DENDROBIOLOGY

2026, vol. 96, 25–33

https://doi.org/10.12657/denbio.096.003

Anna Wierzbicka, Piotr Robakowski, Radosław Jagiełło, Marlena Baranowska, Bartosz Bułaj, Robert Korzeniewicz, Adrian Łukowski, Marcin Zadworny, Wojciech Kowalkowski*

Oribatid mite communities and species diversity in selected forest stands in Wigry National Park (NE Poland)

Received: 10 June 2026; Accepted: 11 July 2026

Abstract: Oribatid mites are abundant species-rich soil arthropods that can play an important role in long-term ecological monitoring. However, despite their significant contribution to decomposition processes and soil functioning, their diversity and their relationship with forest stand characteristics remain insufficiently studied. Previous work recorded 127 species from the Wigry National Park, but detailed analyses linking mite assemblages with forest structure were lacking.

This study aimed to characterise oribatid mite assemblages in selected permanent forest monitoring plots in Wigry National Park, with particular emphasis on abundance, species richness, diversity, dominance structure, and the potential relationship between tree diversity and mite diversity.

Soil samples were collected in 2024–2025 from 46 randomly selected permanent monitoring plots. Three samples were taken from each plot, giving 138 samples in total. Soil fauna were extracted using Berlese–Tullgren funnels, preserved in alcohol, and identified to the species level. Community structure was assessed using species richness, Shannon diversity, Simpson dominance, Pielou's evenness, Berger–Parker dominance, and Hill numbers. Relationships between mite diversity and forest characteristics were evaluated using non-parametric tests and Spearman rank correlations.

A total of 10,689 oribatid mite individuals were recorded, including 8,122 adults and 2,567 juveniles, representing 116 species. Forty-six species were recorded from Wigry National Park for the first time. *Oppiella nova* was the only euconstant species and accounted for 12.63% of the community. Stand species composition, forest habitat type, stand age class, regeneration-layer composition, coarse woody debris, understory cover, and tree diversity indices did not significantly affect mite species richness or diversity. However, Pielou's evenness was positively correlated with the age of the dominant tree species and total canopy cover.

Oribatid mite assemblages in the studied forest stands were species-rich and showed limited dependence on broad forest stand characteristics. The results suggest that, at the studied spatial scale, mite community diversity has not been linked with tree diversity. Forest stands with older dominant trees and denser canopy cover tend to have communities in which species are more evenly represented rather than being dominated by only a few species.

Keywords: soil fauna, Acari, species richness, hill numbers, canopy cover

Address: A. Wierzbicka, P. Robakowski, R. Jagiełło, M. Baranowska, B. Bułaj, R. Korzeniewicz, A. Łukowski, M. Zadworny, W. Kowalkowski, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Wojska Polskiego 71a, 60-625 Poznań, Poland;
AW https://orcid.org/0000-0003-1201-0292, e-mail: anna.wierzbicka@u.poznan.pl;
PR https://orcid.org/0000-0001-5564-7360, e-mail: piotr.robakowski@up.poznan.pl;
RJ https://orcid.org/0000-0001-5915-079X, e-mail: radosław.jagiello@up.poznan.pl;
MB https://orcid.org/0000-0001-9915-3776, e-mail: marlena.baranowska@up.poznan.pl;
BB https://orcid.org/0000-0002-8945-1355, e-mail: bartosz.bulaj@up.poznan.pl;
RK https://orcid.org/0000-0002-4653-9154, e-mail: robert.korzeniewicz@up.poznan.pl;
AŁ https://orcid.org/0000-0002-4860-4984, e-mail: adrian.lukowski@up.poznan.pl;
MZ https://orcid.org/0000-0002-7352-5786, e-mail: marcin.zadworny@up.poznan.pl;
WK https://orcid.org/0000-0002-5801-9818, e-mail: wojciech.kowalkowski@up.poznan.pl

Introduction

National parks play an important role in conserving natural processes and biodiversity. Biodiversity conservation is one of the key issues in nature protection, particularly in forest management (Schmidt, 2005). Understanding the direction and dynamics of processes occurring in natural and protected forests may improve ecosystem conservation, especially when these processes are examined from the perspective of species diversity (Skubała, 2002). Therefore, studies on species richness and diversity in national parks are especially important. In Poland, national parks are covered by long-term monitoring systems in which forest stands and ecosystem measurements are repeated every 5–10 years. The data collected provide valuable information on long-term environmental changes, including those related to climate change (Robakowski et al., 2025).

