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Oribatid mites (Acari, Oribatida) and their seasonal dynamics in a floating bog mat in Jeziorka Kozie Reserve, Tuchola Forest (Poland)

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Abstract: The oribatid mite community from the edge of the *Sphagnum* mat of dystrophic K1 pond (Jeziorka Kozie Reserve, Poland), and its seasonal dynamics was studied in 2006 (29 May, 6 August and 22 October). In all seasons, *Limnozetes foveolatus* dominated, followed by *L. ciliatus*; abundant were also *L. lustrum*, *Trhypochthoniellus longisetus*, *Trhypochthonius nigricans*, and *Trimalaconothrus foveolatus*. In autumn, the mean density of Oribatida was significantly higher than in spring. The percentage of juvenile stages was generally low, but highest in summer (22%), while in the other seasons it was about half as high. *Metabelba sphagni* is new to the Polish fauna.

Keywords: seasonal dynamics, Acari, Oribatida, bog, *Sphagnum*, dystrophic pond, floating bog mat

INTRODUCTION

Bog ecosystems have been well studied by botanists but received only little attention from animal ecologists (Belanger 1976). Mites from bogs are also poorly known, although they are usually the most abundant and diverse group of invertebrates in this habitat (Popp 1962; Belanger 1976) and play an important role as decomposers (Kuriki 2008).

The aquatic Oribatida encompass only a small percentage of all oribatid species (less than 1%) but their abundance can be very high (Rajski 1961; Kuriki 2008; Schatz & Behan-Pelletier 2008). For example, at the edge of the *Sphagnum* mat of Lake Martwe in the Tuchola Forest in northwestern Poland, the density of Oribatida was 165 000 ind./m² (Seniczak et al. 2006b). This is in agreement with Peus (1932), who concluded that mires, particularly *Sphagnum* mats, are optimum biotopes for oribatid mites.

The seasonal dynamics of Oribatida has been studied for a whole year, in 2-month intervals, in a fen in southern Lithuania (Eitminavičiūtė 1966) and for shorter periods in raised bogs in the U.S.A. (Belanger 1976; Donaldson 1996). Kuriki (1993, 1995, 1996) studied in a mire at Yachidaira, Northeast Japan, the life cycle of *Trhypochthoniellus brevisetus* Kuriki, 2005 (as *Trhypochthoniellus setosus* Willmann, 1928), the dominant species, and also of *Limnozetes ciliatus* (Schrank, 1803) (Kuriki 2008).

The aim of this research was to study some parameters of the oribatid mite community of the *Sphagnum* mat of a dystrophic pond, its seasonal dynamics, and some parameters of species.

Study area

The study site is located in Jeziorka Kozie Reserve (Tuchola Forest, northwestern Poland). The reserve has an area of 12.3 ha and protects 3 dystrophic ponds. The mean annual precipitation is 500-600 mm, mean annual temperature is 7.5-8ºC, mean temperature of January ranges from –2 to –3ºC, while mean temperature of July, from 18 to 19ºC. The growing period lasts 210-220 days. It starts on average in early April and ends in early November (Boiński & Boińska 2003).

The studied K1 pond (53°41'20" N, 17°53'33" E) has an area of 0.64 ha, and is located at 119 m a. s. l. It is surrounded by pine-birch forest, in which Scots pine (*Pinus sylvestris* L.) dominates, and silver birch (*Betula pendula* Roth) is less abundant. Water of the pond is acidic (pH 5.0), and a floating *Sphagnum*-dominated mat partly covers its surface.

The sampling site was the plant community Rhynchosporetum albae. In total 8 species were found there, with dominant white beak-sedge Rhynchospora alba (L.) Vahl and flat-topped bog-moss Sphagnum fallax (Klinggr.) Klinggr. Relatively abundant was common cotton grass (Eriophorum angustifolium Honck., straw-coloured water moss Calliergon stramineum (Brid.) Kindb. and common cranberry Vaccinium oxycoccos L. Less abundant were: marsh cinquefoil Comarum palustre L., common sundew Drosera rotundifolia L. and milk-parsley Peucedanum palustre (L.) Moench (Boiński & Boińska 2003).

