DE GRUYTER OPEN

BIOLOGICAL LETT. 2014, 51(2): 93–102
Available online at: http:/www.degruyter.com/view/j/biolet DOI: 10.1515/biolet-2015-0009

Mites (Acari) at the edges of bog pools in Orawa–Nowy-Targ Basin (S Poland), with particular reference to the Oribatida

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(*Received on 9 June 2014; Accepted on 8 June 2015*)

Abstract: Mites, and among them especially the Oribatida, are very abundant in bogs, being good bioindicators of various changes, but little is known about their reaction to heavy industrial exploitation of bogs. This study aimed to compare the acarofauna of the edges of small pools located in 2 bogs of Orawa–Nowy-Targ Basin (Kotlina Orawsko-Nowotarska), namely Łysa Puścizna (LP) and Bór Podczerwony (BP), degraded to different degrees by peat exploitation. The area of bog LP has decreased since the end of the 19th century by 34%, while that of BP has decreased during this time drastically (by 68%). Water in both studied pools differed from that in natural bogs, reported in the literature, especially in pH, colour, and oxygen conditions (COD and BOD_5), and these differences were more pronounced at BP. The abundance of mites was similar to that observed in natural bogs, and the Oribatida dominated among mites, constituting over 99% of them. The species diversity of Oribatida was low in both pools, but especially in pool BP. In both bogs the aquatic species were the most abundant due to the wet study season. The species structure of Oribatida differed, however, from that reported from natural bogs as well as from each other. At the less degraded bog LP the most abundant was *Hydrozetes lacustris* (D = 69%), while at bog BP, with worse water parameters, *Trimalaconothrus maior* highly dominated (D = 93%). This suggests that the latter species is very tolerant to water parameters, being a successful coloniser of degraded bogs.

Keywords: Acari, Oribatida, Mesostigmata, Prostigmata, bog, ecology, species diversity

INTRODUCTION

Bogs have many important functions in the environment. First of all, they regulate water conditions in the landscape, as they accumulate water in wet seasons and let it run in dry seasons. They also serve as natural filters, binding toxic organic substances and heavy metals to sediments and thus cleaning water. Moreover, bogs create interesting habitats, with the specific flora and fauna, and thus increase the landscape biodiversity (Tobolski 2000; Namura-Ochalska 2008). They are also of high economic value, e.g. producing peat or berries. However, intensive peat extraction and the associated bog drainage lead to the degradation of bogs and result in the loss of their values, including the loss of biodiversity.

The bogs of the Orawa–Podhale region (within the current Polish borders) were in good condition until the second half the 19th century and at that time they covered about 4282 ha. Later, however, they were exploited intensively, which led to a decrease in their total area, disappearance of some bogs, and drying of the peat, and that in turn decreased their water retention capacity. The total area of bogs in Orawa–Podhale region decreased in 1894–2000 by 34% and their water accumulation was reduced by 30% (Łajczak 2006).

Mites, and among them especially the Oribatida, are very abundant in bogs, reaching the densities of several hundred thousand per m^2 (Seniczak 2011b). They are known to be good bioindicators of anthropogenic changes, like those caused e.g. by forest drainage, fertilization (Markkula 1981, 1982, 1986a, b) or trampling (Borcard & Matthey 1995). Little is known, however, about the effect of heavy industrial exploitation of bogs, like those in Orawa–Nowy-Targ Basin, on the mite communities.

The aim of this study was to compare the acarofauna at the edges of 2 peat pools located in bogs of Orawa–Nowy-Targ Basin in southern Poland, which were degraded to varying degrees by peat exploitation. We hypothesized that: (1) mite communities of degraded bogs differ from those of natural bogs, known from the literature; among the Oribatida we expected a shift towards eurytopic species; (2) mite communities differ between the 2 studied bogs, depending on their water conditions.

MATERIAL AND METHODS

Study area

Samples were taken from the edges of 2 peat pools located in unprotected bogs: Łysa Puścizna (hereafter referred to as pool LP) and Bór Podczerwony (pool BP), also known as Bór za Lasem Kaczmarka, in Orawa–Nowy-Targ Basin (Kotlina Orawsko-Nowotarska) in southern Poland. Both pools LP (49°25’47’’N; 19°42’50’’E, 650 m a.s.l.) and BP (49°25’80”N; 19°48’10’’E, 700 m a.s.l.) were small (ca. 2 m^2 each). Their edges were formed by the plant association *Eriophorum vaginatum-Sphagnum fallax* Hueck 1928. At pool LP, about 10% of the investigated area were covered by *Eriophorum angustifolium*, 60% by *Sphagnum fallax*, and 30% by *Polytrichum strictum* At BP, 95% were covered by *Sphagnum fallax*, while 5% by *Eriophorum angustifolium* Honck. (Krasicka-Korczyńska, unpublished data).