Oribatid mites utilize organic plant material, particularly in poor and moderately fertile soils, and they are among the most abundant and species-rich groups in undisturbed soils (Koukol et al., 2009). In Poland, approximately 500 species of oribatid mites have been recorded so far (Bogdanowicz et al., 2008). As Niedbała et al. (2024) stated faunistic data about Oribatid mites in Polish national parks are scattered and incompieted, till now data from eight out of 23 national parks are avaible. In Wigry National Park, Starý (2020) described 127 species from a range of forest and non-forest habitats. However, this remains the only study on the diversity of oribatid mites in the park, and no in-depth analysis has yet linked characteristics of the forest environment with mite community structure.

The aim of this study was to characterize the structure and diversity of oribatid mite communities in monitoring plots of Wigry National Park and to identify dominant species as potential indicators of habitat conditions. It was hypothesized that Oribatida communities differ across the habitat types monitored in Wigry National Park and that the species dominance structure reflects the degree of naturalness of the habitats.

Methods

Wigry National Park is located in north-eastern Poland, between 53°57' and 54°10'N and between 22°57' and 23°15'E. It was established in 1989 and covers an area of 151.13 km^2. A detailed description of the study area is provided by Robakowski et al. (2025).

Soil samples were collected in 2024 and 2025 during forest monitoring measurements on permanent monitoring plots. The monitoring network, consisting of 365 permanent plots arranged in a regular 0.5-km grid, was established in 2011.

In this study, 46 plots were randomly selected (Fig. 1) from a larger set of plots previously monitored for dendroflora diversity (Robakowski et al., 2025). At each plot, three soil samples were collected, giving a total of 138 samples. The samples were taken 4 m from the plot centre at azimuths of 0°, 120°, and 240°, using a cylindrical steel corer with a sampling area of 20 cm^2. Each sample included understory vegetation, the litter layer, and the upper 5 cm of mineral soil. The material was placed in plastic bags and transported to the laboratory in a portable cooler. Soil fauna were extracted for seven days using Berlese–Tullgren funnels and subsequently preserved in 95% alcohol. Before identification, specimens were cleared in an 80% lactic acid solution. Species identification was carried out individually under a Nikon SMZ 1000 binocular microscope and a Nikon Optiphot-2 microscope using temporary cavity slides, which allowed specimens to be observed from different sides and angles. Identified oribatid mites were preserved in alcohol in plastic tubes and deposited in the collection of the Department of Game Management and Forest Protection, Poznań University of Life Sciences, Poznań. Species were identified using the keys of Weigmann (2006) and Niedbała (2008) and nomenclature followed Subías (2004).

Species were classified into five dominance classes (D): eudominants (D > 10%), dominants (5.01–10.00%), subdominants (2.01–5.00%), recedents (1.01–2.00%), and subrecedents (< 1.01%). Frequency classes were defined as follows: euconstants

