



Contribution to succession of mite (Acari) communities in the soil of *Tilio-Carpinetum* TRACZ. 1962 in northern Poland*

Katarzyna FALEŃCZYK-KOZIRÓG, Sławomir KACZMAREK, Tomasz MARQUARDT,
and Katarzyna MARCYSIAK

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Abstract. Research on the mite (Acari) succession was carried out within six deciduous forest stands of various ages dominated by lime trees (*Tilia cordata* MILL.). The general mite density was correlated with the age of each stand ($r=0.596$). Four orders of mites were recorded – the Cryptostigmata were dominant and their abundance initially decreased and then increased following the ageing of the forest stands. A similar tendency was recorded for the Mesostigmata. The abundance of the Astigmata presented a general increasing tendency and was positively correlated with the age of the forest stands. High correlations noted between the density of the Cryptostigmata, Mesostigmata and Prostigmata can indicate trophic and competitive relations between those mite communities. Among the families belonging to the Mesostigmata four succession trends of abundance and percentage share changes were found: creative (Macrochelidae and Trematuridae), regressive (Ascidae), rise and fall (Pachylaelapidae, Parasitidae, Veigaiidae and Laelapidae) and restorative (Rhodacaridae).

Key words: soil mites, oak-hornbeam forests, succession trends.

✉ Katarzyna FALEŃCZYK-KOZIRÓG, Kazimierz Wielki University, Institute of Environmental Biology, Department of Zoology, Ossolińskich Av. 12, PL-85-094 Bydgoszcz, Poland. E-mail: kasia.fk@ukw.edu.pl

Sławomir KACZMAREK, Kazimierz Wielki University, Institute of Environmental Biology, Department of Zoology, Ossolińskich Av. 12, PL-85-094 Bydgoszcz, Poland. E-mail: slawkacz@ukw.edu.pl

Tomasz MARQUARDT, Kazimierz Wielki University, Institute of Environmental Biology, Department of Zoology, Ossolińskich Av. 12, PL-85-094 Bydgoszcz, Poland. E-mail: tmarq@ukw.edu.pl

Katarzyna MARCYSIAK, Kazimierz Wielki University, Institute of Environmental Biology, Department of Botany, Ossolińskich Av. 12, PL-85-094 Bydgoszcz, Poland. E-mail: marc@ukw.edu.pl

I. INTRODUCTION

Ecological succession is a process of dynamic changes occurring in ecosystems (TROJAN et al. 1994). Its hierarchic character consisting in the processes taking place at lower organization levels influencing the phenomena apparent at general scale was presented by

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SHUGART (1984) and PRENTICE (1986). Succession changes in zoocenoses can result from e.g. the changes of species composition or the structure and abundance of communities, which help to characterize and interpret those processes.

This paper aims at determining the character and direction of succession changes in soil mite communities populating forest stands dominated by lime trees (*Tilia cordata* MILL.) in *Tilio-Carpinetum* TRACZ. 1962 plant community.

II. STUDY AREA

The research was carried out in northern Poland, in the area of Kwidzyn Forestry Commission, within Iława Lake District and Kwidzyn Valley (KONDRACKI 2009). The study included six forest stands of different ages (16 years old-2.27 ha, 35 yrs-0.94 ha, 57 yrs-1.2 ha, 80 yrs-1.04 ha, 102 yrs-1.64 ha and 125 yrs-2.35 ha) and dominated by small-leaved lime trees (*Tilia cordata* MILL.) in *Tilio-Carpinetum* TRACZ. 1962 community (sub-continental oak-hornbeam forest). Distances between studied stands were sufficient to state that the mite species composition of each stand was not influenced by the others.

Studied habitat remains under clear influence of forest economy consisting in unifying the species and ages of the forest stand. Altogether 77 plant species were recorded there, including 39 of *Quercus-Fagetea* class. Generally in each stand apart from lime trees there also occur single pedunculate oaks and trembling aspens and the all studied stands do not have the multilevel and multispecies structure which is characteristic of oak-hornbeam forests. The shrub layer is not particularly rich and its species composition is simplified. It is created by small-leaved lime trees with largely consistent occurrence of beech trees, less frequently hornbeam, hazel or common maple. The undergrowth's physiognomy is typical of an oak-hornbeam forest – it is luxuriant, multileveled and multispecies.

