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Mites from the Suborder Uropodina (Acari: Mesostigmata) in Bory Tucholskie National Park—One of the Youngest National Parks in Poland

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Abstract: The state of research into acarofauna in Polish national parks is very uneven. One of the least examined areas in this regard is Bory Tucholskie National Park (BTNP), established in 1996. The aim of the current research was to explore the species diversity and community structure of mites from the suborder Uropodina (Acari: Mesostigmata), inhabiting different forest, open, and unstable microhabitats in the area of BTNP. Based on the analysis of over 300 samples collected in BTNP between 2004 and 2024, 29 taxa of Uropodina were identified, with 3839 specimens found in the analyzed material. The highest species diversity has been observed in different types of pine forests (19 species), in transformed alder and alder forests (15 species, each), and in reeds (12 species), while the lowest diversity occurred in peat bog areas (8 species) and inland dunes (5 species). The spatial distribution analyses for Uropodina in the area of BTNP have been made and distribution maps for each species have been drawn. Moreover, the Maturity Index (MI) was also calculated to compare the species diversity of the Uropodina communities in BTNP with those in other Polish national parks. The Uropodina community in BTNP ranked eighth in terms of species richness among 13 national parks explored in Poland so far. Finally, the comparative analysis of the MI for the selected Polish national parks has revealed that BTNP could be ranked fourth in terms of the faunistic value for the discussed mite group.

Keywords: biodiversity; endangered species; mite community; monitoring; protected area; rare species; soil fauna

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1. Introduction

The main objectives for which national parks are established include preserving biodiversity, restoring proper natural resource conditions, and rehabilitating damaged natural habitats for plants, animals, and fungi [1]. Thus, the inventory of faunal resources in individual national parks and continuous monitoring of their status have become extremely important. Soil fauna is a particular component of the faunal resources in each national park because it cannot be directly observed, and the analysis of it requires specialized methodology. Any assessment of mesofauna resources, especially mites (Acari), in a given national park, depends significantly on the number of soil samples collected in different environmental and microhabitat types present in such a place. So far, the accounts about the occurrence of different mite groups in Polish national parks (NP) are usually based on extensive studies on a specific group of mites across the entire country. A good example of such studies is those published in the series Monografie Fauny Polski (Monographs of Polish Fauna), which discuss such mite groups as Zerconidae [2], Brachychthonidae [3], Bdellidae and Cunaxidae [4], and ptyctimous mites [5]. Similar studies were also published

on mites from the family Parasitidae [6], Brachychthonidae [7], Labidostommidae [8], the genus *Trachytes* [9], Tydeidae [10], genus *Tarsonemus* [11], Ixodida [12], Microtrombidiidae [13], as well as Nothridae and Camisidae [14]. Gwiazdowicz and Skorupski [15] also outlined the state of research into the sub-families Antennophorina, Microgyniina, Sejina and Gamasina in Polish national parks. Moreover, a number of co-authored studies have also been published so far, in which the authors present lists of mite species found in various national parks in Poland. Among the national parks listed in these studies are Białowieski NP [16,17], Karkonoski NP [18,19], Świętokrzyski NP [20], and Ojcowski NP [21–24].

The most information about particular groups of mites in a given national park can be found in studies describing the acarofauna of that park. One of the best-studied groups in this respect is mites from the suborder Uropodina (Acari: Mesostigmata). Mites from the suborder Uropodina are one of the most thoroughly studied groups of mites in Poland. According to various reports published so far, the estimated number of Uropodina species in Poland is around 150 [25,26] or slightly lower [23,27]. In the early 1980s, Błoszyk and his co-workers initiated ongoing research into the biology, ecology, and zoogeography of this mite group. These studies largely focus on species composition and Uropodina community structures in various environments and microhabitats in the whole area of Poland, with particular attention paid to protected areas (national parks and nature reserves) [24,28–46].

Since the 1990s, a series of research studies related to Uropodina (as well as other mite groups) in individual national parks of Poland have been published. Such studies have already been published for Białowieski NP [17,38,47–53], Roztoczański NP [54], Karkonoski NP [18,33,55], Ojcowski NP [42,56–59], Gorczański and Pieniński NP [31,34,35], Białowieski NP [60], and Wielkopolski NP [46]. In 1991 [32] Błoszyk published a study, which outlined the state of research into mites from the suborder Uropodina in Polish national parks. Five years later, Wiśniewski [61] published a similar study, which also discusses this group of mites. However, neither of these publications touches upon Bory Tucholskie National Park (BTNP), as they were published before the establishment of this national park. BTNP was established in 1996 and is currently one of the youngest among the 23 national parks in Poland [62]. Until recently, the only study from the area of BTNP, which takes the Uropodina mites into account, is the publication by Gwiazdowicz and Matysiak [63]. In this study [63], authors focus on selected microhabitats and they mention seven Uropodina species inhabiting the dead wood. More recently, another study focusing on BTNP was published, but in this case, it discusses Uropodina communities inhabiting bird nest boxes [41]. The publication lists 19 species from this group, of which two *Leiodinychus orbicularis* (C. L. Koch, 1839) and *Chiropturopoda nidiphila* (Wiśniewski and Hirschmann 1993) were found exclusively in the examined bird nest boxes.

Due to the ongoing deterioration of the environment, including soil quality, and insufficient information about both the biodiversity and the level of threat to soil invertebrates, including mite species [64,65], it is essential to conduct monitoring research aimed at collecting data on the biodiversity of these organisms, especially in legally protected areas. The major objectives of the current study were to explore the species diversity and community structure of Uropodina mites inhabiting various forests, open areas, and unstable microhabitats within the area of BTNP, considering the spatial distribution of the found species within the examined area. Finally, the study is also intended to compare the Uropodina species diversity in BTNP with that of other national parks in Poland, based on the Maturity Index (MI).

2. Study Area

Bory Tucholskie National Park (53°49′ N 17°34′ E) is located in the northern part of Poland. It was established in 1996 [62] to protect a unique sandr-lake district type of landscape, unique to Poland and Europe, with its natural biological diversity. Among its most valuable elements are large pine forests, peat bogs, and 21 lakes, including well-preserved lakes with *Lobelia dortmanna* L. and *Chara* sp. The Park covers an area of 4613 hectares, of which 83% are forest habitats, 11.5% are water, and 5.5% are other forms. The dominant

types of forest habitats are pine forests, constituting almost 98% of the whole area of the park. The remaining forests are mainly alder forests, growing on the edges of lake ditches and stream valleys. A detailed description of the natural environment of the BTPN has been described in many monographic studies [66–69].

3. Materials and Methods

The material for the analysis contains data from 311 samples collected in the area of BTNP between 2004 and 2024, stored in the computer database called "Invertebrate Fauna Bank". The samples were collected from 156 study sites located all over the park (Figure 1). They came from seven types of forest and open-non-forest environments: I. pine forests (i.e., dry pine forest, fresh pine forest, moist pine forest, and swamp pine forest (119 samples)) (Figure A1); II. transformed alder forests (i.e., narrow strips at the boundaries of alder and pine habitats with admixtures of linden (*Tilia* sp.), buckthorn tree (*Frangula alnus* Mill.), and hazel (*Corylus*), occurring along streams and lake ditches) (44 samples) (Figure A2); III. alder forests (33 samples) (Figure A3); IV. peat bogs (14 samples) (Figure A4); V. meadows (31 samples) (Figure A5); VI. inland dunes (21 samples) (Figure A6); and VII. reeds (23 samples) (Figure A7).

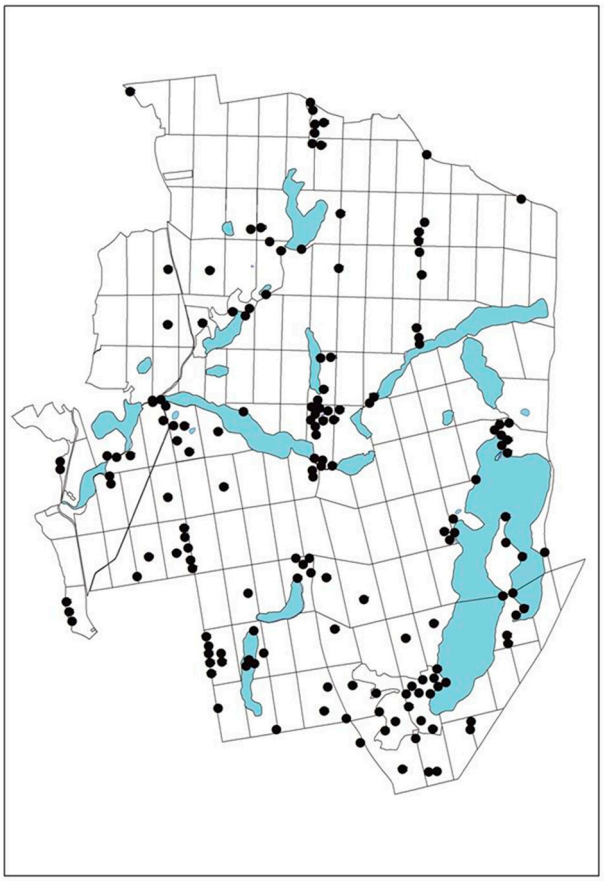

Figure 1. Distribution of examined plots (black dots) in the area of Bory Tucholskie National Park. Blue parts—water tanks.

In forest habitats, several samples differentiating every examined site were taken from each plot: from soil and from dead wood (stumps, fallen logs) (if available, both coniferous and deciduous trees), and occasionally from ant nests. In non-forest habitats (meadows, dunes), only soil samples were collected. These samples include litter and soil siftings. The materials from the period 2023–2024 were collected by the authors during supplementary research sessions for the purpose of a monograph about invertebrates in BTNP and the accomplishing of a research grant funded by the International Union for Conservation of

Nature-IUCN (Grant number SMA-G00-GG-0000000779). The analysis also included data from a number of earlier studies [64], which come from microhabitats of dead wood in the area of BTNP.

Mites from the collected samples were extracted for four to five days by means of Berlese-Tullgren funnels in artificial light (40 watts). The specimens were then sorted out and identified with a stereoscopic microscope Olympus SZX16, and open slides (Grandjean technique) were made for the juvenile stages and then they were identified with a microscope Olympus BX53 with Nomarski Contrast. The identification of the extracted mites was conducted by the first author based on publications by Karg [70], Błoszyk [27], and Mašán [71]. The extracted specimens were then stored in Eppendorf tubes filled with c. 75% ethanol. The preserved samples have been stored in the Natural History Collections (Faculty of Biology) at Adam Mickiewicz University (AMU) in Poznań.

Data Analysis Methods

The structure of the analyzed mite communities found in the area of BTNP and in the examined habitats within the park has been described with the index of dominance (D), and frequency of occurrence (F). The scale has the following classes: dominance D5 eudominants (>30.0%), D4 dominants (15.1–30.0%), D3 subdominants (7.1–15.0%), D2 recedents (3.0–7.0%), and D1 subrecedents (<3.0%); frequency F5 euconstants (>50.0%), F4 constants (30.1–50.0%), F3 subconstants (15.1–30.0%), F2 accessory species (5.0–15.0%) and F1 accidents (<5.0%) [27]. The data have been stored in the computer database Analizator 2.0 in the Natural History Collections department (Faculty of Biology) at AMU.

The MI was used to assess the natural value of soil habitats in the BTNP and other 12 national parks in Poland. MI is a bioindication tool for monitoring forest ecosystems, which is based on the occurrence of species with *K* and *r*-selected life histories [72,73]. In this study, the index is based on classifying mites from the suborder Uropodina according to their life-history traits on the *r*/*K* scale, with values ranging from 1 to 3. The assignment of particular Uropodina species was carried out according to such features as the ecological indices (dominance and frequency), ecological tolerance based on habitat, population growth rate, occurrence of larvae, and the presence and intensity of phoresy [45]. The MI for communities of Uropodina was calculated as the weighted proportion of the K-selected species in the entire Uropodina community. The value of the index should be higher in less environmentally disturbed areas. The MI was calculated on the basis of the formula proposed by Ruf [72] and N'Dri et al. [74]:

$$MI = \frac{\sum_{i=1}^{S} Ki}{\sum_{i=1}^{S} Ki + \sum_{i=1}^{S} ri}$$

with S—number of species, K—*K*-value ranging from 1 to 3, r—*r*-value ranging from 1 to 3 for the species *i*.

The community similarity of the species composition for Uropodina mites in communities found in different types of habitats in BTNP was calculated by means of the Marczewski–Steinhaus species similarity index: S = c/(a + b − c), where *c* is the number of species present in both compared communities, and *a* and *b* stand for the total numbers of species in each community. The full joining analysis, which uses the most distant neighbors, was used to prepare the dendrogram [74]. The graphs of the percentage participation of species found in particular habitats (Figures 2–6) are based on the medium number of specimens in positive samples. The maps of the spatial distribution of the examined plots and particular Uropodina species found in the area of BTNP and the graphs (in Figures 2–6) are original and they were generated with Corel Draw 2020 computer graphics software (version number DCDGS2020ML2EU01).

