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HABITAT PREFERENCES OF THE FOREST DUNG BEETLE *ANOPLOTRUPES STERCOROSUS* (SCRIBA, 1791) (COLEOPTERA: GEOTRUPIDAE) IN THE BIAŁOWIEŻA FOREST

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Abstract. The aim of the study was to discover habitat preferences of the forest dung beetle *Anoplotrupes stercorosus* (Scriba, 1791). Beetle specimens were collected using modified Barber traps in the Białowieża Forest, in 1999. In total, 14980 specimens of the forest dung beetle were collected. According to the obtained results, the optimal habitat types of the beetle in question included fresh broadleaved forest, fresh mixed broadleaved forest, fresh mixed coniferous forest, moist broadleaved forest and fresh coniferous forest. It was discovered that the beetle in question was more abundant in fresh forest habitats than in moist and boggy forest habitats or in alder swamp forests.

Key words: Geotrupidae, *Anoplotrupes stercorosus*, forest habitat type, Białowieża Forest

INTRODUCTION

The forest dung beetle *Anoplotrupes stercorosus* (Scriba, 1791) is a species encountered in Europe, Caucasus and Western Siberia [Burakowski et al. 1983]. In Poland it is the most common and the most abundant representative of the family of earth-boring dung beetles (Geotrupidae) inhabiting forests [Stebnicka 1976]. Its larvae feed on leaf litter buried by imagoes at the depth of ca. 30 cm. Such litter, buried in the form of provision mass enriches deeper, mineral soil layers in organic material. This is of particular importance in coniferous forest habitats, where saprophage macrofauna is scarce [Górny 1975, Rembiałkowska 1980]. Imagoes feed on mouldy litter, animal droppings, fruiting bodies of umbrella mushrooms and tree juice [Rojewski 1980, Burakowski et al. 1983]. Borowski [1960], in his study devoted to the biology of the forest dung beetle, its feeding and habitat preferences, as well as its distribution in the Białowieża Forest, underlines the enormous role played by this beetle in the proper functioning of forest ecosystem. According to this author, burrow excavation and provisioning the nests with

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mouldy litter significantly contribute to soil fertilization and increase its aeration and permeability. An exceptionally important role played by the forest dung beetle in decomposition of forest litter and wild animal droppings has also been stressed in the study by Olszewski [1979] on the correlation between the number of collected individuals of the forest dung beetle and the air temperature at the forest floor, the study by Rembiałkowska [1982] on the growth intensity of the forest dung beetle and in the study by Szyszko [1983] on the structure of Scarabaeoidea assemblages in tree stands of post-agricultural lands and in forests. Byk [2004] has proved that the forest dung beetle is more abundant in tree stands found in post-agriculatural areas than in forests. Inhabiting in mass numbers the tree stands growing on post-agricultural lands, the beetles change the characteristics of post-agricultural soil and accelerate the process of forest soil development.

On the open, hard and rough surfaces forest dung beetles can move with the speed of about 50m per hour. They fly occasionally, comparatively fast, usually in the evenings [Plewińska 2007]. In Człuchów Forest (Lasy Człuchowskie) the forest dung beetles were most abundant in the period from June to September. The peaks in beetle activity were observed in June and September [Byk 2004]. Klimaszewski and Strużyński [2005], conducting a research in the "Sobieski's Forest" ("Las Sobieskiego") near Warsaw also observed two peaks in beetle activity, both in the period from Spetember to October. According to Henry and Prelle [1986], the increased abundance of forest dung beetles observed in September can be explained by the appearance of a new generation of beetles. Plewińska [2007], who analyzed the diurnal/nocturnal activity of forest dung beetle imagoes, observed that they were most active in the afternoon, ca. 6 p.m. Afternoon activity is typical of many species with diurnal rhythm of activity and may be connected with weather conditions [Grosfilley and Buisson 1982, Henry and Prelle 1986].

In the recent years it has been pointed out that the representatives of Geotrupidae might be treated as zooindicators of environmental conditions. The possibilities of making *A. stercorosus* useful in monitoring various threats to forest ecosystems, as well as changes taking place in them, have been described in the studies by Szwałko [1995], Szwałko and Starzyk [1997], Skłodowski et al. [1998], Klimaszewski and Szyszko [2000], Byk [2004], Klimaszewski and Strużyński [2005], Skłodowski and Duda [2007].