MATERIAL AND METHODS

Samples were taken in spring (29 May), summer (6 August), and autumn (22 October) of 2006. In each season, 10 samples of *Sphagnum fallax*, each 10 cm × 10 cm and 5 cm deep, were taken from the edge of the *Sphagnum* mat. The mites were extracted using a modified Tullgren funnel, and Oribatida were identified to species, including the juvenile stages. The names of species follow Weigmann (2006) and partly Subías (2004). Population of each species was characterized with the indices of abundance (A = number of mites of this species per m^2), dominance (D = % of the total number of oribatid mites) and constancy (C = % of samples with this species). The oribatid mite community was characterized by the number of species and Shannon index of diversity (Hs) (Odum 1982). For statistical analyses, the values were ln-transformed (Łomnicki 2010) and analyzed with the Kruskal-Wallis test, followed by the Mann-Whitney U test. The statistical calculations were carried out with STATISTICA 6 software.

RESULTS

In total, 60 782 mites were extracted, including 60 316 of Oribatida. The mean density of mites increased significantly from spring to autumn (Table 1). In all seasons, the dominant oribatid species was *Limnozetes foveolatus* Willmann, 1939, followed by *L. ciliatus* (Schrank, 1803); relatively abundant was also *L. lustrum* Behan-Pelletier, 1989, while *L. rugosus* (Sellnick, 1923) was infrequent (Table 2). High densities were reached also by members of Malaconothroidea: *Trhypochthoniellus longisetus* (Berlese, 1904), *Trhypochthonius nigricans* Willmann, 1928 and *Trimalaconothrus foveolatus* Willmann, 1931. In spring relatively abundant was *Hydrozetes longisetosus* S. Seniczak & A. Seniczak, 2009 and in summer, *Pilogalumna tenuiclava* (Berlese, 1908) and *Oppiella nova* (Oudemans, 1902).

Table 1. Abundance (in 10^3 ind./m²) and species diversity of mites in a floating bog mat in various seasons. SD = standard deviation. Superscripts denote significant differences between spring and summer (^{a}), spring and autumn (^{b}) and summer and autumn (^{c}) at $P \leq 0.05$

Index	Spring	Summer	Autumn
Oribatida abundance mean	153.58	170.01	280.89 ^{b}
Oribatida abundance range	36.80-392.50	54.10-310.00	38.70-552.60
Oribatida abundance SD	103.07	83.82	158.56
% of juveniles among Oribatida	13.42	21.72	12.83
Acari abundance mean	154.58	172.20	282.36 ^{b}
Acari abundance range	37.10-393.80	55.00-316.90	39.10-553.60
Acari abundance SD	103.28	84.97	158.43
Number of species of Oribatida	29	27	30
Shannon index of diversity (*H*s)	1.36	1.66	1.23

In total, 36 oribatid species were recorded, of which 50% were represented in samples both by adults and juveniles (Table 3), 16 species only by adults, whereas *Nothrus palustris* C. L. Koch, 1839 and *Scheloribates laevigatus* (C. L. Koch, 1836) only by juveniles. In the age structure of some species (genera *Hydrozetes* and *Limnozetes*, and *Oppiella nova*), adults predominated, while in others (*Trhypochthonius nigricans*, *Trimalaconothrus foveolatus*, *T. maior*) the juvenile stages were more abundant, irrespective of the season (Table 3). The highest percentage of extracted juvenile stages (22%) was recorded in summer, while in the other seasons it was about half as high.

