved. The trophi have a small fulcrum. The rami are triangular with 5 large and 5–6 smaller teeth. The manubria are triangular an-

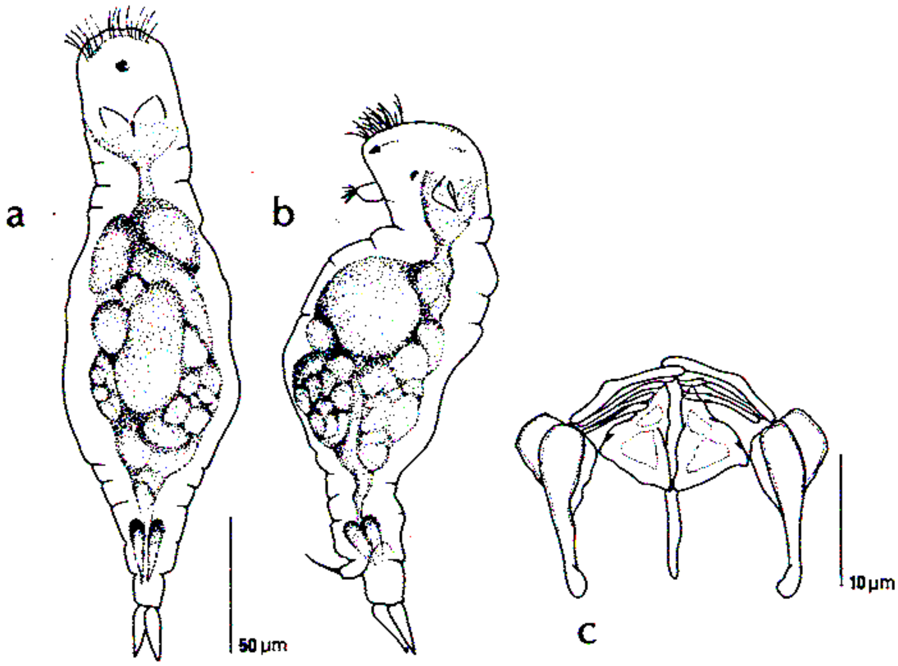

Fig. 4. *Proalinopsis caudatus* (COLLINS, 1872). a) Ventral view. b) Lateral view of a contracted individual. c) Trophi.

teriorly, and the median branch curves posteriorly towards the ventral side (Fig. 4c).

Habitats usually bogs, also in periphyton and mats in acid waters (KOSTE 1978). In the Oberer Seebach (pH: 8.0) the species was found at the sediment surface during drift experiments in August and November 1994 (densities between 0.7 to 1.35 ind. $litre^{-1}$).

Total length: 230 µm, toes: 19 µm, trophi length: 18 µm, fulcrum: 7 µm, manubria: 15 µm, rami: 8 µm.

Geographical distribution: Holarctic. Austria (first record), Czech Republic (BARTOS 1959), Germany (KOSTE 1965, WULFERT 1956), Great Britain (COLLINS 1872 cited by HUDSON & GOSSE 1889), Poland (PAWLOWSKI 1956), Russia (KUTIKOVA 1970), Sweden (PEJLER 1962), USA (HARRING & MYERS 1922).

Dicranophorus difflugiarum (PENARD 1914) (Fig. 5a, b, c)

Female: The body is stout and slightly gibbous dorsally (Fig. 5a). The animal is very transparent and illoricate. The head is large and extremely long, almost half the length of the entire body. The head is separated from the abdomen by a distinct neck. The foot is long, one fifth to one eight of the length of the

