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MITES (ACARI) OF THE SHORES OF FOREST LAKES AND PONDS IN NORTHERN POLAND, WITH SPECIES ANALYSIS OF ORIBATIDA

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1. INTRODUCTION

Forest lakes and ponds constitute ‘environmental islands’ within forests, with specific vegetation, flora and fauna (Waldon 2002), and are important components of the landscape that contributing considerably to landscape biodiversity. They are particularly important in the Tuchola Forest, in northern Poland, where large areas are overgrown by Scots pine monocultures. They were commonly planted at the end of the XIX century and in the first decades of the XX century, when Scots pine was supported by the wood industry, and was a good source of money for forestry. However, the planting of many stands of Scots pine decreased forest biodiversity and its homeostasis. Moreover, Scots pine monocultures were also poor in species that control pest density, leading to the rapid increase in their populations and in forest damage. To limit pest density, chemicals were used that also killed non-target insects, including the natural enemies of pests, further decreasing the homeostasis of the forest.

To avoid more problems, foresters have started to include other tree and bush species to Scots pine monocultures, thereby increasing the plant diversity of Tuchola Forest. They appreciate also the presence of forest lakes and ponds, which are rich in species, and increase the diversity of the forest landscape.

Forest lakes and ponds cover a small area of Poland and are at particular sites rather small; rarely exceeding an area larger than several hundreds m^2. They are found especially in the northern part of the country, with its young, postglacial landscape. They are concentrated on outwash plains with many depressions formed by melting residual ice blocks that are now partly filled with water or by peat, in Bytów Lakeland, Tuchola Forest, Drawsko Lakeland, Charzykowo Plain, Augustów Primeval Forest, and are relatively rare in moraine landscape. They are also quite abundant in Łęczna-Włodawa Lakeland, but are rare and scattered in other parts of lowlands and highlands (Herbichowa 2004a).

In recent years many forest ponds have disappeared rapidly, as a result of natural successional overgrowth and climatic changes, but mainly due to drainage of large areas for agricultural use (Waldon 2002). The loss of these ponds has inestimable effects on entire ecosystems, decreasing water retention (Namura-Ochalska 2008) and leading to the disappearance of wet habitats that provide home to their unique and important flora and fauna. Therefore they harbor numerous interesting objects to study, one of which is the mite fauna.

The mites (Acari) are the most species-rich arachnid taxon, comprising about 48,000 species known worldwide (Dunlop & Alberti 2008), but the estimates of the total fauna are as high as one million species (Walter & Proctor 1999). Oribatida, also called beetle mites, armored mites or moss mites, are the most abundant and species-rich mite groups. Currently, almost 10,000 oribatid species, representing 172 families, have been described (Schatz 2002, 2004; Subías 2004; Norton & Behan-Pelletier 2009), while estimates of the real world oribatid fauna range from 50,000-100,000 species (Schatz & Behan-Pelletier 2008). In Poland we know of more than 550 species (Olszanowski et al. 1996; Boczek et al. 2000). Oribatid mites of the forest lakes and ponds are relatively poorly known, despite the fact that they are the most abundant and species-rich arthropods there (e.g. Popp 1962; Belanger 1976; Rydin & Jeglum 2006; Seniczak et al. 2006a, 2010; Seniczak 2011a).

Oribatida are rather small, but much differentiated in body size (0.1-2.0 mm in length) and in color, general shape and the presence of diverse morphological structures, many of which have value in systematics. They also vary in ecological requirements and occupy different habitats (Niedbała 1980; Boczek 1999), from deep soil horizons or water to the tops of trees. They are the most successful group of soil arthropods in temperate forests (Johnston 1982; Norton 1994), where they are key animals, together with millipedes, isopods and collembolan insects, responsible for decomposition of dead plant material to organic residues (Labandeira et al. 1997). In soil and litter of temperate forests 100-150 species may achieve total densities higher than 100,000 individuals m^{-2} (Norton & Behan-Pelletier 2009) and ‘this diversity and abundance translates into ecological importance’ (Walter & Proctor 1999).

Most oribatid mites are saprophagous or fungivorous and therefore they have important roles in transformation of organic matter (Berthet 1963). They are very active and consume half of the organic matter accumulating in the forest floor during the year (Boczek & Błaszak 2005). The feeding habits of oribatid mites are traditionally categorized based on their gut content analysis (Schuster 1956; Luxton 1972). Macrophytophages (including xylophages, feeding on woody tissue, and phyllophages, feeding on non-vascular tissue) feed on higher plant material. Microphytophages (including mycophages, feeding on fungi, phycophages, feeding on algae, and bacteriophages, feeding on bacteria) feed on microflora. Panphytophages feed on both microbial and higher plant material, either concurrently, or at different stages in their life cycle. Walter (1987) noted that many Oribatida that have been considered mycophagous also graze on algae and act as predators of nematodes; he defined these species as polyphagous.

Oribatid mites have symbiotic microflora in their guts (Stefaniak & Seniczak 1976, 1981, 1983; Seniczak & Stefaniak 1978; Seniczak et al. 2009a), and also transport microbial propagules from one resource patch to another, accelerating the speed of decomposition of soil organic matter (Walter & Proctor 1999). When oribatids and microbes ‘cooperate’, decomposition of litter can be five times faster than with microorganisms alone (Lavelle 1997). The interaction of soil microorganisms, especially bacteria, with soil mites is very important for soil fertility.

Classification of Oribatida is complicated and based mainly on the morphology of adults (Weigmann 2006). Early simple systems divided the Oribatida into so-called lower ‘Macropylina’ and higher ‘Brachypylina’ taxa (Balogh & Mahunka 1979), but the former group has been abandoned and divided into many groups (Weigmann 2006). While most species are dioecious, many are parthenogenetic and reproduce by thelytoky, and this mode of reproduction dominates in aquatic habitats (Norton & Palmer 1991; Norton et al. 1993). The development of Oribatida includes the egg, hexapod prelarva (within the eggshell) and larva, and octopod protonymph, deutonymph, tritonymph and adult. Females differ morphologically from the males, but in most species these differences are indistinct or are restricted to genitalia. The juveniles of Macropylina are usually very similar to the adults, while those of Brachypylina are not, which creates problem with their identification in ecological studies. Juveniles are sometimes abundant, and omitting them in species analysis of ecosystems results in artificially low estimates of abundance, dominance and constancy indices, and generally weakens the validity of ecological analyses of mites. Additionally, the age structure of some species depends on the type of habitat and thus has a bioindicative value (Seniczak 1978a). Therefore, investigations of the morphological characters of poorly known and unknown juveniles are much needed. Oribatida are found mainly in terrestrial habitats, but include some aquatic and semi-aquatic species, which, in contrast to terrestrial ones, are active when submersed (Behan-Pelletier & Eamer 2007). Their number is relatively small, as only about 90 species worldwide can be considered truly aquatic. These represent ten genera (*Mucronothrus*, *Trhypochthoniellus*, *Aquanothrus*, *Chudalupia*, *Tegeocranellus*, *Hydrozetes*, *Limnozetella*, *Limnozetes*, *Heterozetes* and *Zetomimus*) and comprise less than 1% of all known oribatid species (Schatz & Behan-Pelletier 2008), but they usually dominate among the freshwater arthropods and can reach a density of 280,000 individuals m^{-2} (Seniczak 2011a). Oribatid mites play an important role in peatlands as decomposers (Kuriki 2008), similarly to that in soil, and are therefore an important group for understanding the functioning of these ecosystems.

Terrestrial Oribatida are better known than aquatic and semi-aquatic Oribatida and they have been widely used as bioindicators of different changes in their environment (reviewed e.g. by Wallwork 1988; Lebrun & van Straalen 1995; Behan-Pelletier 1999a; Seniczak 2006; Gulvik 2007; Seniczak & Seniczak 2008c; Gergócs & Hufnagel 2009). The bioindicative value of aquatic and semi-aquatic Oribatida has been already shown in some studies in bogs (e.g. Markkula 1981, 1982, 1986a, b; Borcard et al. 1995; Borcard & Matthey 1995; Borcard 1997), but more investigations on both their ecology and systematics are still necessary.

The Oribatida can be also a powerful tool in investigations of paleoclimate, paleoecology, stratigraphy or paleolimnology, as they are common and abundant in different biotopes, easily fossilized and many species have narrow habitat preferences (Erickson 1988; Solhøy 2001; Erickson & Platt 2007). In contrast to fossil pollen and beetles that are commonly used in paleoecology, mites are flightless and are not carried at large distances by wind, so they are likely to be fossilized where they lived (Erickson & Platt 2007). Their evolution is generally slow and most of the fossil species represent extant species (Erickson 1988; Solhøy 2001).

Unfortunately, in many paleoecological studies these mites have been omitted, probably because, as suggested by Erickson & Platt (2007) ‘their study is demanding of a patient fossil picker and a skilled microscopist with systematic knowledge of a group that itself is little known’. In some studies these mites have been considered together, as Oribatida, loosing their full indicative potential (reviewed by Solhøy 2001). In addition to problems with the species identification, the effective use of this group in some paleosciences is limited by insufficient ecological knowledge of the extant aquatic and semi-aquatic mite communities and species. Such knowledge is rather poor and scattered through the literature (reviewed in 2.3.2). If we know more about the sets of species from contemporary bogs and their ecological requirements, we could read far more from the fascinating history that remains in the ‘geological archives’, like the lake sediments. This history is especially important for us today in the context of current global change studies. Based on good fossil indicators, including oribatid mites, it is possible to reconstruct past climates and environments, as well as identify possible causes and mechanisms for these changes, thus allowing a good basis for predicting future changes in the world in which we live today.

The importance of mites in forest ecosystems and their contribution to landscape biodiversity, together with the promising perspectives of their practical use as bioindicators, both in contemporary bog habitats, as well as in the reconstruction of paleoenvironments and paleoclimates, have encouraged me to study the ecology and morphology of this group in selected lakes and ponds in northern Poland.

The main aim of this study was to learn about the mite communities inhabiting the shores of 16 different lakes and ponds, with a particular interest in the ecological requirements of the oribatid species. To achieve this, the following specific goals were set up:

1) analysis of the basic water parameters in all studied lakes and ponds;
2) comparison of mite communities, with a focus on Oribatida, by studying their abundance, species richness and composition, species dominance and age structure:
   a) Orbatida residing in the shores of lakes and ponds in the bogs of Tuchola Forest, with an emphasis on:
      – the marginal zones of lakes and ponds, and how they react to different types of water quality;
      – different seasons (spring, summer and autumn);
      – the humidity gradient – from the water’s edge towards bog;
   b) Orbatida residing in the marginal zones of other lakes and ponds;
3) investigation of the correlations between different water parameters and the associated abundance of mite species;

4) comparison of the similarities of the oribatid communities in the studied shores with cluster analysis.

In the populations of many aquatic and semi-aquatic Oribatida, the juvenile forms are abundant and their identification is very important in ecological studies. These forms are also found in fossil samples. Because there is no complex key for the identification of the juvenile stages, this study also aimed at the construction of such a key for some of the more abundant species.

2. LITERATURE REVIEW

2.1. SOME DEFINITIONS

The terminology concerning peatlands is sometimes confusing, and therefore there is a need to quote some definitions. **Peatlands** develop in places water-soaked throughout the growing season. Not all wetlands are peat-storing. Peat accumulation takes place when plant growth exceeds decomposition. **Bogs** and **fens** are peatlands (also called mires), but **marshes**, **sedge meadows** and **swamps** have aerated soils and accumulate little or no peat (Crum 1988).

Bogs are acid peatlands, poor in elements that are raised above ground water by accumulation of peat and are dominated by *Sphagnum*. **Fens** develop under the influence of mineral-rich ground or surface water. They are characterized by grassy plants, mainly sedges, and can be succeeded by coniferous swamps or bogs, depending on water movement and quality (Crum 1988). When conditions are favorable for *Sphagnum* growth they lead to formation of bogs.

Marshes are open, grassy or sedgy wetlands developed on mineral soil and covered by shallow water at least part of the year. The mineral content of water is high and pH is about neutral. Productivity is high but oxygen saturation favors decomposer activity. **Sedge meadows** are similar to marshes but drier during hot summer. Fens differ from sedge meadows by having a constant supply of water more or less rich in calcium and accumulating peat. **Swamps** are wooded wetlands, rich in minerals and close to neutral or basic pH (Crum 1988).

Within some bogs there are dystrophic lakes and ponds with *Sphagnum* mats entering the water surface (Herbichowa 2004c). Bogs that develop near the surface of these water bodies can be classified as transitional bogs (Herbichowa 2004b). The distinction between **lakes** and **ponds** is still controversial, although the ecological difference between these water bodies has been evident since the beginning of the last century (Oertli et al. 2005). Ponds are ecologically different from lakes by the absence of a deep aphotic zone, but many other criteria have been used, including size, depth, type of water supply, use, geographical location, formation, water quality (Oertli et al. 2005), the occurrence or absence of rooted macrophytes or wave action (Biggs et al. 2005). Many of these criteria are difficult to measure and apply (reviewed by Biggs et al. 2005) and the most practical division between lakes and ponds is based on their size. Regarding this, different concepts have been proposed. For example, in the Ramsar Convention on Wetlands from 1971 lakes were defined as water bodies with an area above 8 ha, and ponds below 8 ha (Ramsar Convention Secretariat 2006). According to some scientists ponds are from 1 m^2 to 2 ha in area (Biggs et al. 2005 and included references) or from 1 m^2 to 5 ha (e.g. Oertli et al. 2005; Céréghino et al. 2008). Żmudziński et al. (2002) consider Polish lakes as bigger than 1 ha, and by implication, ponds as smaller. In this paper I follow the last definition.

Bogs can contain separate **pools**, for example those that occur within quaking mats (Rydin & Jeglum 2006). They are small, relatively deep water bodies (http://www.m-w.com) that are defined by Rydin & Jeglum (2006) as a ‘permanently water-filled basin in bog (bog-pool) or fen (flark-pool), often with some vegetation at its edge. Pools were initiated and deepened after the peatland was formed’. These authors also mention that the length of pools varies between 3-60 m.

Sometimes **floating islands** occur in lakes and ponds, which are formed in many ways as described in detail by Powers (1911). In small water bodies they usually appear when the water level rises, e.g. after excessive rainfall; then a mat that is not sufficiently elastic may break off and form a floating island. An interesting case is when there are two kinds of peat in an overflowed bog; the bottom layer formed by the decomposed woody material is heavy, and the top layer, composed of *Sphagnum*, is light. In this situation the bottom layer may separate from the top layer; the bottom layer remains in its former position, while the upper layer breaks away to form a floating island. In the northern climates the action of ice may sometimes separate masses of floating vegetation from the shore (Powers 1911).

2.2. TYPES OF PEATLANDS, THEIR ROLE AND IMPORTANCE

Peatlands (= mires) are classified in many ways and those classifications vary according to geographical region (Crum 1988). In Finland, for example, where they cover 32% of the area, the classification system once included 80 different types of peatlands. This classification has been simplified, but still seven types are distinguished (Eurola et al. 1984). Despite such regional complications, some general classifications can be made based on similarities.

The best all-purpose classifications are based on water source and movement, and according to these traits one can distinguish bogs, fens and transitional bogs. Bogs develop under ombrotrophic (deriving minerals only from the atmosphere) conditions, when water and nutrients are supplied only from precipitation, because water from mineral soil is blocked by impermeable peat and cannot reach the surface layers (Crum 1988). Some bogs are convex in shape (raised bogs), but other can be flat or even sloping. The peat is usually more than 40 cm deep (Rydin & Jeglum 2006). All earlier phases are minerotrophic (rich in nutrients) fens, in which water and nutrients are derived from above and below, in precipitation and groundwater (Crum 1988). Transitional bogs are an intermediate type where neither precipitation nor surface/groundwater dominates the water balance (Malawska et al. 2006). An alternative classification reflects the nutritional condition and pH of soil water; for the north-western part of Central Europe these comprise eutrophic mires (fens), mesotrophic acid transitional bogs and oligotrophic raised bogs (Succow & Lange 1984).

In Poland peatlands cover 4.1% of the country and are located mainly in its northern part. Most of them are fens, which comprise 93.1% of all peatlands; raised bogs and transitional bogs cover respectively 4.3% and 2.6% (Ilnicki 2002). Special kinds of bogs are Baltic raised bogs, called 'true raised bogs' according to Ellenberg (2009), present only around the Baltic Sea. The Baltic type raised bogs are unique and include only 68 bogs in Poland. These bogs have been distinguished from other raised bogs based on the cupola shape that has a clear edge zone (called 'lagg'), which is submersed. This edge zone is supported by water from the cupola and from surrounding mineral habitats, so this part of bog is richer in nutrients than is the cupola (Herbichowa et al. 2007). The sides of the cupola are sloping, so they are also drier, providing favorable conditions for the growth of single trees or even a bog forest. In contrast, the cupola top is treeless and wet, and has a specific structure of hummocks and holes. On more extensive cupola tops lakes or ponds can be found. Their origin is not fully explained, but according to some scientists their presence indicates the mature stage of the bog (Pawlaczyk et al. 2005). The Baltic raised bogs, similarly like other ombrogenic bogs, are highly dependent on the climatic conditions and can develop only in moderate and cold climates with high precipitation that provides the positive water balance or at least equilibrium between water flowing to and from the bog cupola (Pawlaczyk et al. 2005). In Poland the Baltic type raised bogs reach their southern limits. They are on average 100-200 ha in size, with a height of 1.5 m; only a few are larger. In countries with colder climates and higher precipitation the size of such bogs can extend to 10,000 ha and their cupolas are up to 4.0 m high (Pawlaczyk et al. 2005).

Peatlands have many functions in the environment. First, they are important as landscape water regulators. Like huge sponges they accumulate water during the wet seasons and let it run during dry seasons (Rydén et al. 2003). For example in *Sphagnum* peat the water content is up to 97% (Herbichowa 2004c). Even a small patch of floating mat in the initial stage of overgrowing, with a surface of 100 m^2 and depth of 10 cm, accumulates as much as 10,000 dm^3 of water (Namura-Ochalska 2008). Peatlands with a total volume of 40 billion m^3 can accumulate at least 34 billion m^3 of water, which means that the water accumulated in Polish peatlands could cover the entire area of the country with a layer 1.1 cm deep (Tobolski 2000).

The productivity of some peatlands can be surprisingly high and even exceed the primary production of forest ecosystems (Tobolski 2003). One of the reasons is an effective biological use of carbon dioxide. The primary production of peatlands of the temperate zone may reach 3,000 $g/m^2/yr$, with average values between 1,500-2,000 $g/m^2/yr$ (Tobolski 2003), while the average primary production of tropical rainforest is 2,200 $g/m^2/yr$, that of temperate deciduous forest 1,200 $g/m^2/yr$, that of boreal coniferous forest 800 $g/m^2/yr$, and that of rivers and lakes only 250 g/m^2/yr (Banaszak & Wiśniewski 1999). Among the peatlands, oligotrophic bogs have the lowest primary production; 100-800 g/m^2/yr for vascular plants and 150-500 g/m^2/yr for *Sphagnum* and other mosses (Tobolski 2003).

Peatlands are undoubtedly one of the most fascinating formations of nature as they combine two totally different types of habitats − terrestrial and aquatic. The organisms living there are highly specialized and characterized by a number of adaptations to function and flourish in these specific conditions, so the biocenoses of peatlands are completely different from those of other types of habitats (Herbichowa 2004b; Pawlaczyk et al. 2005) and they contribute markedly to the species richness of a region (Tobolski 2000, 2003; Rydén et al. 2003).

Peatlands also function as natural filters, binding toxic organic substances and heavy metals to sediments and thus cleaning the water. They also have economic value; e.g. producing peat or berries. Finally, they are documents of the past. Within the peat is recorded information about climatic changes, the history of floral transformation and sometimes also material traces of human culture (Tobolski 2000, 2003; Pawlaczyk 2007).

Because of marshy and water-soaked ground, peatlands and other wetlands were relatively inaccessible to people for a long time and remained as a natural and functioning element of the landscape. Later, however, together with the development of civilization and various techniques, they have been gradually exploited and developed for agricultural use, and as a result many of them disappeared or were changed drastically (Pawlaczyk et al. 2005). Today, peatlands are among the most threatened of habitats on the global scale, as they are especially vulnerable to changes in water level, pH and trophic conditions, environmental pollution, and trampling. Therefore they require special care and protection (Herbichowa 2004b).

Lakes and ponds that are present within peatlands, together with their unique flora and fauna, constitute very interesting enclaves to study and preserve. In the course of succession, these habitats will slowly disappear, being overgrown by forest, but the natural processes are usually very slow, taking tens of centuries or more. However, due to intensified negative human influences the successional processes might be accelerated (Pawlaczyk et al. 2005), so these habitats need special attention and protection.

2.3. MITES IN AQUATIC AND SEMI-AQUATIC HABITATS

2.3.1. General background

All terrestrial arthropods evolved from marine ancestors that long ago left water and developed different adaptations to live on land (Walter & Proctor 1999). Mites emerged on land hundreds millions years ago and have lost since then their features of aquatic adaptations. Those taxa that reinvaded water had to adapt again to aquatic conditions (Walter & Proctor 1999). There are approximately 7,000 mite species, from the Mesostigmata, Astigmatina, Oribatida and especially the Prostigmata, that live now in marine and freshwater habitats (Proctor 2004). Mesostigmata and Astigmatina invade quickly temporary habitats filled with water, like tree holes, leaf axils and temporary pools, while other Oribatida and Prostigmata prefer more permanent impoundments (Krantz 2009).

Oribatid mites are an old group and have been known as fossils at least since the Devonian Period (Norton et al. 1988a). Fossil species from the aquatic genus *Hydrozetes* are reported from the Jurassic Period in Sweden (Sivhed & Wallwork 1978), from the Paleocene in Canada (Baker & Wighton 1984), from the Pliocene in Siberia (Druk 1982), and together with *Limnozetes* species from the Pleistocene and early Holocene (Erickson 1988; Krivolutsky et al. 1990; Solhøy & Solhøy 2000; Solhøy 2001; Erickson & Platt 2007). An increase of *Hydrozetes* density in the sediment records reflects increases in water temperature, or depth, and availability of nutrients in the aquatic system, while their low numbers or absence suggests cold climates with reduced nutrient cycling in lakes and bogs, or prolonged dry conditions (Erickson & Platt 2007).

Oribatid mites are common in humid or temporarily flooded habitats like meadows, bogs and tree holes. Some species live in the marine littoral (e.g. Luxton 1964, 1967a, b, c, 1986, 1989, 1990; Schuster 1979, 1989; Søvik 2004), where they feed on algae (Luxton 1990). They also inhabit freshwater habitats: lentic (pools, ponds, lakes, swamps) or flowing waters (springs, rivers and streams), mainly on submerged plants (Schatz & Behan-Pelletier 2008).

Out of all species inhabiting water habitats (**aquatic** and **semi-aquatic**) only some can be designated as **truly aquatic**, with reproduction and all stages of life cycle in water or at its margins (Schatz & Behan-Pelletier 2008). Other species are **amphibious**; they inhabit water but seem to need saturated air to reproduce. Additionally, in aquatic habitats many terrestrial oribatids that are chance stragglers from surrounding habitats, can be found, but are not abundant (Walter & Proctor 1999; Schatz & Behan-Pelletier 2008; Gerecke et al. 2009).

With accumulating knowledge about the ecology of freshwater Oribatida the classification of species as aquatic or amphibious is changing. For example Piffl (1978) considered only the genus *Hydrozetes* to be truly aquatic, while Behan-Pelletier & Eamer (2007) considered species of *Mucronothrus*, *Trhypochthoniellus*, *Hydrozetes* and *Limnozetes* as truly aquatic, as they complete their life cycle while submerged. Weigmann & Deichsel (2006) listed 17 oribatid species from Central Europe that live exclusively or regularly in freshwater habitats. According to most recent publications 87 oribatid species (less than 1% of the total number of Oribatida), from ten genera, seven families, are truly aquatic (Schatz & Behan-Pelletier 2008). The aquatic genera (but not always all their species) include: *Mucronothrus*, *Trhypochthoniellus*, *Aquanothrus*, *Chudalupia*, *Tegeocranellus*, *Hydrozetes*, *Limnozetella*, *Limnozetes*, *Heterozetes* and *Zetomimus*.

Many aquatic species are in the related families Hydrozetidae (32 species) and Limnozetidae (17 species). All known species of Hydrozetidae (Subías 2004; Seniczak et al. 2007, 2009c; Seniczak & Seniczak 2009a) live on or in macrophytes in still or flowing waters (Krantz & Baker 1982; Schatz & Behan-Pelletier 2008) or at the edges of lakes and rivers, especially in *Sphagnum* and other mosses (Seniczak et al. 2007, 2009c; Seniczak & Seniczak 2008a, 2009a). Buford (1976) reported that *Hydrozetes lemnae* (Coggi, 1897) has been collected from several meters below the water line to several centimeters above. Species of *Limnozetes* comprise about 90% of the oribatid fauna adjacent to bog pools in Switzerland, USA and Poland (Borcard 1991c; Donaldson 1996; Seniczak et al. 2006a) and their density declines with decreasing moisture (Donaldson 1996; Kuriki 2008).

Zetomimidae comprises 18 species (Schatz & Behan-Pelletier 2008), all of which live in shallow, eutrophic water bodies, wetlands and wet meadows, wet moss (Shaldybina 1965, 1969). Adults have been observed on the water surface (Willmann 1931), on floating logs and twigs, and submerged, associated with vegetation (Behan-Pelletier & Eamer 2007). Juvenile stages have been observed only during periods of inundation (Behan-Pelletier & Eamer 2003), which suggests their inactivity in dry periods. Shaldybina (1965, 1969) cultured *Heterozetes palustris* (Willmann, 1917) and *Zetomimus furcatus* (Warburton & Pearce, 1905) in very moist, not aquatic, conditions, while Banks (1895) kept *Heterozetes aquaticus* (Banks, 1895) in an aquarium for several months.

Two genera in Trhypochthoniidae are aquatic: *Mucronothrus* and *Trhypochthoniellus*, each with few species. The distribution of *Mucronothrus nasalis* (Willmann, 1929) is worldwide but discontinuous and seems to be limited by temperature to cold bogs or cold streams, springs and bottoms of very cold lakes (Norton et al. 1988b, 1996a). According to Schatz & Gerecke (1996) *M. nasalis* occupied only permanent springs, where it made up 45% of all collected Oribatida. *Trhypochthoniellus longisetus* (Berlese, 1904) (= *Hydronothrus crispus* Aoki, 1964) was found in a taro-patch, on dead leaves of *Hibiscus tiliaceus* L. that were 10 m deep under water (Aoki 1964). It was interesting that the mites were found only on the leaves facing with their abaxial side towards the surface of the bottom, which were partly in contact with the bottom and partly suspended above it. The mites were not found either on floating leaves or on buried ones. The author suggested that this phenomenon was probably connected to the degree of decaying of the dead leaves − floating ones were too fresh, while buried ones were too old for mites. This species (as *Hydronothrus puniceus* Habeeb, 1981) was also found in water falls (Habeeb 1981) while Fain & Lambrechts (1987) reported it from an aquarium.

Some species in the Ameronothridae, Fortuyniidae and Selenoribatidae live in marine littoral habitats (Luxton 1990), but are not truly aquatic (Behan-Pelletier & Eamer 2007). They are active only on wet or moist surfaces, but inactive when dry or submerged. However, there are at least three species of Ameronothridae (in the genera *Aquanothrus* and *Chudalupia*) that can be classified as truly aquatic. They inhabit ephemeral rock-pools in semi-arid or arid regions and when those pools evaporate completely they survive days and weeks inactive, waiting for rain (Norton et al. 1996b). Also *Tegeocranellus* species (Tegeocranellidae) from temporary swamps and streams are probably aquatic, since their immature stages have only been collected during periods of inundation (Behan-Pelletier 1997).

Many other species inhabit freshwater habitats but they seem to need saturated air to reproduce (species of *Platynothrus*, *Trhypochthonius*, *Mainothrus*, *Malaconothrus*, *Trimalaconothrus*, *Astegistes*, *Naiazetes*, *Ceratozetes*, *Edwardzetes*, *Sphaerozetes*, *Minguezetes*, *Allogalumna*, *Orthogalumna* and others) (Schatz & Behan-Pelletier 2008). For example *Edwardzetes elongatus* Wallwork, 1966 (Ceratozetidae) survived over a month while submerged, but was not able to complete its development under water (Pugh 1996). *Platynothrus peltifer* (C.L. Koch, 1839) was abundant in samples from springs in the Bavarian and Italian Alps, but unlike *Mucronothrus nasalis* it also occurred in intermittent springs (Schatz & Gerecke 1996). The majority of hygrophilous and aquatic Oribatida are transported passively with wind (anemohydrochory) (Popp 1962; Vanschoenwinkel et al. 2008a, b, 2009), some with water (hydrochory): by water currents, waves (together with the action of wind), with objects drifting in water (Popp 1962; Vanschoenwinkel et al. 2008b), while transport by amphibians is probably negligible (Vanschoenwinkel et al. 2008b). Some species however can move actively on or in water, by clinging to the surface film of the water (e.g. *Hydrozetes*) (Popp 1962) or can even run on the water surface (*Zetomimus furcatus*, *Heterozetes palustris*) (Willmann 1931).

Moss mites can be abundant in aquatic and semi-aquatic habitats, but their diversity is low. For example in North America 15 genera (representing nine families) in the cohorts Desmonomata (40% of its genera) and Brachypylina (60% of its genera) are present in freshwaters, while the early derivative oribatid taxa Palaeosomata, Enarthronota, Parhyposomata and Mixonomata are absent from these habitats (Behan-Pelletier & Eamer 2007). By contrast, in soil, litter and peatlands all cohorts of Oribatida are represented (Behan-Pelletier 1999b).

Life in water must be a real challenge to the oribatid mites as only a few taxa were able to adapt to it. One of the limiting factors in water is low oxygen content (Zinkler 1999), but some species are able to tolerate it (Messner et al. 1992). Some Oribatida, like adult *Hydrozetes*, use plastron respiration (Crowe & Camara 1973; Krantz & Baker 1982; Travé 1986; Messner & Adis 1992), while others, including most immature Brachypylina, use cuticular respiration (Behan-Pelletier & Eamer 2007). Plastron participates also in the mite's levitation, i.e. rising in the column of water (Crowe & Magnus 1974) that may serve to avoid anaerobic decomposition, lack of oxygen and relocation to a suitable substrate (Newell 1945; Buford 1976; Fernandez & Athias-Binche 1986). *Hydrozetes* responded with levitation to the decreasing light intensity

(Newell 1945), which it was able to detect using a light-sensitive structure called 'lenticulus' (Fig. 1) (Piersig 1895; Oudemans 1916; Tarman 1961; Alberti & Fernandez 1988, 1990; Alberti 1998; Alberti & Coons 1999).

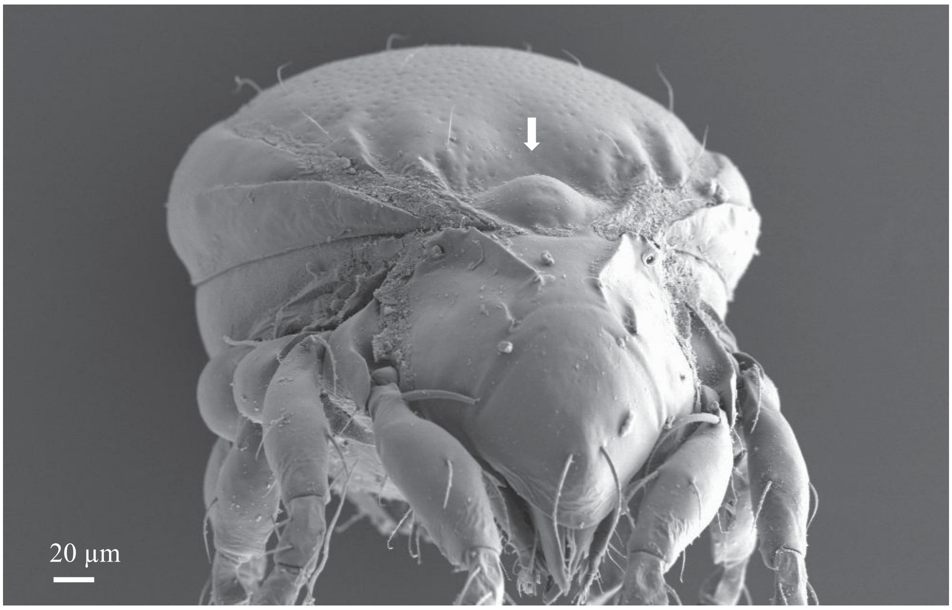


Fig. 1. *Hydrozetes lacustris*; frontal aspect; arrow points the lenticulus
Rys. 1. *Hydrozetes lacustris*; widok z przodu; strzałka wskazuje lenticulus

Life in water also requires effective osmoregulation that is maintained with genital papillae and Claparède organs (Alberti 1979; Evans 1992; Alberti & Coons 1999). Aquatic Oribatida, like Heterozetidae, Hydrozetidae or *Mucronothrus nasalis*, posses morphological modifications of legs and setae that are useful in moving on water surface or in water (Norton et al. 1988b; Seniczak et al. 2007; Seniczak & Seniczak 2008a). In humid environment, where there is a higher risk from fungal parasites, the chemical protection is useful (Raspotnig et al. 2005), while for those living in temporary water bodies the tolerance and survival of desiccation is essential (Behan-Pelletier & Eamer 2007 and included references).

2.3.2. Faunistic and ecological studies of Oribatida in bogs and other wetlands

In bogs, the mites are the most abundant and diverse group of microarthropods, just as in soil (e.g. Belanger 1976; Kuriki 2003), but compared to other ecosystems the acarofauna of bogs is rather poorly studied. Among mites, the most abundant and rich in species, except for open waters, are the Oribatida (e.g. Popp 1962; Belanger 1976; Rydin & Jeglum 2006; Seniczak et al. 2006a, 2010; Seniczak 2011a). Interestingly, they are also the most diverse group in springs, where they comprise 57% of all mite species, despite the fact that the ‘true’ aquatic mites (Hydrachnidia and Halacaridae) are more abundant (Gerecke et al. 2009). However, in comparison with the other ecosystems, the oribatid fauna of bogs is characterized by high density and poor species composition (Rajski 1961; Kuriki & Aoki 1989; Seniczak et al. 2006a, 2010; Seniczak 2011a).

Species inhabiting bogs can be classified according to their fidelity to this habitat. So, there are tyrphobionts, i.e. species restricted only to bogs; tyrphophils, those characteristic of bogs, but not confined to them; and generalists (Spitzer & Danks 2006). Willmann (1928a) and Sellnick (1929), in their thorough studies of Oribatida from bogs, included ecological information on some species, indicating that only a few are restricted exclusively to bogs; most can be found in various wet habitats, while others are ubiquitous.

In Europe the most extensive investigations of the Oribatida from bogs have been carried out in Germany (Harnisch 1926; Beier 1928; Willmann 1928a, 1931, 1932, 1933; Sellnick 1929; Peus 1932; Strenzke 1952; Knülle 1957a, b, c; Popp 1962, 1970; Weigmann 1991; Kehl 1997), Scandinavia [Denmark (Haarlov 1957), Finland (Karppinen 1955a, b, 1958a, b, 1972, 1977; Markkula 1981, 1982, 1986a, b), Norway (Solhøy 1976, 1979; De la Riva-Caballero 2003; Larsen et al. 2006; De la Riva-Caballero et al. 2010; Seniczak et al. 2010, 2011a), Sweden (Dalenius 1950, 1960, 1962; Tarras-Wahlberg 1952, 1954, 1961)], Switzerland (Schweizer 1956; Borcard 1988, 1991a, b, c, d, e, 1992a, b, 1994a, b, 1997; Borcard et al. 1995; Borcard & Matthey 1995; Borcard & von Ballmoos 1997) and Poland (for details see below). Some studies also have been performed in Austria (Klima 1958), Italy (Schatz & Gerecke 1996; Gerecke et al. 2009), Russia (Laskova 1980; Druk 1982; Sidorchuk 2008), Lithuania (Eitminavičiūtė 1966, 1972) and the Czech Republic (Kunst 1959b; Halaskova & Kunst 1960; Starý 1988, 2006). In North America the Oribatida of bogs have been studied in Canada (Behan-Pelletier & Bisset 1994; Behan-Pelletier 1997) and the USA (Belanger 1976; Donaldson 1996). Extensive and long-term studies of Oribatida in bogs have been carried out in Japan (Yoshida & Kuriki 1977, 1979; Kuriki & Aoki 1989; Aoki 1995; Kuriki 1995, 1996, 2003, 2008; Kuriki & Yoshida 1999), where one author, G. Kuriki, has continued his ecological investigations in bogs for 15 years. In addition to the extant fauna, the fossil mites in bogs have been studied widely (Woolley 1969; Karppinen et al. 1979; Baker & Wighton 1984; Erickson 1987, 1988, 2005; Krivolutsky et al. 1990; Solhøy & Solhøy 2000; Solhøy 2001; De la Riva-Caballero 2003; Erickson et al. 2003; Krivolutsky & Sidorchuk 2003; Sidorchuk 2004; Larsen et al. 2006; Erickson & Platt 2007; Erickson & Solod 2007; De la Riva-Caballero et al. 2010).

In Poland the Oribatida of bogs have been studied in the Western Sudetes, in Zieleniec near Duszniki (Sellnick 1923; Harnisch 1926; Willmann 1939) and in the Eastern Sudetes, in Masyw Śnieżnika Kłodzkiego (Willmann 1939, 1956), in Mazurian lake district near Olsztyn (Sellnick 1920), in Pomerania (Strenzke 1952), including bogs near Chełm (bog Linje), Gdańsk (Sellnick 1921) and Koszalin (Lake Lubiatowskie) (Strenzke 1943), in Wielkopolska-Kujawy Lowland, near Poznań (Rajski 1959, 1961, 1967a, b, 1968, 1970) and in Koźle at Oder (Schubert 1934). Willmann (1949) investigated mites of mineral springs in southern Poland and Ciechocinek. Detailed studies of Brachychthoniidae (Niedbała 1974) and ptyctimous mites (Niedbała 1992, 2008) from Poland also included species from bogs. In some of these studies Oribatida of the shores of lakes, ponds and pools in bogs have been also investigated, but mostly from a faunistic aspect. Recent ecological studies have dealt with the oribatid fauna at the shores of water bodies in northern Poland (Seniczak et al. 2005a, b, 2006a, b, c, d; Seniczak 2011a, b) and southern Poland (Mistrzak et al. 2011; Żbikowska-Zdun et al. 2006).

While this seems a long list of references, it includes mainly faunistic studies, few of which have an ecological character. Some of these investigations focused on the ecology of one or a few species only, based on field observations and laboratory experiments. These include *Platynothrus peltifer* (Grandjean 1950; Hartenstein 1962; Block 1965; Harding 1971; Jalil 1972a, b; Olszanowski & Błoszyk 1987; Taberly 1988a, b; Siepel 1990), *Heterozetes palustris* (Shaldybina 1965), *Zetomimus furcatus* (Shaldybina 1969), *Nothrus palustris* (C.L. Koch, 1839) (Lebrun 1970a, b), *Hydrozetes lemnae* (Athias-Binche & Fernandez 1986; Fernandez & Athias-Binche 1986; Ermilov 2006), *Limnozetes* spp. (Behan-Pelletier & Hill 1983; Behan-Pelletier & Bisset 1994), in particular *L. ciliatus* (Schrank, 1803) (Kuriki 2008), species from the superfamily Malaconothroidea (Kehl 1997), and *Nanhermannia* cf. *coronata* Berlese, 1913 (Ermilov & Łochyńska 2007, 2008).

Strenzke (1952) studied oribatid communities of different habitats, including bogs, and he grouped species into 'synusia', i.e. associations of species regularly occurring in a certain proportion in particular habitats, which reflected their requirements for different ecological factors like plant associations, humidity, organic matter content, pH, salinity, etc. (Niedbała 1980). This concept was continued in different countries by other authors who studied bogs (Knülle 1957a; Klima 1958; Rajski 1961, 1967b, 1968, 1970; Popp 1962). Some studies focused only on bogs, and compared different habitats there (Tarras-Wahlberg 1954, 1961; Block 1966; Eitminavičiūtė 1966; Popp 1970; Belanger 1976; Solhøy 1979; Druk 1982; Borcard 1991a, b, c; Weigmann 1991; Kuriki 1995, 1996, 2003; Donaldson 1996; Seniczak et al. 2005a, b, 2006; Sidorchuk 2008) or evaluated the anthropogenic pressure (Markkula 1981, 1982, 1986a, b; Borcard et al. 1995; Borcard & Matthey 1995; Borcard 1997), demonstrating the importance of bog-dwelling Oribatida in bioindication.

3. STUDY AREA

3.1. LAKES AND PONDS IN BOGS OF TUCHOLA FOREST

3.1.1. Jezioro Łyse

‘Jezioro Łyse’ Nature Reserve, in accordance with the physical-geographical regionalization of Poland, is situated in the Southern Pomeranian Lakeland macroregion, in the Tuchola Forest mesoregion (Kondracki 2009) (Fig. 2).

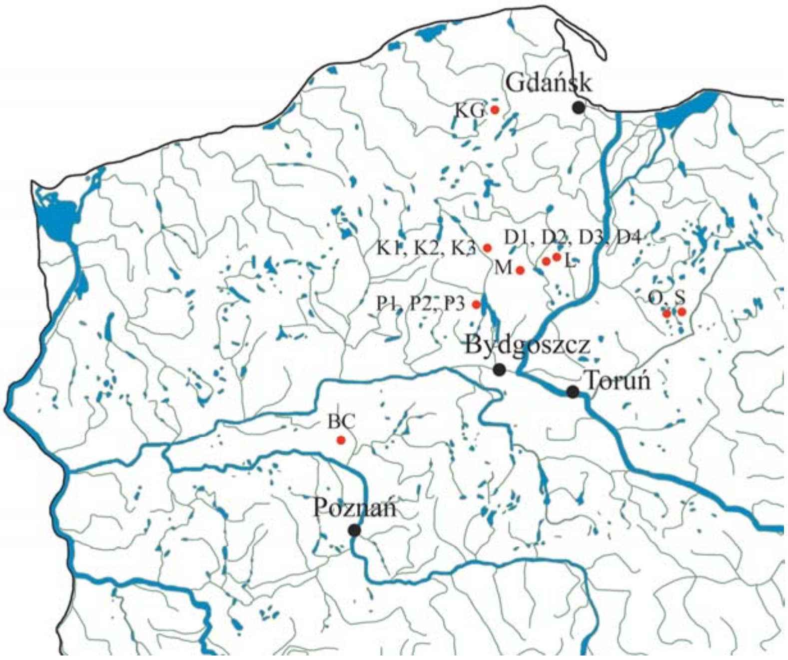


Fig. 2. Locality of the study sites: L – Lake Łyse; D1, D2, D3, D4 – ponds in ‘Dury’ reserve; M – Lake Martwe; K1, K2, K3 – ponds in ‘Jeziorka Kozie’ reserve; P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in ‘Bagno Chlebowo’ reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in ‘Kurze Grzędy’ reserve.

Rys. 2. Położenie terenu badań: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury”; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie”; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo”; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy”.

According to the geo-botanical classification, it is located in the Southern Pomeranian Transitional Belt land and Tuchola Forest district (Szafer 1972), while in the nature-forest classification it belongs to Wielkopolska-Pomerania land and Tuchola Forest district (Trampler et al. 1990). Administratively, the reserve is in Kujawy-Pomerania province, ca. 70 km north-east from its capital − Bydgoszcz, in Świecie district and Warlubie commune. Following forestry administration, it is situated in Osie forest division, Osie forest circle and Nowa Huta forest district (http://www.torun.lasy.gov.pl). Together with several other reserves, it belongs to the Wdecki Landscape Park, which constitutes its buffer zone (Boiński 2003).

The reserve 'Jezioro Łyse' is situated on an undulating terrain of Wda Outwash Plain, ca. 100 m high, cut by river and stream valleys, mostly in the longitudinal direction. The maximum outwash plain height in the reserve is 75 m a.s.l. Other features of the landscape are numerous basins of different sizes, formed by melting residual ice blocks during the glacier retreat. Lake Łyse occupies a small part of such a basin that has ca. 30 ha and is filled with lake water and peatland. The bottom of the basin is ca. 7 m under the water table, and its slopes are gentle, 5º-15º. The prevailing soils in the reserve are peat soils; only in the area covered by forest there is brown gley soil and sand (Rajnik 2004).

The climate is characterized by low precipitation, 500-600 mm a year. The mean annual temperature is 7-8ºC. The coldest month is January, with a mean temperature –3 to –4ºC, and the warmest is July, with the mean temperature 18-19ºC. Spring starts from 5-10 of May, and autumn from 10-15 of September. The vegetation period lasts on average 200-210 days (Trampler et al. 1990).

'Jezioro Łyse' is a bog reserve, established in 2006 (http://www.torun.lasy.gov.pl) to protect the dystrophic lake, *Nymphaeetum candidae* community, *Sphagnum* floating mat, process of overgrowing of the lake, succession of forest communities on the bog and rare lichen and vascular plant species (Rajnik 2004). The entire area of the reserve is 20.32 ha, of which 5.58 ha are covered by the lake, 12.25 ha by bog, 2.43 ha by forest and 0.06 ha by forest section lines (Rajnik 2004).

Lake Łyse is rather shallow, with a maximum depth of 3.5 m. The *Sphagnum* floating mat surrounds the lake; it is only several meters wide in the south-eastern part, and ca. 30 m in the north-western part, where the succession of downy birch (*Betula pubescens* Ehrh.) and silver birch (*Betula pendula* Roth.) proceeds. In this part also the remains of old drainage ditches are present (Rajnik 2004). On the lake there are floating islands with a mosaic of floating mat communities.

The most valuable plant communities include *Nymphaeetum candidae* in the open water, *Caricetum lasiocarpae*, *Sphagno-Caricetum rostratae*, *Caricetum elatae* and *Caricetum limosae* at the edge of the bog, and *Rhynchosporetum albae*, *Sphagnetum medio-rubellii*, *Sphagnetum magellanici*, *Sphagnetum magellanici pinetosum*, *Sphagnetum magellanici sphagnetosum fusci* and *Sphagnetum magellanici sphagnetosum fallacis* in the floating mat (Rajnik 2004).

The reserve is rich in protected plant species, like stiff clubmoss (*Lycopodium annotinum* L.), common sundew (*Drosera rotundifolia* L.), long-leaved sundew (*D. intermedia* Hayne), common bladderwort (*Utricularia vulgaris* L.), lesser bladderwort (*U. minor* L.), Labrador tea (*Ledum palustre* L.) and shining water-lily (*Nymphaea candida* C. Presl.). Glacial relicts are bilberry (*Vaccinium myrtillus* L.), bog bilberry (*V. uliginosum* L.), bog rosemary (*Andromeda polifolia* L.), Labrador tea, one-sided wintergreen [*Pirola secunda* (L.) Garcke], and shining water-lily. Among numerous protected lichen species, especially important is *Usnea wasmuthii* Räsämen, which indicates clean air and *Cladonia incerassata* (Fr.), which is becoming extinct (Rajnik 2004).

The open bog is surrounded by fresh mixed coniferous forest (*Querco roboris-Pinetum*), with common pine (*Pinus sylvestris* L.) dominating. The average age of pine is 76 years; in some places Norway spruce (*Picea abies* L.), downy birch and silver birch, 76-83 years old, are found (Rajnik 2004). The shrub layer is composed mainly of Norway spruce, birch and common juniper [*Juniperus communis* (L.)]. The forest has differentiated height and age structure, due to periodical floods that cause the dying of some trees and then quick growth of successors (Rajnik 2004).

Comparing the maps from 1910 and 1979 and an aerial photograph from 2004, only small changes in the shoreline are noticed. The natural phenomenon in this type of bog is the succession of downy birch, silver birch and common pine that occur especially in the north-western part of the lake. To slow down the succession and preserve this lake as long as possible, cutting of the trees is necessary (Rajnik 2004).

The anthropogenic pressure in the reserve is low. It is located far from industrial centers and cities, so the air is very clean, and the access to the reserve is rather difficult due to poorly developed road infrastructure. There are no energy lines in the vicinity. Only in autumn, the area is exposed to small influence of the local people collecting mushrooms and cranberries (Rajnik 2004).

A study site is located on the western side of the lake (Fig. 3), where the *Sphagnum* mat is well developed (ca. 20 m wide) and a *Caricetum lasiocarpae* association, which is typical for transitional bogs along overgrowing water basins, occupies the water's edge. In this community two layers are distinct; the higher one grows up to 80 cm high, while the other is created by floating *Sphagnum* mosses (Wysocki & Sikorski 2002). The moss carpet (Fig. 4), composed mainly of flat-topped bog-moss [*Sphagnum fallax* (Klinggr.) Klinggr.], was overgrown by turf composed of slender sedge (*Carex lasiocarpa* Ehrh.) and other species, including buckbean (*Menyanthes trifoliata* L.), marsh cinquefoil (*Comarum palustre* L.), bog rosemary and common cranberry (*Vaccinium oxycoccos* L.). In the open water a *Nymphaeetum candidae* association was present (Rajnik 2004).

Fig. 3. Lake Łyse surrounded by wide *Sphagnum* floating mat
Rys. 3. Jezioro Łyse otoczone szerokim płem torfowcowym

Fig. 4. The edge of the *Sphagnum* floating mat at Lake Łyse
Rys. 4. Brzeg pła torfowcowego przy Jeziorze Łyse

3.1.2. Dury

The ‘Dury’ Nature Reserve is located in the same units of physical-geographical, geo-botanical and nature-forest classification as ‘Jezioro Łyse’, and in Kujawy-Pomerania province, 73 km north-east from Bydgoszcz, in Świecie district and Osie commune (Gogołkiewicz et al. 1998). Following the forestry administration, it belongs to Osie forest division, Osie forest circle and Stara Rzeka forest district (http://www.torun.lasy.gov.pl). It is also located within Wdecki Landscape Park, which constitutes its buffer zone (Boiński 2003). The landscape and the climate are the same as in ‘Jezioro Łyse’ reserve and the soils are peat soils (Gogołkiewicz et al. 1998).

The ‘Dury’ Nature Reserve is a bog reserve (http://www.torun.lasy.gov.pl) that has been established in 1975 to protect the bog and water plant communities. The reserve has an area of 12.59 ha, from which 8.59 ha are covered by forest, while 4 ha by water and forestless bog (Gogołkiewicz et al. 1998).

The reserve encompasses five small (1-3 ha) depressions, four of which are filled by dystrophic ponds and peat, and one only by peat. The ponds D1-4 have 0.53 ha, 0.33 ha, 0.39 ha and 0.91 ha, respectively. The water level in ponds is several meters lower than the surrounding terrain and the ponds are 4-10 m deep (Gogołkiewicz et al. 1998). At their origin, these depressions were probably not deep, but they became deeper when the temperature increased and the blocks of residual ice melted out (Gogołkiewicz et al. 1998). During the lake stage of the basin, organic sediments (980-580 cm) were accumulated as limnic gyttja and for ca. 3500 ^{14}C years BP the upper part (580-0 cm) peat has accumulated (Kowalewski & Milecka 2003). The analysis of sediments in the basin D1 revealed that three ponds were present there, but only the largest one exists today (Milecka & Kowalewski 2008).

Dystrophic ponds are surrounded by floating mats entering their water surface. The natural overgrowing of these ponds leads to the formation of transitional and raised bogs (Boiński 1992). Because the bogs are situated close to each other, the speed of their overgrowing depends mainly on the size of their watershed and the gradient of slopes (Gogołkiewicz et al. 1998). The spread of the floating mat probably began when the terrestrial accumulation started, ca. 4000 ^{14}C BP, and its average rate has been 0.25 cm a year. Today, due to anthropogenic pressure, this spread is much faster; the highest, 33 cm a year, was observed at pond D4 (Kowalewski & Milecka 2003).

The main protected objects in the reserve are four dystrophic ponds and a *Nupharo-Nymphaeetum albae* community as well as floating mat communities: *Rhynchosporetum albae*, *Sphagno-Caricetum rostratae*, *Caricetum limosae*, *Caricetum nigrae*, *Sphagnetum magellanici* and *Sphagnetum magellanici sphagnetosum fallacis*. Special attention is also paid to the overgrowth of the dystrophic ponds and the succession of forest communities: *Sphagnetum magellanici pinetosum* and pine bog forest (*Vaccinio uliginosi-Pinetum*) (Gogołkiewicz et al. 1998).

There are also protected and rare plant species, like European white water-lily (*Nymphaea alba* L.), shining water-lily, yellow water-lily [*Nuphar lutea* (L.) Sibth. & Sm], mud sedge (*Carex limosa* L.), slender sedge, white beak-sedge [*Rhynchospora alba* (L.) Vahl], brown beak-sedge [*R. fusca* (L.) W.T. Aiton], English sundew (*Drosera anglica* Huds.), common sundew, long-leaved sundew, small cranberry (*Oxycoccus microcarpus* Turcz. ex Rupr.), which is a glacial relict, and bog rosemary (Gogołkiewicz et al. 1998).

The bog is covered by pine forest, 60-70 years old, in which common pine dominates, with addition of downy birch and silver birch. The shrub layer is composed of the same species. The tree stands have differentiated height and age structure, because this area is temporarily flooded; trees die out, but then quickly regenerate (Gogołkiewicz et al. 1998). The herb layer is composed of: Labrador tea, common cranberry, sheathed cottonsedge (*Eriophorum vaginatum* L.), common cotton-grass (*E. angustifolium* Honck.), bog rosemary, common sedge [*Carex nigra* (L.) Reichard], *Drosera* spp. and bog bilberry, while the moss layer is composed of *Sphagnum* spp. and bog groove-moss [*Aulacomnium palustre* (Hedw.) Schwägr.] (Gogołkiewicz et al. 1998).

The bog has been drained by ditches (Tobolski 2003) and one, connecting basins D1 (Fig. 5) and D2 (Fig. 6), is still functioning (Kowalewski & Milecka 2003).

Fig. 5. The broken *Sphagnum* floating mat with small pools at pond D1 in the ‘Dury’ reserve

Rys. 5. Poprzerywane pło torfowcowe z małymi oczkami przy jeziorze D1 w rezerwacie „Dury”

Fig. 6. The view at pond D2 in the 'Dury' reserve
Rys. 6. Widok na jezioro D2 w rezerwacie „Dury"

High-tension wires situated in the neighborhood of the reserve create other problems, as this forestless zone makes it impossible for the natural growth of the forest. Except this, the risk for the reserve is rather low and it has a natural character unique to the region and the country (Gogołkiewicz et al. 1998).

Study sites were located at ponds D1, D2, D3 (Fig. 7) and D4 (Fig. 8), where the shoreline is occupied by the plant association *Sphagno-Caricetum rostratae*. Characteristic for this community was a flat, green carpet of flat-topped bog-moss, in which moss cover was as high as 100%, and on this carpet were loose groups of bottle sedge (*Carex rostrata* Stokes) (Gogołkiewicz et al. 1998). This was the most common community of the edge of the floating mat. Rarely other communities occurred around the ponds: *Caricetum limosae* and *Rhynchosporetum albae.* Further from the shoreline *Sphagnum* red hummocks, *Sphagnetum magellanici* were present. These communities were surrounded by pine bog forest (Kowalewski & Milecka 2003).

Fig. 7. Pond D3, the most advanced in succession in the ‘Dury’ reserve
Rys. 7. Jezioro D3, najbardziej zaawansowane w sukcesji w rezerwacie „Dury”

Fig. 8. Pond D4 in the ‘Dury’ reserve in autumn
Rys. 8. Jezioro D4 w rezerwacie „Dury” jesienią

3.1.3. Martwe

The ‘Martwe’ Nature Reserve is located in the same physical-geographical, geo-botanical and nature-forest units as ‘Jezioro Łyse’, and in Kujawy-Pomerania province, 78 km north from Bydgoszcz, Świecie district and Osie commune (Boiński 2003). The reserve belongs to the Osie forest division, Szarłata forest circle and Trzebciny forest district (http://www.torun.lasy.gov.pl). It also belongs to the Wdecki Landscape Park (Boiński 2003).

The climate is similar to that of the ‘Jezioro Łyse’ reserve, but the mean temperature of July is a bit lower (17-18ºC) and spring starts earlier (from 30 April to 5 May) (Trampler et al. 1990). The landscape is similar to that of the ‘Jezioro Łyse’ reserve. The dominant soils are peat soils that are formed when precipitation is higher than evapotranspiration, in strongly acid soil conditions. The organic layer, formed during overgrowing of the lake, is 4-10 m thick, while the bottom is made of highly decomposed peat with a large amount of sand, lying on a sandy base. Gley podzolic soils, which are the poorest mineral forest soils, occasionally occur. They were formed from lake sands under the influence of oligotrophic ground water, when the water table was within the soil profile, ca. 80 cm deep (Boiński 2003).

The ‘Martwe’ is a bog reserve (http://www.torun.lasy.gov.pl), created in 1996 to protect the dystrophic lake (Fig. 9), raised and transitional bogs and birch bog. The area of the reserve is 3.96 ha; the lake occupies 1.74 ha, the bog covers 1.82 ha and the remaining part (0.40 ha) is covered by moist mixed coniferous forest (*Querco roboris-Pinetum molinietosum*) (Boiński 2003).

Special attention is paid to the protection of communities: *Nymphaeetum candidae*, *Caricetum limosae*, *Rhynchosporetum albae*, *Caricetum lasiocarpae*, and a community with common rush (*Juncus effusus* L.). Protected plant species include common sundew, stiff clubmoss and shining water-lily, and partly protected species: Labrador tea and alder buckthorn (*Frangula alnus* Mill). Other rare bog species are: white beak-sedge, mud sedge, rannoch-rush (*Scheuchzeria palustris* L.), slim-stem reed grass [*Calamagrostis stricta* (Timm) Koel.], yellowishwhite bladderwort (*Utricularia ochroleuca* R.W. Hartman), common cranberry, bog rosemary, sheathed cottonsedge, and common cotton-grass. Two species, slim-stem reed grass and Labrador tea, are glacial relicts (Boiński 2003).

In the surrounding moist mixed coniferous forest the dominant species is common pine, on average 107 years old, and in some places Norway spruce (65 years old), downy birch and silver birch (65 years old) occur; admixture species are common aspen (*Populus tremula* L.) and black alder (*Alnus glutinosa* Gaertn.). Shrub species are alder buckthorn, common juniper and grey willow (*Salix cinerea* L.).

The main problem in the reserve is fluctuation of the water level and, due to drier conditions, expansion of pine trees and changes towards the formation of pine bog forest. To maintain and protect the unique open bog communities, the oldest and tallest pine trees must be removed. It is also essential not to change the water level in the reserve and its surroundings. A buffer zone, ca. 100 m wide, is planned and should include the entire basin. It is covered now by pine monoculture stands, but in the future should be restocked naturally (Boiński 2003).

A study site was located at the edge of the floating mat (Figs. 9 and 10), which was occupied by the *Sphagno-Caricetum rostratae* plant association, the most common type of floating mat in the 'Martwe' Nature Reserve. The cover of herb and moss layers was respectively 95% and 100%. The dominant species were these characteristic for this community, bottle sedge and flat-topped bog-moss (cover 100%). Common cotton-grass was also relatively abundant (cover 25%) with less abundant species (cover 5%) being straw-colored water moss [*Calliergon stramineum* (Brid.) Kindb.] and tufted loosestrife (*Lysimachia thyrsiflora* L.). A few other species, including white beak-sedge, common cranberry and downy birch, occur singly (Boiński 2003). On the open water the *Nymphaeetum candidae* association was present. Adjacent to the *Sphagno-Caricetum rostratae* was a *Sphagnetum magellanici* association, with magellanic bog-moss (*Sphagnum magellanicum* Brid.), common cranberry, sheathed cottonsedge, common sundew (Fig. 11), strict haircap (*Polytrichum strictum* Brid.) and bog groove-moss; accompanying species were flat-topped bog-moss, common cotton-grass and bog arum (*Calla palustris* L.) (Fig. 12).

Fig. 9. The view at Lake Martwe in the bog reserve with the same name
Rys. 9. Widok na Jezioro Martwe w rezerwacie torfowiskowym o tej samej nazwie

Fig. 10. The edge of the *Sphagnum* floating mat at Lake Martwe
Rys. 10. Brzeg pła torfowcowego na Jeziorze Martwym

Fig. 11. Common sundew (*Drosera rotundifolia* L.) at the shore of Lake Martwe
Rys. 11. Rosiczka okrągłolistna (*Drosera rotundifolia* L.) na brzegu Jeziora Martwe

Fig. 12. Bog arum (*Calla palustris* L.) at the shore of Lake Martwe
Rys. 12. Czermień błotna (*Calla palustris* L.) na brzegu Jeziora Martwe

3.1.4. Jeziorka Kozie

The 'Jeziorka Kozie' Nature Reserve is located in the same units of physical-geographical, geo-botanical and nature-forest regionalization as 'Jezioro Łyse', in Kujawy-Pomerania province, 75 km north from Bydgoszcz, Tuchola district and Tuchola commune (Boiński & Boińska 2003). It belongs to Woziwoda forest division, Woziwoda forest circle and Woziwoda forest district (http://www.torun.lasy.gov.pl).

The 'Jeziorka Kozie' is a water reserve (http://www.torun.lasy.gov.pl) that was created in 1984 to protect the overgrowing ponds with typical raised bog plant communities. The total area of the reserve is 12.30 ha and it includes four complexes (2.27 ha, 4.22 ha, 3.26 ha and 2.55 ha, respectively); three are situated close to each other and have dystrophic ponds surrounded by bogs, and the other one, ca. 600 m distant from them, is covered by pine bog forest. The largest part of the reserve (10.26 ha) is covered by the forest, 1.58 ha by water and 0.46 ha by the bog. Ponds K1, K2 and K3 cover 0.64 ha, 0.40 ha and 0.54 ha, respectively (Boiński & Boińska 2003). There are floating islands on pond K1 (Fig. 13).

The climate is similar to that of the 'Martwe' reserve. The soils are peat soils of raised bogs. They vary however, from oligotrophic peat in the contact zone with the *Sphagnum* mat, to transitional peat at the shore zone (Boiński & Boińska 2003).

Fig. 13. Picturesque pond K1 with floating islands in the 'Jeziorka Kozie' reserve
Rys. 13. Malownicze jezioro K1 z pływającymi wyspami w rezerwacie „Jeziorka Kozie"

The plant communities change much within a small distance from the ponds. The *Sphagnum* mat consists of *Rhynchosporetum albae* and *Sphagnetum magellanici*, its edge is occupied by pine bog forest, and parts of ponds belong to *Scirpetum lacustris* association (Boiński & Boińska 2003).

The main aim of protection in the reserve are 1) four dystrophic ponds in different stages of succession with associations *Nupharo-Nymphaeetum albae* and *Nymphaeetum candidae*, floating mat overgrowing the ponds (associations: *Rhynchosporetum albae*, *Caricetum limosae*, a variant with *Eriophorum angustifolium* Honck., *Caricetum nigrae*, *Caricetum lasiocarpae*, *Calamagrostietum neglectae*, *Sphagnetum magellanici sphagnetosum fallacis* and *Sphagnetum magellanici*), 2) the process of pond overgrowth, 3) the succession of forest communities on the bog, and 4) the succession of bog forests, *Sphagnetum magellanici pinetosum* and *Vaccinio uliginosi-Pinetum ledetosum*.

In the reserve there are many protected, rare and relict plant species, such as English sundew, long-leaved sundew, common sundew, black crowberry (*Empetrum nigrum* L.), brown beak-sedge, small cranberry (a glacial relict), shining water-lily and many others. The majority of the forest in the reserve (8.52 ha; i.e. 69%) is pine bog forest, where the tree layer is composed of common pine, with occasional addition of silver birch; the herb layer consists mainly of sheathed cottonsedge and moss layer of *Sphagnum* mosses. The forest has probably grown naturally and has differentiated age (1-80 years old), with single older pine trees. The rest of the area (2.20 ha) is covered by bog mixed coniferous forest (*Vaccinio uliginosi-Betuletum pubescentis*), with abundant mesophilous species in the herb layer, including spinulose wood fern [*Dryopteris carthusiana* (Vill.) H.P. Fuchs] and broad buckler fern [*D. dilatata* (Hoffm.) A. Gray] (Boiński & Boińska 2003).

Study sites were located at the shoreline of ponds K1 and K2 (Fig. 14), with *Rhynchosporetum albae* plant association, where herb and moss cover was respectively 90% and 100%. In total, eight species were found there, with white beak-sedge (cover 50%) and flat-topped bog-moss (cover 75%) dominant. Common cotton-grass, straw-colored water moss and common cranberry were relatively abundant. Less abundant were: marsh cinquefoil, common sundew and milk-parsley [*Peucedanum palustre* (L.) Moench] (Boiński & Boińska 2003).

Fig. 14. Pond K2 in the 'Jeziorka Kozie' reserve
Rys. 14. Jezioro K2 w rezerwacie „Jeziorka Kozie"

At the shore of pond K3 there was a *Caricetum lasiocarpae* community (Fig. 15), where herb cover was 80% and moss cover, 70%. In total 11 species were represented there, with slender sedge dominant (cover 75%), while in moss layer flat-topped bog-moss and bog groove-moss were abundant. Few other species, including common cotton-grass, buckbean, slender haircap [*Polytrichastrum longisetum* (Sw. ex Brid.) G.L. Smith] and common cranberry were less abundant and other plants, like marsh cinquefoil, white beak-sedge, bowles golden sedge (*Carex elata* All.) and bog rosemary occurred only singly (Boiński & Boińska 2003).