Adults and juveniles of some species (*Hydrozetes longisetosus*, *H. octosetosus* Willmann, 1932, *Limnozetes rugosus*, *Punctoribates sellnicki* Willmann, 1928) achieved higher densities in spring than in other seasons, others (*Limnozetes lustrum*, *Mainothrus badius* (Berlese, 1905), *Nanhermannia* cf. *coronata* Berlese, 1913 and

Table 2. Abundance (A, in 10^3 ind./m²), constancy (C = % of samples), and dominance (D = % of total oribatid mites) in a floating bog mat in various seasons. Superscripts denote significant differences between spring and summer ([a]), spring and autumn ([b]) and summer and autumn ([c]) at $P \leq 0.05$. * Species with $A \leq 1$ are listed under the table, with abbreviations of the seasons when they occurred

Taxon	Spring (Sp)			Summer (Su)			Autumn (Au)		
	A	*C*	*D*	*A*	*C*	*D*	*A*	*C*	*D*
Hydrozetes longisetosus S. Seniczak & A. Seniczak, 2009	5.11	100	3.33	1.35[a]	100	0.79	1.09[b]	90	0.39
H. octosetosus Willmann, 1932	1.02	80	0.66	0.02[a]	20	0.01	0.04[b]	40	0.01
Limnozetes ciliatus (Schrank, 1803)	41.04	100	26.72	45.82	100	26.95	72.02	100	25.64
L. foveolatus Willmann, 1939	86.72	100	56.47	76.85	100	45.20	166.45	100	59.26
L. lustrum Behan-Pelletier, 1989	4.30	100	2.80	15.31[a]	100	9.01	9.89	100	3.52
L. rugosus (Sellnick, 1923)	1.11	100	0.72	0.53	80	0.31	0.21[bc]	50	0.07
Mainothrus badius (Berlese, 1905)	0.00	0	0.00	1.08	30	0.64	0.09	20	0.03
Nanhermannia cf. *coronata* Berlese, 1913	0.12	50	0.08	1.29	50	0.76	0.33	50	0.12
Oppiella nova (Oudemans, 1902)	0.37	70	0.24	2.54	70	1.49	0.84	70	0.30
Pilogalumna tenuiclava (Berlese, 1908)	1.20	50	0.78	3.82[a]	100	2.25	1.29[c]	80	0.46
Punctoribates sellnicki Willmann, 1928	1.14	80	0.74	0.37[a]	30	0.22	0.21[b]	70	0.07
Trhypochthoniellus longisetus (Berlese, 1904)	0.32	90	0.21	9.51[a]	100	5.59	6.36[b]	100	2.26
Trhypochthonius nigricans Willmann, 1928	4.53	100	2.95	6.74	80	3.96	2.89	90	1.03
Trimalaconothrus foveolatus Willmann, 1931	4.61	100	3.00	1.92[a]	100	1.13	16.04[bc]	100	5.71

* *Brachychthonius berlesei* Willmann, 1928 (Su); *Eupelops hygrophilus* (Knülle, 1954) (Sp, Au); *Platynothrus peltifer* (C. L. Koch, 1839) (Sp, Su, Au); *Hoplophthiracarus illinoisensis* (Ewing, 1909) (Sp, Su, Au); *Hydrozetes lacustris* (Michael, 1882) (Sp, Su, Au); *Hypochthonius rufulus* C. L. Koch, 1835 (Sp, Au); *Liochthonius alpestris* (Forsslund, 1958) (Sp, Su, Au); *L. peduncularis* (Strenzke, 1951) (Sp, Su, Au); *Metabelba sphagni* Strenzke, 1950 (Sp, Su, Au); *Moritzoppia translamellata* (Willmann, 1923) (Au); *Nothrus palustris* C. L. Koch, 1839 (Sp); *Parachipteria willmanni* Hammen, 1952 (Au); *Ramusella furcata* (Willmann, 1928) (Sp, Su, Au); *Scheloribates laevigatus* (C. L. Koch, 1836) (Su); *Suctobelbella latirostris* (Strenzke, 1950) (Sp, Su, Au); *S. longirostris* (Forsslund, 1941) (Sp); *S. palustris* (Forsslund, 1953) (Au); *S. sarekensis* (Forsslund, 1941) (Sp); *S. subcornigera* (Forsslund, 1941) (Sp, Su); *Trimalaconothrus maior* (Berlese, 1910) (Sp, Su, Au); *T. vietsi* (Willmann, 1925) (Sp); *Zetomimus furcatus* (Warburton & Pearce, 1905) (Su, Au).