III. MATERIAL AND METHODS

Samples for the study were collected in autumn 2006 and spring 2007. There were 100 samples collected from each forest stand, 50 cm³ each, including 20 samples from the litter and each of the four artificially marked organic-mineral levels (each 5 cm thick), up to depth of 20 cm.

Overall, there were 1 200 samples (6 stands x 2 seasons x 100 samples), from which after a six-day extraction in Tullgren funnels 15 297 mites were obtained. All the mites were identified to the order level (according to EVANS 1992), and the Mesostigmata to the family level, including all developmental forms.

Zoocenological analysis was performed using the indices of abundance (A in ind./m²) and share (D in %) (MAGURRAN 1988). Statistical significance of the differences in abundance distribution of particular mite orders between the studied forest stands was assessed by one-way ANOVA with Bonferroni post-hoc test using Statistica 10 (WINER et al. 1991). Correlation between the age of the forest stand and the density of mite orders was assessed using Pearson's correlation coefficient (ŁOMNICKI 2010). Abundance fluctuations of selected mite families were shown using polynomial curves fitting (second degree polynomial equations) prepared in MS Excel 2007

IV. RESULTS

General mite density in all the studied forest stands was positively correlated with the age of the stand ($r=0.596$), and statistically significant differences in the mite abundance distribution were only recorded between the two oldest forest stands (Table I and II).

Four mite orders were recorded within the studied area: Cryptostigmata, Prostigmata, Astigmata and Mesostigmata (Table I). The Cryptostigmata were dominant and their abundance initially decreased from 26 915 ind./m² (in the 16 year old forest stand) to

Table I

Abundance (A in ind./m²) of the Acari, Cryptostigmata, Prostigmata, Mesostigmata, and Astigmata and statistical significance of the differences in abundance distribution (ns – statistically not significant; ** $p<0.01$; *** $p<0.001$) between the studied forest stands

	Age of the tree stand [yrs]											
	16		35		57		80		102		125	
Acari	38 380	ns →	36 519	ns →	33 573	ns →	38 174	ns →	39 027	*** →	41 953	
Cryptostigmata	26 915	ns →	26 458	ns →	24 124	ns →	14 923	** →	27 607	ns →	27 751	
Mesostigmata	7 742	ns →	6 001	ns →	6 160	ns →	4 286	ns →	6 041	*** →	10 011	
Prostigmata	2 179	ns →	2 468	ns →	2 861	** →	15 784	*** →	1 602	ns →	1 955	
Astigmata	1 542	ns →	1 582	ns →	427	*** →	3 179	ns →	3 776	ns →	2 234	

Table II

Correlation between mite abundance and the age of the forest stands and the correlation between the abundance of the studied groups of Acari

	Age	Acari	Cryptostigmata	Mesostigmata	Prostigmata	Astigmata
Age	1					
Acari	0.596	1				
Cryptostigmata	-0.011	0.206	1			
Mesostigmata	0.279	0.586	0.688	1		
Prostigmata	0.086	-0.022	-0.980	-0.624	1	
Astigmata	0.569	0.617	-0.215	-0.218	0.358	1

14 923 ind./m² (in the 80 year old forest stand), and subsequently rose to 27 751 ind./m² (in the 125 year old forest stand). Percent share of the Cryptostigmata in acarofauna was stable and amounted to 70% in most forest stands, with the exception of the 80 year old stand where it was significantly lower (39%). Statistically significant differences in the abundance distribution were recorded only between the 80 and 102 year old forest stands.

Similarly to the Cryptostigmata, abundance changes were also found for the Mesostigmata. Initially, their abundance dropped from 7 742 ind./m² (in the 16 year old forest stand) to 4 286 ind./m² (in the 80 year old forest stand), and it subsequently increased to 10 011 ind./m² (in the 125 year old forest stand). Percentage share of those mites fluctuated between ca. 11% (in the 80 year old forest stand) and 24% (in the 125 year old forest stand) of the entire acarofauna. Statistically significant differences in the abundance distribution of the Mesostigmata were recorded only between the two oldest forest stands.

