



SPIXIANA

Zeitschrift für Zoologie



SPIXIANA

ZEITSCHRIFT FÜR ZOOLOGIE

published by the

BAVARIAN STATE COLLECTION OF ZOOLOGY

(ZOOLOGISCHE STAATSSAMMLUNG MÜNCHEN)

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One volume with two issues is published each year.

Monographs can be published as SPIXIANA Supplement.

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ZOOLOGISCHE STAATSSAMMLUNG MÜNCHEN

Münchhausenstraße 21, 81247 München, Germany

Tel. +49 (0)89 8107-0 – Fax +49 (0)89 8107-300

E-mail: SPIXIANA@zsm.mwn.de

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Publication of full-length articles in SPIXIANA is subject to peer reviewing.

After publication, PDF files of all articles are made available for research purposes.

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data are available in the Internet at
<http://dnb.d-nb.de>.

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ISSN 0341-8391

Printed in the European Union

Verlag Dr. Friedrich Pfeil, Wolfratshauser Straße 27, 81379 München, Germany

Tel. +49 (0) 89 742827-0 – Fax +49 (0) 89 7242772 – E-Mail: info@pfeil-verlag.de – www.pfeil-verlag.de

SPIXIANA	34	2	153–194	München, Dezember 2011	ISSN 0341–8391
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An interesting water mite fauna in springs near the city of Munich (Bavaria, Germany) – a pilot study for the monitoring of prealpine and alpine springs

(Acari, Hydrachnidia)

Tom Goldschmidt & Roland R. Melzer

Goldschmidt, T. & Melzer, R. R. 2011. An interesting water mite fauna in springs near the city of Munich (Bavaria, Germany) – a pilot study for the monitoring of prealpine and alpine springs (Acari, Hydrachnidia). Spixiana 34 (2): 153–194.

Very diverse and complex water mite assemblages have been found in five spring complexes (containing helo-, rheo-, rheohelo- and rheopsammocrene areas) and a spring brook south of Grünwald (Munich, Upper Bavaria, Germany). All springs are situated at about 580 m a.s.l., closely together on the right bank of the river Isar, at the foot of a cliff in fluvio-glacial gravel deposits.

In the study 819 water mite specimens were collected, 32 species were identified including a new record for the German fauna, *Atractides rivalis* Lundblad, 1956, and five new records for the Bavarian fauna: *Lebertia fimbriata* Thor, 1899; *Lebertia sparsicapillata* Thor, 1905; *Atractides polyporus* (K. Viets, 1922); *Atractides remotus* Szalay, 1953 and *Woolastookia rotundifrons* (K. Viets, 1922).

The dominance structure of the assemblages is analysed, and the ecology and distribution of the species is discussed and compared with other studies on springs.

Tom Goldschmidt (corresponding author); e-mail: tomgoldschmidt@web.de

Roland R. Melzer; e-mail: melzer@zsm.mwn.de

Bavarian State Collection of Zoology, Section Arthropoda varia, Muenchhausenstr. 21, 81247 Munich, Germany

Introduction

Springs are hotspots of aquatic biodiversity inhabited by complex assemblages of specialised crenobiont and crenophil taxa (Goldschmidt 1994, 2009; Cantonati et al. 2006; Staudacher & Füreder 2007; Stoch et al. 2011). Due to their habitat binding, the spring fauna provides unique monitoring potential for climate change (Hogg & Williams 1996), as well as changes in land use, both at local and regional scale. Furthermore, the study of spring fauna offers direct access to the examination and management of groundwater quality. In view of global climate change the monitoring of groundwater resources is of growing importance, as “changes in temperature

will directly affecting water quality by increasing temperatures and altering levels of dissolved materials such as nutrients and oxygen” (Hogg & Williams 1996). Furthermore, changes in quantity and distribution patterns of groundwater are most likely and consequently massive changes in spring habitats can be expected (Hogg & Williams 1996).

Therefore springs are not only ecologically important habitats for a very diverse and specific fauna but also important as resources for drinking water. Moreover, they provide powerful monitoring tools (Cantonati et al. 2006). Within the last decade long-term studies started on springs in the northern and southern Alps to provide the background of natural variation over time essential for any environmental

monitoring program (Gerecke et al. 2011).

Studies of the fauna and ecology of springs started during the early decades of the 20th century in Northern Germany and Switzerland (Thienemann 1907, 1923, 1925; Bornhauser 1912). Based upon these first studies, according to their morphology, three spring types (limno-, helo- and rheocrenes) have been distinguished (Steinmann 1915, Thienemann 1925). Later on the intermediate types, rheohelocrene (Schwoerbel 1959) and rheopsammocrene (Gerecke 1991), have been added to this typology. In various studies from North America and Europe water mites proved to be the most characteristic group of spring inhabitants in terms of high percentage of crenobiont species, very diverse and species rich assemblages in spring habitats and particular habitat preference (Young 1969, Smith 1991, Gerecke & Di Sabatino 1996, Williams & Williams 1996, Gerecke et al. 1998, Stoch et al. 2011). Meanwhile even the existence of specific water mite assemblages in tropical springs has been shown (Goldschmidt 2009). Compared with crenobiont Crustacea (Ostracoda, Copepoda) water mites are much more perceptible towards disturbance (Gerecke et al. 2005). Furthermore, water mites play an outstanding role within the invertebrate communities of spring habitats also with regard to their high population densities and particular significance within the food web (Gerecke et al. 2009): Due to their life cycle – deutonymphs and adults are predators mainly of aquatic insects and crustaceans, larvae are parasitic on aerial insects – water mites are connected in a complex way with other elements of the spring fauna. Furthermore, two pupae-like resting stages (proto- and tritonymph) depend on stable and protected conditions in the sediment. Besides the direct effects of abiotic factors such as substrate structure, temperature and water chemistry on the water mite species, these factors also have an indirect influence via the hosts of their larvae and the prey of their deutonymphs and adults. Due to these very complex habitat demands, water mite assemblages provide an integrated view on the ecology of crenic habitats and their coenoses, far beyond the proper ecological demands of the species. Despite of the exceptional importance of spring mites, details of the ecology of many species are hardly known and the mechanisms of the crenobiosis of the individual species is not understood in detail (Gerecke et al. 1998). Furthermore, many species of spring mites are very rare and their distribution patterns unknown. Consequently their great monitoring potential is currently still hampered by poor knowledge. Summarising, water mites are by far the most appropriate group for the characterisation of spring types and monitoring of springs in general (Cantonati & Ortler 1998, Di Sabatino et al. 2003, Gerecke 2006, Gerecke

et al. 2009). Specific water mite assemblages can be found in different spring types (Gerecke et al. 1998; Cantonati et al. 2006).

Approaches towards a faunistic spring typology have first been made by Schwoerbel (1959). In his study on water mites from springs and streams of the southern Black Forest (South-western Germany), he stated that these mites are often important “leading organisms” of different habitats. Within the framework of morphological spring typology he characterised different types according to their water mite faunas, as the “*Sperchon-Lebertia*-type” of helocrenes in montane meadows, with *Sperchon squamosus* Kramer, 1879, *S. glandulosus* Koenike, 1886, *S. mutilus* Koenike, 1895, *Lebertia stigmatifera* Thor, 1900 and *L. cuneifera* Walter, 1922 as characteristic dominant and subdominant species. However, for all other spring types, Schwoerbel (1959) renounced of naming “water-mite-types” and just described the faunas. In total he collected 135 species from 260 sample sites (Schwoerbel 1959) – 22 of these species were also found in the present study (see below). Cluster analysis of water mites in Mediterranean springs showed that rheohelocrenes, rheopsammocrenes and rheocrenes are inhabited by most specific water mite communities (Gerecke & Di Sabatino 1996). In springs of different types at different elevations, different characteristic species are dominant. The authors therefore hypothesized specific local typical differentiation of the fauna of springs of these three types (Gerecke & Di Sabatino 1996). In long-term studies on spring faunas in the Berchtesgaden National Park (Upper Bavaria, Germany) distinct water mite communities were found in different spring types (Gerecke et al. 1998, Nationalparkverwaltung Berchtesgaden 2006). Accumulation curves of the water mite fauna of individual springs over ten years level out, indicating that a “representative taxonomic survey of this group is possible in a reasonable time” (Gerecke et al. 2011). However, the studies in the north-eastern Alps also showed, that “selected study sites and their communities should be documented as complex individuals” (Gerecke et al. 1998). Intensive spring studies in the south-eastern Alps emphasised the mosaic structure and high degree of individuality of springs as well (Cantonati et al. 2006). Different spring types clearly differ in the composition and diversity of their faunas, with the highest diversity (not only for water mites) found in helocrenes (Gerecke et al. 2011).

Approximately 600 species are so far recorded from Central Europe, with about 400 species from the Alps (Walter 1922, Gerecke & Lehmann 2005, Di Sabatino et al. 2010). Several studies showed that $\frac{1}{3}$ of the species of an area is regularly found in springs, and $\frac{1}{5}$ is strictly confined to these habitats (Gerecke

et al. 2009). Until now, 297 species of water mites are reported from Bavaria (Mauch et al. 2003, König et al. 2006, Nationalparkverwaltung Berchtesgaden 2006). The knowledge on the Bavarian water mite fauna is mainly based upon few very local studies: K. Viets (1939) reported 38 species from springs, streams and lakes in the area of Garmisch-Partenkirchen (Upper Bavaria), mainly collected between 1933 and 1935 (in total 30 sample sites at 750–1560 m a.s.l. – 15 species from 10 springs).

K. O. Viets (1954–1958) listed 241 water mite species from Bavaria outside the Alps, and gave a complete literature list on Bavarian water mites from 1803 to 1954. In these studies on water mites from Northern Bavaria 57 species have been found in springs – 17 of these also collected in the present study.

The very few systematic data so far available from the Bavarian spring fauna are restricted to two studies from (1) the National Park Berchtesgaden (Martin 2003, Nationalparkverwaltung Berchtesgaden 2006) and (2) the Benninger Ried, a typical quaternary carbonate fen complex (König et al. 2006). The latter area is situated in the same hydrogeological region, the “fluvio-glacial gravel”, at a similar elevation of about 600 m a.s.l., just about 100 km east of the area of the present study.

In regard to the specific characters of springs on the one hand, and the low number of samples on the other hand, the present study mainly focuses on a detailed analysis and documentation of a complex of characteristic springs in an unique area near the city of Munich (Bavaria, Germany) (see below). This study should contribute to the understanding of the complexity of spring faunas by providing data on special springs and aims to describe ‘typical’ water mite assemblages of these springs.

A further aim of the survey is to initialise broader studies on springs on a transect through different elevations in the northern limestone Prealps and Alps. In the long term ‘typical’ water mite assemblages and characteristic, ‘leading’ species of different spring types will be described. A regional faunistic spring typology will be worked out, in order to provide a tool for management and protection of groundwater and springs as well as monitoring of climate change and other types of disturbance in alpine and prealpine springs.



Fig. 1. Map, location of sample sites south of Grünwald (Munich, Bavaria).

Material and methods

Sampling, preparation and measurements

Samples were collected with a hand-net – mesh size 250 µm. In springs with stronger current the substratum was stirred by hand, moss carpets and leaf packages were washed in the current, so that the fine detritus together with the dislodged organisms was swept into the net by the current. In the seepage areas of springs with little flow and in helocrenes, substratum was gathered in the net by hand. The material collected was washed through a sieve (mesh size approximately 2 mm), transferred to plastic containers (1 l, wide opening), transported to the lab and sorted alive.

The samples were taken semi-quantitatively, all microhabitats (gravel, sand, fine and coarse detritus, moss carpets) were sampled according to the percentage cover of the substrate type. Collections were made with the same duration and intensity at each site to allow for comparison among samples (for discussion of sampling techniques in springs see Goldschmidt 1994 and Gerecke et al. 1998).

Water mites were picked up individually with eye droppers and fine tweezers and preserved in Koenike's solution (10 parts Glycerine : 3 parts Glacial Acetic Acid : 6 parts Water). Representative individuals of all species were mounted in glycerine jelly for species identification (for details on mounting techniques, see Goldschmidt 2007). All other invertebrate groups (mainly early instars of insect larvae) were preserved in 70 %

ethanol and deposited at the ZSM for later studies.

All measurements are given in µm; lengths of leg- and palp-segments are given as dorsal length without sheaths (terminal segments as maximal length), heights are given as maximal heights.

The following abbreviations are used: Ac-1,-2,-3 – anterior, central, posterior acetabula; bs – basal segment; chel – chelicera; Cx – coxa; H – height; Id – idiosoma; L – length; mL – medial length; P1-5 – palp segments; post W – posterior width; S1 / S2 – pair of strong sword-setae at ventro-distal margin of I-leg-5; V1 – ventroglandularium 1; W – width.

The samples will be deposited at the Bavarian State Collection of Zoology (ZSM), Munich, Germany.

Morphological data on the species are depicted here in the form of a pictorial atlas. Series of photos along the z-axis were made with a Leica DMRBE microscope, extended depth of field pictures were calculated using freeware program CombineZM.

Environmental parameters

The exact location of the sample sites were taken with a GPS (Garmin GPSMAP 76CSx). Temperature and conductivity were measured with a conductivity meter (WTW LF 318).

Hydrogeologically the investigated area is part of the fluvioglacial gravel deposits, characterised by quaternary gravel beds of the large prealpine rivers. These gravel beds are very porous and productive groundwater bodies of regional and supra-regional importance and intensively used areas of water supply management. Most springs in this area are limnocrenes (Projektgruppe Aktionsprogramm Quellen 2004). However, the springs investigated in the present study represent rheocrenes with relatively strong current, flowing springs with slow current (mainly under the surface) characterised by fine organic (rheohelocrene) or fine inorganic (rheopsammocrene) material. One spring can

be characterised as helocrene. Several sample sites represent typical “spring complexes” of closely linked springs of different types.

Results

Abiotic data

Samples were taken 10th and 17th of September 2008; temperature and conductivity was measured 17th of September 2008 and 16th of February 2009.

The unstable temperature at site 2 and 3 indicates strong seasonal changes in discharge (slow flowing spring), whereas the stable temperature at site 4 and 5 is a clear indication for a year-round strong constant discharge. The variability in the conductivity of different parts of the spring complex 1 is a typical phenomenon in weakly seeping helocrenes (Goldschmidt 1994).

Abundance patterns

In total 819 water mite specimens were collected in the present study, representing 32 species, 12 genera, 7 families. The five most abundant species of the present study represent more than half of all specimens (441), whereas the eight rarest species are just found as singletons (see table 2).

Faunistic data

Previous findings of the species treated in the present paper in recent spring studies are given as: BNP – Berchtesgaden National Park (Nationalparkverwaltung Berchtesgaden 2006); BR – springs of the Benninger Ried (König et al. 2006); C – CRENODAT, a study on 104 springs in the Trentino Region (North-

Table 1. Abiotic data of the investigated springs and spring complexes (1-5), as well as spring brook. Spring types: hc – helocrene spring; rc – rheocrene spring; rhc – rheohelocrene spring; rpc – rheopsammocrene spring. Substrates: c.o.m. – coarse organic matter; f.o.m. – fine organic matter; gr. – gravel; st. – stones; veg. – vegetation.

	1a		1b		2a			2b	3
spring type	hc	hc	rhc	rhc	rhc	rhc	rhc	out-flow	rc
17.9.2008									
conductivity [µS/cm]	762		436		506	516		515	394
temperature [°C]	8.9				12.0	11.9		11.2	9.4
16.2.2009									
conductivity [µS/cm]	656	571		760	436	429	413	430	390
temperature [°C]	5.3	2.9		8.1	4.4	3.9	3.1	2.2	2.2
main substrate	f.o.m.	sand, gr., c.o.m.			rich in organic matter			gr., c.o.m.	gr., sand
discharge, current	weak, slow				slow			strong	strong (very low in winter)
coordinates	48°01'50" N 11°30'38" E				48°02'08" N 11°30'38" E			48°01'56" N 11°30'39" E	

ern Italy) (Gerecke et al. 2009); Lux – faunistic survey of 41 springs in Luxembourg (Gerecke et al. 2005).

Hydryphantidae

Euthyadinae

Panisus torrenticolus Piersig, 1898

Present study: 1 specimen in a rheohelocrene spring (2a).

Habitat and distribution: Low- and middle-order streams, occasionally in rheocrenes; Western Palaearctic (Di Sabatino et al. 2010).

Protziinae

Partnunia steinmanni Walter, 1906

Present study: 11 specimens in 2 spring complexes (2a, 4 – rheohelo-, rheopsammo-, rheocrene).

Habitat and distribution: Crenobiont, preferably in shaded rheo- and rheohelocrenes rich in gravel and mosses; in lower mountain ranges typical species of forest springs; Alps, Tatra, Central and Western European lower mountain ranges (Di Sabatino et al. 2010).

Previous findings: Lux – exclusively in 2 rheohelocrenes and 2 rheocrenes; BNP – very common, mainly <1400 m a.s.l.; C – most frequent, second most abundant species, preference for rheo- and rheohelocrenes rich in gravel and moss, especially in forested areas.

Protzia squamosa Walter, 1908

Present study: 45 specimens in 3 rheocrenes (3, 4, 5 (80 % of all specimens)).

