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Water mite (Acari, Hydrachnidia) assemblages in relation to differentiation of mesohabitats in a shallow lake and its margins

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Abstract

The main objective of the study was to present an analysis of the Hydrachnidia species composition in the highly varied Lake Świdwie ecosystem at the macro- and mesohabitat level. 73 species were recorded. Species associated with small water bodies were most abundant, together with lake species. The most individuals and species were caught in the *Phragmites*-Close mesohabitat. The fewest individuals were caught in the *Phragmites-Typha* mesohabitat, and the fewest species in the *Chara* mesohabitat. Three groups of species associated with particular mesohabitats were recorded: 1) species associated with the *Phragmites*-Close mesohabitat, 2) species associated with the *Thelypteris palustris-Phragmites australis* and *Phragmites-Typha* mesohabitats; 3) species associated with the *Chara* and *Ceratophyllum-Myriophyllum* mesohabitats. The high similarity between the fauna of the two lake basins and the marked faunal distinctiveness of the Hydrachnidia assemblages in the small pools on the margins of Lake Świdwie indicate that it was the character of the water bodies that determined the composition of the Hydrachnidia assemblages in each of the macrohabitats of the Świdwie reserve, whereas the influence of their surroundings was negligible. The results obtained confirm our hypothesis that in the highly varied system of water bodies and habitats one can expect substantial diversity of Hydrachnidia.

Keywords: lake ecosystem, macrohabitats, mesohabitats, synecological groups, species diversity.

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Introductıon

Research on the Hydrachnidia of the lakes of Poland clearly stands out in comparison to other European countries. Thus far about 200 lakes have been studied, and several dozen publications have been devoted to them. Many years of research on the ecology of water mites of lakes were summed up by Pieczyński (1976). Another important synthesis was a study by Biesiadka and Kowalik (1991) dealing with the links between water mite fauna and the trophic state of lakes.

In recent years the rate and scale of the negative impact of human activity on aquatic ecosystems have been increasing. Severe transformations have affected water bodies of all types, but this process is particularly troublesome in lakes. Changes in lakes are taking place so rapidly that more specialized species (deep-water species characteristic of cold and well-oxygenated environments) are unable to adapt to the changing environmental conditions and thus die out (Biesiadka, 1987). The rate and scale of lake degradation due to human activity necessitates urgent documentation of the current state of Hydrachnidia, particularly in water bodies that have been little affected by human impact, with relatively well-preserved fauna. These water bodies include lakes situated in protected areas. The data collected can be used to determine the rate and direction of changes in the Hydrachnidia of lakes over multi-year periods and to evaluate the degree of human impact on lake ecosystems.

Because of its substantial variety of vegetation, Lake Świdwie and its margins are an ideal location for investigating the distribution and dynamics of Hydrachnidia in various types of mesohabitats. The main hypothesis of this study was that in such a diverse system of water bodies and habitats we can expect to see a great diversity of Hydrachnidia fauna. The main aim of the present work was to present an analysis of the water mite species composition in the Lake Świdwie ecosystem at the macrohabitat and mesohabitat level. Additional objectives were as follows: (1) to valorize the water mite fauna of this protected area and propose it as a reference ecosystem for this type of water body (shallow lakes); (2) to determine the influence of the lake's character and its close surroundings on the composition of Hydrachnidia assemblages, including an analysis of their migratory tendencies between water bodies; (3) to identify assemblages of species characteristic of the mesohabitats distinguished.

Materials and Methods

The Study Area

Lake Świdwie (N: 53°33'30", E: 14°22'20") lies in western Pomerania in Wkrzańska Forest (Ueckermünde Heath), a forest area near the city of Szczecin (NW Poland). This shallow lake and the surrounding marshy grounds constitute an environmentally valuable protected area called the Świdwie Nature Reserve; it is also a Ramsar site. The former area of the lake covered 1,216 ha (Jasnowski and Jasnowska, 1960). Up to the mid-nineteenth century the open surface of the lake covered 467.1 ha, but intense wetland reclamation work conducted before World War II reduced this area substantially. In 1994 the water level rose owing to the construction of a sluice on the Gunica River. The water rise hindered or even reversed the process of lake overgrowth, which was manifested by the recession of reed rushes.

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Currently the lake, with its complexes of rush vegetation, covers 358 ha (Pieńkowski and Kupiec, 2001). It is composed of two water bodies: lake A (hereafter Świdwie Wielkie), which covers 54.40 ha and has a maximum depth of 2.5 m, and lake B (Świdwie Małe), with an area of 13.16 ha and a maximum depth of 1.9 m (Figure 1). The surface area of the open lake is currently only 5.6% of its former area.