The abundance of the Prostigmata in the studied forest stands fluctuated, with the lowest value of 1 602 ind./m² (in the 102-year-old forest stand), rising to 2 861 ind./m² in the 57-year-old forest stand and reaching as many as 15 784 ind./m² only in the 80-year-old forest stand. Their share on most of the studied stands never passed 10%, only in the 80 year old forest stand they constituted for 40% of the entire acarofauna, which was connected with the occurrence of numerous populations of the Tarsonemidae in that stand (they constituted ca. 70% of the Prostigmata there). Statistically significant differences in the abundance distribution of the Prostigmata were recorded between the 57 and 80 year old forest stands as well as between the 80 and 102 year old ones.

The abundance of the Astigmata fluctuated between 427 ind./m² (in the 57 year old forest stand) and 3 776 ind./m² (in the 102 year old forest stand) and presented a general increasing tendency. Their share constituted the average of 5% of the entire acarofauna. Statistically significant differences in the abundance distribution were found only between the 57 and 80 year old forest stands. Correlation coefficient of abundance changes and ageing of forest found for the Astigmata was the highest ($r=0.569$) among the studied mite orders (Table II).

What greatly influenced the changes in mite density during succession were the changes in density of both the Mesostigmata and Astigmata, which is supported by the high positive value of the correlation coefficient (Table II). The highly positive correlation was also noted between the abundance of the Cryptostigmata and Mesostigmata whereas the highly negative one was marked between the abundance of Prostigmata and Cryptostigmata as well as between the Prostigmata and Mesostigmata.

Altogether 18 families belonging to the Mesostigmata were recorded within the studied area (Table III). The Rhodacaridae were dominant in the 16, 57, 102 and 125 year old forest stands while the Parasitidae were dominant in the 80 year old forest stand.

Among eight families belonging to the Mesostigmata there were recorded four models of abundance changes accompanying the ageing of the forest stand. The first – creative (Fig. 1) – which is characterized by constant increase in density, was represented by the Macrochelidae ($y = 0.0062x^2 - 0.0221x + 0.0717$; $R^2 = 0.6612$) and Trematuridae ($y = 0.0113x^2 - 0.056x + 0.096$; $R^2 = 0.3771$). The second – rise and fall (Fig. 2) – in which a drop in density occurs after an initial increase, was represented by four families: the Pachylaelapidae ($y = -0.0419x^2 - 0.3155x + 0.211$; $R^2 = 0.9503$) reached the highest density in the 57-year-old forest stand, the Veigaiidae ($y = -0.0384x^2 - 0.1951x + 0.5066$; $R^2 =$

0.2512) and Laelapidae ($y = -0.0117x^2 - 0.0689x + 0.0826$; $R^2 = 0.0404$) reached the highest densities in the 35-year-old forest stand, while the Parasitidae ($y = -0.09x^2 - 0.7425x + 0.21$; $R^2 = 0.5173$) reached the highest density in the 80 year old forest stand. The Rhodacaridae ($y = 0.7212x^2 - 4.8319x + 8.762$; $R^2 = 0.7087$) represented the third model – restorative (Fig. 3) – in which an increase in density occurs after an initial drop. The fourth model – regressive (Fig. 4) – was recorded in case of the Ascidae family ($y = 0.0205x^2 - 0.1823x + 0.4797$; $R^2 = 0.5974$), whose abundance presented constant decrease following the ageing of the forest stand.

Table III

Share (in %) of Mesostigmata families in the studied forest stands

Family [% of Mesostigmata]	Age of the tree stand [years]					
	16	35	57	80	102	125
Ascidae	3.21	5.47	1.78	0.17	1.15	1.54
Celaenopsidae	–	–	–	0.17	–	–
Eviphididae	0.71	0.83	0.97	0.58	0.33	1.44
Halolaepidae	–	–	–	–	0.08	–
Laelapidae	0.96	4.98	3.23	0.58	3.38	–
Macrochelidae	1.03	0.17	1.13	1.74	2.64	1.39
Pachylaelapidae	0.58	4.48	6.38	8.24	4.78	1.94
Parasitidae	13.11	20.07	19.63	52.52	27.51	13.17
Phytoseiidae	–	–	–	0.35	0.16	0.65
Rhodacaridae	63.3	13.27	38.93	15.56	30.07	61.43
Sejidae	–	0.17	–	–	–	–
Trachytidae	0.58	4.89	2.02	0.58	6.1	0.5
Trachyuropodidae	–	–	–	0.58	–	–
Trematuridae	0.13	1.08	1.86	–	0.25	2.24
Urodinychidae	1.67	6.47	2.42	0.75	5.44	2.49
Uropodidae	2.25	12.11	4.12	3.66	4.04	6.46
Veigaiidae	5.4	18.99	14.86	5.57	8.65	4.08
Zerconidae	7.07	7.05	2.67	8.94	5.44	2.68