4				5	brook	
rc	rpc	rc	rc	rc	riffle	veg.
809	812	793	766	740	775	
9.8	10.0	9.7	9.2	10.0	9.3	
754	777	754		732	755	757
9.2	9.2	8.8		8.7	7.5	8.5
sand, gr., organic matter				gr.	gr., st.	veg.
strong				moderate		
48°01'51"N				48°01'51"N	48°01'51"N	
11°30'39"E				11°30'34"E	11°30'39"E	

Habitat and distribution: Crenobiont; preferably in rheohelocrenes at low and middle elevations; rheo- and helocrenes in forest (Nationalparkverwaltung Berchtesgaden 2006); Central and Eastern Europe (Di Sabatino et al. 2010).

Previous findings: BNP – one sample site at 800 m a.s.l.; C – rare (2 sites), rheo- and helocrenes in forested areas.

Lebertiidae

Lebertia (Lebertia) fimbriata Thor, 1899

Present study: 3 specimens in a rheohelocrene (2a just in spring mouths).

Habitat and distribution: Low to high order streams, between mosses, under stones, in northern Europe also in lakes (Di Sabatino et al. 2010); rhithrobiont, interstitial (Gerecke et al. 2005); Western Palaearctic (Di Sabatino et al. 2010), widely distributed (Gerecke 2009).

Remarks: The species is described as rhithrobiont by Gerecke (2009). However, in the same publication a lot of sample sites in springs are listed, especially from the Mediterranean. Therefore the finding in a spring in the present study is not too surprising. However, it seems to be the first record from a spring habitat north of the Alps. The species should probably be characterised as crenophilous.

Previous findings: Lux – 1 sample site in interstitial; C – one specimen at 250 m a.s.l., characterised as crenoxene.

New for Bavaria.

Lebertia (Lebertia) glabra Thor, 1897

Present study: 6 specimens in a spring brook (riffle & vegetation).

Habitat and distribution: Rhithrobiont, in the Mediterranean crenophilous, spring-dwelling populations in Sweden and Luxembourg with preference for mineral substrata and elevated conductivity (Di Sabatino et al. 2010); rhithrobiont, crenophilous (Gerecke et al. 2005); Western Palaearctic (Di Sabatino et al. 2010).

Previous findings: Lux – 1 helocrene, 4 rheohelocrenes, 3 rheocrenes.

Lebertia (Lebertia) maglioi Thor, 1907

Present study: 7 specimens in a rheohelocrene and its outflow (2a, 2b).

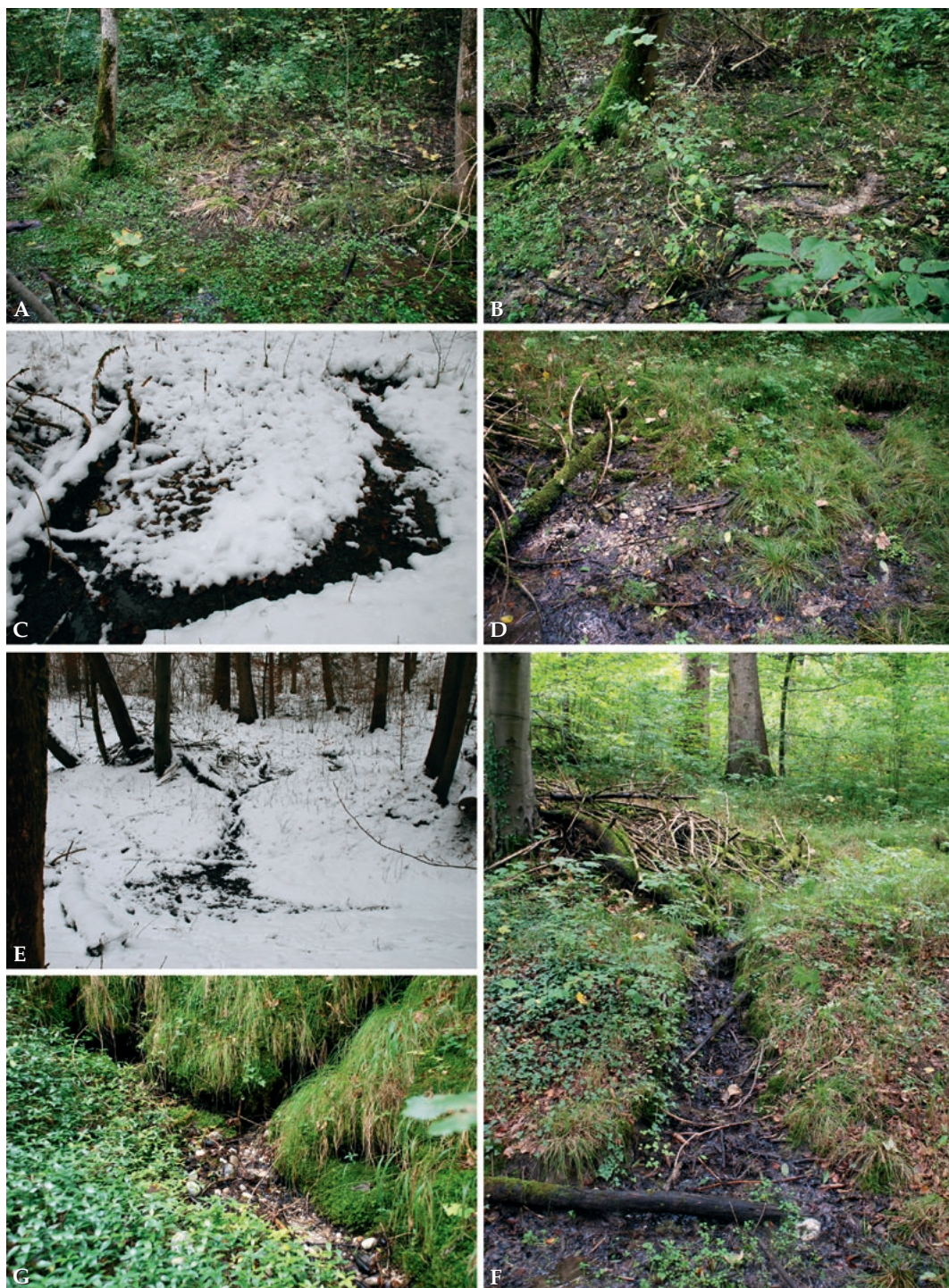


Fig. 2. Photos of sample sites, taken September 17th 2008 (summer aspect) and February 16th 2009 (winter aspect). A. 1a. B. 1b. C. 2a. D. 2a. E. 2a+b. F. 2b. G. 3.



Fig. 3. Photos of sample sites, taken September 17th 2008 (summer aspect) and February 16th 2009 (winter aspect). A–E. 4. F, G. 5. H. brook (vegetation). I. brook (riffle).

Habitat and distribution: Middle order streams; Western Palaearctic (wide distribution) (Di Sabatino et al. 2010).

***Lebertia (Lebertia) salebroza* Koenike, 1908**

Present study: 1 specimen in a rheohelocrene (2a).

Habitat and distribution: Stream-dwelling in Western and Central Europe, crenobiont at southern margin of its area; frequent in Western and Central European mountains and lowlands, patchy records from Western Alps, Pyrenees, North Africa (Di Sabatino et al. 2010).

***Lebertia (Lebertia) sparsicapillata* Thor, 1905**

Present study: 1 specimen in a rheohelocrene (2a).

Habitat and distribution: Rhithrobiont; Europe except most northern and eastern parts (Di Sabatino et al. 2010).

New for Bavaria.

***Lebertia (Mixolebertia) helocrenica* Gerecke, 2009**

Present study: 26 specimens in a rheohelocrene and its outflow (2a, 2b).

Habitat and distribution: Crenobiont, in weakly seeping springs rich in organic debris; Alps, Central

Europe; rare – so far only known from one spring in northern Italy and two springs in the northern prealps (Di Sabatino et al. 2010) (described from Berchtesgaden, Upper Bavaria, Germany).

***Lebertia (Mixolebertia) holsatica* K. Viets, 1920**

Present study: 1 specimen in a rheohelocrene (2a).

Habitat and distribution: Crenobiont, preferably in habitats rich in macrophytes and fine detritus (Gerecke et al. 2005), characteristic element of weakly seeping helocrenes (Gerecke 2006). In Southern Europe often in weakly flowing rheohelocrenes at

low altitudes, probably thermophilous (Di Sabatino et al. 2010); Alps, Central and Southern European mountains (Gerecke et al. 2009).

Previous findings: Lux – 1 helocrene, 3 rheohelocrenes, 2 rheocrenes; BR – 1 rheohelocrene (3 specimens); C – 6 sites, mainly rheo- and rheohelocrenes.

***Lebertia (Mixolebertia) sefvei* Walter, 1911**

Present study: 10 specimens in a rheohelocrene (1b – 80 % of all specimens) and a spring brook.

Habitat and distribution: Crenobiont (Gerecke et al. 2005); cold-stenothermous, rhithrobiont and creno-

Table 2. Abundances of all water mite species from springs and a brook treated in the present study. For abbreviations see Table 1. Main habitats are given in bold.

	Σ	1a hc	1b rhc	2a rhc	2b out-flow	3 rc	4 rc+rpc	5 rc	brook r+v
<i>Sperchon thienemanni</i>	137	1	3				18	12	103
<i>Sperchon longissimus</i>	86	1	29	3	4	19	5	11	14
<i>Sperchon resupinus</i>	82		4	15	10	34	1	14	4
<i>Atractides rivalis</i>	74		6			1	50	7	10
<i>Atractides protendens</i>	62	1		29	10	2	2	11	7
<i>Atractides fonticolus</i>	53						10	3	40
<i>Lebertia stigmatifera</i>	51	1	19					8	23
<i>Protzia squamosa</i>	45					1	8	36	
<i>Ljania bipapillata</i>	55	2	8	5	2	1		8	29
<i>Lebertia helocrenica</i>	26			17	9				
<i>Atractides pennatus</i>	26								26
<i>Sperchon setiger</i>	22				5				17
<i>Chelomideopsis annemiae</i>	14		1	12	1				
<i>Atractides polyporus</i>	13			3	2			8	
<i>Partnunia steinmanni</i>	11			1			10		
<i>Lebertia sefvei</i>	10		8						2
<i>Atractides remotus</i>	10			6	4				
<i>Lebertia maglioi</i>	7			3	4				
<i>Lebertia glabra</i>	6								6
<i>Lebertia semireticulata</i>	6			1			5		
<i>Aturus scaber</i>	6			4	2				
<i>Hygrobates fluviatilis</i>	4								4
<i>Lebertia fimbriata</i>	3			3					
<i>Sperchon squamosus</i>	2					2			
<i>Panisus torrenticolus</i>	1			1					
<i>Lebertia holsatica</i>	1			1					
<i>Lebertia salebroza</i>	1			1					
<i>Lebertia sparsicapillata</i>	1			1					
<i>Torrenticola anomala</i>	1			1					
<i>Hygrobates norvegicus</i>	1	1							
<i>Atractides latipes</i>	1			1					
<i>Woolastookia rotundifrons</i>	1			1					
sum specimens	819	7	78	109	53	60	109	118	285
sum species		6	8	20	11	7	9	10	13

philous in northern part of distribution area, crenobiont in the Alps (various spring types, avoiding helocrenes with weak flow) (Di Sabatino et al. 2010); frequent but in low population densities (Gerecke et al. 2009); Europe (Di Sabatino et al. 2010).

Previous findings: Lux – 1 helocrene, 1 rheohelocrene; BNP – 14 sites (different spring types, not in slow flowing helocrenes), 600–2000 m a.s.l.; BR – 3 rheohelocrenes (2, 2 and 1 specimens); C – 5 springs of different types, frequent but in low population densities.

Lebertia (Mixolebertia) semireticulata K. Viets, 1925

Present study: 6 specimens in a rheohelo-, a rheopsammo- and a rheocrene (2a, 4).

Habitat and distribution: Weakly seeping rheohelocrenes; Central European mountains, northern prealps and Alps; rare (Di Sabatino et al. 2010).

Lebertia (Mixolebertia) stigmatifera Thor, 1900

Present study: 51 specimens in a helocrene (1a), a rheohelocrene (1b), a rheocrene (5) and a spring brook.

Habitat and distribution: Crenobiont (Gerecke et al. 2005); cold stenothermous, in Northern Europe springs and streams, Central, Western and Southern Europe crenobiont; springs of various types, mainly lower elevations (Gerecke 2009); Northern, Western, Central Europe, Pyrenees, Apennines, Balkan (Di Sabatino et al. 2010).

Previous findings: Lux – 1 rheohelocrene; BNP – 3 sites (rheohelocrenes), 610–1280 m a.s.l.; BR – 1 rheohelocrene (3 specimens); C – 1 site.

Sperchontidae

Sperchon (Hispidosperchon) setiger Thor, 1898

Present study: 22 specimens in the out-flow of a rheohelocrene spring complex (2b) and a spring brook.

Habitat and distribution: Middle-order streams (adults also in pools); Western Palaearctic, widely distributed in Europe, Maghreb (Di Sabatino et al. 2010).

Sperchon (Sperchon) longissimus K. Viets, 1920

Present study: 86 specimens in all sample sites (5 spring complexes (helo-, rheohelo-, rheopsammo-, rheocrenes), 1 spring brook).

Habitat and distribution: Crenobiont, slow flowing rheohelocrenes (Gerecke et al. 2005); preferably helocrenes in lowland and lower mountain ranges. In the Southern Black Forest exclusively in montane forest helocrenes (Schwoerbel 1959); England, Central and SE Europe, Asia Minor, not recorded from Alpine areas (Di Sabatino et al. 2010); rare (Gerecke et al. 2005).

Remarks: Since in most studies the species has been found in small frequencies and abundance, the finding of large populations in various springs in the present study is remarkable.

Previous findings: Lux – exclusively in 1 rheocrene.

Sperchon (Sperchon) resupinus K. Viets, 1922

Present study: 82 specimens mainly in 3 rheocrenes (3 (41 % of all specimens), 4, 5), 2 rheohelocrenes (1b, 2a, 2b) and a spring brook.

Habitat and distribution: Crenobiont, preferably helocrenes (also habitats exposed to sunlight and organic input), character species of detritus-rich helo- and rheohelocrenes, also organically polluted sites, always small populations, rare (Nationalparkverwaltung Berchtesgaden 2006, Gerecke et al. 2009); Central and Southern Europe, southern Scandinavia (Di Sabatino et al. 2010).

Remarks: As most studies emphasise that the species is rare and always found in small populations (Nationalparkverwaltung Berchtesgaden 2006, Gerecke et al. 2009), the high frequencies and abundance of the species in the present study is remarkable.

Previous findings: BNP – 3 sites at 1200 m a.s.l.; C – 3 sites (4 specimens).

Sperchon (Sperchon) squamosus Kramer, 1879

Present study: 2 specimens in a rheocrene (3).

Habitat and distribution: Crenobiont, rhithrophilous; in Central Europe mainly springs and small streams with groundwater influence (Gerecke et al. 2005); rhithrobiont, crenophilous (Gerecke et al. 2009), often in helocrenes (in northern part of distribution area also lake littoral, in southern part exclusively in spring habitats); Western Palaearctic, preferably in lowlands and lower mountain ranges (Di Sabatino et al. 2010).

Previous findings: Lux – 2 helocrenes, 4 rheohelocrenes, 2 rheocrenes, 2 limnocrenes; BNP – 3 sites at 600–1400 m a.s.l., only rheohelocrenes, crenophilous; BR – 1 rheohelocrene (1 specimen); C – 8 sites.

***Sperchon (Sperchon) thienemanni* Koenike, 1907**

Present study: 137 specimens (by far most abundant species of the present study) mainly in spring brook (75 % of all specimens), 2 rheocrenes (4, 5), a rheohelocrene (1b) and a singleton in a helocrene (1a).

Habitat and distribution: Crenobiont, rhithrophilous (Gerecke et al. 2005); crenophilous, often large populations in springs of various typology, with preference for rheohelocrenes rich in organic material, in Central and Northern Europe frequently in low order streams; Europe (detailed distribution unclear, due to late clear separation of *thienemanni*/*glandulosus*) (Gerecke et al. 2005, Di Sabatino et al. 2010).

Remarks: According to Di Sabatino et al. (2010), *Sperchon thienemanni* has often been confused with *Sperchon glandulosus*, and most of the older records from spring habitats published as *S. glandulosus*, in fact refer to *S. thienemanni* – probably also the findings of “*S. glandulosus*” in ten springs in the area of Garmisch-Partenkirchen (K. Viets 1939).

Previous findings: Lux – 1 helocrene, 8 rheohelocrenes, 7 rheocrenes (very abundant); BNP – abundant in different spring types (40 sites), mainly in detritus rich rheohelocrenes, 600–2000 m a.s.l.; C – 18 sites, abundant.

Torrenticolidae

***Torrenticola anomala* (Koch, 1837)**

Present study: 1 specimen in a rheohelocrene (2a).

Habitat and distribution: Middle-order streams, often in riffles (also pools); Holarctic (Di Sabatino et al. 2010).

Previous findings: Lux – 1 interstitial site.

Hygrobatidae

***Hygrobatas fluviatilis* (Ström, 1768)**

Present study: 4 specimens in a spring brook (in vegetation).

Habitat and distribution: Rheobiont (in submerse vegetation); occasionally in high abundance in strong flowing rheocrenes (Gerecke et al. 2005), characteristic in stronger flowing parts of rheohelocrenes (Gerecke 2006); Palaearctic (Gerecke et al. 2009).