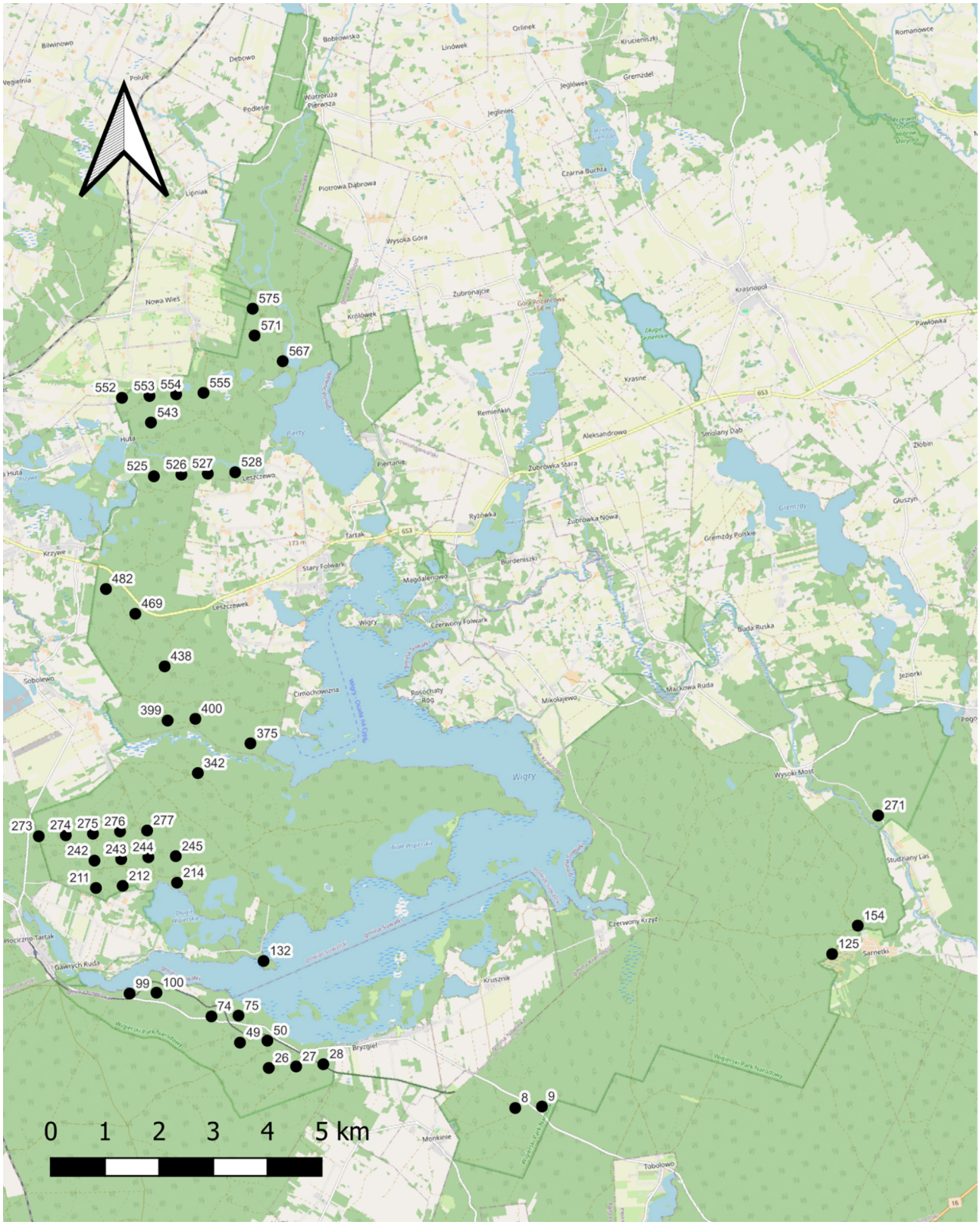

Fig. 1. Geographic location of the study sites within the Wigry National Park. Points indicate sampling locations labeled with their respective plot numbers. Map background data derived from OpenStreetMap (© OpenStreetMap contributors, licensed under ODbL)

(C > 75.01%), constants (50.01–75.00%), accessory species (25.01–50.00%), and accidental species (< 25.01%) (Niedbała et al., 1981).

To evaluate the biodiversity and community structure of oribatid assemblages, several standard ecological and biocoenotic indices were calculated for each sampling plot. The structure of the mite communities was characterised using the following parameters:

Species Richness (*S*): Defined as the total number of distinct species (or taxa) identified within a given sample.

$$^{0}D = S$$

All species counted equally regardless of their abundance; rare and common species are treated the same.

Shannon-Wiener Diversity Index (*H'*): Calculated to assess overall species diversity, accounting for both the number of species and their relative abundance. The following equation was applied:

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i)$$

where p_i represents the proportion of individuals belonging to the *i*-th species:

$$p_i = \frac{n_i}{N}$$

A higher value of H' indicates higher diversity, and a lower value points to lower diversity.

- n_i = abundance of the *i*-th species,
- N = number of individuals of all species.

$$^{1}D = e^{H'}$$

where:

- ^{1}D = exponential Shannon entropy (the Hill number of order 1),
- e = base of the natural logarithm.

The exponential Shannon entropy informs the number of equally abundant species that would produce the same Shannon entropy as the observed community (Jost, 2006; Chao et al., 2014).

Simpson's Dominance Index (*D*): Used to measure the dominance of the most abundant species in the community. It was calculated using the formula:

$$D' = 1 - \sum_{i=1}^{s} p_i^2$$

where p_i represents the proportional abundance of the *i*-th species.

The inverse Simpson index (^{2}D – the effective number of dominant species or the Hill number of order 2) increases with increasing biodiversity.

$$^{2}D = 1 / D'$$

The high value of ^{2}D means high diversity and an equilibrium of number of individuals among the species. The low value of 2D can be interpreted as dominance of one species (Hill, 1973; Chao et al., 2014).

Pielou's Evenness Index (*J'*): Applied to evaluate how evenly the individuals are distributed among the different species present in the community. The index was calculated as follows:

$$J' = \frac{H'}{\ln(S)}$$

where H' is the calculated Shannon-Wiener index and S is the species richness.

The Berger-Parker Index (*BP*) evaluates dominance within a community by quantifying the relative abundance of the most common species:

$$BP = \frac{N_{max}}{N}$$

where N_{max} is the abundance of the most numerous species, and *N* is the total abundance of all species.

Considering the conclusions of Ricotta and Feoli (2024) on the advantages and disadvantages of different diversity measures, we decided to calculate both Hill numbers (Chao et al., 2014) and traditional diversity indices. Our approach was based on two assumptions: (1) Hill numbers were used in our previous study from Wigry National Park, which allows consistency between studies, and (2) Hill numbers are still not widely used in descriptions of mite communities. Therefore, including the more commonly used ecological indices seemed practical for readers.