Fig. 15. Pond K3 in the ‘Jeziorka Kozie’ reserve
Rys. 15. Jezioro K3 w rezerwacie „Jeziorka Kozie”

3.2. OTHER LAKES AND PONDS

3.2.1. Forest ponds near Pruszcz Bagienica

The forest ponds near Pruszcz Bagienica are situated in the Southern Pomeranian Lakeland macroregion and Brda Valley mesoregion (Kondracki 2009). In geo-botanical classification, they belong to the same units as ‘Jezioro Łyse’, while according to nature-forest classification they are in Wielkopolska-Pomerania land, Krajeńskie Lakeland district and Brda Valley mesoregion (Trampler et al. 1990). They are located in Kujawy-Pomerania province, ca. 50 km north from Bydgoszcz, in Tuchola district and Gostycyn commune (http://www.torun.lasy.gov.pl). In forestry administration they are situated in Zamrzenica forest division, Zamrzenica forest circle and Pieńkowo forest district (http://www.torun.lasy.gov.pl).

The Brda Valley was a route for melting waters flowing from the Charzykowo Plain and Tuchola Plain during the Pomeranian phase of the Vistulian glaciation. The valley is 50 km long and has 11 terraces. The landscape has outwash plain, lake character (Trampler et al. 1990). It is rich with water; the Brda River is fed by many smaller rivers and streams, and there are abundant lakes and ponds, many created by melting of the residual ice blocks. The biggest water body, Koronowo Reservoir, is an artificial lake, and was created by building a dam (23 m high) and a hydroelectric power station on the Brda River;

some adjacent ponds formed by melting residual ice blocks have been added to it (Kondracki 2009). Building of the dam took place in the years 1956-1960 and after this Koronowo Reservoir was filled with water, achieving the maximum level in 1962. Creating of the Koronowo Reservoir resulted in many transformations in the surrounding area, as described in detail by Kowalewski (2003), including the appearance of numerous lakes and ponds. Due to rather poor soils (mainly brown rusty soil and loose sandy soil), the main type of forest here is fresh pine forest (*Leucobryo-Pinetum*) and fresh mixed coniferous forest.

The precipitation is 500-600 mm a year and the mean annual temperature is 7-8ºC. The coldest month is January, with the mean temperature –2 to –3ºC, and the warmest is July, with the mean temperature 18-19ºC. Compared to the reserves described above, spring and autumn start earlier (25-30 April and 5-10 September, respectively). The vegetation period lasts 210-220 days (Trampler et al. 1990).

The investigated ponds P1, P2 and P3 are located in forest section 211, with pond P2 partly in section 210. These ponds appeared after the dam was built; earlier in their place there were swamps, which had in 1951 an area of 3,918 m^2, 994 m^2 and 328 m^2, respectively (Kowalewski 2003). According to aerial photo from 1985 the area of these swamps was 5,570 m^2, 3,408 m^2 and 1,299 m^2 and open water occupied 5,570 m^2, 2,002 m^2 and 871 m^2, respectively.

These ponds are surrounded by fresh mixed coniferous forest dominated by common pine, 91-103 years old. In the section 211 silver birch and pedunculate oak (*Quercus robur* L.), 91-year old, also occur. The shrub layer consists of common juniper, birch, oak, European beech (*Fagus sylvatica* L.) and pine. In section 210 locally occurs pedunculate oak (on average 103-years old), silver birch (73-years old) and sessile oak [*Quercus petraea* (Mattuschka) Liebl., 53-years old]. In the shrub layer there is common juniper, alder buckthorn, pine, birch and oak (based on forest records from the Zamrzenica forest division office).

Along the shore of pond P1 (Figs. 16 and 17) there was a *Caricetum ripariae* plant association. Cover of the shrub layer was 1%, herb layer 70% and moss layer 40%. In total 32 species were recorded and most abundant was great pond sedge (*Carex riparia* Curtis) with a cover of 50%. Relatively abundant (cover 25%) were: large bittercress (*Cardamine amara* L.), cypress-like sedge (*Carex pseudocyperus* L.), two-ranked sedge (*C. disticha* Hudson) and neat feather-moss [*Pseudoscleropodium purum* (Hedw.) M. Fleisch. ex Broth.]. Less abundant (cover 5%) were: creeping bentgrass (*Agrostis stolonifera* L.), purple smallreed [*Calamagrostis canescens* (Weber ex F.H. Wigg.) Roth], spinulose wood fern, common marsh bedstraw (*Galium palustre* L.), common rush, wood-sorrel (*Oxalis acetosella* L.), rough bluegrass (*Poa trivialis* L.), eastern marsh fern (*Thelypteris palustris* Schott), red-stemmed feather-moss [*Pleurozium schreberi* (Willd. ex Brid.) Mitt.] and glittering wood-moss [*Hylocomium splendens* (Hedw.) Schimp.]. Other species occurred singly.

At pond P2 (Figs. 18 and 19) there was a *Scirpetum sylvatici* plant association.

Fig. 16. Forest pond P1 near Pruszcz Bagienica
Rys. 16. Śródleśne jezioro P1 koło Pruszcza Bagienicy

Fig. 17. Moss *Pseudoscleropodium purum* at the shore of pond P1
Rys. 17. Mech *Pseudoscleropodium purum* na brzegu jeziora P1

Fig. 18. Forest pond P2 near Pruszcz Bagienica
Rys. 18. Śródleśne jezioro P2 koło Pruszcza Bagienicy

Fig. 19. *Sphagnum* patches at the shore of pond P2
Rys. 19. Płaty torfowca na brzegu jeziora P2

Cover of the shrub layer was 2%, herb layer 80% and moss layer 40%. In total 27 species were recorded and several had a cover of 25%: two-ranked sedge, slender tufted-sedge (*Carex gracilis* Curt.), slender sedge, bottle sedge, water horsetail (*Equisetum fluviatile* L.), floating pondweed (*Potamogeton natans* L.), woodland bulrush (*Scirpus sylvaticus* Fernald), neat feather-moss and flat-topped bog-moss. Less abundant, with a cover of 5%, were: creeping bentgrass, purple smallreed, cypress-like sedge, spinulose wood fern, marsh willowherb (*Epilobium palustre* L.), red-stemmed feather-moss and glittering wood-moss. Few other species occurred only occasionally.

At pond P3 (Fig. 20) there was a *Caricetum lasiocarpae* plant association. Cover of shrub layer was 1%, herb layer 70% and moss layer 50%. In total 25 species were recorded and slender sedge was most abundant (cover 50%). Relatively abundant (cover 25%) were great pond sedge, neat feather-moss and spiky bog-moss (*Sphagnum squarrosum* Crome). Less abundant (cover 5%) were creeping bentgrass, large bittercress, star duckweed (*Lemna trisulca* L.), purple moor-grass [*Molinia caerulea* (L.) Moench], yellow water-lily, floating pondweed, bracken [*Pteridium aquilinum* (L.) Kuhn] and red-stemmed feather-moss, glittering wood-moss, bank haircap (*Polytrichastrum formosum* (Hedw.) G.L. Smith] and flat-topped bog-moss, while other species occurred only singly.

Fig. 20. Forest pond P3 near Pruszcz Bagienica
Rys. 20. Śródleśne jezioro P3 koło Pruszcza Bagienicy

3.2.2. Bagno Chlebowo

The ‘Bagno Chlebowo’ Nature Reserve is situated in the Toruń-Eberswald Ancient Valley macroregion and Gorzów Valley mesoregion (Kondracki 2009). Following the geo-botanical classification, it is located in the Wielkopolska-Kujawy land and Noteć district (Szafer 1972). According to nature-forest classification it belongs to Wielkopolska-Kujawy land, Gorzów Valley district and Noteć Forest mesoregion (Trampler et al. 1990). The reserve is located in Wielkopolska province, 35 km north from Poznań, Oborniki district and Ryczywół commune; on the territory of Krucz forest division, but is not managed by forest administration (http://www.pila.lasy.gov.pl).

‘Bagno Chlebowo’ Nature Reserve covers an area of 4.63 ha (Gawroński et al. 2008) that is only a small, central part of the entire bog, which has an area of 465.30 ha (Szkudlarz et al. 2002). The reserve occupies a basin, with a slightly western exposure, surrounded from the north, west and south by dune ridges. Its outer zone, due to drainage, is covered by meadow and transitional bog communities, and the central part by dead bog. The area is surrounded by pine forest cut by small patches of heathlands, sand grasslands and agricultural fields (Szkudlarz et al. 2002).

The climate of ‘Bagno Chlebowo’ is characterized by low precipitation, 500-600 mm and a mean annual temperature of 7-8ºC. The mean temperature of January is –2 to –3ºC, and the mean temperature of July, 18-19ºC. Spring starts from 30 April to 5 May and, and autumn from 5-10 September. The vegetation period lasts 210-220 days (Trampler et al. 1990).

The average depth of peat is 2.5 m, and gyttja 1.1 m, and the total depth of deposits is 3.7 m. Raised bog peat is present only in the central part of the ‘Bagno Chlebowo’ complex and it is not deep (roof layer 0.2-0.9 m). Below there are poorly and moderately decomposed fen deposits with *Carex* and mosses, deeper − detritus gyttja, below it mineral-lime gyttja and organic-loamy and loamy gyttja, and a still deeper sand layer (Peplińska 1995).

The reserve was created in 1959 to protect the raised bog, which was destroyed more than 100 years ago by peat mining. The preliminary drainage of the bog, by the Ludomicki Canal and system of ditches, started in the 19th century. Later, melioration was carried out to protect the arable fields of the neighboring villages from flooding (Ilnicki 1989). Lowering of the water table enabled peat-cutting, but negatively influenced the peat vegetation. Before the Second World War the peat was cut manually in the outer zone of the complex, in the northern and western part, and after the war it was exploited mechanically, even from deep deposits, in the central part of the complex. Peat mining resulted in formation of several dozens of peat ponds, which are up to several hectares in area and up to 2.5 m deep. In some places peat is still exploited, so these ponds are continuously being enlarged (Szkudlarz & Celka 2004). In the central part of bog the water level in ponds and ground is 0.3-0.6 m

(Peplińska 1995). The use of mechanical equipment resulted in building of hard surface roads in the bog (Celka & Szkudlarz 2010).

The habitat conditions and plant communities have been changed considerably but regeneration can be already observed in different stages (Peplińska 1995). The flora in the bog is still rich and includes over 300 species (Celka & Szkudlarz 2006). The outer zone, where peat was cut at a shallow depth, is now covered by forest and shrub communities with downy birch and common pine, and places where peat was exploited are now not easily distinguishable (Szkudlarz & Celka 2004). Succession does not result in the restoration of the previously existing plant communities, but leads to favorable conditions for some typical bog species, like sheathed cottonsedge, common cranberry, common sundew or Labrador tea (Celka & Szkudlarz 2006). The regeneration of peat-forming communities is possible, but it is a slow process and dependent on several factors; most important among them is preservation or raising the ground-water table (Ilnicki 1996, 2002).

A study site was located at the shore of the pond (Fig. 21) in the central part of the bog, where plant community was dominated by broadleaf cattail (*Typha latifolia* L.), which grows on silty, acid bottom. On one side it adjoined open water and on the other side it neighbored a *Scheuchzerio-Caricetea fuscae* and *Phragmitetea* community.

Fig. 21. Peat pond in the ‘Bagno Chlebowo’ reserve
Rys. 21. Dół potorfowy w rezerwacie „Bagno Chlebowo”

The shrub cover was 10%, herb cover 60%, moss cover 95%, and in total 13 species were recorded. In the herb layer broadleaf cattail and common cranberry dominated (cover 50%). Relatively abundant (cover 25%) were: silvery sedge (*Carex canescens* L.), Labrador tea, common cotton-grass, common rush, creeping bentgrass, great yellow loosestrife (*Lysimachia vulgaris* L.). Other species, like marsh willowherb and gypsywort (*Lycepus europaeus* L.) occurred only singly. The moss layer was composed of flat-topped bog-moss (Fig. 22) with 100% cover.

Fig. 22. Peat moss at the shore of peat pond in the 'Bagno Chlebowo' reserve
Rys. 22. Mech torfowiec na brzegu dołu potorfowego w rezerwacie „Bagno Chlebowo"

Present in the shrub layer were: downy birch and alder buckthorn (cover 25%) (Kępczyński & Peplińska 1998).

3.2.3. Okonek

The 'Okonek' Nature Reserve is situated in the Chełmińsko-Dobrzyńskie Lakeland macroregion and Brodnica Lakeland mesoregion (Kondracki 2009). Following the geo-botanical classification, it is located in the Pomeranian Lakeland land and Iława district (Szafer 1972). According to nature-forest classification it belongs to the Baltic land, Iława-Brodnica Lakeland district and Brodnica Lakeland mesoregion (Trampler et al. 1990). It is in Kujawy-Pomerania province, Brodnica district and Zbiczno commune (Rejewski 1995a). Following forestry administration, the reserve is situated in the Brodnica forest division, Zbiczno forest circle and Grabiny forest district (http://www.torun.lasy.gov.pl). It belongs to the Brodnica Landscape Park (Rejewski 1995a).

The reserve was established in 1963, although much earlier it has been considered as a very valuable area with many rare plant species (Czubiński

1937). The reserve has an area of 9.04 ha, including 3.18 ha of forest, 4.82 ha of lake and 1.04 ha of bog. There is a buffer zone around the reserve, formed by the forest of an area 18.27 ha (Rejewski 1995a).

The reserve is situated on an undulating outwash plain terrain, created during the last glaciation. The dominant landscape is outwash plain, lake landscape. Four soil types have been distinguished in the reserve. Peat soils of raised bogs, created from peat moss, ca. 120 cm deep, together with growing on them communities are the most valuable in the reserve. Peat soils of transitional bogs, created from *Sphagnum* and *Carex* peat, occupy a relatively large area of the reserve (2.50 ha) and are typical for poorer birch bogs. Podzolic soils and gley soils cover small areas in the reserve and are formed from outwash plain sands; the former type is covered by fresh mixed coniferous forest, the latter by moist mixed coniferous forest (Rejewski 1995a).

The climate of the area is characterized by precipitation of 580-620 mm per year, with ca. 230 mm during the growing season (Rejewski 1995a). The mean annual temperature is 7-8ºC. In the coldest month, January, the mean temperature is –3 to –4ºC, and in the warmest month, July, 17-18ºC. Spring starts from 30 April to 5 May, and autumn starts from 5-10 September. The vegetation period lasts on average 200-210 days (Trampler et al. 1990).

Okonek is a dystrophic lake (Fig. 23) that is poor in water plants, and water community *Nupharo-Nymphaeetum albae* rarely occurs here.

Fig. 23. Initial stages of pine bog forest at Lake Okonek in Brodnica Lakeland

Rys. 23. Inicjalne stadium boru bagiennego nad Jeziorem Okonek na Pojezierzu Brodnickim

A floating mat has been formed in the process of overgrowing of the lake. On the edge or in the depressions of this mat the communities from the class *Scheuchzerio-Caricetea fuscae*, mainly *Rhynchosporetum albae*, *Caricetum limosae* and *Caricetum lasiocarpae* are present. In higher parts of the mat there is mainly a community of *Sphagnetum magellanici*, in some parts with a dwarf form of common pine. The floating mat communities include many interesting plants, like small cranberry (a glacial relict), long-leaved sundew, common sundew, rusty bog-moss [*Sphagnum fuscum* (Schimp.) Klinggr.], red bog-moss (*S. rubellum* Wils.) and *Cephalozia fluitans* (Nees.) Spruce.

On the border of the floating mat and stable bog there are small phytocenoses of young pine bog forest, with abundant Labrador tea in the herb layer. Around the floating mat, in the contact zone with mineral soils, there are belts of birch thickets that represent developmental stages of bog mixed coniferous forest. This forest is composed mainly of downy birch and some common pine, ca. 4-12 years old. In the herb layer sheathed cottonsedge and stiff clubmoss are present. At the edge of the bog there are small groups of *Salicetum pentandro-cinereae* and mesotrophic *Sphagno squarrosi-Alnetum*. Within of the reserve, the bog is surrounded by fresh mixed coniferous forest and in some parts by moist mixed coniferous forest. In the fresh mixed coniferous forest common pine dominates, with addition of European larch (*Larix decidua* Mill.) and some downy birch. Common pine is 102-117 years old (Rejewski 1995a).

The lake is being overgrown, with succession leading to the replacement of the forestless areas by the forest communities. The excessive development of birch bog forest might be a threat for the floating mat and its valuable communities. However, due to cyclic floods that occur in the reserve every few years or every few decades, the floating mat can exist.

A study site was located at the edge of floating mat, with *Rhynchosporetum albae* plant association (Fig. 24), and in the open water there was *Nupharo-Nymphaeetum albae* community. Herb cover was 70% and moss cover was 100%. In total 17 species were recorded and white beak-sedge, flat-topped bog-moss and red bog-moss were dominant (cover 50%). Relatively abundant (cover 25%) was common sundew, and less abundant (cover 5%): common cotton-grass, *Cephalozia fluitans*, straw-colored water moss, common cranberry, and bog rosemary and magellanic bog-moss. The other species occurred only singly: rannoch-rush, mud sedge, silvery sedge, English sundew, small cranberry, and small pine trees and downy birch (Rejewski 1995a).

Fig. 24. *Rhynchosporetum albae* plant community at Lake Okonek
Rys. 24. Zespół *Rhynchosporetum albae* nad Jeziorem Okonek

3.2.4. Stręszek

The ‘Stręszek’ Nature Reserve is situated in the same physical-geographical, geo-botanical, nature-forest, and administrative units as ‘Okonek’, in the Brodnica forest division, Zbiczno forest circle and Ryte Błota forest district (http://www.torun.lasy.gov.pl) and belongs to the Brodnica Landscape Park (Rejewski 1995b).

The presence of unique and rare plant communities around Lake Stręszek has drawn the attention of botanists, including Czubiński (1937) and Kępczyński (1959), and based on their detail studies of the flora, the reserve was established in 1963. The reserve covers an area of 4.46 ha, including 1.15 ha of forest, 2.46 ha of lake and 0.85 ha of bog. Around the reserve there is a buffer zone of 13.68 ha (Rejewski 1995b).

The landscape and climate are the same as in the ‘Okonek’ reserve. The soils belong to two types: peat soils of transitional bogs, created from *Sphagnum* and *Carex* peat, occupy the edge of the reserve and create stands of bog mixed coniferous forest; and peat soils of raised bogs, which occur under floating mat around the lake and are created from *Sphagnum* peat, ca. 120 cm deep (Rejewski 1995b).

The most interesting phytocenoses occur on the floating mat surrounding the lake, which has irregular shape (Fig. 25) and often creates peninsulas or even islands. At the edge of this floating mat, and in the depressions, *Rhynchosporetum albae* is the most common association, while *Caricetum limosae* and *Caricetum lasiocarpae* seldom occur. In higher parts of the mat a *Sphagnetum magellanici* community develops, overgrown with a few dwarf trees of common pine. The characteristic species in the reserve is small cranberry; also abundant is common sundew, white beak-sedge, mud sedge, rannoch-rush, rusty bog-moss, red bog-moss and *Cephalozia fluitans* (Rejewski 1995b).

Fig. 25. Lake Stręszek in Brodnica Lakeland has irregular shape
Rys. 25. Jezioro Stręszek na Pojezierzu Brodnickim ma nieregularny kształt

In the parts of mat most distant from the lake there are small patches of pine bog forest, most often represented by developmental stages, with young pine trees, and abundant Labrador tea. Forest stands are also represented by young growth of downy birch and silver birch, which are developmental stages of *Betuletum pubescentis*. The birch and pine is in the first age class and their mean height is 3 m and 1 m, respectively. Different types of birch forest can be found in the reserve, from more dry, with wavy hairgrass [*Deschampsia flexuosa* (L.) Trin.] in herb layer, through moister, with sheathed cottonsedge, to wet, with bottle sedge or common cotton-grass. In the birch forest there are also enclaves of forestless communities, like degenerated *Sphagnetum magellanici*, with dominant sheathed cottonsedge, or *Caricetum lasiocarpae* community, or, in wet places *Sphagno-Caricetum rostratae*, or community with common cotton-grass (Rejewski 1995b).

The young birch forest has grown naturally since ca. 1982 or 1983, when after heavy rains and flooding, the pine forest died. The development of birch forest might be problematic for the bog in the future, as forest biomass will increase and develop high pressure on the peat surface. Also, the transpiration of considerable amounts of water may change water conditions in the neighboring floating mat, so careful observations are necessary (Rejewski 1995b). However, at the moment no action is needed, either with birch forest or with the floating mat that is slowly overgrowing the lake. The aim of protection is to retain the present bog ecosystems without changes. However, e.g. English sundew, which has been reported previously from the reserve, is not found here any longer, which indicates gradual changes of the plant communities in the bog (Rejewski 1995b).

A study site was located at the edge of floating mat, in a *Rhynchosporetum albae* plant association (Fig. 26).

Fig. 26. The edge of the *Sphagnum* mat at Lake Stręszek
Rys. 26. Brzeg pła torfowcowego nad Jeziorem Stręszek

Herb cover was 75% and moss cover was 95%. In total 13 species were recorded and dominant was beak-sedge and flat-topped bog-moss (cover 75%). Relatively abundant (cover 25%) were: magellanic bog-moss and blunt-leaved bog-moss (*Sphagnum palustre* L.), while less abundant (cover 5%) were: common cotton-grass, common sundew and red bog-moss. Only singly occurred: mud sedge, *Cephalozia fluitans*, straw-colored water moss, common cranberry, common pine and silver birch (Rejewski 1995b).

3.2.5. Kurze Grzędy

The 'Kurze Grzędy' Nature Reserve is located in Eastern Pomeranian Lakeland macroregion and Kashubian Lakeland mesoregion (Kondracki 2009).

Following the geo-botanical classification, the reserve is in the Pomeranian Lakeland land and Kartuzy district (Szafer 1972). According to nature-forest classification it belongs to Baltic land, Drawsko-Kashubian Lakeland district and Kashubian Lakeland mesoregion (Trampler et al. 1990). It is in Pomerania province, Kartuzy district and its major part (165.87 ha = 97%) is situated in Kartuzy commune and remaining area (4.83 ha = 3%), in Sierakowice commune (Herbich et al. 2009a). Following forestry administration, it is situated in the Kartuzy forest division, Mirachowo forest circle and Bącka Huta forest district (http://www.gdansk.lasy.gov.pl).

The Nature Reserve, with an area 39.95 ha, was established in 1916 to protect the breeding site of a capercaillie (*Tetrao urogallus* L.). After the Second World War the area of the reserve was 82.07 ha, and since 1989 it occupies 170.70 ha, i.e. it covers the entire peat deposit and is the largest such complex in the Kashubian Lakeland (Herbichowa et al. 2007; Herbich et al. 2009a). The name 'Kurze Grzędy' (meaning 'Hens Roosts') originates from the capercaillie. Although this species became extinct here before 1969, the reserve still constitutes a very important site for the protection of birds (Jakubas 2009).

The bog is situated on postglacial Sierakowice Upland, composed of boulder clays and sandy-clay deposits. The landscape is undulating and hilly (10-30 m), with numerous basins without runoff, which are filled with lakes, ponds and peatlands. The highest point of the bog cupola is 220 m a.s.l. and the lowest, at the edges, 214 m a.s.l. (Herbich et al. 2009a). The depth of the peat layer is relatively low; on average 2-3 m. Within the peat deposits several mineral hills occur.

The prevailing soils have developed from the raised bog peat and on the deposit edge, from the transitional peat. Both soil types have been transformed into muck, during artificial drainage of the peat deposits. On the moraine deposits most common are podzolic soils, formed from sands and loamy sands. Quite common are also brown podzolic and brown acid soils formed from moraine deposits, from sandy loams to loamy sands. In the lowest part, at the peat edge, there is podzolic muck. In some places there are rusty soils that originate from sands (Herbich et al. 2009a).

The climate in the central part of the Kashubian Lakeland is the coldest in the whole region. It is characterized by a high precipitation (700-800 mm year), the lowest absolute minimum temperature, a long period of snow cover, and many cloudy and foggy days (Herbich et al. 2009a). The mean annual temperature is 6-7ºC, the mean temperature of January is –2 to –3ºC, and the mean temperature of July, 17-18ºC. Spring starts from 5-10 May, and autumn from 10-15 September. The vegetation period lasts on average only 190-200 days (Trampler et al. 1990).

The reserve includes a complex of the Baltic raised bog (which is a special type of raised bogs as described in Chapter 2), transitional bogs and four dystrophic ponds in the area of the bog cupola (Herbichowa et al. 2007). In the southern part of the reserve the moss areas are cut by small pools and puddles

(Ciechanowski et al. 2009). The reserve ‘Kurze Grzędy’ was an open bog in the past, even at the end of the 19th century, but today, due to drainage, it is covered mostly by forest formed mainly by artificial tree stands. Some treeless moss areas are present only around the dystrophic ponds (Herbichowa et al. 2007; Pawlaczyk 2007).

The drainage of the bogs probably started in the middle of the 19th century (Herbich et al. 2009b), with the aim of decreasing the moisture conditions in the forest and increasing wood production (Herbich 2009). The system of drainage ditches was established and they drained off the water to the adjacent subglacial channels and ponds. Because the peat deposits are relatively shallow in ‘Kurze Grzędy’, the dewatering efficiency is high (Herbichowa et al. 2007). The drainage has resulted in lowering of the water table and this led, together with improper forest management, to the dramatic changes in the vegetation (Herbich & Herbichowa 2009b). The open bog communities were first supplanted by forest, which caused the recession and disappearance of herb- and moss-layer open bog species, especially *Sphagnum* mosses, *Baeothryon caespitosum* ssp. *germanicum* (Palla) A. Löwe & D. Löwe, and cross-leaved heath (*Erica tetralix* L.). Temporarily, luxuriant development of vegetation characteristic for pine bog forest (e.g. Labrador tea and bog bilberry) and birch bog forest (e.g. mass occurrence of stiff clubmoss and broad buckler fern) was observed. However, with the progressive drainage these forest communities have gradually deteriorated. Spruce monocultures, planted on stands of birch bog forest, were favored by these drier conditions and expanded there and also to other natural forest communities, occupying all forest layers. Little by little, the species characteristic for pine bog and birch bog forests disappeared; some places have been invaded by purple moor-grass, and generally impoverishment in species composition and age structure of many forest phytocenoses has been observed (Herbich & Herbichowa 2009b).

Today, the dominant vegetation types in the reserve are pine bog forest and bog mixed coniferous forest. A considerable area is also occupied by monocultures of spruce, which is an alien species in this region (Szydlarski 2009). The conservation of drainage ditches was stopped in 1985 so some of them have been overgrown; others were dammed (Herbichowa et al. 2007). Still more damming barriers on ditches are planned, and another important step to preserve the bog is removal of spruce within 20 years (Herbichowa et al. 2007).

A study site was located at the pond (Fig. 27) situated in the forest district 102i; it does not have a name, but, together with the neighboring smaller pond, it is called ‘Bule Oczy’ by the local people (Herbich et al. 2009a). This pond has an area of ca. 0.13 ha and, like other ponds in the reserve, is polyhumus and surrounded by *Sphagnum* mat, which shows the characteristics of the transitional bog. Water in the pond is cold, very acid, little fertile and poor in oxygen (Ciechanowski et al. 2009). Because of very acid water, no fish lives there, but other interesting specific fauna have been found (Ciechanowski et al. 2009).

Fig. 27. Regeneration of the floating *Sphagnum* mat and dying out of trees as result of water table rise in dystrophic pond in the ‘Kurze Grzędy’ Nature Reserve
Rys. 27. Regeneracja pła mszarnego i zamieranie drzew w efekcie podniesienia poziomu wody w jeziorze dystroficznym w Rezerwacie Przyrody „Kurze Grzędy”

At the pond shore the plant community was *Eriophoro angustifolii-Sphagnetum recurvi* (Herbich & Herbichowa 2009a). Phytocenoses of this community are poor in species and dominated by common cotton-grass and flat-topped bog-moss. Sometimes other species, like common cranberry or feathery bog-moss (*Sphagnum cuspidatum* Ehrh. ex Hoffm.), were also present. The pond is surrounded by bog mixed coniferous forest that is composed of common pine, Norway spruce and downy birch; in some places additional species, including European larch, European beech and pedunculate oak can be found (Szydlarski 2009).

4. METHODS

4.1. WATER ANALYSES

Water was taken from 16 water bodies located in northern Poland (Fig. 2); those larger than 1 ha are called lakes and smaller − ponds. Nine of them were located in the bog reserves in Tuchola Forest, Pomerania: Lake Łyse (referred later as L; Figs. 3 and 4), four ponds (D1, D2, D3, D4; Figs. 5-8) in 'Dury' reserve, Lake Martwe (M; Figs. 9-12) and three ponds (K1, K2, K3; Figs. 13-15) in 'Jeziorka Kozie' reserve. Other water bodies included three forest ponds (P1, P2, P3; Figs. 16-20) near Pruszcz Bagienica in Tuchola Forest, the peat pond (BC; Figs. 21 and 22) in 'Bagno Chlebowo' reserve in Wielkopolska province, two lakes (O, S; Figs. 23-26) in 'Okonek' and 'Stręszek' bog reserves in Brodnica Lakeland and a pond (KG; Fig. 27) located in 'Kurze Grzędy' reserve in Kashubian Lakeland.

For the water analyses 3 dm^3 of water were taken from each lake and pond at a distance 2 m from the shoreline in summer. The water analyses were performed in the Laboratory of Environmental Protection of Naftobazy Baza Paliw nr 2 in Nowa Wieś Wielka, near Bydgoszcz. The analyses followed the standard protocols of analytical manual, designations of which are given in the parenthesis next to each analyzed parameter and they included: pH (pH meter, PN-90/C-04540.01), conductivity (PN-EN 27888:1999), color (PN-EN ISO 7887), COD (PN-74/C-04578.03), BOD_5 (PN-EN 1899-1:2002, PN-EN 1899-2:2002), chlorides (PN-75/C-04617.02, PN-ISO 9297:1994), sulphates (PN-74/C-04566.09), total phosphorus (PN-88 C-04537/04, PN-EN 1189:2000) and total iron (PN-ISO 6332:2001); all measurements were done at 20ºC.

4.2. INVESTIGATION OF MITES

Samples of mosses, each 100 cm^2 and 5 cm deep, were cut out with knife from the substrate at the edges of lakes and ponds in 10 replicates. At the edges of nine water bodies in the reserves in Tuchola Forest (L, D1, D2, D3, D4, M, K1, K2, K3) mites were sampled in three seasons (spring, summer and autumn) of 2006, while in the other water bodies (P1, P2, P3, BC, O, S, KG) samples were taken in summer or autumn. Except for pond P1, where neat feather-moss occurred, *Sphagnum* mosses were present at all water bodies, with flat-topped bog-moss dominating. The localities of all 16 water bodies and the dates of sampling are given in Table 1.

Additionally, at lake M a transect of four plots at different distances from the water's edge was investigated. Plot 1 was located at the water's edge, while plots 2, 3 and 4 were 1 m, 3 m and 5 m away from open water, respectively. From each plot 10 samples of *Sphagnum*, each 100 cm^2 and 5 cm deep, were taken in spring of 2006. Each sample was weighted before and after the extraction, to determine the water content in mosses and for each plot the average water content was calculated.

Table 1. Locality of the study sites and sampling dates
Tabela 1. Położenie terenu badań i daty pobrania prób

Lake/Pond Jezioro	Locality Położenie	Geographical coordinates Współrzędne geograficzne	Height above sea level Wysokość nad poziomem morza (m)	Sampling dates Daty pobrania prób
L	‘Jezioro Łyse’ Nature Reserve Rezerwat Przyrody „Jezioro Łyse”	53°40’53” N, 18°26’11” E	87	29.05.2006 22.07.2006 17.09.2006
D1	‘Dury’ Nature Reserve Rezerwat Przyrody „Dury”	53°38’20” N, 18°21’14” E	102	29.04.2006 28.07.2006 17.09.2006
D2		53°38’20” N, 18°21’22” E	104	
D3		53°38’02” N, 18°21’32” E	105	
D4		53°37’56” N, 18°21’42” E	102	
M	‘Martwe’ Nature Reserve Rezerwat Przyrody „Martwe”	53°37’05” N, 18°12’07” E	118	28.05.2006 19.08.2006 17.09.2006
K1	‘Jeziorka Kozie’ Nature Reserve Rezerwat Przyrody „Jeziorka Kozie”	53°41’21” N, 17°53’33” E	117	29.05.2006 06.08.2006 22.10.2006
K2		53°41’20” N, 17°52’59” E	123	
K3		53°41’07” N, 17°53’00” E	124	
P1	Forest near Pruszcz Bagienica Las koło Pruszcza Bagienicy	53°26’08” N, 17°53’10” E	93	09.10.2005
P2		53°26’05” N, 17°53’14” E	92	
P3		53°26’04” N, 17°53’12” E	92	
BC	‘Bagno Chlebowo’ Nature Reserve Rezerwat Przyrody „Bagno Chlebowo”	53°44’17” N, 16°45’26” E	65	19.08.2007
O	‘Okonek’ Nature Reserve Rezerwat Przyrody „Okonek”	53°23’08” N, 19°24’29” E	84	27.08.2006
S	‘Stręszek’ Nature Reserve Rezerwat Przyrody „Stręszek”	53°22’57” N, 19°23’58” E	86	27.08.2006
KG	‘Kurze Grzędy’ Nature Reserve Rezerwat Przyrody „Kurze Grzędy”	54°23’52” N, 17°57’51” E	221	21.06.2007

The mites were extracted in Tullgren funnels for two weeks (temperature above the samples was 33ºC the first week, and 43ºC the second), and preserved in 70% ethanol. Adult and juvenile Oribatida were separated from Mesostigmata and other Acari, cleared in concentrated lactic acid and identified to species level or genus, and some juveniles to family. The names of species and systematics follow Weigmann (2006). The juveniles of abundant species were investigated earlier, and I identified them based on diagnostic morphological characters from many sources (Willmann 1931; Tuxen 1943, 1952; Shaldybina 1965, 1969; Seniczak 1971/1972a, b, 1975, 1978a, b, 1980, 1988, 1989, 1991, 1992, 1993; Seniczak & Solhøy 1988; Seniczak & Klimek 1990; Seniczak et al. 1990, 1998, 2007, 2009b, c; Seniczak & Żelazna 1992; Seniczak & Norton 1994; Weigmann 2006; Seniczak & Seniczak 2007a, b, 2008a, b, 2009a, b, c, 2010; Ermilov 2009). Only Brachychthoniidae were pooled together, because of problematic diagnostic characters of tritonymphs (they are similar to freshly molted adults). Other species were determined based on my own observations, not yet published. For difficult determinations of juvenile oribatid mites I consulted with prof. dr. hab. S. Seniczak (Department of Ecology, University of Technology and Life Sciences, Bydgoszcz, Poland).

The morphological methods of studies of the juvenile stages of Oribatida are described in the following papers: Seniczak et al. (2007, 2009b, c), Seniczak & Seniczak (2007a, b, 2008a, b, 2009a, b, c, 2010). Based on these earlier studies, the key for determination of some abundant species was prepared. In figures I used the following abbreviations: prodorsal setae (*ro*, *le*, *in*, *exs* = *ex*, *exi*), bothridium (*bo*), sensillus (*ss*), gastronotal setae of Hypochthonioidea and Crotonioidea (*c*-, *d*-, *e*- *f*-, *h*- and *p*-series), and Brachypylina (*c*-, *d*-, *l*-, *h*- and *p*-series), opisthonotal gland opening (*gla*), and cupules (*ia*, *im*, *ip*).

Oribatid mite population density was characterized by abundance (*A*), dominance (*D*) and constancy (*C*) indices. The oribatid mite communities were characterized by the number of species (*S*) and the Shannon diversity index (*H*s) (Odum 1982). The classes of dominance follow Seniczak (1978a) and include:

Superdominants	$D > 40$
Eudominants	$20 < D\ \Omega 40$
Dominants	$10 < D\ \Omega 20$
Subdominants	$5 < D\ \Omega 10$
Recedents	$1 < D\ \Omega 5$
Subrecedents	$D\ \Omega 1$

The basic statistical analyses included the minimum, maximum, mean values and standard deviation. The abundance of mites between lakes and ponds was compared in summer, except ponds P1, P2, P3, where autumn samples were considered. For the other statistical analyses the values were log-transformed LN (x+1) (Berthet & Gerard 1965; McDonald 2009; Łomnicki 2010). The normality of the distribution was tested with the Kolmogorov-Smirnov test and the equality of variance in different samples with the Levene's test. When the assumption of normality or equality of variance was not met a non-parametric Kruskal-Wallis test was used, followed by Mann-Whitney U test. The Spearman rank correlation coefficient (Bolboacă & Jäntschi 2006) was used to measure the correlation between the variables, i.e. different water parameters and the density of mites in summer (except for ponds P1, P2 and P3 where only autumn samples were collected). The interpretation of the correlation coefficient (r_{Spm}) follows Stanisz (2006). Accordingly, the correlation is considered almost certain when correlation coefficient is between 0.9 and 1, very high when it is between 0.7 and 0.9, high when it is between 0.5 and 0.7, moderate when it is between 0.3 and 0.5, and weak with correlation coefficients between 0 and 0.3. The above statistical calculations were carried out with STATISTICA8 software, while the cluster analysis was performed with MVSP3.1.

Scanning electron microscopy (SEM) micrographs were taken in the Laboratory of Electron Microscopy at the Faculty of Mathematics and Natural Sciences at the University of Bergen (Norway), during 4-month stays in 2005 and 2008 that were supported by scholarships from the Norwegian Research Council. For SEM the mites were fixed in 70% ethanol and then dehydrated using graded ethanol. After an intermediate step with amylacetate, specimens were dried with a Polaron Critical Point Drying Apparatus E3000 (using liquid CO_2 as the final medium). Specimens were coated with Au/Pd in a Polaron SC502 Sputter coater and placed on Al-stubs with a double-sticky carbontape. Observations and most micrographs were made with a ZEISS Supra 55VP scanning electron microscope, except Figs. 85, 86, 91 and 92 that were made with JEOL JBM6400 scanning electron microscope.

5. RESULTS

5.1. ECOLOGICAL STUDIES

5.1.1. Water parameters

The highest pH value (7.77) was noted in forest pond P1; water was neutral in two neighboring ponds, P2 and P3 (Table 2). In lake L the pH was slightly lower, while other water bodies had acid water. The lowest pH value (3.60) was observed in pond KG.

Water conductivity was the highest in lake L (450.2 σS·cm^{-1}), and was relatively high in ponds K1, K2, K3, P1, P2 and P3. It was a bit lower in ponds BC and KG and several times lower in the remaining water bodies; the lowest value was noted in D3 (17.5 σS·cm^{-1}).

Color value was low in almost all studied water bodies (15-40 mg Pt·dm^{-3}); except for ponds BC and KG, where it was several-fold higher, 240 and 700 mg Pt·dm^{-3}, respectively. The COD and BOD_5 values were the highest in pond KG (137.4 and 6.5 mg O_2·dm^{-3}, respectively), indicating poor oxygen conditions. About half of these values were noted in pond BC (85.6 and 3.3 mg O_2·dm^{-3}, respectively), while in other studied water bodies oxygen conditions were much better. The lowest COD value (14.4 mg O_2·dm^{-3}) was noted in D1 and the lowest BOD_5 value (0.5 mg O_2·dm^{-3}) in pond K1.

The concentration of chlorides varied from 13.7 mg·dm^{-3} in pond K3 to 46.2 mg·dm^{-3} in BC. The concentration of sulphates was the highest in P1 (35.4 mg·dm^{-3}) and was relatively high in BC (11.8 mg·dm^{-3}), P3 and O (8.2 mg·dm^{-3} in both water bodies). In D3 the concentration of sulphates was lowest (1.5 mg·dm^{-3}).

The phosphorus content was highest in pond P2 (0.172 mg·dm^{-3}), and was relatively high in ponds P1 and P3, which indicates their eutrophication. In other lakes and ponds phosphorus content was lower. The total iron content varied from 0.19 mg·dm^{-3} in pond K1 and lake O to 1.10 mg·dm^{-3} in pond P2.

5.1.2. The mites at shores of lakes and ponds in bogs of Tuchola Forest

5.1.2.1. Abundance of groups and richness of Oribatida

The density of mites in the investigated shores of forest lakes and ponds varied between 69,800-306,800 individuals·m^{-2}. The most abundant mites lived at the shore of pond D2; they were also abundant at ponds D4 and D1 and lake M, while the least abundant were at lake L (Table 3). At all studied lakes and ponds the Oribatida dominated in mite communities, making 96.4-99.8% of total Acari, and the abundance of this group created the abundance of all mites. These mites were the most abundant at the shore of pond D2, where their density was significantly different from that at the shores of L, D3, K2 and K3.

Table 2. Water measurements in forest lakes and ponds of northern Poland: L – Lake Łyse; D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve; P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in 'Bagno Chlebowo' reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in 'Kurze Grzędy' reserve

Tabela 2. Parametry wody w jeziorach śródleśnych północnej Polski: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury"; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo"; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy"

Lake/Pond Jezioro	Parameter – Parametr								
	pH	Conductivity Przewodnictwo	Color Barwa	COD ChZT	BOD_5 BZT_5	Chlorides Chlorki	Sulphates Siarczany	Total phosphorus Fosfor ogólny	Total iron Żelazo ogólne
	Unit – Jednostka								
	–	σS · cm^{-1}	mg Pt · dm^{-3}	mg O_2 · dm^{-3}		mg · dm^{-3}			
L	6.50	450.2	40	58.5	1.7	20.6	4.1	0.037	0.32
D1	5.62	20.9	20	14.4	1.7	26.7	3.5	0.067	0.90
D2	5.78	23.2	20	29.6	2.4	36.8	2.9	0.019	1.00
D3	5.19	17.5	20	32.0	3.5	26.7	1.5	0.020	0.90
D4	5.51	20.7	30	37.6	3.6	33.4	2.5	0.025	0.50
M	5.73	22.5	30	24.8	1.2	33.4	1.8	<0.004	0.60
K1	5.05	330.8	20	17.0	0.5	17.2	3.3	0.006	0.19
K2	5.13	306.1	30	25.4	0.8	17.2	4.9	0.019	0.32
K3	5.06	296.1	30	41.6	1.2	13.7	4.1	0.026	0.38
P1	7.77	348.0	40	32.8	2.5	27.0	35.4	0.129	0.60
P2	7.43	294.0	20	33.6	3.7	25.3	8.2	0.172	1.10
P3	7.28	232.0	30	32.8	1.4	23.6	2.5	0.089	1.00
BC	5.22	153.0	240	85.6	3.3	46.2	11.8	0.026	0.80
O	4.74	44.5	20	21.6	1.1	17.2	8.2	0.010	0.19
S	4.46	42.1	15	19.1	1.0	17.2	4.9	0.008	0.25
KG	3.60	138.0	700	137.4	6.5	36.3	5.3	0.027	0.54

The lowest density of Oribatida was at lake L and it was significantly different from all other lakes and ponds.

Other groups of mites were not numerous; the second most abundant were 'other Acari', represented mostly by Prostigmata, and less abundant, Mesostigmata. The most abundant 'other Acari' occurred at the shore of lake L, where their proportion among Acari was 3%, while most abundant Mesostigmata lived at the shore of pond D2, but they constituted only 0.3% of mites (Table 3).

Table 3. Abundance (*A* in 1000 m^{-2}) of some taxa of Acari, number of species (*S*) and Shannon index (*H*s) of Oribatida in lakes and ponds in bogs of Tuchola Forest, in summer: L – Lake Łyse; D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve; $\overline{x}$ – mean, SD − standard deviation

Tabela 3. Wskaźnik liczebności (*A* w 1000 m^{-2}) wybranych taksonów roztoczy, liczba gatunków (*S*) i wskaźnik Shannona (*Hs*) Oribatida w jeziorach na torfowiskach Borów Tucholskich, latem: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury"; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"; $\overline{x}$ – średnia, SD − odchylenie standardowe

Lake/Pond Jezioro	*A* $\overline{x}$ ± SD range 4 zakres				*S*	*H*s
	Acari	Oribatida	Mesostigmata	other Acari inne Acari	Oribatida	
L	69.8 ± 28.7 23.1-118.0	67.3 ± 28.7 21.5-115.1	0.5 ± 0.4 0-1.1	2.1 ± 1.6 0-4.5	25	1.46
D1	238.9^{a} ± 132.1 87.1-498.0	238.1^{a} ± 132.1 85.8-498.0	0.3 ± 0.3 0-0.7	0.5^{a} ± 1.0 0-3.3	27	0.45
D2	306.8^{a} ± 199.0 107.8-656.5	304.8^{a} ± 199.0 105.1-654.5	0.9^{b} ± 0.6 0.1-2.1	1.1 ± 1.6 0-4.6	25	0.41
D3	115.6^{abc} ± 44.4 55.0-195.4	114.2^{abc} ± 45.0 54.6-194.2	0.4 ± 0.4 0-1.2	0.9 ± 1.4 0-3.5	22	1.16
D4	261.4^{ad} ± 223.3 89.6-852.9	260.7^{ad} ± 223.3 87.7-852.2	0.2^{c} ± 0.3 0-0.9	0.4^{a} ± 0.4 0-1.0	24	0.46
M	204.4^{ad} ± 65.6 118.3-326.8	203.2^{ad} ± 65.8 117.5-326.3	0.3^{c} ± 0.3 0-0.7	0.9 ± 1.0 0.2-3.5	22	1.09
K1	172.2^{a} ± 85.0 55.0-316.9	170.0^{a} ± 83.8 54.1-310.0	0.2^{c} ± 0.1 0-0.4	2.0^{be} ± 2.0 0-6.7	27	1.66
K2	128.3^{abcef} ± 67.4 33.3-251.1	126.8^{abcef} ± 67.3 33.3-250.2	0.1^{ac} ± 0.2 0-0.5	1.3^{be} ± 1.1 0-3.3	21	0.82
K3	126.5^{abcef} ± 42.8 66.3-206.5	125.2^{abcef} ± 42.9 65.0-205.6	0.3^{c} ± 0.4 0-1.2	0.9^{b} ± 0.6 0.1-1.7	23	0.67

^{abcdefgh} – Significant differences between: ^{a} – L and D1, D2, D3, D4, M, K1, K2, K3; ^{b} – D1 and D2, D3, D4, M, K1, K2, K3; ^{c} – D2 and D3, D4, M, K1, K2, K3; ^{d} – D3 and D4, M, K1, K2, K3; ^{e} – D4 and M, K1, K2, K3; ^{f} – M and K1, K2, K3; ^{g} – K1 and K2, K3; ^{h} – K2 and K3; at $p \leq 0.05$

^{abcdefgh} – Istotne różnice pomiędzy: ^{a} – L i D1, D2, D3, D4, M, K1, K2, K3; ^{b} – D1 i D2, D3, D4, M, K1, K2, K3; ^{c} – D2 i D3, D4, M, K1, K2, K3; ^{d} – D3 i D4, M, K1, K2, K3; ^{e} – D4 i M, K1, K2, K3; ^{f} – M i K1, K2, K3; ^{g} – K1 i K2, K3; ^{h} – K2 i K3; przy $p \leq 0{,}05$

At the shores of lakes and ponds in Tuchola Forest 68 oribatid species, from 31 families, were found (Table 4), but only 20 of them (Table 7) had the dominance index above 1%. In these water bodies the species number of Oribatida varied between 21 (K2) to 27 species (D1 and K1). The Shannon index (*Hs*) of Oribatida was the highest in pond K1, relatively high in L and D3, while it was the lowest in pond D2.

5.1.2.2. Species composition and dominance structure of Oribatida

At all studied shores *Limnozetes foveolatus* Willmann, 1939 highly dominated as a superdominant ($D > 40$) (Fig. 28), achieving in summer the dominance indices between 45.2 and 93.5 (Table 5). At all lakes and ponds it was present in all samples ($C = 100$), but preferred the shores of ponds D2, D4 and D1, where the mean density of oribatid mites was the highest due to a high density of this species (it made over 90% of all Oribatida there). Its highest maximum density was observed at D4 in summer (825,200 individuals m^{-2}) (Table 7). The lowest mean density of *L. foveolatus* was at lake shore L that differed significantly from all other water bodies, except K1. At the latter pond the lowest dominance index of this species was noted.

Among other species relatively abundant was *L. ciliatus*, which was at many ponds the second most abundant (Fig. 28). At the shore of pond K1 it achieved the highest density ($A = 45.8$), significantly higher from all other lakes and ponds, and the highest dominance index ($D = 27.0$). At the same pond also *L. lustrum* Behan-Pelletier, 1989 had its highest density and dominance index, but it was several times lower in comparison to *L. foveolatus* or *L. ciliatus*. Other *Limnozetes* species were even less abundant. *Limnozetes rugosus* (Sellnick, 1923) was present at most lakes and ponds, but only at D4 more abundantly (Table 8), while *Limnozetes* sp. 2 and *L. guyi* Behan-Pelletier, 1989, were rare and in low densities. This is the first record of *L. guyi* in Poland and Europe. *Limnozetes* sp. 2 can be a new species to the science, but it needs more morphological investigations.

At studied shores relatively abundant was also *Trimalaconothrus maior* (Berlese, 1910), which was at several water bodies the second most abundant species. It was dominant ($10 < D$ Ω20) at L, D3, M and recedent ($1 < D$ Ω5) at D1, D2, D4, K2 and K3. At the shore of lake M it achieved its highest abundance that was significantly higher than at all other lakes and ponds, except for D3. Interestingly, another species from the same genus, *T. foveolatus* Willmann, 1931, also achieved its highest abundance at lake M that significantly differed from all water bodies, except for D3. However, the abundance of *T. maior* was at all lakes and ponds several times higher than that of *T. foveolatus*; only at K1, where the density of *T. maior* was very low, the situation was the opposite.

Table 4. The occurrence of Oribatida in forest lakes and ponds of northern Poland: L – Lake Łyse; D1, D2, D3, D4 – ponds in ‘Dury’ reserve; M – Lake Martwe; K1, K2, K3 – ponds in ‘Jeziorka Kozie’ reserve; P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in ‘Bagno Chlebowo’ reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in ‘Kurze Grzędy’ reserve; Sp – spring, Su – summer, Au – autumn; ○ adults predominated; ● juveniles predominated; ◙ the same percentage of adults and juveniles; □ only adults were found; ■ only juveniles were found

Tabela 4. Występowanie Oribatida w jeziorach śródleśnych północnej Polski: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury”; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie”; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo”; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy”; Sp – wiosna, Su – lato, Au – jesień; ○ dominowały dorosłe; ● dominowały młodociane; ◙ ten sam udział dorosłych i młodocianych; □ znaleziono tylko dorosłe; ■ znaleziono tylko młodociane

	Lake/Pond – Jezioro																																	
Family – Rodzina Taxon – Takson	L			D1			D2			D3			D4			M			K1			K2			K3			P1	P2	P3	BC	O	S	KG
	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Au	Au	Au	Su	Su	Su	Su
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Brachychthoniidae Thor, 1934																																		
□ *Brachychthonius berlesei* Willmann, 1928								+												+												+		
□ *Liochthonius alpestris* (Forsslund, 1958)	+	+			+	+	+		+	+	+			+	+		+	+	+	+	+	+	+	+	+		+	+	+		+	+		+
□ *L. brevis* (Michael, 1888)																													+					
□ *L. hystricinus* (Forsslund, 1942)																												+						
□ *L. peduncularis* (Strenzke, 1951)	+	+	+		+		+	+			+		+	+		+		+	+	+	+				+						+	+		
□ *L. perfusorius* Moritz, 1976																																+		
□ *L. sellnicki* (Thor, 1930)	+																																	
Hypochthoniidae Berlese, 1910																																		
● *Hypochthonius rufulus* C.L. Koch, 1835	+						+		+	+						+			+		+							+	+	+	+			+
Phthiracaridae Perty, 1841																																		
□ *Atropacarus striculus* (C.L. Koch, 1835)																						+						+	+	+	+			+
□ *Hoplophthiracarus illinoisensis* (Ewing, 1909)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					+	+	
□ *Phthiracarus clavatus* Parry, 1979																													+					
□ *Ph. longulus* (C.L. Koch, 1841)																																		+
□ *Steganacarus carinatus* (C.L. Koch, 1841)																												+	+	+				
Euphthiracaridae Jacot, 1930																																		
◙ *Euphthiracarus cribarius* (Berlese, 1904)																															+			
□ *Microtritia minima* (Berlese, 1904)																									+						+			
□ *Rhysotritia ardua* (C.L. Koch, 1841)																													+	+	+			
□ *Rh. duplicata* (Grandjean, 1953)																																		+

Table 4 continued – cd. tabeli 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Malaconothridae Berlese, 1916																																		
○ *Malaconothrus monodactylus* (Michael, 1888)			+		+												+									+	+	+	+	+				+
● *Trimalaconothrus angulatus* Willmann, 1931																																		+
● *T. foveolatus* Willmann, 1931	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+	+	+	
● *T. maior* (Berlese, 1910)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+	+	+	+
○ *T. vietsi* (Willmann, 1925)	+		+	+			+	+			+		+	+					+			+		+	+								+	
Trhypochthoniidae Willmann, 1931																																		
● *Mainothrus badius* (Berlese, 1905)			+		+	+	+	+	+		+		+							+	+	+			+	+						+		
● *Trhypochthonius nigricans* Willmann, 1928	+	+	+	+	+	+	+	+		+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+					+	+	
Trhypochthoniellidae Knülle, 1957																																		
○ *Trhypochthoniellus longisetus* (Berlese, 1904)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Nothridae Berlese, 1896																																		
■ *Nothrus palustris* C.L. Koch, 1839																			+					+										
● *N. pratensis* Sellnick, 1928	+				+			+										+					+	+								+		+
Camisiidae Oudemans, 1900																																		
■ *Camisia biurus* (C.L. Koch, 1839)																											+	+						
□ *C. spinifer* (C.L. Koch, 1835)																																		+
□ *Heminothrus longisetosus* Willmann, 1925																																		+
● *Platynothrus peltifer* (C.L. Koch, 1839)	+	+	+							+		+		+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+			+
Nanhermanniidae Sellnick, 1928																																		
● *Nanhermannia* cf. *coronata* Berlese, 1913	+	+		+	+	+	+	+		+	+				+		+	+	+	+	+	+	+	+	+	+	+	+		+		+	+	+
Damaeidae Berlese, 1896																																		
■ *Damaeidae*																																		+
□ *Epidamaeus glabriseta* (Willmann, 1931)																+																		
○ *Metabelba sphagni* Strenzke, 1950								+		+							+		+	+	+	+		+	+	+	+					+		
Cepheidae Berlese, 1896																																		
□ *Cepheus cepheiformis* (Nicolet, 1855)																															+			
Eremaeidae Oudemans, 1900																																		
■ *Eueremaeus oblongus* (C.L. Koch, 1835)														+																				
Astegistidae Balogh, 1961																																		
○ *Astegistes pilosus* (C.L. Koch, 1840)																											+	+						
□ *Cultroribula bicultrata* (Berlese, 1905)																+																		+

Table 4 continued – cd. tabeli 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Liacaridae Sellnick, 1928																																		
□ *Adoristes ovatus* (C.L. Koch, 1839)				+			+																					+	+	+				
□ *Liacarus coracinus* (C.L. Koch, 1841)																																		+
Carabodidae C.L. Koch, 1843																																		
□ *Carabodes areolatus* Berlese, 1916																																		+
□ *C. femoralis* (Nicolet, 1855)																												+	+	+				+
□ *C. labyrinthicus* (Michael, 1879)												+																	+	+				
□ *C. ornatus* Štorkán, 1925																														+				
□ *C. reticulatus* Berlese, 1913																													+					
□ *C. subarcticus* Trägårdh, 1902																																		+
Tectocepheidae Oudemans, 1900																																		
○ *Tectocepheus velatus* (Michael, 1880)	+																						+		+					+				+
Oppiidae Grandjean, 1951																																		
□ *Graptoppia foveolata* (Paoli, 1908)																+																		
□ *Microppia minus* (Paoli, 1908)																						+												
□ *Moritzoppia translamellata* (Willmann, 1923)																					+											+		+
○ *Oppiella nova* (Oudemans, 1902)	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
□ *O. subpectinata* (Oudemans, 1900)																													+	+				+
□ *Ramusella furcata* (Willmann, 1928)		+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+				+	+	+	
Suctobelbidae Jacot, 1938																																		
□ *Suctobelbella acutidens lobata* (Strenzke, 1951)																+												+		+				
□ *S. arcana* Moritz, 1970																																		+
□ *S. falcata* (Forsslund, 1941)																									+									+
□ *S. hamata* Moritz, 1970																																		+
□ *S. latirostris* (Strenzke, 1950)	+	+	+		+		+	+	+	+		+		+			+	+	+	+	+			+	+	+	+					+		+
□ *S. longirostris* (Forsslund, 1941)																			+															
□ *S. palustris* (Forsslund, 1953)									+							+					+				+		+				+			
□ *S. perforata* (Strenzke, 1950)																																		+
□ *S. sarekensis* (Forsslund, 1941)																			+															+
□ *S. similis* (Forsslund, 1941)																																		+
□ *S. subcornigera* (Forsslund, 1941)																			+	+											+			
□ *S. subtrigona* (Oudemans, 1916)																									+									

Table 4 continued – cd. tabeli 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Thyrisomidae Grandjean, 1954																																		
□ *Banksinoma lanceolata* (Michael, 1885)				+																										+		+		
Hydrozetidae Grandjean, 1954																																		
□ *Hydrozetes confervae* (Schrank, 1781)									+																									
○ *H. lacustris* (Michael, 1882)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+	+	+	+
○ *H. lemnae* (Coggi, 1897)						+																						+	+	+	+	+		
○ *H. longisetosus* S. Seniczak & A. Seniczak, 2009	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					+	+	
○ *H. octosetosus* Willmann, 1932	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+				+	+		
○ *H. thienemanni* Strenzke, 1943																												+	+	+				
Limnozetidae Grandjean, 1954																																		
□ *Limnozetes* sp. 2				+	+												+																	
○ *L. ciliatus* (Schrank, 1803)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					+	+	+
□ *L. guyi* Behan-Pelletier, 1989	+	+	+																															
○ *L. lustrum* Behan-Pelletier, 1989	+	+	+	+	+		+	+								+			+	+	+	+		+	+	+	+				+	+		
○ *L. foveolatus* Willmann, 1939	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+
○ *L. rugosus* (Sellnick, 1923)	+	+	+	+	+	+				+		+	+	+	+				+	+	+			+	+	+	+				+			
Cymbaeremaeidae Sellnick, 1928																																		
□ *Cymbaeremaeus cymba* (Nicolet, 1855)													+																	+				
Micreremidae Grandjean, 1954																																		
□ *Micreremus brevipes* (Michael, 1888)				+			+																								+			
Phenopelopidae Petrunkevich, 1955																																		
● *Eupelops hygrophilus* (Knülle, 1954)	+	+	+		+		+	+	+	+	+	+		+		+	+	+	+		+	+	+	+	+	+	+				+	+	+	
○ *E. torulosus* (C.L. Koch, 1839)												+																+	+	+	+			
Achipteriidae Thor, 1929																																		
● *Achipteria coleoptrata* (Linné, 1758)																												+	+	+				
□ *Parachipteria willmanni* Hammen, 1952				+												+					+				+									
Galumnidae Jacot, 1925																																		
○ *Acrogalumna longipluma* (Berlese, 1904)																													+					
● *Pergalumna altera* (Oudemans, 1915)																															+			
□ *P. nervosa* (Berlese, 1914)																														+				
● *Pilogalumna tenuiclava* (Berlese, 1908)	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+

Table 4 continued – cd. tabeli 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Ceratozetidae Jacot, 1925																																		
● *Fuscozetes setosus* (C.L. Koch, 1839)																																		+
□ *Trichoribates novus* (Sellnick, 1928)							+						+			+									+			+	+	+				
□ *T. trimaculatus* (C.L. Koch, 1835)			+																												+			
Zetomimidae Shaldybina, 1966																																		
○ *Zetomimus furcatus* (Warburton & Pearce, 1905)	+	+	+							+						+	+	+		+	+	+			+	+	+		+	+	+	+		
● *Heterozetes palustris* (Willmann, 1917)	+	+											+	+																			+	
Chamobatidae Grandjean, 1954																																		
□ *Chamobates borealis* (Trägårdh, 1902)					+																													
□ *Ch. cuspidatus* (Michael, 1884)									+																			+	+	+	+			+
□ *Ch. pusillus* (Berlese, 1895)																																		+
Mycobatidae Grandjean, 1954																																		
□ *Minunthozetes semirufus* (C.L. Koch, 1841)																												+						
○ *Punctoribates sellnicki* Willmann, 1928	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+	+	+	
Euzetidae Grandjean, 1954																																		
□ *Euzetes globulus* (Nicolet, 1855)																												+						+
Scheloribatidae Grandjean, 1933																																		
○ *Scheloribates initialis* (Berlese, 1908)											+	+	+									+					+	+	+	+				+
● *S. laevigatus* (C.L. Koch, 1836)	+				+		+	+	+	+	+			+		+				+			+		+			+	+	+				+
○ *S. latipes* (C.L. Koch, 1844)	+			+												+							+					+	+	+	+			
Oribatulidae Thor, 1929																																		
□ *Oribatula* sp. 1																														+				
□ *O. tibialis* (Nicolet, 1855)																												+		+				

Table 5. Abundance (*A* in 1000 m^{-2}), dominance (*D*) and constancy (*C*) indices of some Oribatida (with $D > 1$) in lakes and ponds in bogs of Tuchola Forest, in summer: L – Lake Łyse; D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve

Tabela 5. Wskaźniki liczebności (*A* w 1000 m^{-2}), dominacji (*D*) i stałości występowania (*C*) wybranych Oribatida ($D > 1$) w jeziorach na torfowiskach Borów Tucholskich, latem: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury"; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"

Species Gatunek	Index Wskaźnik	Lake/Pond – Jezioro								
		L	D1	D2	D3	D4	M	K1	K2	K3
1	2	3	4	5	6	7	8	9	10	11
Eupelops hygrophilus	*A*	0.8	0.1^{a}	1.1^{b}	0.1^{ac}	0.7^{a}	0.2^{ac}	0^{acd}	0.1^{acd}	0.1^{ac}
	D	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	0	<1.0	<1.0
	C	90	20	90	40	40	80	0	20	50
Hydrozetes longisetosus	*A*	1.1	0.2	1.6^{b}	0.3	0.5	0.1^{ace}	1.4^{bdf}	1.2^{bdf}	1.0^{bdf}
	D	1.7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0	<1.0
	C	90	70	90	80	80	60	100	100	100
H. octosetosus	*A*	0.1	2.6^{a}	0.5^{ab}	0.1^{bc}	0.5^{b}	1.9^{acde}	$<0.1^{bcef}$	0^{bcef}	$<0.1^{bcef}$
	D	<1.0	1.1	<1.0	<1.0	<1.0	<1.0	<1.0	0	<1.0
	C	40	100	80	40	70	100	20	0	10
Limnozetes ciliatus	*A*	3.5	8.7	1.7^{b}	7.3^{ac}	5.2^{c}	3.4^{bd}	45.8^{abcdef}	$16.8^{abcdefg}$	6.2^{cgh}
	D	5.2	3.6	<1.0	6.3	2.0	1.7	27.0	13.3	5.0
	C	90	90	80	100	100	90	100	100	100
L. foveolatus	*A*	43.1	217.0^{a}	284.9^{a}	74.9^{abc}	240.5^{ad}	137.3^{ad}	76.9^{bcef}	100.2^{abce}	108.4^{abc}
	D	64.0	91.1	93.5	65.6	92.2	67.6	45.2	79.0	86.6
	C	100	100	100	100	100	100	100	100	100
L. lustrum	*A*	2.2	$<0.1^{a}$	$<0.1^{a}$	0^{a}	0^{a}	0^{a}	15.3^{abcdef}	0^{ag}	$1.3^{bcdefgh}$
	D	3.2	<1.0	<1.0	0	0	0	9.0	0	1.1
	C	100	10	10	0	0	0	100	0	90
Oppiella nova	*A*	1.6	0.2^{a}	2.4^{a}	0.1^{a}	1.2^{b}	0.2^{a}	2.5^{b}	0.4^{a}	2.0^{bcdfh}
	D	2.3	<1.0	<1.0	<1.0	<1.0	<1.0	1.5	<1.0	1.6
	C	100	20	20	40	70	40	70	40	90

Table 5 continued – cd. tabeli 5

1	2	3	4	5	6	7	8	9	10	11
Pilogalumna tenuiclava	*A*	2.7	0.5^{a}	1.1	1.6	0.7^{a}	0.7^{a}	3.8^{bef}	1.7^{b}	2.4^{b}
	D	3.9	<1.0	<1.0	1.4	<1.0	<1.0	2.3	1.3	1.9
	C	90	60	90	90	90	100	100	100	100
Trhypochthoniellus longisetus	*A*	1.8	0.3	1.3	3.0^{b}	2.6^{b}	12.3^{abc}	9.5^{abc}	0.3^{defg}	0.2^{adefg}
	D	2.6	<1.0	<1.0	2.6	1.0	6.0	5.6	<1.0	<1.0
	C	80	40	70	90	90	100	100	50	60
Trhypochthonius nigricans	*A*	<0.1	<0.1	0.9	0.8^{ab}	0.7^{ab}	0de	6.7^{abcf}	<0.1^{deg}	0.1^{dg}
	D	<1.0	<1.0	<1.0	<1.0	<1.0	0	4.0	<1.0	<1.0
	C	20	10	40	90	70	0	80	10	50
Trimalaconothrus foveolatus	*A*	0.7	0.5	0.6	3.0^{abc}	1.3^{d}	4.8^{abce}	1.9^{abce}	0.9^{dfg}	0.4^{dfg}
	D	1.0	<1.0	<1.0	2.6	<1.0	2.4	1.1	<1.0	<1.0
	C	90	90	50	100	80	90	100	90	70
T. maior	*A*	7.8	6.6	3.7	21.8^{bc}	3.7^{d}	38.3^{abce}	0.1^{abcdef}	3.2^{dfg}	1.4^{adef}
	D	11.6	2.8	1.2	19.0	1.4	18.8	<1.0	2.5	1.1
	C	100	80	90	100	100	100	20	80	60
Zetomimus furcatus	*A*	0.7	0^{a}	0^{a}	0^{a}	0^{a}	2.6^{bcde}	<0.1^{af}	0^{af}	0.3^{f}
	D	1.0	0	0	0	0	1.3	<1.0	0	<1.0
	C	70	0	0	0	0	100	10	0	50

^{abcdefgh} – Significant differences between: ^{a} – L and D1, D2, D3, D4, M, K1, K2, K3; ^{b} – D1 and D2, D3, D4, M, K1, K2, K3; ^{c} – D2 and D3, D4, M, K1, K2, K3; ^{d} – D3 and D4, M, K1, K2, K3; ^{e} – D4 and M, K1, K2, K3; ^{e} – M and K1, K2, K3; ^{f} – K1 and K2, K3; ^{g} – K2 and K3; at $p \leq 0.05$

^{abcdefgh} – Istotne różnice pomiędzy: ^{a} – L i D1, D2, D3, D4, M, K1, K2, K3; ^{b} – D1 i D2, D3, D4, M, K1, K2, K3; ^{c} – D2 i D3, D4, M, K1, K2, K3; ^{d} – D3 i D4, M, K1, K2, K3; ^{e} – D4 i M, K1, K2, K3; ^{f} – M i K1, K2, K3; ^{g} – K1 i K2, K3; ^{h} – K2 i K3; przy $p \leq 0,05$

Fig. 28. Dominance structure of some Oribatida (with $D > 1$) in lakes and ponds in bogs of Tuchola Forest, in summer: L – Lake Łyse; D1, D2, D3, D4 – ponds in ‘Dury’ reserve; M – Lake Martwe; K1, K2, K3 – ponds in ‘Jeziorka Kozie’ reserve; Su – superdominants, Eu – eudominants, Do – dominants, Sd – subdominants, Re – recedents, Sr – subrecedents; full list of species is presented in Table 4

Rys. 28. Struktura dominacji wybranych Oribatida ($D > 1$) w jeziorach na torfowiskach Borów Tucholskich, latem: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury”; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie”; Su – superdominanty, Eu – eudominanty, Do – dominanty, Sd – subdominanty, Re – recedenty, Sr – subrecedenty; pełna lista gatunków znajduje się w Tabeli 4

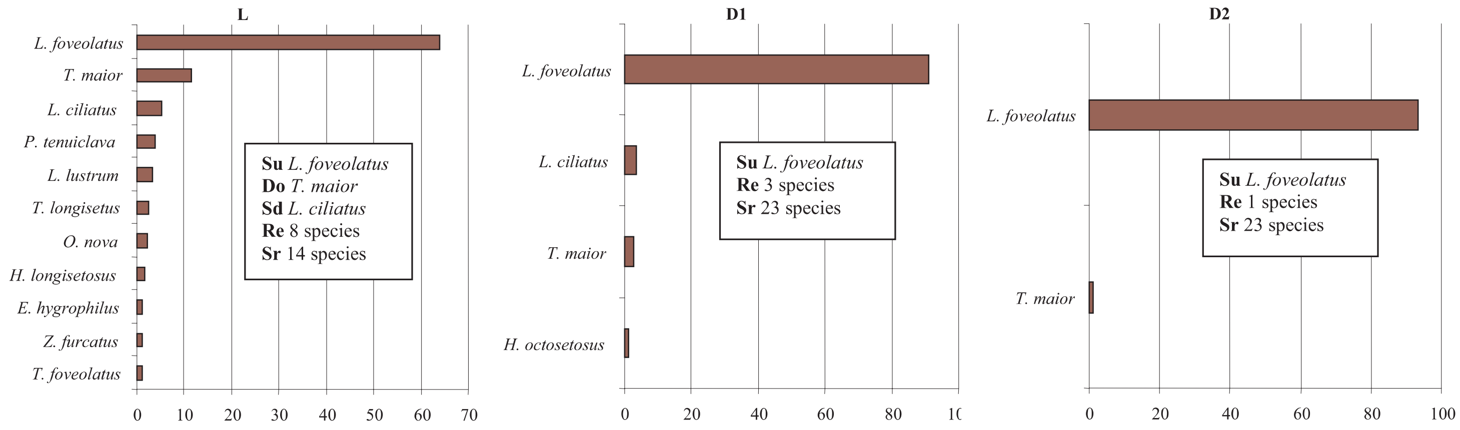
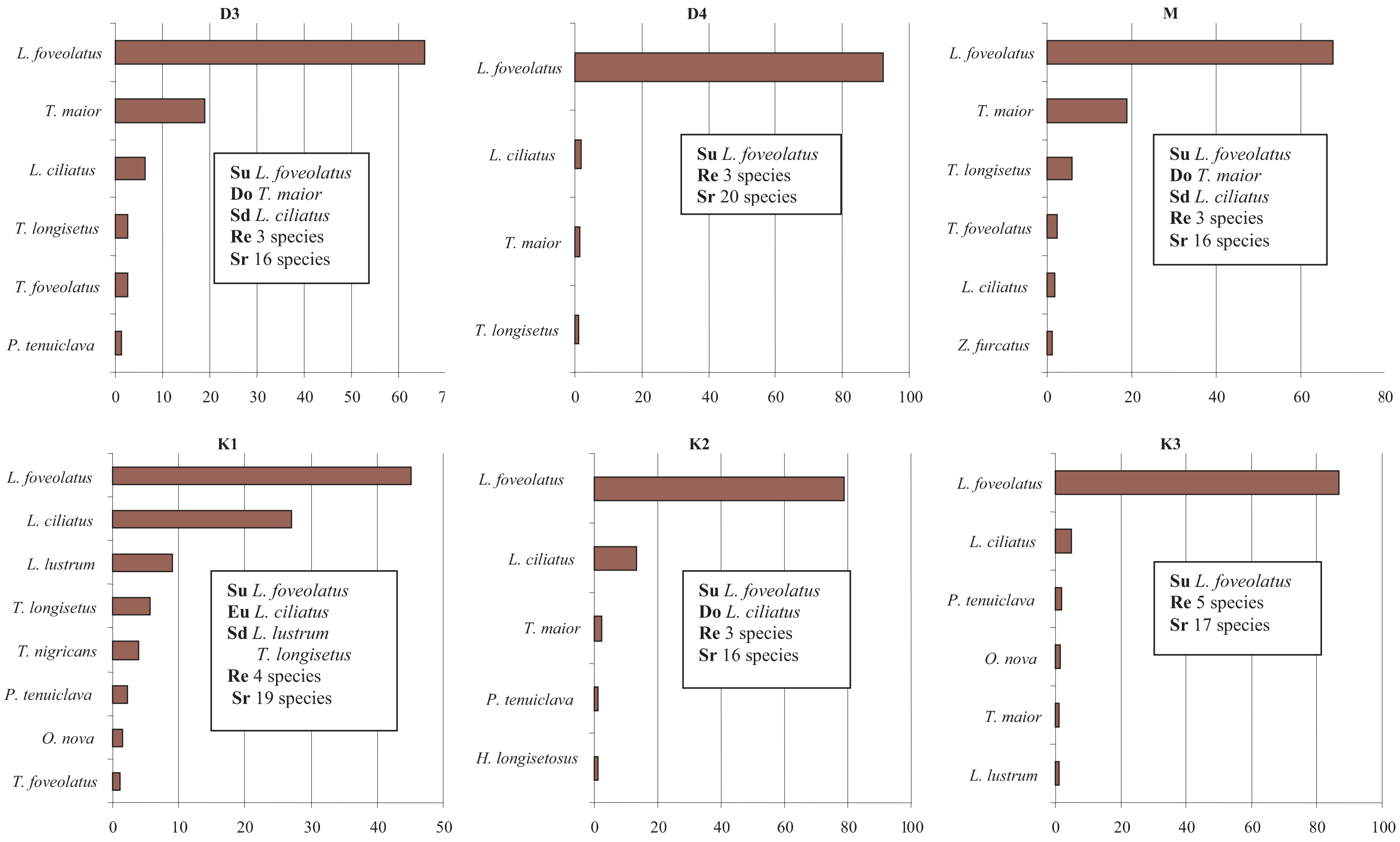


Fig. 28 continued – cd. rysunku 28



One of two closely related species, *Trhypochthonius nigricans* Willmann, 1928 was most abundant at pond K1, while another one, *Trhypochthoniellus longisetus*, was the most abundant at lake M, but was also relatively abundant at the shore of K1. From other species remarkable density achieved *Zetomimus furcatus* at lake M, and *Oppiella nova* (Oudemans, 1902) and *Pilogalumna tenuiclava* (Berlese, 1908) at pond K1. Other species occurred in low numbers.