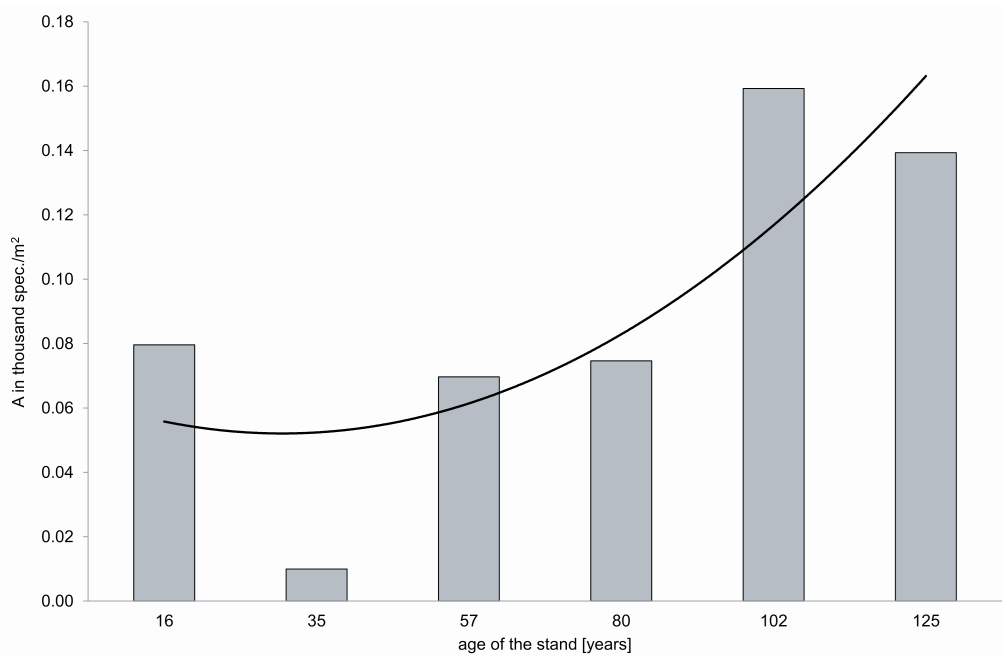


Fig. 1. Creative model of succession changes in Mesostigmata communities based on the example of the Mac-rochelidae in the studied forest stands.