Remarks: The species is very common in clean running waters, in general found in small populations. Due to the tolerance against organic pollution, in

polluted water *H. fluviatilis* is often the only water mite species and is forming very large populations. Therefore *H. fluviatilis* probably is the most abundant water mite in running waters in Germany. Furthermore, the species shows a preference for vegetation-rich strong karst springs (Gerecke 2006).

Previous findings: Lux – 1 interstitial site; BNP – 1 strong flowing rheocrene, 610 m a.s.l.; BR – 3 rheohelocrenes (80, 17, 19 specimens), 1 pond (2 specimens), most abundant species; C – 2 sites, 14 specimens.

***Hygrobatas norvegicus* (Thor, 1897)**

Present study: 1 specimen in a helocrene (1a).

Habitat and distribution: Crenobiont; preferably habitats rich in macrophytes and with a lot of fine detritus, mainly rheohelocrenes (Gerecke et al. 2005; Gerecke 2006); various spring types (Gerecke et al. 2009); Northern, Central, Eastern Europe (Gerecke et al. 2009).

Previous findings: Lux – 1 helocrene, 2 rheohelocrenes, 1 limnocrene; BNP – most abundant spring mite, 24 sites (different types, mainly detritus rich), 600–1800 m a.s.l. (mainly <1400 m a.s.l.); BR – 3 rheohelocrenes (37 (main habitat), 6 and 2 specimens); C – 12 sites (107 specimens, all spring types).

***Atractides fonticolus* (K. Viets, 1920)**

Present study: 53 specimens mainly in a spring brook (75 % of all specimens) and in 2 rheocrenes (4, 5).

Habitat and distribution: Crenobiont or at least crenophilous (Gerecke 2003); preferably in habitats with hard substrate and high conductivity (Gerecke et al. 2005); Western Palaearctic, except British Isles and Fennoscandia (Gerecke et al. 2005).

Previous findings: Lux – 3 rheohelocrenes, 6 rheocrenes (characteristic species, abundant).

***Atractides latipes* (Szalay, 1935)**

Present study: 1 specimen in a rheohelocrene (2a).

Habitat and distribution: Rhithrobiont, hyporheophilous; Eastern, Southern, Central Europe (Gerecke 2003).

Previous findings: Lux – 1 interstitial site.

***Atractides pennatus* (K. Viets, 1920)**

Present study: 26 specimens in a spring brook.

Habitat and distribution: Crenobiont (at least crenophilous); eventually rhithrophilous (large popula-

tions in streams (Gerecke et al. 2005); Europe (except Fennoscandia, Caucasus) (Gerecke 2003).

Previous findings: Lux – 1 rheohelocrene, 1 rheocrene (rare but in high individual numbers); BR – exclusively 1 shaded rheohelocrene (29 specimens), character species of this site.

Atractides polyporus (K. Viets, 1922)

Present study: 13 specimens in a rheohelocrene (2a, 2b) and a rheocrene (5).

Habitat and distribution: Crenobiont, weakly flowing rheohelocrenes, mainly at low elevations (never found in high alpine areas) (Gerecke et al. 2009); Central and Southern Europe, North Africa (Gerecke 2003).

Previous findings: C – 3 sites (4 specimens)

New for Bavaria.

Atractides protendens K. O. Viets, 1955

Present study: 62 specimens mainly in a rheohelocrene (2a, 2b – in total 63 % of all specimens), 3 rheocrenes (3, 4, 5), spring brook and helocrene (1a).

Habitat and distribution: Crenobiont, characteristic element of weakly seeping rheohelocrenes (Gerecke 2006), rheo- and rheohelocrenes (Gerecke et al. 2009); Central Europe, Alps, Apennine, Balkan (Gerecke 2003, Nationalparkverwaltung Berchtesgaden 2006, Pešić et al. 2010), mainly lowland (Nationalparkverwaltung Berchtesgaden 2006).

Previous findings: BNP – 5 sites (rheocrenes) 600–1600 m a.s.l.; BR – 3 rheohelocrenes (8, 3 and 1 specimens), 1 limnocrene (1 specimen); C – 1 specimen.

Atractides remotus Szalay, 1953

Present study: 10 specimens in a rheohelocrene (2a, 2b).

Habitat and distribution: Rhithrobiont, hyporheophilous; Central Europe, Alps, Carpathians, Balkan, Turkey (Gerecke 2003, Pešić et al. 2010, Erman et al. 2010).

New for Bavaria.

Atractides rivalis Lundblad, 1956

Present study: 74 specimens mainly in 3 rheocrenes (3, 4 (68 % of all specimens), 5), a spring brook and 1 rheohelocrene (1b).

Habitat and distribution: Rhithrobiont (Gerecke 2003); (but described from springs and spring brooks (Lundblad 1956)); after description (from

Austria) only three further records from Austria and Poland (Gerecke 2003) as well as Turkey (Pešić & Erman 2006).

New for Germany.

Aturidae

Woolastookia rotundifrons (K. Viets, 1922)

Present study: 1 specimen in a rheohelocrene (2a).

Remarks: Possibly several species in Europe (Gerecke et al. 2005).

Habitat and distribution: Springs, streams, interstitial (Gerecke 1994); rhithrobiont, hyporheophilous (Gerecke et al. 2005); Central, Eastern Europe (K. Viets 1956), Balkan, Turkey (Pešić et al. 2010, Erman et al. 2010).

Previous findings: Lux – 1 interstitial site.

New for Bavaria.

Ljanja bipapillata Thor, 1898

Present study: 55 specimens mainly in a spring brook (64 % of all specimens), 1 helocrene (1a), 2 rheohelocrenes (1b, 2a, 2b), 2 rheocrenes (3, 5).

Habitat and distribution: Crenophilous, rheophilous (cold upstream regions) (K. Viets 1936); rhithrobiont, crenophilous (Gerecke et al. 2005), flowing parts of rheohelocrenes (Gerecke 2006), crenophilous in the lowland, in Alpine springs mainly in the hypocranal (Gerecke et al. 2009); Western Palaearctic (Gerecke et al. 2009), wide distribution, but usually found in few specimens (K. Viets 1956).

Previous findings: Lux – 1 helocrene, 6 rheohelocrenes, 5 rheocrenes (abundant, wide distribution, mainly shaded forest springs with leaf litter and hard substrate; BNP – 11 sites (detritus rich springs), 600–1400 m a.s.l.; BR – 3 rheohelocrenes (2, 6 and 6 specimens), 1 ditch (1 specimen); C – 8 sites, 11 specimens.

Aturus scaber Kramer, 1875

Present study: 6 specimens in a rheohelocrene (2a, 2b).

Habitat and distribution: Rheophilous (cold, fast flowing streams) (K. Viets 1936); rhithrobiont (Gerecke et al. 2005); Europe (K. Viets 1956); Western Palaearctic, wide distribution, abundant (Gerecke et al. 2005).

Previous findings: Lux – 2 interstitial sites.



Fig. 4. *Lebertia fimbriata*, male. **A.** Ventral view of idiosoma. **B.** IV-leg-5/-6. **C.** Detail of IV-leg-6 (see terminal swimming setae at IV-leg-5). **D.** Lateral view of palp. **E.** Gnathosoma (palp in medial view). Scale bars A=100 µm, B-E=50 µm.

Athienemanniidae

Chelomideopsis annemiae Romijn, 1920

Present study: 14 specimens in 2 rheohelocrenes (1b, 2a, 2b).

Habitat and distribution: Springs (K. Viets 1936); crenobiont, mainly muddy, slow flowing areas in springs (Gerecke et al. 2005); rare, characteristic

for helocrene springs, ecology largely unknown (Gerecke 2006); northern part of Central Europe (Northern Germany, The Netherlands, Denmark, Southern Sweden) (K. Viets 1936); Southern and Central Europe, including Great Britain (Gerecke et al. 2005).

Previous findings: Lux – exclusively in 1 rheocrene; BR – exclusively 1 specimen in an open helocrene.



Fig. 5. *Lebertia fimbriata*, female. **A.** Ventral view of idiosoma. **B.** IV-leg. **C.** Detail of IV-leg-6 (see terminal swimming setae at IV-leg-5). **D.** Lateral view of palp. **E.** Gnathosoma (palp in medial view). Scale bars A, B=100 µm, C-E=50 µm.

Systematic data

In the following the differences between the populations of the present study and data/figures published in the recent revisions of the genera *Atractides* (Gerecke 2003) and *Lebertia* (Gerecke 2009) are documented and discussed – these two genera are the most diverse in the present study. A special focus is laid upon infrequently or sparsely documented species and species new for the Bavarian (German)* fauna: *Lebertia fimbriata* Thor, 1899; *Lebertia sparsicapitata* Thor, 1905; *Atractides polyporus* (K. Viets, 1922); *Atractides remotus* Szalay, 1953; *Atractides rivalis* Lundblad, 1956*. *Woolastookia rotundifrons* (K. , 1922),

also found for the first time in Bavaria, therefore is documented as well.

Detailed descriptions of the species of *Atractides* and *Lebertia* are found in the revisions mentioned above. Only morphological details are discussed here which differ from these revisions in order to contribute to the knowledge of the variety of these – often rare – species. Differences mentioned within species of the genus *Lebertia* refer to Gerecke 2009, within species of the genus *Atractides* refer to Gerecke 2003. This part of our study aims towards the extension of the knowledge on the morphology and variability of these species.

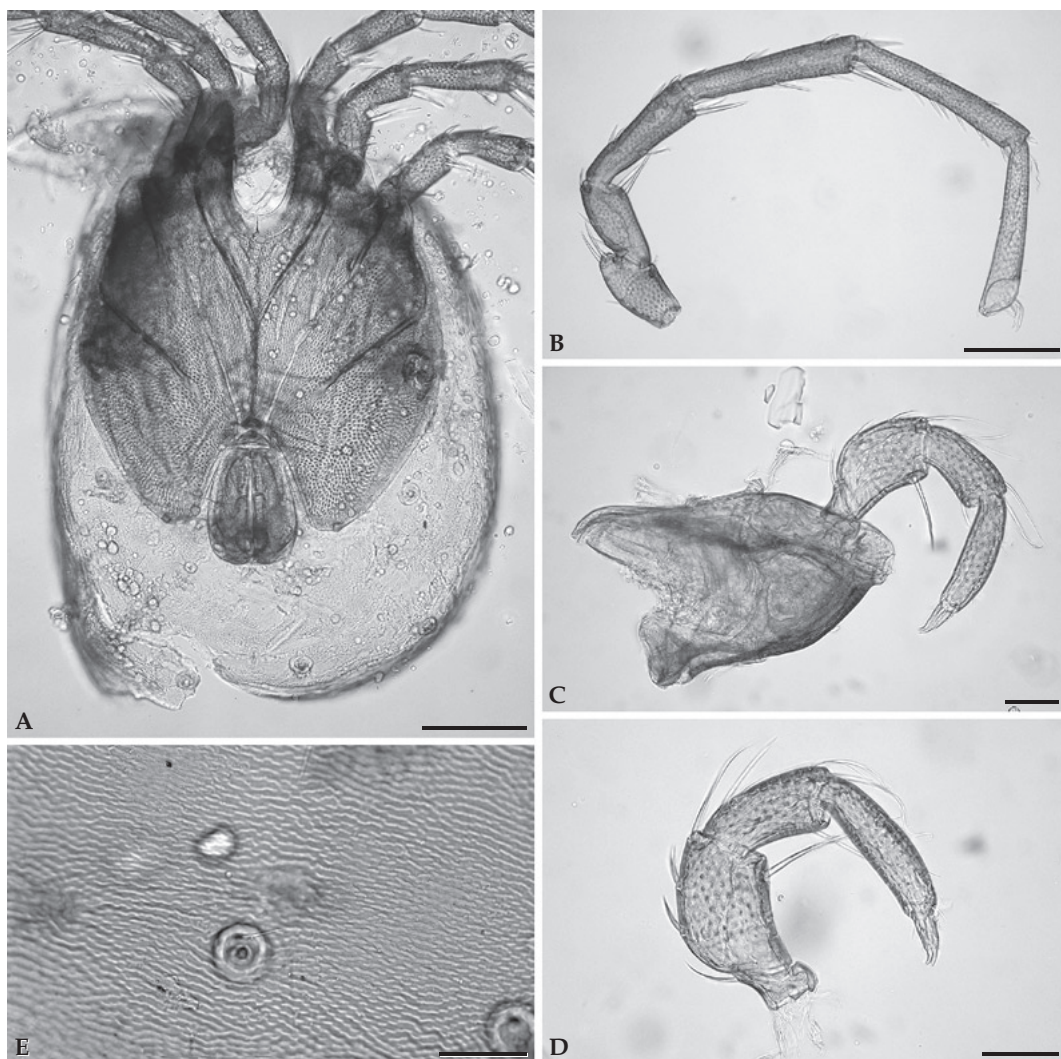


Fig. 6. A–D. *Lebertia sparsicapillata*, male. **A.** Ventral view of idiosoma. **B.** IV-leg. **C.** Gnathosoma (palp in lateral view). **D.** Medial view of palp. **E.** *Lebertia sefvei*, male. Dorsal integument with glandularium. Scale bars A, B = 100 µm, C–E = 50 µm.

Lebertia

Lebertia fimbriata

Figs 4, 5

Male. Idiosoma – not illustrated in Gerecke (2009), see Fig. 4A. IV-leg-5, -6 – slightly more robust, IV-leg-6 distally higher (Figs 4B,C). Palp – P4 more club-shaped; medio-distal seta (arrow in Fig. 4D) rather medial than ventral (Figs 4D,E).

Female. Coxal field – more slender (Fig. 5A). IV-leg – similar to male (Figs 5B,C). Palp – not illustrated in Gerecke (2009); medio-distal seta P4 more ventral than in male (Figs 5D,E).

Lebertia sparsicapillata

Figs 6A–D

Male. Idiosoma – not illustrated in Gerecke (2009), see Fig. 6A. IV-leg – segment 5 with more, slightly longer ventral setae; segment 6 straight (dorsally

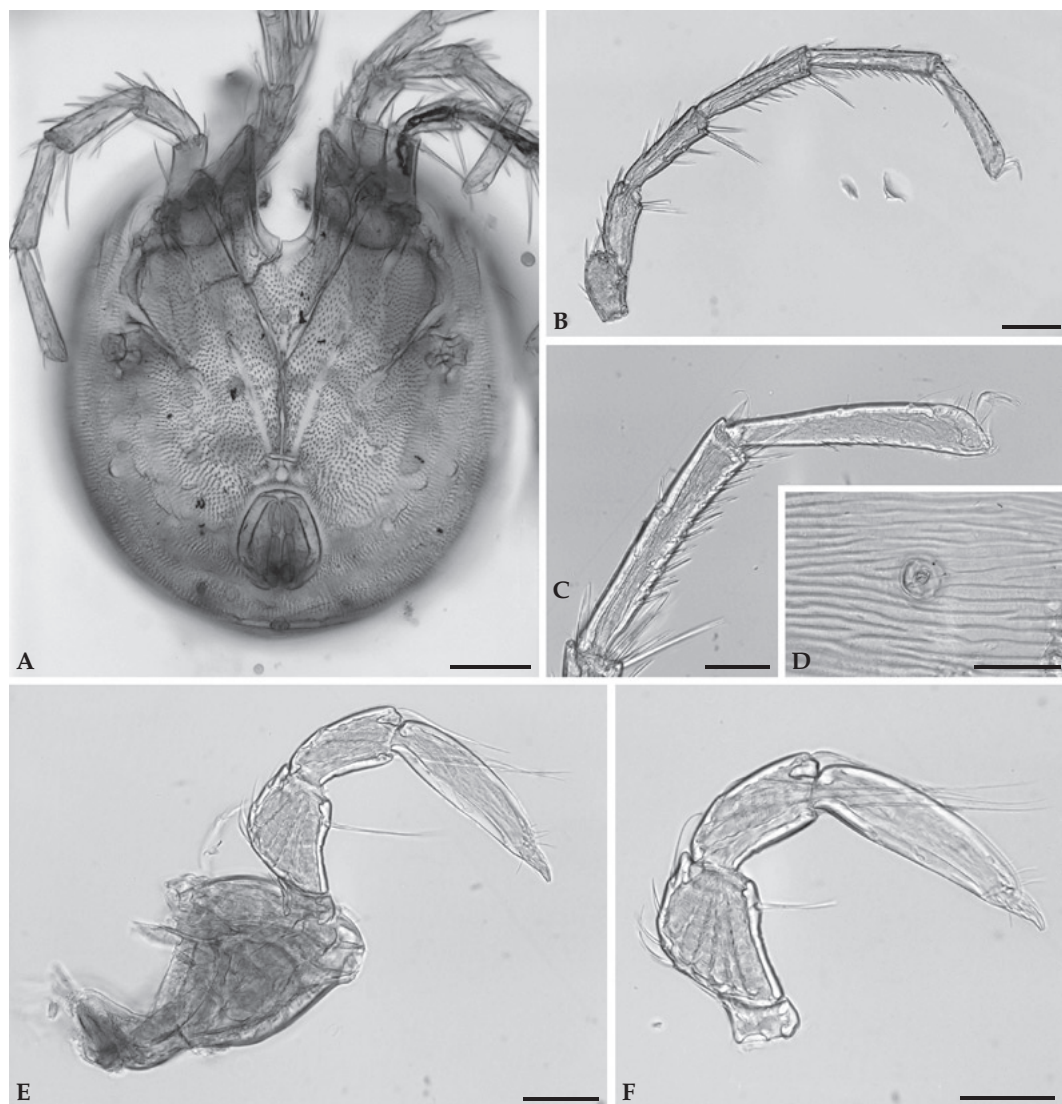


Fig. 7. *Lebertia helocrenica*, male. **A.** Ventral view of idiosoma. **B.** IV-leg. **C.** Detail of IV-leg-5/-6. **D.** Dorsal integument with glandularium. **E.** Gnathosoma (palp in lateral view). **F.** Medial view of palp. Scale bars A,B=100 μ m, C-F=50 μ m.

not curved) with longer claws (Fig. 6B). Palp – more slender (Fig. 6C,D).