Worthy of notice are also species of *Hydrozetes*, which are typical aquatic mites. They were generally not abundant, but the most common and usually most abundant among them was *H. longisetosus* S. Seniczak & A. Seniczak, 2009. Only at pond D1 and lake M, this species was less abundant and was outcompeted by *H. octosetosus* Willmann, 1932. *Hydrozetes lacustris* (Michael, 1882) was also a common species, but less abundant than two previous ones, while *H. confervae* (Schrank, 1781) and *H. lemnae* occurred only singly.

At some water bodies several oribatid species achieved high abundance, while at others very few species highly dominated and others occurred only at very low densities. At lake L the number of species that had the dominance index above 1% was the highest (11) (Fig. 28). *Limnozetes foveolatus* was there a superdominant, accompanied by *Trimalaconothrus maior*, which was dominant, and *Limnozetes ciliatus*, which was subdominant ($5 < D \Omega 10$), and eight recedent species, while 14 species were subrecedent ($D \Omega 1$). Also at pond K1 several species had the dominance above 1%. *Limnozetes ciliatus* occurred abundantly there being eudominant ($20 < D \Omega 40$), *L. lustrum* and *Trhypochthoniellus longisetus* were subdominant and four other species were recedent. In contrast, at pond D2 only one species, besides *Limnozetes foveolatus*, had dominance above 1%.

5.1.2.3. Age structure of Oribatida

Most of the oribatid species (34) were represented in extracted samples only by the adult stage, while three species were found only as the juveniles (Table 4). The adults predominated in 19 species, including nearly all species of genera *Hydrozetes* and *Limnozetes*, as well as *Malaconothrus monodactylus* (Michael, 1888) and *Trhypochthoniellus longisetus*. In 12 other species, e.g. *Eupelops hygrophilus* (Knülle, 1954), *Nanhermannia* cf. *coronata*, *Pilogalumna tenuiclava*, *Platynothrus peltifer*, *Trhypochthonius nigricans*, *Trimalaconothrus foveolatus* and *T. maior*, the juveniles were more abundant than the adults.

5.1.3. Seasonal dynamics of mites

5.1.3.1. Abundance of groups and richness of Oribatida

The abundance of Acari and Oribatida was usually the lowest in spring, except for L and K3, where these mites were the least abundant in summer (Table 6).

Table 6. Abundance (*A* in 1000 m^{-2}) of some taxa of Acari, number of species (*S*) and Shannon index (*Hs*) of Oribatida in lakes and ponds in bogs of Tuchola Forest: L – Lake Łyse; D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve; Sp – spring, Su – summer, Au – autumn; $\bar{x}$ – mean, SD − standard deviation

Tabela 6. Wskaźnik liczebności (*A* w 1000 m^{-2}) wybranych taksonów roztoczy, liczba gatunków (*S*) i wskaźnik Shannona (*H*s) Oribatida w jeziorach na torfowiskach Borów Tucholskich: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury"; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"; Sp – wiosna, Su – lato, Au – jesień; $\bar{x}$ – średnia, SD − odchylenie standardowe

Lake/Pond Jezioro	Season Sezon	*A* $\bar{x}$ ± SD range 4 zakres				*S*	*H*s
		Acari	Oribatida	Mesostigmata	other Acari inne Acari	Oribatida	
1	2	3	4	5	6	7	8
L	Sp	89.5 ± 44.2 24.8-178.2	84.6 ± 41.0 23.1-165.6	2.2 ± 1.1 0.7-4.5	2.6 ± 3.2 0.2-10.1	31	2.23
	Su	69.8 ± 28.7 23.1-118.0	67.3 ± 28.7 21.5-115.1	0.5^{a} ± 0.4 0-1.1	2.1 ± 1.6 0-4.5	25	1.46
	Au	75.9 ± 49.0 22.7-164.6	75.7 ± 49.1 22.2-164.2	0.1^{bc} ± 0.1 0-0.2	0.2^{bc} ± 0.2 0-0.5	27	1.45
D1	Sp	53.5 ± 27.8 28.2-119.3	53.1 ± 27.4 28.2-118.2	0.1 ± 0.3 0-1.1	0.3 ± 0.5 0-1.4	23	1.27
	Su	238.9^{a} ± 132.1 87.1-498.0	238.1^{a} ± 132.1 85.8-498.0	0.3 ± 0.3 0-0.7	0.5 ± 1.0 0-3.3	27	0.45
	Au	240.5^{b} ± 113.4 103.5-471.2	239.4^{b} ± 113.4 103.3-470.2	0.1 ± 0.2 0-0.5	1.0^{b} ± 0.9 0-2.4	17	0.45
D2	Sp	177.7 ± 89.0 55.4-322.7	176.7 ± 89.3 51.9-322.5	0.5 ± 0.7 0-2.2	0.5 ± 0.9 0-3.0	27	0.70
	Su	306.8 ± 199.0 107.8-656.5	304.8 ± 199.0 105.1-654.5	0.9 ± 0.6 0.1-2.1	1.1 ± 1.6 0-4.6	25	0.41
	Au	234.1 ± 135.5 50.6-489.2	232.9 ± 135.6 49.3-488.8	0.4 ± 0.3 0-1.0	0.8 ± 1.1 0-3.8	22	0.39
D3	Sp	109.0 ± 76.2 33.4-259.2	108.9 ± 76.3 33.4-259.1	<0.1 ± <0.1 0-0.1	0.1 ± 0.3 0-0.9	24	1.14
	Su	115.6 ± 44.4 55.0-195.4	114.2 ± 45.0 54.6-194.2	0.4^{a} ± 0.4 0-1.2	0.9^{a} ± 1.4 0-3.5	22	1.16
	Au	158.7^{c} ± 42.5 87.5-201.0	158.1^{c} ± 42.8 86.2-200.3	0.2 ± 0.3 0-0.8	0.4^{b} ± 0.4 0-1.1	22	0.92
D4	Sp	144.0 ± 76.4 48.2-281.5	143.9 ± 76.5 47.7-281.5	0.1 ± 0.2 0-0.5	0	22	0.72
	Su	261.4 ± 223.3 89.6-852.9	260.7 ± 223.3 87.7-852.2	0.2 ± 0.3 0-0.9	0.4^{a} ± 0.4 0-1.0	24	0.46
	Au	203.3 ± 93.2 87.4-350.6	202.7 ± 92.9 87.4-350.1	0.1 ± 0.2 0-0.5	0.4^{b} ± 0.5 0-1.1	18	0.88
M	Sp	72.6 ± 52.6 9.4-200.3	72.4 ± 52.7 9.4-200.2	0.1 ± 0.2 0-0.5	0.1 ± 0.2 0-0.5	28	1.43
	Su	204.4^{a} ± 65.6 118.3-326.8	203.2^{a} ± 65.8 117.5-326.3	0.3^{a} ± 0.3 0-0.7	0.9^{a} ± 1.0 0.2-3.5	22	1.09
	Au	142.4^{bc} ± 79.6 56.4-327.5	141.6^{bc} ± 79.4 55.0-326.4	0.1 ± 0.3 0-1.1	0.7^{b} ± 0.6 0-1.6	22	1.05

Table 6 continued – cd. tabeli 6

1	2	3	4	5	6	7	8
K1	Sp	154.6 ± 103.3 37.1–393.8	153.6 ± 103.1 36.8–392.5	0.8 ± 0.6 0–2.0	0.2 ± 0.3 0–1.1	29	1.36
	Su	172.2 ± 85.0 55.0–316.9	170.0 ± 83.8 54.1–310.0	0.2^a ± 0.1 0–0.4	2.0^a ± 2.0 0–6.7	27	1.66
	Au	282.4^b ± 158.4 39.1–553.6	280.9^b ± 158.6 38.7–552.6	0.3^b ± 0.3 0–0.8	1.2^b ± 1.0 0–2.9	30	1.23
K2	Sp	97.0 ± 28.0 67.8–142.0	96.5 ± 27.6 67.8–140.6	0.2 ± 0.4 0–1.1	0.3 ± 0.5 0–1.4	25	0.96
	Su	128.3 ± 67.4 33.3–251.1	126.8 ± 67.3 33.3–250.2	0.1 ± 0.2 0–0.5	1.3^a ± 1.1 0–3.3	21	0.82
	Au	134.6 ± 60.9 68.3–247.8	133.9 ± 61.1 67.9–247.2	<0.1 ± 0.1 0–0.2	0.7 ± 0.7 0–2.2	25	1.07
K3	Sp	172.7 ± 120.8 78.5–470.2	172.4 ± 120.5 78.0–468.8	0.3 ± 0.4 0–1.3	<0.1 ± <0.1 0–2.0	33	0.90
	Su	126.5 ± 42.8 66.3–206.5	125.2 ± 42.9 65.0–205.6	0.3 ± 0.4 0–1.2	0.9^a ± 0.6 0.1–1.7	23	0.67
	Au	207.6^c ± 75.6 117.8–314.0	206.5^c ± 75.3 117.2–311.2	0.3 ± 0.3 0–1.1	0.8^b ± 0.8 0–2.3	27	0.72

^{abc} – Significant differences between: ^{a} – Sp and Su, ^{b} – Sp and Au, ^{c} – Su and Au; at $p \leq 0.05$
^{abc} – Istotne różnice pomiędzy: ^{a} – Sp i Su, ^{b} – Sp i Au, ^{c} – Su i Au; przy $p \leq 0,05$

At most shores (D1, D3, K1, K2, K3) the Oribatida achieved the highest abundance in autumn, while at the other water bodies their maximum number occurred in summer (D2, D4, M) or in spring (L). In most cases the abundance of Oribatida was significantly higher in summer or/and autumn than in spring. The densities of Mesostigmata and Prostigmata were low in all seasons and were statistically insignificant.

At the shores of most lakes and ponds (L, D2, D3, M, K3) the highest number of oribatid species was noted in spring, at some (D1, D4), in summer or in autumn (K1), while at pond K2 this number was evenly high in spring and autumn. The lowest number of species was recorded in summer (L, K1, K2, K3) or in autumn (D1, D2, D4). At shores of pond D3 and lake M the number of species of Oribatida was evenly low in summer and autumn.

At shores of most water bodies (L, D1, D2, M, K3) the Shannon species diversity index (*H*s) of Oribatida was the highest in spring, but in some ponds in summer (D3, K1) or in autumn (D4, K2). The lowest value of this index was in autumn (L, D2, D3, M, K1) or in summer (D4, K2, K3). At the shore of D1 the Shannon index (*H*s) was evenly low in summer and autumn.

5.1.3.2. Species composition and dominance structure of Oribatida

The dominant species, *Limnozetes foveolatus*, was most abundant at most lakes and ponds (D1, D2, D4, M, K2) in summer and in the others (L, D3, K1, K3) in autumn, but only in few cases the differences were significant (Table 7).

Table 7. Abundance (*A* in 1000 ḿ$^{-2}$), dominance (*D*) and constancy (*C*) indices of some Oribatida (with $D > 1$) in lakes and ponds in bogs of Tuchola Forest: L – Lake Łyse; D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve; Sp – spring, Su – summer, Au – autumn; $\bar{x}$ – mean, SD − standard deviation

Tabela 7. Wskaźniki liczebności (*A* w 1000 ḿ$^{-2}$), dominacji (*D*) i stałości występowania (*C*) wybranych Oribatida ($D > 1$) w jeziorach na torfowiskach Borów Tucholskich: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury"; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"; Sp – wiosna, Su – lato, Au – jesień; $\bar{x}$ – średnia, SD − odchylenie standardowe

Species Gatunek	Lake/Pond Jezioro	Sp			Su			Au		
		A $\bar{x} \pm$ SD range – zakres	*D*	*C*	*A* $\bar{x} \pm$ SD range – zakres	*D*	*C*	*A* ± SD range – zakres	*D*	*C*
1	2	3	4	5	6	7	8	9	10	11
Eupelops hygrophilus	L	0.8 ± 0.8 0-2.3	<1.0	80	0.8 ± 0.6 0-1.8	1.2	90	0.5 ± 0.6 0-1.8	<1.0	70
Hoplophthiracarus illinoisensis	L	1.4 ± 3.8 0-12.2	1.7	70	0.2 ± 0.3 0-0.7	<1.0	50	$<0.1^{b} \pm 0.1$ 0-0.2	<1.0	20
	D1	0.8 ± 1.0 0-3.2	1.6	80	$<0.1^{a} \pm <0.1$ 0-0.2	<1.0	40	$<0.1^{b} \pm <0.1$ 0-0.1	<1.0	10
	K2	0.3 ± 0.7 0-2.1	<1.0	30	0.4 ± 0.4 0-1.1	<1.0	70	$1.4^{bc} \pm 1.1$ 0.1-3.4	1.1	100
Hydrozetes lacustris	D4	0.7 ± 0.5 0-1.4	<1.0	90	0.7 ± 0.7 0-2.0	<1.0	90	2.5 ± 3.6 0-10.3	1.2	80
H. longisetosus	L	4.0 ± 3.5 0.3-10.7	4.8	100	$1.1^{a} \pm 1.8$ 0-6.2	1.7	90	2.2 ± 3.0 0.1-10.1	2.8	100
	D1	1.3 ± 1.7 0-5.4	2.4	70	0.2 ± 0.2 0-0.7	<1.0	70	0.1 ± 0.2 0-0.7	<1.0	30
	D2	1.7 ± 1.7 0.2-5.4	1.0	100	1.6 ± 1.6 0-4.8	<1.0	90	1.3 ± 1.4 0-3.6	<1.0	60
	D3	1.8 ± 1.4 0.1-4.5	1.7	100	$0.3^{a} \pm 0.3$ 0-1.0	<1.0	80	$3.6^{c} \pm 3.2$ 0.1-9.2	2.2	100
	D4	4.2 ± 2.5 1.1-9.3	2.9	100	$0.5^{a} \pm 0.4$ 0-1.1	<1.0	80	$2.2^{b} \pm 2.9$ 0-9.4	1.1	90

Table 7 continued – cd. tabeli 7

1	2	3	4	5	6	7	8	9	10	11
H. longisetosus	K1	5.1 ± 4.8 1.1-17.5	3.3	100	$1.3^{a} \pm 1.5$ 0.2-5.1	<1.0	100	$1.1^{b} \pm 1.3$ 0-3.8	<1.0	90
	K2	2.2 ± 1.9 0.3-7.0	2.3	100	1.2 ± 0.9 0.2-3.1	1.0	100	$0.4^{bc} \pm 0.8$ 0-2.5	<1.0	80
	K3	3.8 ± 3.3 0.5-10.1	2.2	100	$0.9^{a} \pm 0.6$ 0.1-2.1	<1.0	100	$2.8^{c} \pm 1.7$ 0.9-5.3	1.3	100
H. octosetosus	D1	2.2 ± 1.6 0.3-4.6	4.0	100	2.5 ± 2.3 0.5-8.4	1.1	100	$0.8^{bc} \pm 0.7$ 0.1-2.2	<1.0	100
	M	3.8 ± 3.6 0.3-10.0	5.2	100	1.9 ± 1.6 0.1-5.8	<1.0	100	$0.7^{bc} \pm 0.8$ 0-2.3	<1.0	90
Limnozetes ciliatus	L	17.9 ± 11.2 3.2-39.7	21.2	100	$3.5^{a} \pm 5.5$ 0-14.6	5.2	90	$4.8^{b} \pm 7.7$ 0.9-26.2	6.4	100
	D1	15.4 ± 10.3 3.8-36.3	29.0	100	8.7 ± 5.5 0-19.0	3.6	90	$18.5^{c} \pm 7.8$ 8.8-31.5	7.7	100
	D2	8.4 ± 6.1 2.0-20.4	4.7	100	$1.7^{a} \pm 1.8$ 0-5.3	<1.0	80	$0.7^{b} \pm 0.7$ 0-2.4	<1.0	70
	D3	8.0 ± 8.8 0.5-29.4	7.3	100	7.3 ± 3.7 1.9-13.0	6.3	100	6.5 ± 7.7 0.6-23.7	4.1	100
	D4	10.0 ± 6.8 1.6-22.3	6.9	100	5.2 ± 3.5 1.4-12.7	2.0	100	$15.4^{c} \pm 7.7$ 3.2-28.7	7.6	100
	M	5.5 ± 4.3 1.4-14.1	7.6	100	3.4 ± 2.9 0-10.5	1.7	90	$10.5^{c} \pm 9.3$ 1.1-25.4	7.4	100
	K1	41.0 ± 28.1 16.2-111.5	26.7	100	45.8 ± 27.1 5.1-90.9	27.0	100	72.0 ± 56.5 12.0-182.5	25.6	100
	K2	25.0 ± 15.3 4.2-53.3	25.9	100	16.8 ± 4.2 11.1-26.5	13.3	100	$31.9^{c} \pm 12.3$ 10.7-51.2	23.8	100
	K3	19.0 ± 9.9 6.0-32.8	11.0	100	$6.2^{a} \pm 6.2$ 0.4-22.0	5.0	100	$7.7^{b} \pm 8.3$ 1.1-27.1	3.7	100

Table 7 continued – cd. tabeli 7

1	2	3	4	5	6	7	8	9	10	11
L. foveolatus	L	30.4 ± 29.4 2.3-91.8	36.0	100	43.1 ± 25.4 13.5-88.1	64.0	100	50.6 ± 34.6 9.0-126.7	66.9	100
	D1	30.1 ± 16.9 15.8-72.9	56.6	100	$217.0^{a} \pm 135.9$ 74.6-480.0	91.1	100	$213.7^{b} \pm 110.9$ 85.7-444.7	89.3	100
	D2	152.0 ± 83.6 34.2-292.2	86.0	100	284.9 ± 199.5 38.1-620.2	93.5	100	217.5 ± 130.0 44.1-460.8	93.4	100
	D3	63.8 ± 53.5 18.9-170.4	58.6	100	74.9 ± 30.6 28.2-131.3	65.6	100	$120.2^{bc} \pm 44.2$ 35.5-172.8	76.0	100
	D4	121.3 ± 75.7 25.2-265.5	84.3	100	240.5 ± 221.7 64.0-825.2	92.2	100	157.8 ± 84.9 33.4-315.6	77.8	100
	M	41.4 ± 34.1 0.3-117.5	57.2	100	$137.3^{a} \pm 43.8$ 55.5-205.0	67.6	100	$104.8^{b} \pm 68.6$ 23.9-250.8	74.0	100
	K1	86.7 ± 79.5 5.7-283.4	56.5	100	76.9 ± 50.8 16.4-152.2	45.2	100	166.5 ± 130.7 4.5-390.7	59.3	100
	K2	64.5 ± 28.0 28.4-107.1	66.8	100	100.2 ± 67.9 10.3-224.1	79.0	100	87.0 ± 53.9 16.5-176.5	65.0	100
	K3	135.6 ± 111.8 42.3-413.7	78.7	100	108.4 ± 41.7 54.7-192.3	86.6	100	$175.8^{c} \pm 70.4$ 78.3-268.2	85.1	100
L. lustrum	L	3.0 ± 2.1 0.8-8.4	3.6	100	2.2 ± 2.5 0.1-7.8	3.2	100	1.9 ± 1.7 0.2-4.7	2.5	100
	K1	4.3 ± 3.0 0.3-9.7	2.8	100	$15.3^{a} \pm 10.1$ 0.6-29.6	9.0	100	9.9 ± 8.7 1.0-29.1	3.5	100
	K3	0.6 ± 0.6 0.1-2.3	<1.0	100	1.3 ± 1.2 0-3.6	1.1	90	$2.4^{b} \pm 1.8$ 0.3-5.3	1.1	100
L. rugosus	D4	0.2 ± 0.4 0-1.3	<1.0	60	<0.1 ± 0.1 0-0.2	<1.0	20	2.2 ± 2.7 0.1-7.8	1.1	100
Liochthonius alpestris	K2	0.1 ± 0.1 0-0.3	<1.0	20	0.2 ± 0.3 0-0.8	<1.0	30	$1.4^{b} \pm 2.3$ 0-7.3	1.1	70

Table 7 continued – cd. tabeli 7

1	2	3	4	5	6	7	8	9	10	11
L. peduncularis	L	0.4 ± 0.9 0-3.0	<1.0	70	$0.1^{a} \pm 0.1$ 0-0.4	<1.0	50	$1.2^{c} \pm 1.4$ 0-4.3	1.6	80
	D2	2.7 ± 2.5 0.6-7.4	1.5	100	$0.5^{a} \pm 0.7$ 0-2.2	<1.0	70	0^{bc}	0	0
Oppiella nova	L	6.2 ± 7.7 0.4-25.4	7.3	100	$1.5^{a} \pm 2.4$ 0.1-8.3	2.3	100	2.8 ± 3.4 0-8.5	3.7	90
	K1	0.4 ± 0.7 0-2.2	<1.0	70	2.5 ± 6.4 0-20.7	1.5	70	0.8 ± 1.2 0-3.8	<1.0	70
	K3	2.3 ± 4.2 0-14.1	1.4	80	1.9 ± 2.8 0-8.7	1.6	90	2.9 ± 6.2 0-20.3	1.4	90
Pilogalumna tenuiclava	L	1.0 ± 1.3 0-3.4	1.2	50	2.7 ± 3.0 0-10.6	3.9	90	$0.4^{c} \pm 0.6$ 0-2.2	<1.0	80
	D3	0.5 ± 1.1 0-3.4	<1.0	60	$1.6^{a} \pm 1.9$ 0-5.7	1.4	90	0.6 ± 0.6 0-1.7	<1.0	90
	K1	1.2 ± 1.5 0-4.1	<1.0	50	$3.8^{a} \pm 3.4$ 0.1-10.7	2.3	100	$1.3^{c} \pm 1.6$ 0-5.1	<1.0	80
	K2	0.3 ± 0.7 0-2.0	<1.0	30	$1.7^{a} \pm 1.9$ 0.1-6.6	1.3	100	$0.3^{c} \pm 0.5$ 0-1.6	<1.0	80
	K3	0.7 ± 1.0 0-2.6	<1.0	80	$2.4^{a} \pm 2.5$ 0.2-6.8	1.9	100	$0.5^{c} \pm 0.5$ 0-1.3	<1.0	80
Platynothrus peltifer	L	1.7 ± 0.9 0.1-3.0	2.0	100	$0.1^{a} \pm 0.1$ 0-0.2	<1.0	60	0.8 ± 1.1 0-2.7	1.1	70
	M	1.1 ± 1.0 0.1-2.9	1.6	100	0.5 ± 0.5 0-1.2	<1.0	80	2.8 ± 4.1 0-9.4	1.9	90
Punctoribates sellnicki	L	1.3 ± 0.9 0.2-2.7	1.5	100	$0.5^{a} \pm 0.8$ 0-2.5	<1.0	80	1.0 ± 0.8 0.1-2.8	1.3	100
	K3	3.3 ± 2.4 0.6-7.8	1.9	100	$0.9^{a} \pm 0.7$ 0-2.2	<1.0	90	$1.1^{b} \pm 0.9$ 0.2-2.9	0.5	100

Table 7 continued – cd. tabeli 7

1	2	3	4	5	6	7	8	9	10	11
Trhypochthoniellus longisetus	L	3.5 ± 5.7 0.2-19.1	4.1	100	1.8 ± 2.2 0-4.9	2.6	80	$3.7^{b} \pm 10.2$ 0-32.8	4.9	50
	D2	2.3 ± 2.2 0.5-7.1	1.3	100	1.3 ± 1.6 0-4.2	<1.0	70	1.5 ± 1.8 0-4.8	<1.0	80
	D3	3.2 ± 3.0 0.1-8.4	2.9	100	3.0 ± 4.4 0-14.9	2.6	90	3.8 ± 5.4 0-15.6	2.4	90
	D4	2.0 ± 2.0 0-5.2	1.4	90	2.6 ± 1.9 0-5.6	1.0	90	$0.5^{c} \pm 0.7$ 0-2.4	<1.0	90
	M	1.1 ± 2.4 0-7.9	1.5	70	$12.3^{a} \pm 12.9$ 0.4-41.6	6.0	100	$12.7^{b} \pm 13.9$ 0.2-42.1	9.0	100
	K1	0.3 ± 0.3 0-1.1	<1.0	90	$9.5^{a} \pm 7.3$ 0.3-21.9	5.6	100	$6.4^{b} \pm 6.2$ 0.1-18.7	2.3	100
Trhypochthonius nigricans	L	1.0 ± 1.4 0.1-3.5	1.2	100	$<0.1^{a} \pm <0.1$ 0-0.1	<1.0	20	$0.8^{c} \pm 1.6$ 0-5.2	1.0	70
	K1	4.5 ± 3.7 1.5-13.8	3.0	100	6.7 ± 8.9 0-25.4	4.0	80	2.9 ± 2.6 0-8.5	1.0	90
Trimalaconothrus foveolatus	L	1.2 ± 1.3 0-4.0	1.5	90	0.6 ± 0.8 0-2.4	1.0	90	$0.1^{bc} \pm 0.1$ 0-0.3	<1.0	50
	D3	0.3 ± 0.5 0-1.6	<1.0	70	$3.0^{a} \pm 1.6$ 0.6-5.0	2.6	100	$0.5^{c} \pm 0.3$ 0-0.9	<1.0	90
	M	6.1 ± 6.2 0-17.7	8.5	90	4.8 ± 6.3 0-21.2	2.4	90	3.1 ± 2.6 0.5-7.9	2.2	100
	K1	4.6 ± 2.4 1.6-8.7	3.0	100	$1.9^{a} \pm 1.2$ 0.2-3.5	1.1	100	$16.0^{bc} \pm 10.5$ 4.3-37.6	5.7	100
	K2	1.1 ± 0.8 0.4-2.5	1.2	100	0.9 ± 0.8 0-2.4	<1.0	90	$7.4^{bc} \pm 3.0$ 3.7-12.9	5.5	100
	K3	2.2 ± 2.0 0.5-6.7	1.3	100	$0.4^{a} \pm 0.5$ 0-1.6	<1.0	70	$3.9^{bc} \pm 1.9$ 1.4-7.7	1.9	100

Table 7 continued – cd. tabeli 7

1	2	3	4	5	6	7	8	9	10	11
T. maior	L	1.9 ± 1.4 0.7-5.7	2.2	100	7.8 ± 11.9 0.1-40.8	11.6	100	3.5 ± 2.7 1.0-7.8	4.6	100
	D1	1.3 ± 2.2 0-6.5	2.4	60	6.6 ± 12.1 0-37.9	2.8	80	4.6^{b} ± 4.1 0.3-11.2	1.9	100
	D2	4.6 ± 6.7 0.6-23.1	2.6	100	3.7 ± 6.8 0-22.5	1.2	90	5.8 ± 6.1 0.7-19.0	2.5	100
	D3	30.2 ± 23.3 4.4-66.5	27.7	100	21.8 ± 22.4 0.6-56.9	19.0	100	20.4 ± 14.7 2.5-57.4	12.9	100
	D4	1.9 ± 1.5 0.4-4.6	1.3	100	3.7 ± 4.7 0.2-15.1	1.4	100	18.5^{bc} ± 17.3 3.4-57.7	9.1	100
	M	11.8 ± 12.2 0.8-43.3	16.4	100	38.3^{a} ± 61.0 8.5-210.3	18.8	100	3.6^{bc} ± 2.5 0.1-7.8	2.6	100
	K2	1.3 ± 2.8 0-9.0	1.4	80	3.1 ± 5.0 0-15.9	2.5	80	1.4 ± 2.5 0-8.2	1.0	70
	K3	2.8 ± 3.1 0.3-9.1	1.6	100	1.4 ± 2.4 0-7.5	1.1	60	8.3^{bc} ± 7.2 0.4-24.8	4.0	100
Zetomimus furcatus	L	4.5 ± 3.3 0.5-9.4	5.3	100	0.7^{a} ± 1.2 0-3.9	1.0	70	0.4^{b} ± 0.5 0-1.7	<1.0	80
	M	<0.1 ± <0.1 0-0.1	<1.0	40	2.6^{a} ± 1.2 0.5-4.6	1.3	100	0.1^{bc} ± 0.1 0-0.2	<1.0	80

^{abc} – Significant differences between: ^{a} – Sp and Su, ^{b} – Sp and Au, ^{c} – Su and Au; at $p \leq 0.05$

^{abc} – Istotne różnice pomiędzy: ^{a} – Sp i Su, ^{b} – Sp i Au, ^{c} – Su i Au; przy $p \leq 0{,}05$

Usually this species achieved the lowest density in spring and in two ponds (K1 and K3) in summer. Its constancy index was 100, while the dominance index was the highest in summer or in autumn, and was usually the lowest in spring.

Different seasonal dynamics represented *L. ciliatus*, which was at some lakes and ponds (D1, D4, M, K1, K2) the most abundant in autumn and at the others (L, D2, D3, K3), in spring. This species had usually the lowest density in summer (L, D1, D4, M, K2, K3) and rarely in autumn (D2 and D3) or in spring (K1). Constancy index of *L. ciliatus* was usually 100, while the dominance index was usually the highest in spring and was the lowest in summer. Interestingly, the picks of density of *L. ciliatus* never cover the picks of density of *L. foveolatus*, which reduces the competition between these species. Similarly, *L. rugosus*, which was most abundant at pond D4, had there the highest abundance and constancy index in autumn, and the lowest in summer. The other species of this genus, *L. lustrum*, was the most abundant at the shore of pond K1, with a maximum density in summer, and a minimum density in spring. Constancy index of this species was usually 100.

Among *Hydrozetes* the most common and usually most numerous was *H. longisetosus.* Almost at all lakes and ponds (except D3) it achieved the highest abundance in spring, while its lowest density was observed in summer (L, D3, D4, K3) or autumn (D1, D2, K1, K2) and in most cases these differences were statistically significant. The dominance and constancy indices followed the same pattern as the abundance of this species, being the highest in spring and lowest in summer or autumn. Similarly, *H. octosetosus*, which achieved its highest abundance at lake M, was most abundant in spring and least abundant in autumn. In D1, where this species was also relatively numerous, the highest abundance was noted in summer and the lowest in autumn. In both water bodies the constancy index was usually 100 and the dominance index was the highest in spring and lowest in autumn. In contrast, *H. lacustris* was most abundant in autumn and had equally low abundance in spring and summer.

From the other species a clear pattern of the seasonal dynamics showed *Pilogalumna tenuiclava* that was most abundant in summer, and its densities were always significantly different from spring or/and autumn. Also the constancy and dominance indices were the highest in summer and lowest in spring or autumn. In contrast, *Punctoribates sellnicki* Willmann, 1928 had the highest abundance in spring that differed significantly from summer (L) or summer and autumn (K3), and it was the least abundant in summer. Also *Platynothrus peltifer* had the lowest abundance in summer, while the highest 4 in spring or autumn.

In many species no clear seasonal dynamics of abundance was observed. For example, *Trimalaconothrus maior*, which occurred abundantly and with high constancy at almost all lakes and ponds, had its peak abundance at different water bodies in various seasons. At the shores of L, D1, M and K2 it was most abundant in summer, at D2, D4 and K3 4 in autumn, and at pond D3 4 in spring. Another representative of this genus, *T. foveolatus* was in most cases (K1, K2, K3) the most abundant in autumn and least abundant in summer, but at lakes L and M it had the highest density in spring and lowest in autumn, and at D3 it had the highest density in summer and lowest in spring. The dominance index of this species followed its density, while the constancy index was usually high. No clear tendencies of the seasonal dynamics could be also observed in *Trhypochthoniellus longisetus* that occurred abundantly at many shores, and in closely related *Trhypochthonius nigricans*, as well as in few other species [*Eupelops hygrophilus*, *Hoplophthiracarus illinoisensis* (Ewing, 1909), *Oppiella nova*, *Zetomimus furcatus*] that occurred abundantly only at few water bodies.

5.1.3.3. Age structure of Oribatida

Generally, at the shores of lakes and ponds the adult Oribatida dominated, and their average density was the lowest in spring, and the highest in autumn (Table 8). Also the juveniles had the lowest density in spring, but the highest in summer. The proportion of juvenile stages varied from 9.9% of total Oribatida in autumn to 14.8% in summer.

The age structure of Oribatida depended greatly on the most abundant species, *Limnozetes foveolatus*, which was represented in the samples mainly by adults. They made from 92.0% of the samples in summer to 97.2% in spring. In this species the adults had usually the lowest density in spring and the highest in autumn, while the juveniles were the least abundant in spring or autumn and the most abundant in summer, and in many cases these differences were significant. At all shores the proportion of the juveniles in the samples was the highest in summer (Fig. 29). Similar pattern of the age structure represented *L. lustrum*, while *L. ciliatus* and *L. rugosus* had the highest percentage of juveniles in autumn, and at many lakes these differences were statistically significant.

Also in the genus *Hydrozetes* the adults predominated in the samples. The highest proportion of the juveniles was in all species in autumn, but the seasonal dynamics of adults and juveniles varied among the species. For example, in *H. lacustris* the average abundance of adults was only slightly higher in autumn than in spring, while that of juveniles increased more than 10 times from spring to autumn, suggesting the reproduction in late summer and autumn. In contrast, *H. longisetosus* and *H. octosetosus* had a similar abundance of juveniles in spring and autumn, and in summer it was lower, while the abundance of adults was more than two times higher in spring than in autumn, suggesting the reproduction from autumn to spring. In some Oribatida the juveniles were more abundant than the adults. In *Trhypochthonius nigricans*, *Trimalaconothrus maior* and *Trhypochthoniellus longisetus* the mean proportion of juveniles was the lowest in spring and the highest in summer.

Table 8. Abundance (*A* in 1000 m^{-2}) of adults (Ad) and juveniles (Juv) of some Oribatida (with $D > 1$ and represented by Ad and Juv) in lakes and ponds in bogs of Tuchola Forest: L – Lake Łyse; D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve; Sp – spring, Su – summer, Au – autumn; $\bar{x}$ – mean

Tabela 8. Wskaźnik liczebności (*A* w 1000 m^{-2}) dorosłych (Ad) i młodocianych (Juv) wybranych Oribatida ($D > 1$ i reprezentowanych przez Ad i Juv) w jeziorach na torfowiskach Borów Tucholskich, w różnych sezonach: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury"; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"; Sp – wiosna, Su – lato, Au – jesień; $\bar{x}$ – średnia

Lake/Pond Jezioro	Stage Stadium	Species – Gatunek														
		Eupelops hygrophilus			*Hydrozetes lacustris*			*Hydrozetes longisetosus*			*Hydrozetes octosetosus*			*Limnozetes ciliatus*		
		Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au
L	Ad	0.4	0.6	<0.1^{bc}	0.2	0.1	0.1	3.2	1.1^{a}	1.5	0.6	0.1	0.2	16.8	3.5^{a}	4.3^{c}
	Juv	0.4	0.2	0.5	<0.1	0	0.2^{bc}	0.8	<0.1^{a}	0.6^{c}	0	0	0.1^{bc}	1.1	0^{a}	0.5^{c}
D1	Ad	0	0.1	0	0.4	0.2	0.2	1.2	0.1	0.1^{b}	2.0	1.8	0.6^{bc}	14.6	8.5	17.4^{c}
	Juv	0	<0.1	0	<0.1	<0.1	0.2^{bc}	0.1	0.1	<0.1	0.2	0.7	0.2	0.8	0.2^{a}	1.1^{c}
D2	Ad	0.1	0.3	0.1	0.1	0.1	0.4^{bc}	1.3	1.2	0.5^{b}	0.2	0.3	0.2	7.1	1.6^{a}	0.6^{b}
	Juv	0.5	0.8	1.0	<0.1	0.1	0.6^{bc}	0.4	0.4	0.8	0.1	0.2	0.4^{bc}	1.3	0.1^{a}	0.1^{b}
D3	Ad	0	0.1	<0.1	0.1	0.1	0.3	1.7	0.2^{a}	2.2^{c}	0.1	0.1	0.6^{bc}	7.8	7.3	6.3
	Juv	0.1	<0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	1.4^{bc}	<0.1	<0.1	0.1	0.2	<0.1	0.3
D4	Ad	0	0.2	0	0.6	0.6	1.1	3.8	0.4^{a}	1.4^{b}	0.1	0.3	0.6	9.4	4.4	14.6^{c}
	Juv	0	0.4	0	0.1	0.1	1.3	0.4	0.1	0.8	<0.1	0.1	0.6^{b}	0.6	0.8	0.7
M	Ad	<0.1	0,1^{a}	<0.1^{b}	0.1	<0.1^{a}	<0.1^{b}	0.3	0.1	<0.1^{b}	2.9	1.3	0.4^{bc}	5.3	3.2	10.5
	Juv	0.1	0.1	<0.1	<0.1	0	0	<0.1	<0.1	0	0.8	0.5	0.2	0.3	0.2	0.1
K1	Ad	<0.1	0	<0.1	0.2	0.3	0.2	2.7	1.3^{a}	1.0^{b}	0.7	<0.1^{a}	<0.1^{b}	36.4	38.4^{a}	60.0
	Juv	0	0	0	0.1	0.1	0.2	2.4	0.1^{a}	0.1^{b}	0.3	0	<0.1	4.7	7.4	12.0
K2	Ad	<0.1	0	<0.1	0.3	0.5	0.2	2.2	1.1	0.4^{bc}	0	0	0	23.9	14.7	26.5^{c}
	Juv	<0.1	0.1	0	<0.1	<0.1	0.2^{b}	0.1	0.1	0.1	0	0	<0.1	1.1	2.1^{a}	5.4^{b}
K3	Ad	<0.1	<0.1	0	0.1	0.1	0.3^{c}	3.3	0.8^{a}	1.9^{c}	0.2	<0.1^{a}	0.1	17.8	5.5^{a}	4.6^{b}
	Juv	<0.1	0.1	0.2	<0.1	<0.1	0.1	0.5	0.2	0.9	0	0	0.1	1.3	0.8	3.2^{c}
$\bar{x}$	Ad	0.1	0.2	<0.1	0.2	0.2	0.3	2.1	0.7	1.0	0.8	0.4	0.3	12.7	10.0	18.6
	Juv	0.1	0.2	0.2	<0.1	<0.1	0.3	0.5	0.1	0.5	0.2	0.2	0.2	1.3	1.2	2.7

Table 8 continued – cd. tabeli 8

Lake/Pond Jezioro	Stage Stadium	Species – Gatunek														
		Limnozetes foveolatus			*Limnozetes lustrum*			*Limnozetes rugosus*			*Oppiella nova*			*Pilogalumna tenuiclava*		
		Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au
L	Ad	29.8	38.1	50.3^{bc}	2.4	1.9	1.7^{bc}	0.1	0.1	0.1	5.9	1.5^{a}	2.8	0.2	1.2^{a}	0.3^{c}
	Juv	0.6	5.0^{a}	0.3^{c}	0.6	0.3	0.2	0	<0.1	<0.1	0.3	0.1	<0.1	0.8	1.4	0.1^{c}
D1	Ad	29.8	206.4^{a}	213.3^{b}	0.2	<0.1	0	0.1	<0.1^{a}	0.2^{c}	<0.1	0.2	0	0.1	0.3	0^{c}
	Juv	0.3	10.6^{a}	0.4^{c}	0	0	0	<0.1	<0.1	<0.1	0	0	0	<0.1	0.3	0
D2	Ad	150.5	265.1	215.1	<0.1	<0.1	0	0	0	0	0.3	2.1	0.1	0.1	0.5^{a}	0.8^{b}
	Juv	1.5	19.8^{a}	2.4^{c}	0	0	0	0	0	0	<0.1	0.3	0	0.2	0.6	0.3
D3	Ad	62.0	67.2	119.5^{c}	0	0	0	0.1	0	0.3	0.1	0.1	0.1	0.3	0.9^{a}	0.4
	Juv	1.8	7.7^{a}	0.7^{c}	0	0	0	0	0	0.1	0	0.1	0	0.2	0.6	0.2
D4	Ad	119.8	217.3	156.6	0	0	0	0.2	<0.1	1.5^{bc}	0.3	1.2	1.3	<0.1	0.4	0.1
	Juv	1.5	23.1^{a}	1.2^{c}	0	0	0	0	0	0.7^{bc}	0	0	0	<0.1	0.3	0.1
M	Ad	40.4	132.8^{a}	102.9^{c}	<0.1	0	0	0	0	0	0.3	0.2	0.3	<0.1	0.4^{a}	0.8^{b}
	Juv	1.0	4.5^{a}	1.9^{c}	0	0	0	0	0	0	0	0	0	<0.1	0.3	0.2^{b}
K1	Ad	82.5	71.1	163.6^{b}	4.2	12.3	8.5	1.0	0.5	0.2^{bc}	0.4	2.5	0.8	0.3	1.7^{a}	0.8
	Juv	4.2	5.7	2.9	0.2	3.0^{a}	1.4^{b}	0.1	<0.1	<0.1	<0.1	<0.1	0	0.9	2.2	0.5^{c}
K2	Ad	62.3	90.7	85.9	0.1	0	<0.1	0	0	<0.1	0.3	0.3	0.1	0.1	0.6^{a}	0.2^{c}
	Juv	2.2	9.5^{a}	1.2^{c}	0	0	<0.1	0	0	0	0	0.1	0	0.3	1.1^{a}	0.2^{c}
K3	Ad	131.9	105.1	173.4^{c}	0.6	0.6	1.2	<0.1	0.1	<0.1	2.3	1.8	2.9	0.2	0.7^{a}	0.4
	Juv	3.7	3.3	2.4	<0.1	0.8^{a}	1.2^{b}	0	<0.1	0.1	0	0.2^{a}	0^{c}	0.5	1.7	0.1^{c}
$\bar{x}$	Ad	65.0	124.3	168.0	0.8	1.4	2.4	0.2	0.1	0.3	1.1	1.1	0.7	0.1	0.7	0.4
	Juv	1.9	10.8	2.1	0.1	0.5	0.5	<0.1	<0.1	0.1	<0.1	0.1	0	0.3	0.9	0.2

Table 8 continued – cd. tabeli 8

Lake/Pond Jezioro	Stage Stadium	Species – Gatunek														
		Platynothrus peltifer			*Punctoribates sellnicki*			*Trhypochthoniellus longisetus*			*Trhypochthonius nigricans*			*Trimalaconothrus foveolatus*		
		Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au
L	Ad	0.7	$<0.1^{a}$	0.1^{b}	0.7	0.2^{a}	0.9^{c}	2.9	0.7^{a}	3.2^{b}	0.1	$<0.1^{a}$	0.1^{c}	0.3	0.1	$<0.1^{b}$
	Juv	1.0	$<0.1^{a}$	0.7^{c}	0.6	0.4	0.1^{b}	0.6	1.1	0.5	0.9	$<0.1^{a}$	0.6^{c}	1.0	0.5	$<0.1^{b}$
D1	Ad	0	0	0	0.1	0.2	0.1	0.1	<0.1	0.2	0.1	0^{a}	0.1	0.2	0.2	0.1
	Juv	0	0	0	<0.1	0.1	0	0	0.3	0.1	0.2	$<0.1^{a}$	0.3	0.1	0.3	$<0.1^{c}$
D2	Ad	0	0	0	<0.1	0.4^{a}	0.1^{bc}	1.9	0.1^{a}	1.1^{c}	<0.1	<0.1	0	0.3	0.4	0.4
	Juv	0	0	0	0	0.4^{a}	0^{c}	0.4	1.3	0.4	0.1	0.9	0	0.1	0.3	0.1
D3	Ad	<0.1	0	0	0.1	0.2	0.1	2.9	0.2^{a}	2.3^{c}	<0.1	0	0	0.2	1.3^{a}	0.3^{c}
	Juv	<0.1	0	<0.1	0	0.1	<0.1	0.3	2.8^{a}	1.5	<0.1	0.8^{a}	$<0.1^{c}$	0.1	1.7^{a}	0.2^{c}
D4	Ad	0	0.2	0	0.1	0.1	0.3	1.5	0.1^{a}	0.3	0.4	0.1	<0.1	0.2	0.5	0.3
	Juv	0	0.3	<0.1	0.1	0	0	0.6	2.5^{a}	0.3^{c}	0.8	0.6	<0.1	0.2	0.8	0.1
M	Ad	0.3	0.1	0.9	0.2	0.5^{a}	0.5	0.9	1.0	6.8^{bc}	0	0	<0.1	1.8	2.1	1.0^{c}
	Juv	0.9	0.4^{a}	1.8	0.1	0.1	0	0.2	11.3^{a}	6.0^{b}	0	0	<0.1	4.3	2.7	2.2
K1	Ad	0.1	0.2	0.1	0.4	0.2	0.2	0.1	0.7^{a}	3.9^{bc}	1.7	0.4^{a}	0.5^{b}	1.1	0.2^{a}	2.9^{bc}
	Juv	0.2	0.3	0.6	0.8	0.1^{a}	0^{b}	0.2	8.8^{a}	2.4^{bc}	2.9	6.3	2.4	3.5	1.7^{a}	13.2^{bc}
K2	Ad	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0	0.8^{bc}	0.1	0	0	0.4	0.2	1.9^{bc}
	Juv	0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.3	0.3^{b}	0.1	<0.1	<0.1	0.8	0.7	5.5^{bc}
K3	Ad	<0.1	0	0	1.8	0.5	1.1	0.1	<0.1	0.1	<0.1	0	0	1.0	0.1^{a}	1.0^{c}
	Juv	0	0	<0.1	1.5	0.4^{a}	0^{bc}	0.1	0.2	0.1	0.1	0.1	<0.1	1.2	0.3^{a}	2.9^{bc}
$\bar{x}$	Ad	0.1	0.1	0.1	0.4	0.3	0.4	1.2	0.3	2.1	0.3	0.1	0.1	0.6	0.6	0.9
	Juv	0.2	0.1	0.3	0.3	0.2	<0.1	0.3	3.2	1.3	0.6	1.0	0.4	1.3	1.0	2.7

Table 8 continued – cd. tabeli 8

Lake/Pond Jezioro	Stage Stadium	Species – Gatunek								
		Trimalaconothrus maior			*Zetomimus furcatus*			Oribatida		
		Sp	Su	Au	Sp	Su	Au	Sp	Su	Au
L	Ad	0.9	2.5	0.9	1.7	0.2^{a}	0.3^{b}	71.0	52.4	68.3
	Juv	1.0	5.3^{a}	2.6^{b}	2.8	0.5^{a}	0.2^{b}	13.6	14.8	7.4
D1	Ad	0.4	1.0	0.5	0	0	0	50.5	219.5^{a}	232.8
	Juv	0.9	5.6	4.1^{b}	0	0	0	2.6	18.6	6.6^{b}
D2	Ad	1.0	0.6^{a}	0.5^{bc}	0	0	0	167.9	275.1	221.2
	Juv	3.6	3.2	5.3^{bc}	0	0	0	8.8	29.6	11.6
D3	Ad	9.5	6.1	3.4	<0.1	0	0	85.3	84.7	136.5^{c}
	Juv	20.7	15.6	17.0	0	0	0	23.6	29.6	21.6
D4	Ad	0.6	1.0	6.0^{bc}	0	0	0	138.4	228.8	184.5
	Juv	1.3	2.7	12.5^{bc}	0	0	0	5.5	32.0^{a}	18.3^{b}
M	Ad	2.9	8.3	1.0^{c}	<0.1	2.6^{a}	0.1^{bc}	55.7	153.0^{a}	126.3
	Juv	8.9	30.0^{a}	2.7^{bc}	0	<0.1	0	16.7	50.2^{a}	15.3^{c}
K1	Ad	0.2	$<0.1^{a}$	0^{b}	0	<0.1	0.1	133.0	133.1	244.9
	Juv	0.3	0.1	0.1	0	0	0	20.6	36.9	36.0
K2	Ad	0.5	0.4	0.3	<0.1	0	0	90.9	109.9	119.8
	Juv	0.8	2.7	1.1	0	0	0	5.6	17.0^{a}	14.1^{b}
K3	Ad	0.9	0.2^{a}	1.5^{c}	0.1	0.1	0.1	161.4	115.8	188.4^{bc}
	Juv	1.9	1.2	6.9^{bc}	0.1	0.2	0	11.0	9.4	18.0^{c}
$\bar{x}$	Ad	1.9	2.2	2.1	0.2	0.3	0.1	90.7	134.9	141.7
	Juv	4.4	7.4	5.2	0.3	0.1	<0.1	11.6	23.4	15.5

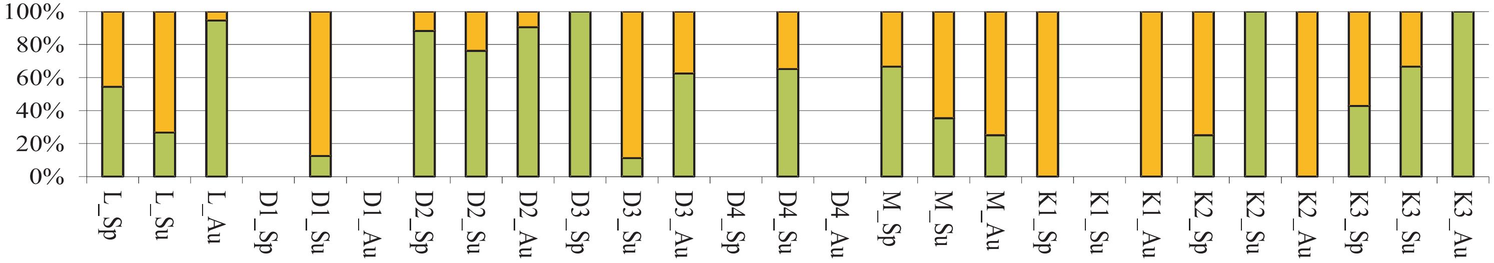
^{abc} – Significant differences between: ^{a} – Sp and Su, ^{b} – Sp and Au, ^{c} – Su and Au; at $p \leq 0.05$

^{abc} – Istotne różnice pomiędzy: ^{a} – Sp i Su, ^{b} – Sp i Au, ^{c} – Su i Au; przy $p \leq 0,05$

Fig. 29. Age structure of some Oribatida (with $D > 1$ and represented in samples by adults and juveniles) in lakes and ponds of Tuchola Forest: L – Lake Łyse, D1, D2, D3, D4 – ponds in 'Dury' reserve; M – Lake Martwe; K1, K2, K3 – ponds in 'Jeziorka Kozie' reserve; S – spring, Su – summer, Au – autumn; 🟩 juveniles, 🟨 adults

Rys. 29. Struktura wiekowa wybranych Oribatida ($D > 1$ i reprezentowanych w próbach przez dorosłe i młodociane) w jeziorach na torfowiskach Borów Tucholskich: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury", M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie"; Sp – wiosna, Su – lato, Au – jesień, 🟩 młodociane, 🟨 dorosłe

Eupelops hygrophilus



Hydrozetes lacustris

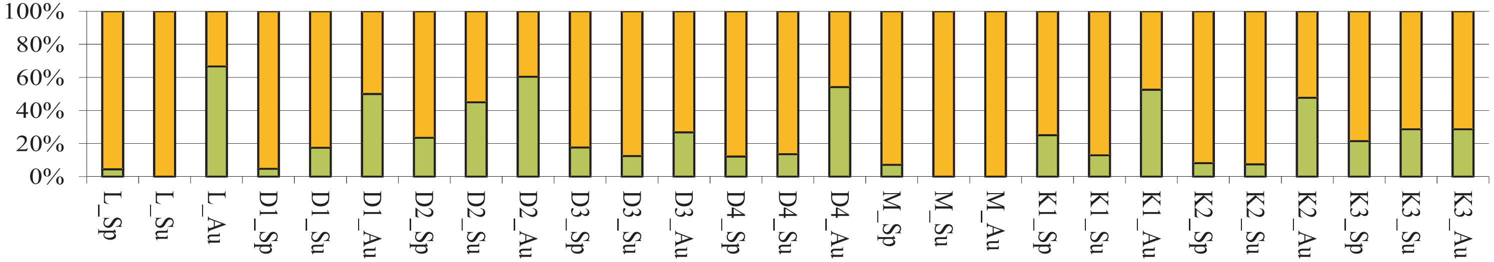


Fig. 29 continued – cd. rysunku 29

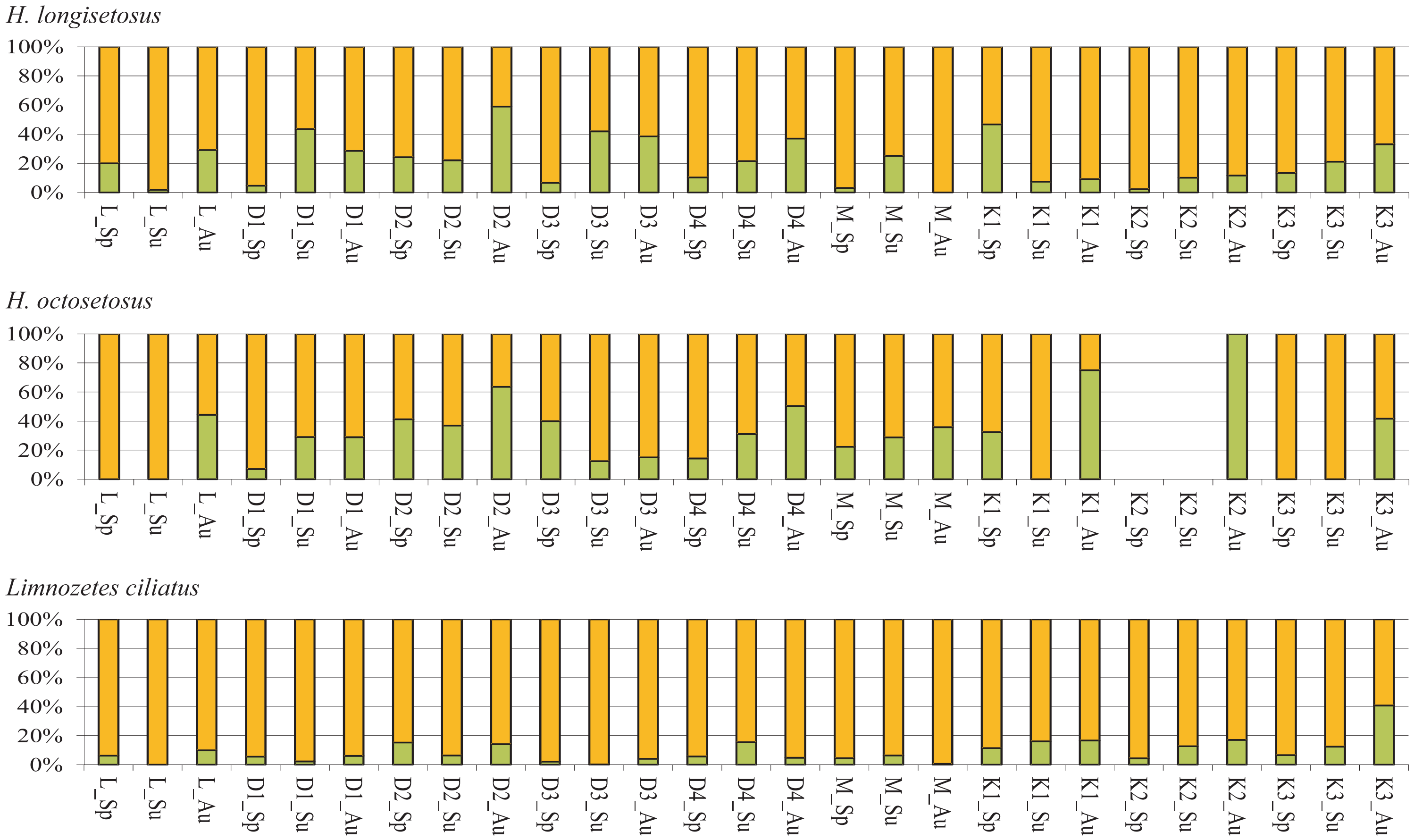
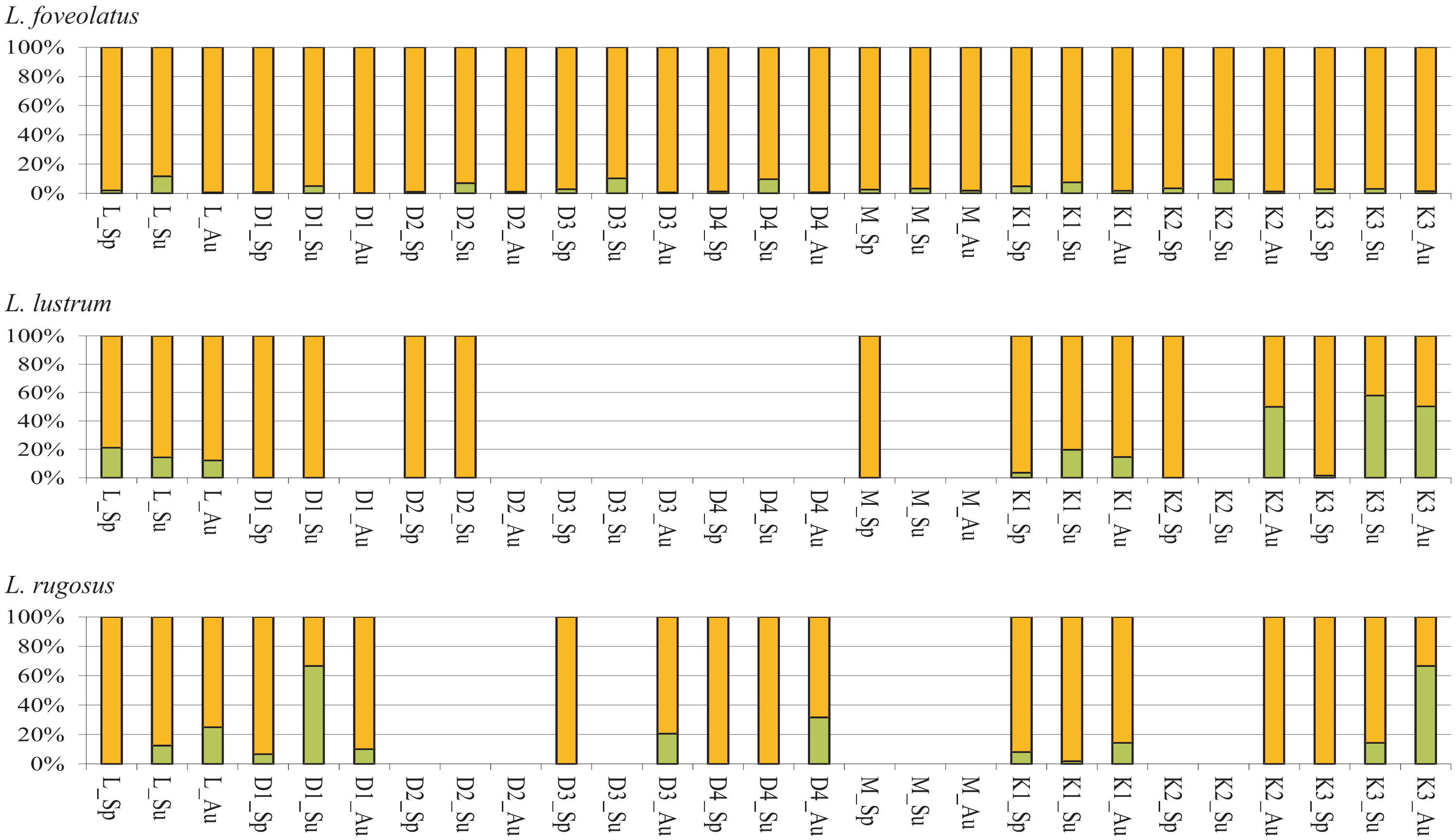