4. Results

4.1. Species Composition and Community Structure of Uropodina Mites in BTNP

In 311 samples collected in the area of BTNP, 29 taxa of mites from the suborder Uropodina were recorded, of which two (*Uroobovella* sp. and *Oplitis* sp.) were identified only at the genus level, with a total of 3839 specimens (Table 1). The mites found in the area of PNBT belong to two superfamilies, i.e., Polyaspidoidea and Uropodoidea. The first is represented here only by three species (i.e., *T. aegrota*, *T. pauperior*, and *P. sansonei*), which constitute 10.3% of all species in the community, but statistically, these species constitute nearly one-third of all Uropodina specimens (Table 1). The second superfamily is diverse and includes 25 species, which constitute 89.7% of the total community, but statistically, they make up 69.99% of the community.

Table 1. Species composition and community structure of Uropodina in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average ± standard deviation.

Species *	N	D%	F%	Ave. ± SD
Oodinychus ovalis (C. L. Koch, 1839)	878	22.87	31.19	9.1 ± 14.7
Trachytes aegrota (C. L. Koch, 1841)	817	21.28	25.40	10.3 ± 15.9
Pulchellaobovella pulchella (Berlese, 1904)	491	12.79	8.36	18.9 ± 39.0
Olodiscus minima (Kramer, 1882)	364	9.48	23.15	5.1 ± 6.7
Trachytes pauperior (Berlese, 1914)	286	7.45	8.68	10.6 ± 24.8
Uroobovella minima (C. L. Koch, 1841)	220	5.73	4.82	14. 7 ± 25.8
Urodiaspis tecta (Kramer, 1876)	113	2.94	12.54	2.9 ± 3.9
Oodinychus karawaiewi (Berlese, 1904)	112	2.92	2.57	14.0 ± 25.2
Dinychus arcuatus (Trägårdh, 1943)	111	2.89	2.89	12.3 ± 13.1
Dinychus inermis (C. L. Koch, 1841)	110	2.87	3.86	9.2 ± 14.4
Olodiscus misella (Berlese, 1916)	103	2.68	5.79	5.7 ± 8.6
Polyaspis sansonei (Kramer, 1882)	49	1.28	2.57	6.1 ± 4.6
Dinychus perforatus Kramer, 1882	47	1.22	4.18	3.6 ± 3.9
Trematurella elegans (Kramer, 1882)	24	0.63	0.96	8.0 ± 6.2
Uropoda undulata Hirschmann and Zirngiebl-Nicol, 1969	23	0.60	0.32	23.0
Uroobovella obovata (Canestrini and Berlese, 1884)	19	0.49	0.96	6.3 ± 8.4
Uropolyaspis hamulifera (Michael, 1894)	17	0.44	0.96	5.7 ± 6.4
Dinychus carinatus Berlese, 1903	16	0.42	1.29	4.0 ± 2.5
Urotrachytes formicarius (Lubbock, 1881)	10	0.26	0.32	10.0
Uroobovella pyriformis (Berlese, 1920)	9	0.23	0.64	4.5 ± 3.5
Uroobovella sp.	6	0.16	0.96	2.0 ± 1.7
Trachyuropoda coccinea (Michael, 1891)	4	0.10	0.64	2.0 ± 1.4
Discourella modesta (Leonardi, 1889)	2	0.05	0.64	1.0
Dinychus woelkei Hirschmann and Zirngiebl-Nicol, 1969	2	0.05	0.64	1.0
Apionoseius infirmus (Berlese, 1887)	2	0.05	0.64	1.0
Leiodinychus orbicularis (C. L. Koch, 1839)	1	0.03	0.32	1.0
Olodiscus kargi (Hirschmann and Zirngiebl-Nicol, 1969)	1	0.03	0.32	1.0
Uropoda orbicularis (O. F. Müller, 1776)	1	0.03	0.32	1.0
Oplitis sp.	1	0.03	0.32	1.0
Total		3839		

* This tabulation does not include *Ch. nidiphila* found in the area of BTNP only in nest boxes of birds [41].

The dominant species in the examined Uropodina community in BTNP were two species, i.e., *O. ovalis* (D = 22.87%) and *T. aegrota* (D = 21.28%), which were also the most frequently found in the analyzed samples (with frequencies 31.19% and 25.40%, respectively) (Table 1). The third most frequent species in the community was *O. minima* (F > 20%) whereas *P. pulchella* was relatively numerous in the analyzed material (D = 12.79%). The percentage of other species did not exceed 10%. This group of moderately numerous species with varied frequencies included species such as *T. pauperior*, *U. minima*, *O. karawaiewi*, *D. arcuatus*, *D. inermis*, and *U. tecta*, with the latter being relatively common in this location (F > 12%). The other species usually occurred in a low number and rarely. Among these, the least numerous and with very rare occurrence were *T. coccinea*, *A. infirmus*, *D. woelkei*, *D. modesta*,

L. orbicularis, *O. kargi*, and *U. orbicularis*. Among the rare species in the Uropodina community of BTNP, *U. minima* deserves special attention, as it has been recorded for the first time in Poland.

4.2. Spatial Distribution of Mite Species in BTNP

The distribution of Uropodina species found in the area of BTNP is given below (Figures A8–A14). As can be seen, it varied and was dependent on the ecological requirements of the found species, which are also briefly characterized here mainly on the basis of catalogue of Wiśniewski, Hirshmann [25] and monographs by Błoszyk [27] and Mašán [71].

Superfamily: Polyaspidoidea

Family: Trachytidae

Genus: *Trachytes* Michael, 1894

1. *Trachytes aegrota* (C. L. Koch, 1841)

It is a common, eurytopic European species, also recorded in Mongolia. It occurs in almost all types of environments. This species particularly prefers litter of various types of forests, especially deciduous ones. It is less numerous in open environments and merocenoses. In BTNP, it is the second most abundant and frequent species, being an important component of the Uropodina mite communities (Table 1). It is noteworthy that this species has been recorded in all types of the examined types of environments and microhabitats within the park (Figure 2-I). Moreover, it also belongs to the group of dominant species in each case, with a clear preference for meadows, transformed alder forests, and peat bogs in BTNP, where it had the highest average abundance in the positive samples. However, it was significantly less numerous in alder forests and pine forests. The species is evenly distributed throughout the entire park area (Figure A8A).

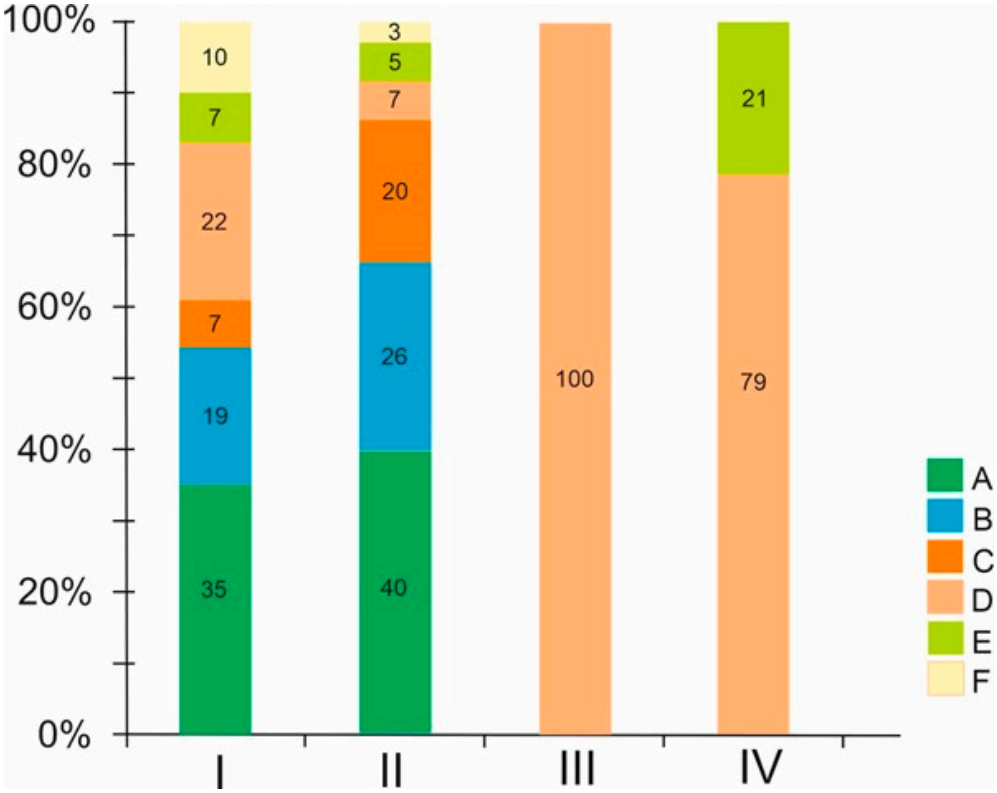

Figure 2. Percentage participation of found species (I—*Trachytes aegrota*, II—*Trachytes pauperior*, III—*Apionoseius infirmus*, *Trematurella elegans*, IV—*Polyaspis sansonei*) in examined habitats in the area of BTNP (A—meadow, B—peatland, C—alder forest, D—transformed alder forest, E—pine forest, F—reeds).

2. *Trachytes pauperior* (Berlese, 1914)

It is a widely distributed European eurytopic species, preferring forest environments with higher levels of humidity. In Poland, it is evenly distributed, although less common than *T. aegrota*. In BTNP, it is the fifth most abundant but relatively rare species (Table 1). It has been recorded in all types of the examined types of environment and microhabitats, and in each of them, it is in the group of dominant species (Figure 2-II). In BTNP, this species, similarly to *T. aegrota*, prefers meadows, pine forests, and peat bogs, where it had the highest average abundance in the positive samples. It is significantly less numerous in alder forests, reed beds, and transformed alder forests. It is evenly distributed in the entire park area (Figure A8B).

Genus: *Apionoseius* Berlese, 1904

3. *Apionoseius infirmus* (Berlese, 1887)

It is a widely distributed but rare European species, also found in Kazakhstan and Mongolia. The species is a typical nidicole, which occurs in the nests of many bird species, as well as in decayed stumps and tree hollows. It is a phoretic species [75]. In BTNP, this species was recorded in two locations, in the northern and western parts of the park (Figure A8C), and in transformed alder forests (Figure 2-III).

Family: Polyaspidae

Genus: Polyaspis Berlese, 1891

4. *Polyaspis sansonei* Berlese, 1916

It is a relatively rare and not very numerous European species, also recorded in Slovakia, the Czech Republic, Germany, Poland, and France. In Poland, it has been recorded at several sites located in different parts of the country. It inhabits litter of oak–hornbeam forests and pine forests, as well as the nests of *Lasius fuliginosus* (Latr) ants. In BTNP, this species was found in only two types of habitat, i.e., in transformed alder forests and pine forests (Figure 2-IV). The sites where this species occurred in the park are located in the central-western and southern parts of BTNP (Figure A8C).

Superfamily: Uropodoidea

Family: Discourellidae

Genus: Discourella Berlese, 1910

5. *Discourella modesta* (Leonardi, 1889)

It is a widely distributed Holarctic species, recorded in many countries in Europe and the USA. It is distributed all over the area of Poland, and found in all types of habitats, with a clear preference for forest habitats. This species prefers dry and warm locations, not found above 700 m ASL [29]. In BTNP, it was found in only one type of habitat, i.e., in meadows (Figure 3-V). The occurrence sites of this species in the park are in the southern parts (Figure A9A).

Family: Dinychidae

Genus: *Dinychus* Kramer, 1882

6. *Dinychus arcuatus* Trågärdh, 1922

It is a European species, recorded so far in the Czech Republic, Slovakia, Poland, and Sweden. In Poland, it is distributed quite evenly, except for the northern part of the country. It prefers forest habitats, although it is also found in other types of habitats. It is a lowland species, with its optimum occurrence range below 500 m ASL [29]. This species in BTNP was found in three types of habitat, i.e., in pine forests, alder forests, meadows, and dead wood (Figure 3-VI). Four occurrence sites of this species in the park are located in the central-western and southern parts (Figure A9B).

7. *Dinychus carinatus* Berlese, 1903

It is a widely distributed European species, found so far in Italy, France, Germany, the Czech Republic, Slovakia, Poland, Romania, and Russia. In Poland, it is evenly distributed all over the entire area of the country. It is clearly associated with various types of merocenoses, mainly with dead wood and tree hollows. The optimum height for this species is below 500 m ASL [29]. This species in BTNP was found in three types of habitat, i.e., in alder forests, where it was most numerous, transformed alder forests, and pine forests

(Figure 3-VII). Four occurrence sites of this species in the park are located in the north, western, and southern parts of the park (Figure A9C).