Genital skeleton – unfortunately the genital skeleton (as in *L. fimbriata*) in the mounted specimen is not clearly visible due to attached tissue. However, it looks like the brachia distalia of *L. sparsicapillata* laterally are more smoothly curved, whereas in *L. fimbriata* they are sharply bent (Figs 11 A,B).

The differentiation of *Lebertia fimbriata* and *L. sparsicapillata* remains problematic (Gerecke 2009,

Di Sabatino et al. 2010). Therefore detailed measurement data of the specimens treated in the present study and attributed to these two species are given, together with the ‘diagnostic standards’ of the two species (Gerecke 2009) (Tab. 3).

The few specimens (one male of *L. sparsicapillata* and two males, one female of *L. fimbriata*) were found in the same spring complex. However, according to the diagnostic measurement data (Gerecke 2009) they have to be attributed to different species (see Tab. 3).

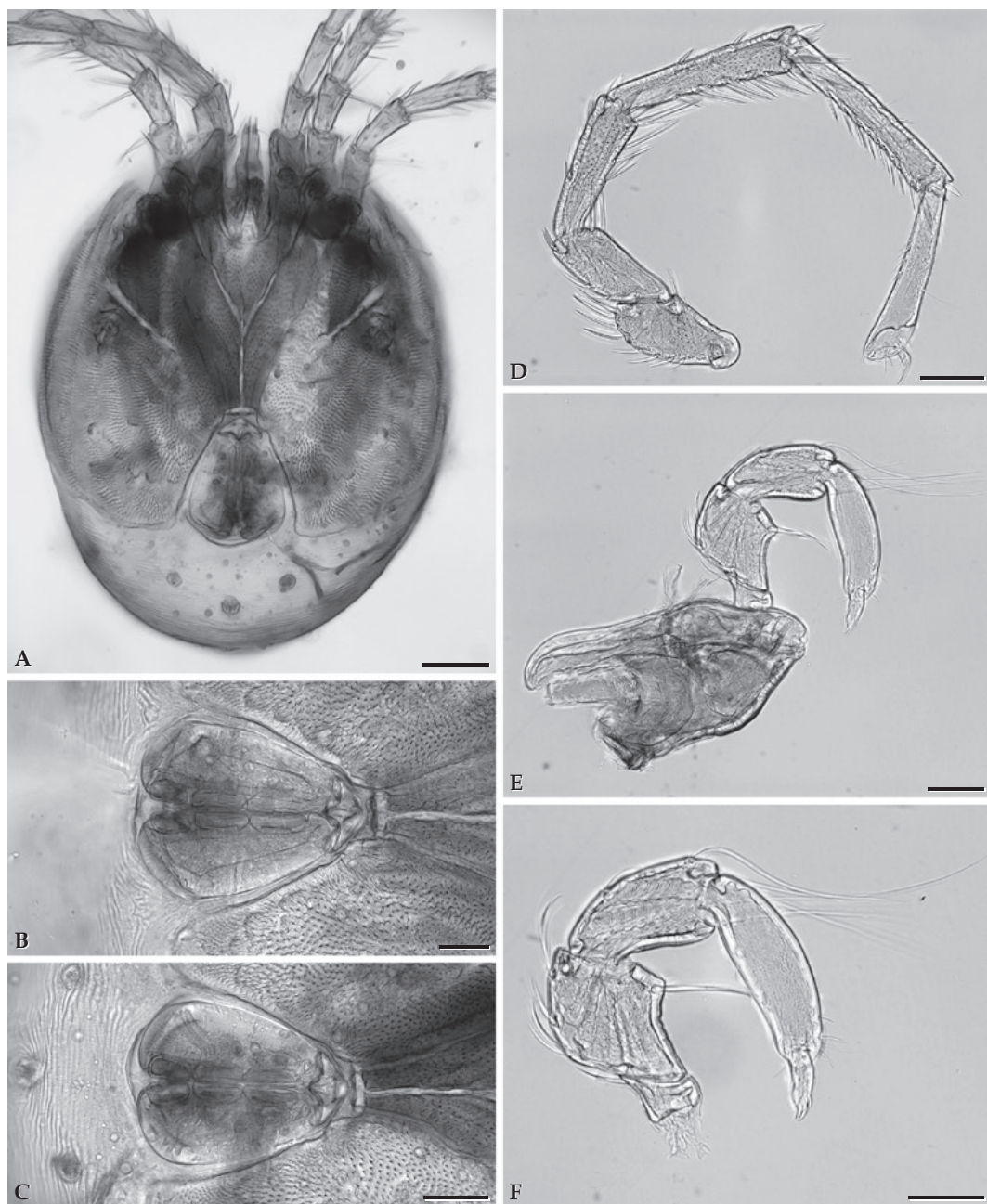


Fig. 8. *Lebertia helocrenica*, female. **A.** Ventral view of idiosoma. **B, C.** Genital field. **D.** IV-leg. **E.** Gnathosoma (palp in medial view). **F.** Lateral view of palp. Scale bars A=100 μ m, B-F=50 μ m.



Fig. 9. *Lebertia semireticulata*, male. **A.** Ventral view of idiosoma. **B.** IV-leg. **C.** Dorsal integument with glandularium. **D.** Gnathosoma with both palps. Scale bar A,B=100 μ m, C,D=50 μ m.

Lebertia helocrenica

Figs 7, 8

So far just known from three sites in Southern Germany and Northern Italy.

Male. Apart from P4 being slightly more slender than illustrated for the type specimen (Figs 7E,F), the males of the present study (Figs 7A–D) correspond well with the species description (Gerecke 2009).

Female. Coxal field – posterior margin of Cx-IV narrower (Fig. 8A). Genital field – larger than in species description (Gerecke 2009), clearly projecting beyond posterior margin of coxal field (Figs 8A–C). IV-leg – terminal segments (4, 5, 6) more slender than in male; IV-leg-6 with four ventral setae (Fig. 8D). Palp – P3 and P4 distally higher than in male (Figs 8E,F).

Lebertia sefvei

Fig. 6E

The integument structure of *L. sefvei* is described as “lined” by Gerecke (2009) whereas Lundblad (1956) described the integument with very short to longer listels [“z.T. sehr kurzen, z.T. längeren Leistchen” (Lundblad 1956, p. 119)]. The specimens of the present study correspond with the description given by Lundblad (1956) with short listels on the integument (Fig. 6E).

Lebertia semireticulata

Figs 9, 10

As the species is described as “obviously rare” by Gerecke (2009) as well as Di Sabatino et al. (2010), some morphological details of the population found in the present study are given.

Male. Idiosoma – the coxal field and especially genital field is more slender; a broad postgenital sclerite is visible (Fig. 9A). The reticulation of the dorsal integument is clearly recognisable (Fig. 9C).



Fig. 10. *Lebertia semireticulata*, female. **A.** Ventral view of idiosoma. **B.** Detail of Cx-I. **C.** IV-leg. **D.** Gnathosoma (palp in lateral view). **E.** Medial view of palp. Scale bars A = 100 μ m, B–E = 50 μ m.

Table 3. Measurements of *Lebertia fimbriata* and *L. sparsicapillata* from Grünwald (present study) and published by Gerecke (2009). The ‘diagnostic standards’ for the separation of *L. fimbriata* and *L. sparsicapillata* given by Gerecke (2009) are in bold. Measurements are in µm.

	<i>sparsicapillata</i> (present study)		<i>fimbriata</i> (present study)		<i>sparsicapillata</i> (Gerecke 2009)		<i>fimbriata</i> (Gerecke 2009)	
	male	male	male	female	male	female	male	female
Id L / W	960 / 732	852 / 624	882 / 594	864 / 546	850-1300 / 650-1000	850-1200 / 600-900	600-950	650-1000
Cx-I / -II mL	168 / 174	146 / 155	143 / 179	153 / 162	150-200 / 150-190	170-200 / 130-190	122-158 / 131-180	135-178 / 135-207
Cx-II post W	33	35	33	33	35-60	35-50		
IV-leg-4 L / H	282 / 56	212 / 47	230 / 52	230 / 56	230-300 / 50-60	290-300 / 60		
IV-leg-5 L / H	296 / 47	240 / 42	259 / 45	259 / 47	250-310 / 40-50	300-320 / 50-55	≤250	<270
IV-leg-6 L / H	273 / 52	226 / 52	249 / 47	244 / 54	245-290 / 48-55	285-310 / 50-55		
genital flap L	188	150	160	179	160-190	190-210	95-176	135-185
Ac-1 L	70	54	60	63	60-70	60-70	29-63	43-67
Ac-2 L	56	48	54	58	50-60	50-60	34-49	38-58
Ac-3 L	40	33	34	36	30-45	30-45	18-38	27-40
P1 L / H	35 / 38	30 / 42	33 / 45	31 / 45	30-35 / 33-38	30-40 / 38-43		
P2 L / H	96 / 61	80 / 52	83 / 57	89 / 58	83-103 / 55-68	100-110 / 65-73		
P3 L / H	92 / 42	72 / 36	82 / 40	82 / 40	78-98 / 38-48	88-108 / 45-55		
P4 L / H	108 / 29	86 / 28	95 / 31	95 / 30	98-118 / 28-35	113-123 / 35-39	71-100	76-106
P5 L / H	40 / 14	36 / 12	36 / 15	36 / 15	35-38 / 14-18	35-38 / 14-18		
palp total L	371	304	329	333	325-388	365-413		

Table 4. Measurements of *Atractides fonticolus* from Grünwald (present study) and published by Gerecke (2003). Data from the present study given as min-max, outlier in square brackets. Measurements are in µm.

	<i>fonticolus</i>				
	present study			Gerecke 2003	
	males (n=7)	females (n=6)	nymph (n=1)	male, paralectotype	female, paralectotype
Id L	564-720	558-666 [1020]	576	660	950
glandularia W	12-24	9-24	16	28	35
Cx field L	312-336	324-396	204	350	383
Cx-I / -II mL	102-114	90-114	60	105	112
I-leg-5 dL / H	186-207 / 49-52	209-275 / 52-59	108 / 38	192 / 52	225 / 54
ratio L/H	3.73-4.00	3.92-4.88	2.88	3.69	4.17
S1 L / S2 L	68-75 / 56-61	78-82 / 61-66	56 / 56	73 / 55	79 / 60
ratio / interspace	1.15-1.29 / 9-12	1.18-1.35 / 12-14	1.00 / 2	1.33 / 12	1.32 / 13
I-leg-6 L / H	108-118 / 21-24	120-132 / 21-24	80 / 16	111 / 22	140 / 23
ratio L/H	4.60-5.56	5.40-5.89	4.86	5.04	6.09
ratio I-leg-5/-6 L	0.68-1.80	1.73-2.21	1.35	1.73	1.61
genital field L / W	99-122 / 122-146	136-169 [212] / 157-190 [226]	63 / 85	121 / 134	198 / 216
ac L	28-45	35-47	24	35-41	35-41
Chel bs L / claw L		188 / 75			172 / 78
ratio bs/claw L		2.50			2.21
P2 L	71-75	73-82	38	70	82
P3 L / H	60-68 / 45-47	78-89 / 38-42	42 / 24	63 / 46	87 / 43
ratio L/H	1.27-1.47	2.00-2.31	1.80	1.37	2.02
P4 L	87-96	103-113	66	91	109

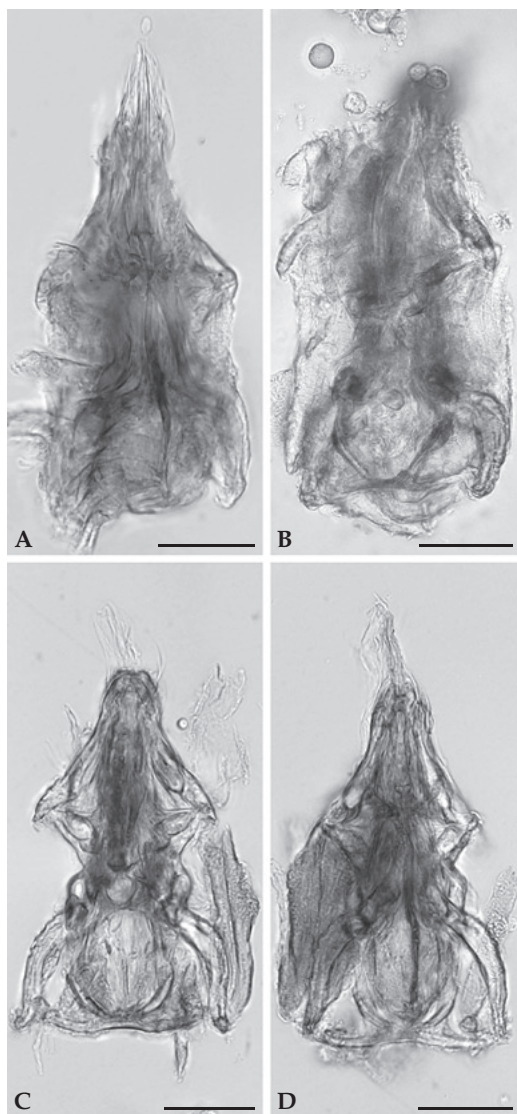


Fig. 11. Genital skeletons of *Lebertia*. **A.** Genital skeleton of *L. fimbriata* in anterior view. **B.** Genital skeleton of *L. sparsicapillata* in anterior view. **C,D.** Genital skeleton of *L. helocrenica* in anterior view. Scale bars = 50 µm.

IV-leg, palps – the morphology of the appendages corresponds with the illustrations given in Gerecke (2009) (Figs 9 B,D).

Female. Coxal field – Cx-I is apically bearing two tips (Fig. 10B); Cx-II is medially much longer (Cx-I/II mL 0.97 (1.1–1.3) and distally narrower (Fig. 10A); the posterior margin of Cx-IV is more pointed and closely approaches the genital field (Fig. 10A), in

general the coxal field is more similar to the coxal field of the male (Figs 9A, 10A). Genital field – posterior wider, with a broad postgenital sclerite; V1 more laterally (Fig. 10A). Palp – P4 more slender (Figs 10D,E).

Atractides

Atractides fonticolus

Figs 12, 13

Male. Coxal field – not illustrated in Gerecke (2003) (Fig. 12A). Genital field – whereas in most specimens the anterior margin is straight to convex (as in the description given by Gerecke 2003), in one specimen from Grünwald there is a central protrusion (Fig. 12A). I-leg-5 – the distal sheath is large (in all specimens) (Fig. 12B); in one specimen (at one leg) the seta S1 is doubled (Fig. 12C). Palp – the ventral setae at P4 are more distanced from each other (with a variation between left and right palp), the large medial seta is inserted slightly proximal of the distal ventral seta (Figs 12 D,E).

Table 5. Measurements of *Atractides latipes* from Grünwald (present study) and published by Gerecke (2003). Measurements given in µm.

	<i>latipes</i>	
	present study male (n=1)	Gerecke 2003 male
Id L	528	400
glandularia W	28	45
Cx field L	276	200
Cx-I / -II mL	108	72
I-leg-5 dL / H	157 / 52	118 / 51
ratio L/H	3.05	2.31
S1 L / S2 L	89 / 61	70 / 48
ratio / interspace	1.46 / 28	1.46 / 21
I-leg-6 L / H	122 / 14	94 / 12
ratio L/H	8.67	7.83
ratio I-leg-5/-6 L	1.29	1.26
genital field L / W	89 / 96	72 / 81
ac L	26	17–22
Chel bs L / claw L	113 / 45	
ratio bs / claw L	2.53	
P2 L	56	43
P3 L / H	52 / 31	45 / 28
ratio L/H	1.69	1.61
P4 L	80	62



Fig. 12. *Atractides fonticolus*, male. **A.** Ventral view of idiosoma. **B.** I-leg. **C.** Detail of I-leg-5/-6. **D.** Lateral view of palp. **E.** Medial view of palp. Scale bars A, B=100 μ m, C-E=50 μ m.

Female. Genital field – genital plates more elongated, pre- and postgenital sklerites more slender, posterior acetabula larger (Fig. 13A). I-leg-5/-6 – both segments slightly more slender than in male (Fig. 13B). Palp – ventral protrusion of P2 larger; P4 more slender, the ventral setae at P4 more distanced from each other (with a variation between left and right palp), the large medial seta is inserted slightly proximal of the distal ventral seta (Figs 13C,D).

Atractides latipes

Fig. 14

Male. Idiosoma and coxal field – more slender (Fig. 14A); larger than the specimen described by Gerecke (2003) (Id L 528 (400), Cx field L 276 (200)), similar to a specimen described from interstitial samples in Luxembourg (Gerecke 2003). Genital field – more setae, acetabula larger, posterior indentation less deep (Fig. 14B). I-leg-5/-6 – both segments more slender, sword-like setae less pointed (Fig. 14C).