Fig. 29 continued – cd. rysunku 29



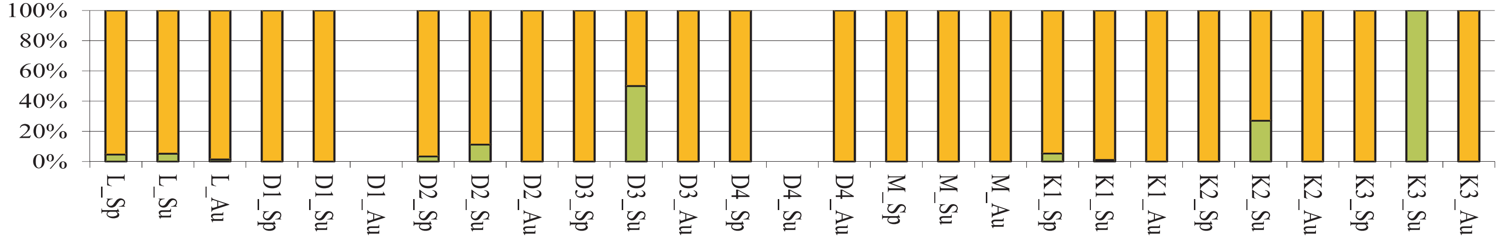
L. foveolatus

L. lustrum

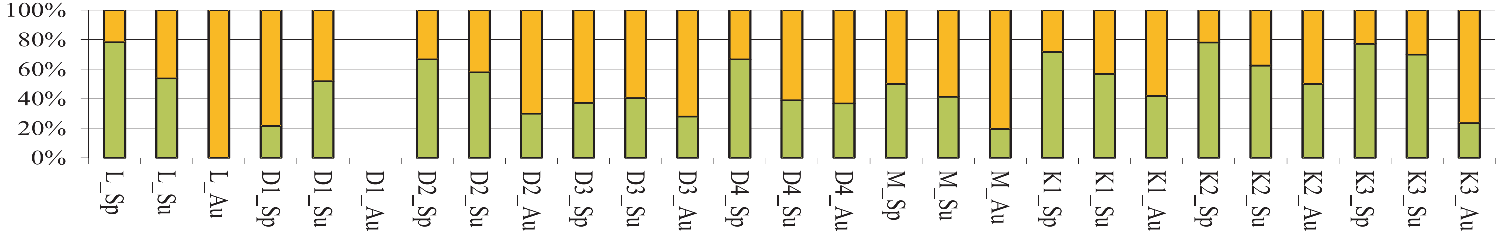
L. rugosus

Fig. 29 continued – cd. rysunku 29

Oppiella nova



Pilogalumna tenuiclava



Platynothrus peltifer

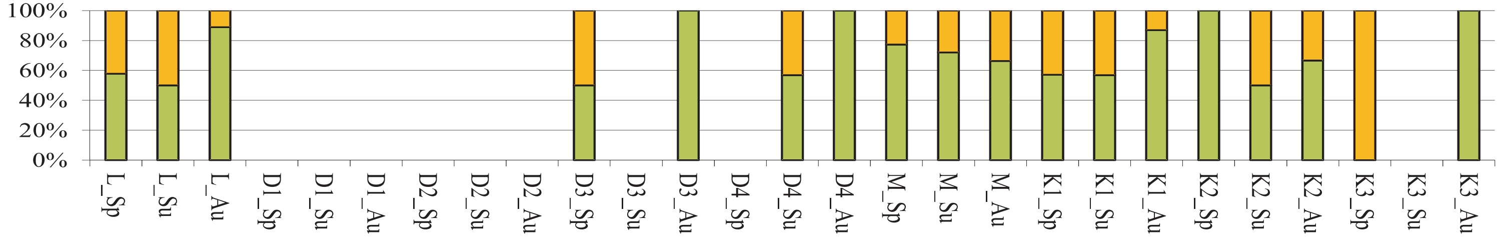
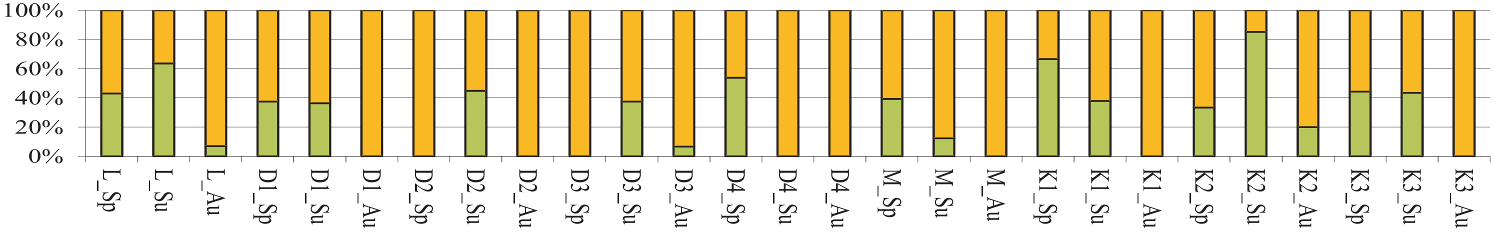
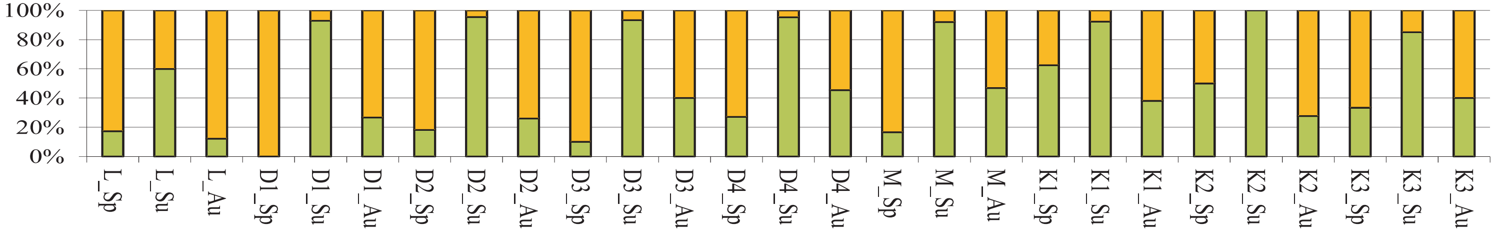


Fig. 29 continued – cd. rysunku 29

Punctoribates sellnicki



Trhypochthoniellus longisetus



Trhypochthonius nigricans

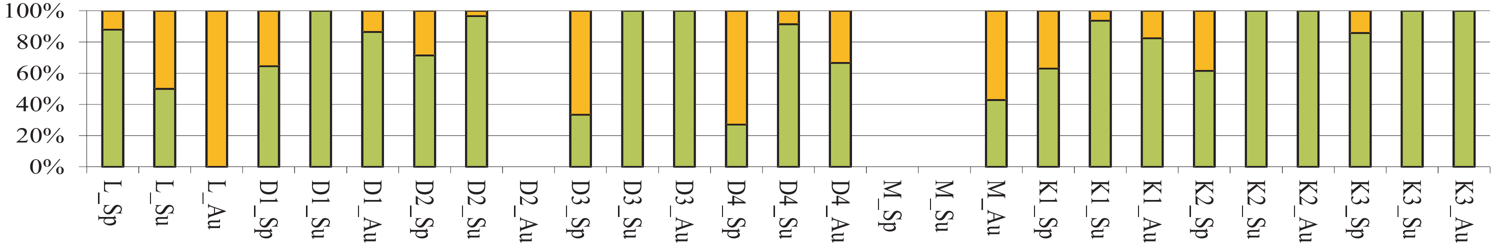
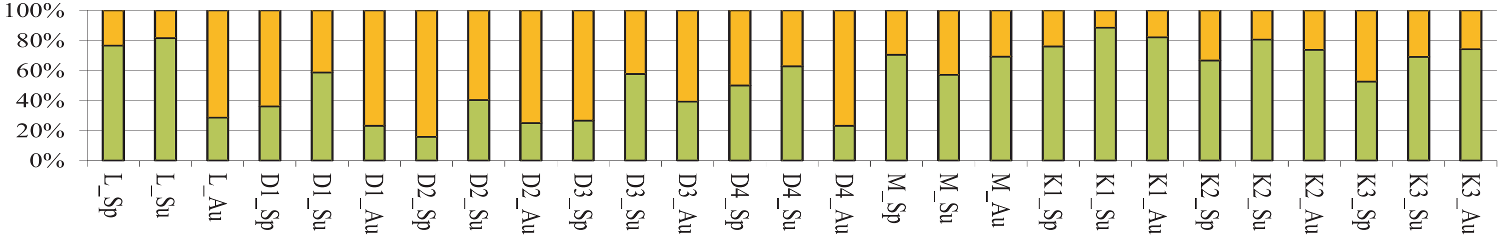
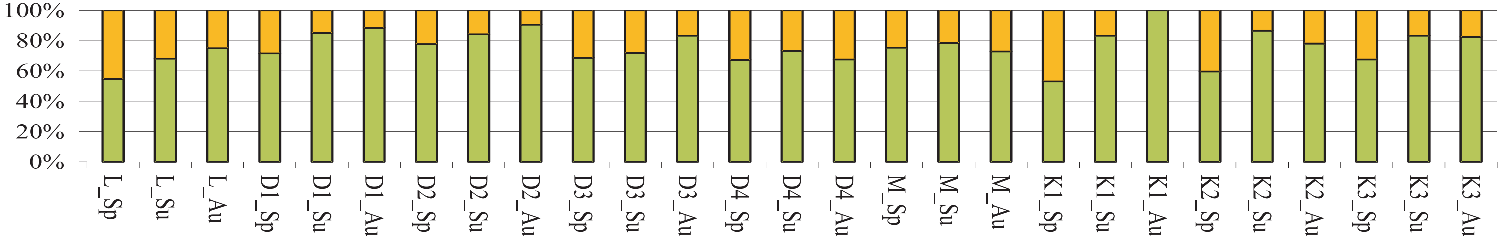


Fig. 29 continued – cd. rysunku 29

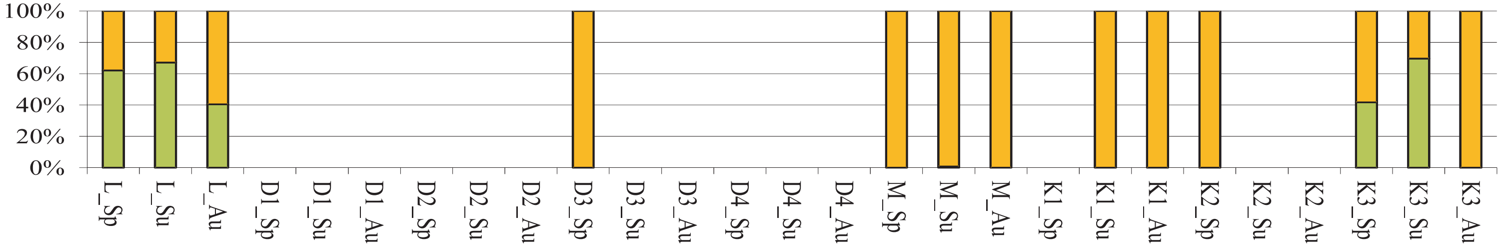
Trimalaconothrus foveolatus



T. maior



Zetomimus furcatus



For example, in *Trhypochthoniellus longisetus* the juveniles made only 20.0% of the samples in spring, and 91.4% in summer. Interestingly, in all studied lakes and ponds the highest percentage of juveniles of this species was observed in summer. In *Trimalaconothrus foveolatus* the mean proportion of juveniles varied from 62.5% in summer to 75.0% in autumn. Also in some other species, like *Eupelops hygrophilus*, *Platynothrus peltifer*, *Pilogalumna tenuiclava*, *Punctoribates sellnicki* and *Zetomimus furcatus* the juveniles dominated in some seasons, and the adults in the other seasons, but the density of these species was rather low.

5.1.4. Ecotone between the water's edge of lake M and bog

5.1.4.1. Abundance of groups and richness of Oribatida

The water content in the floating mat varied from 97% at the water's edge to 95% in the plot situated 5 m from it. The total density of mites was highest at the water's edge and decreased with distance from it (Table 9).

Table 9. Abundance (*A* in 1000 m^{-2}) of some taxa of Acari, number of species (*S*) and Shannon index (*H*s) of Oribatida in plots at lake M; $\bar{x}$ – mean, SD − standard deviation

Tabela 9. Wskaźnik liczebności (*A* w 1000 m^{-2}) wybranych taksonów roztoczy, liczba gatunków (*S*) i wskaźnik Shannona (*Hs*) Oribatida na powierzchniach przy jeziorze M; $\bar{x}$ – średnia, SD − odchylenie standardowe

No of plot (distance from water's edge) Nr powierzchni (odległość od krawędzi wody)	*A* $\bar{x}$ ± SD range – zakres				*S*	*H*s
	Acari	Oribatida	Mesostigmata	other Acari inne Acari	Oribatida	
1 (0 m)	72.7 ± 52.6 9.4-200.3	72.5 ± 52.6 9.4-200.2	0.1 ± 0.2 0-0.5	0.1 ± 0.2 0-0.5	29	1.43
2 (1 m)	47.3 ± 25.1 8.7-74.7	43.4 ± 23.4 7.8-78.0	0.4^{a} ± 0.4 0-1.3	3.5^{a} ± 4.5 0-15.5	26	1.99
3 (3 m)	41.6 ± 23.2 8.1-77.5	37.7 ± 21.7 7.2-72.0	2.2^{ab} ± 1.1 0.4-3.3	1.7^{a} ± 1.4 0-4.4	26	2.23
4 (5 m)	37.1 ± 21.9 4.4-68.4	33.6^{a} ± 20.9 3.8-63.0	2.2^{ab} ± 1.7 0-4.9	1.2^{a} ± 1.1 0-3.7	30	2.26

^{abc} – Significant differences between plots: ^{a} – 1 and 2, 3, 4; ^{b} – 2 and 3, 4; ^{c} – 3 and 4; at $p \leq 0.05$

^{abc} – Istotne różnice pomiędzy powierzchniami: ^{a} – 1 i 2, 3, 4; ^{b} – 2 i 3, 4; ^{c} – 3 i 4; przy $p \leq 0,05$

This pattern was due to the Oribatida, which highly dominated in all plots. In contrast, the Mesostigmata were least abundant at the water's edge, and their density increased with distance from it. The density of 'other Acari' was also lowest at the edge of the lake, but was highest 1 m from this edge, and then decreased in more distant plots. The species richness of Oribatida was the highest 5 m from the water's edge, relatively high at the water's edge and lowest 1 m and 3 m from it. The Shannon index (*H*s) of Oribatida increased with the distance from the water's edge.

5.1.4.2. Species composition and dominance structure of Oribatida

Some species, like *Limnozetes foveolatus*, *Hydrozetes octosetosus*, *Punctoribates sellnicki*, *Trhypochthoniellus longisetus* and *Trimalaconothrus maior* were abundant only at the water's edge, while in other plots their density was significantly lower (Table 10). Some other species (*Limnozetes ciliatus*, *Pilogalumna tenuiclava*, *Platynothrus peltifer* and *Trimalaconothrus foveolatus*) had the highest density 1 m from the water's edge, while in other plots their abundance was significantly lower. Most other species, including *Hoplophthiracarus illinoisensis*, *Nanhermannia* cf. *coronata*, *Nothrus pratensis* Sellnick, 1928, *Oppiella nova*, *Ramusella furcata* (Willmann, 1928) and *Tectocepheus velatus* (Michael, 1880) were either absent or not abundant at the water's edge, and their density significantly increased with distance from it.

5.1.4.3. Age structure of Oribatida

The proportion of juveniles in the plots was rather low, comprising 15-29% of Oribatida (Table 11).

The highest was noted 1 m from the water's edge, it was slightly lower at the water's edge, and distinctly lower in plots more distant from it. In most species adults highly dominated; equal abundance was seen only in *Pilogalumna tenuiclava* and only in *Eupelops hygrophilus*, *Nanhermannia* cf. *coronata*, *Nothrus pratensis* and *Platynothrus peltifer* were juveniles more abundant than adults. In most species the proportion of juveniles was similar in all plots. Only in *Eupelops hygrophilus* and *Trimalaconothrus foveolatus* did the percentage of juveniles decrease with distance from the water's edge.

5.1.5. Other lakes and ponds

5.1.5.1. Abundance of groups and richness of Oribatida

Total mite density at the shore of lake O was significantly higher than at the shore of any other lake or pond (Table 12); it was lowest at the shore of pond P1. Oribatida dominated among mites, with the highest proportion at lake O (99.8%), and the lowest at pond P1 (90.3%). At most shores Mesostigmata were second most abundant, comprising from less than 0.1% at lake O to almost 10.0% at pond P1. Other Acari were less abundant. The shore of pond KG was richest in species of Oribatida (41 species) and consequently, the Shannon index (*H*s) was highest there, while the shore of lake S was poorest (17 species). Interestingly, the Mesostigmata were most abundant at pond KG, where species diversity of Oribatida was highest.

Table 10. Abundance (A in 1000 m^{-2}), dominance (D) and constancy (C) indices of some Oribatida in plots at lake M; $\bar{x}$ – mean, SD − standard deviation; * species with D Ω1 are listed under the table with the number of plot where they occurred

Tabela 10. Wskaźniki liczebności (A w 1000 m^{-2}), dominacji (D) i stałości występowania (C) wybranych Oribatida na powierzchniach przy jeziorze M; $\bar{x}$ – średnia, SD − odchylenie standardowe; * gatunki z D Ω1 są wyszczególnione pod tabelą wraz z numerem powierzchni, na której wystąpiły

Species – Gatunek	No of plot (distance from water's edge) − Nr powierzchni (odległość od krawędzi wody)											
	1 (0 m)			2 (1 m)			3 (3 m)			4 (5 m)		
	A $\bar{x} \pm$ SD range – zakres	D	C	A $\bar{x} \pm$ SD range – zakres	D	C	A $\bar{x} \pm$ SD range – zakres	D	C	A $\bar{x} \pm$ SD range – zakres	D	C
1	2	3	4	5	6	7	8	9	10	11	12	13
Atropacarus striculus	0			0.1 ± 0.2 0-0.6	<1.0	20	0.3^{a} ± 0.3 0-1.0	<1.0	70	0.7^{a} ± 0.8 0-2.6	2.0	60
Eupelops hygrophilus	0.1 ± 0.1 0-0.3	<1.0	50	0.3 ± 0.3 0-0.9	<1.0	70	0.6^{a} ± 0.6 0-1.6	1.5	90	1.0^{a} ± 1.0 0-3.5	3.0	80
Hoplophthiracarus illinoisensis	0.1 ± 0.1 0-0.2	<1.0	30	1.4^{a} ± 1.3 0.1-3.5	3.3	100	9.7^{ab} ± 4.5 3.7-18.8	25.8	100	5.0^{abc} ± 4.7 0.3-14.5	15.0	100
Hydrozetes octosetosus	3.8 ± 3.6 0.3-10.0	5.2	100	<0.1^{a} ± <0.1 0-0.1	<1.0	10	0^{a}			<0.1^{a} ± <0.1 0-0.1	<1.0	10
Hypochthonius rufulus	<0.1 ± <0.1 0-0.1	<1.0	20	<0.1 ± <0.1 0-0.1	<1.0	30	1.3^{ab} ± 1.0 0.2-3.5	3.6	100	1.1^{ab} ± 0.6 0.1-2.1	3.2	100
Limnozetes ciliatus	5.5 ± 4.3 1.4-14.1	7.6	100	18.0 ± 17.7 1.0-47.0	41.5	100	0.3^{ab} ± 0.4 0-1.2	<1.0	40	0.4^{ab} ± 1.1 0-3.4	1.3	30
L. foveolatus	41.4 ± 34.1 0.3-117.5	57.2	100	0.8^{a} ± 1.5 0-5.0	1.8	80	0.4^{a} ± 0.8 0-2.5	1.0	30	0.2^{a} ± 0.6 0-2.0	<1.0	30
Liochthonius alpestris	0			0.6^{a} ± 1.0 0-3.5	1.3	80	0.3 ± 0.6 0-1.9	<1.0	30	0.3 ± 0.5 0-1.6	<1.0	50
Nanhermannia cf. *coronata*	0			1.8^{a} ± 1.5 0.4-5.1	4.1	100	2.6^{a} ± 2.8 0.4-9.0	6.9	100	5.2^{a} ± 7.6 0.2-24.2	15.6	100
Nothrus pratensis	0			0.3^{a} ± 0.3 0-1.0	<1.0	70	3.2^{ab} ± 2.6 0.2-7.8	8.5	100	2.6^{ab} ± 1.7 0-5.2	7.8	90

Table 10 continued – cd. tabeli 10

1	2	3	4	5	6	7	8	9	10	11	12	13
Oppiella nova	0.3 ± 0.4 0-1.2	<1.0	70	$2.8^{a} \pm 3.1$ 0-9.8	6.4	90	$9.0^{a} \pm 7.7$ 0.5-22.6	23.8	100	$9.9^{ab} \pm 8.1$ 0.8-22.5	29.3	100
Pergalumna nervosa	0			0			$0.7^{ab} \pm 0.7$ 0-2.4	1.8	90	$0.4^{ab} \pm 0.4$ 0-1.1	1.3	90
Pilogalumna tenuiclava	$<0.1 \pm 0.1$ 0-0.2	<1.0	30	$4.9^{a} \pm 5.4$ 0.2-18.5	11.4	100	$0.8^{ab} \pm 0.7$ 0.1-2.2	2.2	100	$0.3^{abc} \pm 0.2$ 0-0.6	<1.0	90
Platynothrus peltifer	1.1 ± 1.0 0.1-2.9	1.6	100	$2.8^{a} \pm 1.8$ 0.6-6.2	6.4	100	$0.2^{ab} \pm 0.3$ 0-0.7	<1.0	70	$0.1^{ab} \pm 0.1$ 0-0.3	<1.0	50
Punctoribates sellnicki	0.3 ± 0.3 0-1.2	<1.0	90	$0.1^{a} \pm 0.1$ 0-0.4	<1.0	30	0^{a}			0^{a}		
Ramusella furcata	0.1 ± 0.1 0-0.3	<1.0	30	$1.9^{a} \pm 2.7$ 0-9.0	4.3	90	$2.6^{a} \pm 1.8$ 0.2-4.6	6.8	100	$0.5^{ac} \pm 0.3$ 0-1.0	1.4	90
Suctobelbella latirostris	$<0.1 \pm 0.1$ 0-0.2	<1.0	30	$0.3^{a} \pm 0.3$ 0-1.0	<1.0	70	0.7 ± 1.5 0-4.8	1.8	50	0.2 ± 0.3 0-0.7	<1.0	30
Tectocepheus velatus	0			0			$4.2^{ab} \pm 4.7$ 0-12.9	11.2	90	$3.7^{ab} \pm 3.9$ 0-12.1	11.0	80
Trhypochthoniellus longisetus	1.1 ± 2.4 0-7.9	1.5	70	0.2 ± 0.3 0-0.8	<1.0	40	$0.1^{a} \pm 0.2$ 0-0.5	<1.0	10	0^{a}		
Trimalaconothrus foveolatus	6.1 ± 6.2 0-17.7	8.5	90	6.7 ± 3.8 1.9-13.5	15.4	100	$0.5^{ab} \pm 0.5$ 0-1.6	1.2	80	$1.2^{abc} \pm 0.9$ 0-2.8	3.6	90
T. maior	11.4 ± 12.5 0-43.3	15.8	90	$0.1^{a} \pm 0.4$ 0-1.3	<1.0	20	0^{a}			0^{a}		

^{abc} – Significant differences between plots: ^{a} – 1 and 2, 3, 4; ^{b} – 2 and 3, 4; ^{c} – 3 and 4; at $p \leq 0.05$

^{abc} – Istotne różnice pomiędzy powierzchniami: ^{a} – 1 i 2, 3, 4; ^{b} – 2 i 3, 4; ^{c} – 3 i 4; przy $p \leq 0,05$

* *Carabodes labyrinthicus* (2), *Cultroribula bicultrata* (1), *Cepheus cepheiformis* (4), *Cymbaeremaeus cymba* (3), *Epidamaeus glabriseta* (1), *Graptoppia foveolata* (1), *Hydrozetes lacustris* (1, 4), *H. longisetosus* (1), *H. thienemanni* (3, 4), *Limnozetes lustrum* (1), *L. rugosus* (1), *Liochthonius peduncularis* (1), *Mainothrus badius* (3, 4), *Malaconothrus* sp. 2 (2), *Malaconothrus monodactylus* (2, 3, 4), *Metabelba sphagni* (2, 3, 4), *Parachipteria willmanni* (1), *Scheloribates initialis* (4), *S. laevigatus* (2, 4), *S. latipes* (1, 2, 3, 4), *Suctobelbella palustris* (1), *Trichoribates novus* (1, 3, 4), *Trhypochthonius nigricans* (2), *Trimalaconothrus vietsi* (2, 3, 4), *Zetomimus furcatus* (1, 4)

Table 11. Abundance (*A* in 1000 m^{-2}) and percentage of adults (Ad) and juveniles (Juv) of some Oribatida (with $D > 1$ and represented by Ad and Juv) in plots at lake M; $\bar{x}$ – mean, SD – standard deviation

Tabela 11. Wskaźnik liczebności (*A* w 1000 m^{-2}) i procent dorosłych (Ad) i młodocianych (Juv) wybranych Oribatida ($D > 1$ i reprezentowanych przez Ad i Juv) na powierzchniach przy jeziorze M; $\bar{x}$ – średnia, SD – odchylenie standardowe

Taxon – Takson	Stage Stadium	No of plot (distance from water's edge) – Nr powierzchni (odległość od krawędzi wody)							
		1 (0 m)		2 (1 m)		3 (3 m)		4 (5 m)	
		A $\bar{x}$ ± SD range – zakres	%	*A* $\bar{x}$ ± SD range – zakres	%	*A* $\bar{x}$ ± SD range – zakres	%	*A* $\bar{x}$ ± SD range – zakres	%
1	2	3	4	5	6	7	8	9	10
Eupelops hygrophilus	Ad	<0.1 ± 0.1 0-0.2	33	0.1 ± 0.1 0-0.4	38	0.3^{a} ± 0.4 0-1.2	53	0.6^{a} ± 0.6 0-1.9	55
	Juv	0.1 ± 0.1 0-0.2	67	0.2 ± 0.2 0-0.8	63	0.3 ± 0.3 0-1.0	47	0.5^{a} ± 0.5 0-1.6	45
Hydrozetes octosetosus	Ad	2.9 ± 2.9 0.3-7.1	78	$<0.1^{a}$ ± <0.1 0-0.1	100	0^{a}	0	$<0.1^{a}$ ± <0.1 0-0.1	100
	Juv	0.8 ± 1.3 0-3.3	22	0^{a}	0	0^{a}	0	0^{a}	0
Hypochthonius rufulus	Ad	<0.1 ± <0.1 0-0.1	50	<0.1 ± <0.1 0-0.1	67	0.8^{ab} ± 0.5 0.1-2.0	60	0.8^{ab} ± 0.5 0-1.6	72
	Juv	<0.1 ± <0.1 0-0.1	50	<0.1 ± <0.1 0-0.1	33	0.5^{ab} ± 0.5 0-1.5	40	0.3^{ab} ± 0.3 0-1.0	28
Limnozetes ciliatus	Ad	5.3 ± 4.0 1.4-12.9	95	16.7 ± 16.3 1.0-42.1	93	0.2^{ab} ± 0.3 0-0.9	80	0.4^{ab} ± 1.0 0-3.3	98
	Juv	0.3 ± 0.3 0-1.2	5	1.3 ± 1.7 0-4.9	7	$<0.1^{a}$ ± 0.1 0-0.4	20	$<0.1^{ab}$ ± <0.1 0-0.1	2
L. foveolatus	Ad	40.4 ± 32.7 0.3-112.8	98	0.7^{a} ± 1.5 0-5.0	96	0.4^{a} ± 0.8 0-2.5	100	0.2^{a} ± 0.6 0-1.9	96
	Juv	1.0 ± 1.7 0-4.7	2	$<0.1^{a}$ ± 0.1 0-0.3	4	0^{a}	0	$<0.1^{a}$ ± <0.1 0-0.1	4

Table 11 continued – cd. tabeli 11

1	2	3	4	5	6	7	8	9	10
Nanhermannia cf. *coronata*	Ad	0	0	$0.9^{a} \pm 0.9$ 0.1-3.1	50	$1.0^{a} \pm 1.1$ 0-3.8	37	$3.0^{a} \pm 5.2$ 0.1-16.9	57
	Juv	0	0	$0.9^{a} \pm 0.7$ 0-2.0	50	$1.6^{a} \pm 1.8$ 0.3-5.2	63	$2.2^{a} \pm 2.5$ 0.1-7.3	43
Nothrus pratensis	Ad	0	0	0.1 ± 0.2 0-0.6	34	$1.1^{ab} \pm 0.9$ 0.1-2.8	36	$0.8^{ab} \pm 0.5$ 0-1.9	30
	Juv	0	0	0.2 ± 0.2 0-0.6	66	$2.1^{ab} \pm 1.8$ 0-5.2	64	$1.8^{ab} \pm 1.3$ 0-3.9	70
Oppiella nova	Ad	0.3 ± 0.4 0-1.2	100	$2.7^{a} \pm 3.1$ 0-9.8	100	$8.8^{a} \pm 7.6$ 0.5-22.5	98	$9.8^{ab} \pm 8.1$ 0.8-22.5	99
	Juv	0	0	<0.1 ± <0.1 0-0.1	<1	0.1 ± 0.2 0-0.5	2	0.1 ± 0.1 0-0.3	1
Pergalumna nervosa	Ad	0	0	0	0	$0.5^{ab} \pm 0.4$ 0-1.6	80	$0.3^{ab} \pm 0.3$ 0-0.9	80
	Juv	0	0	0	0	0.1 ± 0.2 0-0.8	20	0.1 ± 0.1 0-0.4	20
Pilogalumna tenuiclava	Ad	<0.1 ± <0.1 0-0.1	50	$1.6^{a} \pm 1.6$ 0.1-4.2	33	$0.4^{a} \pm 0.3$ 0.1-1.0	54	$0.2^{abc} \pm 0.1$ 0-0.4	64
	Juv	<0.1 ± 0.1 0-0.2	50	$3.3^{a} \pm 4.4$ 0-14.6	67	$0.4^{b} \pm 0.6$ 0-1.9	46	$0.1^{b} \pm 0.1$ 0-0.5	36
Platynothrus peltifer	Ad	0.3 ± 0.3 0-1.1	23	0.6 ± 0.5 0.1-1.5	22	$0.1^{b} \pm 0.2$ 0-0.4	52	$<0.1^{ab} \pm <0.1$ 0-0.1	25
	Juv	0.9 ± 0.7 0.1-2.0	77	$2.2^{a} \pm 1.6$ 0.4-5.6	78	$0.1^{ab} \pm 0.1$ 0-0.3	48	$0.1^{ab} \pm 0.1$ 0-0.2	75
Punctoribates sellnicki	Ad	0.2 ± 0.1 0-0.5	61	0.1 ± 0.1 0-0.4	100	0^{a}	0	0^{a}	0
	Juv	0.1 ± 0.2 0-0.7	39	0	0	0	0	0	0

Table 11 continued – cd. tabeli 11

1	2	3	4	5	6	7	8	9	10
Ramusella furcata	Ad	<0.1 ± 0.1 0-0.3	100	$1.4^{a} \pm 1.6$ 0-5.2	77	$2.6^{a} \pm 1.8$ 0.2-4.6	100	$0.5^{ac} \pm 0.3$ 0-1.0	100
	Juv	0	0	0.4 ± 1.2 0-3.8	23	0	0	0	0
Tectocepheus velatus	Ad	0	0	0	0	4.0 ± 4.5^{ab} 0-12.3	96	3.5 ± 3.9^{ab} 0-12.1	94
	Juv	0	0	0	0	0.2 ± 0.2 0-0.6	4	0.2 ± 0.2^{ab} 0-0.6	6
Trhypochthoniellus longisetus	Ad	0.9 ± 2.0 0-6.5	83	0.2 ± 0.3 0-0.7	80	$<0.1 \pm 0.1^{a}$ 0-0.5	100	0^{a}	0
	Juv	0.2 ± 0.4 0-1.4	17	<0.1± 0.1 0-0.2	20	0	0	0	0
Trimalaconothrus foveolatus	Ad	1.8 ± 1.5 0-4.7	30	2.9 ± 1.6 0.4-6.0	44	0.3 ± 0.3^{ab} 0-1.0	71	0.9 ± 0.9^{b} 0-2.4	73
	Juv	4.3 ± 4.7 0-13.0	70	3.7 ± 2.6 1.5-9.8	56	0.1 ± 0.2^{ab} 0-0.6	29	0.3 ± 0.3^{ab} 0-1.1	27
T. maior	Ad	2.8 ± 2.8 0-9.2	24	$<0.1 \pm 0.1^{a}$ 0-0.2	21	0^{a}	0	0^{a}	0
	Juv	8.6 ± 10.0 0-34.1	76	0.1 ± 0.3^{a} 0-1.1	79	0^{a}	0	0^{a}	0
Oribatida	Ad	55.8 ± 37.4 6.9-141.7	77	30.8 ± 17.7 4.6-55.1	71	32.0 ± 17.9 5.9-59.3	85	27.7 ± 17.7^{a} 2.5-51.8	82
	Juv	16.7 ± 16.1 2.5-58.5	23	12.6 ± 7.1 3.2-23.5	29	5.7 ± 4.5^{ab} 0.7-13.1	15	5.9 ± 3.5^{ab} 1.3-11.3	18

^{abc} – Significant differences between plots: ^{a} – 1 and 2, 3, 4; ^{b} – 2 and 3, 4; ^{c} – 3 and 4; at $p \leq 0.05$

^{abc} – Istotne różnice pomiędzy powierzchniami: ^{a} – 1 i 2, 3, 4; ^{b} – 2 i 3, 4; ^{c} – 3 i 4; przy $p \leq 0{,}05$

Table 12. Abundance (*A* in 1000 m^{-2}) of some taxa of Acari, number of species (*S*) and Shannon index (*H*s) of Oribatida in forest lakes and ponds in northern Poland: P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in 'Bagno Chlebowo' reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in 'Kurze Grzędy' reserve; $\bar{x}$ – mean, SD − standard deviation

Tabela 12. Wskaźnik liczebności (*A* w 1000 m^{-2}) wybranych taksonów roztoczy, liczba gatunków (*S*) i wskaźnik Shannona (*H*s) Oribatida w jeziorach śródleśnych północnej Polski: P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo"; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy"; $\bar{x}$ – średnia, SD − odchylenie standardowe

Pond/Lake Jezioro	*A* $\bar{x}$ ± SD range – zakres				*S*	*H*s
	Acari	Oribatida	Mesostigmata	other Acari inne Acari	Oribatida	
P1	24.8 ± 41.0 0.9-138.6	22.4 ± 37.8 0.8-127.1	2.4 ± 3.4 0.1-11.5	0	30	1.85
P2	49.6 ± 35.3 4.4-97.4	45.3 ± 32.8 4.2-87.6	4.3 ± 3.9 0.2-9.8	0.1 ± 0.1 0-0.3	28	1.70
P3	47.9 ± 42.8 2.2-114.5	46.9 ± 41.9 2.2-113.5	1.0^{b} ± 1.4 0-4.6	0	32	1.32
BC	55.4^{a} ± 40.4 17.3-134.4	53.2^{a} ± 39.6 14.6-129.9	1.7 ± 1.1 0.2-3.6	0.6^{abc} ± 0.6 0-1.6	31	1.85
O	236.3^{abcd} ± 84.5 64.7-334.7	235.9^{abcd} ± 84.6 64.6-334.0	0.1^{abd} ± 0.1 0-0.3	0.3^{ac} ± 0.4 0-1.4	29	0.71
S	75.3^{ae} ± 53.7 20.8-166.7	74.7^{abe} ± 53.5 20.4-164.9	0.1^{abd} ± 0.1 0-0.4	0.5^{abc} ± 0.6 0-1.7	17	0.73
KG	63.2^{ae} ± 56.6 21.7-211.8	57.6^{ae} ± 53.2 18.7-195.9	5.4^{acdef} ± 4.1 1.1-15.9	0.1^{adf} ± 0.1 0-0.4	41	1.96

[abcdef] – Significant differences between: [a] – P1 and P2, P3, BC, O, S, KG; [b] – P2 and P3, BC, O, S, KG; [c] – P3 and BC, O, S, KG; [d] – BC and O, S, KG; [e] – O and S, KG; [f] – S and KG; at $p \leq 0.05$

[abcdef] – Istotne różnice pomiędzy: [a] – P1 i P2, P3, BC, O, S, KG; [b] – P2 i P3, BC, O, S, KG; [c] – P3 i BC, O, S, KG; [d] – BC i O, S, KG; [e] – O i S, KG; [f] – S i KG; przy $p \leq 0{,}05$

5.1.5.2. Species composition and dominance structure of Oribatida

The oribatid fauna of studied shores of lakes and ponds was rich in species, but most of them were not abundant. In total, 92 species from 34 families were found (Table 4), but few of them occurred at high density (Table 13). The highest number of species with a dominance index above 1% was at pond P1 (12 species) and the lowest (3 species) at lake O (Fig. 30).

These lakes and ponds varied a lot, so their oribatid fauna was more differentiated than in bogs of Tuchola Forest. For example, *Limnozetes foveolatus* and *L. ciliatus* had high density only at the shores of lakes O and S, while at the other shores they were few or absent. Interestingly, the former species was most abundant at lake O, while the latter one at lake S.

Table 13. Abundance (*A* in 1000 m^{-2}), dominance (*D*) and constancy (*C*) indices of some Oribatida (with $D > 1$) in forest lakes and ponds in northern Poland: P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in 'Bagno Chlebowo' reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in 'Kurze Grzędy' reserve; $\bar{x}$ – mean, SD − standard deviation

Tabela 13. Wskaźniki liczebności (*A* w 1000 m^{-2}), dominacji (*D*) i stałości występowania (*C*) wybranych Oribatida ($D > 1$) w jeziorach śródleśnych północnej Polski; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo"; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy"; $\bar{x}$ – średnia, SD − odchylenie standardowe

Species – Gatunek	Index Wskaźnik	P1	P2	P3	BC	O	S	KG
1	2	3	4	5	6	7	8	9
Achipteria coleoptrata	*A* $\bar{x}$ ± SD range – zakres	0.4 ± 1.0 0-0.3	0.6 ± 1.0 0-0.3	0.6 ± 0.9 0-2.7	0	0	0	0
	D	2.0	1.3	1.2				
	C	30	20	60				
Adoristes ovatus	*A* $\bar{x}$ ± SD range – zakres	0.4 ± 0.7 0-2.3	1.2 ± 2.4 0-7.9	0.1 ± 0.2 0-0.5	0^{abc}	0^{abc}	0^{abc}	0^{abc}
	D	1.7	2.6	<1.0				
	C	70	80	60				
Astegistes pilosus	*A* $\bar{x}$ ± SD range – zakres	0.3 ± 0.3 0-0.9	0.1 ± 0.2 0-0.7	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}
	D	1.2	<1.0					
	C	70	50					
Atropacarus striculus	*A* $\bar{x}$ ± SD range – zakres	0.3 ± 0.8 0-2.5	0.8 ± 1.9 0-6.0	0.6 ± 0.7 0-2.0	$<0.1^{c} \pm 0.1$ 0-0.1	0^{c}	0^{c}	$1.9^{abcdef} \pm 1.7$ 0.1-4.9
	D	1.3	1.8	1.3	<1.0			3.3
	C	50	40	90	10			100
Hydrozetes lacustris	*A* $\bar{x}$ ± SD range – zakres	0	0	0	$1.2^{abc} \pm 0.9$ 0-2.9	$0.1^{d} \pm 0.1$ 0-0.2	$<0.1^{d} \pm <0.1$ 0-0.2	$<0.1^{d} \pm <0.1$ 0-0.1
	D				2.3	<1.0	<1.0	<1.0
	C				90	50	20	10

Table 13 continued – cd. tabeli 13

1	2	3	4	5	6	7	8	9
H. lemnae	*A* $\bar{x}$ ± SD range – zakres	1.3 ± 1.4 0-3.1	7.0^{a} ± 4.5 0.1-14.7	<0.1^{ab} ± 0.1 0-0.2	0.6^{bc} ± 0.6 0-1.7	0.1^{abd} ± 0.1 0-0.4	0^{abd}	0^{abd}
	D	6.0	15.5	<1.0	1.1	<1.0		
	C	80	100	10	70	20		
H. thienemanni	*A* $\bar{x}$ ± SD range – zakres	11.2 ± 1.3 0.4-71.1	14.0 ± 19.5 0.1-57.9	0.1^{ab} ± 0.2 0-0.5	0^{ab}	0^{ab}	0^{ab}	0^{ab}
	D	50.0	30.9	<1.0				
	C	100	100	20				
Hypochthonius rufulus	*A* $\bar{x}$ ± SD range – zakres	0.5 ± 1.6 0-5.1	1.5 ± 3.9 0-12.5	0.2 ± 0.4 0-1.2	<0.1 ± 0.1 0-0.2	0	0	0.4 ± 1.0 0-3.2
	D	2.3	3.4	<1.0	<1.0			<1.0
	C	10	40	40	10			40
Limnozetes ciliatus	*A* $\bar{x}$ ± SD range – zakres	0	0	0	0	11.6^{abcd} ± 13.3 1.4-42.3	12.6^{abcd} ± 12.0 1.3-33.3	<0.1^{ef} ± <0.1 0-0.1
	D					4.9	16.9	<1.0
	C					100	100	10
L. foveolatus	*A* $\bar{x}$ ± SD range – zakres	<0.1 ± <0.1 0-0.1	0	0	2.3^{abc} ± 3.3 0-8.7	197.4^{abc} ± 97.9 29.8-306.0	58.4^{abcd} ± 48.4 4.4-147.3	0.1^{bcde} ± 0.1 0-0.3
	D	<1.0			4.4	83.7	78.2	<1.0
	C	20			80	100	100	60
L. lustrum	*A* $\bar{x}$ ± SD range – zakres	0	0	0	17.3^{abc} ± 20.8 0.4-56.5	<0.1^{d} ± <0.1 0-0.1	0^{d}	0^{d}
	D				32.5	<1.0		
	C				100	10		
Liochthonius alpestris	*A* $\bar{x}$ ± SD range – zakres	0.3 ± 0.8 0-2.6	<0.1 ± 0.1 0-0.3	0	<0.1 ± <0.1 0-0.1	<0.1 ± 0.1 0-0.3	0	1.3^{abcdef} ± 1.4 0-3.5
	D	1.2	<1.0		<1.0	<1.0		2.2
	C	10	10		10	10		80

Table 13 continued – cd. tabeli 13

Malaconothrus monodactylus	*A* $\bar{x} \pm SD$ range – zakres	0.1 ± 0.2 0-0.6	0.9 ± 1.5 0-4.6	$3.2^{ab} \pm 3.2$ 0-9.0	0^{c}	0^{c}	0^{c}	$7.0^{abdef} \pm 4.8$ 1.1-17.5
	D	<1.0	2.0	6.8				12.2
	C	40	50	90				100
Moritzoppia translamellata	*A* $\bar{x} \pm SD$ range – zakres	0	0	0	0	<0.1 ± <0.1 0-0.1	0	$0.7^{abdef} \pm 0.8$ 0-2.1
	D					<1.0		1.1
	C					10		70
Nanhermannia cf. *coronata*	*A* $\bar{x} \pm SD$ range – zakres	<0.1 ± <0.1 0-0.1	0	0.1 ± 0.2 0-0.5	0	0.9 ± 2.5 0-7.9	<0.1 ± 0.1 0-0.2	$3.6^{abcdef} \pm 3.0$ 0.3-8.6
	D	<1.0		<1.0		<1.0	<1.0	6.2
	C	10		20		50	20	100
Oppiella nova	*A* $\bar{x} \pm SD$ range – zakres	1. 3± 4.0 0-12.8	0.4 ± 1.2 0-3.9	10.9 ± 20.9 0-52.9	$3.4^{ab} \pm 5.9$ 0-18.3	$0.1^{d} \pm 0.2$ 0-0.5	$0.1^{d} \pm 0.3$ 0-1.0	$20.0^{abef} \pm 44.2$ 0.2-139.6
	D	5.7	<1.0	23.3	6.5	<1.0	<1.0	34.8
	C	10	20	60	80	20	10	100
Platynothrus peltifer	*A* $\bar{x} \pm SD$ range – zakres	2.3 ± 4.6 0-15.2	$16.7^{a} \pm 25.0$ 0.7-81.2	3.0 ± 2.9 0.3-8.3	$1.7^{b} \pm 3.2$ 0-9.1	0^{abcd}	0^{abcd}	$8.1^{acdef} \pm 3.7$ 3.7-14.0
	D	10.2	36.9	6.5	3.2			14.1
	C	90	100	100	50			100
Scheloribates laevigatus	*A* $\bar{x} \pm SD$ range – zakres	0.3 ± 0.6 0-1.8	0.2 ± 0.5 0-1.7	0.1 ± 0.1 0-0.2	0	0	0	$0.5^{abcdef} \pm 0.6$ 0.1-2.0
	D	1.2	<1.0	<1.0				<1.0
	C	50	40	50				100

Table 13 continued – cd. tabeli 13

1	2	3	4	5	6	7	8	9
Trhypochthoniellus longisetus	*A* $\bar{x} \pm SD$ range – zakres	2.9 ± 6.2 0-20.2	0^{a}	$27.0^{ab} \pm 31.0$ 0.1-31.0	$2.4^{b} \pm 4.1$ 0.4-13.9	$1.2^{bc} \pm 2.4$ 0-8.0	$0.1^{acde} \pm 0.2$ 0-0.7	$<0.1^{acde} \pm 0.1$ 0-0.4
	D	13.0		57.5	4.5	<1.0	<1.0	<1.0
	C	80		100	100	80	30	10
Trhypochthonius nigricans	*A* $\bar{x} \pm SD$ range – zakres	0	0	0	0	$1.6^{abcd} \pm 2.3$ 0.1-8.0	$1.3^{abcd} \pm 1.2$ 0.1-3.9	0^{ef}
	D					<1.0	1.8	
	C					100	100	
Trimalaconothrus angulatus	*A* $\bar{x} \pm SD$ range – zakres	0	0	0	0	0	0	$11.3^{abcdef} \pm 10.3$ 0.3-29.1
	D							19.6
	C							100
T. maior	*A* $\bar{x} \pm SD$ range – zakres	0	0	0	$5.1^{abc} \pm 6.7$ 0.1-21.9	$17.8^{abcd} \pm 11.6$ 0.6-32.9	$0.8^{abcde} \pm 1.3$ 0-4.4	$1.6^{abce} \pm 1.3$ 0-4.5
	D				9.5	7.5	1.1	2.8
	C				100	100	80	90
Zetomimus furcatus	*A* $\bar{x} \pm SD$ range – zakres	0	$<0.1 \pm <0.1$ 0-0.1	$<0.1 \pm 0.1$ 0-0.2	$17.3^{abc} \pm 26.5$ 1.4-88.6	$<0.1^{d} \pm 0.1$ 0-0.1	0^{d}	0^{d}
	D		<1.0	<1.0	32.6	<1.0		
	C		20	30	100	10		

^{abcdef} – Significant differences between: ^{a} – P1 and P2, P3, BC, O, S, KG; ^{b} – P2 and P3, BC, O, S, KG; ^{c} – P3 and BC, O, S, KG; ^{d} – BC and O, S, KG; ^{e} – O and S, KG; ^{f} – S and KG; at $p \leq 0.05$

^{abcdef} – Istotne różnice pomiędzy: ^{a} – P1 i P2, P3, BC, O, S, KG; ^{b} – P2 i P3, BC, O, S, KG; ^{c} – P3 i BC, O, S, KG; ^{d} – BC i O, S, KG; ^{e} – O i S, KG; ^{f} – S i KG; przy $p \leq 0,05$

Fig. 30. Dominance structure of some Oribatida (with $D > 1$) in forest lakes and ponds in northern Poland: P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in ‘Bagno Chlebowo’ reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in ‘Kurze Grzędy’ reserve; Su – superdominants, Eu – eudominants, Do – dominants, Sd – subdominants, Re – recedents, Sr – subrecedents; full list of species is presented in Table 4

Rys. 30. Struktura dominacji wybranych Oribatida ($D > 1$) w jeziorach śródleśnych północnej Polski: P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo”; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy”; Su – superdominanty, Eu – eudominanty, Do – dominanty, Sd – subdominanty, Re – recedenty, Sr – subrecedenty; pełna lista gatunków znajduje się w Tabeli 4

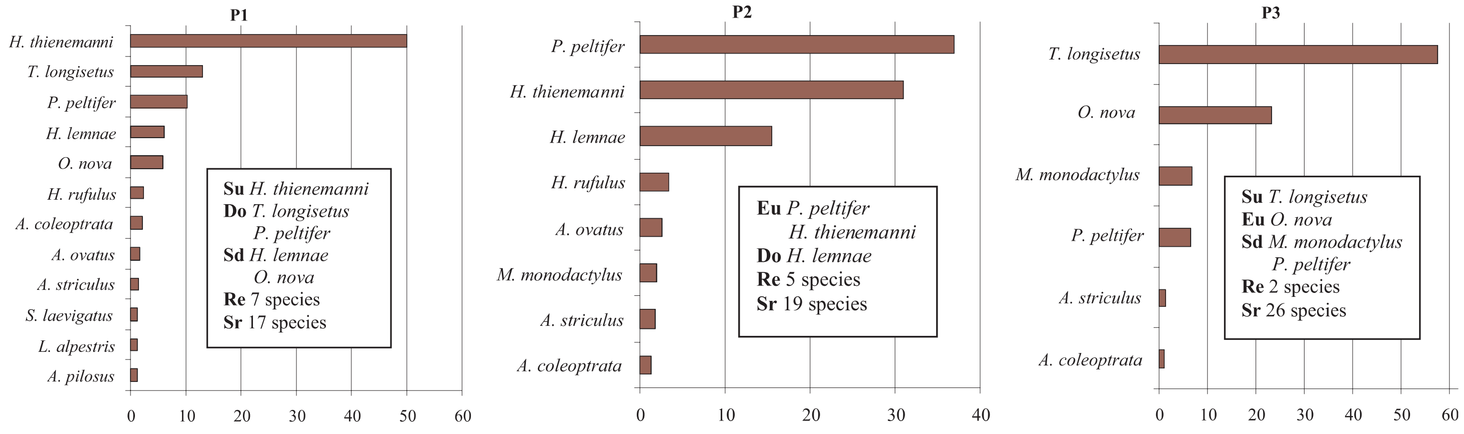
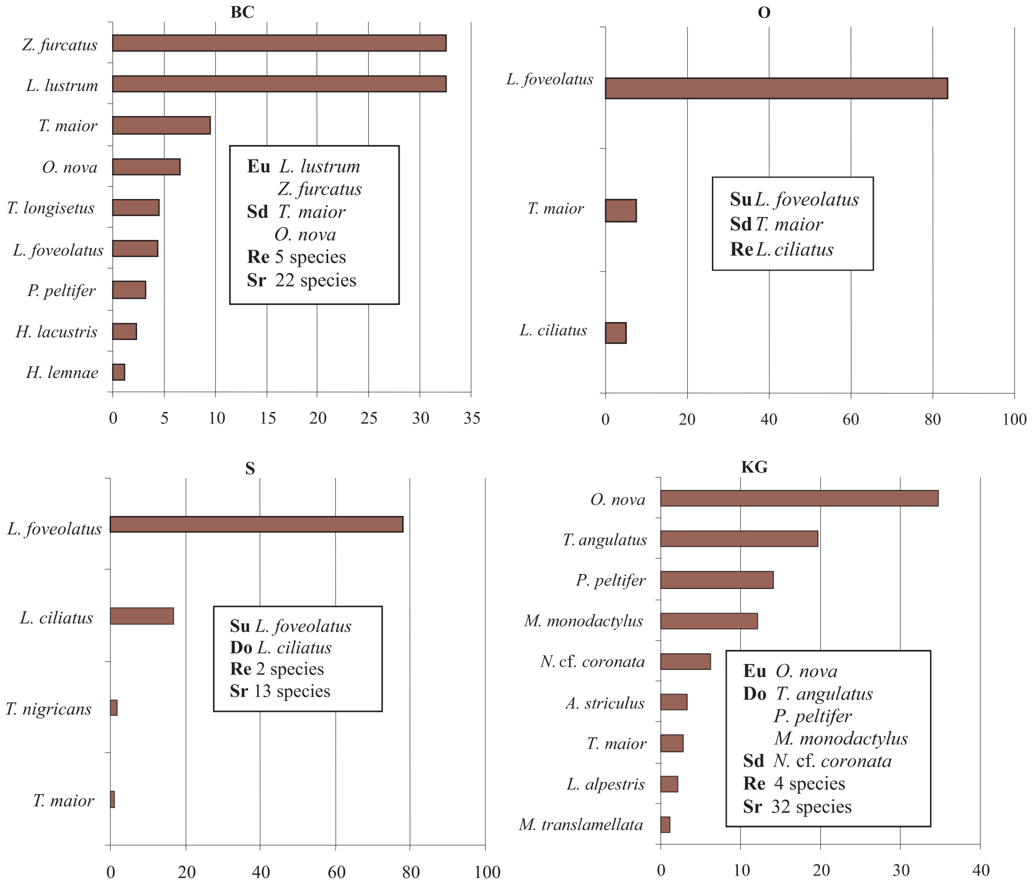


Fig. 30 continued – cd. rysunku 30



Limnozetes lustrum had relatively high density at the shore of peat pond BC, where it was, together with *Zetomimus furcatus*, the most abundant and eudominant species, but at the shores of other water bodies these two species were usually absent.

The occurrence of *Hydrozetes* also differed from that in the bog reserves in Tuchola Forest. Only three species of this genus were present here, of which *H. lacustris* was either not abundant or absent; *H. thienemanni* Strenzke, 1943 achieved high abundance at ponds P2 and P1, was uncommon at pond P3 and was absent from other water bodies. *Hydrozetes lemnae* was significantly more abundant at P2 than at the other shores.

Some species were abundant at particular shores – *Trhypochthoniellus longisetus* (P3), *Oppiella nova* (KG, P3), *Trimalaconothrus maior* (O, BC), *Zetomimus furcatus* (BC), *Platynothrus peltifer* (P2, KG), *Trimalaconothrus angulatus* Willmann, 1931 (KG) and *Malaconothrus monodactylus* (KG, P3) – but at shores of other lakes they were uncommon or absent. Other species occurred in low densities.

5.1.5.3. Age structure of Oribatida

Among oribatid mites the adults predominated, with the proportion ranging from 53.6% at P2 to 94.2% at S (Table 14). In most species, including those of *Limnozetes* and *Hydrozetes*, the adults were more abundant than the juveniles, but in some [*Achipteria coleoptrata* (Linné, 1758), *Platynothrus peltifer*, *Trhypochthonius nigricans*, *Trimalaconothrus angulatus* and *T. maior*] juveniles dominated the samples (Fig. 31).

Platynothrus peltifer had the highest proportion of juveniles, which varied from 70.6% at BC to 93.5% at pond P3. *Trimalaconothrus maior* also had a high percent of juveniles, from 75.0% at lake S to 87.5% at pond KG.