The bogs of Orawa–Nowy-Targ Basin were heavily exploited in 1894–2000, and that resulted in drastic changes in their area and water regime. Bog LP covers 101.25 ha, so its area has decreased by 34% in comparison to the year 1894. The average peat depth is 1.68 m and the maximum is 3.80 m. Bog BP today covers 116.25 ha, so its area has decreased by 68% in comparison to 1894. The mean peat depth in the part of the bog that was industrially exploited is 1.35 m, while the maximum peat depth of the part that was not exploited industrially is 3.65 m (Łajczak 2006).

Water analyses

For the water analyses, 3 dm^3 of water were taken from each pool. The samples were analysed in the authorized Laboratory of Environmental Protection (Naftobazy Baza Paliw No. 2) in Nowa Wieś Wielka. The measured parameters and used methods are given in Table 1.

Table 1. Physicochemical parameters of water in peat pools located in bogs in Orawa–Nowy-Targ Basin: Łysa Puścizna (LP) and Bór Podczerwony (BP)

Parameter	Method	Pool	
		LP	BP
pH	pH meter, PN-90/C-04540.01	4.5	3.6
Conductivity (mS/cm)	PN-EN 27888:1999	140.0	210.0
Colour (mgPt/l)	PN-EN ISO7887	42.4	130.9
COD (mgO_2/1)	PN-74/C-04578.03	114.2	218.4
BOD_5 (mgO_2/1)	PN-EN 1899-1:2002, PN-EN 1899-2:2002	5.4	9.1
Chlorides (mg/1)	PN-75/C-04617.02, PN-ISO 9297:1994	33.0	46.2
Sulphates (mg/1)	PN-74/C-04566.09	4.5	4.1
Total phosphorus (mg/1)	PN-88 C-04537/04, PN-EN 1189:2000	0.05	0.16
Total iron (mg/1)	PN-ISO 6332:2001	2.0	1.4

Mite analyses

From the edges of the pools, samples of *Sphagnum* mosses (each 100 cm^2 in area and 5 cm in depth) were taken in replicates of 10 in spring in 2009. The mites were extracted in Tullgren funnels and preserved in 70% ethanol. The nomenclature of the mite groups follows Lindquist et al. (2009), while that of Oribatida follows Weigmann (2006) and partly Behan-Pelletier (1989) and Seniczak et al. (2007).

The basic statistical analyses included the minimum, maximum, and mean values of mite abundance (*A*, in 10^3 individuals/m^2). For the other statistical analyses, the values were log-transformed ln (x+1) (Łomnicki 2010). Normality of the distribution was tested with the Kolmogorov-Smirnov test, while the equality of variance in different samples, with the Levene test. The assumption of normality or equality of variance was not met, so the non-parametric Kruskal-Wallis one-way analysis of variance (ANOVA) by ranks was used and then multiple comparison test average ranks were used. The level of significance for all statistical tests was accepted at α = 0.05. The Kruskal-Wallis test was followed by the Mann-Whitney *U* test. Statistical calculations were carried out with STATISTICA 10.0 software.

Additionally, the dominance (*D*) and constancy (*C*) indices of major oribatid species, the total number of species (*S*) of Oribatida, as well as Shannon (*H*'), Jaccard (*Ja*), and Renkonen (*Re*) indices of Oribatida were calculated.

RESULTS

Water in pool BP had lower pH but higher values of most other physicochemical parameters than water in pool LP (Table 1). The major differences were in water colour and phosphorus concentration, which were 3-fold higher in pool BP than in pool LP. Chemical oxygen demand (COD) and biological oxygen demand (BOD_5) were nearly 2-fold higher, while conductivity and concentration of chlorides were 1.5-fold higher in pool BP than in pool LP.

The analyses of acarofauna were based on 22 054 mites obtained from a total of 20 samples, including 21 950 oribatid mites (12 103 juveniles) of 36 species. In both bogs the Oribatida dominated among mites, making up over 99% of them. The second most abundant group in pool BP were the Mesostigmata, followed by ‘other Acari’ (represented mostly by Prostigmata), while in pool LP, ‘other Acari’ were followed by the Mesostigmata (Table 2). The abundance of all mites and of the Oribatida was 2-fold higher in pool BP than in pool LP. The number of species and the species diversity of Oribatida were low in both pools. The compared pools were also characterised by low values of Jaccard index (*Ja*) and Renkonen index (*Re*), respectively.