The appearance of the lake basin and the degree of overgrowth of Lake Świdwie indicate that it is in its final stage of succession, leading to the status of a fen. At the same time, hydrochemical data (Gałczyńska *et al*., 2004; Rawicki and Siwek, 2014) indicate that this is a lake bordering between mesotrophy and eutrophy. Water transparency extends to the bottom, which is entirely covered with submerged vegetation, mainly *Ceratophyllum demersum* L., *C. submersus* L., *Myriophyllum spicatum* L. and *Chara*. The presence of *Chara* confirms the good condition of the water body. It can thus be presumed that this is an example of natural succession, during which the lake becomes shallow and overgrown and biogenic substances mainly reach the sediment, contributing to the development of macrophytic vegetation while leaving the water unburdened by additional nitrogen and phosphorus, thereby preserving high habitat diversity.

Lake Świdwie, together with the surrounding ditches, small ponds, rushes and bogs, provides an exceptionally diverse complex of habitats for invertebrate fauna. The whole area of the lake is densely covered with richly varied littoral vegetation composed of different various types of rushes and underwater meadows (elodeids) forming separate patches with diverse species composition (Bacieczko and Kowalski, 1993).

Terms used

We use the term macrohabitat to mean 'a habitat of sufficient extent to present considerable variation of environment, contain varied ecological niches, and support a large and usually complex flora and fauna' (Merriam-Webster Dictionary). We use this term to refer to the basin of Lake Świdwie Wielkie (macrohabitat A), the basin of Lake Świdwie Małe (macrohabitat B) and the Świdwie margins (macrohabitat C) (Figure 1).

The term mesohabitat refers to visually varied habitats that can be recognized subjectively by their physical similarity (e.g. a sandbank or gravel bank or a particular plant community). This term introduces a dimension of scale and should be distinguished from microhabitats (e.g. a leaf stem or the surface of a stone) and macrohabitats, e.g. entire fragments of water bodies (Armitage and Prado, 1995). The following lake mesohabitats have been differentiated (abbreviations are given in brackets):

1. Rushes.

1.1. *Phragmites*-*Typha* Rushes (Ph-Typh). The eastern banks of Lake Świdwie (both Świdwie Wielkie and Świdwie Małe) are overgrown with *Phragmites australis* or *Typha angustifolia* rushes (Fig. 1). This habitat is characterized by a hard bottom composed of a dense mat of rhizomes and roots and practically devoid of soft sediment. It has direct contact with the open waters of the lake.

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1.2. *Thelypteris*-*Phragmites* Rushes (Thel-Ph). The western edges of the lake are overgrown with *Thelypteris palustris* and *Phragmites australis* rushes forming a floating mat with very loose organic sediment underneath. The habitat has direct contact with the open waters of the lake (Fig. 1).

1.3. *Phragmites*-Close (Ph-Close). Between water bodies A and B *Phragmites australis* rushes grow and a complex of small ponds and canals covers an area of 15.87 ha. This habitat differs from the reed rushes overgrowing the banks of the lake owing to the limited exchange with lake waters, a thick layer of very soft, hydrated organic sediment and the mosaic structure formed by the small ponds and reed rushes. The ponds and canals are either overgrown with *Myriophyllum* and *Hydrocharis* or the bottom is devoid of vegetation.

2. Underwater Meadows (Elodeids).

2.1. *Ceratophyllum* and *Myriophyllum* Underwater Meadow (Cer-Myr). A surface of very soft, organic sediment with high water content is overgrown by vegetation which creates underwater meadows. The meadows of *Ceratophyllum* sp. and *Myriophyllum* sp. form a more or less compact growth which allows contact between the organisms living there and the bottom sediment.

2.2. Charophyta Underwater Meadows (Chara). The Charophyta meadows form a dense growth which makes access to the bottom sediment rather difficult. The area formed by these plants is so compact that it markedly limits the number of accessible hiding places for macroinvertebrates. In the period from July to October the vegetation is so lush that in many places the underwater meadows almost reach the water surface, with only 30–40 cm of water above them.

Sampling Methods

The research was conducted at three times during the year: in May, July and October of 2010. To a depth of 1 m the samples were collected using a hydro-biological sampler with a triangular hoop: side length 30 cm, mesh size 200 μm. The sampling method involved 20 sweeps performed directly above the surface of the bottom over an area of about 1 m^2. Samples from greater depths were collected using a dredge with a triangular hoop: side length 30 cm, mesh size 200 μm. The dredge was dragged across a length of about 30 m, which is comparable to sampling with hydrobiological sampler.

The sampling sites were distributed so as to capture the full habitat diversity of the lake. The number of sites in a given mesohabitat was directly proportional to the surface area of the habitat: 2.1.1. (Ph-Typh) – 4 sites, 2.1.2. (Thel-Ph) – 2 sites, 2.1.3. (Ph-Close) – 8 sites, 2.2.1. (Cer-Myr) – 9 sites, 2.2.2. (Chara) – 2 sites.