Table 14. Abundance (*A* in 1000 m^{-2}) of adults (Ad) and juveniles (Juv) of some Oribatida (with $D > 1$ and represented by Ad and Juv) in forest lakes and ponds in northern Poland; P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in 'Bagno Chlebowo' reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in 'Kurze Grzędy' reserve

Tabela 14. Wskaźnik liczebności (*A* w 1000 m^{-2}) dorosłych (Ad) i młodocianych (Juv) wybranych Oribatida ($D > 1$ i reprezentowanych przez Ad i Juv) w jeziorach śródleśnych północnej Polski; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo"; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy"

Species – Gatunek	Stage Stadium	P1	P2	P3	BC	O	S	KG	Average Średnia
1	2	3	4	5	6	7	8	9	10
Achipteria coleoptrata	Ad	<0.1	0.3	0.1	0	0	0	0	<0.1
	Juv	0.4	0.3	0.5	0^{c}	0^{c}	0^{c}	0^{c}	0.2
Astegistes pilosus	Ad	0.2	0.1	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	<0.1
	Juv	<0.1	0	0	0	0	0	0	<0.1
Hydrozetes lacustris	Ad	0	0	0	1.1^{abc}	0.1^{d}	$<0.1^{d}$	$<0.1^{d}$	0.2
	Juv	0	0	0	0.1^{abc}	0^{d}	0^{d}	0^{d}	<0.1
H. lemnae	Ad	1.3	6.3^{a}	$<0.1^{ab}$	0.6^{bc}	$<0.1^{abd}$	0^{abd}	0^{abd}	1.2
	Juv	0.1	0.7	0	0	<0.1	0	0	0.1
H. thienemanni	Ad	8.7	11.3	$<0.1^{ab}$	0^{ab}	0^{ab}	0^{ab}	0^{ab}	2.9
	Juv	2.5	2.7	$<0.1^{a}$	0^{a}	0^{a}	0^{a}	0^{a}	0.7
Hypochthonius rufulus	Ad	0.4	0.5	0.2	<0.1	0	0	<0.1	0.2
	Juv	0.1	1.0	<0.1	<0.1	0	0	0.3	0.2
Limnozetes ciliatus	Ad	0	0	0	0	10.5^{abcd}	11.4^{abcd}	$<0.1^{ef}$	3.1
	Juv	0	0	0	0	1.1^{abcd}	1.2^{abcd}	0^{ef}	0.3
L. foveolatus	Ad	<0.1	0	0	2.3^{abc}	196.3^{abcd}	57.8^{abcde}	0.1^{bcdef}	36.6
	Juv	0	0	0	<0.1	1.1^{abcd}	0.6^{abcd}	$<0.1^{ef}$	0.2
L. lustrum	Ad	0	0	0	15.6^{abc}	$<0.1^{d}$	0^{d}	0^{d}	2.2
	Juv	0	0	0	1.6^{abc}	0^{d}	0^{d}	0^{d}	0.2
Malaconothrus monodactylus	Ad	0.1	0.4	2.5^{ab}	0^{c}	0^{c}	0^{c}	4.9^{abcdef}	1.1
	Juv	0	0.5	0.6	0	0	0	2.1^{abdef}	0.5
Nanhermannia cf. *coronata*	Ad	<0.1	0	0.1	0	0.6	<0.1	1.4^{abcdef}	0.3
	Juv	0	0	0	0	0.2	<0.1	2.2^{abcdef}	0.3

Table 14 continued – cd. tabeli 14

1	2	3	4	5	6	7	8	9	10
Oppiella nova	Ad	1.3	0.4	10.9	3.0^{ab}	0.1^{d}	<0.1^{cd}	20.0^{abef}	5.1
	Juv	0	0	0	0.4	0	0.1	<0.1	0.1
Platynothrus peltifer	Ad	0.4	1.3^{a}	0.2^{b}	0.5^{b}	0^{bc}	0^{bc}	1.0^{acdef}	0.5
	Juv	1.9	15.4^{a}	2.9^{a}	1.2^{bc}	0^{abc}	0^{abc}	7.1^{acdef}	4.1
Scheloribates laevigatus	Ad	<0.1	0.1	0.1	0	0	0	0.1	<0.1
	Juv	0.2	0.1	<0.1	0	0	0	0.4^{bcdef}	0.1
Trhypochthoniellus longisetus	Ad	2.3	0^{a}	24.9^{ab}	1.2^{b}	0.2^{bc}	<0.1^{acde}	0^{acde}	4.1
	Juv	0.6	0^{a}	2.0^{b}	1.2^{b}	1.0^{c}	0.1^{cde}	<0.1^{cde}	0.7
Trhypochthonius nigricans	Ad	0	0	0	0	0.5^{abcd}	0.1	0^{e}	0.1
	Juv	0	0	0	0	1.0^{abcd}	1.2^{abcd}	0^{ef}	0.3
Trimalaconothrus angulatus	Ad	0	0	0	0	0	0	4.0^{abcdef}	0.6
	Juv	0	0	0	0	0	0	7.3^{abcdef}	1.0
T. maior	Ad	0	0	0	1.1^{abc}	3.9^{abcd}	0.2^{abce}	0.2^{abce}	0.8
	Juv	0	0	0	4.0^{abc}	13.8^{abcd}	0.6^{abcde}	1.4^{abce}	2.8
Zetomimus furcatus	Ad	0	<0.1	<0.1	16.3	<0.1	0	0	2.3
	Juv	0	0	0	1.0	0	0	0	0.1
Oribatida	Ad	16.3	24.3	40.8	43.0^{a}	216.7^{abcd}	70.4^{abe}	36.4^{aef}	64.0
	Juv	6.0	21.0^{a}	6.1	10.2^{a}	19.2^{ac}	4.3^{de}	21.2^{acdf}	12.6

^{abcdef} – Significant differences between: ^{a} – P1 and P2, P3, BC, O, S, KG; ^{b} – P2 and P3, BC, O, S, KG; ^{c} – P3 and BC, O, S, KG; ^{d} – BC and O, S, KG; ^{e} – O and S, KG; ^{f} – S and KG; at $p \leq 0.05$

^{abcdef} – Istotne różnice pomiędzy: ^{a} – P1 i P2, P3, BC, O, S, KG; ^{b} – P2 i P3, BC, O, S, KG; ^{c} – P3 i BC, O, S, KG; ^{d} – BC i O, S, KG; ^{e} – O i S, KG; ^{f} – S i KG; przy $p \leq 0{,}05$

Table 15. The Spearman correlation coefficient (r_{Spm}) between the water measurements and abundance of some mites taxa; only the oribatid species with $D > 1$ were considered; † $p > 0.05$; * $p < 0.01$

Tabela 15. Współczynnik korelacji Spearmana (r_{Spm}) pomiędzy parametrami wody i wskaźnikiem liczebności wybranych taksonów roztoczy; brano pod uwagę tylko gatunki Oribatida z $D > 1$; † $p > 0,05$; * $p < 0,01$

Taxon – Takson	r_{Spm}								
	pH	Color Barwa	Conductivity Przewodnictwo	COD ChZT	BOD_5 BZT_5	Chlorides Chlorki	Sulphates Siarczany	Total P P ogólny	Total Fe Fe ogólne
1	2	3	4	5	6	7	8	9	10
Achipteria coleoptrata	0.4^{*}	$0.1^{\dagger}$	0.2	$0.1^{\dagger}$	$0.1^{\dagger}$	$0^{\dagger}$	0	0.3^{*}	0.3^{*}
Adoristes ovatus	0.6^{*}	$0^{\dagger}$	0.3^{*}	$0.1^{\dagger}$	0.3^{*}	$0^{\dagger}$	0.3^{*}	0.5^{*}	0.4^{*}
Astegistes pilosus	0.4^{*}	$0.1^{\dagger}$	0.3^{*}	$0.1^{\dagger}$	0.3^{*}	$0.1^{\dagger}$	0.4^{*}	0.4^{*}	0.2^{*}
Atropacarus striculus	$0.1^{\dagger}$	0.4^{*}	0.2	0.4^{*}	0.4^{*}	0.2	0.2	0.6^{*}	0.3^{*}
Eupelops hygrophilus	$0.2^{\dagger}$	$0.1^{\dagger}$	$-0.1^{\dagger}$	0.2	$0.1^{\dagger}$	0.2^{*}	–0.2	–0.2	$0.1^{\dagger}$
Hoplophthiracarus illinoisensis	–0.2	-0.3^{*}	$-0.1^{\dagger}$	-0.3^{*}	-0.3^{*}	-0.3^{*}	–0.2	-0.4^{*}	-0.3^{*}
Hydrozetes lacustris	$-0.1^{\dagger}$	$0^{\dagger}$	$-0.1^{\dagger}$	$0^{\dagger}$	$0^{\dagger}$	$0.1^{\dagger}$	0	–0.2	$-0.1^{\dagger}$
H. lemnae	0.4^{*}	$0.1^{\dagger}$	0.3^{*}	0.3^{*}	0.4^{*}	0.2	0.6^{*}	0.4^{*}	0.4^{*}
H. longisetosus	-0.3^{*}	-0.3^{*}	$0^{\dagger}$	-0.3^{*}	-0.5^{*}	-0.4^{*}	-0.2^{*}	-0.5^{*}	-0.5^{*}
H. octosetosus	0.2	$-0.1^{\dagger}$	-0.5^{*}	-0.3^{*}	$0.1^{\dagger}$	0.4^{*}	-0.5^{*}	–0.2	0.2^{*}
H. thienemanni	0.6^{*}	$0.1^{\dagger}$	0.4^{*}	$0.2^{\dagger}$	0.3^{*}	$0.1^{\dagger}$	0.5^{*}	0.5^{*}	0.4^{*}
Hypochthonius rufulus	$0.1^{\dagger}$	$0.2^{\dagger}$	$0.1^{\dagger}$	0.2^{*}	0.3^{*}	$0.1^{\dagger}$	$0.1^{\dagger}$	0.4^{*}	0.3^{*}
Limnozetes ciliatus	-0.5^{*}	-0.5^{*}	$-0.1^{\dagger}$	-0.6^{*}	-0.6^{*}	-0.5^{*}	-0.3^{*}	-0.6^{*}	-0.6^{*}
L. foveolatus	-0.3^{*}	-0.4^{*}	-0.4^{*}	-0.4^{*}	-0.4^{*}	–0.2	-0.4^{*}	-0.6^{*}	-0.4^{*}
L. lustrum	$-0.1^{\dagger}$	0.2^{*}	0.5^{*}	0.2^{*}	-0.2^{*}	–0.2	$0.1^{\dagger}$	$-0.1^{\dagger}$	-0.3^{*}
Liochthonius alpestris	–0.2	0.2	$0^{\dagger}$	$0.1^{\dagger}$	0.2	$0.1^{\dagger}$	$0^{\dagger}$	$0.1^{\dagger}$	$0^{\dagger}$

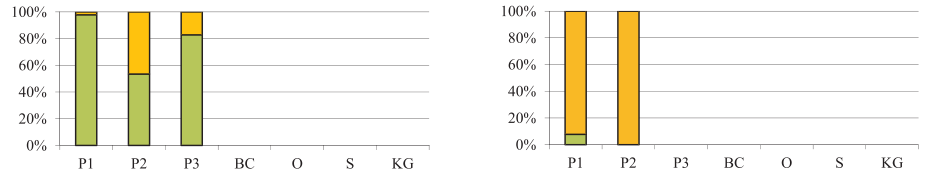
Table 15 continued – cd. tabeli 15

1	2	3	4	5	6	7	8	9	10
Malaconothrus monodactylus	0.1†	0.3*	0.1†	0.4*	0.4*	0.2	0.1†	0.6*	0.3*
Moritzoppia translamellata	–0.4*	0.3*	0†	0.3*	0.3*	0.2	0.2	0.3*	–0.1†
Nanhermannia cf. *coronata*	–0.4*	0.1†	0.1†	0†	0†	0†	0.1†	0.1†	–0.2*
Oppiella nova	–0.1†	0.4*	0.2	0.5*	0.1†	0.1†	0†	0.2	–0.1†
Pilogalumna tenuiclava	–0.1†	0†	0.1†	–0.1†	–0.3*	–0.2†	–0.4*	–0.4*	–0.2*
Punctoribates sellnicki	–0.1†	–0.2*	–0.2	–0.2	–0.3*	–0.2†	–0.3*	–0.5*	–0.2
Platynothrus peltifer	0.3*	0.4*	0.3*	0.4*	0.4*	0.3*	0.2*	0.5*	0.3*
Scheloribates laevigatus	0.1†	0.1†	–0.1†	0.2	0.4*	0.4†	0†	0.4*	0.4*
Trhypochthoniellus longisetus	0.2	0.1†	–0.1†	–0.1†	–0.1†	0.1†	–0.4*	–0.3*	0†
Trhypochthonius nigricans	–0.5*	–0.5*	–0.3*	–0.4*	–0.3*	–0.3*	–0.2	–0.5*	–0.4*
Trimalaconothrus angulatus	–0.4*	0.4*	0†	0.4*	0.4*	0.3*	0.2	0.4*	0†
T. foveolatus	–0.1†	–0.3*	–0.2	–0.4*	–0.3*	–0.2	–0.6*	–0.5*	–0.2
T. maior	–0.2*	0†	–0.4*	0†	0†	0.2	–0.2	–0.3*	–0.2†
Zetomimus furcatus	0.2	0.4*	0.1†	0.3*	0†	0.2	0†	–0.1†	0.1†
Oribatida	–0.2	–0.2	–0.3	–0.2*	–0.1†	0†	–0.3*	–0.3*	–0.2
Mesostigmata	0.2	0.3*	0.1†	0.5*	0.5*	0.4*	0.3*	0.5*	0.4*
Other Acari – Inne Acari	–0.2	–0.1†	0.1†	–0.1†	–0.3*	–0.2	–0.2	–0.4*	–0.3*
Acari	–0.2	–0.3*	–0.3*	–0.4*	–0.2*	0†	–0.4*	–0.4*	–0.2

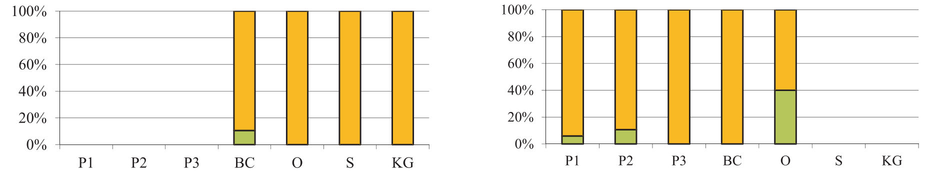
Fig. 31. Age structure of some Oribatida (with $D > 1$ and represented in samples by adults and juveniles) in forest lakes and ponds in northern Poland: P1, P2, P3 – ponds near Pruszcz Bagienica, BC – peat pond in 'Bagno Chlebowo' reserve; O – Lake Okonek, S – Lake Stręszek; KG – pond in 'Kurze Grzędy' reserve; 🟩 juveniles, 🟨 adults

Rys. 31. Struktura wiekowa wybranych Oribatida ($D > 1$ i reprezentowanych w próbach przez dorosłe i młodociane) w jeziorach śródleśnych północnej Polski; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo"; O – Jezioro Okonek; S – Jezioro Stręszek: KG – jezioro w rezerwacie „Kurze Grzędy"; 🟩 młodociane, 🟨 dorosłe

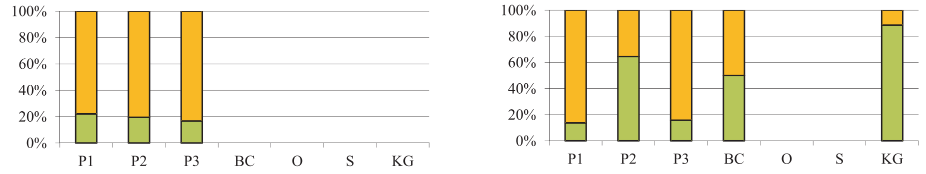
Achipteria coleoptrata *Astegistes pilosus*



Hydrozetes lacustris *H. lemnae*



H. thienemanni *Hypochthonius rufulus*



Limnozetes ciliatus *L. lustrum*

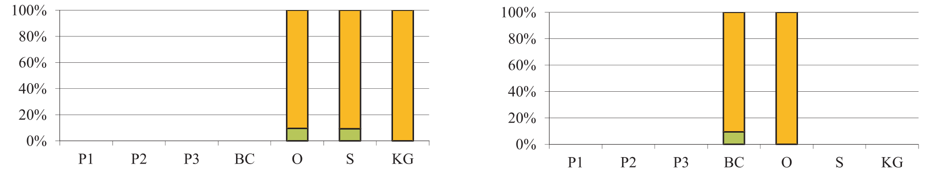


Fig. 31 continued – cd. rysunku 31

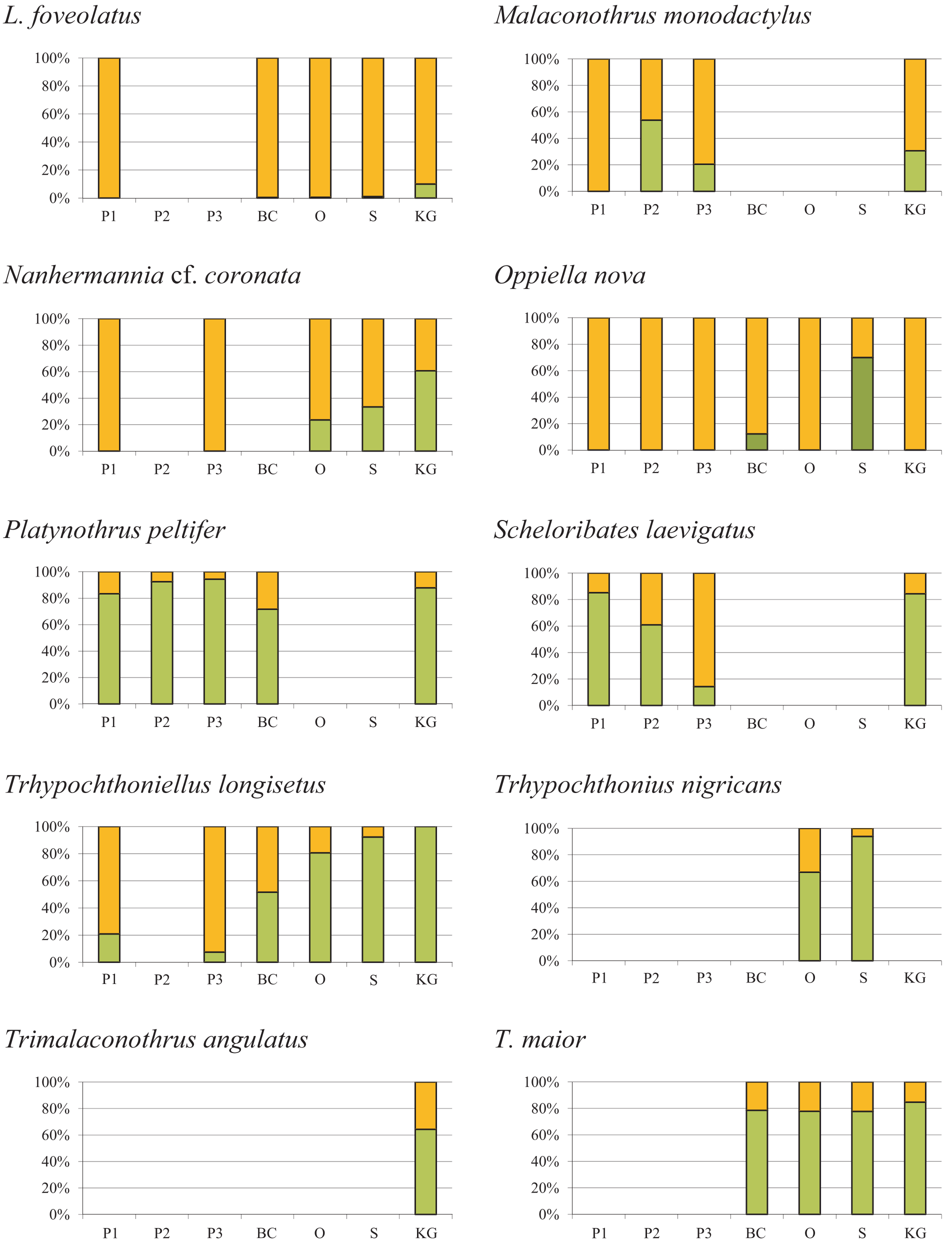
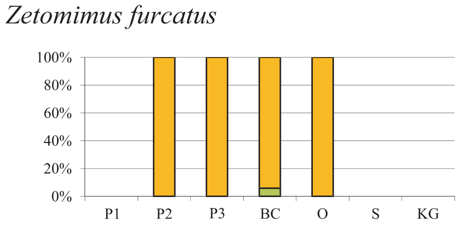


Fig. 31 continued – cd. rysunku 31



5.1.6. Preferences of Oribatida to lake and pond shores

From a total of 370 samples, more than 505,000 mites were obtained, including 499,500 Oribatida (almost 61,000 juveniles), belonging to 106 species and 34 families. From all recorded species (Tables 4 and 10) only 38 had higher dominance index than 1% (Tables 7, 10 and 13).

There was no high correlation between the water parameters and the total abundance of Acari (Table 15), while at the level of orders high correlations were seen only for Mesostigmata, which reacted to oxygen conditions and content of the phosphorus. For the oribatid species the most important, among water parameters, seems to be phosphorus content, which causes water eutrophication; the density of many species had high correlation with this parameter, but in different directions.

The abundance of some species – *Adoristes ovatus* (C.L. Koch, 1839), *Atropacarus striculus* (C.L. Koch, 1835), *Astegistes pilosus* (C.L. Koch, 1840), *Hydrozetes thienemanni*, *Malaconothrus monodactylus* and *Platynothrus peltifer* – was positively correlated with phosphorus, while that of others – *Hydrozetes longisetosus*, *Limnozetes ciliatus*, *L. foveolatus*, *Punctoribates sellnicki*, *Trhypochthonius nigricans* and *Trimalaconothrus foveolatus* – was negatively correlated.

Some species showed clear preferences for pH, either to lakes with neutral conditions (P1, P2, P3) (e.g. *Hydrozetes thienemanni*), or acid reaction (L, D1, D2, D3, D4, M, K1, K2, K3, O, S) (e.g. *Limnozetes foveolatus*, *L. ciliatus*). Some preferred the peat pond (BC) (*L. lustrum*, *Zetomimus furcatus*) and others the very acid water in KG (*Trimalaconothrus angulatus*). A few other species [*Oppiella nova*, *Scheloribates laevigatus* (C.L. Koch, 1836) and *Trhypochthoniellus longisetus*] achieved high abundances in different types of lakes and ponds and their preferences, if any, could not be established.

The cluster analysis classified the oribatid communities from the shores of all lakes into three groups, according to the similarity of species composition (Fig. 32).

Communities from D1, O, D4 and D2 were different from those of other lakes and ponds, as were those of P1, P2, P3, KG and BC. On the other hand, similarity is seen e.g. between D3, L and K1, which were the water bodies with the most advanced succession.

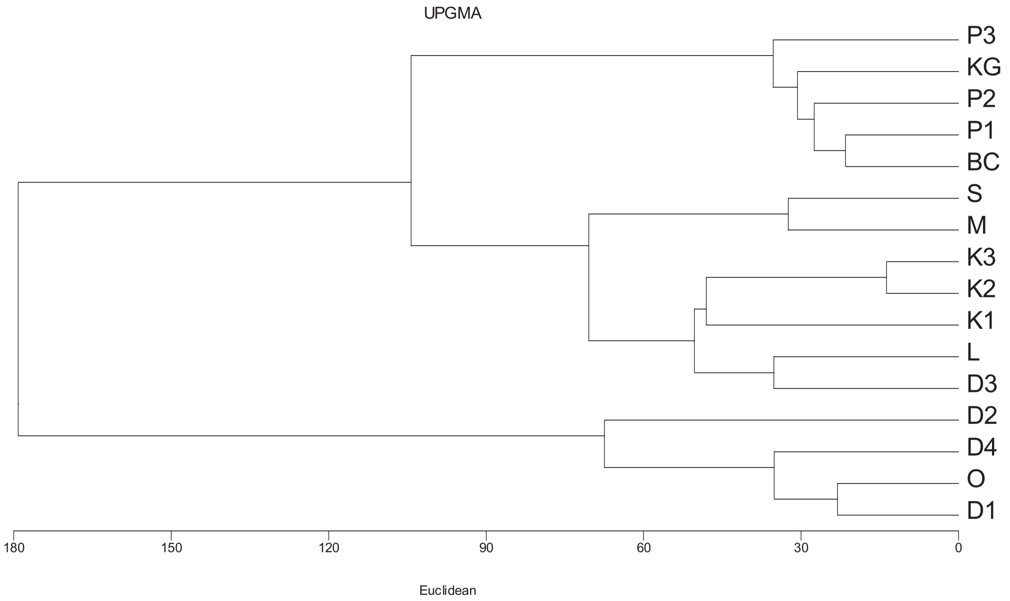


Fig. 32. Similarity dendrogram (Euclidean distance) of oribatid communities in forest lakes and ponds in northern Poland L – Lake Łyse; D1, D2, D3, D4 – ponds in ‘Dury’ reserve; M – Lake Martwe; K1, K2, K3 – ponds in ‘Jeziorka Kozie’ reserve; P1, P2, P3 – ponds near Pruszcz Bagienica; BC – peat pond in ‘Bagno Chlebowo’ reserve; O – Lake Okonek; S – Lake Stręszek; KG – pond in ‘Kurze Grzędy’ reserve

Rys. 32. Dendrogram podobieństwa (odległość euklidesowa) zgrupowań Oribatida w jeziorach śródleśnych północnej Polski: L – Jezioro Łyse; D1, D2, D3, D4 – jeziora w rezerwacie „Dury”; M – Jezioro Martwe; K1, K2, K3 – jeziora w rezerwacie „Jeziorka Kozie”; P1, P2, P3 – jeziora koło Pruszcza Bagienicy; BC – dół potorfowy w rezerwacie „Bagno Chlebowo”; O – Jezioro Okonek; S – Jezioro Stręszek; KG – jezioro w rezerwacie „Kurze Grzędy”

5.2. KEY TO IDENTIFICATION OF LARVAE AND NYMPHS OF SOME AQUATIC AND SEMI-AQUATIC ORIBATID SPECIES

During ecological studies of aquatic and semi-aquatic species in the forest lakes and ponds, the investigations on the morphology of juveniles of most abundant species have been also conducted, which makes it possible to determine them and know the age structure of these species. In total the morphology of juveniles of 16 species have been studied (*Hydrozetes confervae*, *H. lacustris*, *H. lemnae*, *H. longisetosus*, *H. octosetosus*, *H. parisiensis* Grandjean, 1948, *H. thienemanni*, *Hypochthonius rufulus* C.L. Koch, 1835, *Limnozetes ciliatus*, *L. foveolatus*, *L. lustrum*, *L. rugosus*, *Malaconothrus monodactylus*, *Pilogalumna tenuiclava*, *Punctoribates sellnicki*, *Trimalaconothrus angulatus*) and published (Seniczak et al. 2007, 2009b, c; Seniczak & Seniczak 2007a, b, 2008a, b, 2009a, b, c, 2010). All these species can be distinguished morphologically, regardless of the stage of ontogeny, and these differences have been incorporated into separate diagnostic keys for larvae and nymphs. The morphology of larva of *Pilogalumna tenuiclava* is added from Seniczak (1971/1972b). Notation of setae is given on figures. These developmental stages can be distinguished by characters that are typical of all oribatid mites (Weigmann 2006; Norton & Behan-Pelletier 2009). The figures presented here are from Annales Zoologici (Figs. 34, 37, 39, 40, 49, 50, 53, 55, 56), Belgian Journal of Zoology (Figs. 38, 41, 54, 57), Biologia (Figs. 46, 47, 61, 62), Bulletin de la Societé des Amis des. Sciences et des Letters de Poznań (Fig. 33), Journal of Natural History (Figs. 43, 44, 45, 58, 59, 64), and Zoologisher Anzeiger (Figs. 35, 36, 42, 48, 51, 52, 60, 63) due to kind permissions I have got from these Journals.

Key to the larvae

1. Body drop-shaped or almost so 2
   –. Body oval 3
2. Rostrum smooth, head of sensillus lanceolate, barbed, seta *ex* rather short, gastronotum roundish, gastronotal setae short, except slightly longer setae c_2, c_3, *dp* and h_1, body length about 255 µm (Fig. 33) .. ***Pilogalumna tenuiclava***
   –. Rostrum serrated, sensillus long, setiform, with short posterior and longer anterior tines, seta *exs* short, seta *exi* longer, gastronotum rather square in shape, most gastronotal setae long, body length about 340 µm (Fig. 34) .. ..***Hypochthonius rufulus***
3. Gastronotum with transverse folds 4
   –. Gastronotum with small tubercles 10
4. Sensillus absent, prodorsal and gastronotal setae thin and rather long, with longest e_2 and h_1, seta *exs* rather short, alveolus of seta *exi* present 5
   –. Sensillus present 6
5. Seta *in* rather short, not reaching basal part of seta *le*, body length about 220 µm (Fig. 35) .... ***Malaconothrus monodactylus***

–. Seta *in* long, reaching seta *ro*, body length about 360 µm (Fig. 36) ....***Trimalaconothrus angulatus***

6. Head of sensillus clavate, gastronotal setae thick, barbed, sharp, and rather long, body length about 195 µm (Fig. 37) ....***Punctoribates sellnicki***
   –. Sensillus setiform 7
7. Cuticle of prodorsum and gastronotum plicate, gastronotal setae small and smooth, body length about 215 µm (Fig. 38) ....***Limnozetes rugosus***
   –. Prodorsal and gastronotal cuticle smooth or with few folds 8
8. Seta *le* distinctly longer than *ro*, seta *da* as long as *la*, and barbed, body length about 170 µm (Fig. 39) ....***L. foveolatus***
   –. Seta *in* as long as *ro* 9
9. Seta *da* distinctly shorter than *la*, and smooth, body length about 185 µm (Fig. 40) ....***L. ciliatus***
   –. Seta *da* slightly shorter than *la*, stiff and barbed, body length about 200 µm (Fig. 41) ....***L. lustrum***
10. Seta *lm* inserted posterior to opisthonotal gland opening (*gla*) 11
    –. Seta *lm* inserted medial or anterior to *gla* 12
11. Setae *le* and *la* rather long and stiff (about 40 µm and 45 µm, respectively), length of *d*-series setae increasing from anterior to posterior, body length about 250 µm (Fig. 42) ....***Hydrozetes parisiensis***
    –. Setae *le* and *la* shorter (about 30 µm and 15 µm, respectively), length of *d*-series setae similar, body length about 240 µm (Fig. 43) ***H. octosetosus***
12. Seta *le* not reaching base of seta *ro*, setae of *l*-series slightly longer than *d*-series, body length about 230 µm (Fig. 44) ....***H. lacustris***
    –. Seta *le* protruding base of seta *ro* 13
13. Setae *le* and *in* smooth (25-30 µm, 13-40 µm, respectively), seta *da* longer than seta *ro*, body length about 230 µm (Fig. 45) ....***H. longisetosus***
    –. Setae *le* and *in* barbed 14
14. Seta c_2 distinctly longer than c_1, seta *le* 37-40 µm, seta *in* 32-35 µm, body length about 170 µm (Fig. 46) ....***H. lemnae***
    –. Seta c_2 about as short as c_1 15
15. Seta *dp* as short as c_1, seta *le* 25-35 µm, seta *in* 18-21µm, body length about 225 µm (Fig. 47) ....***H. thienemanni***
    –. Seta *dp* distinctly longer than c_1, seta *le* about 20 µm, seta *in* about 30 µm, body length about 280 µm (Fig. 48) ....***H. confervae***

Key to the nymphs

1. Body drop-shaped or almost so 2
   –. Body oval 3
2. Rostrum smooth, head of sensillus lanceolate, barbed, seta *ex* rather short, gastronotum roundish, gastronotal setae short, except longer setae c_2 and c_3 (Fig. 49) ....***Pilogalumna tenuiclava***

–. Rostrum serrated, sensillus long, setiform, with short posterior and longer anterior tines, seta *exs* short, seta *exi* longer, gastronotum oval, most gastronotal setae long (Fig. 50) ....***Hypochthonius rufulus***

3. Gastronotum with transverse folds or smooth 4

–. Gastronotum with small tubercles 10

4. Sensillus absent, prodorsal and gastronotal setae thin and rather long, with longest e_2 and h_1, seta *exs* rather short 5

–. Sensillus present 6

5. Setae of *c*-series relatively long, length of c_1 about 1/2 of *in* (Fig. 51) ....***Malaconothrus monodactylus***

–. Setae of *c*-series short, length of c_1 about 1/6 of *in* (Fig. 52) ....***Trimalaconothrus angulatus***

6. Head of sensillus clavate, gastronotal setae thick, barbed, sharp, and rather long, except rather short setae *da* and *dm* (Fig. 53) ....***Punctoribates sellnicki***

–. Sensillus setiform 7

7. Cuticle of prodorsum and gastronotum plicate, gastronotal setae small and smooth (Fig. 54) ....***Limnozetes rugosus***

–. Prodorsal and gastronotal cuticle smooth or with few folds, gastronotal setae longer 8

8. Seta *le* longer than *ro*, setae of *d*-series of medium size (about 18 µm), setae of *l*-series thinner than *h*-series (Fig. 55) ....***L. foveolatus***

–. Seta *le* as long as *ro*, setae of *d*-series small (about 8 µm), setae of *l*-series as thick as *h*-series 9

9. Posterior gastronotal setae rather long (26-33 µm) (Fig. 56) ....***L. ciliatus***

–. Posterior gastronotal setae rather short (19 µm) (Fig. 57) ....***L. lustrum***

10. Seta *lm* as long as body, inserted posterior to *gla* opening 11

–. Seta *lm* short, inserted medial or anterior to *gla* 12

11. Setae h_3 and p_1 long, anterior or central gastronotal setae sometimes long (Fig. 58) ....***Hydrozetes longisetosus***

–. Setae h_3 and p_1 rather short and stiff, anterior or central gastronotal setae short or medium size 13

12. Three pairs of *h*-series setae present (Fig. 59) ....***H. octosetosus***

–. More than three *h*-series setae present (number may be asymmetrical) (Fig. 60) ....***H. parisiensis***

13. Seta *lp* similar in shape to seta h_3 (Fig. 61) ....***H. thienemanni***

–. Seta *lp* distinctly longer than seta h_3 14

14. Setae *la* and *lm* of medium size, rather thick and stiff (Fig. 62) ..***H. lemnae***

–. Setae *la* and *lm* short and thin 15

15. Setae h_3 and p_1 barbed, seta *in* as short as setae of *d*-series (Fig. 63) ....***H. confervae***

–. Setae h_3 and p_1 smooth, seta *in* longer than setae of *d*-series (Fig. 64) ....***H. lacustris***

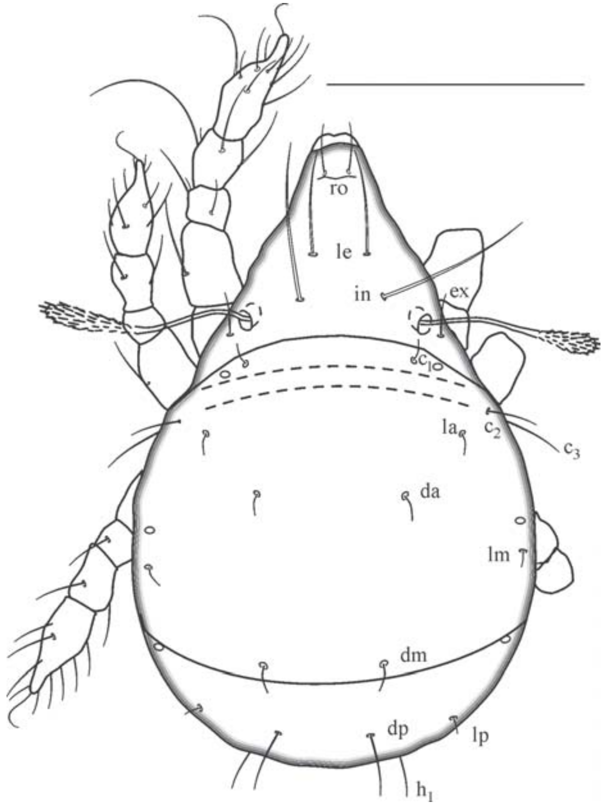


Fig. 33. *Pilogalumna tenuiclava*, larva, dorsal aspect (Seniczak 1971/1972b). Scale bar 100 µm

Rys. 33. *Pilogalumna tenuiclava*, larwa, strona grzbietowa. Skala 100 µm

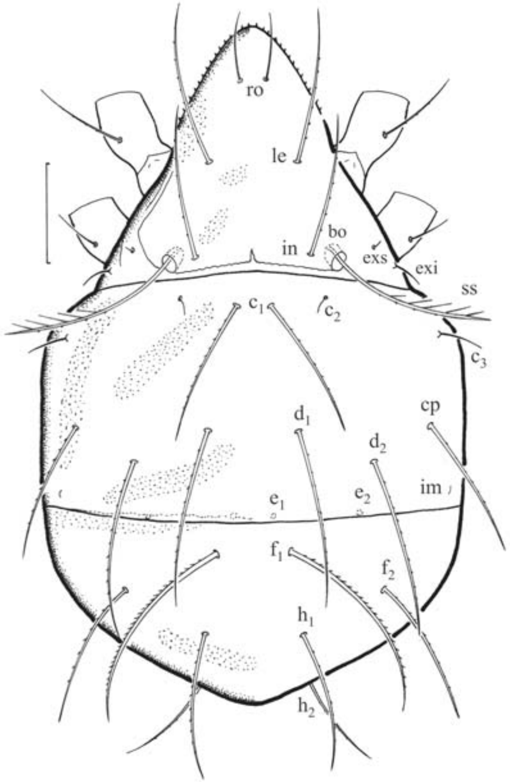


Fig. 34. *Hypochthonius rufulus*, larva, dorsal aspect. Legs partially drawn (Seniczak et al. 2009b). Scale bar 50 µm

Rys. 34. *Hypochthonius rufulus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

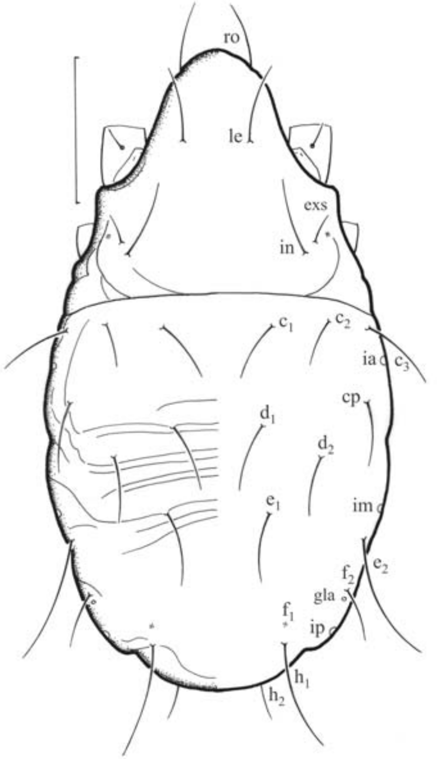


Fig. 35. *Malaconothrus monodactylus*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009c). Scale bar 50 µm

Rys. 35. *Malaconothrus monodactylus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

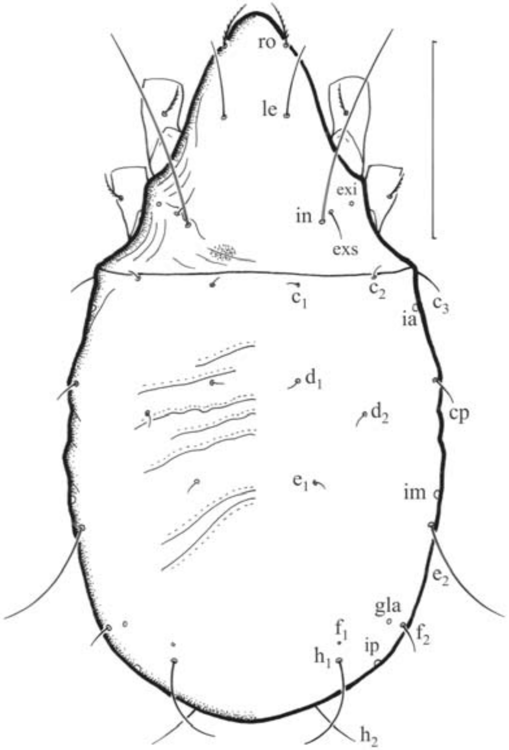


Fig. 36. *Trimalaconothrus angulatus*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009c). Scale bar 50 µm

Rys. 36. *Trimalaconothrus angulatus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

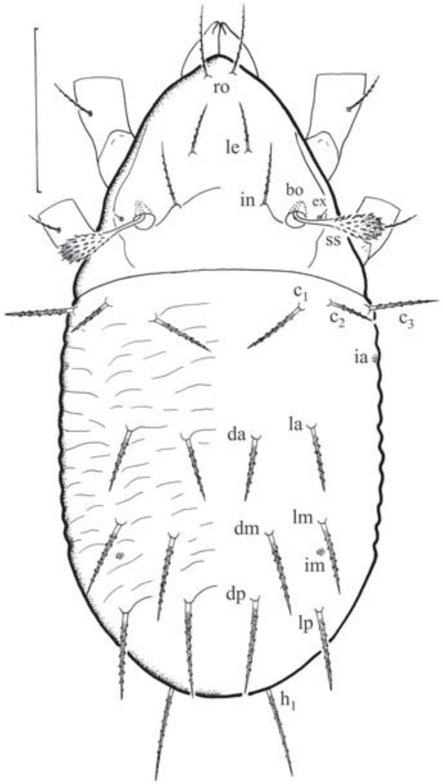


Fig. 37. *Punctoribates sellnicki*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2008b). Scale bar 50 µm

Rys. 37. *Punctoribates sellnicki*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

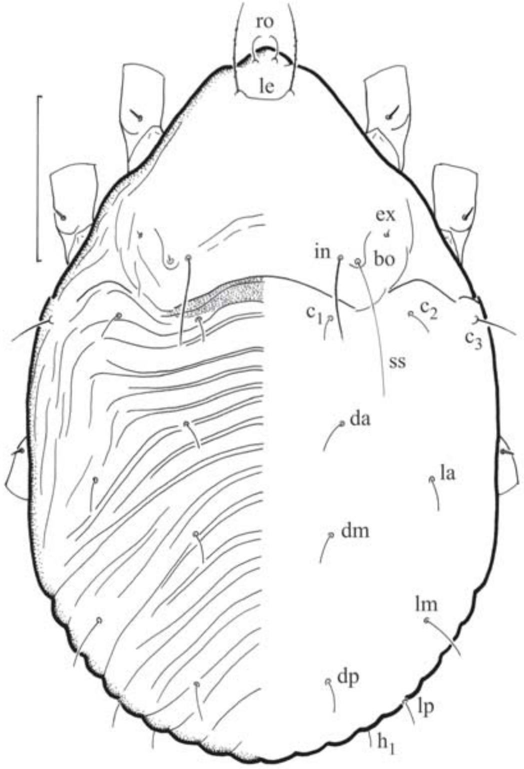


Fig. 38. *Limnozetes rugosus*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2010). Scale bar 50 µm

Rys. 38. *Limnozetes rugosus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

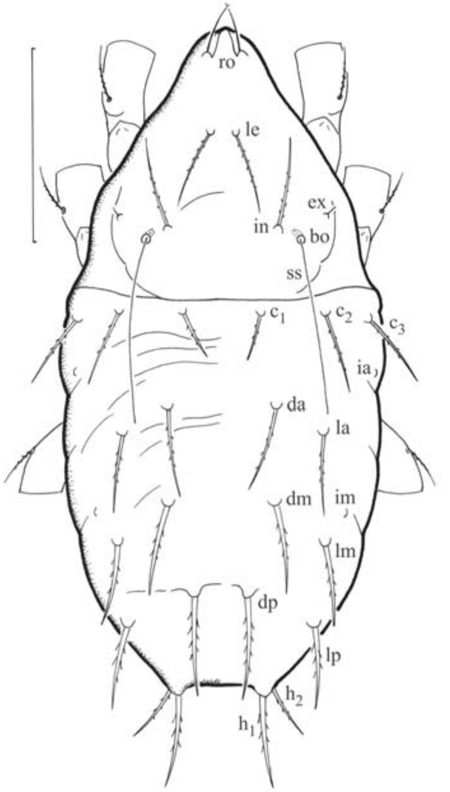


Fig. 39. *Limnozetes foveolatus*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009b). Scale bar 50 µm

Rys. 39. *Limnozetes foveolatus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

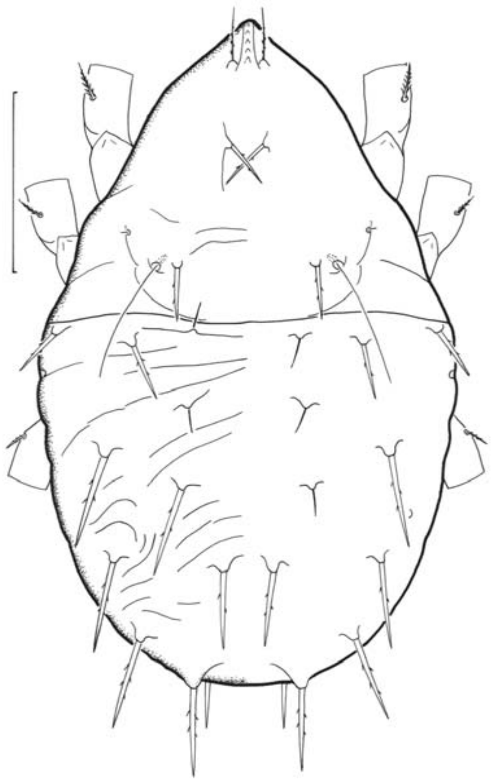


Fig. 40. *Limnozetes ciliatus*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009b). Scale bar 50 µm

Rys. 40. *Limnozetes ciliatus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

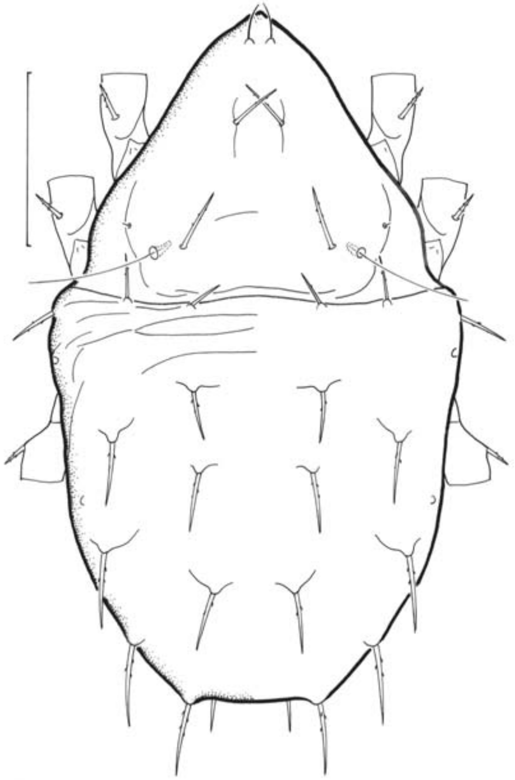


Fig. 41. *Limnozetes lustrum*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2010). Scale bar 50 µm

Rys. 41. *Limnozetes lustrum*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

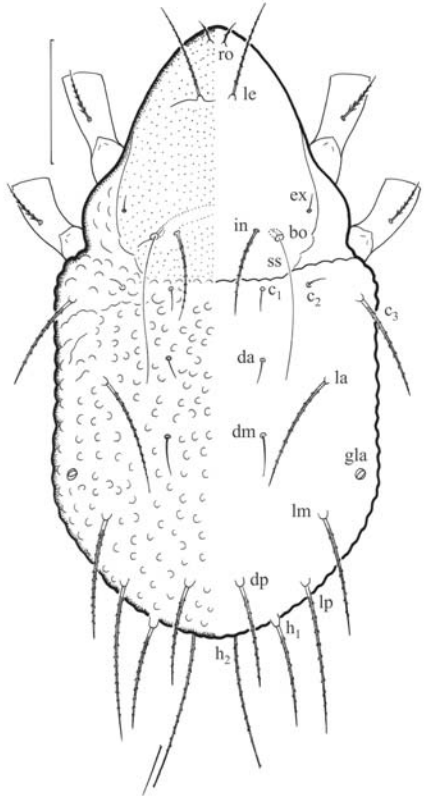


Fig. 42. *Hydrozetes parisiensis*, larva, dorsal aspect. Legs partially drawn (Seniczak et al. 2009c). Scale bar 50 µm

Rys. 42. *Hydrozetes parisiensis*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

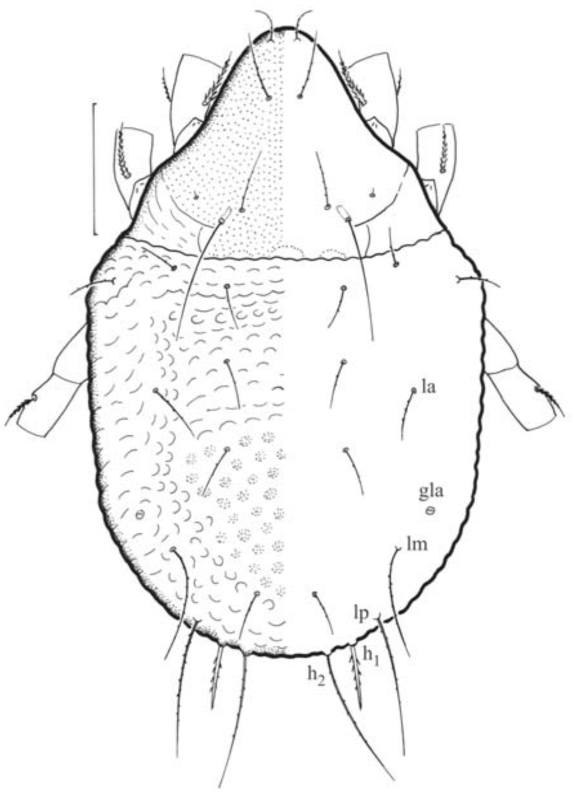


Fig. 43. *Hydrozetes octosetosus*, larva, dorsal aspect. Legs partially drawn (Seniczak et al. 2007b). Scale bar 50 µm

Rys. 43. *Hydrozetes octosetosus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

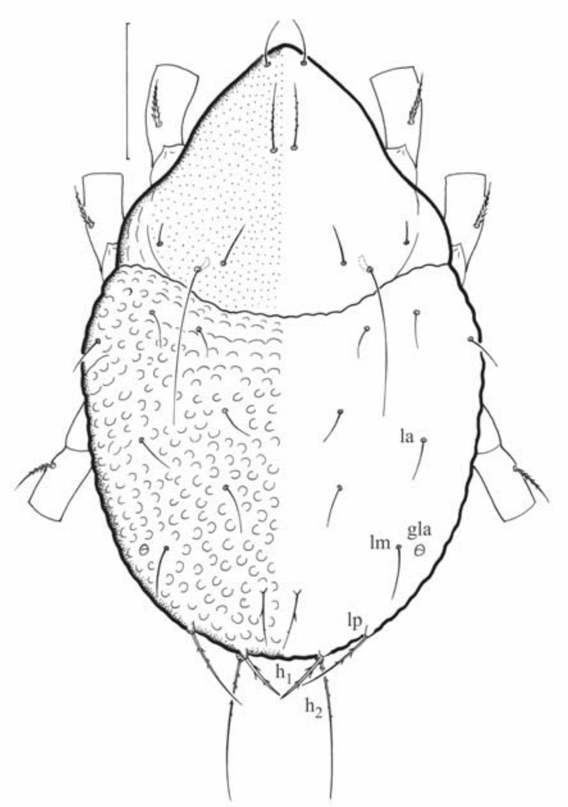


Fig. 44. *Hydrozetes lacustris*, larva, dorsal aspect. Legs partially drawn (Seniczak et al. 2007b). Scale bar 50 µm

Rys. 44. *Hydrozetes lacustris*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

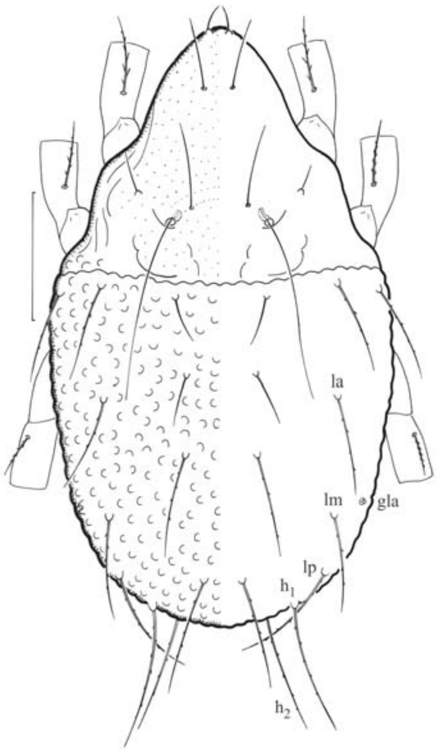


Fig. 45. *Hydrozetes longisetosus*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009a). Scale bar 50 µm

Rys. 45. *Hydrozetes longisetosus*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

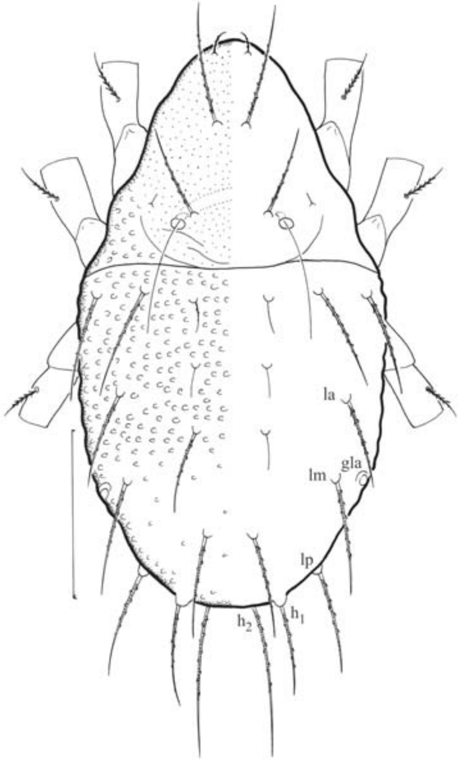


Fig. 46. *Hydrozetes lemnae*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2008a). Scale bar 50 µm

Rys. 46. *Hydrozetes lemnae*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

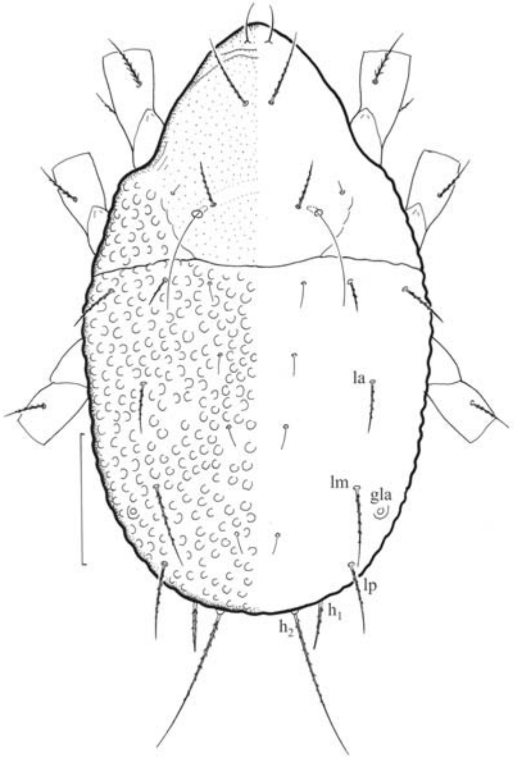


Fig. 47. *Hydrozetes thienemanni*, larva, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2008a). Scale bar 50 µm

Rys. 47. *Hydrozetes thienemanni*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

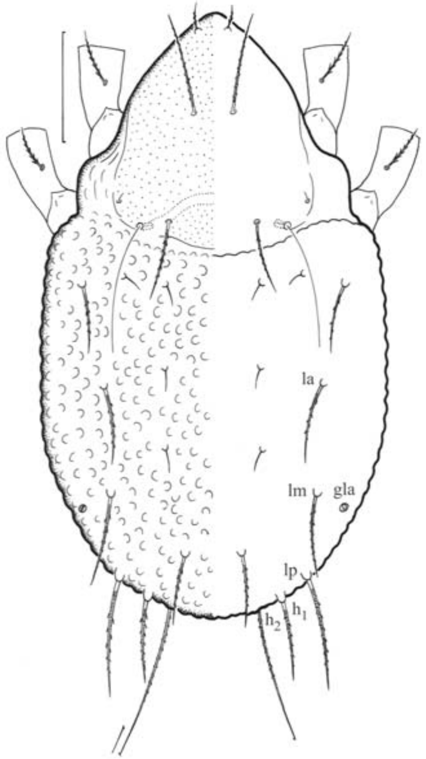


Fig. 48. *Hydrozetes confervae*, larva, dorsal aspect. Legs partially drawn (Seniczak et al. 2009c). Scale bar 50 µm

Rys. 48. *Hydrozetes confervae*, larwa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

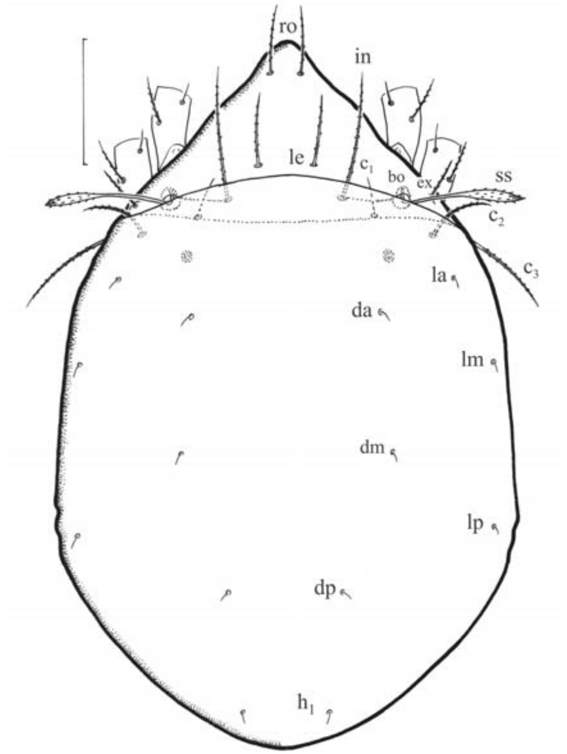


Fig. 49. *Pilogalumna tenuiclava*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2007a). Scale bar 100 µm

Rys. 49. *Pilogalumna tenuiclava*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

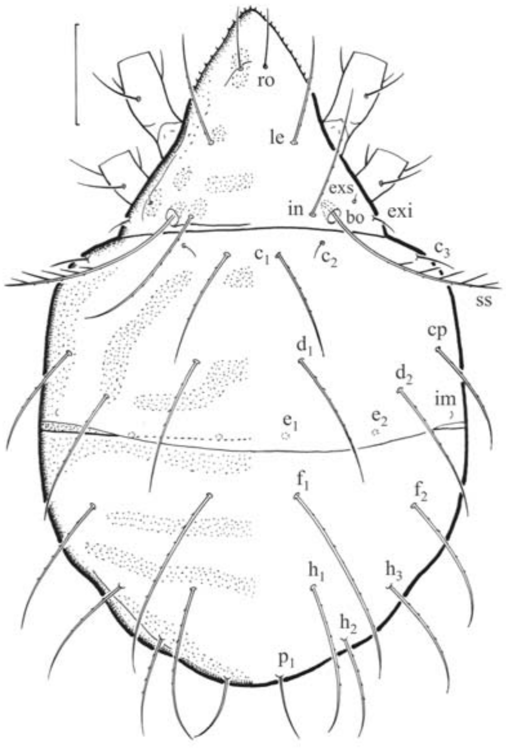


Fig. 50. *Hypochthonius rufulus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak et al. 2009b). Scale bar 100 µm

Rys. 50. *Hypochthonius rufulus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

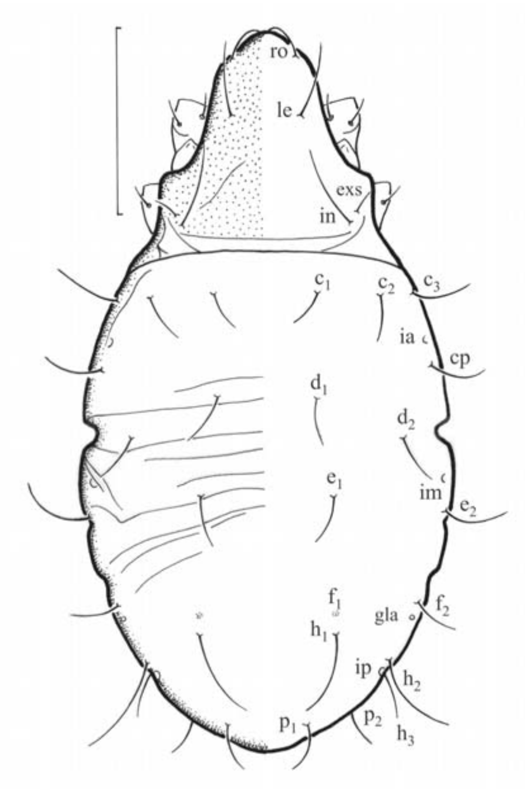


Fig. 51. *Malaconothrus monodactylus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009c). Scale bar 100 µm

Rys. 51. *Malaconothrus monodactylus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

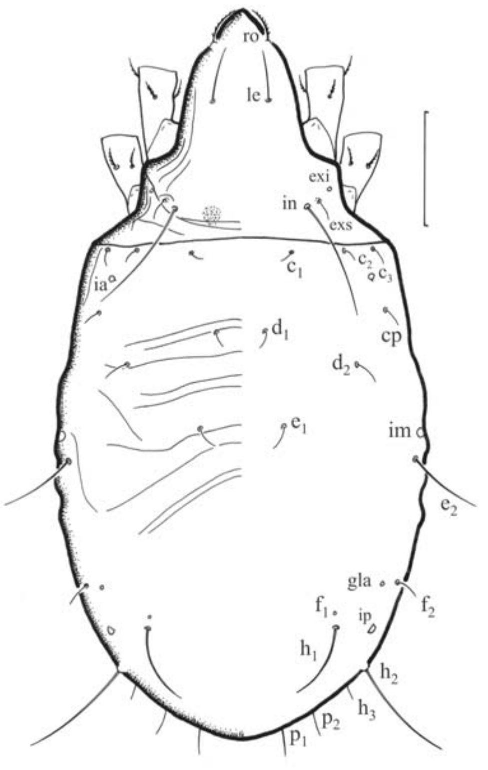


Fig. 52. *Trimalaconothrus angulatus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009c). Scale bar 100 µm

Rys. 36. *Trimalaconothrus angulatus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

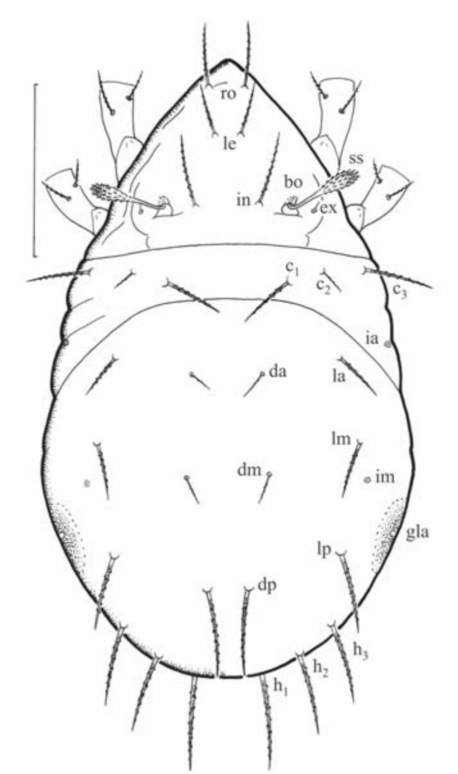


Fig. 53. *Punctoribates sellnicki*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2008b). Scale bar 100 µm

Rys. 53. *Punctoribates sellnicki*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

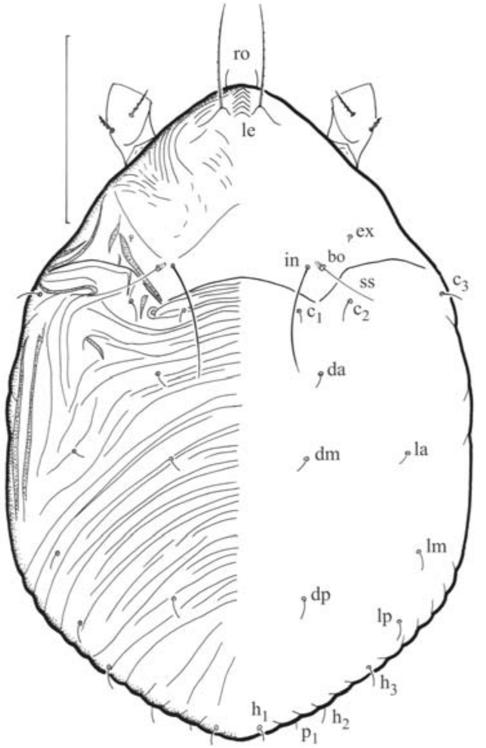


Fig. 54. *Limnozetes rugosus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2010). Scale bar 100 µm

Rys. 54. *Limnozetes rugosus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

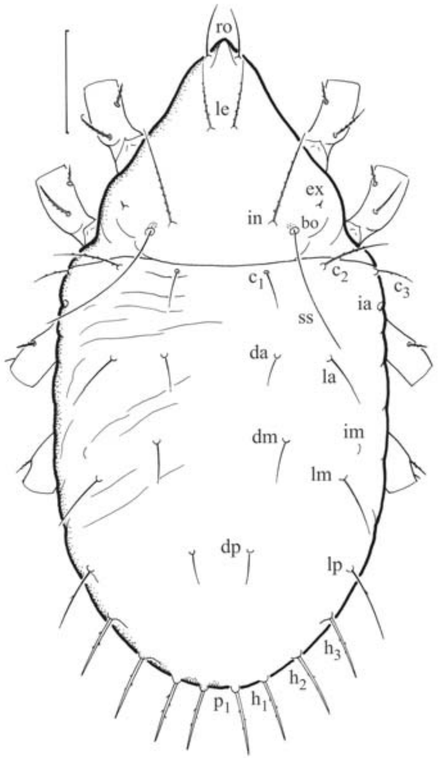


Fig. 55. *Limnozetes foveolatus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009b). Scale bar 50 µm

Rys. 55. *Limnozetes foveolatus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

Fig. 56. *Limnozetes ciliatus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009b). Scale bar 50 µm

Rys. 56. *Limnozetes ciliatus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 50 µm

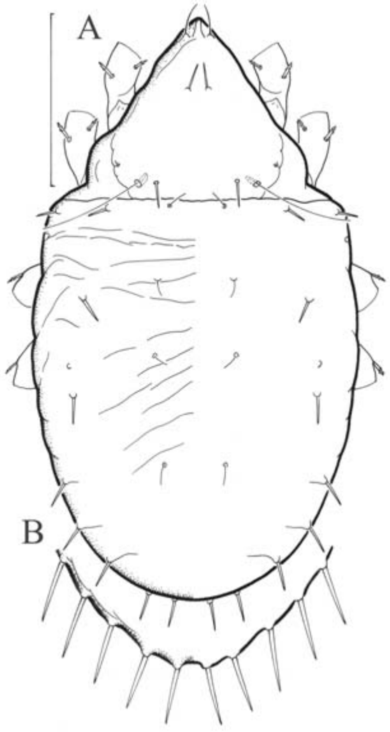


Fig. 57. Tritonymph. (A) *Limnozetes lustrum*, dorsal aspect. Legs partially drawn; (B) posterior marginal setae of *L. ciliatus* (Seniczak & Seniczak 2010). Scale bar 100 µm

Rys. 57. Tritonimfa. (A) *Limnozetes lustrum*, strona grzbietowa. Widoczne fragmenty nóg; (B) tylne szczeciny *L. ciliatus* Skala 100 µm

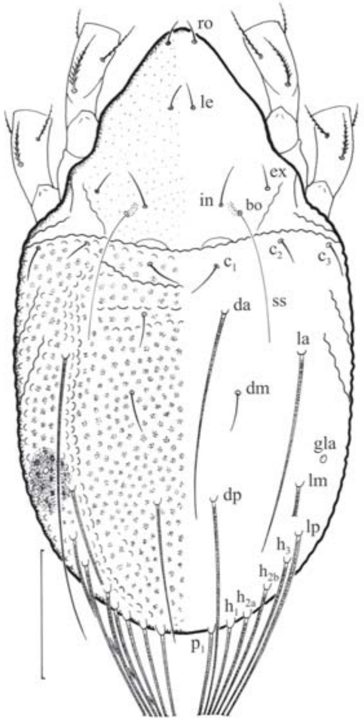


Fig. 58. *Hydrozetes longisetosus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2009a). Scale bar 100 µm

Rys. 58. *Hydrozetes longisetosus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

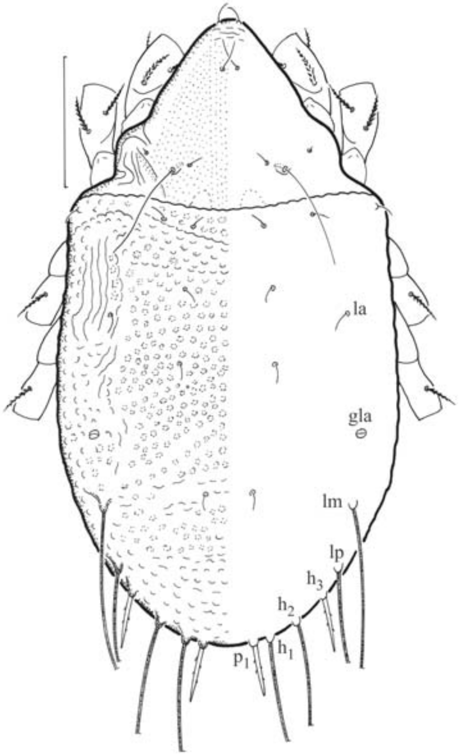


Fig. 59. *Hydrozetes octosetosus*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak et al. 2007b). Scale bar 100 µm

Rys. 59. *Hydrozetes octosetosus*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

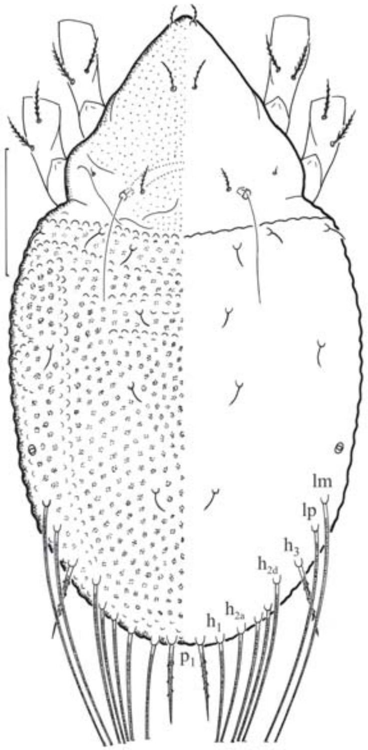


Fig. 60. *Hydrozetes parisiensis*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak et al. 2009c). Scale bar 100 µm

Rys. 60. *Hydrozetes parisiensis*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

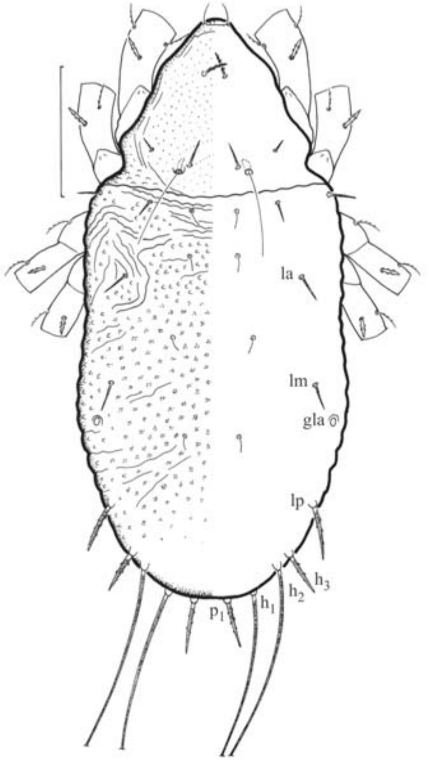


Fig. 61. *Hydrozetes thienemanni*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2008a). Scale bar 100 µm

Rys. 61. *Hydrozetes thienemanni*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

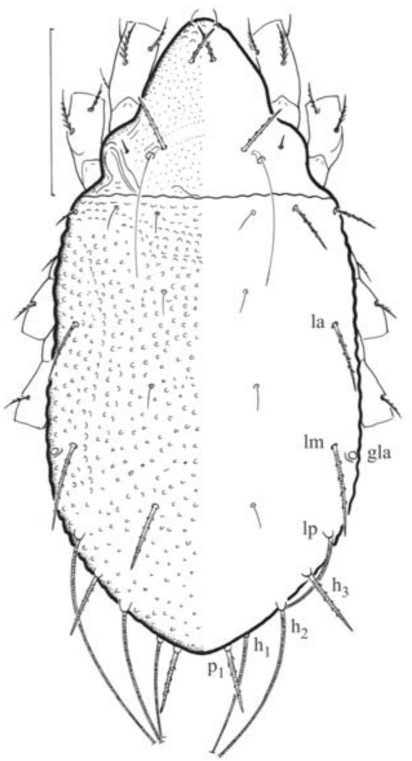


Fig. 62. *Hydrozetes lemnae*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak & Seniczak 2008a). Scale bar 100 µm

Rys. 62. *Hydrozetes lemnae*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

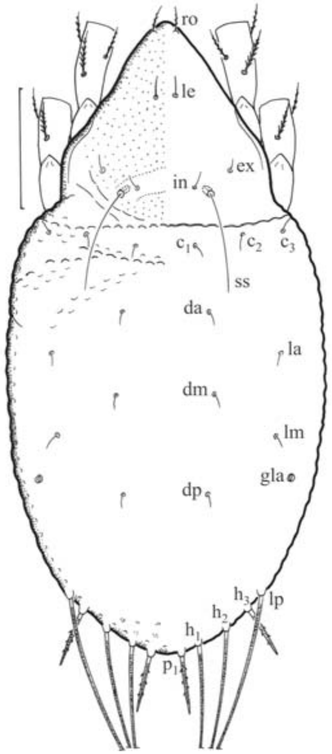


Fig. 63. *Hydrozetes confervae*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak et al. 2009c). Scale bar 100 µm

Rys. 63. *Hydrozetes confervae*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

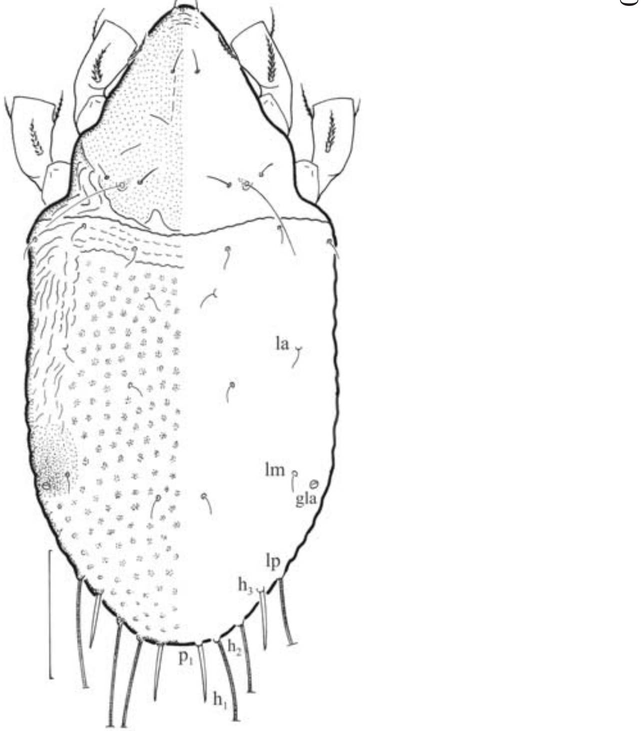


Fig. 64. *Hydrozetes lacustris*, tritonymph, dorsal aspect. Legs partially drawn (Seniczak et al. 2007b). Scale bar 100 µm

Rys. 64. *Hydrozetes lacustris*, tritonimfa, strona grzbietowa. Widoczne fragmenty nóg. Skala 100 µm

6. ECOLOGY OF SELECTED ORIBATID SPECIES

6.1. *Hoplophthiracarus illinoisensis* (Ewing, 1909)

Hoploderma illinoisensis Ewing, 1909.
Atropacarus illinoisensis: Ewing 1917.
Steganacarus illinoisensis: Jacot 1930.
Hoplophthiracarus paludis Jacot, 1938: Marshall et al. 1987; Niedbała 2001.
'*Hoplophthiracarus pavidus*' (Berlese, 1913) sensu Hammen (1963) and Aoki (1980): Niedbała 1992, 2001; Olszanowski et al. 1996.
Hoplophthiracarus illinoisensis: Behan-Pelletier 1987, 2010; Marshall et al. 1987; Niedbała 2001, 2002, 2008; Subías 2004; Weigmann 2006.
Hoplophthiracarus vanderhammeni Niedbała, 1991: Niedbała 2001; Niedbała & Olszanowski 2008.