Statistical analysis

All statistical analyses were performed using JMP® software, version Student Edition 19 (SAS Institute Inc., Cary, NC, USA). Ecological indices for Oribatida communities, including Hill numbers (q = 0, 1, 2), Pielou's evenness index (J'), and the Berger–Parker dominance index, were calculated using the 'vegan' package in R software version 4.2.2. Descriptive statistics for continuous variables are presented as means ± standard errors of the mean (SEM), while categorical data are presented as absolute frequencies and percentages.

To assess the influence of environmental characteristics on oribatid mite assemblages, the structural and environmental forest parameters were divided

into categorical and continuous variables. Categorical factors included stand species composition (dominant tree species), forest habitat type (fresh mixed coniferous, fresh mixed broadleaf, fresh broadleaf forest), stand age class, and dominant species in the regeneration layer. Continuous variables comprised the density of living stands (basal area for coniferous and deciduous species), amount of coarse woody debris, percentage cover of the understory, shrub, and regeneration layers, age of the dominant tree species, total canopy cover, and tree diversity indices (Margalef index, Hill numbers).

Differences in Oribatida biodiversity indices across the categorical forest parameters were evaluated using the non-parametric Kruskal–Wallis test. To assess the strength and direction of relationships between continuous environmental variables and mite diversity indices, a correlation analysis was conducted using Spearman's rank correlation. Additionally, linear regression models were fitted to visualize the relationships between tree diversity and community diversity of Oribatida. A p-value < 0.05 was considered statistically significant for all performed tests.

Results

In total, 10,689 oribatid mite individuals were recorded, including 8,122 adults and 2,567 juveniles, with juveniles comprising 24% of the total. The mites represented 116 species (Appendix A). The number of species per sample ranged from 0 to 30, and the mean number of species per sample was 19.3. The average density was 38,728 ± 37,713 individuals per m^2. *Oppiella* (*O.*) *nova* was the only euconstant species and accounted for 12.63% of the entire community. In addition, the dominant and constant species were *Achipteria* (*A.*) *coleoptrata*, *Chamobates* (*C.*) *pusillus*, *Microppia minus*, and *Tectocepheus velatus*.

Table 1 shows indices mean values and standard error.

Table 1. Mean value ± SE of indices (H' – Shannon's diversity Index, D' – Simpson's Dominance Index, *J'* – Pielou's Evenness Index, BP – the Berger-Parker Index, ^0q, ^1q, ^2q – Hill numbers) for oribatid mites from permanent monitoring plots in Wigry NP

Index	Value (mean ± SE)
H'	2,425 ± 0,076
D'	0,839 ± 0,017
J'	0,774 ± 0,016
BP	0,292 ± 0,022
^0D	24 ± 1,202
^1D	12,558 ± 0,729
^2D	8,396 ± 0,534

To assess the relation between forest characteristics and oribatid mite fauna diversity non-parametric Kruskal–Wallis test was applied to evaluate differences in biodiversity indices (Hill numbers q = 0,1,2, Pielou's evenness index, and the Berger–Parker dominance index). The results indicate that none of the examined categorical variables describing the forest significantly determined the diversity of Oribatida assemblages.

Stand species composition, defined by the dominant tree species according to timber volume, affected neither the species richness of the oribatid mites (Hill q0: $\chi^2 = 0.55$, $p = 0.9083$) nor their diversity accounting for species proportions (Hill q1: $\chi^2 = 1.17$, $p = 0.7592$; Hill q2: $\chi^2 = 0.44$, $p = 0.9325$). Likewise, dominance and evenness indices remained independent of this factor (respectively for BP_Index: $p = 0.8664$; Pielou_J: $p = 0.6115$).

A similar lack of differentiation was observed among forest habitat types (FHP). Oribatida assemblages occurring in different habitat types (fresh mixed coniferous forest, fresh mixed broadleaf forest, fresh broadleaf forest) were characterised by remarkably similar structures. Differences for all analysed indices, including total species richness ($\chi^2 = 0.26$, $p = 0.8788$) and the Shannon index ($\chi^2 = 0.02$, $p = 0.9900$), were statistically non-significant. Furthermore, forest age was shown not to be a differentiating factor for the studied mites. Stand age class had no significant effect on any aspect of Oribatida diversity (for all indices $p>0.05$;). Similarly, the dominant species in the regeneration layer showed no significant effect on the structure of these animal assemblages (e.g., for Hill q0: $\chi2 = 6.44$, $p = 0.4893$; for BP_Index: $\chi^2 = 6.64$, $p = 0.4669$).