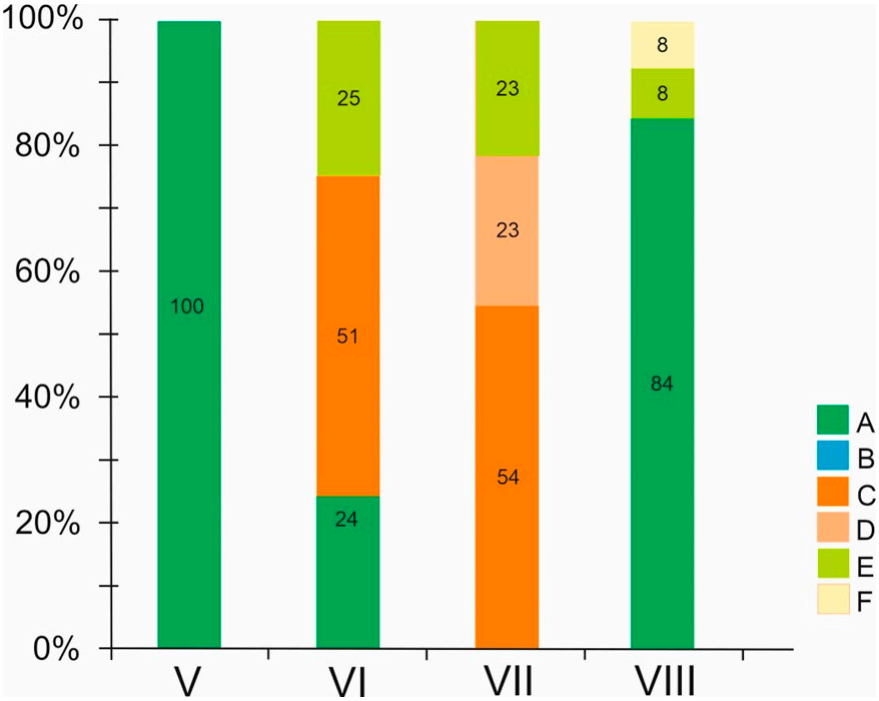

Figure 3. Percentage participation of selected species (V—*Discourella modesta*, VI—*Dinychus arcuatus*, VII—*Dinychus carinatus*, VIII—*Dinychus inermis*) in examined types of habitat in BTNP (A—meadow, B—peatland, C—alder forest, D—transformed alder forest, E—pine forest, F—reeds).

8. *Dinychus inermis* (C. L. Koch, 1841)

It is a widely distributed European species, occurring in the United Kingdom, Germany, Switzerland, Austria, Poland, Lithuania, the Czech Republic, Slovakia, Hungary, and Romania. In Poland, it is evenly distributed in the whole area of the country. It is one of the few hygrophilous species among Uropodina. This species in BTNP was found in three types of habitats with the highest humidity, i.e., in wet meadows, where it was the eudominant species in the examined community, as well as in alder forests and reed beds (Figure 3-VIII). Eight of the occurrence sites of this species in the park were located in the northern, western, and southern parts (Figure A9D).

9. Dinychus perforatus Kramer, 1882

It is a widely distributed European species, also recorded in Mongolia. In Poland, it is evenly distributed all over the entire country. It is a polytopic species, which prefers various types of forests and avoids merocenoses. The most preferable height of occurrence for this species is below 500 m ASL, but it can also be found in mountainous areas up to 1300 m [29]. The species was found in three environments in BTNP, i.e., in wet meadows, where it dominated, as well as in alder forests and reed beds (Figure 4-IX). Five of the occurrence sites of this species in the park were located in the western and southern parts of the park (Figure A10A).

10. *Dinychus woelkei* Hirschmann et Zirgiebl-Nicol, 1969

The species has been recorded in several Central European countries, including Germany, Poland, the Czech Republic, Austria, Hungary, Slovakia, and Romania [28]. It is mainly associated with dead wood in various stages of decay. It occurs both in decayed trunks and hollows, and has also been found in fruiting bodies of fungi from the genus Polyporus, ant nests, and gardens. In BTNP, it was found at two sites (Figure A10B) in one type of habitat, i.e., transformed alder forests (Figure 4-X) and in dead wood (Table 9), where its occurrence was very low and did not exceed 1%.

Family: Trachyuropodidae
Genus: *Trachyuropoda*

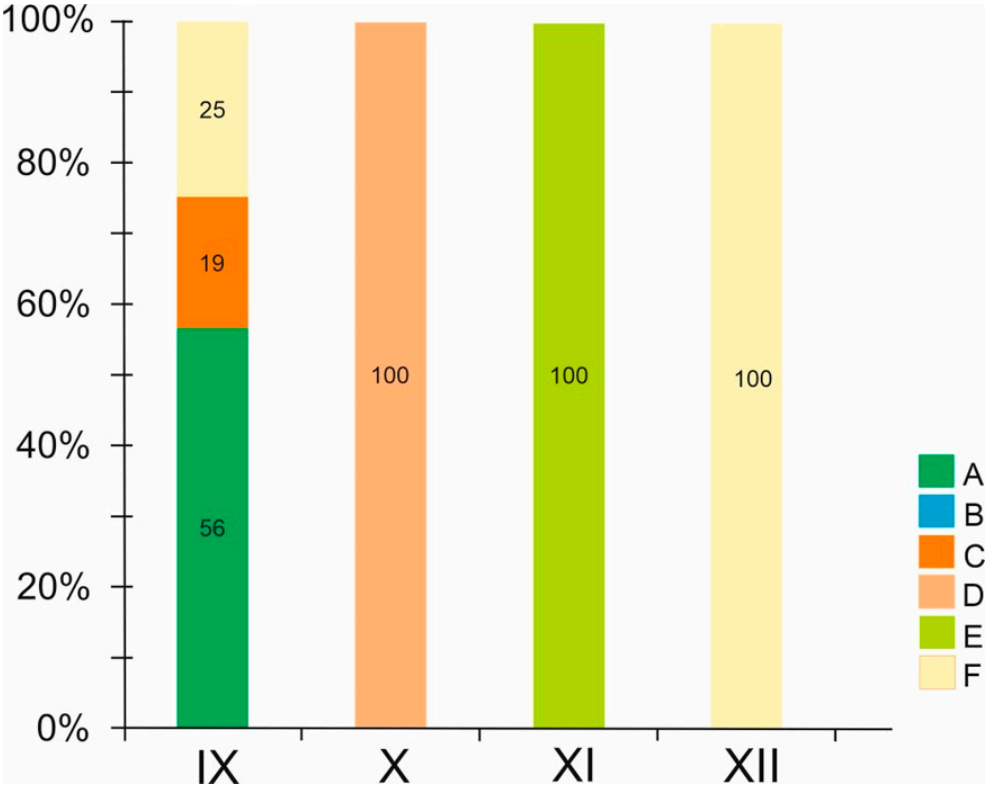

Figure 4. Percentage participation of selected species (IX—Dinychus perforatus, X—Dinychus woelkei, XI—Trachyuropoda coccinea, Urotrachytes formicarius, Uroobovella obovata, Uroobovella pyriformis, XII—Uropoda undulata) in examined types of habitat in BTNP (A—meadow, B—peatland, C—alder forest, D—transformed alder forest, E—pine forest, F—reeds).

11. *Trachyuropoda coccinea* (Michael, 1891)

It is a European species recorded so far in Poland, the Czech Republic, Slovakia, and Russia. It occurs in forest habitats, in ant nests, in soil, under stones, as well as in xerothermic habitats and forest edges. The discussed species was found in pine forest habitats (Figure 4-XI), and in dead wood merocenoses (Table 9), located in the southern part of the BTNP (Figure A10C).

Genus: *Urotrachytes*

12. *Urotrachytes formicarius* (Lubbock, 1881)

It is a widely distributed European species. In Poland, it has been recorded in the southeastern part of the country and in Greater Poland (Wielkopolska). It is a xerophilous species, preferring xerothermic areas [28]. It has also been found in ant hills. In the area of BTNP, the species was found only in pine forests (Figure 4-XI), where it was rare (Table 2). One location of the species was situated in the southern part of the park (Figure A10D).

Family: Uropodidae
Genus: *Uropoda*

13. *Uropoda orbicularis* (Müller, 1776)

It is a widely distributed European, phoretic species. In Poland, it has been recorded in the central and southern parts of the country. It occurs in parks, Carpathian beech forests, agricultural lands, as well as in microhabitats, such as mammal and bird nests, ant nests, compost piles, moss, animal droppings, and dead wood. In the area of BTNP, only one specimen of this species was found in an alder forest (Table 4) located near the northern boundary of the park (Figure A11A).

14. *Uropoda undulata* Hirschmann et Zirgiebl-Nicol, 1969

The species has been reported so far in the areas of Germany, Poland, Lithuania, and Russia. It prefers damp areas, often found in leaf litter and moss, and it also inhabits peat bogs, alder forests, and riparian forests [76]. During the presented project research project, this species was found in dead wood in transformed alder forests (Figure 4-XII), at only one site in the south-eastern part of BTNP (Figure A11B).

Genus: *Olodiscus* (Kramer, 1882)

15. *Olodiscus kargi* Hirschmann et Zirgiebl-Nicol, 1969

It is a rare Central European species, recorded so far in Austria, Poland, Slovakia, and France. In Poland, it is evenly distributed, except for the northwestern part of the country. The species is associated with deciduous forests and is rarely found in other types of habitats. Its optimal altitude of occurrence is below 500 m ASL. In BTNP, the species was found in only one habitat the reeds (Figure 5-XIII) by Ostrowite Lake. The occurrence site of this species in the park is located in its southeastern area (Figure A11C).

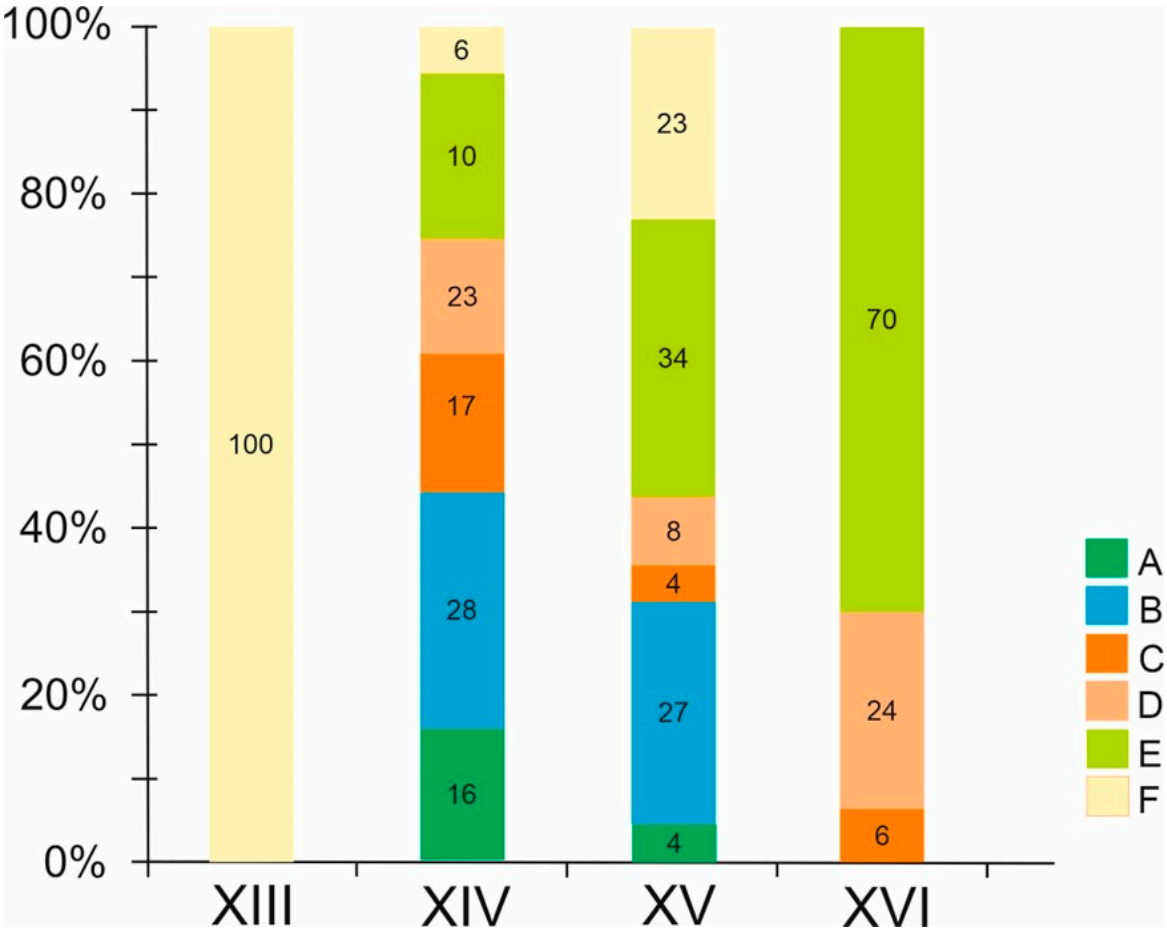

Figure 5. Percentage participation of found species (XIII—*Olodiscus kargi*, *Leiodinychus orbicularis*, XIV—*Olodiscus minima*, XV—*Olodiscus misella*, XVI—*Pulchellaobovata pulchella*) in examined habitats in the area of BTNP (A—meadow, B—peatland, C—alder forest, D—transformed alder forest, E—pine forest, F—reeds).

16. *Olodiscus minima* (Kramer, 1882)

It is a common, widely distributed species in Europe, also recorded in Algeria. In Poland, it is evenly distributed all over the country. It is a eurytopic species, occurring in all types of habitats, but with a clear preference for leaf litter and soil in forests. It often inhabits nests of small mammals, especially the mole (*Talpa europea*). Its optimal altitude of occurrence is below 500 m ASL. It is a species with high ecological tolerance. In BTNP, this species was found in all examined sites (Figure 5-XIV) and in dead wood (Table 9). The species was recorded at 45 sites distributed all over the entire park (Figure A11D).