Table 2. Abundance (*A*, in 10^3 individuals/m^2) of some groups of Acari, number of species (*S*), Shannon (*H*’), Jaccard (*Ja*), and Renkonen (*Re*) indices of Oribatida in peat pools located in bogs in Orawa–Nowy-Targ Basin: Łysa Puścizna (LP) and Bór Podczerwony (BP). SD = standard deviation; *H* = result of Kruskal-Wallis analysis of variance (ANOVA) between LP and BP

	Pool LP	Pool BP	Kruskal-Wallis ANOVA	
			H	*p*
Abundance mean±SD (and range)				
Total Acari	71.2±0.5 (25.0-153.1)	149.3±0.4 (62.8-236.4)	8.251	0.004
Oribatida	71.0±0.5 (25.0-152.8)	148.5±0.4 (62.7-236.3)	8.252	0.004
Mesostigmata	0.0±0.0 (0.0-0.1)	0.8±0.5 (0.0-2.1)	3.150	0.046
Other Acari	0.2±0.2 (0.0-0.6)	0.1±0.0 (0.0-0.3)	0.773	0.379
Oribatida				
No. of species (*S*)	21	24		
Shannon index (*H*’)	0.959	0.387		
Jaccard index (*Ja*)	25%			
Renkonen index (*Re*)	17%			

Most of the recorded oribatid species had low abundance at the studied pools and only 5 of them had dominance indices above 1%: *Hydrozetes lacustris* (Michael, 1882), *Limnozetes ciliatus* (Schrank, 1803), *L. foveolatus* Willmann, 1939, *Trimalaconothrus foveolatus* Willmann, 1931, and *T. maior* (Berlese, 1910).

Interestingly, the compared pools differed significantly in the species composition of Oribatida (Table 3). In pool LP, *Hydrozetes lacustris* highly dominated (D = 69%), while *Trimalaconothrus foveolatus* was the second most abundant, followed by *Trimalaconothrus maior* and *Limnozetes foveolatus*. The other 17 species found in this pool had dominance indices below 1%. In pool BP, *T. maior* highly dominated the oribatid community, with a dominance index of 93%, and only 2 other species (*T. foveolatus* and *Limnozetes ciliatus*) out of the total of 24, had dominance indices above 1%.

Table 3. Abundance (A, in 10^3 individuals/m^2), dominance (D) and constancy (C) indices of major Oribatida (with $D > 1\%$) in peat pools located in bogs in Orawa–Nowy-Targ Basin: Łysa Puścizna (LP) and Bór Podczerwony (BP). SD = standard deviation; H = result of Kruskal-Wallis analysis of variance (ANOVA) between LP and BP. Species with $D \leq 1$ are listed under the table, with the abbreviation of the pool where they occurred

Species	Pool LP			Pool BP			Kruskal-Wallis ANOVA	
	A mean±SD and range	*D*	*C*	*A* mean±SD and range	*D*	*C*	*H*	*p*
Hydrozetes lacustris (Michael, 1882)	49.3±0.7 10.7-143.6	69.5	100	0.6±0.3 0.0-1.2	0.4	90	14.339	0.000
Limnozetes ciliatus (Schrank, 1803)	0.3±0.2 0.1-0.7	0.4	100	1.8±0.5 0.5-8.1	1.2	100	12.506	0.001
L. foveolatus Willmann, 1939	1.5±0.6 0.1-5.6	2.2	100	1.0±0.4 0.0-3.3	0.7	90	0.416	0.519
Trimalaconothrus foveolatus Willmann, 1931	11.2±0.6 3.1-34.0	15.8	100	5.7±0.5 1.9-13.8	3.8	100	3.025	0.082
T. maior (Berlese, 1910)	8.0±0.5 2.6-15.9	11.2	100	137.6±0.5 58.0-226.9	92.7	100	14.285	0.000