Analysis of Data

Characterization of water mite fauna was based on the dominance structure and the Shannon-Wiener biodiversity index. Taking into account all sites, the following dominance classes were established: eudominants (>10.0%), dominants (5.01-10.0%), subdominants (1.01-5.00%), recedents (0.50-1.00%), subrecedents (<0.50%) (Zawal *et al*., 2013). The water mites caught in the Świdwie Reserve were assigned to four synecological groups (after Cichocka,

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1998): lake species, small water body species, vernal astatic water body species, and tyrphobiontic and tyrphophilous species.

The difference between the number of individuals caught in particular macro- and mesohabitats was calculated and statistical significance was tested by the Kruskal-Wallis test. Similarities between the water mite fauna inhabiting particular macro- and meso-habitats was calculated by Bray-Curtis Cluster Analysis.

CANOCO v.4.5 multivariate statistical analysis (Ter Braak and Šmilauer, 2002) was used to examine the dependence between species composition and environmental variables. Detrended Correspondence Analysis (DCA) was used to determine the structure of data and to select the next type of analysis to investigate the distribution of species with respect to environmental variable correspondence analysis (Jongman *et al*., 1987). The ln (n + 1) transformation of species data was used in the DCA analyses. Each transformation used must lead to the presentation of the data in the form of a normal distribution. In this case the transformation ln(n+1) fulfils this condition.

DCA analysis for the water mite species recorded in each habitat showed that the length of the gradient represented by the first ordination axis was 5.961, which indicates that the species realizes the full Gauss spectrum, which in turn made it possible to conduct direct ordination analyses of the CCA type in order to determine the relationships between the occurrence of species and the environmental parameters (ter Braak, 1986; ter Braak and Verdonschot, 1995). The eigenvalues of the axes show that the gradient represented by the first ordination axis substantially differentiates the occurrence of species (0.826), as its eigenvalue is greater than 0.5. The first axis explains 11.8% of the variation in the water mite species composition, and the second only 5.9%.

Results

Analysis of the occurrence of Hydrachnidia in the macrohabitats

A total of 3,651 water mite individuals (3,109 adults and 542 deutonymphs) were collected, belonging to 73 species (Table 1). Among the water mites collected 1,726 individuals belonging to 49 species were caught in Lake Świdwie Wielkie (macrohabitat A), 909 individuals belonging to 39 species were caught in Lake Świdwie Małe (macrohabitat B), and 1,016 individuals belonging to 53 species were collected in the water bodies at the margins of the reserve (macrohabitat C) (Table 1). The differences in the number of individuals caught in each macrohabitat were not statistically significant: H(3, N=701)=0.8835202 (p=0.8294). The differences in the abundance of water mites caught at particular sites were also statistically insignificant: H(24, N=701)=29.09680 (p=0.2165).

On the dendrogram of similarities between macrohabitats, a cluster grouping the lakes Świdwie Wielkie and Świdwie Małe can be seen (Figure 2). The similarity between the fauna of these two water bodies was 49.7%. The Hydrachnidia fauna of the water bodies in the margins of Lake Świdwie was distinct from that of the lakes.

One indicator species of mesotrophy was recorded in the material collected, *Piona paucipora*, but its quantitative share was negligible (0.1%). The group of indicator species of moderate eutrophy comprised *Oxus musculus*, *Unionicola gracilipalspis*, *U. minor*, *Piona stjoerdalensis*, *Axonopsis complanata* and *Arrenurus perforatus*. Together these species accounted for 8.2% of the water mites collected. Two indicator species of dystrophy were noted as well –

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Piona carnea and *Arrenurus tetracyphus*, but these were present in small numbers (2 and 7 individuals, respectively) and accounted for only 0.2% of all the fauna (Table 1).

The combined species diversity of the Hydrachnidia of the Świdwie Reserve was 1.58. Species diversity was highest in Lake Świdwie Małe (H=1.55), lower in the water bodies located in the lake margins (H=1.49, and lowest in Świdwie Wielkie, where the Shannon index was 1.37 (Table 1).

The most numerous group in the fauna of the Reserve was small water body species – the contribution of the 28 species from this synecological group was 44.3% of the material collected (Figure 3). The share of lake species was also substantial (37.5%, 18 spp.). The share of vernal species was markedly lower (13.8%, 18 spp.), and the least numerous group was the tyrphobiontic and tyrphophilous species (4.4%, 9 spp.). In Świdwie Wielkie lake species were dominant (53.9%, 14 spp.), with a substantial share of small water body species (41.0%, 23 spp.). In Lake Świdwie Małe clear dominance of small water body species was observed (70.2%, 23 spp.). Considerably fewer lake water mites were caught in this lake (25.7%, 11 spp.). In the lake margins the most abundant synecological element was species associated with vernal astatic water bodies (44.5%, 17 sp.). Small water body species were quite abundant as well (29.9%, 17 spp.) (Figure 3).

The ratio of the number of individuals belonging to small water body species to the number of individuals belonging to lake species was 1.31 in Lake Świdwie Wielkie and 0.36 in Lake Świdwie Małe. For the two lake basins combined the ratio was 0.84.