Fig. 13. *Atractides fonticolus*, female. **A.** Genital field. **B.** Detail of I-leg-5/-6. **C.** Lateral view of palp. **D.** Medial view of palp. Scale bars = 50 µm.

Palps – more slender, dorso-distal setae at P2 larger, ventral margin of P4 protruding at insertion of proximal seta (Figs 14D,E).

Atractides pennatus
Fig. 15

Male. Idiosoma – not illustrated in Gerecke (2003) (Fig. 15A). Genital field – posterior indentation narrower, anterior acetabula larger, caudally extended, nearly touching posterior acetabula (Fig. 15B). I-leg – segments 3, 4, 5 with large terminal sheaths (Fig. 15C). Palp – with characteristic setation at P4 (Figs 15D,E).

Atractides polyporus
Fig. 16

Male. Dorsal shield – not illustrated in Gerecke (2003) (Fig. 16B). Genital field – less and larger acetabula; excretory pore sclerite and Vgl-1+2 not fused to genital plate (Figs 16A,D). Palp – P4 with large medial seta broad, lance-shaped (Fig. 16C, arrow).

Atractides protendens
Figs 17, 18

Male. Idiosoma – secondary sclerotization of coxal field (mainly posterior margin of Cx-IV) and genital field very variable (Figs 17A–C). Genital field – acetabula larger than in the holotype (Gerecke 2003), anterior part of the genital field much wider (Fig. 17C). Palp – large dorsal setae at P2 and P3 pennate (Figs 17E,F).

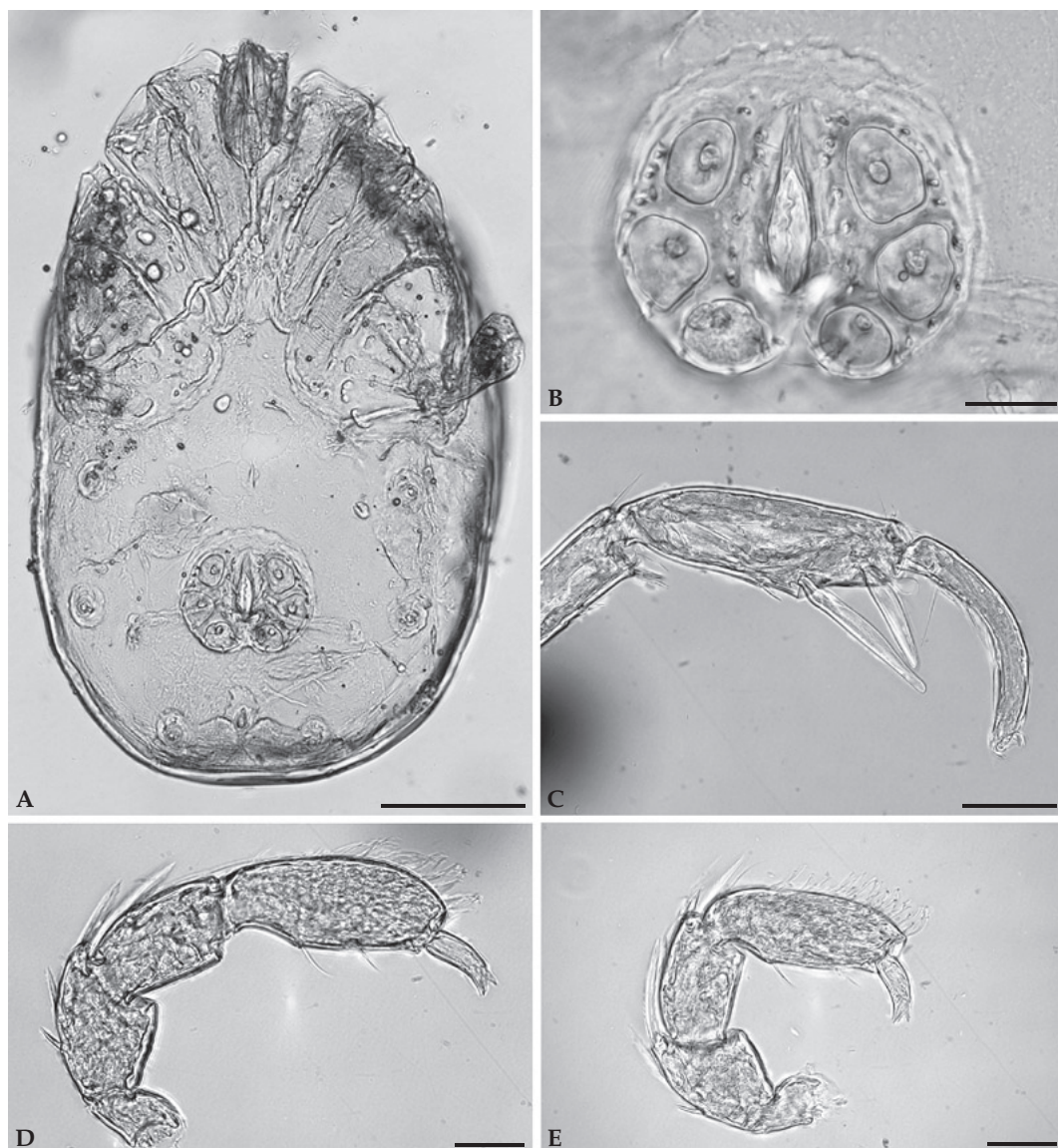


Fig. 14. *Atractides latipes*, male. **A.** Ventral view of idiosoma. **B.** Genital field. **C.** Detail of I-leg-5/-6. **D.** Lateral view of palp. **E.** Medial view of palp. Scale bars A,B,D,E=100 μ m, C=50 μ m.

Female. Genital field – acetabula larger than illustrated in Gerecke (2003) (Fig. 18A). I-leg-5/-6 – similar to male; not illustrated in Gerecke (2003) (Figs 17D, 18B). Palp – ventral margin of P4 proximal with strong sharp bend (Fig. 18C).

Atractides remotus

Figs 19, 20

The species is very similar to several other *Atractides* species (*fonticolus*, *pennatus*, *panniculatus*, *fissus*), and few figures are published. Therefore, we are adding some information on the morphological variety of the species.

Table 6. Measurements of *Atractides pennatus* from Grünwald (present study) and published by Gerecke (2003). Data from the present study given as min-max, outlier in square brackets. Measurements are in μm .

	<i>pennatus</i>			
	present study		Gerecke 2003	
	males (n=5)	female (n=1)	male, holotype	female
Id L	696–894		830	820
glandularia W	16–24	16	29	24
Cx field L	390–414		392	460
Cx-I / -II mL	114–144		108	99
I-leg-5 dL / H	244–261 / 61–68	322 / 78	234 / 61	302 / 67
ratio L/H	3.82–4.00	4.15	3.84	4.51
S1 L / S2 L	99–106 / 82–92	122 / 108	98 / 78	105 / 92
ratio / interspace	1.08–1.26 / 16–19	1.13 / 21	1.26 / 16	1.14 / 20
I-leg-6 L / H	[106] 146–150 / 24–26	188 / 31	145 / 25	176 / 25
ratio L/H	[4.50] 5.73–6.20	6.15	5.8	7.04
ratio I-leg-5/-6 L	1.67–1.73 [2.40]	1.71	1.61	1.72
genital field L / W	150–179 / 179–204		152 / 175	184 / 211
ac L	63–73	92	48–64	63–81
Chel bs L / claw L			288 (total L)	336 (total L)
ratio bs/claw L			2.56	2.00
P2 L	82–89	108	83	105
P3 L / H	78–85 / 52–59	122 / 59	83 / 54	123 / 54
ratio L/H	1.43–1.57	2.08	1.54	2.28
P4 L	108–118	141	112	134

Table 7. Measurements of *Atractides protendens* from Grünwald (present study) and published by Gerecke (2003). Data from the present study given as min-max, outlier in square brackets. Measurements given in μm .

	<i>protendens</i>			
	present study		Gerecke 2003	
	males (n=9)	females (n=3)	male, holotype	female, paratype
Id L	540–678	606–768	515	870
glandularia W	24–33	28–33	24	36
Cx field L	312–384	348–432	270	392
Cx-I / -II mL	126–162	156–174	108	126
I-leg-5 dL / H	139–153 [174] / 38–45	193–209 / 52	130 / 34	170 / 45
ratio L/H	3.33–3.94	3.73–4.05	3.82	3.78
S1 L / S2 L	54–66 / 56–66	75–80 / 75–78	53 / 54	74 / 71
ratio / interspace	0.92–1.08 / 7 [9]	1.00–1.03 / 9–12	0.98 / 8	1.04 / 12
I-leg-6 L / H	120–127 [146] / 26–31	160–181 / 33	112 / 23	150 / 29
ratio L/H	4.15–4.91	4.86–5.50	4.87	5.17
ratio I-leg-5/-6 L	1.15–1.23	1.16–1.21	1.16	1.13
genital field L / W	99–146 [160] / 125–169	150–188 / 150–207	117 / 117	193 / 207
ac L	28–49	42–47	32–38	47–55
Chel bs L / claw L	132–165 / 61–68	216–226 / 89–94		
ratio bs/claw L	2.15–2.59	2.30–2.53		
P2 L	61–71		54	76
P3 L / H	66–75 [82] / 35–40 [47]	99–106 / 47–49	65 / 34	85 / 43
ratio L/H	1.75–2.00	2.00–2.14	1.91	1.98
P4 L	94–106 [125]		92	94

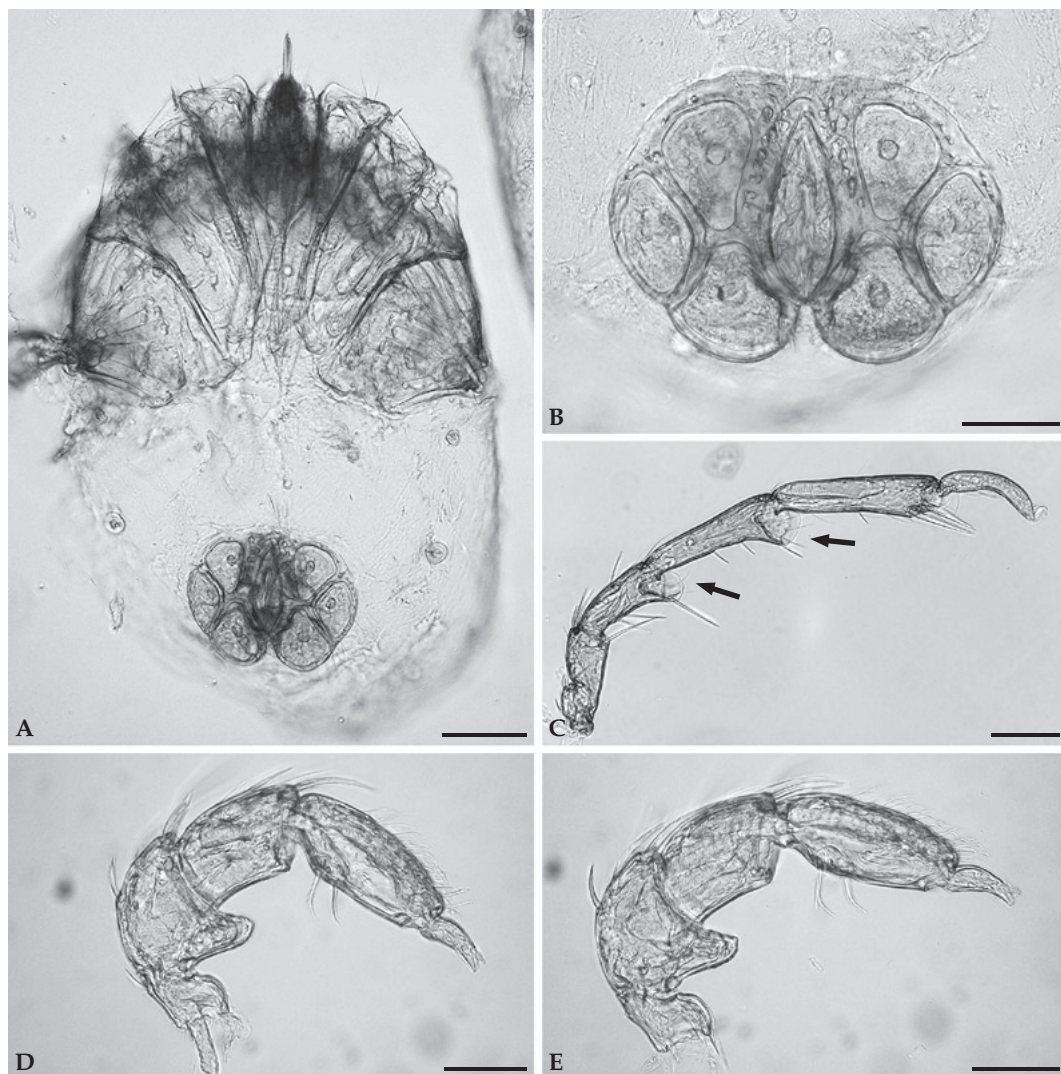


Fig. 15. *Atractides pennatus*, male. **A.** Ventral view of idiosoma. **B.** Genital field. **C.** I-leg. **D.** Lateral view of palp. **E.** Medial view of palp. Scale bars A, C = 100 µm, B, D, E = 50 µm.

Male. Idiosoma – coxal field not fused (Fig. 19A). Genital field – anterior flatter, rather broad oval than round (Figs 19A, B). I-leg – leg segments 4, 5, 6 more slender, distal sheath at segment 5 larger (Fig. 19C). Slender distal leg segments are characteristic differentiation from the similar species mentioned above. Palp – P3 and P4 more slender, large medial seta at P4 (Fig. 19D, arrow) further distal.

Female. Idiosoma – not illustrated in Gerecke (2003) (Fig. 20A). Genital field – anterior and central acetabula larger (Figs 20A, B). I-leg – as in male, leg segments 4, 5, 6 even more slender, distal sheath at segment 5 larger (Figs 19C, 20C). Palp – P4 more slender; distance of ventral setae at P4 variable, in some specimens clearly larger (Figs 20D–F).

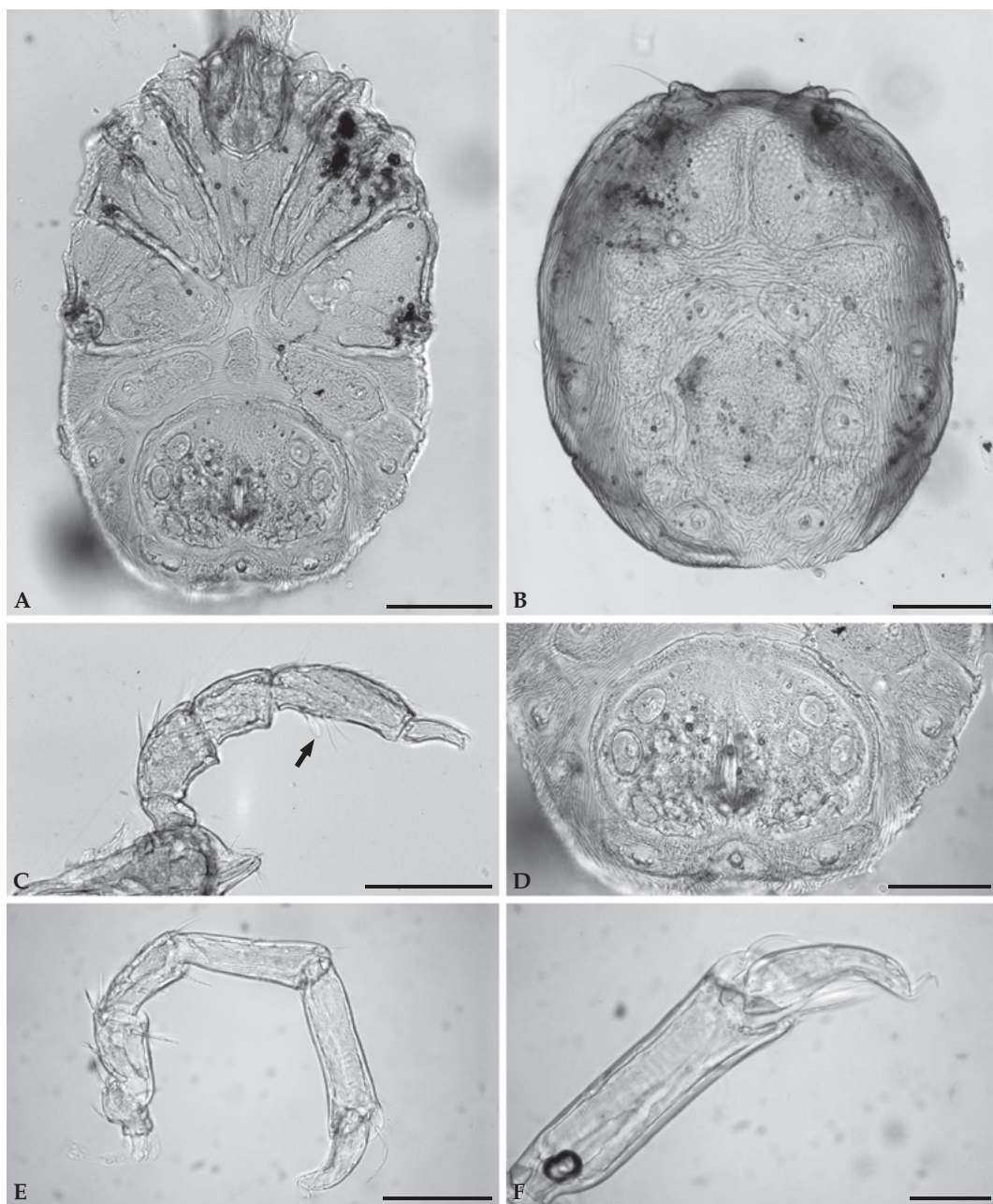


Fig. 16. *Atractides polyporus*, male. **A.** Ventral view of idiosoma. **B.** Dorsal view of idiosoma. **C.** Lateral view of palp. **D.** Genital field. **E.** I-leg. **F.** Detail of I-leg-5/-6. Scale bars A,B,D=100 μ m, C,E,F=50 μ m.