17. *Olodiscus misella* (Berlese, 1916)

It is s European species, so far recorded in France, Austria, Germany, Poland, the Czech Republic, and Slovakia. In Poland, this species should be considered an Atlantic element, and its distribution coincides with the natural range of the beech (Fagus sylvatica). It is found in various types of habitats, with a clear preference for forests. Its optimal occurrence altitude is below 700 m ASL. In BTNP, this species was found in all examined habitats, except for microhabitats (Table 9), with the highest abundance in pine forests, peat bogs, and reed beds (Figure 5-XV). The species was recorded at 10 sites located in the central and southern parts of the park (Figure A12A).

Genus: *Uropolyaspis*

18. *Uropolyaspis hamulifera* (Michael, 1894)

It is a very rare European species, found in Poland, the Czech Republic, Hungary, Slovakia, and Austria. It prefers forest habitats and is found in ant nests of the genus *Lasius*, especially those located under the bark of decaying trees. In the area of BTNP, this species was of the rare and scarce species, found in pine forests and dead wood microhabitats (Table 2 and Table 9), at three sites in the north and south of the park (Figure A12B).

Family: Urodinychidae

Genus: Pulchellaobovata

19. *Pulchellaobovata pulchella* (Berlese, 1904)

It is a European species, distributed evenly all over the area of Poland. It is most numerous in microhabitats, especially in tree hollows, decayed tree trunks, or rotting logs. It is less common in forest litter. In the examined national park, this species is among those most numerous and frequent, and occurred in four types of habitats, including pine forests and dead wood (Table 9), where it was a eudominant in the communities, and also in alder forests and transformed alder forests (Figure 5-XVI). It was recorded at several sites in the northern, central, western, and southern parts of the park (Figure A12C).

Genus: *Uroobovella*

20. *Uroobovella minima* (C. L. Koch, 1841)

This species has already been recorded in the Czech Republic, Austria, Slovakia, and Hungary, and was found in various types of organic substrates such as feces of large herbivores, manure, compost, and silage. It is a phoretic species, with deutonymphs observed on coprophilous beetles *Paederus schoenkeri* Czwalina and *Philonthus fuscipennis* (Mann.) (Staphylinidae). BTNP is the first location in Poland where U. minima has been recorded. The species was found in samples collected in pine forests, alder forests and transformed alder forests, peat bogs, meadows, and reeds (Figure 6-XVII), situated in a few locations in central, northern, and southern parts of the park (Figure A12D).

21. *Uroobovella obovata* (Canestrini et Berlese, 1884)

U. obovata is a species which has been recorded in several European countries so far, including Poland, the Czech Republic, Slovakia, Austria, and Hungary. This species occurs evenly in the whole area of Poland. It can be found in many types of habitats, but mainly in forests. It is frequently found in nests of small mammals, peat bogs, calcareous rock grasslands, decayed tree trunks and hollows, and on meadows. It is also found in ant nests, under tree bark, and in bumblebee nests. In the area of BTNP, *U. obovata* was found in pine forests (Figure 4-XI) and dead wood microhabitats (Table 9), recorded at three sites located in the southern parts of the park (Figure A13A).

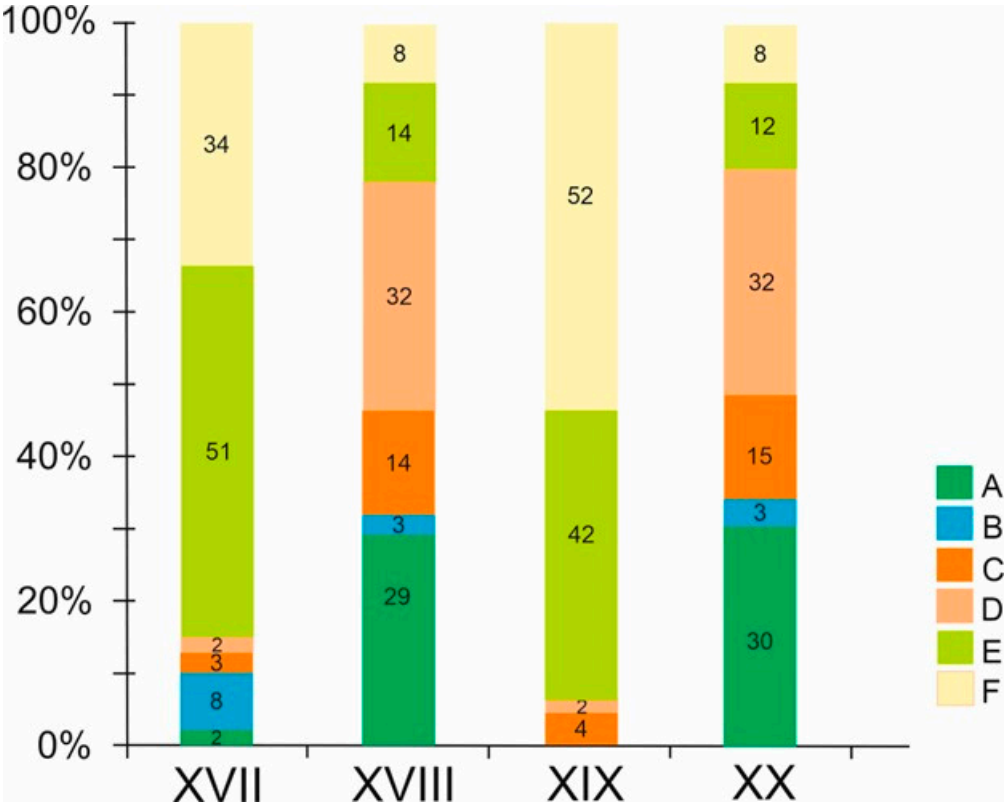

Figure 6. Percentage participation of found species (XVII—*Uroobovella minima*, XVIII—*Urodiaspis tecta*, XIX—*Oodinychus karawaiewi*, XX—*Oodinychus ovalis*) in examined habitats in the area of BTNP (A—meadow, B—peatland, C—alder forest, D—transformed alder forest, E—pine forest, F—reeds).

22. *Uroobovella pyriformis* (Berlese, 1920)

It is a European species found so far in Poland, the Czech Republic, Slovakia, and Austria. This species is common in Poland, and it prefers merocenoses. It is most frequently found in tree hollows, decayed trunks, ant nests, and bird nests. The species can be phoretically carried on dung beetles (Scarabaeidae) and centipedes [75]. In the area of BTNP, it has been recorded in pine forests (Figure 4-XI) and dead wood microhabitats (Table 9), only at one site in the southern part of the park (Figure A13B).

Genus: *Urodiaspis*

23. *Urodiaspis tecta* (Kramer, 1876)

It is a common European species with a wide range of occurrence. In Poland, it occurs all over the entire area of the country, except for the Bieszczady Mountains. It is a typical forest species, rarely found in other types of habitats. It is most often found in litter of oak forests, yew and larch tree stands, mixed forests, beech forests in the south of Poland, beech-fir forests, deciduous forests with a large admixture of pine, multi-species deciduous forests, deciduous forests with a large admixture of spruce, riparian forests, and alder forests. In other types of habitats, larger populations of this species can be found in peat bogs, on dunes, in tree hollows, and in decayed tree trunks. Moreover, this species has also been found in bird and small mammal nests. In the area of BTNP, this species was recorded among the most numerous in the examined Uropodina communities. It occurred in all examined habitats, with a different percentage in each case, and in transformed alder forests it was most numerous (Figure 6-XVIII). The sites where the species was found were located in almost the entire park area, except for the northern part of BTNP (Figure A13C).

Family: Trematuridae

Genus: *Trematurella*

24. *Trematurella elegans* (Kramer, 1882)

It is a European species, quite widely distributed in northern and central Europe. In Poland, it occurs all over the whole country, except for the higher mountain regions. It is found in a litter of various types of forests, parks, and multi-species deciduous forests with an admixture of pine. It is also often found in merocenoses of dead wood, such as decayed tree trunks and hollows, as well as, in bird nests. In BTNP, *T. elegans* occurred in transformed alder forests (Figure 2-III) only in one location in the western part of the park (Figure A13D).

Genus: *Oodinychus*

25. *Oodinychus karawaiewi* (Berlese, 1903)

The discussed species has been reported from Russia, Switzerland, Austria, Romania, Poland, Ukraine, and Hungary. In Poland, it is widely distributed, most commonly found in parks, field thickets, leaf litter of riparian forests, mixed deciduous forests, managed forests, and other environments also those subjected to anthropogenic pressure [28,77,78]. It has also been found in open environments, such as xerothermic grasslands and agrocenoses. Among merocenoses, it prefers nests of small mammals and decayed tree trunks. In BTNP, *O. karawaiewi* was most abundantly found in meadows, and additionally in the litter of pine forests, alder forests, and transformed alder forests (Figure 6-XIX), at six sites (Figure A14A).

26. *Oodinychus ovalis* (C. L. Koch, 1839)

It is a widely distributed European species. In Poland, it occurs in the whole area of the country. It is an eurytopic species, which is found most frequently and in a large number in litter of various types of forests and in some microhabitats, mainly in decayed tree trunks and hollows. This species plays a significant role in Uropodina communities in such environments as parks, deciduous forests with a high proportion of pine, yew stands, spruce stands in lowland Poland, pine forests, and hollows but it is rather rare and scarce in open habitats. This species is also found in nests of birds, and mammals, in compost, and under tree bark. It is a phoretic species carried by insects and centipedes [75]. In the community of the discussed national park, *O. ovalis* was the dominant species (Table 1), which occurred in all examined habitats (Figure 6-XX), and was most abundant in alder forests and transformed alder forests. The sites of occurrence of this species were located in the whole area of the park (Figure A14B).

Genus: *Leiodinychus*

27. *Leiodinychus orbicularis* (C. L. Koch, 1839)

The species occurs in Europe, but also Algeria and India. In Poland, it can be found in the whole area of the lowlands. The major habitats of this species are bird nests, tree hollows, and decayed tree trunks [75]. It is found in various types of rotting substrates, compost, and feces, as well as in nests of moles (*Talpa europea*), and bird nests [41]. The species also occurs sporadically in a litter of forests. In BTNP, the species was found only in reeds (Figure 5-XIII), and only in one location in the northern part of the park (Figure A14C).

4.3. Community Structure of Uropodina in Examined Habitats in BTNP

The tabulations given below present the characteristics of Uropodina communities in the six examined types of habitats in the area of BTNP.

4.3.1. Pine Forests

In this study, 119 samples were collected from various types of coniferous habitats (dry coniferous forest, fresh coniferous forest, moist coniferous forest, and swamp coniferous forest) (Figure A1). The analyzed material contained 19 species of Uropodina, with a total of 1115 specimens (Table 2).

Table 2. Uropodina community in pine forests * in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average number in a sample ± standard deviation.

Species	N	D%	F%	Ave. ± SD
P. pulchella	443	39.73	15.13	24.6 ± 45.6
O. ovalis	258	23.14	31.09	7.0 ± 8.4
T. aegrota	135	12.11	21.85	5.2 ± 8.4
O. minima	104	9.33	21.01	4.2 ± 6.2
D. arcuatus	34	3.05	3.36	8.5 ± 8.8
O. karawaiewi	22	1.97	0.84	22.0
U. obovata	19	1.70	2.52	6.3 ± 8.4
U. hamulifera	17	1.52	2.52	5.7 ± 6.4
P. sansonei	16	1.43	4.20	3.2 ± 1.8
U. tecta	15	1.35	8.40	1.5 ± 0.5
U. minima	11	0.99	0.84	11.0
U. formicarius	10	0.90	0.84	10.0
U. pyriformis	9	0.81	1.68	4.5 ± 3.5
D. carinatus	6	0.54	1.68	3.0 ± 2.8
Uroobovella sp.	5	0.45	1.68	2.5 ± 2.1
T. pauperior	4	0.36	1.68	2.0 ± 1.4
T. coccinea	4	0.36	1.68	2.0 ± 1.4
O. misella	2	0.18	1.68	1.0
D. woelkei	1	0.09	0.84	1.0
Total	1115			

* the analyzed material contained samples from soil and unstable microhabitats.

The most numerous species, though with moderate frequency in this type of habitat, was *P. pulchella*. Besides this, *O. ovalis*, *T. aegrota*, and *O. minima* were also abundant and fairly common. These four most numerous species constituted as much as 84.31% of the entire community. The examined mite community also included several rare species like *U. hamulifera*, *U. minima*, *Uroobovella* sp., and *T. coccinea*.

4.3.2. Transformed Alder Forests

The analyzed material contained 44 samples from this type of habitat (Figure A2), in which 15 Uropodina species were recorded, with 751 specimens (see Table 3).