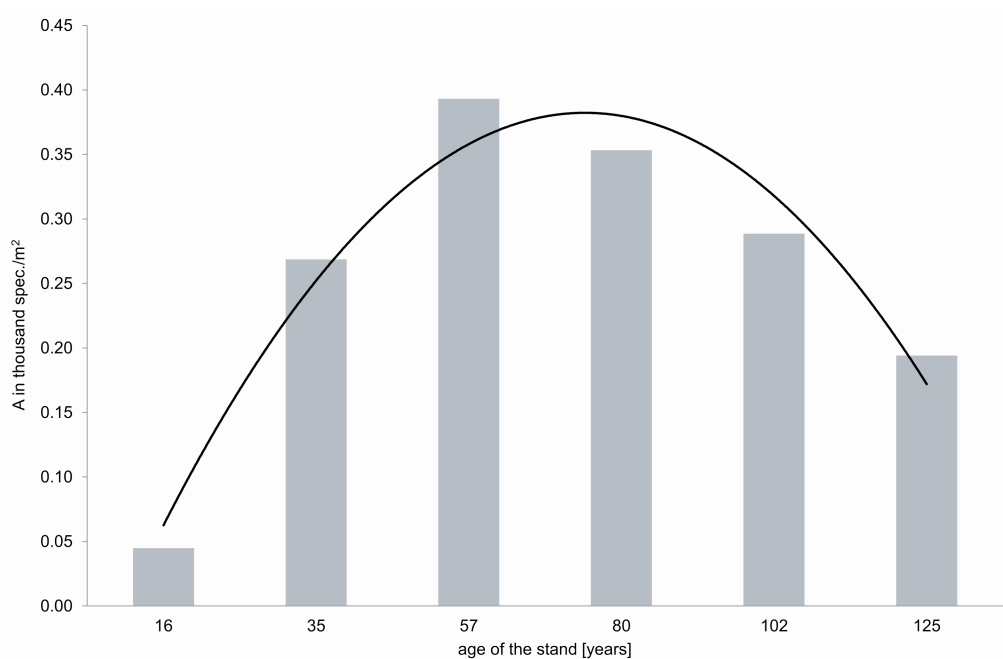


Fig. 2. Rise and fall model of succession changes in Mesostigmata communities based on the example of the Pachylaelapidae in the studied forest stands.

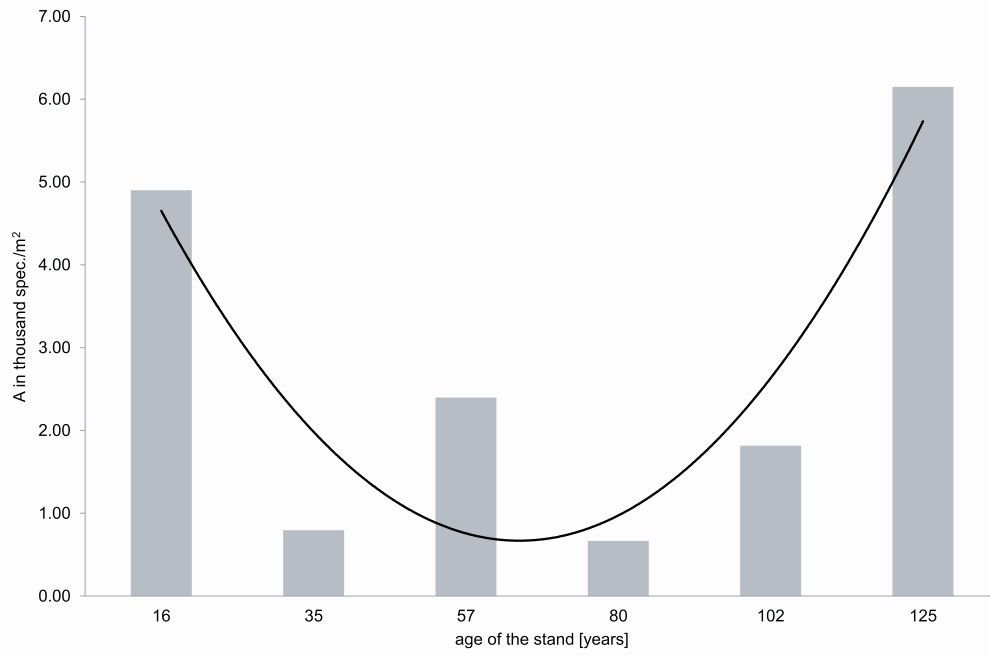


Fig. 3. Restorative model of succession changes in Mesostigmata communities based on the example of the Rhodacaridae in the studied forest stands.