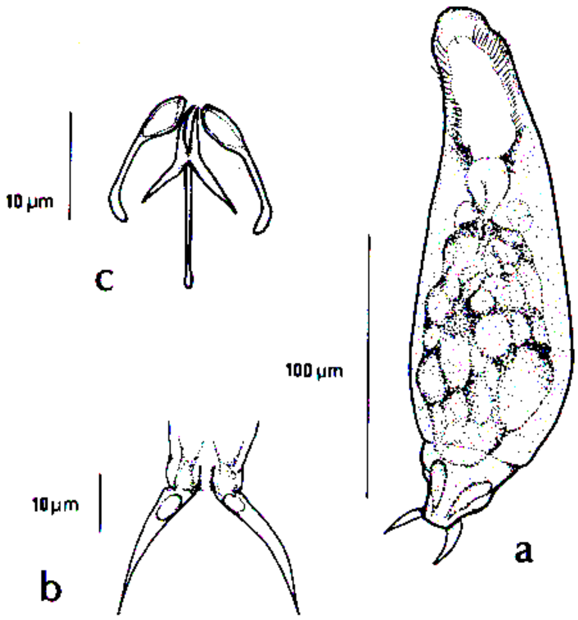

Fig. 5. *Dicranophorus difflugiarum* (PENARD, 1914). a) Dorsal view. b) Toes. c) Trophy.

body. The toes are half the foot length, lancet-shaped and acutely pointed (Fig. 5 b). The trophi are simple (Fig. 5 c). The rami arrow-shaped with a narrow, elongate median opening. The distal ends are slender and slightly incurved. The alulae are conspicuous and pointed. The single toothed unci are short, pointed and slightly curved. This characteristic can be seen with difficulty under a light microscope. The manubria are as long as the unci, also curved.

The species has been cited as parasitic in *Difflugia acuminata* EHRB. by HARRING & MYERS (1928). However, in the gravel stream Oberer Seebach, this species has often been found swimming freely at the sediment surface (drift samples, personal observations) as well as within the hyporheos (10–20 and 30–40 cm).

Total length: 210 µm, toes: 26 µm, trophi length: 18 µm, fulcrum: 12 µm, manubria: 13 µm, rami: 11 µm.

Geographical distribution: Austria (first record), Switzerland (PENARD 1914), Russia (KUTIKOVA 1970).

Wigrella depressa WISZNIEWSKI 1932 (Fig. 6 a, b, c)

Female: The body is strongly flattened dorsally and transparent (Fig. 6 a, b). As it was described by WISZNIEWSKI in 1934, this rotifer clearly at first resembles a *Dicranophorus*. The same author reported that the lorica is not divided into plates and that when the animal moves, 2 longitudinal folds can be distinguished. The specimens found in the gravel stream Oberer Seebach have these folds, but also longitudinal ribs (Fig. 6 a). The rostrum is wide and curves strongly ventrally. The foot has two segments and long strong toes. In ventral view the toes are distinctly inserted into a kind of plate and they diverge (Fig. 6 b). According to WISZNIEWSKI's description, the trophi resemble those of the genus *Encentrum* (Fig. 6 c). They are symmetric with pointed rami without teeth, and a long fulcrum. The manubria are long, with knob-like posterior ends. The intramallei are oval and the unci are strong, ending acutely pointed.

The habitat where it was found is the lake psammon. In the gravel stream Oberer Seebach this animal lives at the sediment surface as well as in the hyporheic zone (sometimes seen at depths of 30–40 cm).

Total length: 140 µm, toes: 35–38 µm, trophi length: 20 µm, fulcrum: 5 µm, manubria: 14 µm, Unci: 6 µm.

Geographical distribution: Austria (first record), Poland (WISZNIEWSKI 1934, PAWLOWSKI 1958), Rumania (RUDESCU 1960), USA (MYERS 1936).