Analysis of The Occurrence of Hydrachnidia in The Mesohabitats

The abundances of water mite fauna recorded in particular habitats were statistically significant: H(4, N=701)=13.47244 (p=0.0092). The most individuals and species of water mites were caught in the *Phragmites*-Close habitat – 1,124 individuals and 59 species. The species diversity index in this habitat was 1.63 and was the highest noted in all of the mesohabitats. The fewest individuals (484) were caught in the *Phragmites*-*Typha* habitat, and the fewest species in the underwater meadows covered with Charophyta (22 species). The lowest species diversity was also noted in this habitat, with a Shannon index of only 0.99 (Table 1).

Two clusters can be observed in the faunal similarity between the mesohabitats (Figure 4). The first cluster comprises elodeid habitats. The similarity between the fauna inhabiting the *Ceratophyllum* and *Myriophyllum* community (Cer-Myr) and the Charophyta underwater meadows (Chara) was 36.6%. The second cluster comprises two habitats in rushes – *Thelypteris*-*Phragmites* (Thel-Ph) and *Phragmites*-*Typha* (Ph-Typh). The similarity of the fauna of these two mesohabitats was 34.0%. The Hydrachnidia of the *Phragmites*-Close mesohabitat (Ph-Close) was clearly distinct (Figure 4).

In the ordination diagram illustrating the results of CCA, three groups of species can be seen (Figure 5). Group 1 shows the relationship between the species grouped here and the Ph-close mesohabitat. The species belonged to group 1 were caught in the greatest numbers in the Ph-close mesohabitat or were found only in this mesohabitat (Table 1). Group 2, located around the Thel-Ph and Ph-Typh vectors, indicates a relationship between the species grouped here and these

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two mesohabitats, but only the relationship with Thel-Ph is statistically significant. Group 3, located around the Chara and Cer-Myr vectors, groups together species associated with elodeids. The species most correlated with the Chara and Cer-Myr mesohabitats were *Oxus musculus* (96.8% of the population of this species was caught in elodeids), *O. tenuisetis* (all individuals were caught in the Chara and Cer-Myr mesohabitats) and *Arrenurus perforatus* (92.6% of the population was caught in elodeids) (Table1).

Discussion

Over 200 water mite species have been recorded in the contemporary fauna of Polish lakes, of which about 50 can be included among specifically lake forms, i.e. those which do not occur or are encountered only sporadically and in small numbers outside of lake environments (Biesiadka, 1987, 2008). The number of water mite species caught in individual lakes of Poland is highly varied; from 3 to 96 species have been found in the lakes that have been studied thus far (Pieczyński, 1976; Biesiadka, 1980, 1987, 2003; Kowalik, 1978; Zawal, 1992, 2007; Cichocka and Biesiadka, 1994; Cichocka, 2000, 2005; Stryjecki, 2012; Zawal *et al*., 2013). In other regions of Europe, the number of species caught in lakes has ranged from 4 to 56 (Viets, 1979; Davids *et al*., 1994; Bagge, 1999; Di Sabatino *et al*., 2004; Baker *et al*., 2008). A large number of species is usually recorded in large, deep lakes in which all zones – littoral, sublittoral and profundal – are well developed, enabling the development of rich and diverse Hydrachnidia (Kowalik, 1978; Cichocka and Biesiadka, 1994; Biesiadka, 2003). Lake Świdwie Wielkie is small and shallow, and the basin of Lake Świdwie Małe is even smaller and shallower. Considering the small surface area of the lakes studied and the lack of deep-water habitats, the 46 species noted in Lake Świdwie Wielkie and 36 in Lake Świdwie Małe (for a combined total of 54 in the two basins of Lake Świdwie) should be regarded as rather high numbers.

Lake Świdwie Wielkie (macrohabitat A) and Lake Świdwie Małe (macrohabitat B) were grouped in one cluster, whereas the fauna of the water bodies of the lake margins (macrohabitat C) was clearly distinct from that of the lakes. The faunal similarity between the two basins of the lake is obvious, as these are water bodies of the same type, situated close together, historically originating in one water body (Jasnowski and Jasnowska, 1960). The faunal distinctiveness of the assemblages of water mites inhabiting the margins of the Reserve is a consequence of the completely different limnological character of the habitats there (small pools with well-developed astatic zones) and the resulting distinct character of the fauna inhabiting them. The high similarity of the fauna of the two lake basins and the marked faunal distinctiveness of the Hydrachnidia assemblages in the lake margins indicates that despite the direct proximity of the two main types of habitat, i.e. lakes and small pools in the lake margins, there was little migration of water mites between these types of water body (directly, through periodic water flow between them, or indirectly, as larvae parasitizing aquatic insects). Thus the composition of the Hydrachnidia assemblages in the various macrohabitats of the Świdwie Reserve was determined by the character of the water body, while the influence of the surroundings (the presence of other types of water body) was negligible.