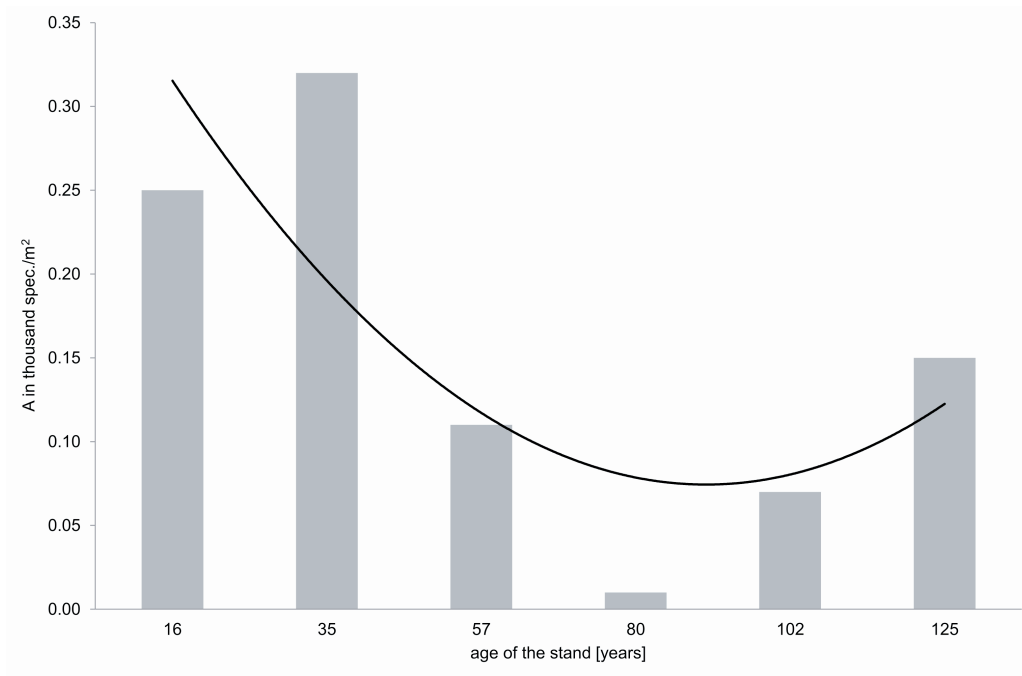


Fig. 4. Regressive model of succession changes in Mesostigmata communities based on the example of the Ascidiae in the studied forest stands.

V. DISCUSSION

Ecological succession is an ordered process of biocenosis development which includes changes in the species structure and biocenotic processes that occur over a period of time. Succession depends on biocenosis although abiotic qualities of the environment define its direction and rate and frequently mark the limit of its progress. Secondary succession proceeds faster than the primary one because it takes place on a previously populated substrate which provides more favorable conditions compared to a barren one. Such succession occurs in ecosystems that are naturally devastated (e.g. as a result of flood) or in ecosystems undergoing severe anthropopression (e.g. due to forest clearing or agro-technical procedures). Most succession theories are based on vegetation studies and the dissimilarities between plant and animal succession were demonstrated by: NIEDBAŁA (1972, 1980), FALIŃSKA (1991), TROJAN et al. (1994), TROJAN & WYTWER (1995), MADEJ (2004) and SKUBAŁA (2004). Ecological succession of fauna is a multifaceted process and its nature can be creative, stabilizing, rise and fall, regressive and restorative (TROJAN et al. 1994; TROJAN & WYTWER 1995). According to ODUM's theory (1977), both abundance and species diversity grow together with succession processes, although not all organism groups are characterized by an increase in those parameters in the succession sequence (e.g. SCHULZ 1991; TROJAN 1994; UVAROV 1994; BAŃKOWSKA 1995; BRZESKI 1995; SCHEU & SCHULZ 1996; KOEHLER 1998; MADEJ 2004).

Slight fluctuations of mite density in the studied succession sequence can prove that the studied forest stand is characterized by a stabilized soil acarofauna structure. Average mite density level within the studied area was similar to mite density of broadleaved forest habitats dominated with *Robinia pseudoacacia*, *Quercus petraea* and *Populus canadensis* (SENICZAK et al. 1991). Mite density in the examined oak-hornbeam forest soil was clearly lower compared to the soil of coniferous forests, riparian forests or alder swamp forests (e.g. BUKOWSKI et al. 2004; KACZMAREK et al. 2008, 2010).

In the studied succession sequence the density of the Cryptostigmata slightly fluctuated. Different changes in the abundance of the Cryptostigmata were recorded in coniferous forests where their density increased following the forest stand's ageing (BUKOWSKI et al. 2004; KACZMAREK et al. 2010). Density changes of the Mesostigmata reflected the restorative model of succession, whereas in coniferous forests and post-industrial areas the creative model was ascribed to those mites (BUKOWSKI et al. 2004; MADEJ 2004; KACZMAREK et al. 2008, 2010). Density of the Prostigmata on most of the studied forest stands was stable. The 80-year-old forest stand was the only one indicating significantly larger density, because of the occurrence of numerous Tarsonemidae hypopi populations. It most probably results from their phoretic relationship with insects (KIELCZEWSKI & WIŚNIEWSKI 1980; MOSER 1995; KRANTZ & WALTER 2009) but at the time it is only our suggestion, since it is not deeply investigated. In case of the Astigmata, there was a clear increase in their density along virtually entire succession sequence, which is in accordance with both the creative model of succession course and general succession theory which, among others, says that the abundance increases from the simple initial stages to the complex, climacteric stages (ODUM 1977).