Table 3. Uropodina mite community in transformed alder forests in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Species	N	D%	F%	Ave. ± SD
O. ovalis	339	45.14	47.73	16.1 ± 19.8
T. aegrota	160	21.30	34.09	10.7 ± 22.6
O. minima	85	11.32	31.82	6.1 ± 6.8
U. tecta	45	5.99	25.00	4.1 ± 6.4
P. pulchella	40	5.33	9.09	10.0 ± 15.4
P. sansonei	24	3.20	4.55	12.0 ± 4.2
T. elegans	24	3.20	6.82	8.0 ± 6.2
U. undulata	23	3.06	2.27	23.0
D. carinatus	3	0.40	2.27	3.0
O. misella	2	0.27	2.27	2.0
A. infirmus	2	0.27	4.55	1.0
T. pauperior	1	0.13	2.27	1.0
O. karawaiewi	1	0.13	2.27	1.0
D. woelkei	1	0.13	2.27	1.0
U. minima	1	0.13	2.27	1.0
Total	751			

The most frequently and abundantly occurring species in this type of habitat in BTPN was *O. ovalis*. Note that *T. aegrota* and *O. minima* were also quite numerous and frequently found. Moreover, *U. tecta* occurred fairly often (F = 25%), though in a lower number (D about 6%). These four species constituted 83.75% of the entire community. Among the rare species found in BTNP, there were *U. undulata* and *U. minima.*

4.3.3. Alder Forests

In the examined alder forests (Figure A3) in the area of BTNP 33 samples were collected, which contained 15 Uropodina species (379 specimens) (Table 4).

Table 4. Uropodina mite community in alder forests in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Species	N	D%	F%	Ave. ± SD
O. ovalis	112	27.86	48.48	7.0 ± 12.8
T. aegrota	83	20.65	27.27	9.2 ± 9.3
D. arcuatus	69	17.16	12.12	17.2 ± 17.9
T. pauperior	32	7.96	21.21	4.6 ± 7.3
O. minima	32	7.96	27.27	3.6 ± 3.2
U. tecta	20	4.98	15.15	4.0 ± 4.2
P. pulchella	8	1.99	12.12	2.0 ± 1.2
O. karawaiewi	7	1.74	9.09	2.3 ± 1.5
D. carinatus	7	1.74	3.03	7.0
O. misella	3	0.75	9.09	1.0
D. perforatus	3	0.75	6.06	1.5 ± 0.7
D. inermis	1	0.25	3.03	1.0
U. orbicularis	1	0.25	3.03	1.0
U. minima	1	0.25	3.03	1.0
Total	379			

The most frequent and numerous species in the examined alder forests in BTPN were *O. ovalis* and *T. aegrota*. *Olodiscus minima*, and *T. pauperior* were also quite frequent (F > 20%) but less numerous (D < 10%). The rare species found in this habitat were *U. orbicularis* and *U. minima.*

4.3.4. Peat Bogs

In the examined peat bogs areas (Figure A4), 14 samples were collected, in which the presence of 8 *Uropodina* species was recorded, with a total of 101 specimens (Table 5). The community in this type of damp habitat was dominated by two species, i.e., *T. aegrota* and *O. minima*, which constituted 71.28% of the entire community.

Table 5. Uropodina mite community in peat bogs in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Species	N	D%	F%	Ave. ± SD
T. aegrota	39	38.61	28.57	9.7 ± 14.2
O. minima	33	32.67	21.43	11.0 ± 17.3
T. pauperior	9	8.91	7.14	9.0
U. minima	8	7.92	7.14	8.0
U. tecta	7	6.93	21.43	2.3 ± 2.3
O. ovalis	3	2.97	14.29	1.5 ± 0.7
O. misella	1	0.99	7.14	1.0
Uroobovella sp.	1	0.99	7.14	1.0
Total	101			

4.3.5. Meadows

In the examined meadows (Figure A5), 31 samples were collected, which contained 12 Uropodina species, with a total of 679 specimens (Table 6).

Table 6. Uropodina mites on meadows in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Species	N	D%	F%	Ave. ± SD
T. pauperior	140	20.62	16.13	28.0 ± 55.0
T. aegrota	138	20.32	22.58	19.7 ± 26.4
O. ovalis	116	17.08	25.81	14.5 ± 28.5
D. inermis	108	15.91	32.26	10.8 ± 15.4
O. karawaiewi	82	12.08	9.68	27.3 ± 40.4
D. perforatus	40	5.89	29.03	4.4 ± 4.5
O. minima	38	5.60	22.58	5.4 ± 7.5
D. arcuatus	8	1.18	3.23	8.0
U. tecta	3	0.44	9.68	1.0
D. modesta	2	0.29	6.45	1.0
O. misella	2	0.29	6.45	1.0
U. minima	2	0.29	6.45	1.0
Total	679			

In the area of meadows located in BTPN, four species were numerous and frequently found, namely *T. pauperior*, *T. aegrota*, *O. ovalis* and *D. inermis*. The most common species in the community was *D. perforatus* (F = 29%) which was not numerous (D = 5.9%).

4.3.6. Inland Dunes

On the inland dunes (Figure A6) within the park, 21 samples were collected, which contained only 5 common Uropodina species, with a total of 62 specimens (Table 7). The community was dominated by one of the most common species in Europe, namely *T. aegrota*, which constituted over 70% of the entire community. It is noteworthy that the frequency of all species occurring on the examined dunes was very low (<10%).

Table 7. Uropodina mites on inland dunes in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Species	N	D%	F%	Ave. ± SD
T. aegrota	44	70.97	4.76	44.0
O. minima	8	12.90	9.52	4.0 ± 4.2
U. tecta	5	8.06	4.76	5.0
O. ovalis	4	6.45	9.52	2.0
T. pauperior	1	1.61	4.76	1.0
Total	62			

4.3.7. Reeds

In this type of habitat (Figure A7) within the park, 23 samples were collected, which contained 12 Uropodina species, with a total of 195 specimens (Table 8). The community was dominated by *U. minima*. Also, *T. aegrota* and *O. misella* were quite numerous and frequent in the community. This type of habitat also hosted species with high moisture preferences from the genus *Dinychus*, such as *D. perforatus* and *D. intermis*. There were two rare species like *O. kargi* and a species from the genus *Oplitis.* present in the community.

Table 8. Uropodina mite community in reeds in BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Species	N	D%	F%	Ave. ± SD
U. minima	93	47.69	17.39	23.25 ± 27.35
T. aegrota	31	15.90	21.74	6.20 ± 6.30
O. misella	25	12.82	17.39	6.25 ± 9.18
O. ovalis	21	10.77	21.74	4.20 ± 7.16
T. pauperior	10	5.13	13.04	3.33 ± 1.53
O. minima	6	3.08	13.04	2.00 ± 1.73
D. perforatus	4	2.05	8.70	2.00 ± 1.41
L. orbicularis	1	0.51	4.35	1.00
U. tecta	1	0.51	4.35	1.00
O. kargi	1	0.51	4.35	1.00
D. inermis	1	0.51	4.35	1.00
Oplitis sp.	1	0.51	4.35	1.00
Total	195			

4.4. Importance of Merocenoses in Preserving Uropodina Diversity in BTNP

The material for the analysis mainly comes from merocenoses of dead wood and five ant hills of the genus *Formica*, with only one Uropodina species, namely *O. ovalis*, found in the examined ant hills, with a total of 12 specimens. That is why the species composition of the community presented below (Table 9) is characteristic of dead wood merocenoses.

Table 9. Uropodina mite communities in different dead wood merocenoses (e.g., lying trunks and stumps) in the area of BTNP. N—number of specimens, D%—dominance, F%—frequency, Ave. ± SD—average abundance ± standard deviation.

Gatunek	N	D%	F%	Ave. ± SD
P. pulchella	368	49.60	25.00	36.8 ± 58.8
O. ovalis	256	34.50	52.50	12.1 ± 17.0
T. aegrota	36	4.85	17.50	5.1 ± 6.7
P. sansonei	34	4.58	10.00	8.5 ± 4.7
U. undulata	23	3.10	2.50	23.0
O. minima	6	0.81	5.00	3.0 ± 1.4
U. hamulifera	4	0.54	5.00	2.0 ± 1.4
Uroobovella sp.	4	0.54	2.50	4.0
D. woelkei	2	0.27	5.00	1.0
U. obovata	2	0.27	2.50	2.0
U. pyriformis	2	0.27	2.50	2.0
T. pauperior	1	0.13	2.50	1.0
U. tecta	1	0.13	2.50	1.0
D. arcuatus	1	0.13	2.50	1.0
U. minima	1	0.13	2.50	1.0
T. coccinea	1	0.13	2.50	1.0
Total	742			

The Uropodina community in the examined dead wood merocenoses in BTNP consists of 16 species. The community was dominated by *P. pulchella*, which constituted nearly 50% of the whole community, with *O. ovalis* (D = 34.5%) being the second most numerous species. The percentage of other species did not exceed 5%, with *T. aegrota* being a fairly frequent species (occurring in about 1/5 of the samples).

4.5. Similarity in Species Composition of Examined Forest and Open Habitats

The communities of the examined habitats in BTNP differed both in species composition and the number of taxa present in each of them. The highest similarity in species composition (S = 75%) has been observed in inland dunes and peat bogs, where number

of species was the lowest and communities were formed by eurytopic, ubiquitous species (Tables 5 and 7). Another group has been formed by meadows, alder forests, and reeds; however, the latter habitat was the most distinct (S = 50%). In communities of forest habitats, i.e., pine forests and transformed alder forests the species composition was also very similar (S > 60%) (Figure 7).

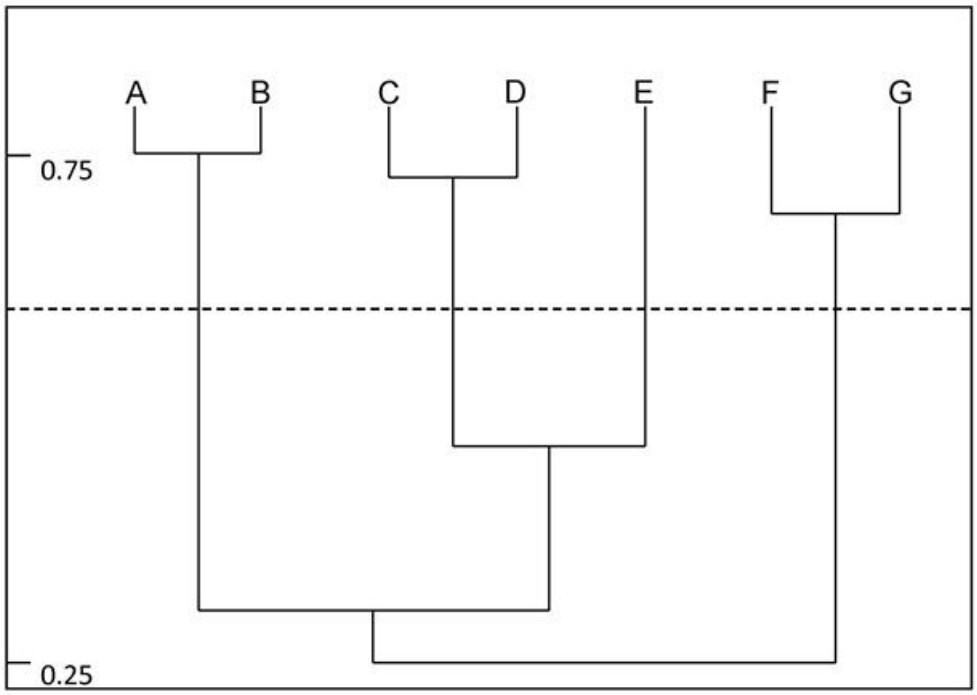

Figure 7. Similarity (S) in species composition of Uropodina communities in examined habitats (S): A—inland dunes, B—peat bogs, C—meadows, D—alder forests, E—reeds, F—transformed alder forests, G—pine forests.

4.6. Uropodina Mite Community of BTNP Against Other National Parks in Poland

So far, the highest number of Uropodina species has been recorded in Białowieża NP (54 species) (Figure 8). Świętokrzyski NP, Ojcowski NP, Bieszczady NP, Tatra NP, Roztocze NP, and Pieniny NP have higher species diversity than BTNP. Furthermore, fewer species have also been recorded so far in Wielkopolski NP, Gorce NP, Karkonosze NP, Wolin NP, and Babia Góra NP (Figure 8).

The comparative analysis of the 13 national parks in Poland based on the MI has revealed that this index is highest for Białowieża NP (MI = 0.66). This park also had the highest species diversity of Uropodina communities (54 species) and the highest percentage of *K*-strategy species (Table 10). The next most valuable, in terms of natural value, was Świętokrzyski NP (MI = 0.52, number of species 41). Regarding the MI value, BTNP was the fourth park (with 0.45) among the discussed national parks in Poland. Despite the average number of Uropodina species found in this park (28), BTNP is characterized by a relatively high percentage of -strategy species (46.4%), which is also reflected in the MI value.