Overall, these findings strongly suggest that, at the analysed spatial scale, Oribatida assemblages exhibit a high degree of independence from macrostructural forest characteristics such as stand composition, stand age, and habitat classification.

To investigate more thoroughly the relationships between quantitative stand parameters and oribatid mite diversity indices, a Spearman rank correlation analysis was conducted. Consistent with the results of non-parametric tests for categorical variables, most continuous environmental and structural forest variables showed no statistically significant effect on species richness (Hill numbers q = 0,1,2) or on the dominance index (Berger–Parker) of the studied mites ($p>0.05$).

No significant correlations were found between the diversity of Oribatida assemblages and the density of living stands, expressed as basal area (G) separately for coniferous and deciduous species. Similarly, the amount of coarse woody debris lying on the forest floor (both coniferous and deciduous) as well as the degree of cover of the understory, shrub, and

regeneration layers did not determine the taxonomic structure of oribatid mites ($p>0.05$). The analysis also confirmed the absence of correlations between tree diversity indices (including the Margalef index and Hill numbers) and any parameters of Oribatida diversity, indicating a decoupling of these two trophic levels at the studied spatial scale (Fig. 2).

Despite the lack of influence of the examined factors on species richness itself, the analysis revealed statistically significant relationships concerning dominance structure within Oribatida assemblages. A significant positive correlation was found between Pielou's evenness index (J') for Oribatida and the age of the dominant tree species in the stand (Spearman's $\rho = 0.37$, $p = 0.0108$). In addition, Pielou's evenness index was positively correlated with total canopy cover (Spearman's $\rho = 0.33$, $p = 0.0464$).

This indicates that, with increasing stand age and greater forest canopy closure, the structure of Oribatida assemblages becomes more even, with a reduced contribution of eudominant species and a more balanced distribution of individuals among co-occurring species.