Many studies can be found in world subject literature investigating the complex character of relations between coprophages and the environment [Rainio 1966, Desiere 1973, Koskela and Hanski 1977, Grosfilley and Buisson 1982, Henry and Prelle 1986, Hanski and Cambefort 1991, Lobo 1993, Mittal and Bhati 1998]. However, in spite of the enornous role played by the forest dung beetle in the decomposition of forest litter and its usefulness in monitoring changes taking place in forest ecosystems, the knowledge about its ecological requirements is still unsatisfactory. This fact has been a premise to undertake the present study focusing on habitat preferences of forest dung beetles.

MATERIAL AND METHODS

For the purposes of the study 52 research areas were established, 4 per each of the 13 forest habitat types in the Białowieża Forest. These habitat types included: Bśw – fresh coniferous forest, Bw – moist coniferous forest, Bb – boggy coniferous forest, BMśw – fresh mixed coniferous forest, BMw – moist mixed coniferous forest, BMb – boggy mixed coniferous forest, LMśw – fresh mixed broadleaved forest, LMw – moist mixed broadleaved forest, LMb – boggy mixed broadleaved forest, Lśw – fresh mixed broadleaved forest, Lw – moist broadleaved forest, OlJ – ash-alder swamp forest, Ol – alder swamp forest (Fig. 1, Table 1).

Beetle specimens were collected in 1999. In each of the research areas there were installed 5 modified Barber pitfall traps (Fig. 2). During the period of the research 260 traps were functioning in each research area, arranged in the patterns of squares with diagonal lines (the so-called envelope pattern). The sides of the squares were 25 m long. Beetles were collected from the traps every 40 days, since 1 June until 10 November.

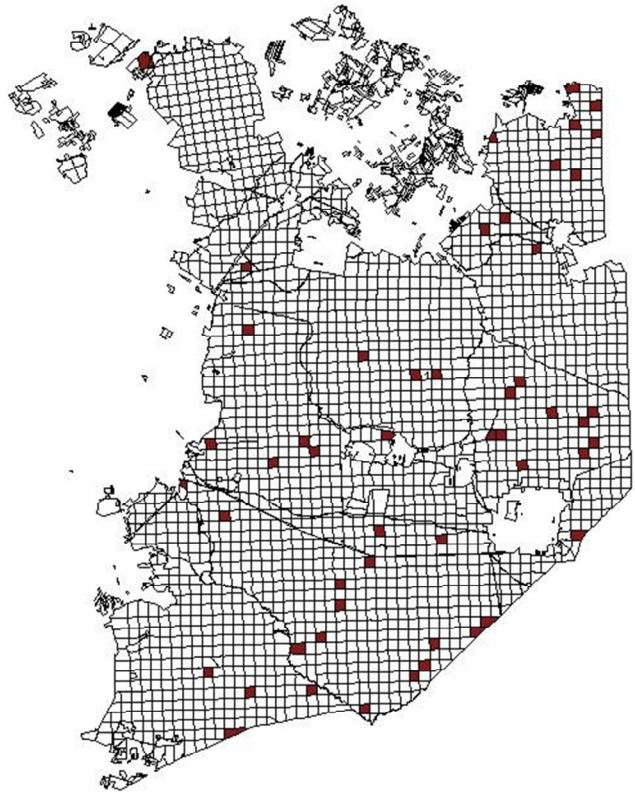

Fig. 1. Location of research areas where representatives of *Anoplotrupes stercorosus* (Scriba) were collected in the Białowieża Forest

Rys. 1. Rozmieszczenie powierzchni badawczych do odłowu żuka leśnego *Anoplotrupes stercorosus* (Scriba) w Puszczy Białowieskiej

Table 1. List of research areas where representatives of *Anoplotrupes stercorosus* (Scriba) were collected in the Białowieża Forest
Tabela 1. Wykaz powierzchni badawczych do odłowu żuka leśnego *Anoplotrupes stercorosus* (Scriba) w Puszczy Białowieskiej