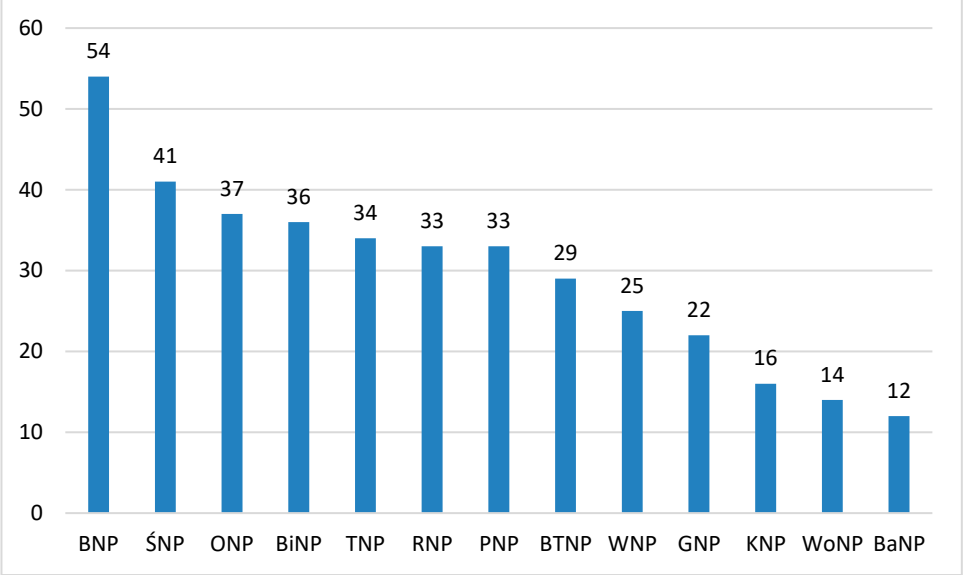

Figure 8. Number of Uropodina species recorded in the digital database *Invertebrate Fauna Bank* for the 13 analyzed national parks in Poland. BNP—Białowieski PN, ŚNP—Świętokrzyski NP, ONP—Ojcowski PN, BiNP—Bieszczadzki NP, TNP—Tatrzański NP, RNP—Roztoczański NP, PNP—Pieniński NP, BTNP—Bory Tucholskie NP, WNP—Wielkopolski NP, GNP—Gorczański NP, KNP—Karkonoski NP, WoNP—Woliński NP, BaNP—Babiogórski NP.

Table 10. The values of the Maturity Index (MI) for the examined national parks in Poland and the percentage of K-species in the communities. NP—name of national park, N—number of Uropodina species, MI—Maturity Index, TA—Tatrzański NP, BT—Bory Tucholskie NP, WI—Wielkopolskie NP, RO—Roztoczański NP, PI—Pieniński NP, GO—Gorczański NP, OJ—Ojcowski NP, SW—Świętokrzyski NP, BE—Bieszczadzki NP, BI—Białowieski NP, WO—Woliński NP, KA—Karkonoski NP, BA—Babiogórski NP.

NP	BT	TA	WI	RO	PI	GO	OJ	SW	BE	BI	WO	KA	BA
N	28 *	34	25	33	33	22	37	41	36	54	14	21	12
% of K-species	46.4	41.2	40.0	45.5	39.4	36.4	54.1	53.7	47.2	66.7	35.7	33.3	16.7
MI	0.45 *	0.32	0.33	0.43	0.33	0.26	0.48	0.52	0.40	0.66	0.26	0.35	0.10

* including *Ch. nidiphila* found in bird nest boxes [41].

5. Discussion

The Uropodina communities in the area of BTNP largely consist of common and widely distributed soil species inhabiting Poland and Europe, such as *O. ovalis*, *T. aegrota*, and *P. pulchella* [27,28,71]. However, there are some rare species, which also have been found in the examined community, such as *U. undulata*, *U. minima*, *U. hamulifera*, *U. formicarius*, and *T. coccinea* [27,28,71]. Among them, *U. minima* deserves special attention as it was recorded in Poland, in the area of BTNP, for the first time. It is a European, hydrophilous species, which was found in the Czech Republic, Slovakia, Austria, and Romania [71]. This species occurred in large numbers in samples from wet meadows, alder forests, and reeds (Table 8), i.e., high-humidity environments that had not been frequently examined so far for the occurrence of Uropodina mites [40]. This example shows that there is a clear need for further inventory studies considering various environments and microhabitats, which may result in finding new or very rare Uropodina species. A similar situation can be observed in the case of *Ch. nidiphila*, the species which has been found in BTNP in bird nest boxes [41]. This species was described in 1993 by Wiśniewski and Hirschmann and found in dead wood samples of a pine tree in Wielkopolska (Western Poland). The

second occurrence of this species was recorded in material collected from tree hollows of the woodpecker in Lower Silesia [79]. The third place of occurrence of this species in Poland is BTNP [41]. Most Uropodina species (almost 70%) are steno- and oligotopic, usually associated with one specific type of habitat [27]; hence, disregarding various types of environment and microhabitats in studies may result in not detecting such species. The fact that two of the aforementioned rare Uropodina species have been found in BTNP makes this location extremely important for the conservation of the biodiversity of this group of mites in Poland.

The spatial distribution of individual Uropodina species in the area of BTNP varied (Figures A8–A14). Some species did not exhibit any particular habitat preferences and occurred in various types of plant communities, ranging from forests through alder forests to open habitats with different moisture levels, such as meadows and dunes. These include common, eurytopic species with a wide range of ecological tolerance; for example, *O. minima* and *O. ovalis* [27,28,71,80]. A significant factor determining the distribution of the found species was soil humidity. The community in dry and warm habitats, for example, inland dunes, is not frequently inhabited by Uropodina [27,71]. That is why only five species were recorded there (Table 7). The examined community was dominated by one of the most common Uropodina species in Europe, namely *T. aegrota* [8,27,28,71,74,80]. On the other hand, hygrophilous species with higher moisture requirements, including *U. minima*, *D. inermis*, *D. perforatus*, and *U. undulata* [27,28,81], occurred only in humid habitats, i.e., meadows and alder forests near lakes (Tables 4 and 6). The presence of *O. karawaiewi* in these sites is not so much due to the moisture of the habitat but rather the probable influence of strong anthropopressure, as it has been proved that this species occurs in areas under human pressure and it is a good indicator of this factor [78]. The community found in the wet reeds was much more diverse in Uropodina species. The number of recorded species (i.e., 12) was comparable to that typically recorded in various types of forest complexes [43,81], and this community was dominated by a new species for the Polish fauna, i.e., *U. minima*. The presence in the reeds community of all three species from the genus *Olodiscus*, which prefers humid habitats more than most Uropodina species [27,28], has also been recorded in this case. In addition to the common *O. minima*, the much rarer *O. misella* and the rarest species from this genus, i.e., *O. kargi* [27,28], were also found in the analyzed material. This community also contained one species from the rarely found soil genus *Oplitis* [27,28,71]. The obtained results indicate that the reed beds in BTNP are an important habitat for mites from the discussed group.

The role of merocenoses as a significant element in increasing biodiversity, particularly in relation to saprophagous mites, including Uropodina among them, has been addressed in many earlier studies [27,37,38,41,63,82–84]. Thus, in the presented studies from the area of BTNP, merocenoses of dead wood and ant nests were also discussed. Due to the fact that the only species found in the examined ant nests of the *Formica* genus was the eurytopic *O. ovalis* [27,71], it can be assumed that the Uropodina community found in the merocenoses is essentially typical for dead wood. This is also proved by the dominance of *P. pulchella*, which is a species characteristic of various microhabitats of dead wood [37,82]. The dominance structure in this community is also typical for Uropodina communities inhabiting microhabitats, as the two dominant species, i.e., *P. pulchella* and *O. ovalis*, constitute over 80% of the whole community [82]. It should be emphasized that some of the species found in the examined merocenoses are specific to microhabitats and can only occasionally be found in soil [27,82,84]. Among these species, there were *P. pulchella*, *U. hamulifera*, *D. woelkei*, *U. obovata*, *U. pyriformis*, and *T. coccinea*, found exclusively or almost exclusively in dead wood collected in BTNP. Their occurrence, determined by the presence of dead wood, increases the overall biodiversity of Uropodina in the area of BTNP. Furthermore, two species inhabiting unstable microhabitats in BTNP, namely *L. orbicularis* and *Ch. nidiphila* [85], found in bird nest boxes [41], also increase the overall biodiversity of Uropodina in BTNP and are an important element of the whole ecosystems in this area.

Only 13 out of 23 Polish national parks can be considered fairly well studied in relation to the discussed group of mites. A few samples were also collected from several other locations, but they were not used in this analysis. Regarding parks such as Magurski, Drawieński, or Wigierski, our computer database called *Invertebrate Fauna Bank* lacks any data on the mites occurring there, including Uropodina. In terms of species diversity of Uropodina, BTNP is the eighth among the examined national parks. However, the presence of *U. minima*, a species new to the fauna of Poland, makes this community unique. On the other hand, the comparative analysis of the species diversity of BTNP based on MI, an index that evaluates an object based on the community of a selected group of soil invertebrates, considering not only the number of species but also their life strategies, which include traits such as rarity, specific habitat requirements, or species biology [45,72,73] and other national parks, has revealed that BTNP can be ranked as fourth, just after Białowieża, Świętokrzyski, and Ojców National Parks. This high position among the examined national parks is due to the high (over 46%) percentage of species with the *K*-strategy, which are considered the most valuable in the community [45]. Among these species, there is also the previously mentioned *U. minima* due to its rarity has been classified as a *K*3 strategy species, i.e., the most valuable species in the community.

6. Conclusions

The results presented in this study clearly show that BTNP, despite being a relatively 'young' national park in Poland, has a high natural value, also in terms of its soil fauna. This is indicated by the high species richness of the mites from the suborder Uropodina, in comparison to other national parks in Poland, as well as the demonstrated presence of rare species belonging to this group. However, further research is still necessary, focusing on both new areas and those poorly examined habitats and microhabitats within the park, as well as monitoring studies of potential changes occurring in already examined sites. These are very important because many adverse changes in the soil environment, including legally protected areas, have been observed recently. Such observations have been made on the basis of studies on temporal changes in Uropodina communities in two nature reserves in Wielkopolska [81,86,87]. Thus, it is necessary to intensify the collection of material for research from the most valuable areas in the country, which will enable the estimation of biodiversity for different soil fauna groups in these areas, as well as conducting many comparative analyses in the future.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Figure A1. Examined plots in the area of Bory Tucholskie National Park. (**A**)—fresh pine forest near Zielone Lake, (**B**)—swamp pine forest in the central part of the park (phot. J. Wendzonka).

Figure A2. Examined plots in the area of Bory Tucholskie National Park. (**A**)—transformed alder forest near Główka Lake, (**B**)—transformed alder forest near Płęsno Lake (phot. J. Wendzonka).

Figure A3. Examined plots in the area of Bory Tucholskie National Park. (**A**,**B**)—alder forest near The Seven Lakes Stream. (phot. J. Wendzonka).

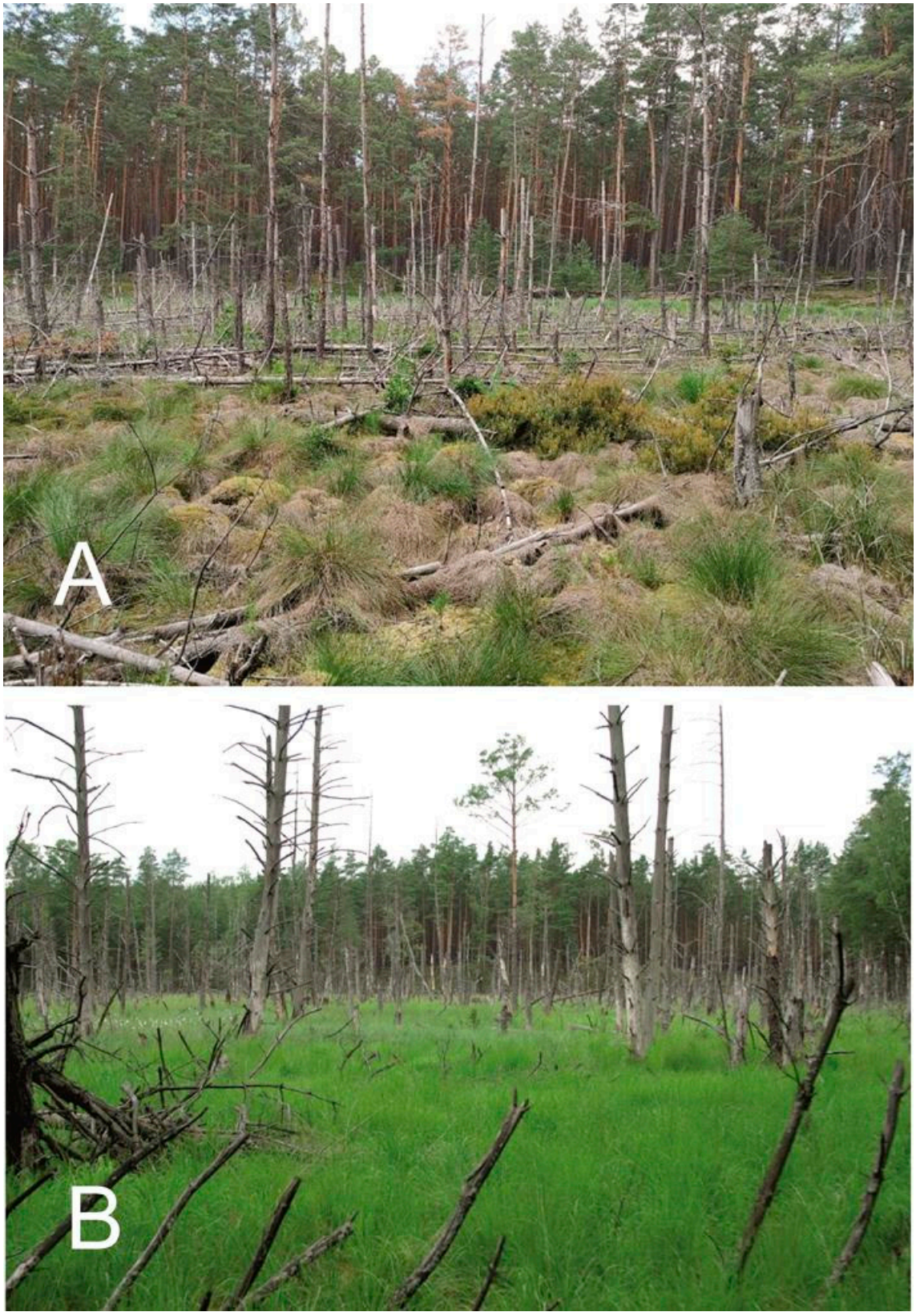

Figure A4. Examined plots in the area of Bory Tucholskie National Park. (**A**,**B**)—Peat bogs near Małe Gacno Lake (phot. J. Wendzonka).