Water mites are very important as bioindicators, and the species composition of communities inhabiting lakes depends on their trophic state. According to Biesiadka and Kowalik (1991), three groups of indicators can be distinguished: mesotrophic, moderately eutrophic, and dystrophic. One indicator of mesotrophy, six indicators of moderate

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eutrophyand two indicators of dystrophy were noted in the fauna of the Reserve. The clear dominance of indicator species of moderate eutrophy over indicators of mesotrophy does not necessarily indicate unfavourable changes in Lake Świdwie towards increasing trophic state. Indicator species of mesotrophy are hemi-stenothermal or cold stenothermal species inhabiting the sublittoral and profundal zones (Biesiadka and Kowalik, 1991). Both lake basins – Świdwie Wielkie and Świdwie Małe – are small and very shallow. The lack of well-developed sublittoral and profundal zones in lake basins of Świdwie Wielkie and Świdwie Małe eliminates many deep-water species of water mites associated with these zones, including indicators species of mesotrophy.

The most numerous synecological groups in lakes are small water body species and lake species. The proportions between these two groups may vary, but usually small water body species are dominant (Kowalik, 1978; Biesiadka, 1980; Biesiadka and Kowalik, 1991; Zawal, 1992; Cichocka and Biesiadka, 1994; Cichocka, 2000, 2005; Stryjecki, 2012). In the Hydrachnidia of the Świdwie Reserve the most numerous group was that of small water body species, but there was also a large percentage of lake species. The quantitative proportions of each synecological group were clearly linked to the limnological character of each of the water bodies. In Lake Świdwie Wielkie (macrohabitat A), the larger lake, lake species were dominant, while in Lake Świdwie Małe (macrohabitat B), the smaller lake, small water body species were dominant. In the lake margins (macrohabitat C), species associated with vernal astatic water bodies were dominant, which was a consequence of the character of this habitat (the presence of numerous temporary water bodies with well-developed astatic zones). Thus the structure of the Hydrachnidia communities in the various water bodies resulted from the limnological character of the macrohabitats.

To determine the degree of degradation of a water body we can use an indicator based on the ratio of the number of individuals belonging to small water body species to the number of individuals belonging to lake species (Cichocka and Biesiadka, 1994; Cichocka, 2000, 2005). This indicator is related to the trophic state of lakes and their degree of degradation. This indicator has been found to range from 0.15 to 4.8 in different Polish lakes (Cichocka and Biesiadka, 1994; Cichocka, 2000, 2005). The value of this indicator calculated for Lake Świdwie Wielkie indicates a very good ecological status of this water body. In Lake Świdwie Małe this indicator had low value, but this does not indicate a high trophic state or an advanced degree of degradation, but rather results from the limnological characteristics of this lake basin (a small, shallow water body lacking deep-water habitats enabling the development of lake species). The good ecological status of Lake Świdwie Wielkie is not only a consequence of its being protected as a reserve. Another small, shallow, overgrown lake, Lake Drążynek, is also protected as a reserve, but it is highly eutrophic and its fauna is very clearly dominated by small water body species (Zawal, 1992). In both Lake Świdwie Wielkie and Lake Drążynek the process of overgrowth is observed, but Lake Drążynek is at a much more advanced stage of succession, which is evidenced by analysis of its bottom sediments and of its Hydrachnidia (Zawal, 1992; Konieczna and Kowalewski, 2009). Thus the considerable share of lake species in Lake Świdwie Wielkie may be due to a less advanced state of successional changes and the preservation of a more lacustrine character than in the case of Lake Drążynek, which in terms of its habitats and fauna is becoming similar to small eutrophic water bodies. Lake Świdwie Wielkie, due to the taxonomic composition of its fauna, the quantitative proportions of synecological groups, the high

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variation in mesohabitats, its good ecological status, its stage of succession and the negligible degree of human impact, can be regarded as a reference for this type of water body (shallow lakes). Comparison of the fauna of other shallow lakes with the fauna of Lake Świdwie Wielkie may provide information on the scale and direction of changes taking place in such lakes.

The littoral is the zone of the lake with the greatest diversity of Hydrachnidia and the species composition in the littoral is influenced by the spatial arrangement of habitats (Pieczyński, 1976; Biesiadka and Kowalik, 1991). Thus it is expedient to determine assemblages of species inhabiting particular mesohabitats present in the littoral zone. Two clusters stand out in the faunal similarity between the mesohabitats of the Świdwie Reserve. The first cluster comprises elodeid habitats. The similarity between the fauna of the elodeid mesohabitats can also be seen in the CCA diagram. Despite the different plant species making up these mesohabitats (the Charophyta community and that of *Ceratophyllum* and *Myriophyllum*), the fauna inhabiting those two mesohabitats was very similar. Thus the primary factor grouping the fauna was the presence of underwater meadows with macrophytes, while the specific plant species in the meadows was a secondary factor. The second cluster comprises two habitats within the rushes – *Thelypteris-Phragmites* and *Phragmites-Typha*. As in the case of the underwater meadows, the similarity between the fauna inhabiting mesohabitats Thel-Ph and Ph-Typh was the result of the similar structure of these mesohabitats, i.e. the presence of rushes.