Distribution: Semicosmopolitan (Niedbała 2008), Holarctic, Oriental and Northern Neotropical (Subías 2004); in Poland it occurs only in bogs in the northern part of the country, and at one site in the eastern part (Niedbała 2008).

Ecology

Hoplophthiracarus illinoisensis (Fig. 65) occurs in wet peatlands and is characteristic of raised bogs (Jacot 1938; Weigmann 2006). In Poland it is very rare (Niedbała 2008) and has been reported from several localities only from bogs (see Olszanowski et al. 1996 for further references). Niedbała (2008) found 239 specimens at seven sites in bogs, where dominance and constancy indices were respectively 1.3 and 1.1.

In this study *H. illinoisensis* was present at all lakes and ponds, except P1, P2, P3, BC and KG, but usually at low densities. Higher density was observed in spring or autumn. In the ecotone between the water's edge of lake M and the bog, *H. illinoisensis* avoided dripping-wet *Sphagnum* at the water's edge, being least abundant there, and its density increased up to 3 m from the water's edge, then was slightly lower 5 m from the edge. Similarly, in the studies of Donaldson (1996), *H. illinoisensis* was absent from hollows but preferred the driest part of the moisture gradient − the hummocks.

6.2. *Malaconothrus monodactylus* (Michael, 1888)

Nothrus monodactylus Michael, 1888.
Lohomannia (sic) (*Malaconothrus*) *egregia* Berlese, 1904.
Malaconothrus monodactylus: Sellnick 1921, 1960; Willmann 1925, 1931; Luxton 1987a, 1996; Olszanowski et al. 1996; Subías 2004; Starý 2006; Weigmann 2006; Weigmann & Deichsel 2006; Niedbała & Olszanowski 2008; Seniczak & Seniczak 2009c; Ermilov et al. 2010.
Malaconothrus egregius: Willmann 1931; Tuxen 1943; Strenzke 1952; Schweizer 1956; Sellnick 1960; Pérez-Íñigo 1968; Balogh & Mahunka 1983; Schatz 1983;

Borcard 1991a, b, c, e; Mahunka 1994; Olszanowski et al. 1996; Niedbała & Olszanowski 2008.

Malaconothrus gracilis Hammen, 1952: Knülle 1957a, b; Rajski 1961, 1967b; Tarras-Wahlberg 1961; Kunst 1971; Sitnikova 1975c; Balogh & Mahunka 1983; Marshall et al. 1987; Starý 1988; Gjelstrup & Solhøy 1994; Kehl 1997.

Malaconothrus mollisetosus Hammer, 1952: Hammer 1955; Sitnikova 1975c; Balogh & Mahunka 1983; Marshall et al. 1987.

Malaconothrus processus Hammen, 1952: Sellnick 1960; Balogh & Mahunka 1983; Luxton 1987a; Borcard 1991a, b, c, e; Subías 2004.

Malaconothrus punctulatus Hammen, 1952: Sellnick 1960; Sitnikova 1975c; Balogh & Mahunka 1983; Olszanowski et al. 1996; Niedbała & Olszanowski 2008.

Malaconothrus pulcher Mihelčič, 1957a.

Distribution: Holarctic and Neotropical (Subías 2004; Weigmann & Deichsel 2006), Holarctic (Weigmann 2006). It has been recorded from many localities in Poland (Olszanowski et al. 1996).

Ecology and biology

Malaconothrus monodactylus (Figs. 35, 51 and 66) has high humidity requirements (Knülle 1957c; Rajski 1967b; Luxton 1987a; Gjelstrup & Solhøy 1994; Kehl 1997), but avoids semi-aquatic habitats, like floating *Sphagnum* (Strenzke 1952; Knülle 1957a, b). In the ecotone between the water's edge of lake M and bog, this species was most abundant 5 m from the water's edge, which supports its preference for unsaturated habitats.

It is euryionic (Popp 1962) and has a wide tolerance of nutrient conditions (Kehl 1997), so it has been found in different habitats, including reeds, bogs, wet meadows, fen woodlands (Weigmann & Deichsel 2006), at springs (Willmann 1931; Tuxen 1944) and in soils of acidophilic forests (Popp 1962). However, in Holocene lake sediments in west Greenland, it was found only in the period of the maximum lake productivity and diversity (6500-3850 ^{14}C years BP) (Presthus-Heggen et al. 2010). Willmann (1933) assumed that *Malaconothrus* prefers acid conditions, but he studied only *M. globiger* Trägårdh, 1910, which has narrower pH tolerance (Popp 1962). *Malaconothrus monodactylus* has been found in willow moss (*Fontinalis antipyretica* L.) in the Alps up to 2600 m a.s.l. (Schweizer 1956), and it has been ascribed to the mesophilous hemiedaphon, i.e. living in the soil, but with a great range of temperature and light, and high humidity (RH = 100%) requirements (Tarras-Wahlberg 1961). It is parthenogenetic (Weigmann & Deichsel 2006) and was considered panphytophagous, although its gut contained mainly fungi (Behan-Pelletier & Hill 1983). It is able to feed on green algae and bacteria in water films covering emergent mosses and herbs (Gjelstrup & Solhøy 1994).

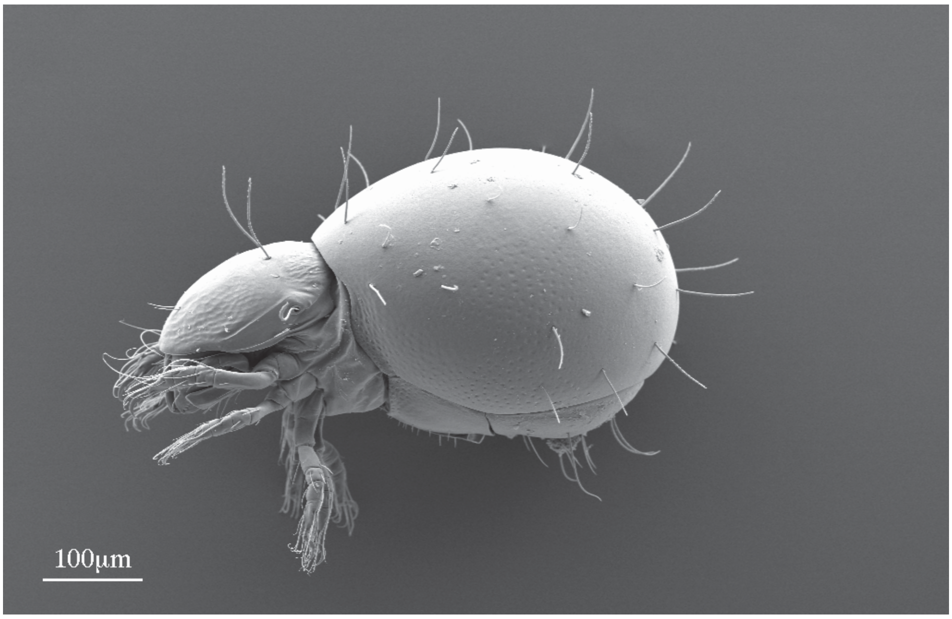


Fig. 65. *Hoplophthiracarus illinoisensis*, adult, lateral aspect
Rys. 65. *Hoplophthiracarus illinoisensis*, dorosły, widok z boku

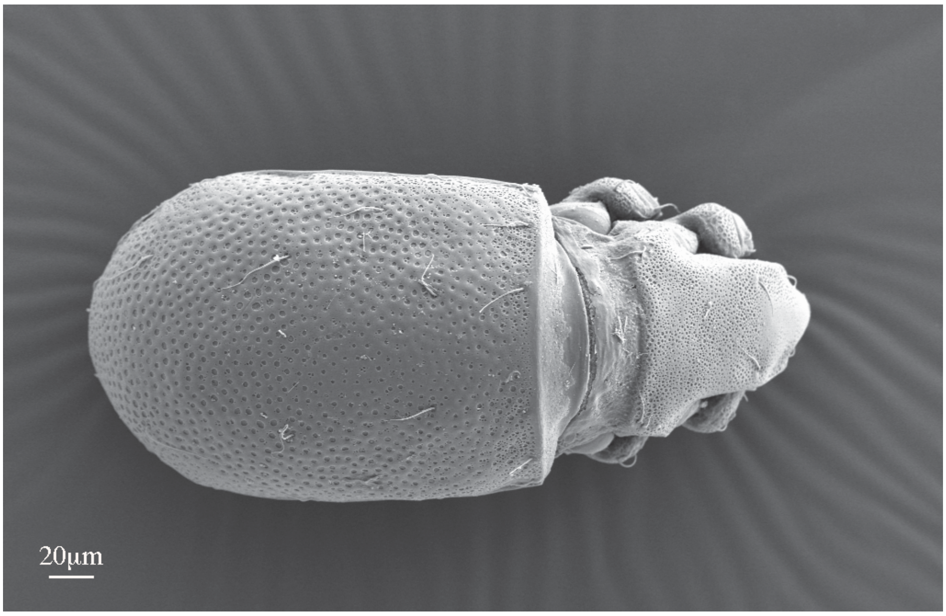


Fig. 66. *Malaconothrus monodactylus*, adult, dorsal aspect
Rys. 66. *Malaconothrus monodactylus*, dorosły, strona grzbietowa

In the present investigation this species was found only in a few water bodies, including forest ponds with neutral pH (P1, P2, P3), some acid lakes and ponds in bogs in Tuchola Forest (L, D1, M, K3), and pond KG in Kashubian Lakeland, which had the highest acidity. It achieved a high density both at ponds KG and P3, which confirms its wide tolerance to pH (Popp 1962) and nutrient conditions (Kehl 1997). The adults predominated in all samples in the present study, while Tarras-Wahlberg (1961) found the proportion of adults and juveniles to be similar. It was found in summer and autumn, but in a Swedish bog its abundance gradually decreased from spring to autumn (Tarras-Wahlberg 1961).

6.3. *Trimalaconothrus angulatus* Willmann, 1931

Trimalaconothus angulatus Willmann, 1931: Sengbusch 1951, Subías 2004, Weigmann 2006, Seniczak & Seniczak 2009.
Trimalaconothrus kuriki Yamamoto, 1997: Weigmann 2006.

Distribution: Europe and Japan (Weigmann 2006), Holarctic (Subías 2004); in present paper it is the first record of this species from Poland.

Ecology

Trimalaconothrus angulatus (Figs. 36 and 52) prefers swamp meadows and bogs (Weigmann 2006). Willmann (1931) found it in mosses and leaves near the river, but it also lives abundantly in *Sphagnum* at the edges of lakes and ponds (Seniczak & Seniczak 2009c) and in bogs (Yamamoto 1997). It is often found together with *T. glaber* (Michael, 1888) (Weigmann 2006).

In this study *T. angulatus* was present only at the shore of pond KG, where it was abundant and the dominant species. In summer the juveniles predominated, comprising over 60% of the samples, as in Norway (Seniczak et al. 2010).

6.4. *Trimalaconothrus foveolatus* Willmann, 1931

Trimalaconothrus foveolatus Willmann, 1931: Strenzke 1955; Sellnick 1960; Grandjean 1962; Piffl 1967, 1978; Sitnikova 1975c; Balogh & Mahunka 1983; Marshall et al. 1987; Borcard 1991a, c, e; Seniczak 1993; Kuriki & Yoshida 1999; Weigmann 2006; Behan-Pelletier 2010.
Trimalaconothrus (*Tyrphonothrus*) *foveolatus*: Knülle 1957a, b; Rajski 1961, 1967a, b.
Trimalaconothrus (*Trimalaconothrus*) *foveolatus*: Subías 2004.

Distribution: Holarctic (Weigmann 2006), Boreal and Oriental (Indonesia) (Subías 2004). It has been found at many localities in Poland (Olszanowski et al. 1996).

Ecology and biology

Trimalaconothrus foveolatus (Figs. 67 and 68) had been often confused with *T. maior* until it was described by Willmann (Willmann 1931; Strenzke 1952; Knülle 1957b).

Fig. 67. *Trimalaconothrus foveolatus*, adult, frontal aspect
Rys. 67. *Trimalaconothrus foveolatus*, dorosły, widok z przodu

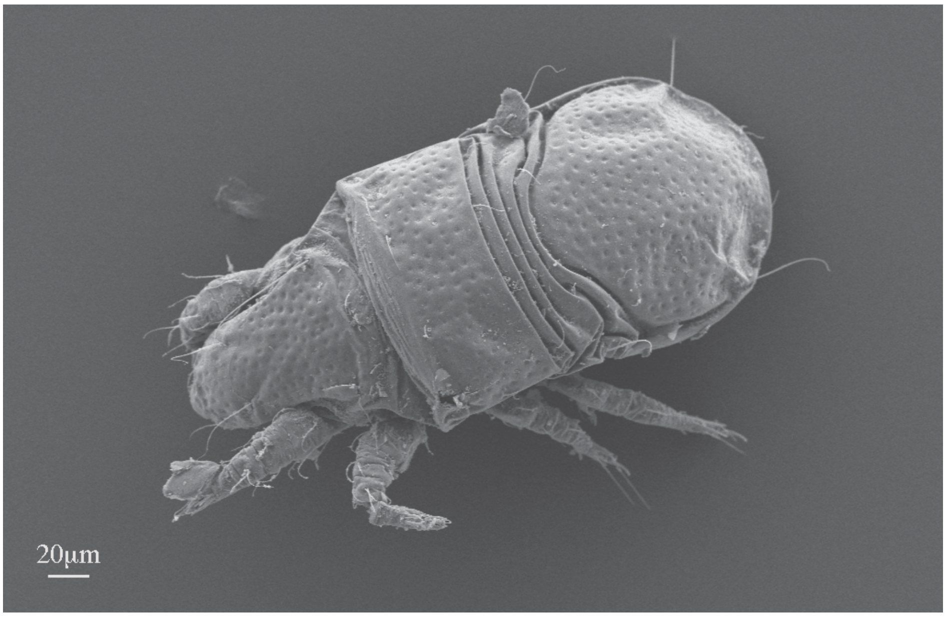


Fig. 68. *Trimalaconothrus foveolatus*, nymph, dorsal aspect
Rys. 68. *Trimalaconothrus foveolatus*, nimfa, strona grzbietowa

Similarly like *T. maior* it is a hygrophilous species and lives in oligotrophic bogs, also submerged (Hammer 1944, 1946; Druk 1982; Borcard 1991b; Weigmann 2006; Weigmann & Deichsel 2006), but it has wider ecological tolerance than *T. maior* and is not restricted only to the floating *Sphagnum* carpet (Kehl 1997). In present study at the water's edge the density of *T. foveolatus* was usually lower than this of *T. maior*. However, in the ecotone between the water's edge of lake M and bog, in contrast to *T. maior* that preferred the water's edge, *T. foveolatus* was present in all plots, with the highest density 1 m from the water's edge, which is in agreement with Kehl (1997).

Erickson & Platt (2007) considered *T. foveolatus* an aquatic species, while Schatz & Behan-Pelletier (2008) considered it amphibious. As a tyrphobiont (i.e. restricted to bogs; Schatz 1983; Spitzer & Danks 2006), this species is characteristic for '*Limnozetes ciliatus* community' of the floating and submerged *Sphagnum* (Strenzke 1952). It was found abundantly on a virgin bog in Finland, together with *Limnozetes ciliatus*, but was absent from ameliorated bogs planted with pine (Markkula 1986a, b). In west Greenland it was found only in hot springs with rich vegetation of mosses, so Hammer (1946) considered it thermophilous. It was also reported from Holocene lake sediments in west Greenland 3850-1750 ^{14}C years BP, when succession of the lake proceeded and moss-dominated marginal mire expanded (Presthus-Heggen et al. 2010). It is parthenogenetic (Weigmann & Deichsel 2006), and is eaten by the odonate naiads (Behan-Pelletier & Bisset 1994).

In this study *Trimalaconothrus foveolatus* was present at the shores of all lakes and ponds, except P1, P2, P3 and KG, supporting observation of Rajski (1967a, b) that the acidity is an essential factor to this species. It was classified as 'polystenohygro-oligostenoion' (Strenzke 1952; Rajski 1967a, b; Kehl 1997), while the content of the organic substance seems to be of secondary importance (Rajski 1967a, b).

Starý (1988) found it abundantly at the edge of bog lakes during the whole year, while Popp (1962) found it only in some seasons (August, September and October). In present study both adults and juveniles of *T. foveolatus* were the most abundant in autumn and the highest proportion of juveniles was in summer, indicating the most intensive reproduction season.

6.5. *Trimalaconothrus maior* (Berlese, 1910)

Malaconothrus maior Berlese, 1910a.
Malaconothrus sphagnicola Trägårdh, 1910: Schweizer 1922.
Malaconothrus novus Sellnick, 1921.
Trimalaconothrus novus: Sellnick 1924, 1926, 1955, 1960; Harnisch 1926; Willmann 1931, 1932, 1933; Hammer 1946; Strenzke 1952, 1955; Grandjean 1961; Eitminavičiūtė 1965; Hammer 1966b; Sitnikova 1975c; Balogh & Mahunka 1983; Schatz 1983; Borcard 1991c, e; Siepel & De Ruiter-Dijkman 1993; Schatz & Gerecke 1996; Behan-Pelletier 2010.
Trimalaconothrus intermedius Cooreman, 1941: Cooreman 1941a, b.

Trimalaconothrus (*Tyrphonothrus*) *novus*: Knülle 1957a, b; Rajski 1961, 1967a, b, 1970; Kunst 1971.
Trimalaconothrus maior: Hammen 1959; Marshall et al. 1987; Norton & Kethley 1989; Seniczak 1993; Olszanowski et al. 1996; Weigmann 2006.
Trimalaconothrus (*Tyrphonothrus*) *maior*: Subías 2004.

Distribution: Holarctic (Weigmann 2006), Semi-cosmopolitan (Subías 2004; Weigmann & Deichsel 2006); in Poland it has been found at many localities (Olszanowski et al. 1996).

Ecology and biology

Trimalaconothrus maior (Figs. 69 and 70) is a hygrophilous and aquatic species (Schatz 1983; Starý 1988; Borcard 1991e; Erickson & Platt 2007), which has been found mainly in very wet, oligotrophic bogs (Hammer 1946; Kehl 1997; Weigmann 2006; Weigmann & Deichsel 2006), in floating *Sphagnum* or at the edges of ponds (e.g. Willmann 1931, 1933; Starý 1988; Seniczak et al. 2006a, 2010; Seniczak 2011a). It was ascribed by Tarras-Wahlberg (1961) to the hygrophilous hemiedaphon, i.e. water-dwelling, living at small variations of temperature, and strong light in free water.

Trimalaconothrus maior is characteristic of the '*Limnozetes ciliatus* community' that occupies floating and submerged *Sphagnum* (Strenzke 1952). It is a dominant oribatid species at the bog studied by Donaldson (1996) in the USA, where it preferred the moistest parts of the studied gradient, being especially abundant on feathery bog-moss and flat-topped bog-moss. It was also reported from flat-topped bog-moss in Switzerland (Borcard 1991e), while in Sweden it was a dominant oribatid species in hollows, in rusty bog-moss (Tarras-Wahlberg 1961).

However, it was also found in a number of other habitats, such as mosses in slowly flowing water (Trägårdh 1910), on beaches and other biotopes along the Baltic Sea (Eitminavičiūtė 1965), a fen (Eitminavičiūtė 1966), in the surface layer of the soil profile in alder woods (Rajski 1967a, b), in a flooded pasture (Haarlov 1957), a meadow, and in a *Arrhenatheretum elatoralis* plant community (Seniczak 1993). Starý (1988) classified it as tyrphophil (i.e. characteristic of bogs but not confined to them; Spitzer & Danks 2006). According to Karppinen (1966) it seems to tolerate dry coastal environments in the archipelago of Finland. In Fennoscandia it occurs to an altitude of 1300 m a.s.l. (Solhøy 2001), but seldom is found above the tree line (Dalenius 1962). Peus (1932) observed that it moves into deeper layers of hummocks for overwintering. It was reported from early Holocene sediments (ca. 9150 ^{14}C years BP) in Norway (Solhøy & Solhøy 2000; Solhøy 2001) and from Holocene sediments in Greenland, where it was most abundant in the period of the maximum aquatic productivity (6500-3850 ^{14}C years BP) (Presthus-Heggen et al. 2010).

Fig. 69. *Trimalaconothrus maior*, adult, dorsal aspect
Rys. 69. *Trimalaconothrus maior*, dorosły, strona grzbietowa

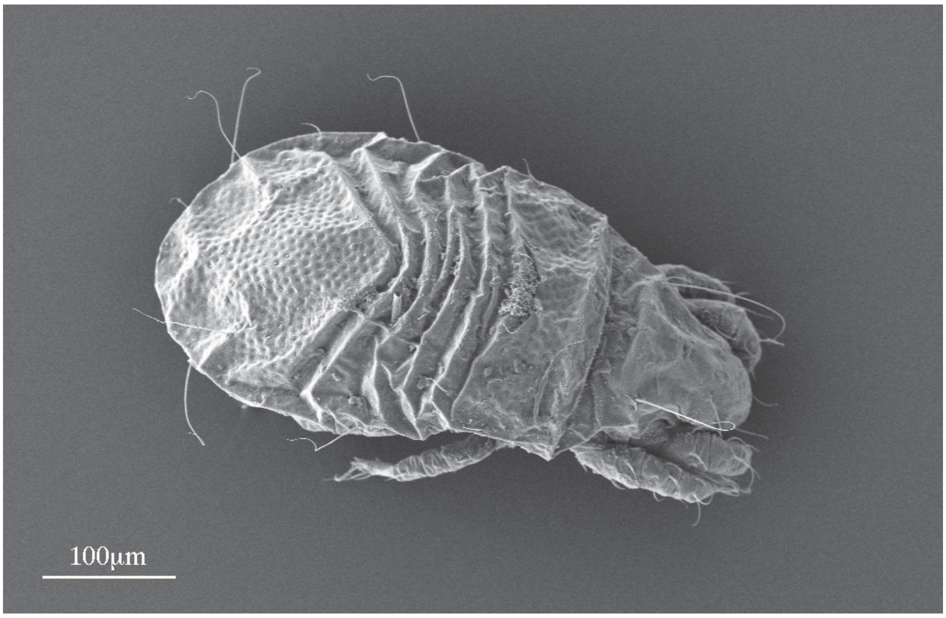


Fig. 70. *Trimalaconothrus maior*, nymph, dorsal aspect
Rys. 70. *Trimalaconothrus maior*, nimfa, strona grzbietowa

All *Trimalaconothrus* species like acid conditions (Willmann 1933), but *T. maior* has wider ecological tolerance to pH and was classified by Strenzke (1952) as polystenohygro-oligoeuryion. In this study *T. maior* was present at the shores of all lakes and ponds, except P1, P2 and P3, often being the second most abundant species. It was most abundant at lake M, but was also relatively numerous at D3 and O. In the transect between the water's edge of lake M and bog it was abundant only at the water's edge; in more distant plots its density was significantly lower, as at Lake Wielkie Gacno (Seniczak et al. 2006d). Its highest abundance was in different seasons at different lakes and ponds, and the lack of clear pattern of seasonal dynamics suggests that it reproduces throughout the year.

It is a parthenogenetic species (Weigmann & Deichsel 2006) and females are viviparous, as larvae are clearly seen in their interior (Haarlov 1957). It has been considered microphytophagous, i.e. feeding on microflora (Borcard 1991e; Olszanowski & Niedbała 2000). However, Siepel & De Ruiter-Dijkman (1993) and Siepel (1994) classified it as an herbivorous grazer, based on carbohydrase activity: it is able to digest cellulose and use both the cell content and cell walls of plants, and it feeds on green plants, including algae, and litter, playing an important role in comminuting organic matter (Siepel & De Ruiter-Dijkman 1993).

6.6. *Trimalaconothrus vietsi* (Willmann, 1925)

Malaconothrus (*Trimalaconothrus*) *vietsi* Willmann, 1925.
Trimalaconothrus vietsi: Sellnick 1960; Sitnikova 1975c; Borcard 1991a, c, e; Weigmann 2006.
Trimalaconothrus (*Trimalaconothrus*) *vietsi*: Subías 2004.

Distribution: Palearctic occidental (Euroatlantic and Caucasius) (Subías 2004), Palearctic (Weigmann 2006). In Poland it has been recorded only from two localities, one in the northern and one in the southern part of the country (see Olszanowski et al. 1996 for further references).

Ecology

Trimalaconothrus vietsi (Willmann, 1925) (Fig. 71) was first found in wet *Sphagnum* at a bog near Saager Meer (Oldenburg, Germany) (Willmann 1925). It is known from floating or dripping-wet *Sphagnum* moss in bogs (Weigmann & Deichsel 2006) and Kehl (1997) found it to be restricted to floating *Sphagnum* carpets with very wet and oligotrophic conditions. It is classified as a tyrphobiont (Willmann 1928a; Peus 1932), but is very rare (Willmann 1931; Popp 1962) and the juveniles have not been yet described (Weigmann & Deichsel 2006). It occurred abundantly in a bog in small cranberry moss (*Sphagnum rubellum* Wilson, 1855) in western Norway (Seniczak et al. 2011a).

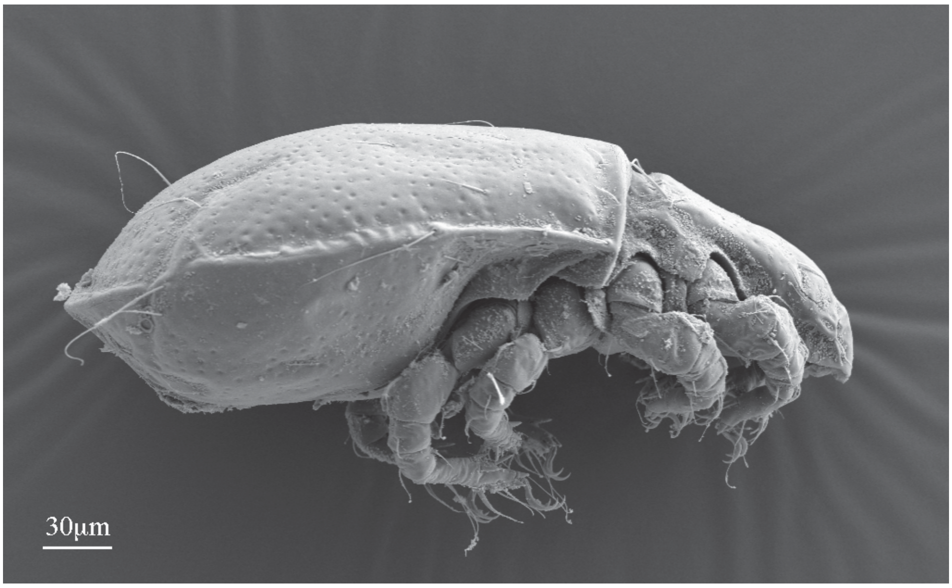


Fig. 71. *Trimalaconothrus vietsi*, adult, lateral aspect
Rys. 71. *Trimalaconothrus vietsi*, dorosły, widok z boku

In these investigations it was present at the water's edge of most lakes and ponds in Tuchola Forest and in Brodnica Lakeland, but in low numbers. The highest abundance, constancy and dominance indices were noted at pond K3 in spring (*A* = 0.09, *C* = 60 and *D* = 0.05). At all water bodies the highest abundance was in spring and juveniles were present only in this season, but in low numbers, with the highest value at pond D2, where their proportion was 25%. At lake M *T. vietsi* was absent from the water's edge, but occurred in other plots, and its abundance increased with distance from the water's edge; at 5 m it was *A* = = 0.10. Also, in the studies of Donaldson (1996) this species was most abundant in the driest part of the moisture gradient.

6.7. *Trhypochthonius nigricans* Willmann, 1928

Malaconothrus (*Trimalaconothrus*) *sphagnicola* Willmann, 1925.
Trhypochthonius nigricans Willmann, 1928b: Willmann 1931; Markkula 1986c; Seniczak & Norton 1994; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Niedbała & Olszanowski 2008.
Trhypochthonius nigrigans (sic): Markkula 1986b.
Trhypochthonius sphagnicola Weigmann, 1997b: Kehl 1997; Weigmann 2006.
Trhypochthonius sphagnicolus: Szywilewska-Szczykutowicz & Olszanowski 2007.

Distribution: Holarctic (Subías 2004; Weigmann & Deichsel 2006), Worldwide (Weigmann 2006). It is known from few localities in western Poland (Olszanowski et al. 1996) and in northern Poland (present paper).

Ecology and biology

Trhypochthonius nigricans (Figs. 72 and 73) was described from material collected from moss at Lake Boden near Wasserburg, in Germany (Willmann 1928b).

Fig. 72. *Trhypochthonius nigricans*, adult, lateral aspect
Rys. 72. *Trhypochthonius nigricans*, dorosły, widok z boku

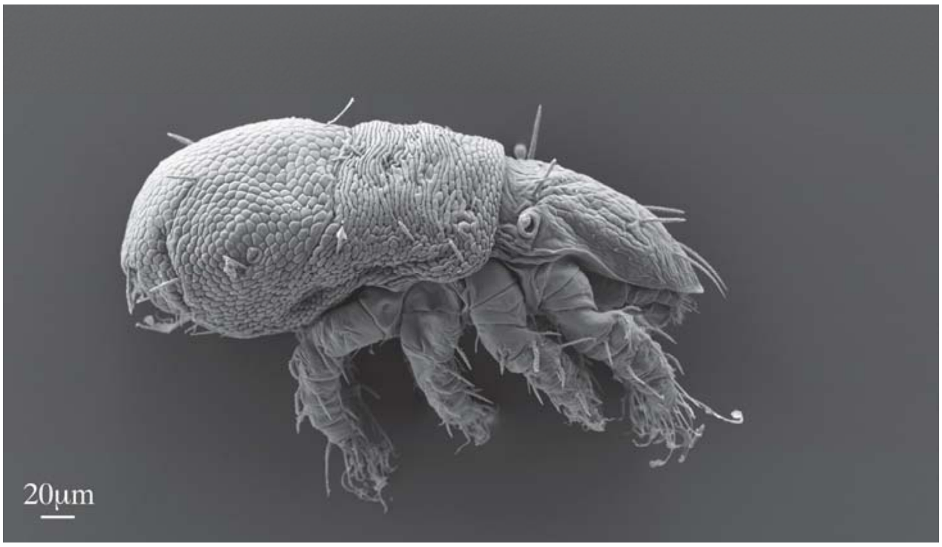


Fig. 73. *Trhypochthonius nigricans*, nymph, lateral aspect
Rys. 73. *Trhypochthonius nigricans*, nimfa, widok z boku

According to Willmann (1931) this species is rather rare. It was not abundant in the '*Limnozetes ciliatus* community' in Germany (Strenzke 1952) and was not recorded from other extensive ecological studies (Knülle 1957b; Popp 1962). In contrast, near Poznań (Poland) it was an exclusively characteristic species of '*Limnozetes ciliatus* community' (Rajski 1961, 1967a, b) and was represented mainly by nymphs, which were several times more abundant than adults. *Trhypochthonius nigricans* occurs abundantly in 5-6 cm of the upper layer of floating and water-saturated *Sphagnum*. Tarras-Wahlberg (1961) found it abundantly in rusty bog-moss at the margin of peatland, and Kehl (1997) in floating *Sphagnum* carpets with very wet and oligotrophic conditions. It was also present, although less abundantly, in periodically flooded meadows (Rajski 1967a, b).

In this investigation it was found at many lakes and ponds in bogs in Tuchola Forest and Brodnica Lakeland, but often in rather low densities. It was absent from ponds with neutral pH (P1, P2 and P3) and from the most acid one (KG), which contrasts with the findings of Rajski (1967a, b), who thought it preferred neutral soil reaction. It achieved highest density at pond K1 in Tuchola Forest and was relatively abundant at lakes O and S in Brodnica Lakeland. Juveniles dominated in all seasons, which is consistent with Rajski (1967a, b), with the highest proportion in summer. Schatz & Behan-Pelletier (2008) considered this genus amphibious. In the transect between the lake M and surrounding bog, it was present only in the plot 1 m distant from the water's edge, but was not abundant there.

6.8. *Trhypochthoniellus longisetus* (Berlese, 1904)

Trhypochthonius longisetus Berlese, 1904.
Nothrus crassus Warburton & Pearce, 1905.
Camisia excavata Willmann, 1919.
Tripochthonius trichosus Schweizer, 1922: Willmann 1931.
Trhypochthonius excavatus: Willmann 1928a, b; Willmann 1931; Peus 1932; Strenzke 1952; Sellnick 1960; Hammer 1966a; Piffl 1967, 1978.
Trhypochthonius (*Trhypochthoniellus*) *setosus* Willmann, 1928b: Sellnick 1929.
Trhypochthoniellus setosus: Willmann 1931; Strenzke 1952; Piffl 1967, 1978; Kunst 1971; Sitnikova 1975d; Balogh & Mahunka 1983; Markkula 1986b, c; Ayyildiz 1988; Starý 1988; Olszanowski et al. 1996; Kuriki & Yoshida 1999; Niedbała & Olszanowski 2008.
Trhypochthoniellus excavatus: Grandjean 1939; Hammen 1952; Rajski 1967b; Balogh & Mahunka 1983; Siepel 1994; Donaldson 1996; Olszanowski et al. 1996; Niedbała & Olszanowski 2008.
Trhypochthoniellus longisetus: Hammen 1959; Balogh & Mahunka 1983; Weigmann 1997b, 1999, 2006; Subías 2004.
Hydronothrus crispus Aoki, 1964: Kuriki & Yoshida 1999.
Hydronothrus puniceus Habeeb, 1981.
Trhypochthoniellus trichosus: Balogh & Mahunka 1983.

Hydronothrus aquariorum Fain & Lambrechts, 1987.
Trhypochthonius crassus: Luxton 1987b.
Trhypochthoniellus crassus: Seniczak et al. 1998.

Distribution: Worldwide (except Antarctica) (Subías 2004; Weigmann & Deichsel 2006), Worldwide (Weigmann 2006). It is known from a few localities in western Poland (Olszanowski et al. 1996), and is common in northern Poland (present paper).

Ecology and biology

Trhypochthoniellus longisetus (Figs. 74 and 75) is an aquatic species (Schatz & Behan-Pelletier 2008) living in raised bogs, especially in acid, wet *Sphagnum* cushions (Willmann 1931; Hammen 1952; Popp 1962; Weigmann 2006), in pools (Warburton & Pearce 1905), in reeds, swamps, grass fens and swamp forests (Strenzke 1952; Popp 1962), in *Carex* hummocks in a wave action zone (Popp 1962), and occasionally in wet meadows and lakes (Weigmann 2006; Weigmann & Deichsel 2006). Strenzke (1952) found it among the '*Gustavia fusifer*-*Liebstadia similis* community'. In South America it was reported from 3500 m a.s.l. (Hammer 1961). It was also found on the decaying leaves of *Hibiscus tiliaceus* L. 10 m deep under water (Aoki 1964), and in water falls (Habeeb 1981). It was present in an aquarium containing Discus fishes (*Symphysodon* spp.) in Antwerp, where the water had the following measurements: 140 mS; pH = 6.50; KH = 0.5; nitrites 0.027 mg; nitrate 30 mg dm^{-3}; temperature 28-30ºC (Fain & Lambrechts 1987). Kuriki & Yoshida (1999) observed this species (as *Hydronothrus crispus*) in the most humid biotope 4 the submerged area 4 but without *Sphagnum*, and also in a raised bog (as *Trhypochthoniellus setosus*). Willmann (1950) reported it from an acratotherm thermal spring at temperature 21ºC and pH = 8.00.

It is an opportunistic herbofungivore, like *Hydrozetes lacustris* and *Limnozetes foveolatus*, and is able to digest cellulose in cell walls of living green plants and trehalose in fungi. Its main food consists of green plants, but it is also able to feed on growing fungi and on lichens, as well as on Cyanothyta (Wallwork 1983; Siepel 1994). It is a parthenogenetic, thelytokous species (Weigmann 1997b; Weigmann & Deichsel 2006); its regional morphotypes and ecotypes were explained by Weigmann (1997b) as resulting from the clonal structure of this species.

In this study *Trhypochthoniellus longisetus* was found at almost all lakes and ponds, but most abundantly at pond P3 with neutral pH, where it comprised over 50% of all Oribatida. Juveniles were most abundant in summer and adults in autumn. In the transect at lake M *T. longisetus* was most abundant at the water's edge and its abundance decreased with distance from it, which confirms its preference for water-saturated substrates (e.g. Strenzke 1952; Knülle 1957b; Popp 1962; Donaldson 1996).

Fig. 74. *Trhypochthoniellus longisetus*, adult, dorsal aspect
Rys. 74. *Trhypochthoniellus longisetus*, dorosły, strona grzbietowa

Fig. 75. *Trhypochthoniellus longisetus*, nymph, dorsal aspect
Rys. 75. *Trhypochthoniellus longisetus*, nimfa, strona grzbietowa

6.9. *Metabelba sphagni* Strenzke, 1950

Metabelba sphagni Strenzke, 1950: Strenzke 1952; Hammen & Strenzke 1953; Kunst 1959b, 1961; Sellnick 1960; Tarras-Wahlberg 1961; Borcard 1991c, 1992a.
Metabelba lanceolata Hammen, 1952.
Parametabelba sphagni: Schatz 1983.
Metabelba (*Parametabelba*) *sphagni*: Subías 2004; Weigmann 2006.

Distribution: Europe: western and central part (Weigmann 2006) [Austria (Schatz 1983), Germany (Strenzke 1950), The Netherlands, Czech Republic (Hammen 1952; Hammen & Strenzke 1953), Switzerland (Borcard 1991c, 1992a), Poland (Seniczak 2011a)], northern part [Sweden (Tarras-Wahlberg 1954, 1961)], Euroatlantic (Subías 2004). In Poland it has been recorded from Pomerania (Seniczak 2011a).

Ecology and biology

Metabelba sphagni Strenzke, 1950 (Fig. 76) was first found in Holstein (Strenzke 1950). It is a hygrophilous to limnic species (Schatz 1983), found in raised bogs (Weigmann 2006), oligotrophic marshes (Borcard 1992a) and at the edges of pools in very damp *Sphagnum* (Hammen 1952).

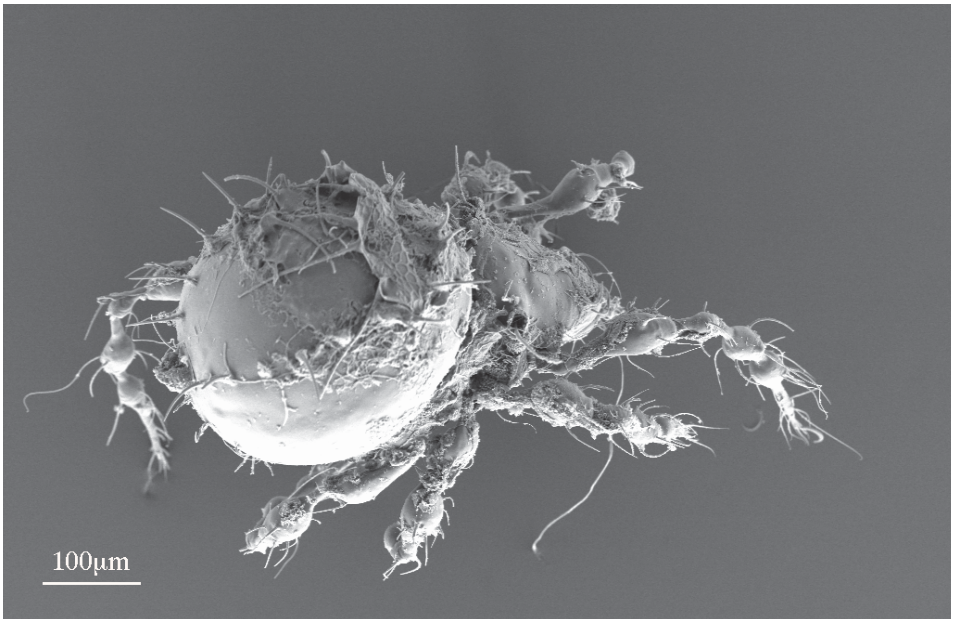


Fig. 76. *Metabelba sphagni*, adult, lateral aspect
Rys. 76. *Metabelba sphagni*, dorosły, widok z boku

This species was present in low numbers in the '*Limnozetes ciliatus* community' that occupied the floating and submerged *Sphagnum*. It was also reported from rusty bog-moss in Sweden and ascribed to the mesophilous hemiedaphon, i.e. living in the soil, and exposed to great variations of temperature and light, and high humidity, RH = 100% (Tarras-Wahlberg 1961).

In Poland *Metabelba sphagni* was first recorded from the edge of a *Sphagnum* mat at the pond (K1) in 'Jeziorka Kozie' reserve in Tuchola Forest (Seniczak 2011a), but was also present at the edge of some other lakes and ponds in Tuchola Forest (D2, D3, M, K2 and K3) and Brodnica Lakeland (O). Its abundance was low there, but increased from spring to autumn. Juveniles were found only in summer, but even then adults highly predominated in samples. Tarras-Wahlberg (1961) found this species in low abundances in a Swedish bog, but juveniles were also present from May to December. In the ecotone between the water's edge of lake M and bog, this species preferred the plot situated 3 m from the water's edge, but was relatively abundant 5 m distant.

6.10. *Hydrozetes confervae* (Schrank, 1781)

Acarus confervae Schrank, 1781.
'Cepheus (*Carabodes*) *coriaceus'* C.L. Koch, 1835 sensu Oudemans 1896: Hammen 1952.
Notaspis lacustris Michael, 1882: Oudemans 1897; Chinaglia 1917; Sellnick 1928.
Oppia confervae: Oudemans 1897.
Eremaeus confervae: Oudemans 1900; Sellnick 1908.
Notaspis confervae: Trägårdh 1904.
Hydrozetes terrestris Berlese, 1910b: Grandjean 1941; Kuriki & Yoshida 1999.
Xenillus confervae: Oudemans 1914, 1916.
Hydrozetes confervae: Schweizer 1922; Beier 1928; Willmann 1929; Sellnick 1932; Willmann 1943; Hammen 1952; Strenzke 1955; Popp 1962; Piffl 1967; Sitnikova 1975a; Walgram 1976; Schatz 1983; Marshall et al. 1987; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Weigmann & Deichsel 2006; Niedbała & Olszanowski 2008; Seniczak et al. 2009c.

Distribution: Holarctic (Subías 2004; Weigmann 2006). This species has been reported from western (see Olszanowski et al. 1996 for further references), northern (Seniczak et al. 2009c) and southern Poland (Mistrzak et al. 2011).

Ecology and biology

Schrank (1781) and Oudemans (1897) found *Hydrozetes confervae* (Figs. 48, 63, 77 and 78) in filamentous algae of the family Confervaceae, but it is also abundant on duckweed (Oudemans 1897; Weigmann 2006; Weigmann & Deichsel 2006; Seniczak et al. 2009c). It is a limnic species (Piffl 1978). According to literature, the mites are always submerged under water and do not come to the surface.

Fig. 77. *Hydrozetes confervae*, adult, lateral aspect
Rys. 77. *Hydrozetes confervae*, dorosły, widok z boku

Fig. 78. *Hydrozetes confervae*, nymph, lateral aspect
Rys. 78. *Hydrozetes confervae*, nimfa, widok z boku

They have been observed on the roots of duckweed or crawling slowly among the threads of algae, and they die when kept out of water (Oudemans 1897). Schrank (1781) collected this species in the second half of March, while Oudemans (1897) found it from March until June and he believed it is present any time that Confervaceae and Lemnaceae are abundant in water.

In studies near Moscow it was present only in eutrophic bogs, in contrast to *H. lacustris*, which occurred in oligotrophic bogs (Druk 1982). It was also found in a spring situated in dwarf birch forest in Swedish Lapland (Willmann 1943). In an experiment, *H. confervae* was a faster recoloniser than other *Hydrozetes* species (Popp 1962). It was the most abundant mite in the early Holocene sediments at Kråkenes, Norway and fluctuations in its density were hypothesized to reflect changes in lake productivity (Solhøy & Solhøy 2000; Solhøy 2001).

In the present study *H. confervae* was the least abundant species of *Hydrozetes*. It occurred sporadically at pond D2 in autumn (30 adults were found in one sample). It was absent in the ecotone between the water's edge of lake M and bog, but it is a typical aquatic species that lives in open water and dripping-wet *Sphagnum* at pond shores (Seniczak et al. 2009c; Mistrzak et al. 2011). In Poland it was collected from duckweed in Brodnica Lakeland (Seniczak et al. 2009c) and *Sphagnum* moss in the Tatra National Park, where it was very abundant (almost 60,000 individuals m^{-2}) and comprised over 98% of all *Hydrozetes* (Mistrzak et al. 2011).

Hydrozetes confervae reproduces sexually (Weigmann & Deichsel 2006), and the sex ratio varies among lakes and seasons (Seniczak et al. 2009c). Popp (1962) studied the phenology of this species and observed adults and juveniles during the whole year, while females were gravid from May to October. It has been observed feeding on duckweed (Weigmann & Deichsel 2006); the juveniles burrow inside duckweed tissue and remain there quiescent for some days before molting (Seniczak et al. 2009c).

6.11. *Hydrozetes lacustris* (Michael, 1882)

Notaspis lacustris Michael, 1882: Piersig 1892, 1895; Nordenskiöld 1901; Ludwig 1908, 1909; Chinaglia 1917.
Notaspis speciosus Piersig, 1895: Chinaglia 1917.
Scutovertex lacustris: Berlese 1896.
Eremaeus lacustris: Oudemans 1900; Sellnick 1908.
Hydrozetes lacustri (sic): Berlese 1902.
Xenillus speciosus Oudemans, 1914: Oudemans 1916.
Hydrozetes lacustris: Hull 1916; Sellnick 1921; Willmann 1931, 1933; Grandjean 1948; Haarlov 1957; Knülle 1957a, c; Klima 1958; Sellnick 1960; Piffl 1967; Sitnikova 1975a; Walgram 1976; Schatz 1983; Borcard 1994b; Gjelstrup & Solhøy 1994; Olszanowski et al. 1996; Schatz & Gerecke 1996; Deichsel 2004; Subías 2004; Weigmann 2006; Weigmann & Deichsel 2006; Seniczak et al. 2007, 2009c; Niedbała & Olszanowski 2008.
Hydrozetes speciosus Piersig, 1895: Buitendijk 1945.

Distribution: Holarctic (Subías 2004; Weigmann 2006). In Poland it has been reported from the western (see Olszanowski et al. 1996 for further references), northern (Seniczak et al. 2009c) and southern parts (Mistrzak et al. 2011) of the country.

Ecology and biology

Hydrozetes lacustris (Figs. 1, 44 and 64) is considered hygrophilus and limnic (Tarras-Wahlberg 1952; Piffl 1978) and lives submerged (Michael 1882; Piersig 1892; Chinaglia 1917; Schatz & Gerecke 1996), often on floating *Sphagnum* moss and algae (Willmann 1931; Popp 1962; Weigmann 2006; Weigmann & Deichsel 2006), together with *Limnozetes ciliatus* (Sellnick 1908), in the '*Limnozetes ciliatus* community' (Strenzke 1952). Popp (1962) considered it extremely euryionic while other authors consider it to strongly prefer acid water (Walgram 1976; Weigmann 2006; Weigmann & Deichsel 2006). Walgram (1976) observed that at pH 3.00-3.50, 100% of collected *Hydrozetes* belonged to *H. lacustris*, while at pH 4.00-4.50, it comprised only 95%. However, this observation has not been confirmed in the Tatra National Park, south Poland, where *H. lacustris* comprised 100% of *Hydrozetes* in a pond with pH = 4.50, and 53% in more acid water (pH = 3.60), where it was accompanied by *H. octosetosus* (Mistrzak et al. 2011). It is very common in northern Germany, where it is found more often than *H. confervae* (Willmann 1931). Druk (1982) found this species in an oligotrophic bog near Moscow, while Eitminavičiūtė (1966) recorded it from a fen in Lithuania, where at the water's edge it was the most abundant oribatid species. In Norway, at the pond at Fløyen Mt., near Bergen, it was at least twice more abundant than the other species present, *H. confervae* (Seniczak et al. 2009c). At another pond near Bergen (located at Ulriken Mt.) it occurred alone and in high density (Seniczak et al. 2007). According to Meuche (1939) it also lives in brackish water, i.e. water with salt concentration intermediate between fresh and marine (Rydén et al. 2003).

It is a parthenogenetic species, reproducing by thelytoky (Grandjean 1948). Popp (1962) found it only in a few months in summer (May, July, August, September) and gravid females were found in July and September. According to Siepel & De Ruiter-Dijkman (1993) and Siepel (1994) it is an opportunistic herbofungivore, potentially feeding on blue-green algae.

Hydrozetes lacustris moves slowly, always underwater (Oudemans 1897; Willmann 1931), and is found 'crawling about subaqueous plants', as described by Michael (1882). It can attach to plants for hours without moving (Willmann 1931). According to Ludwig (1908, 1909), this species is very lively, moving quickly on the water surface, and plays an important role in the pollination of the duckweed, but as suggested by Willmann (1931) this observation probably referred to *Heterozetes palustris* and *Zetomimus furcatus*. *Hydrozetes lacustris* is often found covered with diatoms (Michael 1882). It is a common component of food of carp fry (Eitminavičiūtė 1966).

This species has been used for detailed anatomical studies of the genital papillae that serve in osmoregulation and/or ion regulation (Alberti & Löwenfeld 1990; Alberti & Coons 1999) and for studies of the plastron that is needed for mite respiration underwater (Crowe & Magnus 1974; Krantz & Baker 1982; Messner et al. 1992; Alberti & Coons 1999).

In this investigation *H. lacustris* was found in *Sphagnum* at the water's edge of almost all lakes and ponds (with pH 3.60-6.50), except P1, P2 and P3, which had higher pH, but it was not abundant. The highest percentage of juveniles, at all shores, was in autumn, when they comprised 50% of the samples. In the ecotone between the water's edge of lake M and bog, this species occurred at the edge of the lake and 5 m from it, but in low density. To compare, at oligotrophic lobelia lakes in Tuchola Forest, it was the most abundant among *Hydrozetes*, achieving a high density (4,400 individuals m^{-2}) at Lake Małe Gacno (Seniczak et al. 2005a, b, 2006d).

6.12. *Hydrozetes lemnae* (Coggi, 1897)

Notaspis lemnae Coggi, 1897.
'*Hydrozetes terrestris*' Berlese, 1910 sensu Strenzke 1943: Willmann 1931; Tuxen 1944; Hammer 1946.
Hydrozetes lemnae: Haarlov 1957; Klima 1958; Sellnick 1960; Hammer 1966a, b; Piffl 1967; Kunst 1971; Sitnikova 1975a; Walgram 1976; Schatz 1983; Gjelstrup & Solhøy 1994; Olszanowski 1996; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Seniczak & Seniczak 2008a; Niedbała & Olszanowski 2008; Seniczak et al. 2009c.
Hydrozetes mollicoma Hammer, 1958.

Distribution: *Hydrozetes lemnae* has been variously called cosmopolitan (Weigmann & Deichsel 2006) or semi-cosmopolitan (Subías 2004), or was cited as being in the Palearctic and New Zealand (Weigmann 2006). In Poland it was previously known only from one locality in Silesia (Olszanowski et al. 1996); however it is present all over the country, as it has been also reported from Pomerania (Seniczak & Seniczak 2008a), Wielkopolska province (Seniczak 2011b) and Brodnica Lakeland (in this paper).

Ecology and biology

Hydrozetes lemnae (Figs. 46, 62, 79 and 80) lives mainly in lakes, ponds and slowly flowing water, on submergent vegetation and detritus (Weigmann & Deichsel 2006), and has been collected from several meters below the water line to several centimeters above (Buford 1976). Strenzke (1952) distinguished the '*Hydrozetes lemnae* community' of submergent mosses and algae in eutrophic water bodies, where *H. thienemanni* and rarely, *H. parisiensis* also were present.

Hydrozetes lemnae also has been found in a flooded pasture (Haarlov 1957) and in wet soil near a stream (Bayartogtokh & Akrami 2000).

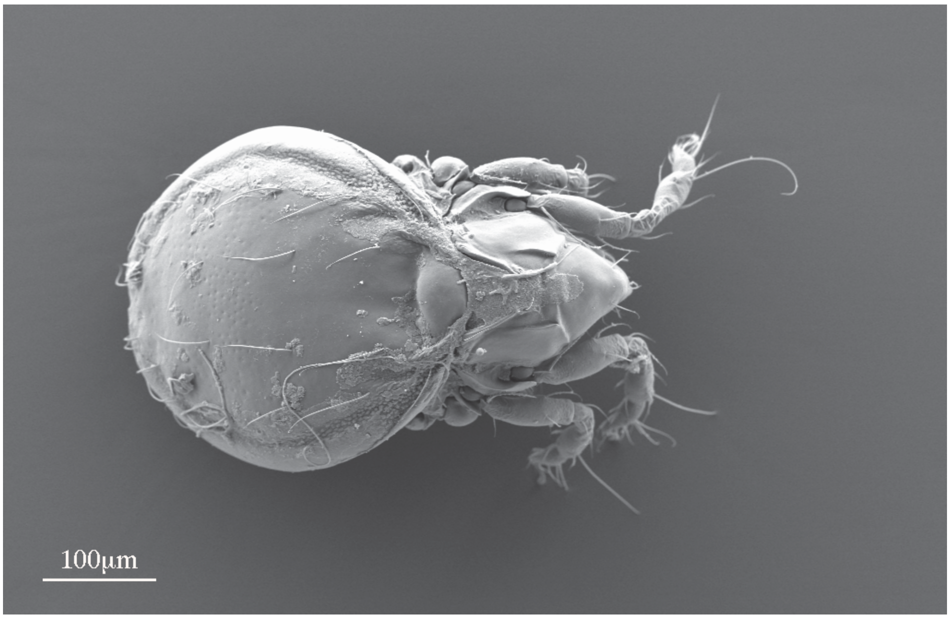


Fig. 79. *Hydrozetes lemnae*, adult, dorsal aspect
Rys. 79. *Hydrozetes lemnae*, dorosły, strona grzbietowa

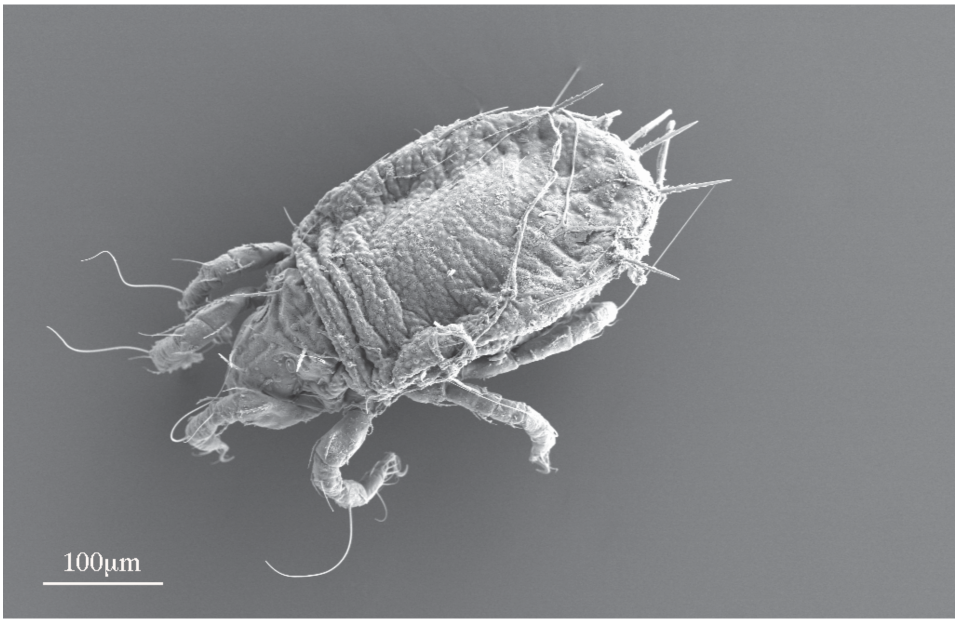


Fig. 80. *Hydrozetes lemnae*, nymph, dorsal aspect
Rys. 80. *Hydrozetes lemnae*, nimfa, strona grzbietowa

Hammer (1975) recorded it from wet biotopes in an oasis in Central Sahara. It was also found in a tank containing breeding tadpoles (Grandjean 1949) and in fish aquaria with neutral reaction (pH = 6.50 and 7.80) and KH (carbonate hardness) of 0.5 and 7.0, respectively (Fain et al. 1988). It was reported from the gills and throat epithelium of fish and other aquatic animals (Grandjean 1949; Fain et al. 1988), but as was clearly explained by Grandjean (1949) it is not a parasite. This species was reported from Holocene sediments in Greenland; it was not abundant in the early lake development (6950-6500 ^{14}C years BP), when water was rich in electrolytes and Chraceae vegetation, but when the water conductivity decreased (6500-3850 ^{14}C years BP) its abundance substantially increased. It was most abundant the in mesotrophic conditions and was accompanied by *Limnozetes guy*i, *L. lustrum* and few wetland Oribatida (Presthus-Heggen et al. 2010).

It was observed feeding on different types of food and seems to be generalist (Behan-Pelletier & Eamer 2003). According to Fernandez & Athias-Binche (1986) its food consists mainly of the duckweed. Adults feed on different *Lemna* species, while the immatures fed exclusively on *Lemna gibba* L. (Athias-Binche & Fernandez 1986; Fernandez & Athias-Binche 1986); they also burrow inside *Lemna* leaves (Walter & Proctor 1999). In Germany *Hydrozetes lemnae* was found mainly on submergent plants and lived there on other foods (Weigmann & Deichsel 2006). In the laboratory both adult and immature *H. lemnae* fed on leaves of aquatic plants that were in an early stage of decomposition (Covarrubias & Mellado 1998). In another laboratory experiment this species preferred *Pleurococcus* and *Spirogyra* algae and fed less willingly on *Cetraria islandica* (L.), but refused other types of food, including raw potatoes, half-decomposed tree leaves, green mosses [*Ceratodon purpureus* (Hedwig), *Leskeella nervosa* (Brid.) Loeske] and lichens [*Cladonia sylvatica* L., *Hypohymnia physodes* (L.) Nyl.; Ermilov 2006]. Levitation in this species has been observed under both laboratory and field conditions (Newell 1945; Buford 1976; Fernandez & Athias-Binche 1986), although Covarrubias & Mellado (1998) did not see it under laboratory conditions.

It is parthenogenetic and reproduces by thelytoky (Grandjean 1948). It was once considered r-selected (Fernandez & Athias-Binche 1986), but as it was explained later its reproductive rate is not higher than for soil Oribatida, which are *K*-selected (Norton 1994). Under field conditions it completed 2 generations per year; spring females became adult in summer and produced juveniles in autumn, which became adult in the winter (Fernandez & Athias-Binche 1986). Under laboratory conditions, at 20ºC and 100% humidity, its embryonic and postembryonic development lasted for 56-67 days (Ermilov 2006).

Hydrozetes lemnae was found abundantly in a pond with neutral pH (7.20) in the Botanical Garden in Myślęcinek, Bydgoszcz (Seniczak 2011b), where it was the only representative of *Hydrozetes* and comprised over 75% of all Oribatida. It was most abundant in moss at the shore (121,000 individuals m^{-2}), but was also present on the water surface 2 m from the shore, where it was less abundant in the duckweed and least numerous in green algae (Seniczak 2011b). It seems to prefer neutral pH, but also tolerates acid water. In the present study it was found abundantly at ponds P2 and P1 in Tuchola Forest, which had neutral pH, but was also relatively abundant at peat pond BC (Wielkopolska province), which was acid, and was rare at pond P3 (Tuchola Forest), with neutral pH, and at some acid water bodies (D1 in Tuchola Forest and O in Brodnica Lakeland). In summer and autumn the adults predominated, comprising on average 82% of the samples.

6.13. *Hydrozetes longisetosus* S. Seniczak & A. Seniczak, 2009

Distribution: Central Europe: Poland and Germany (Seniczak & Seniczak 2009a).

Ecology and biology

Hydrozetes longisetosus (Figs. 45, 58, 81 and 82) was first discovered as a nymph, found in September 2006 at the edge of the *Sphagnum* mat of pond D3 in Tuchola Forest (Pomerania, Poland), and then more animals were found at the edges of several other forest lakes and ponds in Pomerania (Seniczak & Seniczak 2009a). Subsequently, a population from Germany was studied, collected in 1976 by Dr. H.M. Engelmann 40 km north of Görlitz Niederspree, and obtained from Prof. Dr. Roy A. Norton (Syracuse, NY, USA).