Table 3. Seasonal mean abundance (*A*, in 10^3 ind./m²) and percentage of adults (ad) and juveniles (juv) of Oribatida in a floating bog mat. * Species with $A \leq 1$ are listed under the table. SD = standard deviation. Superscripts denote significant differences between spring and summer (^{a}), spring and autumn (^{b}) and summer and autumn (^{c}) at $P \leq 0.05$

Species		Spring		Summer		Autumn	
		A− mean±SD, range	%	*A*− mean±SD, range	%	*A*− mean±SD, range	%
Hydrozetes longisetosus	ad	2.72±1.14 1.1-5.4	53.2	1.25^a±1.44 0.0-4.7	92.6	0.99^b±1.24 0.0-3.6	90.8
	juv	2.39±3.87 0.0-12.1	46.8	0.10±0.15 0.0-0.4	7.4	0.1±0.09 0.0-0.3	9.2
H. octosetosus	ad	0.69±1.53 0.0-5.0	67.6	0.00^a	0.0	0.01^b±0.03 0.0-0.1	25.0
	juv	0.33±0.77 0.0-2.5	32.3	0.00	0.0	0.03±0.05 0.0-0.1	75.0
Limnozetes ciliatus	ad	36.35±26.70 15.9-105.3	88.6	38.44±22.33 4.7-7.8	83.9	60.03±46.96 10.4-145.7	83.3
	juv	4.69±4.86 0.3-16.3	11.4	7.38±5.49 0.1-15.8	16.1	11.99±10.53 1.6-36.8	16.6
L. foveolatus	ad	82.51±78.01 5.7-280.9	95.1	71.12±48.31 13.4-136.2	92.5	163.58±129.64 4.3-387.7	98.3
	juv	4.21±5.24 0.0-17.1	4.8	5.73±5.12 0.0-16.0	7.5	2.87±2.06 0.2-6.5	1.7
L. lustrum	ad	4.15±2.97 0.3-9.6	96.5	12.29±8.23 0.5-26.9	80.3	8.45±7.78 1.0-25.8	85.4
	juv	0.15±0.24 0.0-0.6	3.5	3.02^a±2.85 0.0-9.5	19.7	1.44^b±1.13 0.0-3.3	14.6
L. rugosus	ad	1.02±0.83 0.2-2.8	91.9	0.52±0.41 0.0-1.3	98.1	0.18^b±0.26 0.0-0.8	85.7
	juv	0.09±0.22 0.0-0.7	8.1	0.01±0.03 0.0-0.1	1.9	0.03±0.05 0.0-0.1	14.3
Mainothrus badius	ad	0.00	0.0	0.31±0.95 0.0-3.0	28.7	0.06±0.20 0.0-0.6	66.7
	juv	0.00	0.0	0.77±2.40 0.0-7.6	71.3	0.03±0.07 0.0-0.2	33.3
Nanhermannia cf. *coronata*	ad	0.05±0.07 0.0-0.2	41.7	0.87±1.53 0.0-4.4	67.4	0.23±0.50 0.0-1.6	69.7
	juv	0.07±0.16 0.0-0.5	58.3	0.42±0.77 0.0-2.2	32.6	0.10±0.17 0.0-0.5	30.3
Pilogalumna tenuiclava	ad	0.34±0.51 0.0-1.5	28.3	1.65^a±1.69 0.0-5.0	43.2	0.75±1.04 0.0-3.4	58.1
	juv	0.86±1.18 0.0-3.6	71.7	2.17±1.90 0.0-5.7	56.8	0.54^c±0.57 0.0-1.7	41.9
Punctoribates sellnicki	ad	0.38±0.38 0.0-1.1	33.3	0.23±0.57 0.0-1.8	62.2	0.21±0.21 0.0-0.6	100.0
	juv	0.76±0.58 0.0-1.6	66.7	0.14^a±0.29 0.0-0.9	37.8	0.00^b	0.0