The Hydrachnidia of the *Phragmites*-Close mesohabitat (Ph-Close) was markedly distinct from other mesohabitats. The faunal distinctness of the Ph-Close mesohabitat is a consequence of the completely different habitat conditions prevailing there. Because some of the water bodies within the Ph-Close mesohabitat were temporary, a characteristic component of the fauna caught here were species of the genera *Hydryphantes*, *Parathyas* and *Tiphys*, associated with astatic water bodies (Smit and van der Hammen, 2000; Di Sabatino *et al.*, 2010; Gerecke *et al.*, 2016). In this mesohabitat the most individuals and the most species were caught and species diversity index was the highest. The large number of species and individuals and the high biodiversity noted in the Ph-Close mesohabitat confirm the observations of other authors that habitats with well-developed astatic zones are frequently inhabited by diverse and often distinctive fauna, differing from that found in other habitats (Biesiadka, 1980; Zawal, 1992; Cichocka and Biesiadka, 1994; Biesiadka, 2003).

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Table 1. Species composition and numbers of water mites collected in macro- and mesohabitats of the Lake Świdwie ecosystem. Mesohabitats: Ph-Typh – *Phragmites-Typha*, Thel-Ph – *Thelypteris-Phragmites*, Ph-close – *Phragmites*-close, Cer-Myr – *Ceratophyllum* and *Myriophyllum*, Chara – Charophyta. Macrohabitats: A – the basin of Lake Świdwie Wielkie, B – the basin of Lake Świdwie Małe, C – the Świdwie margins. Σ – sum.

Species	abbr.	Ph-Typh	Thel-Ph	Ph-close	Cer-Myr	Chara	A	B	C	Σ
Hydrachna comosa Koen.	Hyd com			2					2	2
H. conjecta Koen.	Hyd con		1	4			2	3		5
H. cruenta Müll.	Hyd cru		4				4			4
H. globosa (Geer)	Hyd glob	1		1			1	1		2
Hydrachna sp.	Hyd deu				1				1	1
Limnochares aquatica (L.)	Lim aqu	22	21	1	7	1	30	16	6	52
Eylais non det.	Eyl non			3			2		1	3
Piersigia intermedia Williams.	Pie int			1					1	1
Hydryphantes dispar (Schaub)	Hyd dis		1		1		1	1		2
H. hellichi Thon	Hyd hel	1		13			1		13	14
H. octoporus Koen	Hyd oct			1	1				2	2
H. tenuipalpis Thon	Hyd ten			15					15	15
Hydryphantes non det.	Hyd non	4		67					71	71
Hydrphantes sp.	Hyd spc	2		25			2		25	27
Parathyas barbigera (Viets)	Par bar			7					7	7
P.pachystoma (Koen.)	Par pac	4		59			3		60	63
P. palustris (Koen.)	Par pal			1					1	1
Euthyas truncata (Neum.)	Eut tru	1		3					4	4
Hydrodroma despiciens (Müll.)	Hyd des	6	45	2	36	23	62	50		112
Oxus longisetus (Berl.)	Oxu lon				3			3		3
O. musculus (Müll.)	Oxu mus			1	3	28	29	3		32
O. ovalis (Müll.)	Oxu ova	2	2				2	2		4