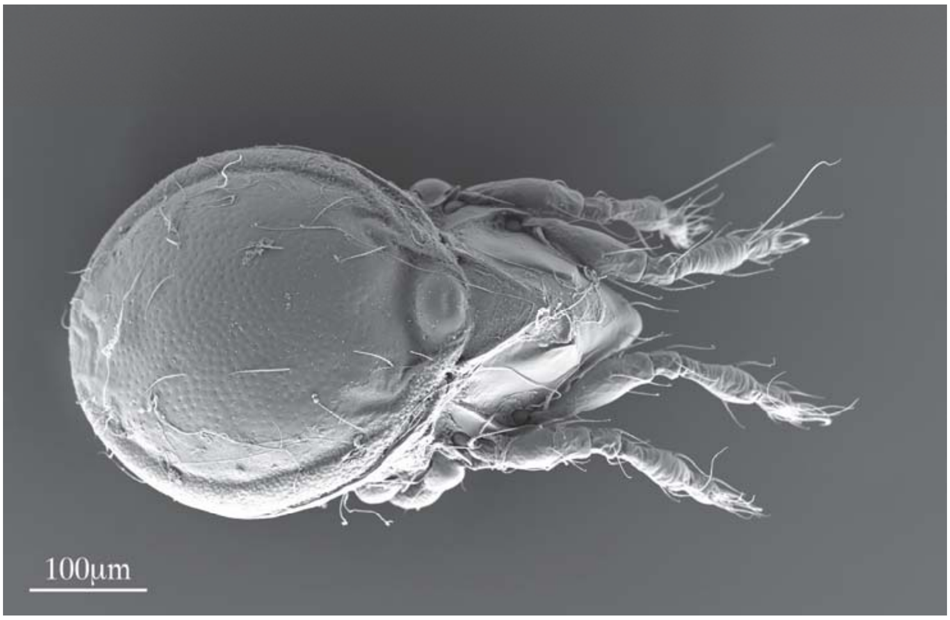


Fig. 81. *Hydrozetes longisetosus*, adult, dorsal aspect
Rys. 81. *Hydrozetes longisetosus*, dorosły, strona grzbietowa

Fig. 82. *Hydrozetes longisetosus*, nymph, dorsal aspect
Rys. 82. *Hydrozetes longisetosus*, nimfa, strona grzbietowa

Hydrozetes longisetosus is a parthenogenetic species (Seniczak & Seniczak 2009a) that is common in lakes and ponds in bogs in Poland. It was present at the edge of *Sphagnum* mat of all studied water bodies in bogs in Tuchola Forest (L, D1, D2, D3, D4, M, K1, K2, K3) and Brodnica Lakeland (O, S), but was absent from ponds P1, P2, P3, BC and KG. It was previously reported to be abundant at pond K1 (Seniczak 2011a), and at most other lakes and ponds studied it was the most abundant *Hydrozetes* species. It was usually found together with *H. lacustris* and *H. octosetosus* and sometimes also with *H. lemnae*, but rarely with *H. confervae*. It usually was most abundant in spring and least abundant in summer. Juveniles were present in all seasons, but their highest percentage was in spring or autumn, suggesting the most intensive reproduction is from autumn to spring. Based on the distribution of this species in the ecotone between the water's edge of lake M and bog, *H. longisetosus* is a typical aquatic species, which lives in water-saturated conditions at the edge of *Sphagnum* mats along the shore.

6.14. ***Hydrozetes octosetosus*** Willmann, 1932

Hydrozetes lacustris octosetosus Willmann, 1932: Peus 1932; Willmann 1933; Newell 1945; Buitendijk 1945; Grandjean 1948; Strenzke 1952; Fernandez & Travé 1984; Subías 2004.
Hydrozetes octosetosus: Piffl 1967, 1978; Schatz 1983; Mahunka 1990; Seniczak et al. 2007, 2009c.
Hydrozetes lacustris (Michael, 1882): Deichsel 2004; Weigmann 2006.

Distribution: Boreal (Subías 2004). In Poland it has been found in Tuchola Forest, Pomerania (Seniczak et al. 2007; Seniczak 2011a, b), Wielkopolska province (Seniczak 2011b) and Brodnica Lakeland (in this paper).

Ecology and biology

Hydrozetes octosetosus (Figs. 43 and 59) is a limnic species that lives submerged (Schatz 1983) in *Sphagnum* at the edges of lakes and ponds (Willmann 1932; Seniczak et al. 2007; Seniczak 2011a). In this study in the ecotone between the water's edge of lake M and bog, it was most abundant at water's edge of the lake, but also occurred in small numbers 1 m and 5 m from it. It is parthenogenetic and reproduces by thelytoky (Seniczak et al. 2009c).

Willmann (1932) first proposed it as a subspecies, differentiated from *H. lacustris* sensu stricto by the setation of nymphs found at the edge of two ponds in a bog in Altvatergebirge, in Eastern Sudetes (Czech Republic). He wrote that the adults were difficult to distinguish, so when no nymphs were present in the sample, it was impossible to notice this subspecies (Willmann 1933).

Many authors have overlooked *H. octosetosus* in ecological investigations, and since Willmann (1932) it has not been recorded in Europe, until it was found in Poland, in Tuchola Forest, at the shores of: Lake Wielkie Gacno, Lake Martwe (Seniczak et al. 2007) and a pond in 'Jeziorka Kozie' reserve (Seniczak 2011a). It was also found in Norway, at Fløyen Mt. and Ulriken Mt. near Bergen (Seniczak et al. 2007, 2010) where it occurred with *H. lacustris*, which was sometimes more and sometimes less abundant (Seniczak et al. 2007, 2010). In Poland it was present with *H. longisetosus* and *H. lacustris* (Seniczak et al. 2007b, Seniczak 2011a). In an earlier paper concerning Lake Martwe, *H. octosetosus* was determined as *Hydrozetes* 1 (Seniczak et al. 2006a).

In the present study *H. octosetosus* occurred in almost all lakes and ponds, but its density was usually low. Only at pond D1 and lake M it occurred more abundantly, being the most numerous *Hydrozetes* species there. It was most abundant in spring (M) and summer (D1), and least abundant in autumn. Usually it was found together with *H. longisetosus* and *H. lacustris* (L, D2, D3, D4, M, K1, K2 and K3), at pond D1 and lake O additionally with *H. lemnae*, at pond D2 with *H. confervae* and at BC together with *H. lacustris* and *H. lemnae*. Juveniles were present in all seasons, but had the highest proportion in autumn.

6.15. *Hydrozetes thienemanni* Strenzke, 1943

Hydrozetes thienemanni Strenzke, 1943: Grandjean 1949; Strenzke 1952; Haarlov 1957; Klima 1958; Piffl 1967, 1978; Sitnikova 1975a; Walgram 1976; Gjelstrup & Solhøy 1994; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Niedbała & Olszanowski 2008; Seniczak & Seniczak 2008a; Akrami & Dinipour 2009; Seniczak et al. 2009c.
Hydrozetes incisus Grandjean, 1948.
Heloribates thienemanni: Grandjean 1966; Schatz 1983.
Hydrozetes Heloribates thienemanni: Fernandez 1984; Fernandez & Travé 1984.

Distribution: Holarctic (Weigmann 2006) or Boreal (Subías 2004). In Poland it has been reported from the northern part of the country: Pomerania Lake district (*locus typicus*), Białowieża Primeval Forest (see Olszanowski et al. 1996 for further references), in the Lower Oder Valley (Weigmann 1997a); Tuchola Forest in Pomerania (Seniczak & Seniczak 2008a); and from southern Poland (Żbikowska-Zdun et al. 2006).

Ecology and biology

Hydrozetes thienemanni (Figs. 47, 61, 83 and 84) is found in lakes, ponds, in standing and slowly flowing water, mainly on submergent vegetation, but also on detritus (Schatz 1983; Weigmann & Deichsel 2006). It was also reported from the waterlogged organic matter and proper soil of reedy thickets, alder wood, eutrophic fens (Strenzke 1943, 1952; Rajski 1968; Żbikowska-Zdun et al. 2006), *Carex* bogs (Gjelstrup & Solhøy 1994) and flooded meadows (Weigmann 1997a, 2006). Rajski (1968) considered it hygrophilous. According to Strenzke (1952) its ecology is similar to that of *H. lemnae*, but reproduces bisexually (Weigmann & Deichsel 2006).

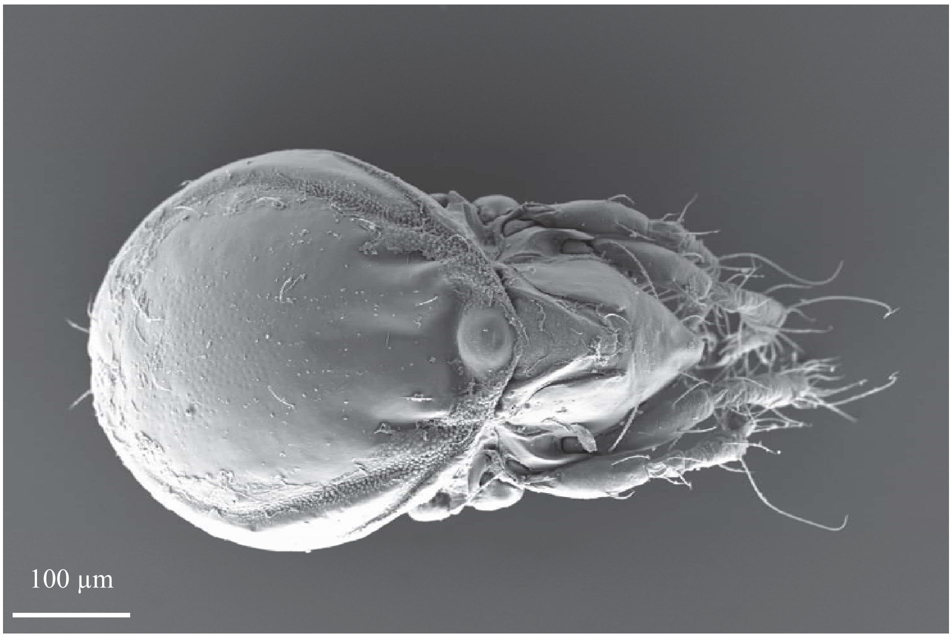


Fig. 83. *Hydrozetes thienemanni*, adult, dorsal aspect
Rys. 83. *Hydrozetes thienemanni*, dorosły, strona grzbietowa

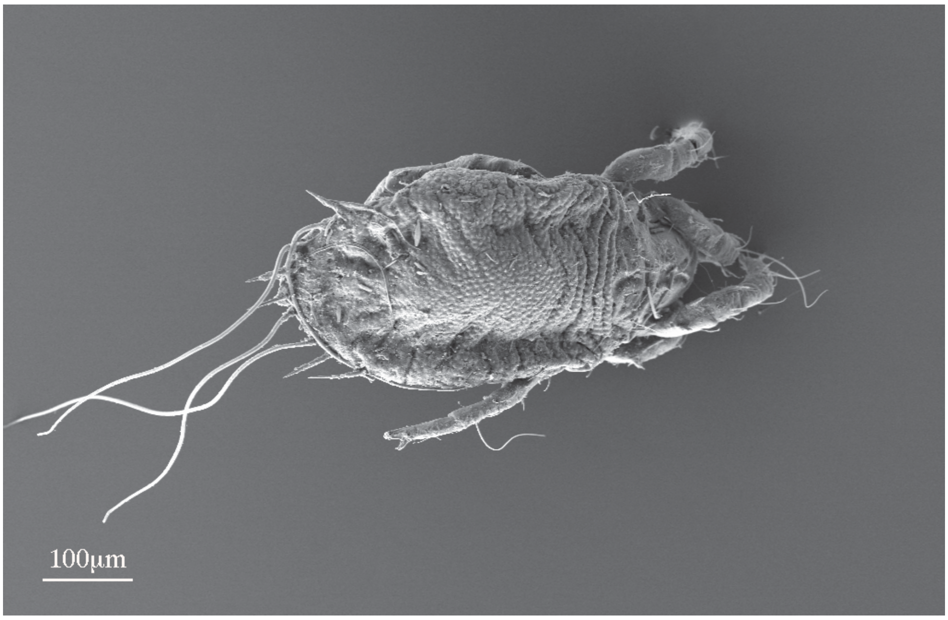


Fig. 84. *Hydrozetes thienemanni*, nymph, dorsal aspect
Rys. 84. *Hydrozetes thienemanni*, nimfa, strona grzbietowa

In this investigation it was present only at the shores of three ponds (P1, P2 and P3) with neutral pH. It was especially abundant at ponds P2 and P1, being the most abundant or the second most abundant oribatid species. Adults predominated, comprising on average 80% of the samples. In the ecotone between the water's edge of lake M and bog it occurred 3 m and 5 m from the edge, but in low density.

6.16. *Limnozetes ciliatus* (Schrank, 1803)

Acarus ciliatus Schrank, 1803.
Oribata sphagni Michael, 1884: Nordenskiöld 1901; Trägårdh 1910; Schweizer 1922; Beier 1928.
Notaspis sphagni: Sellnick 1908.
Sphagnozetes sphagni: Harnisch 1926.
Limnozetes sphagni: Sellnick 1928, 1929; Willmann 1929; Peus 1932; Grandjean 1951; Hammen 1952; Knülle 1957c; Tarras-Wahlberg 1961; Pérez-Íñigo 1972; Sitnikova 1975b; Druk 1982; Markkula 1986a, b; Starý 1988, 2006; Olszanowski et al. 1996; Pérez-Íñigo 1997; Niedbała & Olszanowski 2008.
Limnozetes ciliatus: Willmann 1931, 1932, 1943; Strenzke 1952; Sellnick 1960; Popp 1962; Behan-Pelletier 1989; Borcard 1991a, c; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Kuriki 2008; Niedbała & Olszanowski 2008; Seniczak & Seniczak 2009b.
Sphaerozetes sphagni: Peus 1932.

Distribution: Holarctic (Subías 2004; Weigmann 2006). This species has been noted from several localities in different parts of Poland (Olszanowski et al. 1996; Seniczak et al. 2005a, b, 2006a, b, c, d; Seniczak 2011a; Seniczak & Seniczak 2010).

Ecology and biology

Limnozetes ciliatus (Figs. 40, 56, 85 and 86) is the most common and widely distributed representative of the genus. It was found near ponds and in floating *Sphagnum* in bogs (Behan-Pelletier 1989; Borcard 1991a, 1997; Weigmann 2006; Weigmann & Deichsel 2006) often being one of the most abundant oribatids (Behan-Pelletier & Hill 1983; Behan-Pelletier & Bisset 1994; Donaldson 1996; Seniczak et al. 2005a, b, 2006a, c, d, 2010; Kuriki 2008; Seniczak 2011a). In Holstein, Strenzke (1952) distinguished the '*Limnozetes ciliatus* community' that occupied floating and submerged *Sphagnum*; a similar community was described in northern Germany (Knülle 1957b), southern Germany (Popp 1962), in the Austrian Alps (Klima 1958) and in Poland near Poznań (Rajski 1961). It was classified by Tarras-Wahlberg (1961) as associated with the hygrophilous hemiedaphon, i.e. water-dwelling, living at small variations of temperature, strong light, in free water. This species is dominant in several peatlands in Japan (Yoshida & Kuriki 1977; Aoki 1995; Kuriki 1995) where it was considered hygrophilous (Kuriki & Yoshida 1999).

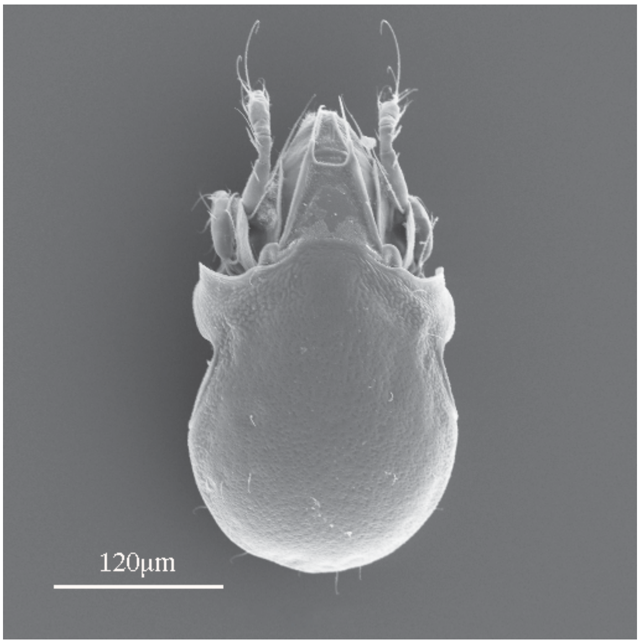


Fig. 85. *Limnozetes ciliatus*, adult, dorsal aspect
Rys. 85. *Limnozetes ciliatus*, dorosły, strona grzbietowa

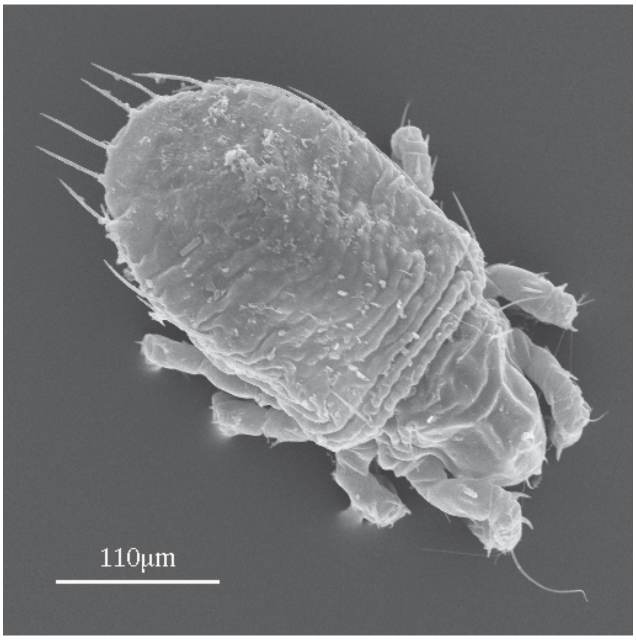


Fig. 86. *Limnozetes ciliatus*, nymph, dorsal aspect
Rys. 86. *Limnozetes ciliatus*, nimfa, strona grzbietowa

Acidity is essential for the presence of *Limnozetes* and it was found in three domed bogs in eastern Canada with pH 4.20-4.70 (Behan-Pelletier & Bisset 1994). In the studies of Donaldson (1996) at Spruce Hole Bog, New Hampshire, USA, *L. ciliatus* preferred the drier and more acid parts of the studied gradient, being most abundant on magellanic bog-moss, and relatively abundant on flat-topped bog-moss, while it was absent from feathery bog-moss. It was also found in willow moss, both in Swedish Lapland (Willmann 1943) and in the Alps, 2300 m a.s.l. (Schweizer 1956). Eitminavičiūtė (1973) reported this species from agricultural soils, but at low densities. It was reported in fossil samples from Holocene lake sediments in Norway, at Kråkenes (Solhøy & Solhøy 2000) and Trettetjørn (De la Riva-Caballero 2003; Larsen et al. 2006; De la Riva-Caballero et al. 2010).

Behan-Pelletier & Hill (1983) first described the feeding habits of *L. ciliatus*. It is a panphytophage and feeds primarily on fungi, but its diet varied depending on the season. Between February and May the mites increased their ingestion of fungal spores, and between February and June they consumed less old, dead plant material; in June they fed mainly on conifer pollen, which comprised 55-87% of their gut content (Behan-Pelletier & Hill 1983). Often, *L. ciliatus* was prey of odonate naiads, comprising 17% of Oribatida found in their guts (Behan-Pelletier & Bisset 1994).

Like all *Limnozetes*, it is parthenogenetic (Behan-Pelletier & Bisset 1994; Weigmann & Deichsel 2006). Under laboratory conditions its metabolism and fecundity were all highest at 25°C. However, its development was fastest at 20°C (77.8 days), longer at 25°C (93.6 days) and the longest at 15°C (142.2 days) (Kuriki 2008). Adults collected from the field showed seasonal differences in fecundity, which was highest in summer and lowest in autumn (Kuriki 2008). Popp (1962) studied the temperature-dependent diurnal migrations of *L. ciliatus* and concluded that temperature does not influence the migrations of this species, so he considered it eurythermic.

In present study *L. ciliatus* had the highest mean density and high dominance index at pond K1. It was usually most abundant in autumn and spring, and least abundant in summer, which is consistent with the findings of Donaldson (1996) and Kuriki (2008). *Limnozetes ciliatus* is an aquatic species. It was the most abundant 1 m from the edge of lake M, while at the water's edge, where it was present together with *L. foveolatus*; its abundance was lower than that of the latter species. In lakes and ponds that lack *L. foveolatus*, *L. ciliatus* was abundant at the water's edge (e.g. Strenzke 1952; Knülle 1957b; Rajski 1961; Borcard 1997; Seniczak et al. 2006a), which suggests that competition may keep *L. ciliatus* density low when they co-occur. It seems to have wider tolerance towards moisture than *L. foveolatus*.

6.17. *Limnozetes foveolatus* Willmann, 1939

Limnozetes ciliatus foveolatus Willmann, 1939: Tarras-Wahlberg 1952, 1961; Rajski 1961, 1968; Olszanowski et al. 1996; Niedbała & Olszanowski 2008.
Limnozetes sphagni foveolatus: Knülle 1957a.
Limnozetes palmerae Behan-Pelletier, 1989: Behan-Pelletier & Bisset 1994; Donaldson 1996; Seniczak et al. 2006a; Seniczak & Seniczak 2009b; Behan-Pelletier 2010; Seniczak & Seniczak 2010.
Limnozetes foveolatus: Siepel & De Ruiter-Dijkman 1993; Siepel 1994; Siepel et al. 2009; Seniczak 2011a.
Limnozetes ciliatus: Subías 2004; Weigmann 2006.

Distribution: Europe [Germany (Willmann 1939; Knülle 1957a); Sweden (Tarras-Wahlberg 1952, 1961); Poland (Rajski 1961, 1968, 1970; Olszanowski et al. 1996; Seniczak et al. 2006a; Seniczak & Seniczak 2009b; Seniczak 2011a); the Netherlands (Siepel et al. 2009)], North America [USA (Behan-Pelletier 1989; Donaldson 1996), Canada (Behan-Pelletier 1989; Behan-Pelletier & Bisset 1994; Behan-Pelletier 2010)].

Ecology and biology

Limnozetes foveolatus (Figs. 39, 55, 87 and 88) was first found in floating *Sphagnum* in a bog in Zieleniec, near Duszniki in Western Sudetes (present Poland), and was described rather briefly, and without drawing, as a subspecies of *L. ciliatus* (Willmann 1939).

Fig. 87. *Limnozetes foveolatus*, adult, dorsal aspect
Rys. 87. *Limnozetes foveolatus*, dorosły, strona grzbietowa

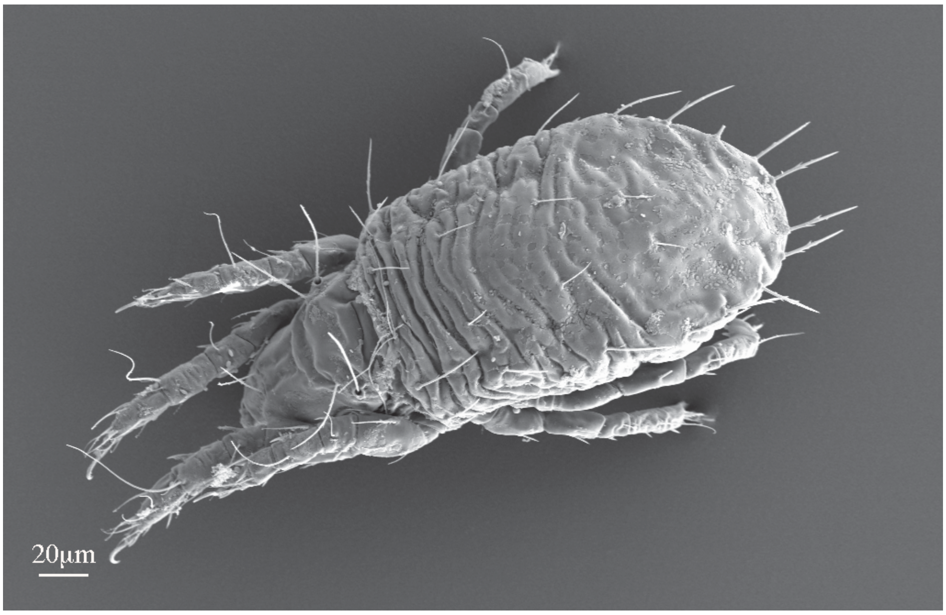


Fig. 88. *Limnozetes foveolatus*, nymph, dorsal aspect
Rys. 88. *Limnozetes foveolatus*, nimfa, strona grzbietowa

It has been reported only from a few countries (see above), but is probably widely distributed in Europe (e.g. in Scotland, my unpublished observations), and has been also found (as *L. palmerae* Behan-Pelletier, 1989) in North America (Behan-Pelletier 1989; Behan-Pelletier & Bisset 1994; Donaldson 1996). The first drawing of the adult was published by Tarras-Wahlberg (1952), who suggested that it is a species distinct from *L. ciliatus*; this judgment was followed by Siepel & De Ruiter-Dijkman (1993) and Siepel et al. (2009), but not by Rajski (1961, 1968), Olszanowski et al. (1996), Subías (2004) and Niedbała & Olszanowski (2008). Later, precise and detailed description and illustrations of the adult and the tritonymph were presented by Behan-Pelletier (1989), and those of larva and protonymph by Seniczak & Seniczak (2009b) – in both cases as *L. palmerae*. Siepel et al. (2009) recently considered *L. palmerae* as a junior synonym of *L. foveolatus*.

Limnozetes foveolatus is found in bogs, bog ponds and pools, in dripping-wet *Sphagnum* and litter by ponds (Behan-Pelletier 1989), always together with either *L. ciliatus* (Willmann 1939; Tarras-Wahlberg 1952; Donaldson 1996; Seniczak et al. 2006a; Seniczak 2011a) or with *L. lustrum* (in present paper). It occurred in domed bogs with low pH (4.20-4.70) in Canada (Behan-Pelletier & Bisset 1994) and was the most numerous oribatid species at Spruce Hole Bog, New Hampshire, USA where it preferred the moistest parts of the studied gradient and was especially abundant on feathery bog-moss and flat-topped bog-moss (Donaldson 1996). It was also very abundant at the edge of the *Sphagnum* mat of Lake Martwe (Seniczak et al. 2006a) and a pond in 'Jeziorka Kozie' reserve, in Tuchola Forest, Pomerania, Poland (Seniczak 2011a).

Limnozetes foveolatus is the smallest species of *Limnozetes* (length 266--292 µm) (Behan-Pelletier 1989; Seniczak & Seniczak 2009b). Donaldson (1996) concluded that small size might be an advantage for an oribatid mite as it can find more habitable spaces to feed or avoid predators (Walter & Norton 1984). It probably feeds on fungi; the adults graze on all surfaces of *Sphagnum* moss, while the juveniles prefer the inner surface of the *Sphagnum* 'leaf' (Behan-Pelletier & Bisset 1994). Siepel & De Ruiter-Dijkman (1993) and Siepel (1994) classified *L. foveolatus* as an opportunistic herbofungivore, which is able to digest cellulose in cell walls of living green plants and trehalose in fungi, potentially feeding on blue-green algae. It is prey of odonate naiads, but less frequently than other species of *Limnozetes*; for example, it comprised only 6% of the Oribatida found in the guts of odonate naiads, compared to 30% for *L. latilamellatus* Behan-Pelletier, 1989 (Behan-Pelletier & Bisset 1994). It reproduces parthenogenetically (Behan-Pelletier & Bisset 1994).

In the present study *L. foveolatus* was the most abundant oribatid species at most lakes and ponds. The highest mean abundance and dominance indices were at pond D2 in summer (A = 284.9, D = 93.5), while the constancy index at all lakes and ponds and in all seasons was 100. It was absent only from ponds P2 and P3, while at P1 and KG it was rare. The highest abundance was either in summer or autumn and the lowest was always in spring. In contrast, Donaldson

(1996) noted the highest density of *L. foveolatus* in early spring and the lowest in late summer.

The species clearly prefers water-saturated substrate (Behan-Pelletier 1989; Behan-Pelletier & Bisset 1994; Donaldson 1996), as the highest number of individuals inhabited the margin of the *Sphagnum* mat. At a distance 1 m from this margin the density was more than 50-fold lower, and decreased further in more distant plots.

6.18. *Limnozetes guyi* Behan-Pelletier, 1989

Distribution: North America: Canada (Behan-Pelletier 1989; Behan-Pelletier & Bisset 1994; Behan-Pelletier 2010), Greenland (Presthus-Heggen et al. 2010) and in present paper is the first record from Europe: Pomerania, Poland.

Ecology

Limnozetes guyi was first found in *Sphagnum* mosses, sedges and *Drosera* in a reticulated bog (Québec, Parc Fontenac), and then at the other sites in Canada (New Brunswick and Newfoundland), from wet habitats such as *Sphagnum* and litter by a pond, submerged tree or grass clumps in muskeg (Behan-Pelletier 1989). In the Avlon bog in Newfoundland, which was a domed bog with pH 4.20-4.60, it was present together with *L. ciliatus*, *L. foveolatus*, *L. atmetos* Behan-Pelletier, 1989, *L. borealis* Behan-Pelletier, 1989 and *L. latilamellatus* (Behan-Pelletier & Bisset 1994). *Limnozetes guyi* was found in the guts of dipteran larvae that were eaten in turn by odonate naiads. It comprised 5% of all Oribatida present in the guts of three odonate species (Behan-Pelletier & Bisset 1994).

This species was found from Holocene sediments in Greenland, where it was the most abundant oribatid in the period 6500-3850 ^{14}C years BP, when water had medium-high conductivity. With continuing oligotrophication, combined with gradual climate cooling from 4000 ^{14}C years BP, its abundance was slowly decreasing (Presthus-Heggen et al. 2010).

In Poland the adults of this species were found in *Sphagnum* at the shore of lake L. It was present in low numbers in all seasons, being the least abundant species among *Limnozetes*. The highest number was collected in spring (18 individuals, D = 0.21, C = 50), while in summer and autumn only 4-5 individuals were found and its dominance and constancy indices were very low (respectively, D = 0.07, C = 30 and D = 0.05, C = 20).

6.19. *Limnozetes lustrum* Behan-Pelletier, 1989

Distribution: North America: USA (Behan-Pelletier 1989; Donaldson 1996), Canada (Behan-Pelletier 1989; Behan-Pelletier & Bisset 1994; Behan-Pelletier 2010). Europe: in Poland it has been recorded from Pomerania and Wielkopolska province (Seniczak & Seniczak 2010) and Brodnica Lakeland (in present paper), it was also found in Norway (Seniczak et al. 2011a).

Ecology

Limnozetes lustrum (Figs. 41, 57, 89 and 90) was first collected in Canada (Ontario, Ottawa, National Capital Region, Mer Bleue) from a wet pocket of *Sphagnum* moss in an otherwise dry bog (Behan-Pelletier 1989). It was also found at other sites in Canada (New Brunswick, Québec and Newfoundland), and in the USA (New York), from wet *Sphagnum* and pond-side litter (Behan-Pelletier 1989). It occurred in domed and kettle bogs in Canada (Ontario and Québec), at pH 4.40-4.70 (Behan-Pelletier & Bisset 1994). *Limnozetes lustrum* was also found at Spruce Hole Bog near Durham, Strafford Co., New Hampshire, USA (Donaldson 1996). It was most abundant in the middle of the moisture gradient, on flat-topped bog-moss, but was also present in the moistest part, on feathery bog-moss, with maximum abundance in the early summer (Donaldson 1996). Only adults have been described from North America. *Limnozetes lustrum* was present in Holocene sediments in west Greenland, where it was found together with *L. guyi*, but in lower numbers than the latter species. The highest number of *L. lustrum* was noted in the period of more advanced lake succession and mire expansion, 3850-1750 ^{14}C years BP (Presthus-Heggen et al. 2010).

In Poland it was abundant and represented by all developmental stages at the edge of peat pond (BC), in ‘Bagno Chlebowo’ reserve in Wielkopolska province (Seniczak & Seniczak 2010). It was also abundant at pond K1 in ‘Jeziorka Kozie’ reserve in Tuchola Forest and occurred at lower densities in other lakes and ponds in Tuchola Forest (L, D1, D2, M, K2, K3) and Brodnica Lakeland (O). As in the populations studied by Donaldson (1996), it was usually most abundant in summer and the least abundant in spring. *Limnozetes lustrum* was also found on twisted bog-moss (*Sphagnum contortum* Schultz) in eutrophic habitat in Western Norway, where it was most abundant oribatid species and in summer 30% of this species were juveniles (Seniczak et al. 2011a). It is an aquatic species, present only at the edge of lake M and absent in further plots, which suggests its preference for water-saturated substrate, consistent with observations of Donaldson (1996).

6.20. *Limnozetes rugosus* (Sellnick, 1923)

Ceratozetes rugosus Sellnick, 1923: Harnisch 1926; Sellnick 1926, 1928, 1929.
Limnozetes rugosus: Willmann 1931; Hammen 1952; Sellnick 1955, 1960; Haarlov 1957; Knülle 1957a, c; Popp 1962; Sitnikova 1975b; Borcard 1994b; Olszanowski et al. 1996; Kuriki & Yoshida 1999; Subías 2004; Weigmann 2006; Weigmann & Deichsel 2006; Niedbała & Olszanowski 2008; Seniczak & Seniczak 2010.

Distribution: Palearctic (Subías 2004; Weigmann 2006), it has been recorded from western Poland (Olszanowski et al. 1996); it is also common in northern Poland as reported in present paper.

Fig. 89. *Limnozetes lustrum*, adult, lateral aspect
Rys. 89. *Limnozetes lustrum*, dorosły, widok z boku

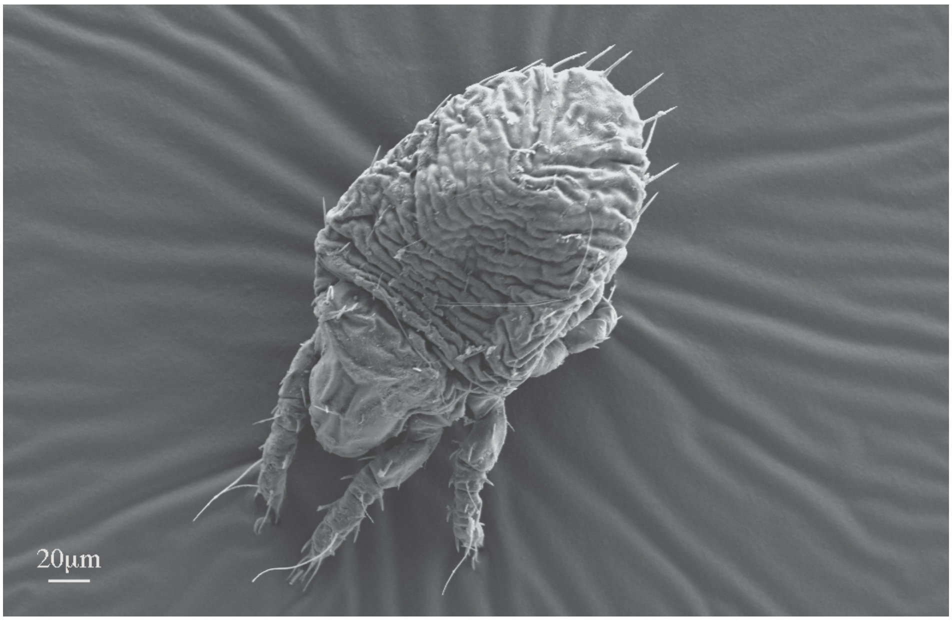


Fig. 90. *Limnozetes lustrum*, nymph, dorsal aspect
Rys. 90. *Limnozetes lustrum*, nimfa, strona grzbietowa

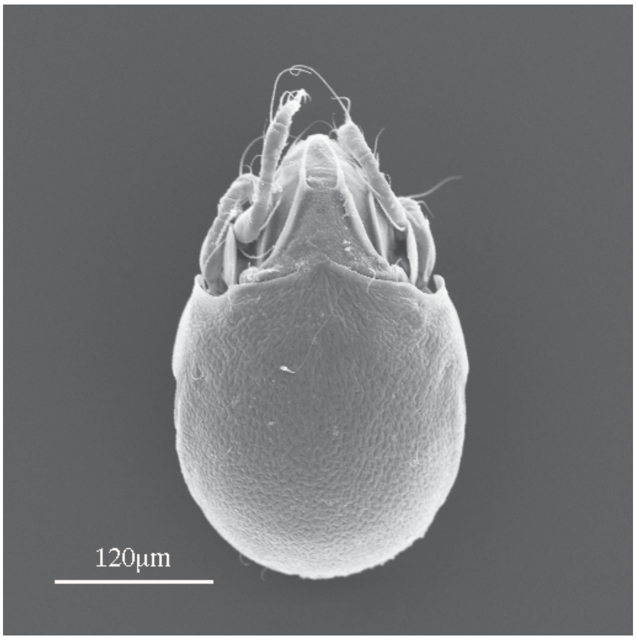


Fig. 91. *Limnozetes rugosus*, adult, dorsal aspect
Rys. 91. *Limnozetes rugosus*, dorosły, strona grzbietowa

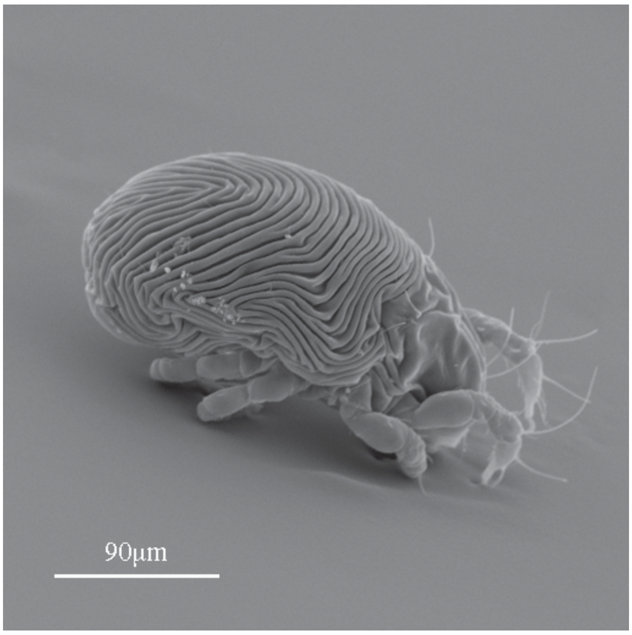


Fig. 92. *Limnozetes rugosus*, nymph, lateral aspect
Rys. 92. *Limnozetes rugosus*, nimfa, widok z boku

Ecology and biology

Limnozetes rugosus (Figs. 38, 54, 91 and 92) was described by Sellnick (1923) on the basis of a single specimen found alive in *Sphagnum* in Western Sudetes, in Zieleniec near Duszniki, present Poland, and from other individuals found later in Zehlaubruch (East Prussia). Willmann (1931) reassigned this species to *Limnozetes* and later described its juveniles (Willmann 1932). With its well-preserved, strong cuticular skeleton, *Limnozetes rugosus* has been found in fossil samples, in Europe in association with *Hydrozetes lacustris* (Willmann 1931; Solhøy & Solhøy 2000) or *Limnozetes ciliatus* (De la Riva-Caballero 2003; Larsen et al. 2006; De la Riva-Caballero et al. 2010) and in North America with *Hydrozetes oryktosis* Woolley (1969) (Erickson 1988).

Limnozetes rugosus lives in floating *Sphagnum* in bogs and in submergent vegetation in oligotrophic lakes (Weigmann 2006; Weigmann & Deichsel 2006). It was found in the eastern Alps (Glockner), 1400-1500 m a.s.l. (Sellnick 1960) and in very moist *Sphagnum*, always together with *L. ciliatus* (= *L. sphagni*) (Hammen 1952). According to Knülle (1957c), it occurs almost exclusively in wet bog *Sphagnum* mosses. Popp (1962) described the '*Limnozetes ciliatus* and *rugosus* community', which inhabits the wettest parts of *Sphagnum* hummocks with low pH. This species prefers the most humid biotopes and submerged areas of the mountain bog Ozegahara in central Japan, where it was present only in the *Sphagnum* community (Kuriki & Yoshida 1999). The latter authors classified *L. rugosus* as an aquatic species, that was also confirmed in present study; in the ecotone between the water's edge of lake M and bog this species occurred only in the moistest part of the transect.

Limnozetes rugosus was the only *Limnozetes* species at the shore of a small pond in Finse, Norway, where its density was high (15,600 individuals m^{-2}) (Seniczak & Seniczak 2010). Its density was far lower (ca. 1,000 individuals m^{-2}) in the ponds at Fløyen, near Bergen, Norway (Seniczak et al. 2010), where this species was outnumbered by *L. ciliatus*. A similar density of *L. rugosus* was noted at the shore of pond K1 in the Tuchola Forest, where it was the least abundant *Limnozetes* species, after *L. foveolatus*, *L. ciliatus* and *L. lustrum* (Seniczak 2011a). It was also present, although at low density, at Lake Martwe (Seniczak et al. 2006a), but was absent from two lobelia lakes in the Tuchola Forest (Seniczak et al. 2005a, b, 2006a, b, c, d).

At the shore of pond K1 the abundance of this species was highest in spring and lowest in autumn (Seniczak 2011a). At the shore of D4 it had the highest dominance index, being most abundant in autumn and least abundant in summer. At most lakes and ponds the highest percentage of juveniles was in autumn and the average from all water bodies was 33%. Similarly, at the edge of a pond in Finse (Norway) in September the juveniles comprised a considerable part of the samples (36%; Seniczak & Seniczak 2010).

6.21. *Eupelops hygrophilus* (Knülle, 1954)

Pelops hygrophilus Knülle, 1954: Knülle 1957a.
Phenopelops hygrophilus: Rajski 1959, 1961, 1968; Sellnick 1960.
Eupelops hygrophilus: Rajski 1970; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Niedbała & Olszanowski 2008.

Distribution: Central Europe: Germany (Knülle 1954) and Poland, where it has been recorded from Wielkopolska-Kujawy Lowland (Rajski 1959, 1961, 1967a, 1968, 1970) and Pomerania (Seniczak 2011a).

Ecology

Eupelops hygrophilus (Figs. 93 and 94) is considered a hygrophilous species (Rajski 1968). Knülle (1954) found it at the shore of Lake Duemmer (Oldenburg County, Germany), where the fen began with ca. 8 m wide reed mannagrass [*Glyceria aquatica* (L.) Wahlenb.] zone, in water-saturated *Glyceria* raw humus that was ca. 20 cm thick (Knülle 1954, 1957a). It has been found in reeds at lakeshores (Weigmann 2006), in *Sphagnum* mosses (Rajski 1959, 1961, 1967a, 1968, 1970; Seniczak 2011a) and in constantly wet grassland (Knülle 1957a). However, Weigmann & Deichsel (2006) did not consider this species exclusively associated with, typical of, or even regularly associated with freshwater habitats.

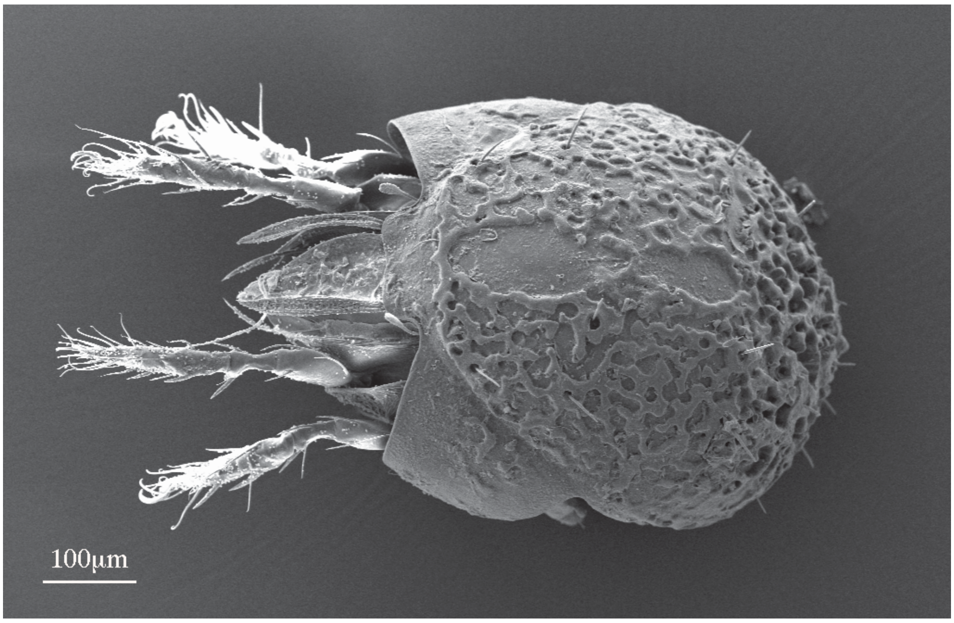


Fig. 93. *Eupelops hygrophilus*, adult, dorsolateral aspect
Rys. 93. *Eupelops hygrophilus*, dorosły, strona grzbietowo-boczna

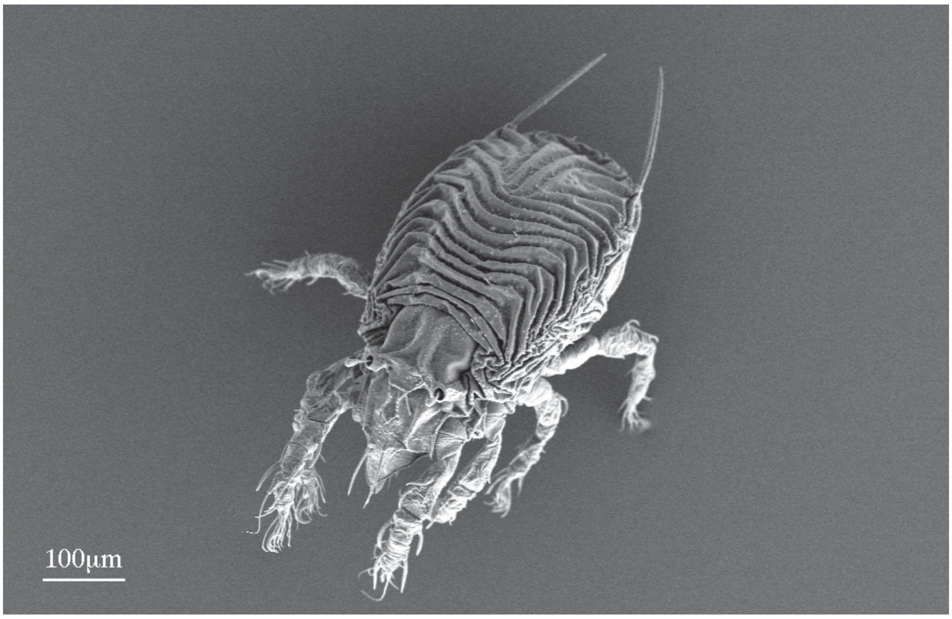


Fig. 94. *Eupelops hygrophilus*, nymph, frontolateral aspect
Rys. 94. *Eupelops hygrophilus*, nimfa, widok przednio-boczny

In Poland this species was first recorded from Lake Skrzynka in Wielkopolska National Park, where a single specimen was found in the upper layer (0-6 cm) of a *Sphagnum* mat (Rajski 1959, 1961, 1967a, 1968). This was the only record of *E. hygrophilus* in Poland (Olszanowski et al. 1996) until it was found at the edge of the pond in 'Jeziorka Kozie' reserve in Tuchola Forest, Pomerania (Seniczak 2011a).

Eupelops hygrophilus was present in relatively low abundance at the shores of all studied lakes and ponds in bogs in Tuchola Forest (L, D1, D2, D3, D4, M, K1, K2, K3), Brodnica Lakeland (O, S) and Wielkopolska province (BC), but was absent from ponds P1, P2, P3 and KG. The highest abundance was at pond D2, but it was most dominant at lake L. In this species the juveniles predominated, with the highest proportion (89%) in autumn and the lowest (54%) in summer. Overall, this species was present in about 50% of shore samples. In the ecotone between the water's edge of lake M and the bog, the density of *E. hygrophilus* increased with distance from the water's edge and was highest 5 m from it.

6.22. *Pilogalumna tenuiclava* (Berlese, 1908)

Oribates tenuiclavus Berlese, 1908: Berlese 1914; Beier 1928.
Galumna tenuiclavus: Oudemans 1917; Sellnick 1921, 1928, 1929, 1932; Willmann 1923, 1931; Peus 1932; Dalenius 1950; Tarras-Wahlberg 1952; Schweizer 1956; Karppinen 1972.

Oribata tenuiclavus: Schweizer 1922.
Galumna areolata Willmann, 1923: Sellnick 1924; Peus 1932.
Galumna radiata Willmann, 1923: Sellnick 1926; Harnisch 1926.
Galumna arenata Willmann, 1924: Krivolutskaja 1952.
Allogalumna tenuiclavus: Grandjean 1936; Willmann 1939, 1949, 1951, 1956; Hammen 1952; Strenzke 1952; Knülle 1957a, c; Klima 1958; Tarras-Wahlberg 1961.
Allogalumna boevi Krivolutskaja, 1952: Subías 2004.
Pilogalumna tenuiclavus: Grandjean 1956; Kunst 1957, 1958, 1959a; Sellnick 1960; Popp 1962; Starý 1988; Borcard 1991a; Pérez-Íñigo 1997.
Allogalumna atra Mihelčič, 1957b.
Allogalumna tenuiclava: Rajski 1961.
Allogalumna tenuiclaves: Piffl 1967, 1978.
Pilogalumna tenuiclava: Rajski 1968; Seniczak 1971/1972b; Shaldybina 1975a; Schatz 1983; Pérez-Íñigo 1993; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Seniczak & Seniczak 2007a; Niedbała & Olszanowski 2008.
Pilogalumna tenuiclaves: Siepel & De Ruiter-Dijkman 1993; Siepel 1994.
Pilogalumna boevi: Olszanowski et al. 1996; Niedbała & Olszanowski 2008.

Distribution: Holarctic (Subías 2004; Weigmann 2006). It has been recorded from many localities in different parts of Poland (see Olszanowski et al. 1996 for further references).

Ecology and biology

Pilogalumna tenuiclava (Figs. 33, 49, 95 and 96) is a hygrophilus species (Schatz 1983) with high humidity requirements. It is the most abundant in water-saturated mosses (Rajski 1968), especially in floating and submergent *Sphagnum* in raised bogs (Sellnick 1928, 1960; Willmann 1951), and therefore is considered a 'true bog animal' (Willmann 1928a; Peus 1932).

Sometimes it has been found in forests and meadows (Strenzke 1952; Knülle 1957a; Kunst 1958). In Bulgaria it was reported from wet *Sphagnum* in a forest bog 1600 m a.s.l. (Kunst 1957) and in the Alps from a high alpine zone 2400-2500 m a.s.l. (Willmann 1951). According to Strenzke (1952) and Rajski (1968) it is a characteristic species of the '*Limnozetes ciliatus* community', while Popp (1962) distinguished a '*Pilogalumna tenuiclavus* community' in the mixed *Sphagnum* hummocks. It tolerates wide pH range, and was found in mires and swamps with high calcium content and high pH (Willmann 1949). This species is considered a micro- or panphytophage by Schatz (1983) and a herbofungivorous grazer, i.e. able to digest green plants and fungi, by Siepel & De Ruiter-Dijkman (1993).

In this investigation *Pilogalumna tenuiclava* was found at the water's edge s of almost all lakes and ponds, both in neutral water reaction (P1 and P3) and acid pH, in Tuchola Forest (L, D1, D2, D3, D4, M, K1, K2, K3), Brodnica Lakeland (O, S), Wielkopolska province (BC) and Kashubian Lakeland (KG). It was most abundant at pond K1 and relatively abundant at P1, P3, L, K2 and K3.

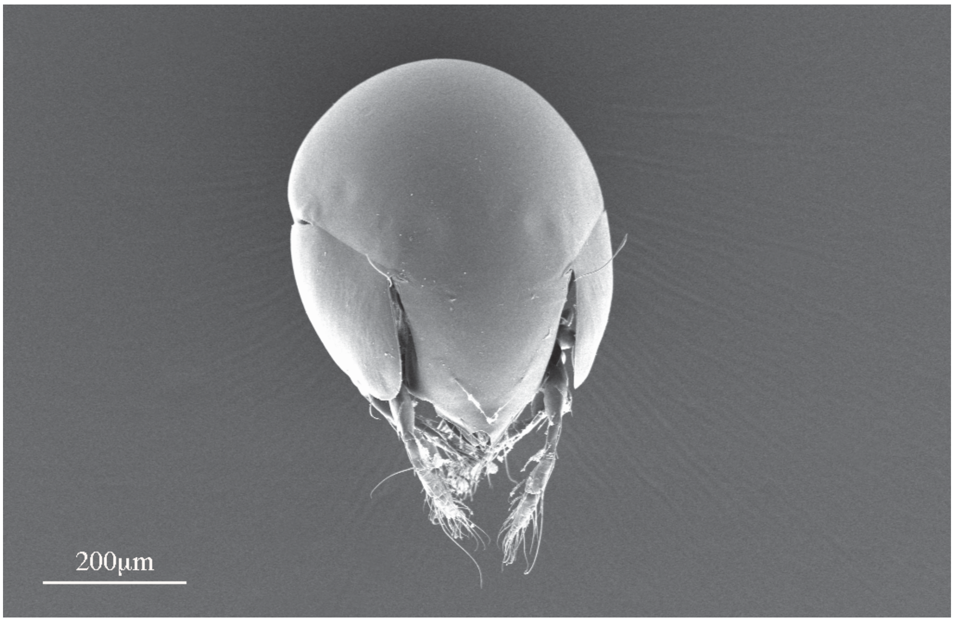


Fig. 95. *Pilogalumna tenuiclava*, adult, frontal aspect
Rys. 95. *Pilogalumna tenuiclava*, dorosły, widok z przodu

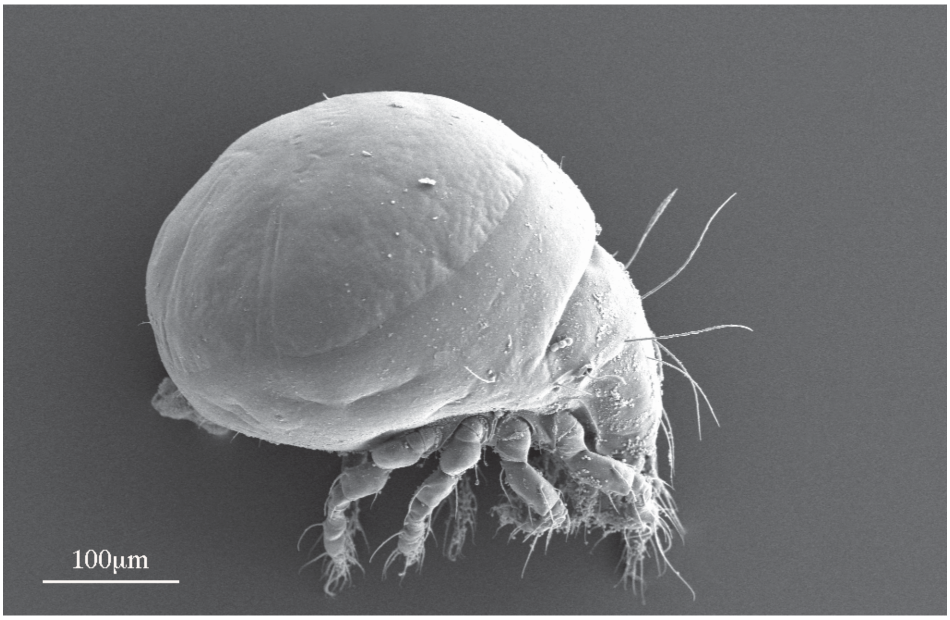


Fig. 96. *Pilogalumna tenuiclava*, nymph, lateral aspect
Rys. 96. *Pilogalumna tenuiclava*, nimfa, widok z boku

In the ecotone between the water's edge of lake M and bog, this species was least abundant at the water's edge and most abundant 1 m from it. Both the adults and juveniles were always most abundant in summer. The mean proportion of juveniles was highest in spring and decreased to autumn.

6.23. *Heterozetes palustris* (Willmann, 1917)

Ceratozetes (*Heterozetes*) *palustris* Willmann, 1917.
Heterozetes palustris: Sellnick 1928; Willmann 1931; Strenzke 1952; Piffl 1967; Shaldybina 1965, 1966, 1975c; Pérez-Íñigo 1993; Pavlichenko 1994; Subías 2004; Weigmann 2006.

Distribution: Palearctic (Subías 2004; Weigmann 2006); in Poland it has been reported from one locality, Koźle at Oder (Schubert 1934; Olszanowski et al. 1996); but it also occurs in Pomerania and Brodnica Lakeland (in this paper).

Ecology and biology

Heterozetes palustris (Figs. 97 and 98) is a limnic species (Strenzke 1952; Schatz 1983; Schatz & Behan-Pelletier 2008) and was first found in samples of Hydracarina (Willmann 1917). It lives in peatland pools on submerged plants (Sellnick 1928; Hammen 1952) and in reeds and fens (Weigmann & Deichsel 2006). It was observed moving on the water surface, like *Zetomimus furcatus* (Warburton & Pearce, 1905) (Willmann 1931). It is characteristic in aquatic mosses of eutrophic waters (Knülle 1957c), being associated with *Sphagnum* and acid conditions (Peus 1932; Weigmann & Deichsel 2006). Like *Zetomimus furcatus*, it is a typical member of the '*Gustavia fusifer*-*Liebstadia similis* community' in reeds, wet meadows and eutrophic fen woodlands (Strenzke 1952). In Spain it was noted in moist humus under forest litter and in flooded areas (Pérez-Íñigo 1993), while in southern Lithuania it occurred at low density in a dry biotope 125 m from a lake (Eitminavičiūtė 1966).

Heterozetes palustris occurred at the shore of L, D4 (Tuchola Forest) and S (Brodnica Lakeland), but in summer it was rather rare (C = 10). Abundance, dominance and constancy indices were higher only at lake L in spring (A = 0.77, D = 0.91, C = 90) and juveniles predominated, comprising 82% of the samples. This is consistent with Sidorchuk (2008), that this species is never abundant in raised bogs; according to her it is found more frequently and in larger numbers in valley fens.

Heterozetes palustris reproduces bisexually (Weigmann & Deichsel 2006). Its development was described by Shaldybina (1965), who collected adults in October from the area near Gorky and fed them in the laboratory with raw potatoes and half-decomposed leaves. After about a month the mites laid eggs and their total development lasted 42-60 days.

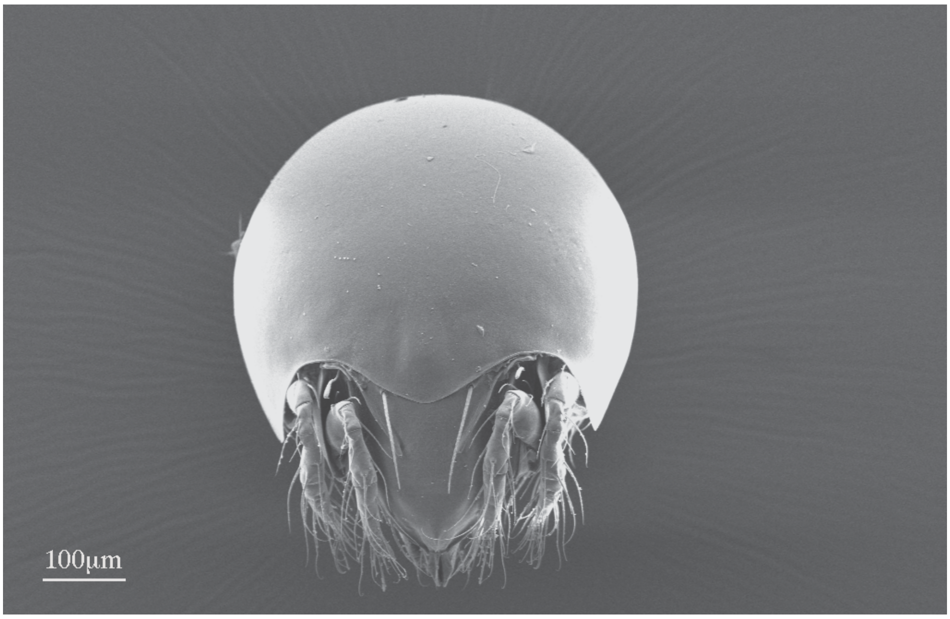


Fig. 97. *Heterozetes palustris*, adult, frontal aspect
Rys. 97. *Heterozetes palustris*, dorosły, widok z przodu

Fig. 98. *Heterozetes palustris*, nymph, lateral aspect
Rys. 98. *Heterozetes palustris*, nimfa, widok z boku

6.24. *Zetomimus furcatus* (Warburton & Pearce, 1905)

Oribata furcata Warburton & Pearce, 1905.
Ceratozetes magnificus Berlese, 1910b: Willmann 1925.
Zetomimus furcatus: Hull 1916; Balogh 1965; Shaldybina 1969, 1975c; Pavlichenko 1994; Weigmann 2006.
Ceratozetes furcatus: Sellnick 1928, 1960; Willmann 1931; Strenzke 1952; Schweizer 1956; Haarlov 1957; Knülle 1957a, c; Klima 1958; Balogh 1961; Eitminavičiūtė 1966; Piffl 1967, 1978; Weigmann 1991.
Ceratozetes argentinensis Hammer, 1958.

Distribution: Palearctic (Weigmann 2006), Palearctic occidental (less common in North) and Argentina (Subías 2004), Palearctic and Neotropic (Weigmann & Deichsel 2006), Holarctic (Olszanowski et al. 1996). In Poland it has been recorded only from Pomerania Lake district, northern part of the country (see Olszanowski et al. 1996 for further references), but occurs also in western Poland and Brodnica Lakeland (in present paper).

Ecology and biology

Zetomimus furcatus (Figs. 99 and 100) was first found in moss in Austwick Bog in Yorkshire, England (Warburton & Pearce, 1905). It is characteristic for aquatic mosses in eutrophic waters (Knülle 1957c); it likes *Sphagnum* and acid conditions (Peus 1932) and is considered aquatic (Erickson & Platt 2007; Schatz & Behan-Pelletier 2008). It lives in reeds, fens, wet meadows, and fen woodlands (Strenzke 1952; Schweizer 1956; Sellnick 1960; Weigmann 2006; Weigmann & Deichsel 2006). In northern Germany it was found in a fen in water-saturated *Glyceria* raw humus, 20 cm thick (Knülle 1957a). In contrast, Eitminavičiūtė (1966) found it only in a dry biotope, most distant (125 m) from the studied lake in southern Lithuania. Schweizer (1956) reported it from humus in a subalpine zone, at 1740 m a.s.l. in Switzerland. It was also found in pastures in Hungary and Romania and some authors (Balogh et al. 1965; Vasiliu et al. 1973) considered it to be an intermediate host of *Moniezia* species, while other authors (Kassai & Mahunka 1965) did not share this opinion. In Poland it has been reported only from Pomerania (Strenzke 1952; Seniczak et al. 2006a; Seniczak 2011a).

Willmann (1931) observed this species as very lively, the fastest oribatid he had ever observed. It is able to run on the surface of water, like *Heterozetes palustris*, and scale the walls of a glass vessel. It is an opportunistic herbo-fungivore (Siepel & De Ruiter-Dijkman 1993; Siepel 1994, 1996) so it can digest cellulose in litter and cell walls of living green plants and trehalose in fungi. Among studied Oribatida it had medium tolerance of food shortage (Siepel 1996). In laboratory conditions it was fed green moss, pieces of partly decomposed tree leaves, grasses and wood (Shaldybina 1969); larvae and nymphs fed mainly on the green moss.

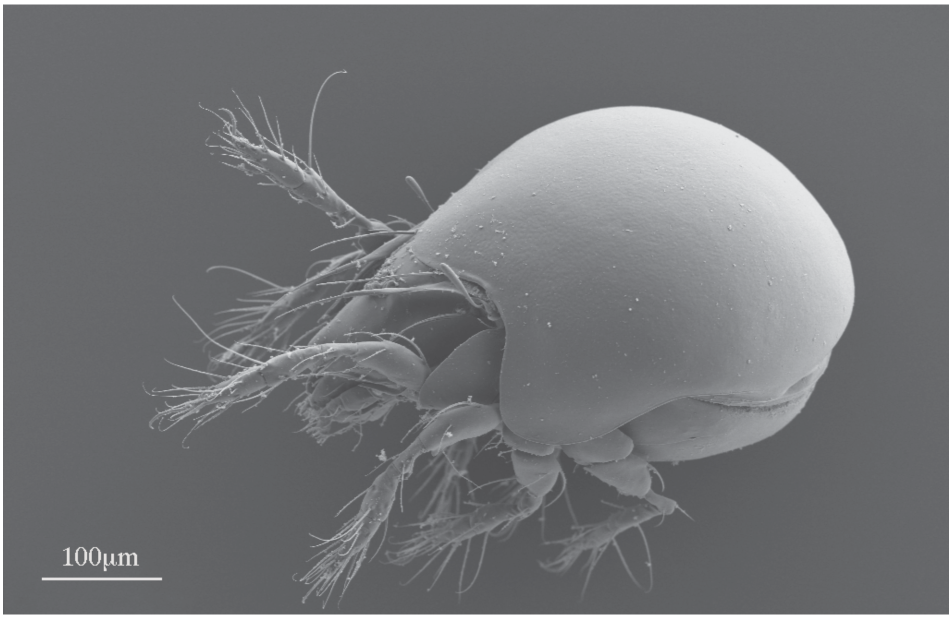


Fig. 99. *Zetomimus furcatus*, adult, lateral aspect
Rys. 99. *Zetomimus furcatus*, dorosły, widok z boku

Fig. 100. *Zetomimus furcatus*, nymph, dorsal aspect
Rys. 100. *Zetomimus furcatus*, nimfa, strona grzbietowa

Zetomimus furcatus is bisexual (Weigmann & Deichsel 2006). Shaldybina (1969) studied its development in the laboratory, starting her cultures from adults collected in June from moss cushions at the shore of Lake Gorkovskoje near Nizhniy Novgorod, Russia, where this species was abundant. After 4 days she observed spermatophore deposition and oviposition. At 18-20ºC the total development lasted 30-61 days, but when food was limited their development lasted much longer (135 days).

In the present study this species achieved highest abundance and was eudominant at the shore of peat pond BC in Wielkopolska province. It was also present, but in lower densities, at some acid lakes and ponds in bogs in Tuchola Forest (L, D3, M, K1, K2, K3) and Brodnica Lakeland (O) as well as at forest lakes with neutral pH (P2, P3). It had the highest abundance in spring or summer and the lowest in autumn. Juveniles were most abundant in spring, adults in summer. In spring juveniles predominated, comprising on average 60%, while in other seasons adults were more abundant; this indicates that reproduction is highest in spring.