Myersinella tetraglena (WISZNIEWSKI 1934) (Fig. 7 a, b)

Female: The body is opaque, fusiform and ventrally stocky (Fig. 7 a). The head is clearly separated from the trunk. The trunk cuticle has no longitudinal

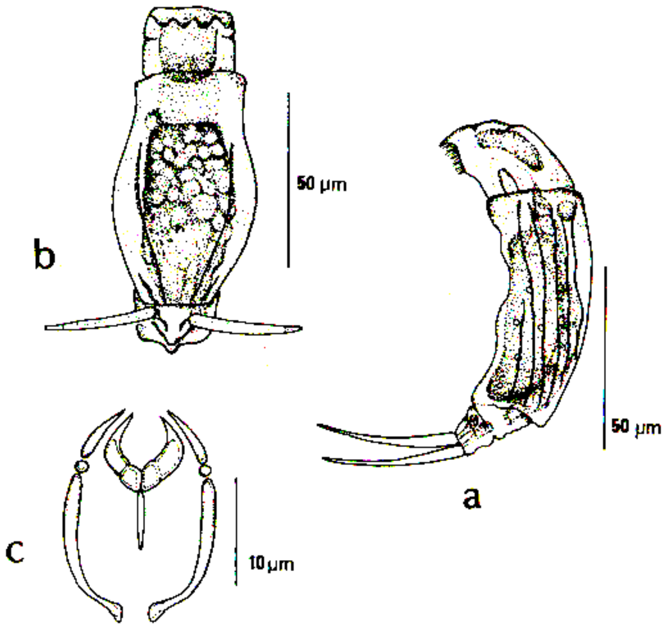

Fig. 6. *Wigrella depressa* WISZNIEWSKI, 1932. a) Lateral view. b) Ventral view. c) Trophi.

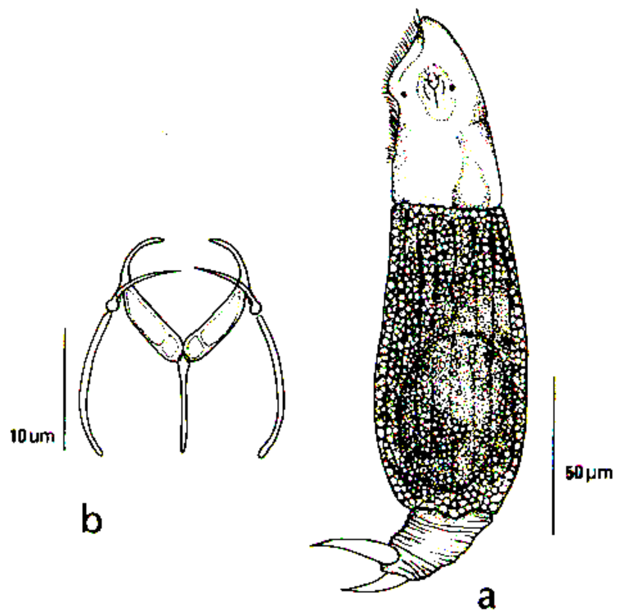

Fig. 7. *Myersinella tetraglena* (WISZNIEWSKI, 1934). a) Dorsolateral view. b) Trophi.

folds, but it is clearly delimited from head and foot. The body is full of small grains of a green-brown colour. According to WISZNIEWSKI (1934), these are not zoochlorellae, but they reflect the nutrition of the species. The foot is large (one quarter of the total body length), and conical in shape. It has irregular transverse wrinkles. The toes are longer than half of the foot length, and strongly pointed. The trophi are small and the parts weak, extremely long and slender (Fig. 7 b). The rami are slightly curved and terminate in obtuse ends. The manubria are slender and also curved. The extremely slender unci are situated at the middle plane of the rami.

The habitat often cited is the lake psammon, and my results are the first records of *M. tetraglaena* in the hyporheos of a gravel stream.

Total length: 210 µm, toes: 28–30 µm, trophi length: 18 µm, fulcrum: 8 µm, manubria: 12 µm, unci: 6 µm.

Geographical distribution: Austria (first record), Poland (WISZNIEWSKI 1934, PAWLOWSKI 1958), Romania (RUDESCU 1960), USA (MYERS 1936).