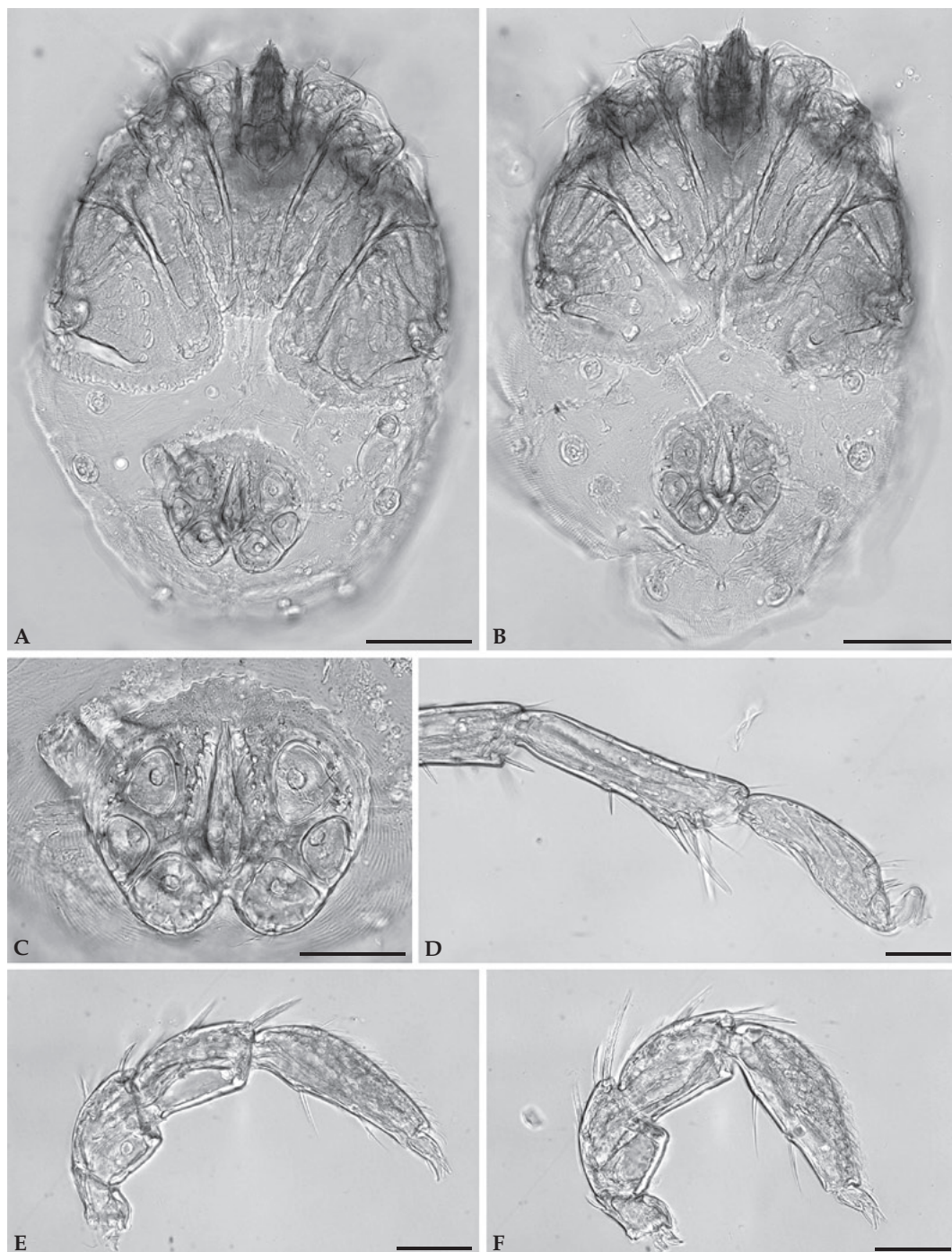


Fig. 17. *Atractides protendens*, male. **A,B.** Ventral view of idiosoma. **C.** Genital field. **D.** Detail of I-leg-5/-6. **E.** Lateral view of palp. **F.** Medial view of palp. Scale bars A,B=100 µm, C-F=50 µm.



Fig. 18. *Atractides protendens*, female. **A.** Ventral view of idiosoma. **B.** Detail of I-leg-5/-6. **C.** Medial view of palp. Scale bars A=100 μ m, B,C=50 μ m.

Atractides rivalis
Figs 21, 22

Until now just four locations of this species are published (two from Austria, one from Poland, one from Turkey), hence also very few information is available on the morphology and variability of the species. The specimens from Grünwald – representing the first record of the species in Germany – are therefore documented in detail. Especially the differences with the most similar species *A. panniculatus* are discussed and documented in Table 7 (see below).

Male. Coxal field – posterior margin of Cx4 is characteristically curved (more rounded in *A. panniculatus*) (Fig. 21A, arrow). Genital field – rounded (wider than long in the illustration given in Gerecke (2003)); posterior acetabula larger (one misshapen specimen with just five acetabula (Fig. 21E)); posterior indentation deeper (Figs 21 A,D,E). I-leg – leg segments 5 and 6 more compact than in *A. panniculatus*; distal sheath at segment 5 larger than illustrated by Gerecke (2003) (Figs 21 B,C). Palp – ventro-distal margin at P2 more rounded, P4 more compact than in *A. panniculatus* (Figs 21 F,G).

Female. Coxal field – similar shape as in male (Fig. 22A). Genital field – genital plates more slender and more apically pointed than in *A. panniculatus*, posterior acetabula larger, however, not surpassing posterior margin of plates (Figs 22 A,C-E). I-leg – leg segments 5 and 6 more slender than in males, however, still more compact than in *A. panniculatus* (Fig. 22B). Palp – P4 more slender than in male, ventral setae clearly more distant from distal margin of segment than in *A. panniculatus* (even more than in holotype (Gerecke 2003)) (Figs 22 F,G).

The genital skeleton (or ejaculatory complex) of *Atractides* “follows the groundplan as found in *Hygrobates*” (Gerecke 2003). However, as there are small differences in the morphology of this organ, the genital skeleton could as well provide additional taxonomic information in this species-rich group. The genital skeleton of *A. panniculatus* (Gerecke 2003 Figs 6G,H) has the brachia distalia more compact and oriented more oblique than in *A. rivalis* (Fig. 23G) – with brachia distalia proximally straight, distally slender and strongly curved in the latter. The genital skeleton therefore provides additional data to separate these two similar species (see above).



Fig. 19. *Atractides remotus*, male. A. Ventral view of idiosoma. B. Genital field. C. I-leg. D. Medial view of palp. Scale bars A, B=100 μ m, C, D=50 μ m.

Table 8. Measurements of *Atractides remotus* from Grünwald (present study) and published by Gerecke (2003). Data from the present study given as min-max, outlier in square brackets. Measurements are in μm .

	<i>remotus</i>			
	present study		Gerecke 2003	
	males (n = 2)	female (n = 4)	male, original description	female, original description
Id L	498–516	[696] 804–840	540	810
glandularia W	16–19	19–28	small	small
Cx field L	294–318	[336] 390–408	342	393
Cx-I / -II mL	114–132	[120] 148–168	135	
I-leg-5 dL / H	169–172 / 45–47	230–247 / 54–61	172 / 46	240 / 67
ratio L / H	3.65–3.79	4.00–4.26	3.74	3.75
S1 L / S2 L	92 / 75	110–125 / 94–103	95 / 80	115 / 102
ratio / interspace	1.22 / 24	1.15–1.25 / 42–47	1.19 / 22	1.13
I-leg-6 L / H	125–132 / 16	132–176 / 14–16	133 / 17	180
ratio L / H	7.57–8.00	9.33–10.71	7.88	
ratio I-leg-5 / -6 L	1.30–1.36	1.36–1.77	1.29	1.33
genital field L / W	89–108 / 110–127	155–165 / 169–193	90 / 127	135 / 162
ac L	33–35	42–52	35–40	
Chel bs L / claw L		174 / 66–68		176 (total L)
ratio bs / claw L		2.55–2.64		3.14
P2 L		75–80	73	73
P3 L / H	61–66 / 38–42	94–108 / 38–40	98 / 36	98 / 36
ratio L / H	1.56–1.63	2.41–2.71	2.72	2.72
P4 L		113–118	119	119

Table 9. Measurements of *Atractides rivalis* from Grünwald (present study) and data on *A. rivalis* and *A. panniculatus* published by Gerecke (2003). Data from the present study given as min-max, outlier in square brackets. Measurements are in μm .

	<i>rivalis</i>				<i>panniculatus</i>	
	present study		Gerecke 2003		Gerecke 2003, paralectotypes	
	males (n = 14)	females (n = 8)	male lectotype	female holotype	male	female
Id L	558–678	750–996	620	860	630	930
glandularia W	19–24	[14] 24–33	25	25	33	30
Cx field L	306–348	396–444	324	405	360	437
Cx-I / -II mL	114–138	114–138	117	168	135	139
I-leg-5 dL / H	157–172 / 47–52	214–226 / 63–68	172 / 52	211 / 63	228 / 65	265 / 72
ratio L / H	3.09–3.55	3.21–3.43	3.31	3.35	3.51	3.68
S1 L	85–96	103–122	90	110	121	130
S2 L	68–78	87–94	72	78	90	108
S1 / S2	1.15–1.37	1.16–1.41	1.25	1.41	1.34	1.20
interspace	14–24	28–33	22	25	32	38
I-leg-6 L / H	122–134 / 17–21	160–172 / 19–21	128 / 20	156 / 20	165 / 20	198 / 20
ratio L / H	6.22–7.13	7.78–9.13	6.4	7.8	8.25	9.9
ratio I-leg-5 / -6 L	1.19–1.37	1.26–1.41	1.34	1.35	1.38	1.34
genital field L / W	118–141 [183] / 133–169	169–242 / 207–282	139 / 180	234 / 270	183 / 196	229 / 261
P2 L	61–66	78–87	65	80	74	90
P3 L / H	63–71 / 42–47	96–103 / 42–52	67 / 45	92 / 46	81 / 47	108 / 47
ratio L / H	1.35–1.67	1.91–2.33	1.49	2.00	1.72	2.30
P4 L	101–108	121–127 [169]	105	119	116	134

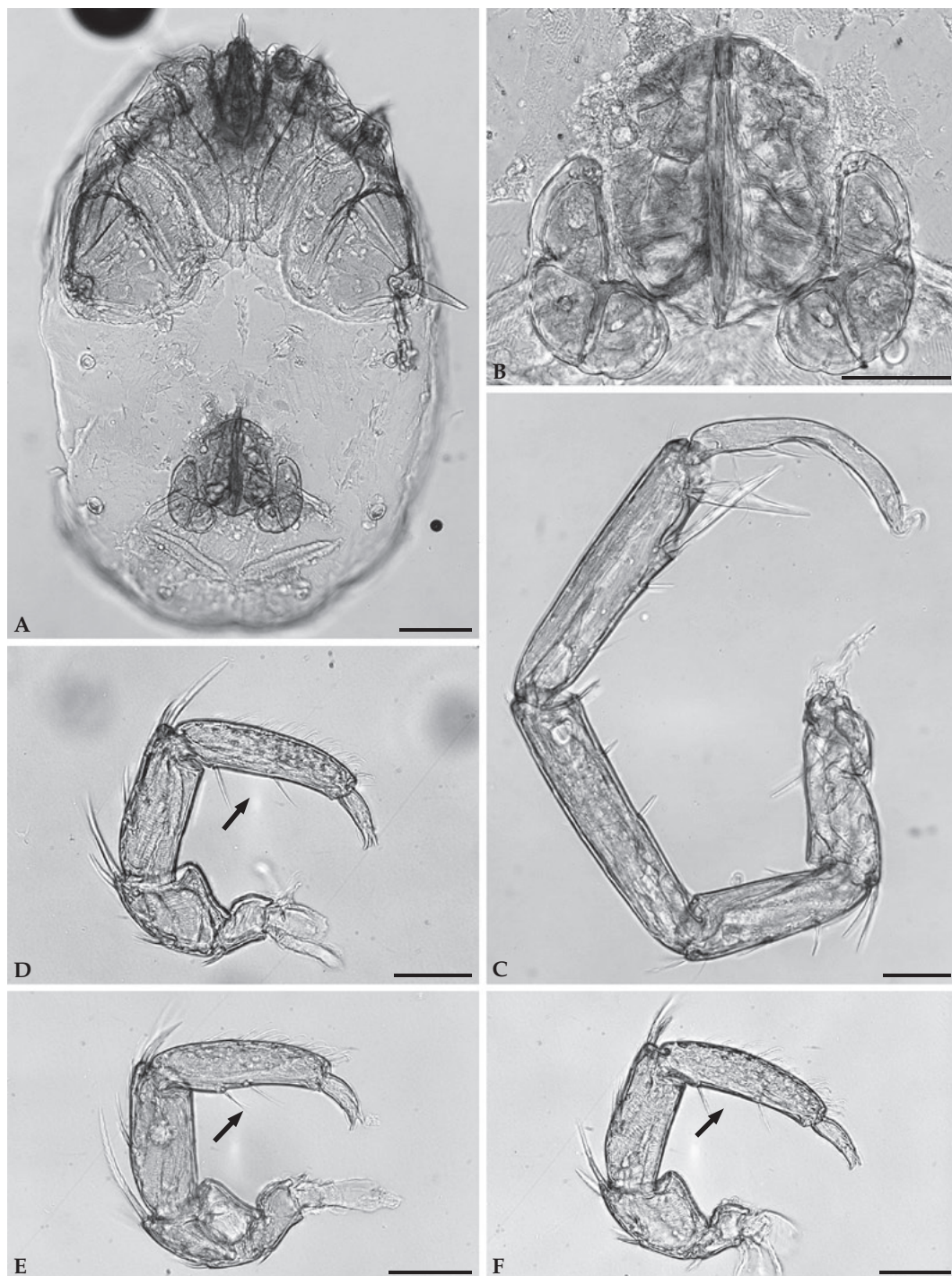


Fig. 20. *Atractides remotus*, female. **A.** Ventral view of idiosoma. **B.** Genital field. **C.** I-leg. **D.** Lateral view of palp. **E, F.** Medial view of palp. Scale bars A = 100 μm, B-F = 50 μm.



Fig. 21. *Atractides rivalis*, male. **A.** Ventral view of idiosoma. **B.** I-leg-4-6. **C.** Detail of I-leg-5/-6. **D,E.** Genital field. **F.** Lateral view of palp. **G.** Medial view of palp. Scale bars A=200 μ m, B,C,F,G=50 μ m, D,E=100 μ m.