Trhypochthoniellus longisetus	ad	0.12±0.15 0.0-0.5	37.5	0.73[a]±0.99 0.0-2.8	7.7	3.94[bc]±3.51 0.1-11.3	61.9
	juv	0.20±0.33 0.0-1.1	62.5	8.78[a]±6.56 0.3-19.1	92.3	2.42[b]±3.47 0.0-11.7	38.0
Trhypochthonius nigricans	ad	1.68±1.10 0.5-4.0	37.1	0.43[a]±0.74 0.0-2.4	6.4	0.51[b]±0.51 0.0-1.4	17.6
	juv	2.85±3.36 0.5-11.7	62.9	6.31±8.29 0.0-23.0	93.6	2.38±2.20 0.0-7.1	82.3
Trimalaconothrus foveolatus	ad	1.11±0.72 0.1-1.9	24.1	0.22[a]±0.30 0.0-0.9	11.5	2.87[bc]±1.80 0.3-5.7	17.9
	juv	3.50±1.84 1.5-6.9	75.9	1.70±0.96 0.2-3.0	88.5	13.17[bc]±8.87 4.0-31.9	82.1

* *Platynothrus peltifer*, *Hydrozetes lacustris*, *Hypochthonius rufulus*, *Oppiella nova*, *Trimalaconothrus maior*

Pilogalumna tenuiclava) were most abundant in summer, and others yet (*Limnozetes ciliatus* and *Trimalaconothrus foveolatus*), in autumn. In some species adults and juveniles achieved highest abundance in different seasons; for example juveniles of *Limnozetes foveolatus*, *Trhypochthoniellus longisetus* and *Trhypochthonius nigricans* were most abundant in summer, while adults of two former species were most abundant in autumn and of *T. nigricans*, in spring.

Interestingly, the juveniles of some closely related species reached their maximum densities in different seasons. For example juveniles of *Limnozetes foveolatus* and *L. lustrum* were most abundant in summer, those of *L. ciliatus* in autumn, and *L. rugosus*, in spring. Some members of Malaconothroidea (*Trhypochthoniellus longisetus* and *Trhypochthonius nigricans*) were the most abundant in summer, *Trimalaconothrus maior* in spring, while *T. foveolatus*, in autumn. Based on the species list of Olszanowski et al. (1996) and Niedbała & Olszanowski (2008), *Metabelba sphagni* Strenzke, 1950 is new to the Polish fauna.

DISCUSSION

Three major environmental factors are a challenge for plants and animals in bogs: (1) waterlogged substrate; (2) low level of nutrients; and (3) fluctuations of temperature and moisture content (Belanger 1976). The extreme habitats, either very wet or dry, are suitable for only few species, which occur there in high numbers (Tarras-Wahlberg 1961; Belanger 1976; Borcard 1997). The edge of the *Sphagnum* mat is a very wet habitat, where the species diversity of Oribatida is rather low, while their abundance is high (Rajski 1961; Donaldson 1996; Seniczak et al. 2006a, b). This is confirmed by this study.