Achipteria coleoptrata (Linné, 1758) (LP); *Chamobates pusillus* (Berlese, 1895) (LP); *Dissorhina ornata* (Oudemans, 1900) (LP); *Eupelops occultus* (C. L. Koch, 1835) (BP); *E. plicatus* (C. L. Koch, 1836) (BP); *Fuscozetes fuscipes* (C. L. Koch, 1844) (BP); *Galumna obvia* (Berlese, 1915) (BP); *Hydrozetes octosetosus* Willmann, 1932 (LP); *Hypochthonius rufulus* C. L. Koch, 1835 (LP); *Limnozetes lustrum* Behan-Pelletier, 1989 (BP); *Liochthonius alpestris* (Forsslund, 1958) (BP); *L. furcillatus* (Willmann, 1942) (BP); *L. peduncularis* (Strenzke, 1951) (BP, LP); *Malaconothrus monodactylus* (Michael, 1888) (LP); *Mucronothrus nasalis* (Willmann, 1929) (LP); *Nanhermannia* cf. *coronata* Berlese, 1913 (BP); *Oppiella nova* (Oudemans, 1902) (BP, LP); *O. translamellata* (Willmann, 1923) (BP, LP); *Oribatula interrupta* (Willmann, 1939) (LP); *Pergalumna nervosa* (Berlese, 1914) (LP); *Pilogalumna tenuiclava* (Berlese, 1908) (LP); *Platynothrus peltifer* (C. L. Koch, 1839) (BP); *Punctoribates sellnicki* Willmann, 1928 (LP); *Scheloribates laevigatus* (C. L. Koch, 1836) (BP); *S. latipes* (C. L. Koch, 1844) (BP, LP); *S. quintus* Wunderle, Beck & Woas, 1990 (BP); *Suctobelbella acutidens lobata* (Strenzke, 1951) (BP); *S. palustris* (Forsslund, 1953) (BP); *Tectocepheus velatus* (Michael, 1880) (BP); *Trimalaconothrus sculptus* Knülle, 1957 (LP); *Zetomimus furcatus* (Pearce & Warburton, 1906) (BP)

DISCUSSION

Bogs offer extreme conditions to the mites living there, due to the waterlogged substrate and low pH. Acidic water is characteristic for bogs, as many *Sphagnum* species growing there decrease water pH (Rydin & Jeglum 2006). However, peat exploitation, connected with drainage, leads to a further decease in water pH and increase in the conductivity of water and its colour value (Banaś & Gos 2004). High water colour values result from the high amount of humic substances suspended in water and lead in turn to worse oxygen conditions (Rydin & Jeglum 2006).

Water of both studied pools differed from that of natural bogs and transitional mires studied in northern Poland (Seniczak 2011b), especially in pH, colour, COD and BOD_5, and these differences were more pronounced in pool BP. The differences among the studied bogs can be probably explained by different degrees of their exploitation (Łajczak 2006). Changed water conditions at degraded bogs did not affect mite density, which was similar as in the natural mires (where it ranged from 53.5 to 177.7 thousand individuals per m^2). The differences in mite abundance between bogs LP and BP can be explained by different species composition there.

In the studied pools the most abundant group of mites were the Oribatida, like in the mires in northern Poland, but the abundance of Mesostigmata differed between the natural mires and those degraded by human activity (Seniczak 2011b). In the natural mires, the Mesostigmata were less abundant than in the bogs degraded by peat exploitation, like bog BP studied here or bog Bagno Chlebowo studied earlier (Seniczak 2011b) or by drainage, like bog Kurze Grzędy (Seniczak 2011b). Similarly, Markkula (1982) observed in Finland that in a drained and fertilized bog the abundance of Mesostigmata increased. It seems that drier conditions in degraded bogs are more favourable for the Mesostigmata, as these mites avoid high humidity (Kaczmarek et al. 2006; Marquardt 2007).

In contrast, the Oribatida are abundant at water edges, in both natural and degraded bogs. However, very few species are adapted to these extreme conditions, and the species diversity of Oribatida in bogs is very low. The number of species in both pools was similar as in the natural mires (where it ranged from 22 to 33 species), while the Shannon (*H*') species diversity index at LP was comparable to that in the natural mires (0.70–2.20) (Seniczak 2011b), but in BP it was lower. Interestingly, the number of species was higher at pool BP (24) than at pool LP (21). In contrast, the Shannon species diversity index (*H*') was at pool LP 2.5-fold higher than at pool BP. That indicates a higher evenness of the species in pool LP.

The species structure of Oribatida differed between the natural mires and those degraded by various forms of human activity. In all the studied natural bogs in northern Poland the most abundant species was *Limnozetes foveolatus* Willmann, 1939, while in bog Bagno Chlebowo, degraded by peat exploitation, the most abundant was *Zetomimus furcatus* (Warburton & Pearce, 1905), followed by *Limnozetes lustrum* Behan-Pelletier, 1989. In bog Kurze Grzędy, degraded by drainage, the dominant was an eurytopic species, *Oppiella nova* (Oudemans, 1902), which was also abundant in exploited bogs in Gorkovskaya Oblast in Russia (Chistyakov 1972). In the present study both pools differed from the natural mires (Seniczak 2011b) as well as from each other.