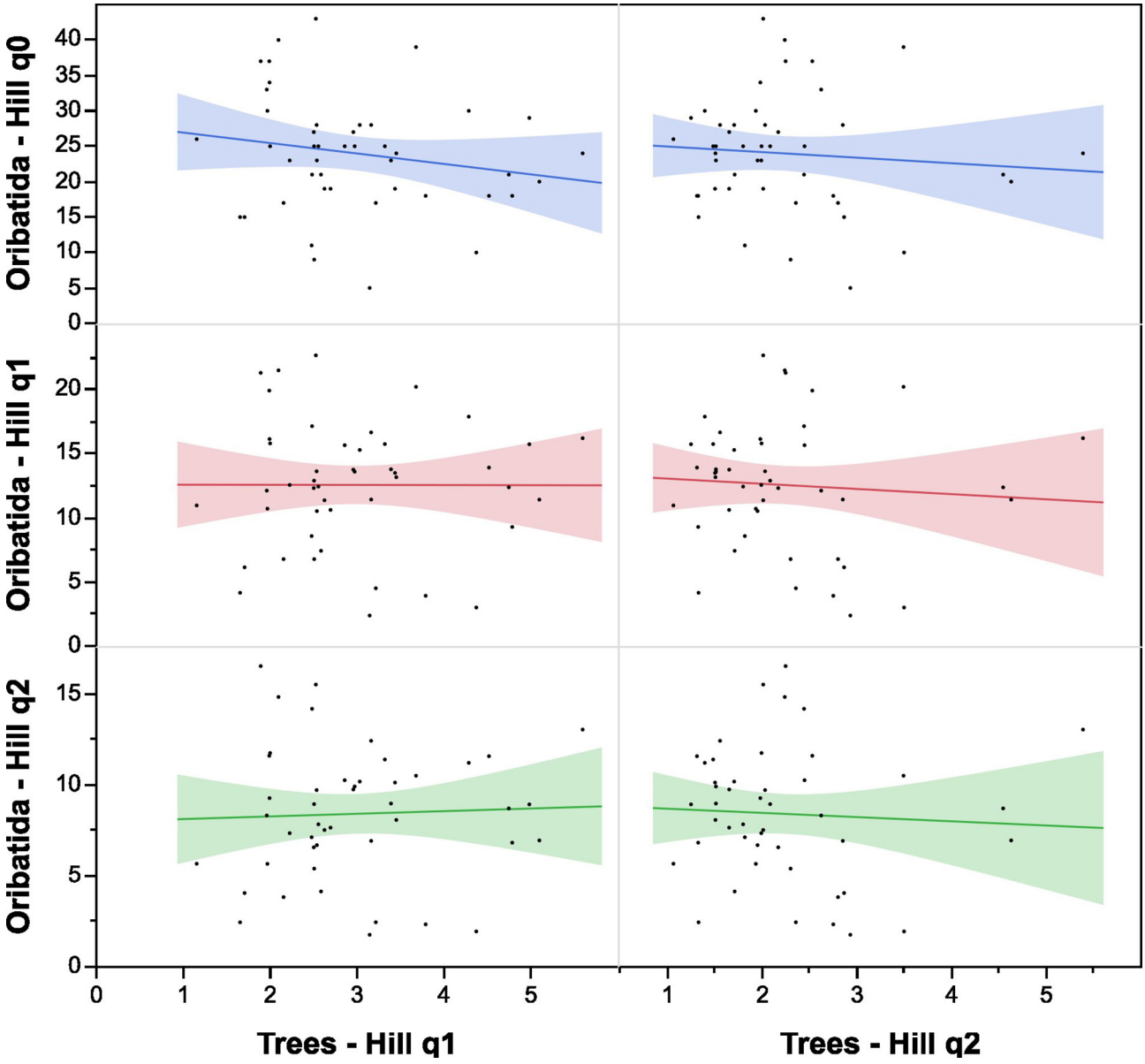

Fig. 2. Relationship between tree diversity and Oribatida community diversity expressed as Hill numbers. The panels illustrate the relationships for different orders of diversity (q). The y-axis represents Oribatida diversity partitioned into: species richness (q = 0, top row, blue), the exponential of Shannon entropy (q = 1, middle row, red), and the inverse Simpson concentration (q = 2, bottom row, green). The x-axis represents tree diversity based on Hill numbers for q = 1 (left column) and q = 2 (right column). Black dots represent individual sampling plots/sites. Solid colored lines indicate the linear regression fit, while the shaded bands represent the 95% confidence intervals of the models.

Discussion

Continuous monitoring of protected areas within Poland's national parks is essential for uncovering the mechanistic drivers of biodiversity dynamics. Our findings about species composition of oribatid mite communities are a step to fill the gap in our knowledge about *Acari* occurring in Wigry National Park, a biodiversity hotspot at the margin of the Atlantic and continental climatic range. Wigry National Park therefore provides an early indicator of directional changes in *Acari* biodiversity under climate changes.

We found 116 species of oribatid mites, 70 species had previously been reported from Wigry National Park by Starý (2020), whereas 46 species are new records for the area. Number of finded species is difficult to compare with other national parks becouse we focuse on one specific, but divers, type of habitat and soil, when other researchers were investigating not only soil but ants or birds nests as well as other microhabitats (e.g. Gdula et al., 2021; Graczyk et al., 2023; Olszanowski & Błoszyk, 1998). Analysing species dominant species ecology one can see that all of them are cosmopolitan euryecious, forest species (Subias, 2004; Weigmann, 2006). The high proportion of *Tectocepheus velatus* (8.00% dominance; 65.22% abundance) indicates the presence of a eurythermal species that tolerates a wide range of habitat conditions. The significant proportion of *Porobelba spinosa* (3.64%; 50.72%) and *Steganacarus carinatus* (2.12%; 36.96%) suggests well-developed forest habitats with a stable organic layer. Even subrecedent species, such as *Berniniella (B.) conjuncta* and *Neoribates (N.) aurantiacus* indicates humid, rich forest habitat (Weigmann, 2006).

Although our results do not support the hypothesis that mite diversity is directly linked to canopy tree diversity, the most important contribution of our study is the species inventory and characterisation of mite communities, which have not previously been described in the Wigry National Park.

Analysed area is located in stands classified in 2011 as the *Tilio cordatae-Carpinetum betuli* Tracz. forest community and was chosen as representative of this vegetation type belonging to three forest types, having Scots pine (*Pinus sylvestris* L.), spruce (*Picea abies* Karst.), birch (*Betula pendula* Roth), oak (*Quercus robur* L.) as main species, and with different ages (between 20 and 140 years old). As no significant differences were found among three forest types, the data was pooled and analysed collectively.

Oribatid mite communities from the WNP area are most similar to mixed forests in terms of average number of specimens per m^2 (Seniczak, 1978; Zaitsev & Wolters, 2006). Number of species is quite high and can be compared to Scots pine stands in Finland (Siira-Pietikäinen et al., 2008) and Switzerland (Cuartero et al., 2025). On the other hand, the share of juveniles was quite low and was similar to pine or beech stands (Dziuba & Skubała, 1987; Skubała & Bielska, 2000) this possibly can be connected more with moisture of soil than forest stand composition itself (Niedbała, 1980). The H' index is higher than in pine stands in the UK (Horwood & Butt, 2000) but lower than in pine stands in Switzerland (Cuartero et al., 2025) or mixed stands (Migge et al., 1998). J' is the most similar to middle age pine stands (65 years old) in the UK (Horwood & Butt, 2000). The relatively high Shannon diversity (H' = 2.43) and evenness (J' = 0.77) indicate that the oribatid communities of Wigry National Park were not dominated by a single species, despite the high abundance of *Oppiella nova* and *Tectocepheus velatus*. Hill numbers further suggest that approximately 12 species represented the effective number of common species, whereas about 8 species constituted the effective number of highly abundant species. Our results indicated that neither the main tree species in the forest canopy and the main tree species in the second layer, the age of main tree species, nor the forest type had any significant influence on oribatid mite communities. The lack of significant differences may be explained by insufficient contrast in site conditions when comparing our study's forest types. All three have the same dominant tree species but at different proportions. In addition, mite diversity and abundance are likely influenced by the interactive effects of many environmental factors such as light availability in the understory, the abundance of an epigeic earthworm species, the amount of phosphorus, soil acidity, and the diversity or mass of fungi, plant litter, and roots (Hasegawa, 2001; Mueller at el., 2016; Scheu & Schulz, 1996). We acknowledge that these numerous environmental factors were not determined which is a limitation of our present study.