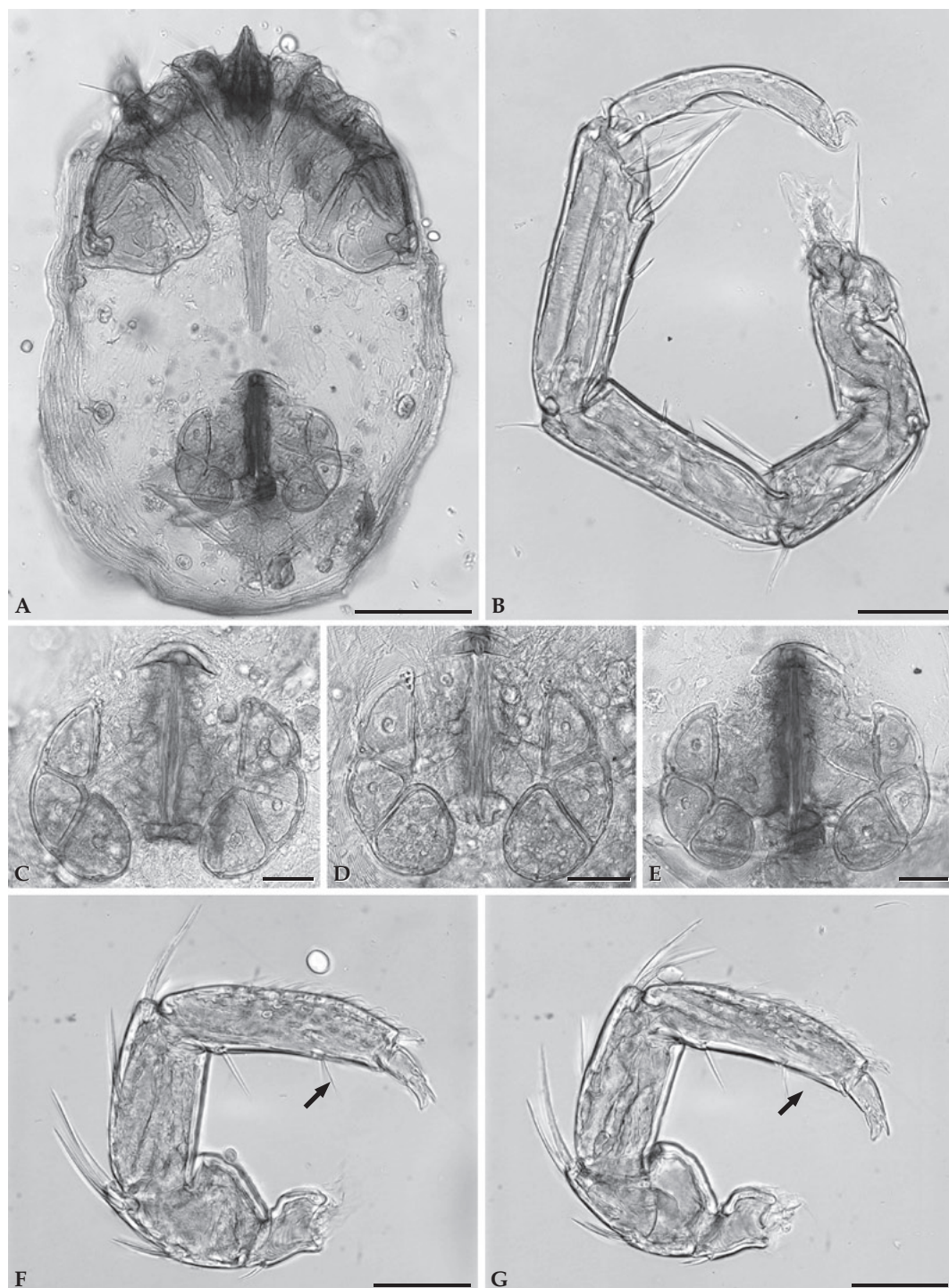


Fig. 22. *Atractides rivalis*, female. **A.** Ventral view of idiosoma. **B.** I-leg. **C,D,E.** Genital field. **F.** Lateral view of palp. **G.** Medial view of palp. Scale bars A = 200 μ m, B–G = 50 μ m.

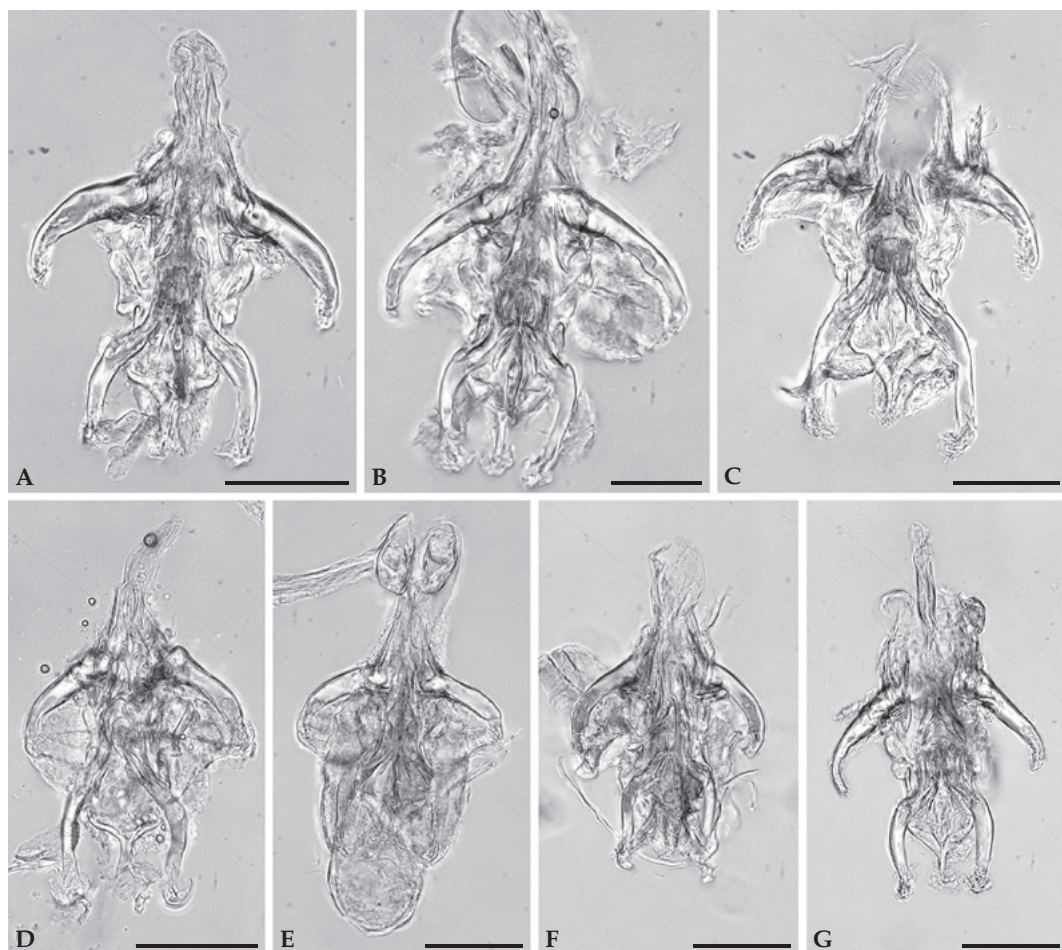


Fig. 23. Genital skeletons of *Atractides*. **A.** Genital skeleton of *A. fonticolus* in anterior view. **B.** Genital skeleton of *A. latipes* in anterior view. **C.** Genital skeleton of *A. pennatus* in anterior view. **D.** Genital skeleton of *A. polyporus* in anterior view. **E.** Genital skeleton of *A. protendens* in anterior view. **F.** Genital skeleton of *A. remotus* in anterior view. **G.** Genital skeleton of *A. rivalis* in anterior view. Scale bars A,C-G=50 μ m, B=100 μ m.

Woolastookia

Woolastookia rotundifrons

Fig. 24

The species – originally described as *Axonopsis rotundifrons* by K. Viets 1922 – is the only representative of this holarctic genus in Central Europe. A second species of this genus, *W. minuta* Pešić, Gerecke & Smit 2010 is known from the Balkan peninsula (Pešić et al. 2010). A single female of *W. rotundifrons* has been found in the present study (Figs 24A–E).

The water mite assemblages

Diversity (Table 10)

The by far highest diversity (20 species, Hs 2.36) was found in the rheohelocrene spring 2a. Similar species numbers (6–10) were found in the other springs, whereas the diversity is rather variable, according to the different evenness and species numbers (Mühlenberg 1989).

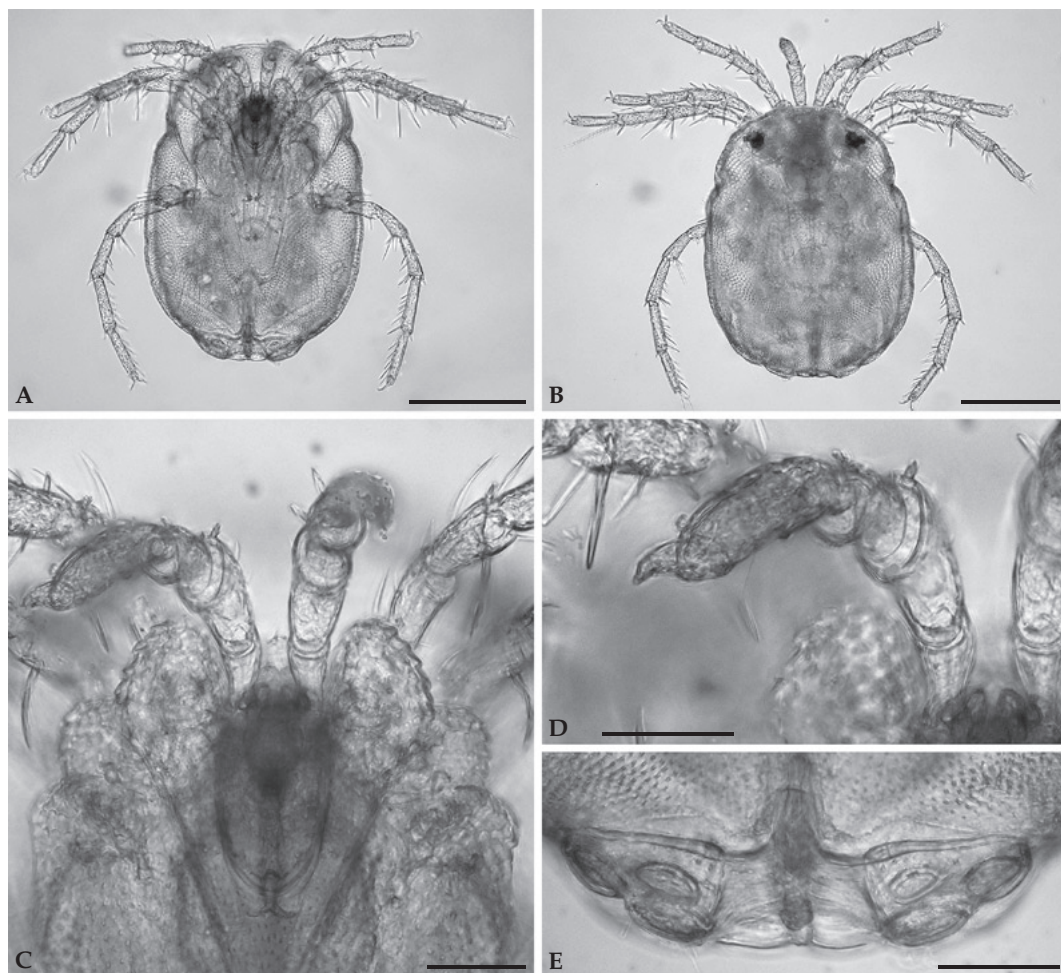


Fig. 24. *Woolastokia rotundifrons*, female, unmounted. A. Ventral view of idiosoma. B. Dorsal view of idiosoma. C. Ventral view of gnathosoma and anterior coxae. D. Medio-ventral view of palp. E. Genital field. Scale bars A, B=200 μ m, C-E=50 μ m.

Dominance structure (Table 11)

The following 11 species – out of 32 species in total – have been the eudominant or dominant principal species in the 6 springs carrying a considerable water mite population: *Sperchon resupinus* in 2 rheocrenes, 1 rheopsammocrene and the outflow of a rheo-/rheopsammocrene spring complex; *Sperchon longissimus* and *Sperchon thienemanni* each in 2 rheocrene respectively rheopsammocrene springs; *Atractides protendens* and *Lebertia helocrenica* each in 1 rheopsammocrene and the outflow of a rheo-/rheopsammocrene spring complex; *Lebertia sefvei*, *Lebertia stigmatifera*, *Ljanja bipapillata*, *Protzia squamosa*, *Atractides rivalis*, *Chelomideopsis annemiae* each in one of the rheocrenes and rheopsammocrenes.

In the helocrene investigated just 7 specimens representing 6 species were found; therefore all species – *Ljanja bipapillata*, *Sperchon thienemanni*, *Sperchon longissimus*, *Atractides protendens*, *Lebertia stigmatifera*, *Hygrobatas norvegicus* – are classified as dominant.

In the spring brook one species – *Sperchon thienemanni* – could be classified as eudominant, two species as dominant: *Atractides fonticolus*, *Ljanja bipapillata*.

Similarity (Table 12)

The by far highest similarity (33.96) can be observed between the water mite assemblages of the spring complex 2a and its outflow 2b (Tab. 12). All other sample sites show very low similarities with these

two sites. This observation corresponds well with the fact, that 2a-b are farther distant from the other sites, which are closer together.

The brook is directly fed by springs 1, 4 and 5, which is reflected in high similarities of its water mite assemblages with these springs.

Less clear is the comparably high similarity of the rheocene 5 with 1b (a slow flowing rheohelocene) as well as with spring 4 (a complex of strong flowing rheo- and rheopsammocene springs with relatively high discharge).

In general the similarities of the water mite assemblages of the investigated sites do not necessarily reflect morphological similarities of the springs (see also next chapter).

Spring typology

In regard of the low number of sampling sites and the high individuality of springs, we prefer to describe the water mite assemblages of several individual springs, rather than generalized, “typical” coenoses of certain spring types. However, for better comparison, the following descriptions and discussions of individual water mite assemblages are sorted according to morphological spring types.

Helocrenes (two springs in spring complex 1a)

Helocrenic springs are not well represented in the present study. Six species – all just singletons, except of *Ljanina bipapillata* in two specimens – were found in the two very small helocrenic areas (1a) within a larger spring complex (1). Three of the six species (*Ljanina bipapillata*, *Lebertia stigmatifera*, *Hygrobatas norvegicus*) have been categorized as typical species of montane forest helocrenes in the Black Forest (Southwest Germany) by Schwoerbel (1959). None of the species named as typical species of helocrenic springs in the Berchtesgaden National Park (Gerecke et al. 1998) were found in the present study.

Just a single *Hygrobatas norvegicus* was exclusively

found in helocrenic springs, all other species were also found in other spring types as well as a spring brook.

Rheohelocrenes (spring complexes 1b, 2)

The water mite assemblages of the two rheohelocrenic springs (1b and 2a) differ a lot (similarity 2.29) (see Tab. 12). Diversity is very high at site 2a (20 species, Hs 2.36) and rather low at site 1b (8 species, Hs 1.71) (see Tab. 10). Both rheohelocrenic spring complexes just have one species in common which was not found in any other spring – *Chelomideopsis annemiae* (Tab. 2). Maybe differences in discharge (lower in 1b than in 2a), or structural variations are responsible for the clear faunistic differences between these – on the first view – very similar springs.

The water mite assemblage of spring complex 1b is characterised by *Sperchon longissimus* and *Lebertia stigmatifera*, with *Lebertia sefvei* and *Ljanina bipapillata* as other dominant species (Tab. 11).

The biocoenosis of spring complex 2a+b is the species richest of the present study, with 20 species in the eucrenal and 11 in the outflow (Tab. 2). Within these just one species (*Sperchon setiger*) is restricted to the outflow – besides spring 2b just found in the spring brook. Nine species found as singletons, as well as *Lebertia fimbriata* restricted to spring 2, are limited to the eucrenal (2a). The water mite assemblage of the rheohelocrenic spring complex 2 is characterised by the dominant species *Atractides protendens*, *Chelomideopsis annemiae* and *Lebertia helocrenica* (Tab. 11), with the latter restricted to spring complex 2a+b. The fourth dominant species, *Sperchon resupinus*, was also found in high abundance in spring complex 3 and 5.

Rheocrenes/Rheopsammocrenes (spring complexes 3, 4, 5)

The substrata of these three spring complexes were dominated by sand and gravel, and therefore show intermediate characteristics of rheocrenic and rheopsammocrenic springs.

Table 10. Diversity (Hs – Shannon-index; Mühlenberg 1989) of the different sample sites at Grünwald. Abbreviations see Table 1.

	1a	1b	2a	2b	3	4	5	brook
Habitat type	hc rich in fine & coarse organic matter	rhc sand, gravel, organic matter	rhc rich in organic matter	out-flow (8-10 m below spring mouth)	rc rich in gravel	rc & rpc rich in sand & gravel	rc gravel (calcareous tuff)	spring brook riffle (gravel & vegetation tuff)
specimens	7	78	109	53	60	109	118	285
species no.	6	8	20	11	7	9	10	13
diversity (Hs)	1.75	1.71	2.36	2.18	1.12	1.68	2.10	2.06

In total 13 water mite species were found in these three spring complexes, with five species found in all springs, three species found in two springs and five species restricted to one of them (Tab. 2). The highest similarity can be observed between sites 4 and 5 (Tab. 12).

Table 11. Organization of the ‘principal’ and ‘accompanying’ species according to the logarithmic classification of Engelmann (1978) (Mühlenberg 1989).