In pool LP the most abundant was an aquatic species, *Hydrozetes lacustris*. This mite prefers very acidic water (Walgram 1976; Weigmann 2006; Weigmann & Deichsel 2006) and is often found on floating *Sphagnum* moss and algae (Willmann 1931; Popp 1962; Weigmann 2006; Weigmann & Deichsel 2006). It is parthenogenetic and reproduces by thelytoky, but seems to reproduce only in summer (Popp 1962; Seniczak 2011b). Interestingly, *H. lacustris* tolerated high concentrations of sulphur and poor oxygen conditions in the peat pool in bog Bagno Chlebowo and achieved high densities there, being accompanied by *H. octosetosus* (Seniczak 2011a, b), although another species, *H. longisetosus* S. Seniczak & A. Seniczak, 2009, was absent there, while it is the most abundant in the natural mires of northern Poland.

In pool BP the dominant species was *Trimalaconothrus maior*, which had a very high dominance index (92.7%). This species is able to live in bogs degraded by peat exploitation and was also found in the peat pool in Bagno Chlebowo (Seniczak 2011b), and in pool LP, but its abundance was far lower there than in pool BP, while its dominance was similar to that in pool LP. *Trimalaconothrus maior* lives mainly in oligotrophic mires (bogs) and was classified by Starý (1988) as a tyrphophile (i.e. species characteristic of bogs but not confined to them). It is an aquatic species and water conditions seem to be the limiting factor for it. In the studied humidity gradients it was always the most abundant in the moistest parts (Donaldson 1996; Seniczak 2011b). In bogs degraded by peat exploitation, water retention capacity is lower than in natural bogs, but in some seasons, after rainfalls, the water conditions can be favourable for some aquatic species, like *T. maior*. It is parthenogenetic like *Hydrozetes lacustris*, but in contrast to the latter species it reproduces throughout the year (Seniczak 2011b), so it is able to multiply quickly and can quickly colonize favourable habitats. *Trimalaconothrus maior* seems to be more tolerant to water parameters than *Hydrozetes lacustris*, as it was abundant in the more degraded bog, with worse water parameters.

The dominance of aquatic species at both bogs indicates good water conditions due to the wet study season. When comparing the obtained results with those from bog LP in spring 2008 (Seniczak et al. 2013), huge differences in the abundance of mites and the species structure of Oribatida can be seen. In spring 2008 the abundance of mites was only one third of that in spring 2009 studied here. In contrast to the present study, one year earlier the most abundant species, with the dominance index 40%, was *Trimalaconothrus foveolatus*, which is more tolerant of the humidity conditions (Seniczak 2011b). The second most abundant was eurytopic species *Oppiella nova* (Oudemans, 1902), with a dominance index of 21%, while the aquatic species were less abundant. These differences can be explained by different climatic conditions in both years, which affected in turn the water regime of bogs. In 2008, the mean annual temperature was 6.7°C and annual rainfall was 655.1 mm, while in 2009 the temperature was lower (5.9°C) but rainfall was higher (723.5 mm), so that probably improved the water conditions in the bog (Mistrzak 2013). In contrast to natural bogs, which have good water retention properties, the bogs degraded by human activity have a much lower capacity to accumulate water and they depend more on the climate. The lower temperature limits the evaporation, and high rainfall improves the water balance. The mites are sensitive indicators of humidity changes and quickly react to them by changing their abundance and community structure; therefore they seem to be a good tool for monitoring the conditions of the bogs.

CONCLUSIONS

1. The mite communities of degraded bogs differ from those of natural bogs known from the literature.
2. In degraded bogs the water conditions, and consequently the mite communities, depend to a large extent on the weather; if the water conditions are favourable due to a wet season, the aquatic Oribatida dominate, while in dry seasons, a shift towards eurytopic species is observed.
3. The species structure of Oribatida differed between the studied bogs. At the less degraded bog LP the most abundant was *Hydrozetes lacustris*, while at bog BP, with worse water parameters, *Trimalaconothrus maior* highly dominated. That suggests the latter species is more tolerant in respect of water conditions and is a good coloniser of degraded bogs.

Acknowledgements: We are grateful to Dr. Ewa Krasicka-Korczyńska (Department of Botany and Ecology, University of Sciences and Technology in Bydgoszcz) for the plant analyses at the study sites.

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