Our results are at least partially consistent with our hypothesis. The significant positive correlations between stand age, canopy closure and Pielou's evenness index provide evidence that mite communities in older stands with a more closed canopy are more evenly distributed, exhibiting lower dominance of eudominant species and a more balanced distribution of individuals among co-occurring species compared with younger stands and those with a more open canopy. This finding suggests that mite assemblages can be more stable in terms of evenness and population size in older forests. However, given the limitations of the present study, this interpretation remains tentative and requires confirmation through further research.

Conclusions

In conclusion, our results do not support the hypothesis that mite diversity is directly related to tree diversity. Nevertheless, the the results indicate that increasing stand age and canopy closure are associated with greater evenness in Oribatida assemblages, reflected in a reduced dominance of eudominant species and a more equitable distribution of individuals among co-occurring species.

Acknowledgments

Authors want to thank Ms Valerie Corey for linguistic adjustments.

Funding

This research was funded from Forest Fund by The State Forests (contract no. EZ.0290.1.61.2024) under the research grant no 29 entitled "Condition, Structure of Dendroflora and Wood Resources in Subcontinental Oak-Hornbeam Forests of Wigry National Park – Part II".

References

Bogdanowicz W, Chudzicka E, Pilipiuk I & Skibińska E (2008) Fauna of Poland–characteristics and checklist of species. Museum and Institute of Zoology Polish Academy of Science, Warsaw, Poland.

Chao A, Gotelli N, Hsieh TC, Sander EL, Ma KH, Colwell RK & Ellison AM (2014) Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84: 45–67. doi:10.1890/13-0133.1.

Cuartero J, Brunner I, Schaub M, Gwiazdowicz DJ, Skubała P, Qin J, Krogh PH & Frey B (2025) Comparing soil microarthropod communities derived directly from soil DNA metabarcoding with those from morphological assessment in a drought-prone and irrigated pine forest. Applied Soil Ecology 209: 106042. doi:10.1016/j.apsoil.2025.106042.

Dziuba S & Skubała P (1987) Oribatida glebowe (Acarina) boru sosnowego na przykładzie Nadleśnictwa Złoty Potok. Acta Biologica Silesiana 6: 164–182.

Gdula AK, Skubała P, Zawieja B & Gwiazdowicz DJ (2021) Mite communities (Acari: Mesostigmata, Oribatida) in the red belt conk, *Fomitopsis pinicola* (Polyporales), in Polish forests. Experimental and Applied Acarology 84: 543–564. doi:10.1007/s10493-021-00635-1.

Graczyk R, Indykiewicz P, Olszewski A & Tobółka M (2023) Mites living in the nests of the White Stork and Black Stork in microhabitats of the forest environment and agrocenoses. Animals 13: 3189. doi:10.3390/ani13203189.

Hasegawa M (2001) The relationship between the organic matter composition of a forest floor and the structure of a soil arthropod community. European Journal of Soil Biology 37: 281–284. doi:10.1016/S1164-5563(01)01099-8.

Horwood JA & Butt KR (2000) Changes within oribatid mite communities associated with Scots pine regeneration. Web Ecology 1: 76–81. doi:10.5194/we-1-76-2000.

JMP Statistical Discovery LLC (2025) JMP (Version 19). JMP Statistical Discovery LLC. https://www.jmp.com.

Koukol O, Mourek J, Janovský Z & Černá K (2009) Do oribatid mites (Acari: Oribatida) show a higher preference for ubiquitous vs. specialized saprotrophic fungi from pine litter? Soil Biology and Biochemistry 41: 1124–1131. doi:10.1016/j.soilbio.2009.02.018.

Migge S, Maraun M, Scheu S & Schaefer M (1998) The oribatid mite community (Acarina) of pure and mixed stands of beech (*Fagus sylvatica*) and spruce (*Picea abies*) of different age. Applied Soil Ecology 9: 115–121. doi:10.1016/s0929-1393(98)00065-1.