Figure A5. Examined plots in the area of Bory Tucholskie National Park: (**A**) Meadow near southern board of Ostrowie Lake, (**B**) Meadow in Józefowo (phot. J. Wendzonka).

Figure A6. Examined plots in the area of Bory Tucholskie National Park. (**A**)—inland dunes near Gacno Małe Lake, (**B**)—inland dunes near Bachorze (phot. J. Wendzonka).

Figure A7. Examined plots in reeds in the area of Bory Tucholskie National Park (phot. J. Wendzonka).

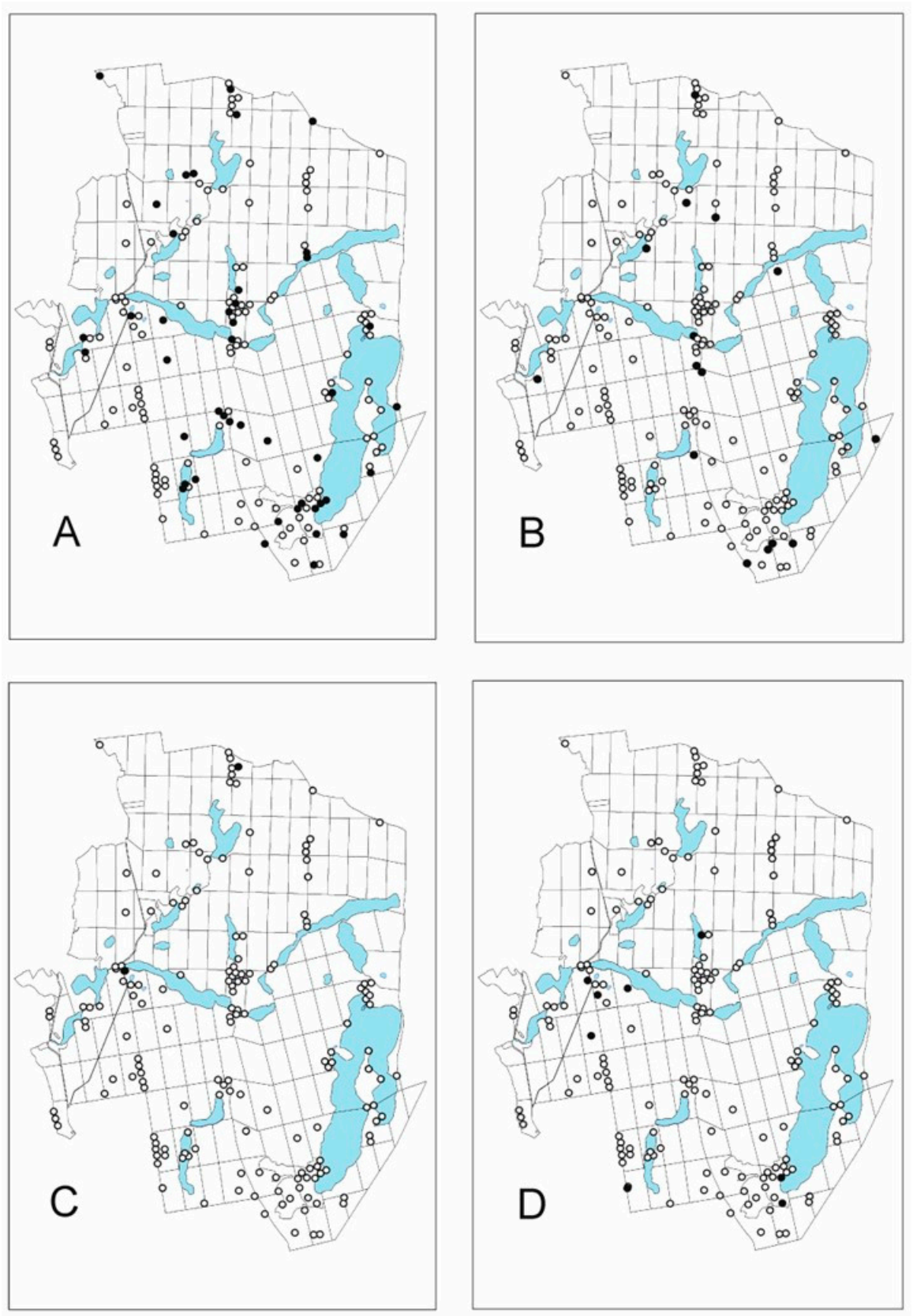

Figure A8. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Trachytes aegrota*, (**B**)—*Trachytes pauperior*, (**C**)—*Apionoseius infirmus*, (**D**)—*Polyaspis sansonei.* Blue parts—water tanks.

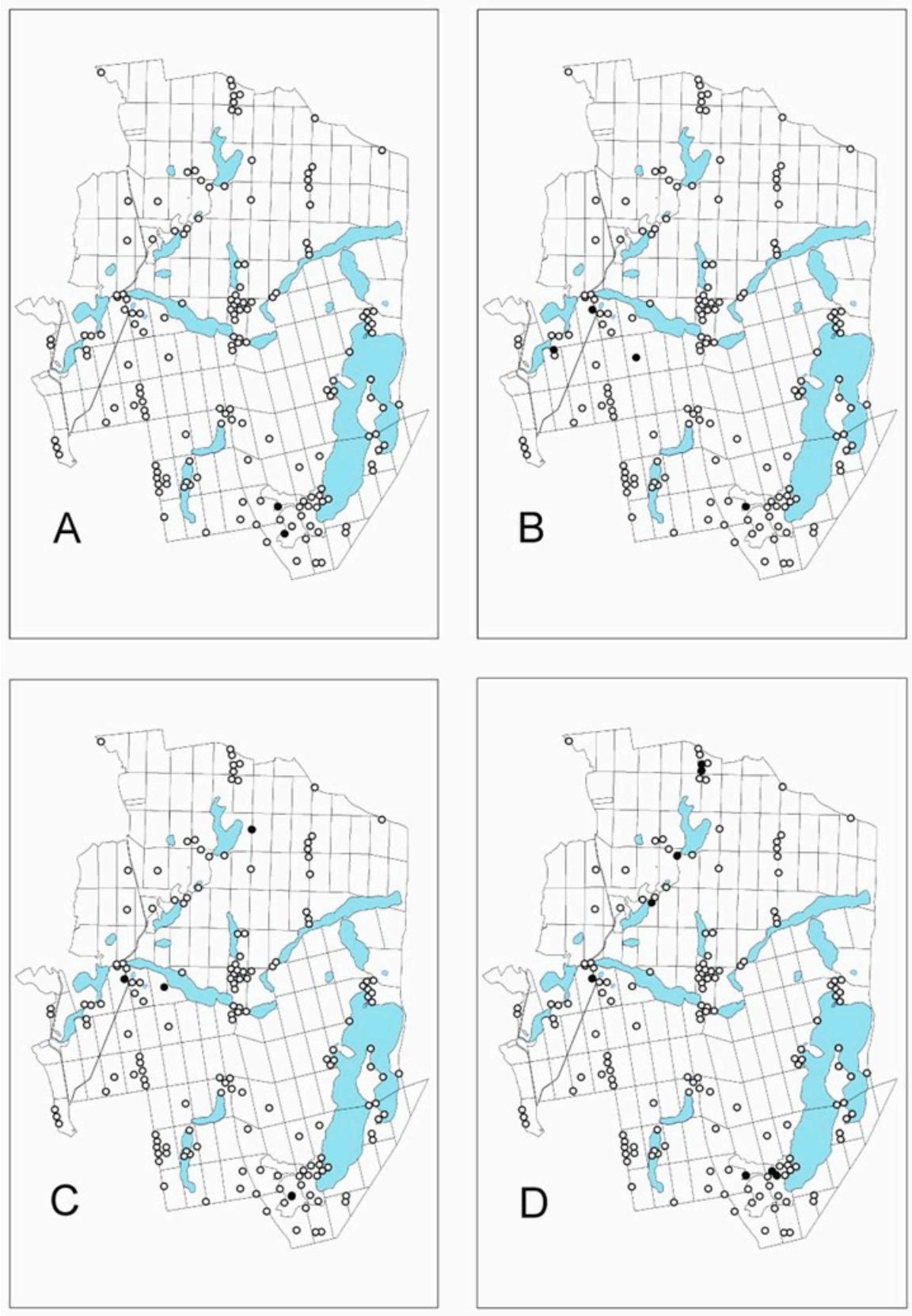

Figure A9. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Discourella modesta*, (**B**)—*Dinychus arcuatus*, (**C**)—*Dinychus carinatus*, (**D**)—*Dinychus inermis.* Blue parts—water tanks.

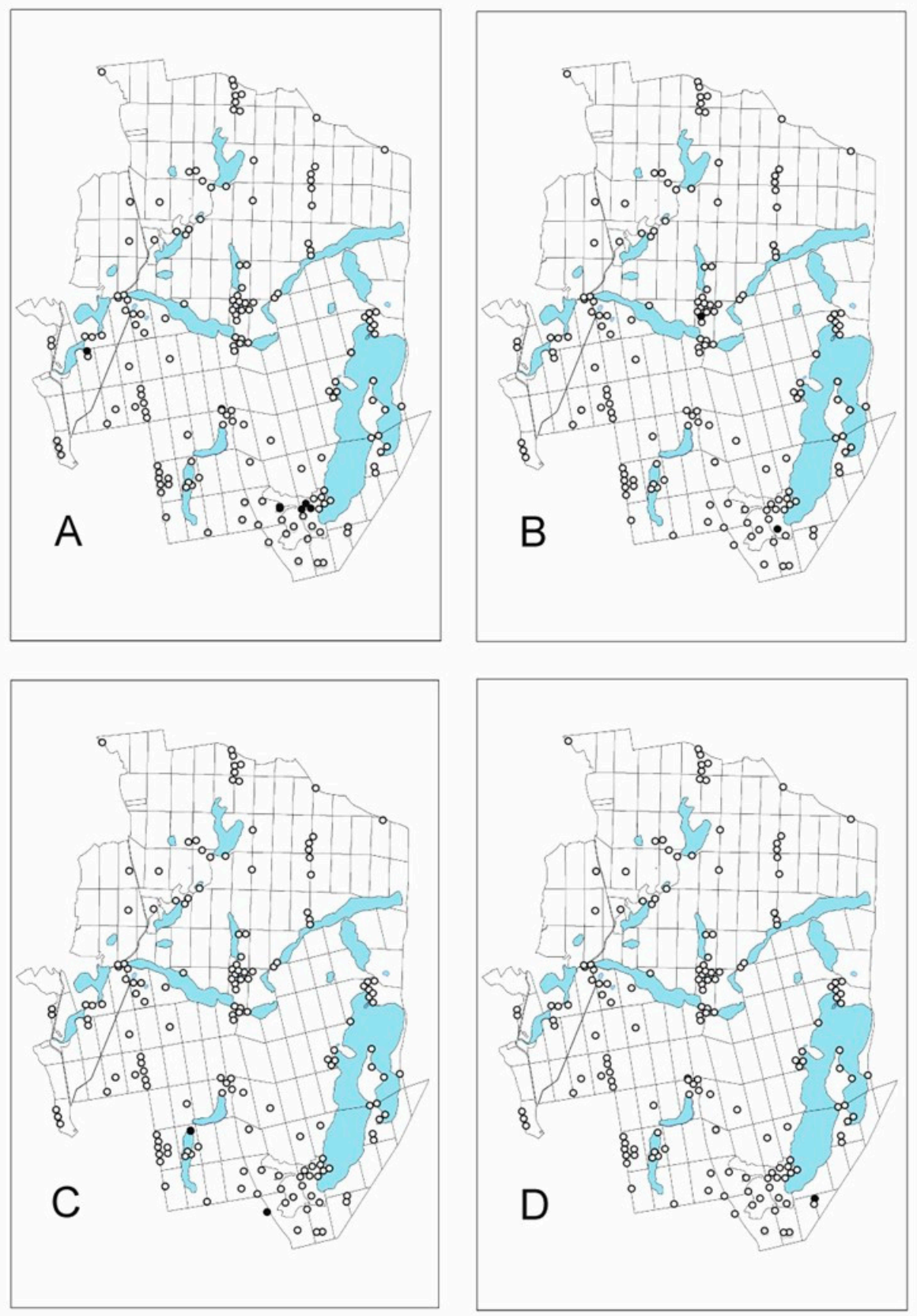

Figure A10. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Dinychus perforatus*, (**B**)—*Dinychus woelkei*, (**C**)—*Trachyuropoda coccinea*, (**D**)—*Urotrachytes formicarius*. Blue parts—water tanks.