6.25. *Punctoribates sellnicki* Willmann, 1928

Punctoribates sellnicki Willmann, 1928a: Willmann 1931; Schubert 1934; Hammen 1952; Sellnick 1960; Shaldybina 1975b; Schatz 1983; Borcard 1991a; Pérez-Íñigo 1993; Pavlichenko 1994; Olszanowski et al. 1996; Subías 2004; Weigmann 2006; Niedbała & Olszanowski 2008; Seniczak & Seniczak 2008b.
„*Punctoribates bicornis*“ Berlese, 1908 sensu Sellnick 1928.

Distribution: Europe (Subías 2004; Weigmann & Deichsel 2006), Palearctic (Weigmann 2006). It has been recorded from many localities in different parts of Poland (see Olszanowski et al. 1996 for further references).

Ecology

Punctoribates sellnicki (Figs. 37, 53, 101 and 102) is a hygrophilous to limnic species (Schatz 1983), which has been found mainly in bogs (Rajski 1968; Weigmann & Deichsel 2006). It was considered characteristic for the '*Limnozetes ciliatus* community' of floating and submerged *Sphagnum* (Strenzke 1952; Rajski 1968). It was also collected in wet meadows and reeds (Willmann 1931; Hammen 1952; Knülle 1957a; Weigmann 2006; Weigmann & Deichsel 2006), at a pond shore (Haarlov 1957) and in wine cultures in Moldavia (Stegaresku 1964). In Switzerland this species preferred a wet transitional zone between the bog and a pasture (Borcard & Ballmoos 1997). It was found in wet *Sphagnum* in a forest bog 1600 m a.s.l. (Kunst 1957).

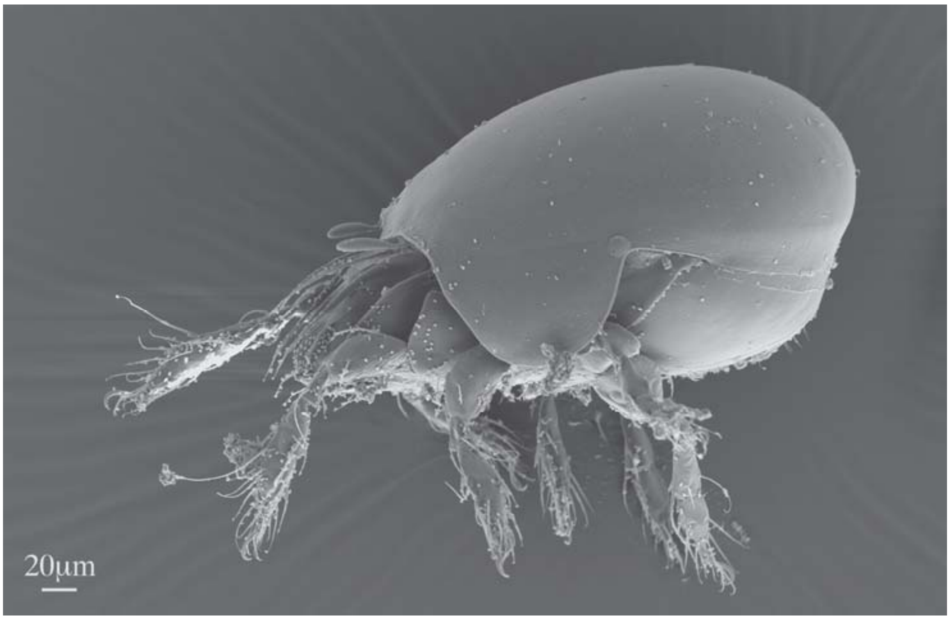


Fig. 101. *Punctoribates sellnicki*, adult, lateral aspect
Rys. 101. *Punctoribates sellnicki*, dorosły, widok z boku

Fig. 102. *Punctoribates sellnicki*, nymph, lateral aspect
Rys. 102. *Punctoribates sellnicki*, nimfa, widok z boku

In Poland *P. sellnicki* was present at the shores of all lakes and ponds, except P1, P2, P3 and KG, but usually at low densities. It was most abundant at pond K3 in spring, and relatively abundant at lake L. Its density was highest in spring and lowest in summer. The density of juveniles was highest in spring and slightly lower in summer. In the ecotone between the water's edge of lake M and bog, this species was most abundant at the water's edge, less abundant 1 m from it and absent from more distant plots, which agrees with the findings of Weigmann (1991), who noted *P. sellnicki* only in the wettest part of his studied transect.

7. DISCUSSION

7.1. WATER PARAMETERS

The shores of forest lakes and ponds create specific, waterlogged habitats for oribatid mites, and are inhabited by unique sets of species. These species are especially important in Scots pine monocultures, because they increase total forest biodiversity, which is important for the landscape. Dystrophic forest lakes and ponds, characteristic for treeless bogs, are especially interesting; their extreme physical and chemical properties of water (Hutorowicz 2004a) are real challenges for the organisms living there. These lakes and ponds are usually small, not exceeding several hectares (Hutorowicz 2004b), poor in nutrients and with a high content of humic substances (Hutorowicz 2004a). The main source of humic acids is water flowing from the surrounding floating mat. Particles of humic acids suspended in water bind calcium and other minerals, and their excessive amount gives an acid reaction and binds dissolved oxygen; also the brown coloration imparted by the particles limits light penetration (Hutorowicz 2004a). However, these lakes and ponds differ in pH, concentration of humic substances and biogenic compounds that depend mainly on the surrounding bog and floating mat, which constitutes together with open water one hydrological system (Hutorowicz 2004b). All these properties of water are important to aquatic and semi-aquatic oribatid mites.

One of the basic chemical properties of water is pH, which expresses the effective concentration (activity) of hydrogen ions (Hem 1970). The reaction of studied lakes and ponds situated in bogs varied from very acid (pond KG, in agreement with Ciechanowski et al. 2009) to almost neutral (lake L). A well-developed *Sphagnum* mat surrounds all these water bodies and many peat mosses are known to decrease water pH very effectively, even over a short period (Rydin & Jeglum 2006). The very low pH of pond KG could have been caused by bog drainage (Banaś & Gos 2004) and spruce planting (Zawał & Stępień 2007). In contrast, at forest ponds in Pruszcz Bagienica *Sphagnum* mosses were absent (P1) or created only small patches at the shores (P2 and P3) and water pH was high there (7.28-7.77).

The pH value is linked to the electrical conductivity of water, Ca content, and base richness. Electrical conductivity has been used for a long time to measure the total ionic concentration in natural waters and is still commonly used in wetland research. When the total ionic concentration of water increases, the electrical conductivity also increases (Rydin & Jeglum 2006). In many water bodies studied here (D1, D2, D3, D4, O and S) the conductivity of water was low, which is consistent with other studies at *Sphagnum*-covered bogs of natural quality (Banaś & Gos 2004). At other lakes and ponds conductivity was higher, either because of more advanced succession (L, K1, K2 and K3) as reported by Rusińska et al. (2009) or bog drainage (BC and KG) that leads to increase of conductivity, acidity and coloration of water (Banaś & Gos 2004).

The studied water bodies had low color values (15-40 mg Pt·dm^{-3}), except for BC and KG, where these values were higher (240 and 700 mg Pt·dm^{-3}, respectively), indicating higher content of humic substances there. The pond BC was created after peat mining, and brown color of water probably results from the presence of matter released during bog reclamation (Banaś & Gos 2004). The pond KG is polyhumus (Ciechanowski et al. 2009), because 'Kurze Grzędy' bog was subjected to drainage (Herbichowa et al. 2007). Water in pond KG is also very poor in oxygen, which results from high content of humic substances in water (Rydin & Jeglum 2006), and is consistent with Ciechanowski et al. (2009). Pond BC was also poor in oxygen, while in other studied lakes and ponds the content of oxygen was higher.

The concentration of sulphates and chlorides was generally low in studied lakes and ponds, as reported by Rusińska et al. (2009), and several-fold lower in comparison to a pond in the Botanical Garden in Bydgoszcz (Seniczak 2011b). Although both substances occur in nature, their main source is anthropogenic pollution (Hem 1970). However, the lakes and ponds studied here are located far from such sources and are protected to a certain degree by the forest.

The phosphorus content was very low in lakes and ponds in bogs and slightly higher in forest ponds near Pruszcz Bagienica. It is consistent with data of Rusińska et al. (2009), who observed low values of nutrients, including phosphorus, in plots with *Sphagnum*, and higher values in plots with dominant brown mosses. Under natural conditions phosphorus is only scantily represented in rainwater or dry deposition, and it requires continual weathering from bedrock and soil (Hem 1970). Because the peat surface is gradually cut off from the mineral soil, the total amount of P tends to be low in peatlands, and especially low in bogs (Rydin & Jeglum 2006).

Iron is widespread in rocks and soil, and concentrations of only a few tenths of a milligram per liter can make water unsuitable for some uses (Hem 1970). High iron concentrations in bogs also limit the density of soil fauna (Laiho et al. 2001). Therefore, information about this element is important, even if the amount of iron in most waters is small (Hem 1970). In the present studies the concentration of iron was high, which is characteristic for oligotrophic acidic lakes of Pomerania region (Gąbka et al. 2004). Of these various properties of water, only pH and nutrients have been studied for their influence on oribatid mites (Strenzke 1952; Rajski 1967a, b, 1968; Walgram 1976; Behan-Pelletier & Bisset 1994; Kehl 1997; Seniczak et al. 2006a).

7.2. THE MITES AT SHORES OF LAKES AND PONDS IN BOGS OF TUCHOLA FOREST

Oribatid mites are the most abundant and species-rich arthropods in bog ecosystems (Popp 1962; Belanger 1976; Rydin & Jeglum 2006), and the second most abundant invertebrates, after nematodes (Vilkamaa 1981). From an ecological aspect, especially valuable is the ecotone (contact zone between floating mat and open water), which is relatively poorly studied, and where occur specific algae, crustaceans, rotifers (Hutorowicz 2004b) and mites (Kaczmarek & Marquardt 2004; 2007a, b, 2008; Seniczak et al. 2005a, b, 2006a, b, c, d, 2007, 2010; Kaczmarek et al. 2006, 2008; Seniczak & Seniczak 2008a, b, 2010; Marquardt & Kaczmarek 2009; Seniczak 2011a, b). Peus (1932) and Belanger (1976) considered raised bogs, and in particular the *Sphagnum* mat, which is neither dry nor submerged, as the optimum biotope for oribatids. At studied shores of lakes and ponds in Tuchola Forest the mean abundance of Oribatida varied from 67,300 to 304,800 individuals m^{-2}, and they constituted 96.4-99.8% of all mites, which is consistent with earlier studies (Rajski 1961; Donaldson 1996; Seniczak et al. 2006a, 2010; Seniczak 2011a). Rajski (1961) observed at the shore of Lake Skrzynka in Wielkopolska province a high density (ca. 315,000 individuals m^{-2}) and a low species diversity (22 species) of Oribatida. At the shores of lakes and ponds in Tuchola Forest the number of oribatid species was similarly low (21-27 species), as was the Shannon index (*H*s = 0.45-1.66). To compare, in Scots pine stands in Tuchola Forest Seniczak et al. (2006d) found 35 species of oribatid mites and *H*s was 2.20, while in other forests over 100 species of these mites have been found (e.g. Niedbała 1980; Walter & Proctor 1999; Norton & Behan-Pelletier 2009). In our climate an important ecological factor for Oribatida is humidity, and most species prefer high or medium values (Rajski 1961; Niedbała 1980), while only few achieve high abundance in water-saturated substrates, like floating mats. Those species with a wide tolerance are usually less abundant (Borcard 1991a).

Other mite groups were not abundant at the studied lakes and ponds in Tuchola Forest. Second most numerous was the suborder Prostigmata, which contains the greatest number of aquatic species (Proctor 2009), and less abundant were Mesostigmata; this pattern is consistent with other studies in bogs (Belanger 1976; Markkula 1982; Kaczmarek & Marquardt 2004; 2007a, b, 2008; Kaczmarek et al. 2006, 2008; Marquardt 2007; Skorupski et al. 2008; Marquardt & Kaczmarek 2009). The density of mesostigmatid mites at water's edges of studied lakes and ponds was very low (300-900 individuals m^{-2}), while in the transitional bog 'Bagno Stawek' in Tuchola Forest it was higher (ca. 7,000 individuals m^{-2}, Marquardt 2007), but those study plots were located at some distance away from the marginal zone of the lake. The species diversity of Mesostigmata was low at this site, as these mites avoid high humidity. Only *Platyseius italicus* (Berlese, 1905), which is characteristic for peatlands and waterlogged habitats (Kaczmarek et al. 2006), highly dominated there (Marquardt 2007).

The total abundance of Oribatida at the shores of acid, dystrophic lakes in Tuchola Forest was dominated by *Limnozetes* species which require water-saturated conditions and pH = 4.20-4.70 (Behan-Pelletier & Bisset 1994). In this study *Limnozetes* was very abundant at lakes and ponds with acid reaction, as well as at lake L, which had pH 6.50. At all studied shores of water bodies in bogs the most abundant among Oribatida was *Limnozetes foveolatus*, with dominance 45.2-93.5%, and the second most abundant was usually *L. ciliatus*, which is consistent with earlier studies (Willmann 1939; Tarras-Wahlberg 1952; Donaldson 1996; Seniczak et al. 2006a; Seniczak 2011a). At some shores *L. lustrum* and *L. rugosus* also occurred, but were less abundant; while *Limnozetes* sp. 2 and *L. guyi* (here reported from Europe for the first time) were rare. At some shores the second most abundant among Oribatida was *Trimalaconothrus maior*, as mites from this genus are, like *Limnozetes*, associated with biotopes having fairly high acidity (Willmann 1933). *Trimalaconothrus foveolatus* was also found, but was usually less abundant.

Relatively abundant at all water bodies were *Trhypochthoniellus longisetus*, which is an aquatic species (Schatz & Behan-Pelletier 2008), and *Pilogalumna tenuiclava*, which usually had high constancy (C = 90-100) and in most cases a dominance above 1%. The shores of studied lakes and ponds also offered favorable conditions for the aquatic genus *Hydrozetes*, which was represented by five species, of which the most abundant was usually *H. longisetosus*, and the second most abundant, *H. octosetosus*. The ecology of these species is poorly known, as the former species was proposed only recently (Seniczak & Seniczak 2009a) and the systematic status of the second species has been unclear for a long time (Seniczak et al. 2007). Generally, these species were not abundant and lived in aggregations. *Hydrozetes lacustris* was even less numerous, despite its known preference for acid pH (Walgram 1976; Weigmann 2006; Weigmann & Deichsel 2006), while *H. lemnae* and *H. confervae* occurred singly. *Hydrozetes lemnae* lives mainly in eutrophic water bodies (Strenzke 1952), with neutral pH (Seniczak 2011b), which explains its low abundance at the studied shores. The ecological preferences of *H. confervae* are still unclear; it is abundant in eutrophic bogs (Druk 1982) and ponds (Seniczak et al. 2010), but also dominates in oligotrophic (Seniczak et al. 2007) and dystrophic ponds (Mistrzak et al. 2011).

7.3. THE MITES AT SHORES OF OTHER LAKES AND PONDS

Considering different geographic regions, the mite communities of the lakeshores in bogs in Brodnica Lakeland were similar to those described from bogs in Tuchola Forest. They were very abundant, but with low species diversity, and had species structure similar to those in Tuchola Forest. In contrast, at the shores of other ponds (P1, P2, P3, BC and KG) the abundance of mites was lower and species richness of Oribatida usually higher than in Tuchola Forest. The lowest abundance of mites was observed at the shore of pond P1, where the proportion of Oribatida was lowest (90%) and that of Mesostigmata was highest (almost 10%). At the shore of this pond the moss layer was composed only of neat feather-moss, which probably offered worse living conditions to Oribatida than *Sphagnum* mosses at other studied water bodies.

At other ponds the species structure of Oribatida was different than in bogs in Tuchola Forest and Brodnica Lakeland. For example, *Limnozetes foveolatus*, the dominant species at lakes and ponds in Tuchola Forest and Brodnica Lakeland, was rare or absent at other ponds. It was relatively abundant only at pond BC, but was several times less abundant than the co-occurring *L. lustrum*. This pond was created artificially after peat mining and is located in a dead bog. Succession proceeds slowly in this bog, but not toward the restoration of the previous plant communities (Celka & Szkudlarz 2006), so the mite communities differ from those in more natural bogs. *Limnozetes foveolatus* was generally absent from ponds with neutral pH, as all *Limnozetes* species require acid conditions (Behan-Pelletier & Bisset 1994). It was also absent from very acid pond KG, where the pH of open water was 3.60; here no *Limnozetes* species was abundant, possibly because of too low pH. Interestingly, also in the studies of the Holocene lake sediments in west Norway *L. ciliatus* and *L. rugosus* disappeared after 1700 ^{14}C years BP and the authors assumed that it was probably due to pH decrease (Larsen et al. 2006).

In ponds with neutral water *Trimalaconothrus* species were absent as they require low pH (Willmann 1933), while at pond KG two species from this genus were present; *T. angulatus*, which occurred exclusively at this pond, was most abundant, accompanied by less abundant *T. maior*. *Trimalaconothrus angulatus* was also found abundantly in oligotrophic ponds in Norway (Seniczak et al. 2010).

Hydrozetes species also varied among studied lakes and ponds. The species typical of dystrophic water bodies of Tuchola Forest (*H. longisetosus*, *H. octosetosus* and *H. lacustris*) were absent from the mesotrophic forest ponds near Pruszcz Bagienica. In contrast, *H. thienemanni* was abundant only in the latter ponds, and not found anywhere else, that is consistent with the literature (for details see in the section 6.15).

Among the species studied, general statements can be made about two others. *Trhypochthoniellus longisetus* was dominant in ponds with neutral pH, but was also present in acid lakes and ponds, while *Zetomimus furcatus* also occurred at different lakes and ponds, but usually at low density, except for peat pond BC, where it was dominant. Both species have a wide ecological tolerance, being found in different habitats (see in sections 6.8 and 6.24).

At ponds with neutral and very acid water some species with wider ecological tolerance were abundant; these include *Liochthonius alpestris* (Forsslund, 1958), *Malaconothrus monodactylus*, *Oppiella nova* and *Platynothrus peltifer*. *Liochthonius alpestris* has been found in bogs (Forsslund 1958; Niedbała 1974; Starý 1988; Seniczak et al. 2006a; Seniczak 2011a), but is not confined to them; it was abundant also at the shores of forest ponds with neutral pH, as reported by Seniczak et al. (2006a). *Malaconothrus monodactylus* also has a wide tolerance to pH (Popp 1962) and nutrient concentration (Kehl 1997).

7.4. SEASONAL DYNAMICS OF ORIBATIDA

In the present study the density of Oribatida varied according to season, and at most lakes and ponds was significantly higher in summer or/and autumn than in spring. The percentage of juvenile stages was highest in summer, which was connected with the reproductive season of dominant species, while species diversity of Oribatida was rather similar in all seasons. Tarras-Wahlberg (1961) and Markkula (1982) observed two peaks of abundance of Oribatida in bogs (spring and autumn), while other authors (Eitminavičiūtė 1966; Wallwork 1967; Belanger 1976; Seniczak 2011a) found population maxima in autumn and winter. In contrast, Donaldson (1996) found no significant seasonal dynamics, either in density or species diversity, but her investigations covered only a short period (from April 21 to July 30).

The seasonal dynamics of Oribatida is caused by many abiotic and biotic factors, including temperature, humidity, nutrient availability, species fecundity, longevity and time of development (Niedbała 1980), which may vary in different bogs or even in their separate biotopes (Eitminavičiūtė 1966; Belanger 1976; Donaldson 1996). For example Eitminavičiūtė (1966) observed in a fen in southern Lithuania that the oribatid mites at the water's edge were most abundant in December, while those most distant reached peak numbers in June.

The same factors control the other groups of mites. For example, Markkula (1982) observed the highest abundance of Prostigmata and Mesostigmata in spring and autumn, while Marquardt (2007) found two-fold higher abundance of Mesostigmata in autumn than in spring. In the present study no significant seasonal differences were observed in either group, mainly due to their very low densities.

Among the species there are different phenological types; some have two peaks of abundance (spring and autumn), others have one peak, while yet others have similar densities throughout the year (Lebrun 1971). Interestingly, some closely related species usually reach their maximum densities in different seasons, which is often thought – but rarely proven – to relate to avoidance of competition. Different seasonal dynamics might be explained as a strategy to facilitate the coexistence of species that have similar ecological requirements (Seniczak & Seniczak 2006). For example the dominant species, *Limnozetes foveolatus*, reproduced intensively in the late spring, the highest proportion of juveniles was observed in summer, and it was usually most abundant in summer or autumn. The second most abundant and closely related *L. ciliatus* reproduced later, had the highest proportion of juveniles in autumn, and consequently was usually most abundant in autumn or spring. This is consistent with Kuriki (2008), who observed in the laboratory that *L. ciliatus* had much higher fecundity at 25ºC than at 20ºC, and adults collected from the field had highest fecundity in summer, and lowest in autumn (Kuriki 2008).

Two *Hydrozetes* species, *H. longisetosus* and *H. octosetosus*, were almost in all cases most abundant in spring; while *H. lacustris* was most abundant in autumn. Of other species showing a clear pattern of seasonal dynamics, *Pilogalumna tenuiclava* was always most abundant in summer, and *Punctoribates sellnicki* in spring. In many species no clear abundance pattern was observed. This was true, for example, of *Trimalaconothrus maior*, which was numerous at almost all lakes and ponds but reached its peak in different seasons.

7.5. MITES OF THE ECOTONE BETWEEN THE WATER'S EDGE AND BOG

The shores of forest lakes and ponds create specific living conditions for oribatid mites, which is well observed in transect of plots near Lake Martwe. Although the water content in samples decreased only slightly between plots 1-5 (from 97% to 95%), which is consistent with Namura-Ochalska (2008), mite density differed significantly among plots. It was highest at the edge of the lake, and decreased with the distance from open water. This pattern was created mainly by the Oribatida, which highly dominated in all plots. Similar observations were made at lobelia Lake Wielkie Gacno in Tuchola Forest (Seniczak et al. 2005a, 2006c, d). However, at Lake Małe Gacno the abundance of Oribatida was lowest at the water's edge (Seniczak et al. 2005b, 2006b, d), which was probably connected with the absence of mosses there. In contrast, Mesostigmata in the present study were least abundant at the edge of the lake, and their density increased with distance, which is consistent with Kaczmarek & Marquardt (2004). It is highly possible that these Oribatida, which were able to adapt to water-saturated conditions at the water's edge, achieved very high abundances there due to low number of predatory Mesostigmata (Karg 1971).

The species composition of Oribatida in the Lake Martwe transect is helpful for knowing better the ecology and interactions of species. The clearest example relates to *Limnozetes*. At the water's margin *L. foveolatus* dominated, accompanied by the second most abundant *L. ciliatus*, while 1 m from this edge *L. ciliatus* was more abundant than *L. foveolatus*. This supports the observation of Popp (1970), that some congeneric species preferred different parts of a bog gradient, which he explained as resulting from 'intrageneric competition and special autecological requirements'. It seems that *L. foveolatus* has narrower tolerance towards humidity than *L. ciliatus* and lives only in dripping-wet and submerged *Sphagnum* and litter (Behan-Pelletier 1989; Seniczak et al. 2006a; Seniczak 2011a). Also at a bog in the USA it preferred the moistest parts of the studied gradient, being especially abundant on feathery bog-moss and flat-topped bog-moss (*Sphagnum recurvum* Palisot de Beauvois = *Sphagnum fallax* (Klinggr.) Klinggr; Flatberg 2004) (Donaldson 1996). Similar conclusions can be made from larger-scale distributions. The dominance of *L. foveolatus* over co-occurring *L. ciliatus* has been widely observed (Willmann 1939; Tarras-Wahlberg 1952; Donaldson 1996; Seniczak et al. 2006a; Seniczak 2011a). However, if *L. ciliatus* occurs without *L. foveolatus* it is abundant at the water's edge; this has been observed in Germany (Strenzke 1952; Knülle 1957b), Poland (Rajski 1961), Switzerland (Borcard 1991a, 1997) and Norway (Seniczak et al. 2010). *Limnozetes foveolatus* therefore seems to have some advantage near the shore. It is much smaller than *L. ciliatus*, and perhaps it can find more habitable spaces to feed or to avoid predators than *L. ciliatus* (Walter & Norton 1984; Donaldson 1996). It probably develops faster, as smaller animals generally do, as is most obvious for related species living under similar conditions (Walter & Proctor 1999). Interestingly, at pond BC *L. lustrum* dominated over *L. foveolatus*.

The second most abundant species at the edge of Lake Martwe was *Trimalaconothrus maior*, which, like *Limnozetes foveolatus*, requires water-saturated conditions, and with distance from the water's edge it disappeared. This species was dominant at the bog studied by Donaldson (1996) in the USA, where it preferred the moistest parts of the gradient. At Lake Martwe *Trimalaconothrus maior* was twice as abundant as the congeneric *T. foveolatus*, consistent with patterns at other lakes and ponds studied here. However, at those lakes and ponds that were more advanced in succession, the proportion of *T. foveolatus* increased and that of *T. maior* decreased. Similar observations were made from Holocene lake sediments in west Greenland, where *T. maior* was most abundant in the earlier stages of the lake development, but then its abundance was strongly reduced, while this of *T. foveolatus* increased with overgrowing of the lake (Presthus-Heggen et al. 2010). *Trimalaconothrus foveolatus* has wider ecological tolerance towards humidity than *T. maior*, and is not restricted to floating *Sphagnum* carpets (Starý 1988; Kehl 1997).

Hydrozetes octosetosus, *Trhypochthoniellus longisetus* and *Punctoribates sellnicki* also were relatively abundant at the water's edge of Lake Martwe, but were rare or absent from other plots. The preference of *Hydrozetes octosetosus* for the water's edge is clear as all known species from the genus *Hydrozetes* are typical aquatic mites associated with open water habitat (Schatz & Behan-Pelletier 2008). Similarly, *Trhypochthoniellus longisetus* is aquatic (Habeeb 1981; Fain & Lambrechts 1987; Seniczak et al. 1998; Proctor 2001; Schatz & Behan-Pelletier 2008). The related species *Trhypochthonius nigricans* was far less abundant, as in Willmann (1931) and Strenzke (1952), but is characteristic for this habitat (Kehl 1997). *Punctoribates sellnicki* is known to prefer dripping-wet, floating and submerged *Sphagnum* (Strenzke 1952; Rajski 1968; Weigmann 1991) and pond's shores (Haarlov 1957), which explains its preference to the water's edge of Lake Martwe. The shores of lakes and ponds in bogs are favorable for *Pilogalumna tenuiclava*, which has a high humidity requirement and is considered a 'true bog animal' (Willmann 1928a; Peus 1932).

In contrast, *Hoplophthiracarus illinoisensis* was rare at the water's edge and more abundant in more distant plots. This species is characteristic for raised bogs (Jacot 1938; Weigmann 2006) but occupies drier habitats (Donaldson 1996). Other species, including *Nanhermannia* cf. *coronata*, *Nothrus pratensis*, *Oppiella nova* and *Tectocepheus velatus*, were rare or absent at the water's edge and their abundance increased with distance from it. These species are common in bogs, mainly due to wide ecological tolerance (Tarras-Wahlberg 1961; Markkula 1986a; Borcard 1991a; Behan-Pelletier & Bisset 1994).

7.6. PREFERENCES OF ORIBATIDA TO LAKE AND POND SHORES

The present study has shown a clear preference of some oribatid species for certain lakes and ponds, and as showed with correspondence analyses (Seniczak et al. 2011b), the most important factor seems to be the phosphorus content, which reflects the trophic conditions of water. For example, the shores of forest mesotrophic ponds were inhabited by species found exclusively there, like *Hydrozetes thienemanni*, which was very abundant, or *Achipteria coleoptrata*, *Adoristes ovatus* and *Astegistes pilosus*. In turn, the dystrophic lakes and ponds situated in bogs were characterized by *Limnozetes* and *Trimalaconothrus* species that are typical for bogs (Markkula 1986a), and by *Hydrozetes longisetosus*, *H. octosetosus* and *H. lacustris*.

The mite communities also differed among bog lakes and ponds, supporting Beier's (1928) opinion that the fauna of each bog pool is specific and highly characteristic, due to slight differences in pH and nutrient content of the water. The majority of studied bogs represent close to natural conditions, but some have been considerably changed by intensive drainage and improper forest management, like 'Kurze Grzędy', or by peat mining, like 'Bagno Chlebowo'. In these bogs water parameters and plant communities differed, followed by the different oribatid communities. The species typical for natural bogs were rare, while others, like *Limnozetes lustrum*, *Zetomimus furcatus* (pond BC) or *Trimalaconothrus angulatus* (pond KG) became abundant. At these ponds some species with a wide ecological tolerance, like *Oppiella nova* and *Platynothrus peltifer* also were abundant. Markkula (1986b) observed that forest amelioration resulted in the decrease of abundance of typical peatland species, including *Limnozetes ciliatus*, and habitat generalists, like *Oppiella nova*, took their place. *Platynothrus peltifer* has been found abundantly in various habitats, including benthos (Schatz & Gerecke 1996), bogs (Sellnick 1921; Tuxen 1943; Dalenius 1960; Borcard 1988, 1991d), and wet forest (Weigmann 1991).

Bogs that are in close to natural conditions are interesting objects to study, as they represent dynamic ecosystems where the succession of biocenoses proceeds with different intensity. Generally, during centuries the lakes and ponds, together with their unique plant and animal communities will disappear, being replaced by the forest. It is interesting to compare oribatid communities from the shores of ponds at different stages of succession within the same reserve. For example in 'Dury' Nature Reserve the abundance of Oribatida was significantly lower at pond D3 than at the other ponds, while the species richness and the number of species with $D > 1$ were the highest there. This pond was the most advanced in succession among those in 'Dury' Nature Reserve.

During the 15-year period (1951-1996) the spread of its floating *Sphagnum* mat was 15.6%, while at the other ponds it ranged between 5.9-9.3%. The predicted time for complete overgrowth of this pond is 289 years, while for ponds 1, 2 and 4 it is, respectively, 533, 765 and 481 years (Kowalewski & Milecka 2003). However, the phenomenon of spreading of the floating *Sphagnum* mat is still poorly investigated and requires wide and complex studies, including lithological research, macrofossil analysis and a good chronology, based especially on flora and fauna bioindicators (Kowalewski & Milecka 2003).

Similarly, when comparing the ponds in 'Jeziorka Kozie' reserve, it is evident that pond K1 is most advanced in succession, as it is characterized by higher species diversity. Among *Limnozetes* three species occur abundantly there (*L. foveolatus*, *L. ciliatus* and *L. lustrum* have respective dominance indices of 45%, 27% and 9%) and high constancy index (100) and *L. rugosus* is less abundant. According to Behan-Pelletier & Bisset (1994) species richness of *Limnozetes* can be used to characterize different bog types. Interestingly, at lake L all five *Limnozetes* species were common, indicating a more advanced stage of succession (Skubała 2004).

A high abundance of Oribatida at the shores of forest lakes and ponds, where they are the most abundant and diverse group of microarthropods, and narrow ecological preferences of some species predispose them as good bioindicators of water quality and succession of biocenose. The number of species of Oribatida in lakes and ponds increased along with the succession of biocenose, with other species from the same genus becoming more common and abundant. These mites also indicate the human activity in lakes and ponds. The bioindicative value of aquatic and semi-aquatic Oribatida can be also used in paleoecology and related sciences (Erickson & Platt 2007).

There is also a need for further study of the oribatid mites living in contemporary bogs, which would provide the ecological and morphological information necessary for better monitoring of the ongoing processes in bogs and improved interpretation of the fossil data. It would be especially interesting to study with a long-term, multidisciplinary approach, the successional transects at overgrowing lakes and ponds, comprising climatic, edaphic and limnological variables, and plant and animal communities, including oribatid mites. Not only would such studies be important for the paleosciences, but they would also increase our understanding of the succession of present bogs. Although the overgrowth of lakes and ponds is unavoidable, it has accelerated recently due to various anthropogenic factors. We should aim to maintain the open bogs for as long as possible, which are essential in their biodiversity and critical for our study and understanding of these ecosystems and their dynamics. Similar long-term, multidisciplinary studies on the bogs destroyed by humans would allow us to follow the restoration process.

As shown in the present study, the ecological requirements of some closely-related oribatid species can vary tremendously, therefore both studies of the extant bogs and the reconstruction of paleoenvironments and paleoclimates, should rely on the identification of Oribatida to the species level, whenever possible. In addition to field studies, model laboratory experiments would be helpful to study the reaction of a particular species to a specific ecological factor, including water chemistry, temperature, food, interactions with other species, etc. In summary, the strength of Oribatida as bioindicators is clearly disproportional to their minute size, and there exists a profound driving power for future multidisciplinary study, which follows ‘hand in hand’ with past and extant bogs.

8. CONCLUSIONS

1. At all lake and pond shores Oribatida highly dominated among mites; their density was high, but species richness was low.
2. The water's edge of most dystrophic, acidic lakes and ponds was inhabited by highly specialized genera (*Limnozetes* and *Trimalaconothrus*) and species (*Hydrozetes longisetosus*, *H. octosetosus* and *H. lacustris*).
3. Characteristic species in mesotrophic ponds with neutral water were *Hydrozetes thienemanni*, *Achipteria coleoptrata*, *Adoristes ovatus* and *Astegistes pilosus*.
4. Hydrophilic species with wide ecological tolerance to water parameters included: *Liochthonius alpestris*, *Malaconothrus monodactylus*, *Platynothrus peltifer* and *Trhypochthoniellus longisetus*.
5. The highest density of Acari and Oribatida was in summer or autumn; the percentage of juvenile stages was highest in summer, indicating the reproductive season of dominant species.
6. Some dominant species had clear seasonal dynamics: e.g. *Limnozetes foveolatus* reproduced in late spring and *L. ciliatus* in summer, presumably avoiding competition, while *Trimalaconothrus maior* reproduced in different seasons.
7. *Limnozetes foveolatus* and *Trimalaconothrus maior* prefer very wet habitat, being very abundant at the water's edge, while *Limnozetes ciliatus* and *Trimalaconothrus foveolatus* have wider tolerance to humidity.
8. Human activity at lakes and ponds changed species composition of Oribatida; in the natural bogs most abundant was *Limnozetes foveolatus*, accompanied by *L. ciliatus*, while in a bog destroyed by peat mining most abundant was *L. lustrum*, while *L. foveolatus* was not abundant. In a bog destroyed by drainage *Limnozetes* species were few, perhaps because of too low pH, and species with a wide ecological tolerance, like *Oppiella nova* and *Platynothrus peltifer*, were abundant.
9. The species richness of Oribatida increased along with the succession of biocenose, and more common and abundant were species from the same genus.
10. From the studied water parameters the most important is phosphorus content that reflects the trophic conditions of water; the abundance of some species (*Adoristes ovatus*, *Atropacarus stirculus*, *Hydrozetes thienemanni*, *Malaconothrus monodactylus* and *Platynothrus peltifer*) was correlated positively with phosphorus concentration in water, while of some others (*Hydrozetes longisetosus*, *Limnozetes ciliatus*, *L. foveolatus*, *Punctoribates sellnicki*, *Trhypochthonius nigricans* and *Trimalaconothrus foveolatus*) was correlated negatively.
11. In this study *Limnozetes guyi* is recorded the first time from Poland and Europe and *Trimalaconothrus angulatus* and *Suctobelbella hamata* Moritz, 1970, from Poland. *Limnozetes* sp. 2 can be a new species to the science, but it needs more morphological investigations.

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Mites (Acari) of the shores of forest lakes and ponds in northern Poland, with species analysis of Oribatida

Summary

Experiments were carried out in 16 water bodies in northern Poland, including nine located in bogs in Tuchola Forest (L, D1, D2, D3, D4, M, K1, K2, K3), three forest ponds near Pruszcz Bagienica, Tuchola Forest (P1, P2, P3), the peat pond in 'Bagno Chlebowo' reserve, Wielkopolska province (BC), lakes in 'Okonek' and 'Stręszek' bog reserves in Brodnica Lakeland (O, S) and a pond in 'Kurze Grzędy' reserve in Kashubian Lakeland (KG). Water was sampled from each lake and pond during the summer, then analyzed for pH, conductivity, color, COD, BOD_5, chlorides, sulphates, total phosphorus, and total iron.

From the edges of the lakes and ponds, samples of mosses, each 100 cm^2 in area and 5 cm in depth, were taken in replicates of 10. Except for pond P1, where only the moss *Pseudoscleropodium purum* occurred, *Sphagnum* mosses were present at all water bodies, with *Sphagnum fallax* as the dominating species. At the edges of nine water bodies (L, D1, D2, D3, D4, M, K1, K2, K3), mites were sampled during spring, summer and autumn of 2006, while at the others, samples were taken only during summer or autumn. Additionally, at lake M a transect of four plots at different distances from the water's edge (at the water's edge, 1 m, 3 m and 5 m away from open water) was investigated. From each plot, 10 samples of *Sphagnum*, each 100 cm^2 in area and 5 cm in depth, were taken during the spring of 2006.

The mites were extracted in Tullgren funnels and preserved in 70% ethanol. From a total of 370 samples, more than 505,000 mites were obtained, including 499,500 Oribatida (almost 61,000 juveniles), belonging to 106 species and 34 families. Furthermore, the Oribatid mite populations were characterized by abundance (*A*), dominance (*D*) and constancy (*C*) indices, and the oribatid communities, by the number of species (*S*) and the Shannon diversity index (*H*s).

The water parameters remarkably differed in the selected lakes and ponds in this study. In forest ponds P1, P2 and P3, the water was neutral, while in other water bodies, located in the bogs, the water was acidic, with the lowest pH value (3.60) in pond KG. In ponds P1, P2 and P3, the water conductivity was high, while in lakes and ponds in bogs it was generally low, except for those more advanced in succession (L, K1, K2 and K3) or affected by drainage (BC and KG). In ponds BC and KG, in contrast to all other water bodies, the color value was high and oxygen conditions poor. The concentration of chlorides and sulphates was generally low, the phosphorus content was higher only in ponds P1, P2 and P3, while the total iron content was generally high, which is characteristic for all acidic lakes in northern Poland.

The density of mites at lakes and ponds in bogs of Tuchola Forest varied between 69,800-306,800 individuals m^{-2}, with the highest density occurring at pond D2 and the lowest density occurring at lake L. Mites of the Oribatida order

were clearly most abundant in these mite communities, as they represented 96.4-99.8% of total Acari, whereas the second most abundant were ‘other Acari’, represented mostly by Prostigmata, and even less abundant were Mesostigmata.

At all these water bodies, the richness of Oribatida was low, and the most abundant was *Limnozetes foveolatus*, which during the summer represented 45.2-93.5% of all the Oribatida. Moreover, this species was also very abundant in ponds D2, D4 and D1, however, in lake L it had lowest abundance. Also relatively abundant was *L. ciliatus*, which was the second most abundant species at a selection of the ponds (D1, D4, K1, K2 and K3), while other *Limnozetes* species were not so abundant, including *L. guyi*, which was recorded for the first time as residing in Poland or Europe. At some water bodies, the second most abundant was *Trimalaconothrus maior*, whereas *Trhypochthoniellus longisetus* and *Pilogalumna tenuiclava* were only relatively abundant. The aquatic genus *Hydrozetes* was represented by five species, out of which *H. longisetosus* was usually most abundant, followed by *H. octosetosus* and *H. lacustris*, while *H. confervae* and *H. lemnae* were fewest. In some water bodies, only a few species occurred abundantly, e.g. in D2, only two species had $D > 1\%$, while, in contrast, in lake L there were 11 species with $D > 1\%$.

The mite communities at the lakes in bog reserves in Brodnica Lakeland were similar to those described from bogs in Tuchola Forest and the Oribatida were very abundant, but with low species diversity and similar species structure as in Tuchola Forest. In contrast, at other ponds (P1, P2, P3, BC and KG), the abundance of mites and Oribatida was lower, but the species richness of Oribatida usually higher than in Tuchola Forest. The lowest abundance of mites was observed at the shore of pond P1, where the proportion of Oribatida was lowest (90%) and that of Mesostigmata was highest (almost 10%). At the shore of this pond, the moss layer was composed only of *Pseudoscleropodium purum*, which presumably offered poorer living conditions to Oribatida than the *Sphagnum* mosses located at the other studied water bodies.

At the other ponds, the species structure of Oribatida was strikingly different from those at bog lakes and ponds. For example, *Limnozetes foveolatus* was generally absent from ponds with either neutral pH (P1, P2 and P3) or from very acidic pH (KG); furthermore, it was relatively abundant only at the peat pond BC, but several times less abundant than the co-occurring *L. lustrum*. In addition, in ponds with neutral water, *Trimalaconothrus* species were also absent, while at the acidic pond KG, *T. angulatus* was most abundant and found only there, albeit accompanied by the less abundant *T. maior*. Also, *Hydrozetes* species, which are characteristic for dystrophic water bodies (*H. longisetosus*, *H. octosetosus* and *H. lacustris*), were absent from the mesotrophic ponds near Pruszcz Bagienica. In contrast, however, *H. thienemanni* was abundant there, and furthermore not found anywhere else. At ponds with neutral and very acidic water pH, the species with a broad ecological tolerance were abundant (*Liochthonius alpestris*, *Malaconothrus monodactylus*, *Oppiella nova* and *Platynothrus peltifer*).

In terms of seasonal variations, Oribatida had usually a higher abundance in summer and autumn than in spring, and furthermore the proportion of juveniles was highest in summer, due to the reproduction season of the dominant species occurring in late spring. For example, *Limnozetes foveolatus* reproduces in late spring, thus the highest proportion of its juveniles was observed in summer, and highest abundance of the species, in summer or autumn. The second most abundant species, *L. ciliatus*, reproduces later, presumably to avoid competition with *L. foveolatus*, thus they had their highest proportion of the juveniles in autumn and highest abundance of the species in autumn or spring. Similarly, *Hydrozetes longisetosus* and *H. octosetosus* were in almost all lakes and ponds most abundantly in spring, while *H. lacustris*, in autumn. A clear pattern of the seasonal dynamics revealed that *Pilogalumna tenuiclava* was most abundant in summer and *Punctoribates sellnicki* had the highest abundance in spring. In contrast, other species, like *Trimalaconothrus maior* reproduced during different seasons.

The distance from the water's edge at lake M affected the mite communities. The total density of mites, and particularly of Oribatida, was highest at the water's edge and decreased with distance away from it. In contrast, the Mesostigmata were least abundant at the water's edge, and their density increased with distance to open water. Some Oribatida (*Limnozetes foveolatus*, *Hydrozetes octosetosus*, *Punctoribates sellnicki*, *Trhypochthoniellus longisetus* and *Trimalaconothrus maior*) preferred the water's edge, while others (*Limnozetes ciliatus*, *Pilogalumna tenuiclava*, *Platynothrus peltifer* and *Trimalaconothrus foveolatus*) were most abundant 1 m from it, and still yet others (*Hoplophthiracarus illinoisensis*, *Nanhermannia* cf. *coronata*, *Nothrus pratensis*, *Oppiella nova*, *Ramusella furcata* and *Tectocepheus velatus*) were absent or few at the water's edge, but their abundance strikingly increased with greater distance to open water. In most species the proportion of juveniles was similar in all plots. Only in *Eupelops hygrophilus* and *Trimalaconothrus foveolatus* did the percentages of juveniles decrease with distance from the water's edge.

Certain species demonstrated clear preferences to particular water bodies, and the most important parameter underlying this preference seemed to be the phosphorus content, which causes water eutrophication. For some species, the pH of the water was also important. The activity of man clearly influenced the composition of the oribatid communities; species typical for the natural bogs were few there, while others became abundant, e.g. *Limnozetes lustrum* and *Zetomimus furcatus* at peat pond BC or *Trimalaconothrus angulatus* at pond KG, as well as those species with a wider ecological tolerance, like *Oppiella nova* and *Platynothrus peltifer*. Oribatid fauna also differed at shores of ponds at different stages of succession. For example, at the shore of pond D3, which is most advanced in succession in the Dury reserve, the abundance of Oribatida was significantly lower than at the other ponds, while the species richness and the number of species with $D > 1$ were highest there. Also, common and abundant occurrences from species of the same genus indicated a more advanced stage of succession.

Roztocze (Acari) strefy brzegowej jezior śródleśnych w północnej Polsce z analizą gatunkową mechowców (Oribatida)

Streszczenie

Jeziora śródleśne występują głównie na północy Polski, szczególnie licznie na równinach sandrowych, gdzie topniejące po ostatnim zlodowaceniu bryły martwego lodu dały początek licznym zagłębieniom, wypełnionym dziś wodą lub torfem. Zbiorniki te pełnią ważną rolę w retencji wody. Podnoszą walory estetyczne krajobrazu, stanowiąc swoiste „wyspy” śródleśne i zwiększając jego bioróżnorodność. Mają szczególne znaczenie w Borach Tucholskich, których znaczne obszary porastają monokultury sosnowe, ubogie w gatunki roślin i zwierząt. W ostatnich latach obserwuje się niestety przyśpieszone zanikanie jezior śródleśnych, szczególnie małych, w wyniku ich naturalnego zarastania, zmian klimatycznych, a głównie z powodu osuszania terenów rolniczych. Zanikanie jezior powoduje utratę wielu cennych gatunków roślin i zwierząt. W pracy przedstawiono wyniki badań roztoczy występujących w strefie brzegowej jezior północnej Polski.

Roztocze (Acari) są najbogatszą grupą pajęczaków, obejmującą około 48000 gatunków, a najliczniejsze i najbogatsze gatunkowo są roztocze z rzędu Oribatida, zwane mechowcami. Obejmują około 10000 gatunków, z tego około 550 występuje w Polsce. Mechowce osiągają niewielkie rozmiary (0,1-2,0 mm długości). Bardzo licznie występują w glebie i ściółce, szczególnie w lesie klimatu umiarkowanego. Pełnią kluczową rolę w rozkładzie materii organicznej. Są także cennymi bioindykatorami różnorodnych zmian w środowisku i są istotne w rekonstruowaniu klimatów i środowisk kopalnych. Mechowce związane są głównie z różnymi typami środowisk lądowych, ale część gatunków opanowała także środowiska wodne i ziemnowodne. W porównaniu z gatunkami lądowymi są one jednak słabo poznane, co skłoniło autorkę pracy do podjęcia badań.

Badaniami objęto 16 śródleśnych zbiorników wodnych, z których 9 znajduje się na torfowiskach w stanie zbliżonym do naturalnego, w rezerwatach w Borach Tucholskich: Jezioro Łyse (oznaczono skrótem L), 4 jeziora w rezerwacie Dury (D1, D2, D3, D4), Jezioro Martwe (M) i 3 jeziora w rezerwacie Jeziorka Kozie (K1, K2, K3). Pozostałe zbiorniki to 3 jeziora śródleśne (P1, P2, P3), położone niedaleko Pruszcza Bagienicy w Borach Tucholskich, dół potorfowy (BC) na torfowisku w rezerwacie Bagno Chlebowo (województwo wielkopolskie), zdegradowanym przez eksploatację torfu, 2 jeziora – Okonek (O) i Stręszek (S), w stanie zbliżonym do naturalnego, znajdujące się w rezerwatach torfowiskowych na Pojezierzu Brodnickim oraz jezioro (KG) w rezerwacie Kurze Grzędy na Pojezierzu Kaszubskim, na torfowisku, które ucierpiało na skutek osuszania i nasadzenia świerka.

Przeprowadzono analizę wody z jezior, którą pobrano latem w odległości 2 m od brzegu (3 dm^3 z każdego jeziora). Właściwości wody, takie jak pH, przewodnictwo, barwę, ChZT, BZT$_5$, zawartość chlorków, siarczanów, fosforu

ogólnego i żelaza ogólnego zbadano w Laboratorium Ochrony Środowiska Naftobazy Baza Paliw nr 2 w Nowej Wsi Wielkiej koło Bydgoszczy.

Próby roztoczy z mchem o powierzchni 100 cm^2 i 5 cm głębokości pobrano z krawędzi pła torfowcowego i lustra wody (w skrócie z jezior), w 10 powtórzeniach. Z 9 jezior w rezerwatach Borów Tucholskich (L, D1, D2, D3, D4, M, K1, K2, K3) próby pobrano w 3 sezonach (wiosną, latem i jesienią) w 2006 roku, a z innych (P1, P2, P3, BC, O, S, KG) – latem lub jesienią. W jeziorze P1 występował mech *Pseudoscleropodium purum*, a w pozostałych – mchy torfowce, w próbach dominował *Sphagnum fallax*. Przy jeziorze M wyznaczono dodatkowo transekt czterech powierzchni usytuowanych przy lustrze wody (0 m) i w odległości 1, 3 i 5 m od lustra wody, z którego próby pobrano wiosną.

Roztocze wypłaszano w aparatach Tullgrena i konserwowano w 70% alkoholu etylowym. Z 370 prób uzyskano ponad 505000 roztoczy, w tym 499500 mechowców (z czego prawie 61000 stadiów młodocianych), należących do 106 gatunków i 34 rodzin. Mechowce oznaczono do gatunku lub rodzaju, a w jednym przypadku do rodziny, łącznie ze stadiami młodocianymi; jedynie roztocze z rodziny Brachychthoniidae traktowano łącznie, ponieważ trudne okazało się oddzielenie tritonimf od świeżo wylęgłych osobników dorosłych. Populacje charakteryzowano za pomocą wskaźników: abundancji (*A*), dominacji (*D*) i stałości występowania (*C*). Klasy dominacji tworzyły: superdominanty ($D > 40$), eudominanty ($20 < D$ Ω40), dominanty ($10 < D$ Ω20), subdominanty ($5 < D$ Ω10), recedenty ($1 < D$ Ω5) i subrecedenty (*D* Ω1). Zgrupowania mechowców scharakteryzowano na podstawie liczby gatunków (*S*) i wskaźnika różnorodności gatunkowej Shannona (*H*s).

Badane jeziora różniły się parametrami wody. W jeziorach koło Pruszcza Bagienicy (P1, P2 i P3) woda miała odczyn obojętny, zaś w innych jeziorach, otoczonych płem torfowcowym – odczyn kwaśny, z najniższą wartością w KG (3,60). W jeziorach P1, P2 i P3 przewodnictwo wody było wysokie, natomiast na torfowiskach – przeważnie niskie; wysokie wartości stwierdzono jedynie przy bardziej zawansowanej sukcesji (L, K1, K2 i K3) lub tam, gdzie miało miejsce osuszenie torfowisk (BC i KG). W jeziorach BC i KG, w przeciwieństwie do wszystkich innych, stwierdzono także wysoką wartość barwy wody oraz słabe warunki tlenowe. Zawartość chlorków i siarczanów była stosunkowo niska, co świadczy o niewielkim wpływie zanieczyszczeń. Zawartość fosforu była wyższa jedynie w jeziorach P1, P2 i P3, a w pozostałych niska, natomiast zawartość żelaza była stosunkowo wysoka. Jest to typowa cecha jezior o kwaśnym odczynie wody, występujących na północy Polski.

W Borach Tucholskich zagęszczenie roztoczy wynosiło 69800-306800 osobników $\cdot m^{-2}$ i było najwyższe w jeziorze D2, stosunkowo wysokie w jeziorach D4, D1 i M, a najniższe w jeziorze L. Mechowce stanowiły aż 96,4-99,8% wszystkich roztoczy, drugie pod względem liczebności były „inne roztocze”, reprezentowane głównie przez Prostigmata, a mniej liczne – Mesostigmata.

W jeziorach Borów Tucholskich odnotowano niewielkie zróżnicowanie gatunkowe mechowców; najliczniejszy był tam *Limnozetes foveolatus*, którego udział w strukturze dominacji wynosił latem 45,2-93,5%. Gatunek ten wystąpił szczególnie licznie w jeziorach D2, D4 i D1, zaś najmniej licznie w jeziorze L.

Stosunkowo licznie wystąpił także *L. ciliatus*, który w niektórych jeziorach (D1, D4, K1, K2 i K3) był pod względem liczebności na drugim miejscu, a najwyższe zagęszczenie i udział w strukturze dominacji miał w jeziorze K1. W niektórych jeziorach wystąpiły także, choć mniej licznie, inne gatunki z rodzaju *Limnozetes*, a wśród nich stwierdzony pierwszy raz w Polsce i Europie *L. guyi*.

W niektórych jeziorach drugi pod względem liczebności był *Trimalaconothrus maior*, a *T. foveolatus* zwykle był nieliczny. Stosunkowo licznie wystąpiły także *Trhypochthoniellus longisetus* i *Pilogalumna tenuiclava.* Typowo wodny rodzaj *Hydrozetes* reprezentowany były przez 5 gatunków, wśród których najliczniejszy był zwykle *H. longisetosus*, drugi z kolei – *H. octosetosus*, a *H. lacustris* był mniej liczny. Pozostałe 2 gatunki, *H. confervae* i *H. lemnae*, wystąpiły nielicznie. W niektórych jeziorach kilka gatunków osiągnęło znaczne liczebności, np. w jeziorze L aż 11 gatunków miało wskaźnik dominacji powyżej 1%, a w D2 – tylko 2 gatunki.

Większość gatunków mechowców (34) w wypłoszonych próbach była reprezentowana tylko przez stadium dorosłe, a 3 gatunki wystąpiły tylko w postaci młodocianej. Osobniki dorosłe przeważały w populacjach 19 gatunków (większość gatunków z rodzajów *Hydrozetes* i *Limnozetes* oraz *Trhypochthoniellus longisetus*), a u 16 gatunków (np. *Eupelops hygrophilus*, *Nanhermannia* cf. *coronata*, *Pilogalumna tenuiclava*, *Platynothrus peltifer*, *Trhypochthonius nigricans*, *Trimalaconothrus foveolatus* i *T. maior*) stadia młodociane były liczniejsze niż okazy dorosłe.

W jeziorach Pojezierza Brodnickiego (O i S) zgrupowania roztoczy były podobne jak w Borach Tucholskich. Cechowała je duża liczebność, mała różnorodność gatunkowa mechowców i podobny skład gatunkowy. W innych zbiornikach wodnych (P1, P2, P3, BC i KG) liczebność roztoczy była natomiast niższa, a różnorodność gatunkowa mechowców zwykle wyższa niż w Borach Tucholskich. Najniższą liczebność roztoczy stwierdzono w jeziorze P1, w którym udział mechowców był najniższy (90%), natomiast udział Mesostigmata – najwyższy (prawie 10%). W tym jeziorze, w odróżnieniu od innych, w warstwie mchów nie było *Sphagnum*, lecz mech *Pseudoscleropodium purum*, który prawdopodobnie stwarzał gorsze warunki życiowe dla mechowców. Inne jeziora różniły się także składem gatunkowym mechowców. Na przykład *Limnozetes foveolatus*, dominujący w jeziorach Borów Tucholskich i Pojezierza Brodnickiego, był nieobecny lub nieliczny w pozostałych zbiornikach wodnych. Licznie występował jedynie w dole potorfowym BC, osiągając tam jednak kilkakrotnie niższe zagęszczenie niż współwystępujący z nim *L. lustrum*. *Limnozetes foveolatus* był nieliczny w zbiornikach o pH neutralnym i bardzo kwaśnym.

W jeziorach o neutralnym pH nie występowały roztocze z rodzaju *Trimalaconothrus*, gdyż podobnie jak *Limnozetes* wymagają niskiego pH, natomiast w jeziorze KG odnotowano 2 gatunki *Trimalaconothrus*; liczniejszy był *T. angulatus*, stwierdzony po raz pierwszy w Polsce i nie spotykany w innych jeziorach, a towarzyszył mu *T. maior*.

Jeziora o neutralnym pH cechował także inny skład gatunkowy *Hydrozetes* – nie stwierdzono w nich gatunków znajdujących się w jeziorach dystroficznych Borów Tucholskich i Pojezierza Brodnickiego (*H. longisetosus*, *H. octosetosus* i *H. lacustris*), natomiast licznie wystąpił *H. thienemanni*, którego obecności nie odnotowano w innych zbiornikach. *Hydrozetes lemnae* był najliczniejszy w jeziorze P2, ale obecny także w zbiornikach o niskim pH wody. Podobnie *Trhypochthoniellus longisetus* wystąpił najliczniej przy neutralnym pH, ale był także obecny w jeziorach o kwaśnym odczynie wody. *Zetomimus furcatus* wystąpił w różnych jeziorach, ale zwykle nielicznie, jedynie w jeziorze BC był liczny i dominował wśród mechowców. W jeziorach o odczynie neutralnym, jak również o pH bardzo niskim, licznie stwierdzono gatunki o szerokim zakresie tolerancji, jak *Liochthonius alpestris*, *Malaconothrus monodactylus*, *Oppiella nova* i *Platynothrus peltifer*.

Zagęszczenie mechowców było zwykle wyższe latem i jesienią niż wiosną, najwięcej osobników młodocianych występowało latem, co było związane z rozmnażaniem się najliczniejszych gatunków. *Limnozetes foveolatus* na przykład rozmnażał się późną wiosną, najwyższy udział stadiów młodocianych obserwowano latem, a najwyższą liczebność gatunku latem lub jesienią. Drugi pod względem liczebności, *L. ciliatus*, rozmnażał się później, miał największy udział młodocianych jesienią i był najliczniejszy jesienią lub wiosną. Różny czas rozmnażania pokrewnych gatunków zmniejsza ich konkurencję. Podobnie *Hydrozetes longisetosus* i *H. octosetosus* były prawie we wszystkich jeziorach najliczniejsze wiosną, a *H. lacustris* – jesienią.

Wyraźną dynamikę sezonową obserwowano u gatunku *Pilogalumna tenuiclava*, który był zawsze najbardziej liczny latem, a *Punctoribates sellnicki* – wiosną. Z kolei pewne gatunki, np. *Trimalaconothrus maior*, nie cechowały się wyraźną dynamiką sezonową i w różnych jeziorach osiągały najwyższą liczebność w różnych sezonach.

Odległość od brzegu jeziora miała wpływ na zgrupowanie roztoczy, o czym świadczy przykład transektu przy jeziorze M. Zagęszczenie ogólne roztoczy i mechowców było najwyższe na brzegu pła torfowcowego i lustra wody i malało wraz z odległością od lustra wody, natomiast zagęszczenie Mesostigmata kształtowało się odwrotnie, tzn. zwiększało się wraz z odległością od lustra wody. Pewne gatunki mechowców, jak *Limnozetes foveolatus*, *Hydrozetes octosetosus*, *Punctoribates sellnicki*, *Trhypochthoniellus longisetus* i *Trimalaconothrus maior*, preferowały brzeg pła torfowców, osiągając tam najwyższą liczebność, a wraz z odległością ich liczebność malała. Niektóre gatunki (*Limnozetes ciliatus*, *Pilogalumna tenuiclava*, *Platynothrus peltifer* i *Trimalaconothrus foveolatus*) osiągnęły najwyższą liczebność 1 m od lustra wody, a jeszcze inne (*Hoplophthira-*

carus illinoisensis, *Nanhermannia* cf. *coronata*, *Nothrus pratensis*, *Oppiella nova*, *Ramusella furcata* i *Tectocepheus velatus*) były na brzegu pła torfowcowego albo nieobecne albo nieliczne, a wraz z odległością od lustra wody ich liczebność rosła. Najwyższy udział stadiów młodocianych stwierdzono 1 m od lustra wody, stosunkowo wysoki był przy lustrze wody, natomiast znacznie niższy na powierzchniach bardziej oddalonych od lustra wody. U większości gatunków udział stadiów młodocianych był podobny w całym transekcie powierzchni, jedynie u *Eupelops hygrophilus* i *Trimalaconothrus foveolatus* udział ten malał wraz z odległością od lustra wody.

Niektóre gatunki wyraźnie preferowały określone zbiorniki wodne i najważniejszym parametrem była dla nich zawartość fosforu, wskazująca na trofię jeziora. Pewne gatunki (*Adoristes ovatus*, *Atropacarus striculus*, *Hydrozetes thienemanni*, *Malaconothrus monodactylus* i *Platynothrus peltifer*) reagowały na zawartość fosforu wzrostem liczebności, zaś inne (*Hydrozetes longisetosus*, *Limnozetes ciliatus*, *L. foveolatus*, *Punctoribates sellnicki*, *Trhypochthonius nigricans* i *Trimalaconothrus foveolatus*) spadkiem liczebności. Mezotroficzne jeziora z neutralnym odczynem wody zamieszkiwały gatunki wyłączne, np. *Hydrozetes thienemanni*, *Achipteria coleoptrata*, *Adoristes ovatus* i *Astegistes pilosus*. Kwaśne zbiorniki dystroficzne na torfowiskach zamieszkiwały z kolei gatunki z rodzajów *Limnozetes*, *Trimalaconothrus* i *Hydrozetes* (*H. longisetosus*, *H. octosetosus* i *H. lacustris*).

Działalność człowieka miała wpływ na skład gatunkowy mechowców jezior. Gatunki typowe dla torfowisk naturalnych były tam nieliczne, natomiast licznie występowały gatunki *Limnozetes lustrum* i *Zetomimus furcatus* (dół potorfowy BC) lub *Trimalaconothrus angulatus* (jezioro KG). W tych zbiornikach liczne były także gatunki o szerokiej tolerancji ekologicznej – *Oppiella nova* i *Platynothrus peltifer*.

Fauna mechowców niektórych jezior była także interesującym obiektem badań pod względem sukcesji biocenoz, wykazywała bowiem pewne zależności od stopnia zaawansowania sukcesji. Na przykład na brzegu jeziora D3, które w świetle literatury jest najbardziej zaawansowane w sukcesji, liczebność mechowców była znacznie niższa niż w innych jeziorach, a różnorodność gatunkowa i liczba gatunków z $D > 1$ były tam najwyższe. Współwystępowanie wielu gatunków z tego samego rodzaju w jeziorze świadczy o bardziej zaawansowanej sukcesji, co widać na przykładzie gatunków *Limnozetes* z jezior K1 i L.

Na podstawie uzyskanych wyników badań sformułowano następujące wnioski:

1. W badanych jeziorach wśród roztoczy dominowały mechowce, które cechowało duże zagęszczenie, lecz mała różnorodność gatunkowa.
2. Dystroficzne, kwaśne jeziora śródleśne zamieszkiwały wysoko wyspecjalizowane rodzaje (*Limnozetes* i *Trimalaconothrus*) oraz gatunki (*Hydrozetes longisetosus*, *H. octosetosus* i *H. lacustris*).

3. Dla jezior mezotroficznych, o neutralnym odczynie wody, charakterystyczne były gatunki *Hydrozetes thienemanni*, *Achipteria coleoptrata*, *Adoristes ovatus* i *Astegistes pilosus*.
4. Gatunki hygrofilne, o szerokim zakresie tolerancji względem parametrów wody, reprezentował *Liochthonius alpestris*, *Malaconothrus monodactylus*, *Platynothrus peltifer* i *Trhypochthoniellus longisetus*.
5. Najwyższe zagęszczenie ogólne roztoczy i mechowców stwierdzono latem lub jesienią, a najwyższy udział stadiów młodocianych 4 latem, co wiązało się z nasileniem rozmnażania się najliczniejszych gatunków.
6. Pewne gatunki cechowała wyraźna sezonowa dynamika liczebności, np. *Limnozetes foveolatus* rozmnażał się późną wiosną, a *L. ciliatus* latem, w ten sposób przypuszczalnie unikając konkurencji, natomiast *Trimalaconothrus maior* osiągał dużą liczebność w różnych porach roku.
7. *Limnozetes foveolatus* i *Trimalaconothrus maior* preferują siedlisko bardzo wilgotne (pło torfowców blisko lustra wody), natomiast *Limnozetes ciliatus* i *Trimalaconothrus foveolatus* mają szerszą tolerancję względem wilgotności środowiska.
8. Działalność człowieka na torfowiskach wpłynęła na skład gatunkowy mechowców; w jeziorach o charakterze zbliżonym do naturalnego najliczniejszy był *Limnozetes foveolatus* a towarzyszył mu *L. ciliatus*, w dole potorfowym najliczniej występował *L. lustrum*, a *L. foveolatus* był mało liczny, zaś w jeziorze na osuszonym torfowisku *Limnozetes* był nieliczny, być może z powodu zbyt niskiego pH, występowały natomiast gatunki o szerokim zakresie tolerancji ekologicznej – *Oppiella nova* i *Platynothrus peltifer*.
9. Różnorodność gatunkowa mechowców w jeziorach wzrastała wraz ze stopniem zaawansowania sukcesji i liczniej występowały gatunki z tego samego rodzaju.
10. Spośród badanych parametrów wody największy wpływ na faunę roztoczy miała zawartość fosforu, odzwierciedlająca warunki troficzne zbiornika; liczebność niektórych gatunków (*Adoristes ovatus*, *Atropacarus striculus*, *Hydrozetes thienemanni*, *Malaconothrus monodactylus* i *Platynothrus peltifer*) była dodatnio skorelowana ze stężeniem fosforu, zaś innych (*Hydrozetes longisetosus*, *Limnozetes ciliatus*, *L. foveolatus*, *Punctoribates sellnicki*, *Trhypochthonius nigricans* i *Trimalaconothrus foveolatus*) była skorelowana ujemnie.
11. *Limnozetes guyi* został wykazany po raz pierwszy w Polsce i Europie, a *Trimalaconothrus angulatus* i *Suctobelbella hamata* Moritz, 1970, po raz pierwszy w Polsce. *Limnozetes* sp. 2 może być nowym gatunkiem dla nauki, ale wymaga dalszych badań morfologicznych.