Mueller KE, Eisenhauer N, Reich PB, Hobbie SE, Chadwick OA, Chorover J, Dobies T, Hale CM, Jagodzinski AM, Kałucka I, Kasprowicz M, Kieliszewska-Rokicka B, Modrzynski J, Rozen A, Skorupski M, Sobczyk Ł, Stasinska M, Trocha LK, Weiner J, Wierzbicka A & Oleksyn J (2016) Light, earthworms, and soil resources as predictors of diversity of 10 soil invertebrate groups across monocultures of 14 tree species. Soil Biology & Biochemistry 92: 184–198. doi:10.1016/j.soilbio.2015.10.010.

Niedbała W (1980) Mechowce – roztocze ekosystemów lądowych. PWN, Warszawa, Poland.

Niedbała W (2008) Ptyctimous mites (Acari, Oribatida) of Poland. Fauna Poloniae. Natura optima dux Foundation, Poland.

Niedbała W, Błaszak C, Błoszyk J, Kaliszewski M & Kaźmierski A (1981) Roztocze (Acari). Fragmenta Faunnistica 26: 105–156.

Niedbała W, Napierała A, Wendzonka J, Lubińska K, Kulczak M & Błoszyk J (2024) Species diversity and spatial distribution of some oribatid mites in Bory Tucholskie National Park (N Poland). Diversity 16: 678. doi:10.3390/d16110678.

R Core Team (2022) R: A language and environment for statistical computing (Version 4.2.2) [Oprogramowanie komputerowe]. R Foundation for

Statistical Computing. https://www.R-project.org/

Ricotta C & Feoli E (2024) Hill numbers everywhere. Does it make ecological sense? Ecological Indicators 161: 111971. doi:10.1016/j.ecolind.2024.111971.

Robakowski P, Jagiełło R, Baranowska M, Bułaj B, Dering M, Hauke-Kowalska M, Korzeniewicz R, Łukowski A, Szmyt J, Zadworny M, Wierzbicka A, Popek R, Przybysz A & Kowalkowski W (2025) Climate warming, ecological dynamics and nature conservation drive tree diversity in Wigierski National Park, Poland. Dendrobiology 94: 73–88. doi:10.12657/denbio.094.005.

Scheu S & Schulz E (1996) Secondary succession, soil formation and development of a diverse community of oribatids and saprophagous soil macro-invertebrates. Biodiversity Conservation 5: 235–250. doi:10.1007/BF00055833.

Schmidt W (2005) Herb layer species as indicators of biodiversity of managed and unmanaged beech forests. Forest Snow and Landscape Research 79: 111–125.

Seniczak S (1978) Stadia młodociane mechowców (Acari, Oribatei) jako istotny składnik zgrupowań tych roztoczy przetwarzających glebową substancję organiczną. Zeszyty Naukowe Uniwersytetu Mikołaja Kopernika, Toruń: 1–171.

Siira-Petikäinen A, Penttinen R & Huhta V (2008) Oribatid mites (Acari: Oribatida) in boreal forest floor and decaying wood. Pedobiologia 52: 111–118. doi:10.1016/j.pedobi.2008.05.001.

Skubała P (2002) Development of oribatid mite communities (Acari, Oribatida) on a mine dump: Acarid Phylogeny and Evolution: Adaptation in Mites and Ticks (ed. by F Bernini, R Nannelli, G Nuzaci & E DeLillo) Springer, Dordrecht, The Netherlands, pp. 209–215. doi:10.1007/978-94-017-0611-7_21.

Skubała P & Bielska A (2000) Oribatid fauna (Acari: Oribatida) in biotopes of the "Góra Chełm" Reserve: Akarologia polska u progu XXI wieku (ed. by S Ignatowicz) SGGW, Warsaw, pp. 135–141.

Starý J (2020) Checklist of oribatid mites (Acari: Oribatida) in the Wigry National Park, North-East Poland. Fragmenta Faunistica 63: 11–28. doi:10.3161/00159301FF2020.63.1.011.

Subias LS (2004) Listado sistemático, sinonímico y biogeográfico de los ácaros oribátidos (Acariformes, Oribatida) del mundo (1758–2002). Graellsia 60: 1–305.

Weigmann G (2006) Hornmilben (Oribatida). Die Tierewelt Deutschlands. Teil 76. Goecke & Evers, Keltern, Germany.

Zaitsev AS & Wolters V (2006) Geographic determinants of oribatid mite communities structure and diversity across Europe; a longitudinal perspective. European Journal of Soil Biology 42: 358–361. doi:10.1016/j.ejsobi.2006.09.006.