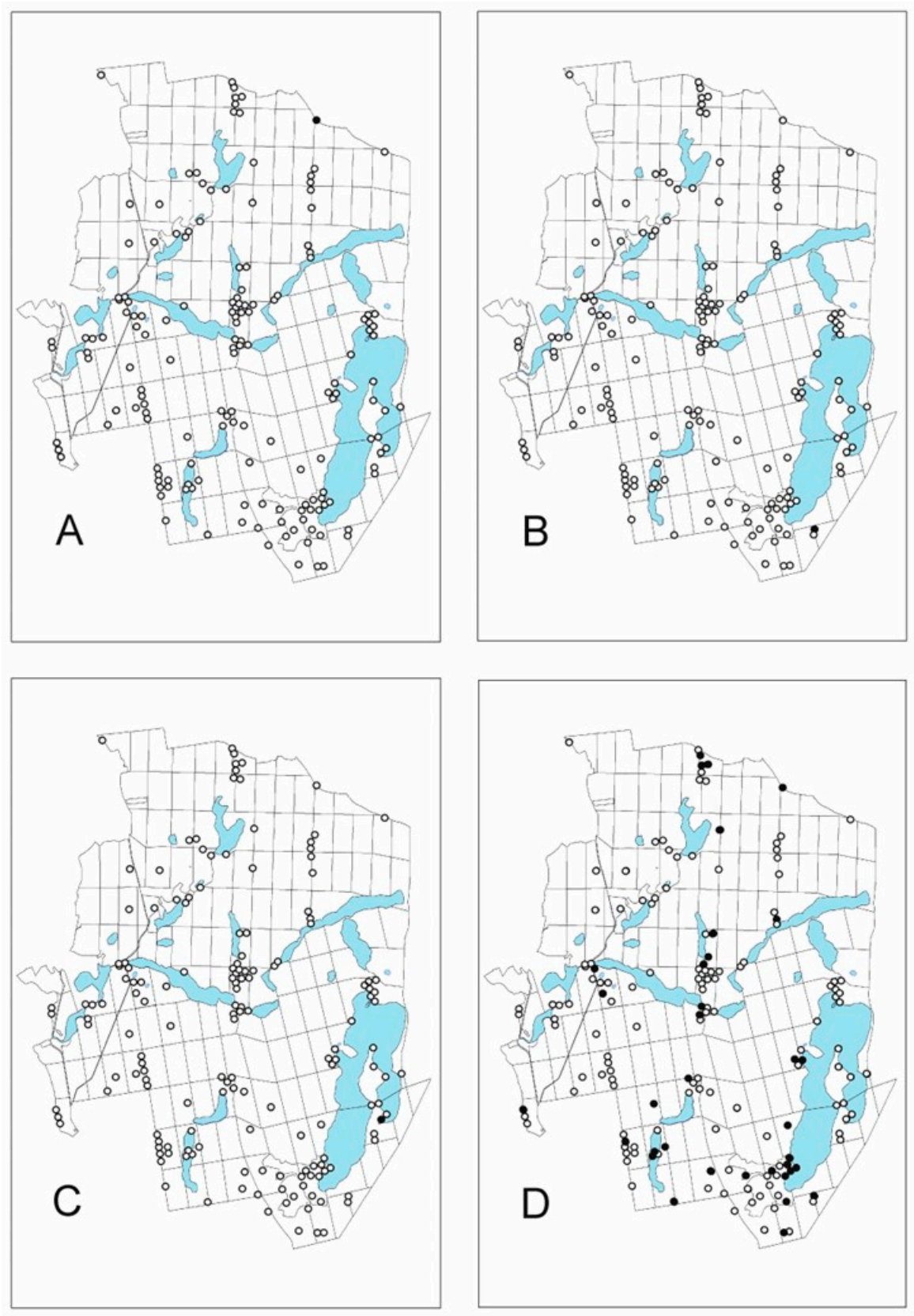

Figure A11. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Uropoda orbicularis*, (**B**)—*Uropoda undulata*, (**C**)—*Olodiscus kargi*, (**D**)—*Olodiscus minima*. Blue parts—water tanks.

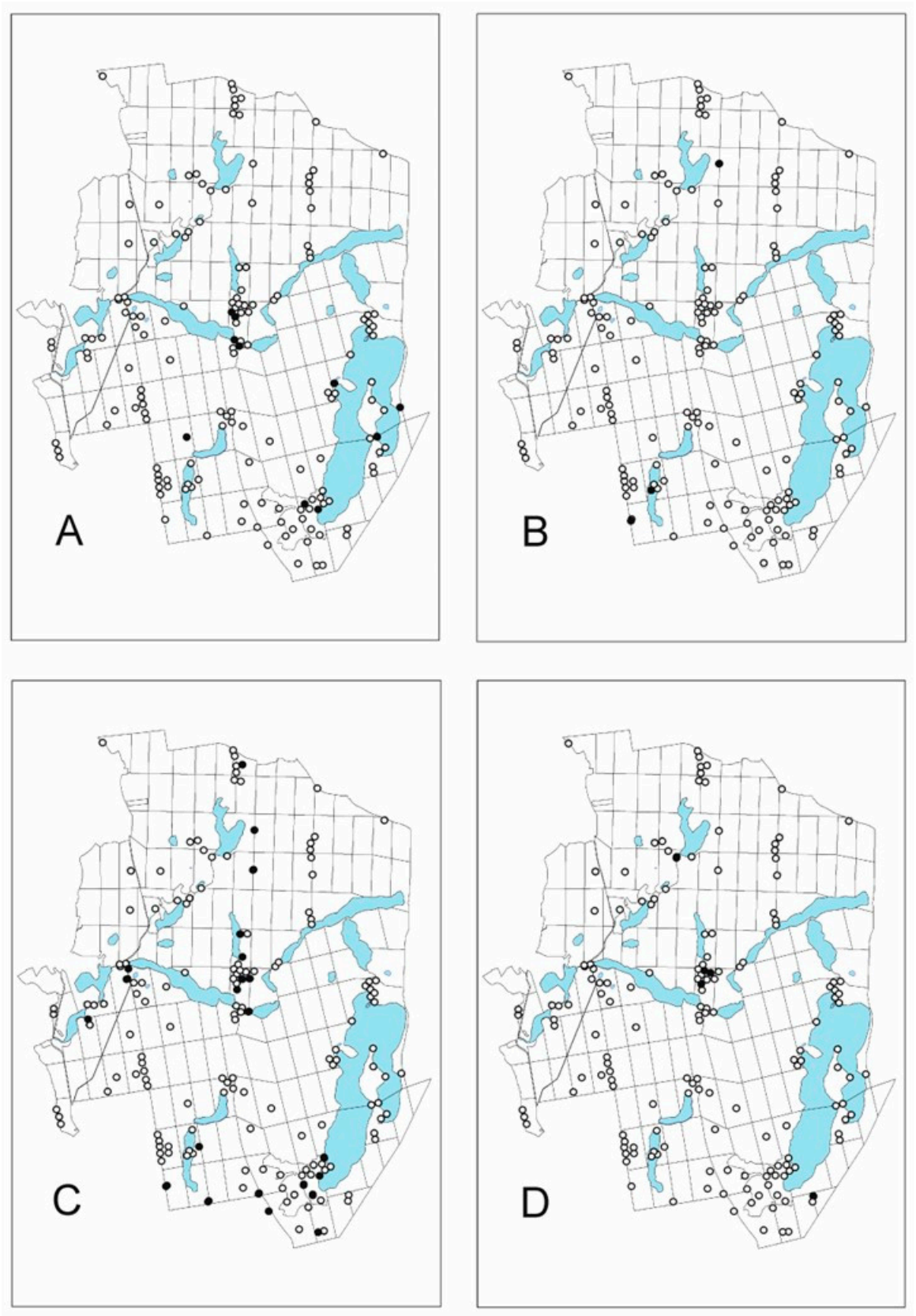

Figure A12. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Olodiscus misella*, (**B**)—*Uropolyaspis hamulifera*, (**C**)—*Pulchellaobovata pulchella*, (**D**)—*Uroobovella minima*. Blue parts—water tanks.

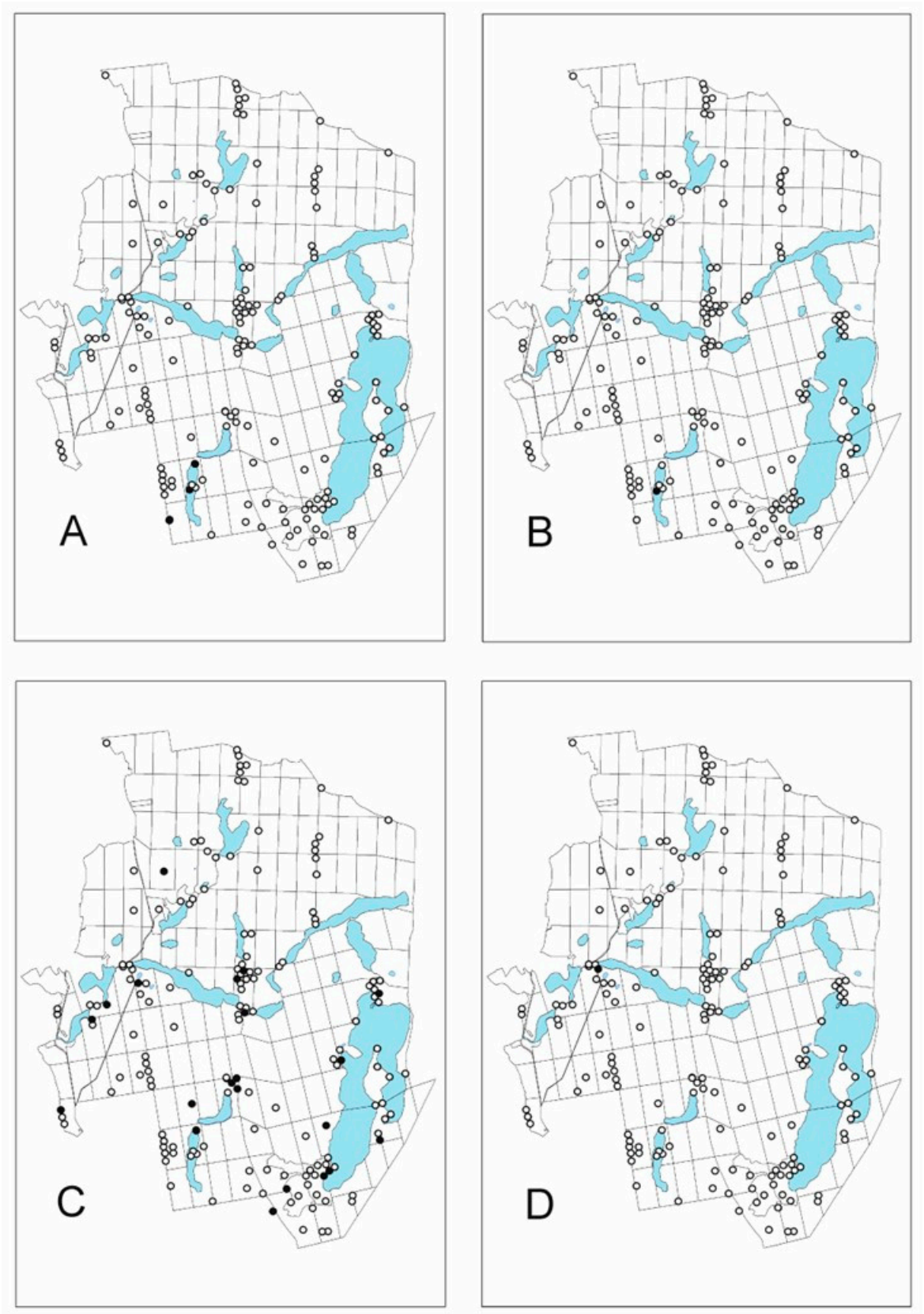

Figure A13. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Uroobovella obovata*, (**B**)—*Uroobovella pyriformis*, (**C**)—*Urodiaspis tecta*, (**D**)—*Trematurella elegans*. Blue parts—water tanks.

Figure A14. Spatial distribution of Uropodina species in BTNP (black dots) against all examined locations (white dots). (**A**)—*Oodinychus karawaiewi*, (**B**)—*Oodinychus ovalis*, (**C**)—*Leiodinychus orbicularis*. Blue parts—water tanks.

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