Discussion

Benthic Rotifera inhabiting the sediment surface (including periphyton, mosses, macrophytes) of running water ecosystems have been known for a long time (see NEISWESTNOWA-SHADINA 1935). The rivers where these studies were conducted had a sandy bottom (riverine psammon), and the methods used were semi-quantitative. Based on literature data about particle size ranges, sand grains can vary between 0.0625 and 2 mm (GORDON et al. 1993). This would imply that interstitial space, as well as oxygen and food concentrations in sand may limit invertebrate distribution when compared to some gravel streams which have a mean particle size of 23.1 mm (SCHMID 1993), a well oxygenated hyporheos (BRETSCHKO 1991), and increasing amounts of organic matter with depth (LEICHTFRIED 1991).

The early distinction of the hyporheos in river ecosystems, as the interstitial spaces below the streambed and above the phreatic zone (ORGHIDAN 1955, SCHWOERBEL 1961), did not report Rotifera, probably due to the mesh size of nets and the fixation methods used. However, later SCHWOERBEL (1965) included total rotifers within the hyporheos of a German stream. In recent years, many publications and reviews, usually using large mesh nets, have considered Rotifera as a poorly represented group in the hyporheos (BOULTON et al. 1992 and references therein) but BRAIONI & GOTTARDI (1979), PALMER (1991, 1992) and SCHMID-ARAYA (1993 a, b, and in press a, b) have shown that Rotifera commonly occur in the hyporheos in significant abundances compared to other meiofaunal groups, and their role has certainly been underestimated. In the benthic food-web of a gravel stream rotifers are important as food for predatory larval Chironomidae (SCHMID 1994). Gut analyses of these predators have revealed the presence of trophi of two of the species treated here: *W. depressa* and *M. tetraglena* (SCHMID-ARAYA, personal observations). Other taxa that feed on Rotifera in the Oberer Seebach stream are large Ciliates (i.e. *Trachelium*), Nematoda (i.e. *Mononchus*), Microturbellaria, Oligochaeta (i.e. *Chaetogaster*) (SCHMID-ARAYA, unpubl. results).

On the other hand, Bdelloidea and some Monogononta rotifers are microphagous, feeding on detritus particles with their associated bacteria (POURRIOT 1977, 1979) and it is now well known that these organic matter particles, as well as the surfaces of stones have an associated biofilm (bacteria, fungi, diatoms and their exudates). The feeding behaviour of *P. paradoxus* is very similar to that of another bdelloid of the same family (Philodinavidae) described by MELONE & RICCI (in press). My video observations show that as soon as it explores the particles with the reduced corona (cilia), the trophi move. It seems to scrape the particle surfaces, taking in the biofilm which includes bacteria, diatoms and fungi. A similar feeding behaviour (i.e. scraping) has been observed for two other species included here: *W. depressa,* and *M. tetraglena.*

In the literature the term "rare" is frequently used either for a small range of distribution in contrast to widespread, or for low abundances compared to common. However, the spatial and temporal scale at which a study is performed may determine not only which species are rare, but also the processes and patterns of their rarity. In most cases, it may be possible that species rarity is just a consequence of sampling design (i.e. not enough samples, sample size too small or one sporadic visit to the area). The geographical distribution of the species treated here demonstrate that their geographical range is wider than expected. In addition, lake psammon species can also be found in other habitats such as gravel streams, and some environmental parameters (e.g. pH and temperature) cannot solely explain their range of distribution. In the gravel stream Oberer Seebach the Rotifera assemblage contains several rare species in terms of abundance, but they re-occur continuously (SCHMID-ARAYA, personal observation).

While there has been enormous effort to draw attention to the relevance of species rarity for large sized organisms (see review of GASTON 1994), smaller organisms have been largely ignored. This situation is broadly explicable, because of the innate attraction of working on large and obvious taxa, and features which render their study more tractable (GASTON 1994). In terms of community structure, and consequently the maintenance of ecosystems, rare species can be regarded as having little significance. However, taking the wider argument for biodiversity and species-interactions, the collective impact of many rare species on the assemblage structure could be of relevance. This is a topic which deserves deeper examination.

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