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O. strigatus (Müll.)	Oxu str	2	4				4	2		6
O. tenuisetis Piers.	Oxu ten				3	2		4	1	5
Oxus sp.	Oxu deu				3	2	2	2	1	5
Torrenticola sp.	Tor spe				1			1		1
Limnesia connata Koen.	Lim con	8	2		7		4	6	7	17
L. curvipalpis Tuzovskij	Lim cur			3	3			6		6
L. fulgida Koch	Lim ful	22	26	35	38		43	26	52	121
L. maculata (Müll.)	Lim mac	20	53	11	66	19	81	82	6	169
L.a undulatoides Davids	Lim und	1	17	5	9	16	39	9		48
Limnesia sp.	Lim deu	8	135	8	21	13	37	145	3	185
Hygrobates longipalpis (Herm.)	Hyg lon	1							1	1
Unionicola crassipes (Müll.)	Uni cra	20	18	20	35	75	143	20	5	168
U. gracilipalspis (Viets)	Uni gra	1			1		1	1		2
U.a minor (Soar)	Uni min	2					2			2
Unionicola sp.	Uni deu			2			1	1		2
Neumania deltoides (Piers.)	Neu del			1	1		1		1	2
Neumania spinipes (Müll.)	Neu spi	4		5	1		1	1	8	10
Piona alpicola (Neum.)	Pio alp	3		11					14	14
P. carnea (Koch)	Pio car			7					7	7
P. clavicornis (Müll.)	Pio cla			1					1	1
P. coccinea (Koch)	Pio coc		1	11	17	1	8	22		30
P. conglobata (Koch)	Pio con	10	9	24	5		25	21	2	48
P. longipalpis (Krend.)	Pio lon	2	1	2	1		6			6
P. nodata (Müll.)	Pio nod	3		18			3		18	21
P. paucipora (Thor)	Pio pau		1	3			1		3	4
P. pusilla (Neum.)	Pio pus	12	3	55	6	6	42	22	18	82
P. stjoerdalensis (Thor)	Pio stj	4	3	14	38	25	45	38	1	84
P. variabilis (Koch)	Pio var	12	26	31	37	16	65	57		122
Piona non det.	Pio non		7	2	4		11	2		13
Piona sp.	Pio deu	21	31	43	62	47	97	76	31	204
Hydrochoreutes krameri Piers.	Hyd kra	14	8	6	8	25	40	20	1	61
Tiphys latipes (Müll.)	Tip lat			1					1	1
T. ornatus Koch	Tip orn			76			1		75	76
Tiphys sp.	Tip deu	1		1	6				8	8
Pionopsis lutescens (Herm.)	Pio lut	3		12			3		12	15
Forelia liliacea (Müll.)	For lil	6	2	24	9	19	30	22	8	60
F. longipalpis Maglio	For lon	1							1	1
Axonopsis complanata (Müll.)	Axo com	3				1	4			4
Brachypoda versicolor (Müll.)	Bra ver	132	129	1	31	88	305	3	73	381
Mideopsis orbicularis (Müll.)	Mid orb	15	1	11	16	20	37	13	13	63
Arrenurus batillifer Koen.	Arr bat	10	7	29	11	1	16	6	36	58
A. bicuspidator Berl.	Arr bic	6	3	6	37	21	45	27	1	73
A. bifidicodulus Piers.	Arr bif	12		66	2		12		68	80
A. bisulcicodulus Piers.	Arr bis			11					11	11
A. bruzelii Koen.	Arr bru	2	3	11	7		3	4	16	23
A. buccinator (Müll.)	Arr buc	4		20	8		3		29	32
A. crassicaudatus Kram.	Arr cra			1				1		1
A. cuspidator (Müll.)	Arr cus	5		8			6	1	6	13
A. fimbriatus Koen.	Arr fim		2	6			2		6	8
A. globator (Müll.)	Arr glo	25	70	65	70	16	103	97	46	246
A. inexploratus Viets	Arr ine	12		41			10		43	53
A. integrator (Müll.)	Arr int	12	1	39			10		42	52

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A. latus Barr. et Mon.	Arr lat	4	2	78	31		56	20	39	115
A. maculator (Müll.)	Arr mac	2		30	3			6	29	35
A. mediorotundatus Thor	Arr med			1					1	1
A. perforatus George	Arr per	8		5	69	93	137	34	4	175
A. radiatus Piers.	Arr rad			1					1	1
A. sinuator (Müll.)	Arr sin	3	3	24	17	2	14	15	20	49
A. tetracyphus Piers.	Arr tet				2			2		2
A. tricuspidator (Müll.)	Arr tri	2	50		19	8	66	13		79
A. truncatellus (Müll.)	Arr tru	2		19					21	21
A. virens Neum.	Arr vir			3					3	3
Arrenurus non det.	Arr non	1	1	5		1	3		5	8
Arrenurus sp.	Arr deu		1	5	5	18	19	2	8	29
Number of specimens		484	694	1124	762	587	1726	909	1016	3651
Number of species		46	32	59	38	22	49	39	53	73
Shannon index		1.02	1.61	1.63	1.35	0.99	1.37	1.55	1.49	1.58

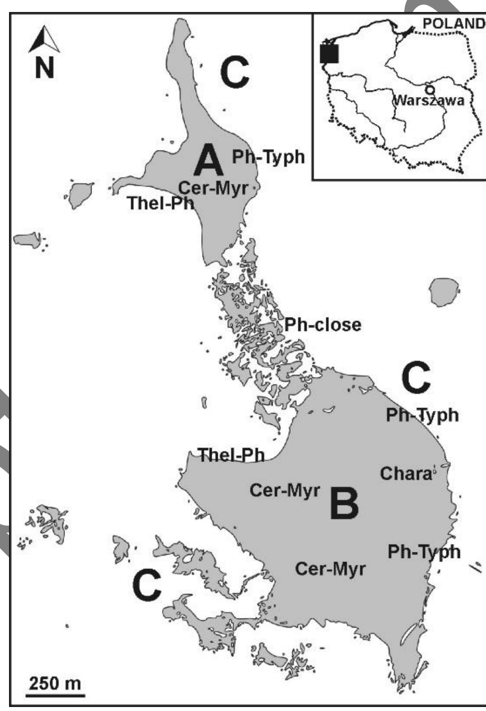

Figure 1. Map of Lake Świdwie. For abbreviations see Table 1.

