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Water mites (Acari: Parasitengona: Hydrachnidia) as inhabitants of groundwater-influenced habitats - considerations following an update of Limnofauna Europaea

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ABSTRACT

Following an update of the survey of the European water mite fauna (Acari: Hydrachnidia) last published by K. Viets (1978), we confirmed the occurrence of 970 species. Based on the evaluation of these data, new bibliography and our own unpublished data, the main habitat preference is determined for each species. The resulting ecological data are analysed with a main focus on species inhabiting groundwater-influenced habitats. No other invertebrate group includes a similarly high share of species with a particular relationship to spring habitats: about one fifth of the European Hydrachnidia has a preference for spring habitats, a total number of 137 (14%) is crenobiontic (living exclusively in springs). The following topics are addressed: (1) the significance of spring habitats for the diversity of water mites − percentage of crenobionts/crenophiles at different geographical latitudes; (2) regional stenotopy − intraspecific differences in habitat preference between populations at different latitudes; (3) communities colonizing springs vs. hyporheic − similarities and differences; (4) evolution of crenobiosis in water mites − potential governing factors; (5) endangered species − direct and indirect anthropogenic threats to the natural diversity of water mites.

1. Introduction

Intense revision work has been done during the past two decades on the taxonomy of European water mites, mostly in the run up to a new standard identification key for central and northern Europe (Gerecke, 2007, 2010, 2016). An updated version of Limnofauna Europaea (based on Viets, 1978, now available on the homepage www.watermite.org; Watermite.org, 2016) shows the resulting change in our knowledge of the water mite diversity of the continent. More than a quarter (28%) of the 1062 species listed in 1978 (this number including also 30 Halacaroidea) have meanwhile been synonymized or excluded being species of uncertain status (*species incertae*). On the other hand, over 200 species (4 of them Halacaroidea) were added − three quarters of these described as new to science, most of the remaining (re)appeared due to taxonomic change. Only 10 species previously known from other continents were recently detected in Europe, but they do not include any obvious example of an invasive species (neozoon). The recent revision work resulted in a net reduction of the European species by 9%, mostly due to the elimination of "taxonomic junk" and the number of valid, well defined species (762 in 1978) has increased by 17% since then.

Obviously, this is a snapshot of a dynamic situation: as discussed below, in southern Europe the presence of many undetected taxa is to be expected, and all over the area, previously hidden species are being detected with new methods of molecular genetics or investigations of larval morphology, or both (Martin et al., 2010; Stålstedt et al., 2013; Tuzovskij, 2014, 2015, 2016; Pešić et al., 2017).

As will be also shown and discussed below, most water mite species have a very distinct preference for well-defined habitat types, and their communities are important indicators for considering the natural conservation status in most types of inland waters (Pieczynski, 1976; Cantonati and Ortler, 1998; Dohet et al., 2008; Goldschmidt, 2016 and bibliography cited there). Notwithstanding these well-documented facts, too little attention is paid to this diverse group of invertebrates in limnological studies. While autecological taxa-catalogues are available for the majority of European freshwater groups (e.g. www.freshwaterecology.info), no such compilation is available for water mites.

The aim of this paper is to present main habitat preference patterns

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of the water mite species presently known in Europe, and to analyse them with a particular focus on habitats at the groundwater/surface water ecotone. Groundwater-influenced habitats are of particular interest for the study of Hydrachnidia as they are found here in high species numbers, and with particular adaptations not known in other invertebrate groups.

2. Material and methods

The information on distribution patterns and habitat preference of the European water mite species provided by Viets (1978) was transferred into a database and updated, taking into account all faunistic data published since then. Taxa recently considered as *(sub)species incertae* were eliminated (but conserved in a separate file for eventual recycling in future), data from junior synonyms were added to the senior species, and new taxa were included.

In a second step, we excluded all representatives of the Halacaroidea (34 species in 2016). As members of this group differ strongly from true freshwater mites in their bionomy (for details, see Bartsch, 2007) and would not fit the considerations made in this paper: (1) Halacarids are much more drought resistant due to their reduced size and ability to survive in smallest spaces; (2) their life cycle includes neither a parasitic stage nor pupa-like resting stages; (3) to different degrees, several halacarid species are bound to groundwater, but no particular relationship to spring habitats is documented.

Furthermore, as this study concentrates on the European fauna, obviously all species in the recent limnofauna list restricted to the extra-European sectors “x” (Maghreb) and “y” (Asia Minor) were excluded.

Our ecological analysis started from the habitat preference interpretation proposed by Viets (1978). This data was critically revised on the basis of new information from recent bibliography (Gerecke, 1991; Gerecke and Di Sabatino, 1996, 1998; Gerecke and Martin, 2006; Gerecke et al., 1998, 2005, 2009, 2011; Goldschmidt and Melzer, 2011; Martin and Rückert, 2011; Fišer et al., 2012; Martin, 2012). In critical cases, unpublished data from ongoing projects were also considered (Luxembourg: Running and standing water studies, Austria: several Alpine and Prealpine areas; Germany: Alps, Black Forest). As a general rule, a principal habitat preference was defined when 90% or more records came from one selected habitat type, a secondary habitat preference when populations of a species were frequently found in a habitat type different from the principal one. For each species, its principal habitat preference (only one entry possible), and, if necessary, its secondary habitat preference (one or several entries possible) was selected from the following possibilities:

(1) Standing waters: lakes, ponds, bogs, swamps.
(2) Running waters: brooks, streams, rivers.
(3) Groundwater influenced: (a) hyporheic, (b) springs.