Generally fluctuations in the density of the Cryptostigmata within the studied oak-hornbeam forests were slight, which is in our assessment linked to the different decay type

developing in that habitat compared to that of coniferous forests. However, currently we cannot explain a conspicuous decrease of Cryptostigmata density in 80 year old stand. In the pine forests, a layer of overlay decay gathers with age, which constitutes a trophic niche for the saprophagous Cryptostigmata, which influences their more frequent occurrence. As for broadleaved forests, the high rate of mineralization makes it impossible for organic matter to gather with time, a phenomenon that is characteristic of coniferous forest habitats. In case of other mite communities, we are currently not able to define the causes for the functioning of succession models according to which their communities develop.

One should bear in mind that the functioning of a particular succession model at the high taxonomic level (e.g. order) does not necessarily coincide with the models operating at lower levels (e.g. within families) – just as the lack of distinct changes in abundance at the order level is not equivalent to the lack thereof at the level of family or genus (e.g. CHACHAJ & SENICZAK 2006). Even though the Mesostigmata as an order represented the restorative type of succession, they represented four models of succession courses at the family level: regressive, creative, restorative and rise and fall.

The regressive model was exemplified by the Ascidae family. Mites of that family are considered to be so called ‘pioneer species’, demonstrating the type-r procreation strategy and occurring at the initial stages of succession in both natural and anthropogenic conditions (KOEHLER 2000; MADEJ 2004; KACZMAREK et al. 2005, 2010; MADEJ & STODÓŁKA 2008).

The Rhodacaridae are also accounted among pioneer species. Their density in the studied succession sequence initially decreased and then increased together with the age of the forest stands, which is in accordance with the restorative succession course and was recorded within rehabilitated areas (MADEJ 2004). The high percentage share of the Rhodacaridae in the entire succession sequence can be explained by unique soil development within broadleaved forests, with strongly compounded organic and mineral elements and small soil expanses. Inhabitation of mineral soil by the Rhodacaridae is undoubtedly connected with their morphology. The relatively narrow idiosoma allows them to easily move between particles of soil to search for nematodes which are the main food base of those mites (KRANTZ & WALTER 2009).

In cases of the Pachylaelapidae, Parasitidae, Veigaiidae and Laelapidae of the studied oak-hornbeam forests, the changes in density taking place following the ageing of the forest stands are reminiscent of the rise and fall succession model. The same succession course was recorded studying the Veigaiidae of coniferous forests (KACZMAREK et al. 2010). As for the changes in abundance of the Parasitidae, they shaped differently in coniferous forests of different age, where a constant rise in their density was recorded (KACZMAREK et al. 2010). A different succession course (creative model) in the Parasitidae, Veigaiidae and Pachylaelapidae was also recorded in the soil of postindustrial areas that underwent rehabilitation, where mites of those families occurred as late as the pre-forest stage and their density increased together with the ageing (MADEJ 2004).

Changes in the density of the Macrochelidae in the studied oak-hornbeam forests are indicative of the creative succession model, however, due to the fact that the mites usually occur in the soil infrequently, it is currently difficult to explain the succession model taking place in that family.

Trophic and competitive relationships most certainly influence the succession changes of mites, e.g. at the order level. The high positive correlation index between the Cryptostigmata and Mesostigmata can result from relationship between those two mite groups as the Cryptostigmata, and especially their juvenile forms, constitute a large trophic base for the predatory Mesostigmata (KACZMAREK 2000). The high negative correlation index between the Mesostigmata and Prostigmata can in turn be indicative of strong competition in obtaining food occurring between those communities that are represented by a series of obligatory and facultative predators (EVANS 1992; BOCZEK & BŁASZAK 2005; KRANTZ & WALTER 2009). The high negative correlation coefficient between the Cryptostigmata and Prostigmata is not, in our assessment, connected with a direct interaction between those groups, yet it is most probably of cascade-like character. The development of Cryptostigmata communities trophically stimulates the development of Mesostigmata communities, which in turn competitively limit Actinedida communities.

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