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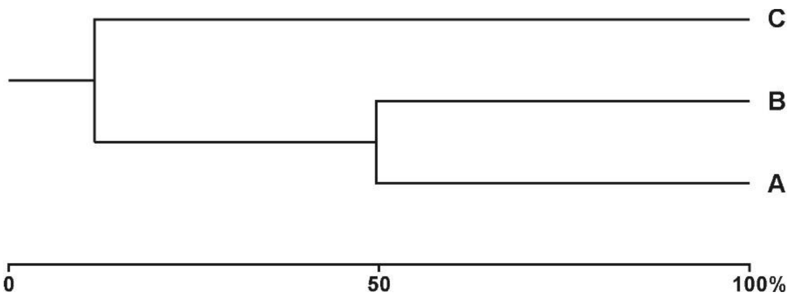

Figure 2. Faunal similarities between macrohabitats (A-C). For abbreviations see Table 1.

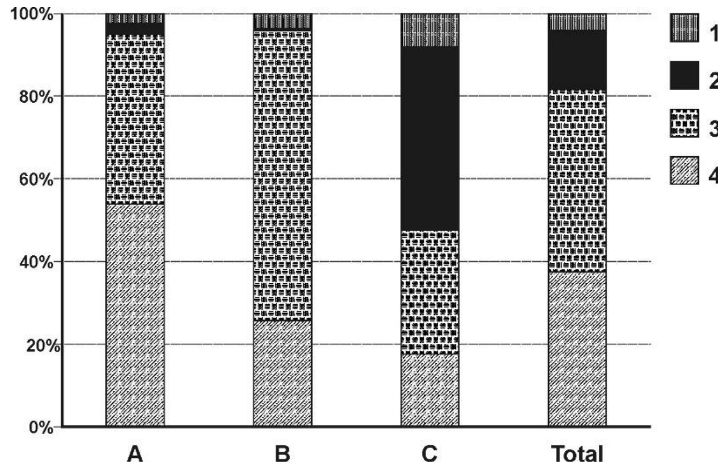

Figure 3. Percentage share of synecological groups in the macrohabitats investigated in the Świdwie Reserve. A-C – macrohabitats (see Table 1), Total – the total material collected, 1-4 – synecological groups (1 – tyrphobionts and tyrphophiles, 2 – vernal astatic water body 580 species, 3 – small water body species, 4 – lake species).

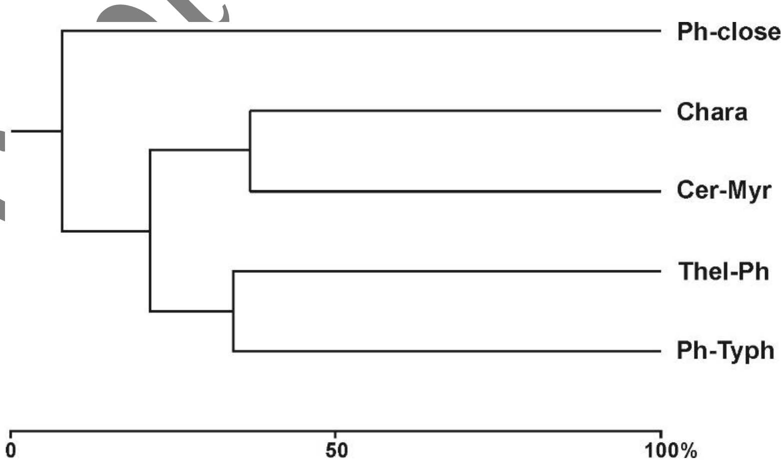

Figure 4. Faunal similarities between mesohabitats. For abbreviations see Table I.

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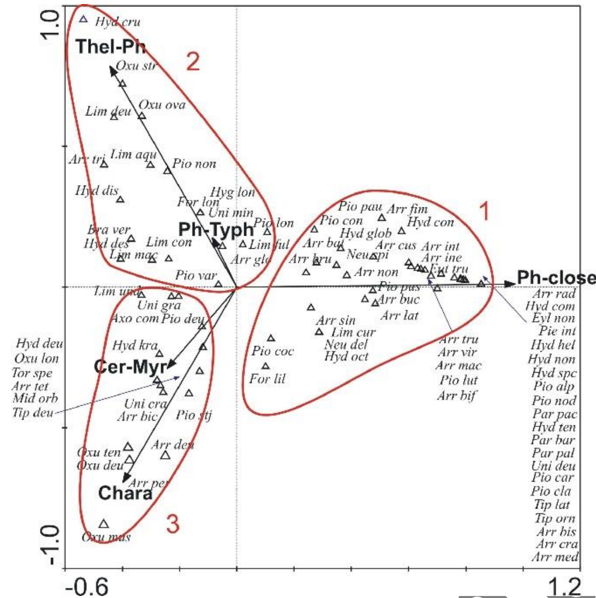

Figure 5. CCA diagram displaying the relationship between the composition of water mite taxa and different types of mesohabitats.