The following additional habitat categories were also differentiated, but are not considered in the analysis due to their low representation:

Hygropetric habitats: Only a few species are reported most of which are easily attributed to the stream- fauna (e.g., *Hydrovolzia cancellata* or species of the genus *Trichothyas*).

Thermal springs: If a thermobiontic mite fauna of springs had existed (as found in other continents: e.g., *Thermacarus* species in Asia and America (Martin and Schwoerbel, 2002; Heron and Sheffield, 2016), it was probably destroyed during early extension of human civilization. The rhithrobiont *Torrenticola algeriensis* (Di Sabatino et al., 1992) is the only water mite species reported from Europe as thermophilous.

Inland salt waters: Only a few species are reported, most interesting the halophilous *Diplodontus semiperforatus* and the halobiont *Ignacarus salarius*. The latter is known only from hypersaline spring habitats (Moreno-Alcaraz et al., 2008; unpubl.) and included in the analysis as a crenobiont.

Brackish/marine: From estuarine areas, a rather high number of potamobiontic and lenitobiontic species variously resistant to elevated salinity is reported (Bagge and Meriläinen, 1985; Smit and Van der Hammen, 1992 and bibliography cited there). To our present knowledge, this sector of the water mite fauna does not include any species with a connection to ground water.

From these basic ecological data, one of four principal ecological categories was defined for each species: crenobiontic = restricted to spring habitats, rhithrobiontic = restricted to stream and river habitats, hyporheobiontic = restricted to the hyporheic, and lenitobiontic = restricted to stagnant waters.

Whenever evidence existed, one or more out of four secondary categories were added, standing for habitat types which are not the preferred ones, but where the species in question is able to complete its life cycle: crenophilous: also in springs, rhithrophilous: also in streams, hyporheophilous: also in the hyporheic, and lenitophilous: also in standing waters. It must be emphasized that all these categories are used for entire habitats only, not for defining a microhabitat preference. This means that a crenobiont may have a preference for standing or running water reaches within a spring, but it is considered as lenitophilous only if it can exist and reproduce in a non-groundwater influenced standing water body. In the same way, a species is rhithrophilous only if it can exist and reproduce in a stream distant from a spring source.

The set of data gained was used for analysing distribution patterns and area sizes based on the 25 European limnofauna areas predetermined by Illies (1978, see Fig. 1). Obviously, Illies defined these areas influenced by postglacial zoogeography theories predominating around the mid 20th century (e.g. Thienemann, 1950), with the consequence that northern parts are divided into a relatively high number of faunistically poorly differentiated areas. Conversely, in the centre and south, reaches with a rather distinct faunal history are merged into rather heterogeneous complexes (area 3, including the whole Apennine peninsula and the Tyrrhenian islands; area 4, including the whole Alpine belt; area 13, including catchments in France draining to the North Sea, the Atlantic and the Mediterranean). However, notwithstanding these restrictions, “Limnofauna Europaea” allows for a rough distinction into three faunistic belts (northern: areas 14–15, 17–23; central: areas 8–13, 16, 24–25; southern: areas 1–3, 5–7) which are here used for more generalized zoogeographical considerations. A more detailed analysis of the European fauna is at present hampered by the lack of updated faunal catalogues, in particular for the important central parts (Germany, Switzerland).

3. Results and discussion

3.1. Large scale species distribution

At present, 970 species of true water mites (Hydrachnidia) are recorded from Europe (Watermite.org, 2016). The fact that a quarter of these (245) is recorded from one site only, and often known from a single specimen, indicates that our knowledge of the fauna is fragmentary. However, as all belts include rather well studied areas (north: Sweden, British Isles; centre: The Netherlands, Germany, Luxembourg, Poland; south: Italy), the state of documentation can be considered as sufficiently balanced to allow the following considerations.

A total of 291 common species is recorded from all three belts. If we add 9 species at present recorded in the northern and southern belt only, but presumed to be present also in the central part (*Arrenurus nielseni* Muenchberg, 1935, *Arrenurus scourfieldi* Soar, 1913, *Arrenurus suecicus* Lundblad, 1917, *Atractides clavipalpis* Lundblad, 1956, *Atractides digitatus* Lundblad, 1954, *Feltria denticulata* Angelier, 1949, *Lebertia sinuata* K. Viets, 1930, *Mesobates forpicatus* Thor, 1901, *Unionicola parvipora* Lundblad, 1920), roughly 30% of the whole fauna has a wide distribution over many latitudes. The distribution of the remaining species indicates a strong north-south gradient (Fig. 2), with only 4% of the species restricted to the northern belt, 19% to the centre, but 24% to the south, a further 10% are recorded from north and centre, 13% from south and centre. The share of species known from