The most abundant species, *Limnozetes foveolatus*, was also abundant (as *L. palmerae* Behan-Pelletier, 1989) in North American bogs (Donaldson 1996) and at Lake Martwe in Tuchola Forest, Poland, where it made up 64% of all Oribatida (Seniczak et al. 2006b). *Limnozetes foveolatus* is the smallest species of the genus *Limnozetes*, with the body length range of 266-292 μm (Behan-Pelletier 1989;

Seniczak & Seniczak 2009). Donaldson (1996) concluded that the small body size might be an advantage for an oribatid mite, which can then find more habitable spaces to feed or avoid predators (Walter & Norton 1984). The second most abundant was *L. ciliatus*, like in the studies of Donaldson (1996) and Seniczak et al. (2006b). At Lake Martwe in the Tuchola Forest, only 2 species from the genus *Limnozetes* were found (Seniczak et al. 2006b), while in this study 4 species were recorded. Coexistence of several species from the same genus indicates a more advanced stage of succession (Skubała 2004).

Relatively abundant were also *Trhypochthoniellus longisetus*, *Trhypochthonius nigricans* and *Trimalaconothrus foveolatus*. Kehl (1997) studied in detail the ecology of Malaconothroidea from bogs, and found that some species, including *Trhypochthoniellus longisetus* and *Trhypochthonius nigricans*, were restricted to floating *Sphagnum* mats, with very wet and oligotrophic conditions. *Trimalaconothrus foveolatus* was among the species well adapted to wet and oligotrophic conditions, but with wider ecological tolerance.

Most studies on bogs have shown that Oribatida were most abundant in autumn or early winter, and this was also confirmed in this study. Eitminavičiūtė (1966) found that seasonal dynamics of Oribatida varied in the biotopes situated at various distances from open water in a fen in southern Lithuania. Oribatid mites more distant from open water were the most abundant in June, while at the water's edge, in December (Eitminavičiūtė 1966). The study of Belanger (1976) covered a shorter period of time, from 11 September to 26 October, at weekly intervals, but showed the highest abundance of Oribatida in the last sampling session. In contrast, Donaldson (1996) did not find any significant seasonal changes, neither in mite density nor in species diversity, but her sampling was done earlier, on 21 April, 9 June, and 30 July. Also in the present study the abundance of Oribatida was similar in spring and summer, while in late autumn it was almost twice as high.

Donaldson (1996) noticed significant seasonal differences in mites from the genus *Limnozetes*; *L. foveolatus* and *L. ciliatus* were the most abundant in early spring, while other species in early or late summer. Also in this study *Limnozetes* spp. showed different seasonal patterns; the density of *L. foveolatus* and *L. ciliatus* was the highest in autumn, while *L. lustrum* in summer, and *L. rugosus* in spring. A high density of *L. ciliatus* in autumn can be easily explained by its high reproduction in summer. The fecundity of this species was much higher at 25ºC than at 20ºC, and the adults collected from the field showed seasonal differences in their fecundity, with the highest value in summer and the lowest in autumn (Kuriki 2008). Similar patterns of seasonal dynamics have been noticed for 2 dominant oribatid species in a mire in Japan, *Trhypochthoniellus brevisetus* and *Limnozetes ciliatus*, with a peak in spring to early autumn, and a decrease during colder seasons (Kuriki 2008).

Also some members of Malaconothroidea had their maximum abundance in different seasons; *Trhypochthoniellus longisetus* and *Trhypochthonius nigricans* were the most abundant in summer, *Trimalaconothrus maior* in spring, and *T. foveolatus* in autumn. Different seasonal dynamics might be explained as a strategy to facilitate the coexistence of species that have similar ecological requirements (Seniczak & Seniczak 2006).

CONCLUSIONS

The density of Oribatida was significantly higher in autumn than in spring, while species diversity did not show any seasonal variation. In all seasons *Limnozetes foveolatus* dominated, followed by *L. ciliatus*; relatively abundant were *L. lustrum*, *Trhypochthoniellus longisetus*, *Trhypochthonius nigricans*, and *Trimalaconothrus foveolatus*. The percentage of juvenile stages was generally low but higher in summer (22%), which was connected with the reproductive season of the dominant species.

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