1a, helocrene		
principal species		
dominant	<i>Ljanja bipapillata</i>	28.6 %
dominant	<i>Sperchon thienemanni</i>	14.3 %
dominant	<i>Sperchon longissimus</i>	14.3 %
dominant	<i>Atractides protendens</i>	14.3 %
dominant	<i>Lebertia stigmatifera</i>	14.3 %
dominant	<i>Hygrobatas norvegicus</i>	14.3 %
1b, rheohelocrene		
principal species		
eudominant	<i>Sperchon longissimus</i>	37.2 %
dominant	<i>Lebertia stigmatifera</i>	24.4 %
dominant	<i>Ljanja bipapillata</i>	10.3 %
dominant	<i>Lebertia sefvei</i>	10.3 %
subdominant	<i>Atractides rivalis</i>	7.7 %
subdominant	<i>Sperchon resupinus</i>	5.1 %
subdominant	<i>Sperchon thienemanni</i>	3.8 %
accompanying species		
recedent	<i>Chelomideopsis annemiae</i>	1.3 %
2a + b, rheohelocrene		
principal species		
dominant	<i>Atractides protendens</i>	24.1 %
dominant	<i>Lebertia helocrenica</i>	16.1 %
dominant	<i>Sperchon resupinus</i>	15.4 %
dominant	<i>Chelomideopsis annemiae</i>	8.0 %
subdominant	<i>Atractides remotus</i>	6.2 %
subdominant	<i>Ljanja bipapillata</i>	4.3 %
subdominant	<i>Aturus scaber</i>	3.7 %
accompanying species		
recedent	<i>Sperchon longissimus</i>	4.3 %
recedent	<i>Atractides polyporus</i>	3.1 %
recedent	<i>Lebertia maglioi</i>	4.3 %
recedent	<i>Lebertia fimbriata</i>	1.9 %
subrecedent	<i>Partnunia steinmanni</i>	0.62 %
subrecedent	<i>Lebertia semireticulata</i>	0.62 %
subrecedent	<i>Paniscus torrenticolus</i>	0.62 %
subrecedent	<i>Lebertia holsatica</i>	0.62 %
subrecedent	<i>Lebertia salebrosa</i>	0.62 %
subrecedent	<i>Lebertia sparsicapillata</i>	0.62 %
subrecedent	<i>Torrenticola anomala</i>	0.62 %
subrecedent	<i>Atractides latipes</i>	0.62 %
subrecedent	<i>Woolastookia rotundifrons</i>	0.62 %

3, rheocrene		
principal species		
eudominant	<i>Sperchon resupinus</i>	56.7 %
dominant	<i>Sperchon longissimus</i>	31.7 %
subdominant	<i>Atractides protendens</i>	3.3 %
subdominant	<i>Sperchon squamosus</i>	3.3 %
accompanying species		
recedent	<i>Atractides rivalis</i>	1.7 %
recedent	<i>Protzia squamosa</i>	1.7 %
recedent	<i>Ljanja bipapillata</i>	1.7 %
4, rheo-, rheopsammocrene		
principal species		
eudominant	<i>Atractides rivalis</i>	45.9 %
dominant	<i>Sperchon thienemanni</i>	16.5 %
subdominant	<i>Atractides fonticolus</i>	9.2 %
subdominant	<i>Partnunia steinmanni</i>	9.2 %
subdominant	<i>Protzia squamosa</i>	7.3 %
subdominant	<i>Sperchon longissimus</i>	4.6 %
subdominant	<i>Lebertia semireticulata</i>	4.6 %
accompanying species		
recedent	<i>Atractides protendens</i>	1.8 %
subrecedent	<i>Sperchon resupinus</i>	0.92 %
5, rheocrene		
principal species		
dominant	<i>Protzia squamosa</i>	30.5 %
dominant	<i>Sperchon resupinus</i>	11.9 %
dominant	<i>Sperchon thienemanni</i>	10.2 %
subdominant	<i>Sperchon longissimus</i>	9.3 %
subdominant	<i>Atractides protendens</i>	9.3 %
subdominant	<i>Lebertia stigmatifera</i>	6.8 %
subdominant	<i>Ljanja bipapillata</i>	6.8 %
subdominant	<i>Atractides polyporus</i>	6.8 %
subdominant	<i>Atractides rivalis</i>	5.9 %
accompanying species		
recedent	<i>Atractides fonticolus</i>	2.5 %
brook, riffle + vegetation		
principal species		
eudominant	<i>Sperchon thienemanni</i>	36.1 %
dominant	<i>Atractides fonticolus</i>	14.0 %
dominant	<i>Ljanja bipapillata</i>	10.2 %
subdominant	<i>Atractides pennatus</i>	9.1 %
subdominant	<i>Lebertia stigmatifera</i>	8.1 %
subdominant	<i>Sperchon setiger</i>	6.0 %
subdominant	<i>Sperchon longissimus</i>	4.9 %
subdominant	<i>Atractides rivalis</i>	3.5 %
accompanying species		
recedent	<i>Atractides protendens</i>	2.5 %
recedent	<i>Lebertia glabra</i>	2.1 %
recedent	<i>Sperchon resupinus</i>	1.4 %
recedent	<i>Hygrobatas fluviatilis</i>	1.4 %
subrecedent	<i>Lebertia sefvei</i>	0.70 %

The water mite assemblage of spring complex 3 is characterised by *Sperchon resupinus* (Tab. 11), a species found in most sites of the present study, reaching here a strong dominance of 57 %. The second dominant species, *Sperchon longissimus*, was also present in all other sample sites, with the highest abundance in the rheohelocrenic spring 1b. These two *Sperchon*-species represent nearly 90 % of all water mites at this site (Tab. 11).

The water mite assemblage of spring complex 4 is characterised by the eudominant (46 %) *Atractides rivalis* (with $\frac{2}{3}$ of all individuals of this study found in this spring complex) and the subdominant (9 %) *Partnunia steinmanni* (90 % of all specimens found here) (Tab. 11).

The water mite assemblage of spring complex 5 is characterised by the dominant (31 %) *Protzia squamosa* (Tab. 11), present only in the three rheocrenic springs; 80 % of all specimens of the present study were found here (Tab. 2).

Spring brook

The strong total discharge of spring complexes 1 and 4 results in a relatively large brook already few meters below the springs, flowing into the river Isar just after about 50 meters.

The samples from riffle zones (with gravel as dominant substratum) and emersed vegetation merely differ in their water mite assemblages and are therefore treated together.

The water mite assemblage of the spring brook is characterised by the dominant species *Sperchon thienemanni*, *Atractides fonticolus* (75 % of all specimens of the present study are found here) and *Ljanina bipapillata* (64 % of all specimens found here) as well as *Sperchon setiger* (77 %) (Tab. 11). The subdominant

and recedent species *Atractides pennatus*, *Lebertia glabra* and *Hygrobatas fluviatilis* are restricted to the spring brook (Tab. 2).

Discussion

Most springs are small and show a very distinct mosaic structure of different substrata and microhabitats with different ecological conditions. This habitat diversity is a main reason for the high diversity of crenic invertebrate communities. Therefore springs can be considered as “hotspots” of aquatic biodiversity (Bottazzi et al. 2011). At the same time, due to the high individuality of springs, these habitats host specialized and often endemic or rare and threatened taxa (Bottazzi et al. 2011). Simultaneously the problem arises of obtaining representative or even quantitative samples from spring habitats without destroying or at least severely damaging the habitat (Goldschmidt 1994, Gerecke et al. 2011). Even though springs are “typical stable habitats”, inter-habitat variation is often high (Van Everdingen 1991). However, relatively small, “integrating patchy samples taken throughout the eucrenal is a robust method for documenting assemblages of non-emerging invertebrates” (Franz et al. 2006, in Gerecke et al. 2011). Due to the “generally steady population densities of meiofauna, single samples are suitable for documenting species diversity” (Gerecke et al. 2011).

In consideration of these aspects, the results of the present study – even though based upon few samples – provide an important contribution to the knowledge and understanding of prealpine springs and the description of typical water mite assemblages of these habitats.

The comparison with previous studies on water mites in springs from Central Europe and the Alps (Tab. 13) shows similarities as well the specific characteristic of the investigated spring complexes in Grünwald. The data emphasize both the speciality as well as the general importance of the documented water mite assemblages for the understanding of prealpine springs.

The first study on water mites from Bavarian springs (K. Viets 1939) lists only three species (out of 15 in total) also found in the present study. Half of the species treated in the present study (16 species) have already been found in a large faunistic survey on water mites from Northern Bavaria by K. O. Viets (1955) (Tab. 13).

The springs treated in the present study can be compared with several spring types discussed in the study of Schwoerbel (1959) on springs and streams in the southern Black Forest. Montane forest helocrenes,

Table 12. Similarity. Wainstein-index (Kw) of the species communities (values between 0 and 100, based upon common species and similar relative abundances) (Mühlenberg 1989). Spring complex 1a is excluded due to the very low specimen number.

		1b	2a	2b	3	4	5
		rhc	rhc	out-flow	rc	rc+rpc	rc
1b	rhc						
2a	rhc	2.29					
2b	out-flow	4.73	33.96				
3	rc	14.59	3.74	8.98			
4	rc+rpc	5.24	1.53	1.30	4.85		
5	rc	18.89	6.26	11.34	16.10	19.44	
brook	br, r+v	16.31	1.54	4.87	4.04	13.70	20.56

Table 13. Results of the present study compared with previous findings in ‘older’ studies on water mites in Bavaria and systematic spring studies in Central Europe: K. Viets 1939* – study on water mites from the Bavarian alps at Garmisch-Partenkirchen; K.O. Viets 1955* – studies on water mites from Northern Bavaria; Black Forest – studies on water mites from Southern Black Forest (Germany) (Schwoerbel 1959)*; LUX – studies on springs and interstitial in Luxembourg* (Gerecke et al. 2005); BR – studies in the springs of the carbonate fen complex Benninger Ried (Bavaria, Germany) (König et al. 2006, Gerecke 2006)*; NPB – studies on springs in the National Park Berchtesgaden (Nationalparkverwaltung Berchtesgaden 2006); CRENO DAT – studies on springs in the southern Alps (Trento, Italy) at 600–2500 m a.s.l. (Gerecke et al. 2009). For each species and study the number of sample sites and number of specimens is given.

	Grünwald (present study)	K. Viets 1939	K.O. Viets 1955**	Black Forest	LUX	BR	NPB	CRENO- DAT
species in total	32	15	55	55	38	32	62	55
sample sites / specimens	8 / 819	10 / 133	63 / ?	125 / 6096	41 / ~650	5 / 635	46 / 7293	104 / 2164
<i>Paniscus torrenticolus</i>	1 / 1		2 / ?	3 / 12				
<i>Partnunia steinmanni</i>	2 / 11	5 / 15		7 / 60	4 / 11		31 / 531	26 / 208
<i>Protzia squamosa</i>	3 / 45		7 / ?				1 / 2	2 / 4
<i>Lebertia fimbriata</i>	1 / 3				1 / 2			1 / 1
<i>Lebertia glabra</i>	1 / 6				8 / 34			
<i>Lebertia helocrenica</i>	2 / 26							
<i>Lebertia holsatica</i>	1 / 1		1 / ?	3 / 6	6 / 17	1 / 3		6 / 12
<i>Lebertia maglioi</i>	2 / 7							
<i>Lebertia salebrosa</i>	1 / 1		1 / ?					
<i>Lebertia sefvei</i>	2 / 10		2 / ?	20 / 105	2 / 4	3 / 5	14 / 76	5 / 7
<i>Lebertia semireticulata</i>	2 / 6			1 / 1				
<i>Lebertia sparsicapillata</i>	1 / 1							
<i>Lebertia stigmatifera</i>	4 / 51		21 / ?	45 / 585	1 / 1	1 / 3	3 / 14	1 / 2
<i>Sperchon longissimus</i>	8 / 86		4 / ?	1 / 1	1 / 3			
<i>Sperchon resupinus</i>	7 / 82		3 / ?	13 / 44			3 / 19	3 / 4
<i>Sperchon setiger</i>	2 / 22		1 / ?					
<i>Sperchon squamosus</i>	1 / 2		4 / ?	41 / 196	10 / 48	1 / 1	3 / 7	8 / 35
<i>Sperchon thienemanni</i>	5 / 137	10 / 76	19 / ?	46 / 859	16 / 147		40 / 359	18 / 60
<i>Torrenticola anomala</i>	1 / 1							
<i>Hygrobates fluviatilis</i>	1 / 4					3 / 116	1 / 41	2 / 14
<i>Hygrobates norvegicus</i>	1 / 1	3 / 4	7 / ?	69 / 824	4 / 12	3 / 45	24 / 739	12 / 107
<i>Atractides fonticolus</i>	3 / 53		6 / ?		9 / 51			
<i>Atractides latipes</i>	1 / 1							
<i>Atractides pennatus</i>	1 / 26		3 / ?		2 / 41	1 / 29		
<i>Atractides polyporus</i>	3 / 13							3 / 4
<i>Atractides protendens</i>	7 / 62		2 / ?			4 / 13	5 / 9	1 / 1
<i>Atractides remotus</i>	2 / 10							
<i>Atractides rivalis</i>	5 / 74							
<i>Woolastookia rotundifrons</i>	1 / 1							
<i>Ljanina bipapillata</i>	7 / 55		6 / ?	4 / 24	12 / 39	3 / 14	11 / 24	8 / 11
<i>Aturus scaber</i>	2 / 6							
<i>Chelomideopsis annemiae</i>	3 / 14				1 / 2	1 / 1		

* Only findings of Hydrachnidia from springs are considered.

** In total 48000 specimens have been collected at 316 sample sites, however it is not possible to give the number of specimens per site.

were described by Schwoerbel as *Thyas-Lebertia*-type, with the dominant species *Lebertia cuneifera*, *Hygrobatas norvegicus*, *Lebertia stigmatifera*, *Sperchon squamosus* as well as *Thyas rivalis* in some springs (if present the species is very abundant in this spring type). A character species of this biocoenosis is also *Ljanina bipapillata*. In helocrenes in the present study, six species are found, among these three species mentioned above: *Ljanina bipapillata*, *Hygrobatas norvegicus* and *Lebertia stigmatifera*. Hence half of the species found in helocrenes in the present study are typical species of the *Thyas-Lebertia*-springs sensu Schwoerbel (1959). In montane rheohelocrenes, principal species in both Black Forest (Schwoerbel 1959) and Grünwald (present study) are *Lebertia stigmatifera*, *L. sefvei* and *Sperchon thienemanni*, with further similar species *Partnunia steinmanni* and *Paniscus torrenticolus*. In montane rheocrenes, principal species in both Black Forest and Grünwald are *Lebertia stigmatifera*, *Atractides fonticolus* and *Sperchon thienemanni*, with further similar species *Sperchon resupinus* and *Partnunia steinmanni*.

In a faunistic survey of 41 springs in Luxembourg (Gerecke et al. 2005), 73 water mite species have been found – 19 of these also found in the present study (Tab. 13).

In five springs of the Benninger Ried (König et al. 2006), in total 40 water mite species have been reported, ten of these also found in the present study (Tab. 13). In every spring mouth a different assemblage of water mite species has been found, according to small differences in the substrate structure, temperature regime, vegetation, presence and absence of potential host insects (König et al. 2006). In the Benninger Ried more constant conductivities (between 570 and 620 $\mu\text{S}/\text{cm}$) and warmer temperature (8–16 °C) have been found compared with the results of the present study (see above).

In a 10 year study on spring faunas in the Berchtesgaden National Park, in 46 springs between 600 and 2100 m a.s.l. (mainly 1200–1300 m a.s.l.), 62 water mite species have been found (47 crenobiont or crenophilous, 10 rheophilous and 5 lenitophilous) (Nationalparkverwaltung Berchtesgaden 2006). Five main spring types have been distinguished, but no preferences of certain species for individual spring types have been found. Even though no indicator species for certain spring types could be defined, clear relationships between the morphology of springs and their fauna has been ascertained. In a multivariate analysis of the fauna of 42 springs, spring type and elevation proved to be the main factors explaining differences in the species compositions. According to the authors the species assemblages rather reflect the continuum of fine graded spring types between “typical” rheocrene

and helocrene springs. Furthermore, the authors emphasise the fact that within an individual spring, areas of very different morphology can be found (Nationalparkverwaltung Berchtesgaden 2006). Only for “springs rich in detritus with slow current”, five character species have been found. One of them – *Sperchon resupinus* Viets, 1922 – was also found in several springs of the present study. In total, 11 species from the Berchtesgaden National Park were collected in the present study (Tab. 13). The water mite assemblages of rheocrenes in Berchtesgaden National Park had no species in common with the present study (Gerecke et al. 1998).

The results of the studies in alpine springs in Berchtesgaden National Park clearly differed from the faunistic survey in the Benninger Ried (König et al. 2006). Despite several species in common (Tab. 13), the water mite fauna in Grünwald springs is clearly different from both cited studies, with a generally stronger similarity towards the alpine springs of the Berchtesgaden National Park. The latter is particularly interesting, as the Benninger Ried is in the same hydrogeological region at a similar elevation as the area of the present study.

In a 10 year study (named CRENODAT) on springs in the Trentino Region (Northern Italy) 104 springs between 600 and 2500 m a.s.l. have been investigated, 55 water mite species have been found (Gerecke et al. 2009), 14 species have also been found in the present study (Tab. 13). However, in that study no attempt has been made to work out the water mite assemblages of different springs or spring types (Gerecke et al. 2009).

In a study on spring communities in the Veneto pre-Alps (Italy) eleven springs of different types at 1100–2000 m a.s.l. have been investigated (Crema et al. 1996). In total 32 water mite species are reported, just five of them have also been found in the present study.

On the basis of the generally large diversity of water mites in springs and the insufficient data on prealpine and alpine water mite assemblages, several new findings for the Bavarian fauna could have been expected in the present study (see above). Furthermore, for several rare species an extension of their known distribution pattern and additional information on their ecology are provided.

The description of the water mite assemblages found in different spring types near Grünwald has to be seen as a very first step towards a water mite based spring typology. These data have to be checked and refined with more data from similar spring complexes at similar elevations as well as compared and extended with data from other regions and elevations. Therefore similar studies along a transect through the Bavarian pre-Alps and Alps are planned.

Further samples have already been taken, interesting new data can be expected from these samples and will be published soon.

In view of the beginning effects of climate change in the Alps, it is urgently necessary to define typical water mite assemblages of characteristic spring types as a baseline for all future investigations, especially for monitoring and management of alpine water sheds and water quality.

Acknowledgements

The authors are grateful to Dr. Harry Smit and Dr. Vladimir Pešić for very helpful comments on the manuscript. The study was partially funded by Förderkreis für allgemeine Naturkunde (Biologie) in Jena.

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