Forest habitat type Siedliskowy typ lasu	Białowieża National Park Białowieski Park Narodowy	Białowieża Forest District Nadleśnictwo Białowieża		Browsk Forest District Nadleśnictwo Browsk			Hajnówka Forest District Nadleśnictwo Hajnówka		
		Białowieża Working Circle Obręb Białowieża	Zwierzyniec Working Circle Obręb Zwierzyniec	Browsk Working Circle Obręb Browsk	Narewka Working Circle Obręb Narewka	Puszcza Ladzka Working Circle Obręb Puszcza Ladzka	Hajnówka Working Circle Obręb Hajnówka	Leśna Working Circle Obręb Leśna	Starzyna Working Circle Obręb Starzyna
Bśw	–	P1-493 Ag	–	–	–	P2-740 Bj	–	P3-519 Bb	P4-669 Ad
Bw	P5-255 Dh	P6-641 Cf	–	P7-64 Ad	–	–	–	P8-575 Dd	–
Bb	P9-373 Bc	P10-641 Bb	–	P11-1Ah	–	–	–	P12-543Bi	–
BMśw	P13-319 Ab	P14-446 Dd	–	P15-9Df	–	–	P16-329Bc	–	–
BMw	P17-285 Ag	–	P18-337 Ch	P19–84 Bb	–	–	–	–	P20-666 Aa
BMb	P21-373Bb	P22-671Ga / P23-583 Bn	–	P24-10 Ab	–	–	–	–	–
LMśw	P25-317 Ab	–	P26-473 Bd	–	P27-75 Ci	–	–	–	P28-730 Ad
LMw	P29-340 Bc	P30-609 Ad	–	P31-49 Cb	–	–	–	–	P32-631 Ab
LMb	P33-384 Aa	P34-477 Af	–	P35-8 Bb	–	–	–	P36-414 Ca	–
Lśw	P37-318 Df	–	P38-217 Ac	P39-27 Df	–	–	P40-334 Ac	–	–
Lw	P41-370 Df	–	P42-252 Ba	P43-26 Bb	–	–	P44-334 Dc	–	–
OlJ	P45-340 C	–	P46-251 Ba	–	P47-148 Da	–	P48-359 Bf	–	–
Ol	P49-345 Cp	–	P50-583 Cd	P51-4Bb	–	–	–	P52-602 Ab	–

Bśw – fresh coniferous forest, Bw – moist coniferous forest, Bb – boggy coniferous forest, BMśw – fresh mixed coniferous forest, BMw – moist mixed coniferous forest, BMb – boggy mixed coniferous forest, LMśw – fresh mixed broadleaved forest, LMw – moist mixed broadleaved forest, LMb – boggy mixed broadleaved forest, Lśw – fresh broadleaved forest, Lw – moist broadleaved forest, OlJ – ash-alder swamp forest, Ol – alder swamp forest.

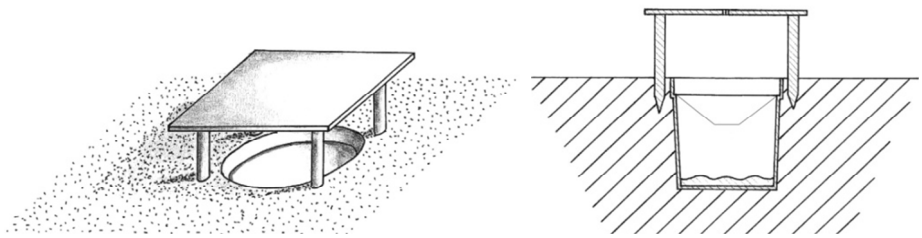

Fig. 2. A trap for collecting coprophagous beetles (drawing by J. Piętka)
Rys. 2. Pułapka do odłowu żuków koprofagicznych (rys. J. Piętka)

Statistical validity of observed disparities in the abundance of forest dung beetles was checked. The application of Kruskal-Wallis test allowed to check the effect of habitat fertility (coniferous habitat, broadleaved habitat, alder habitat) and habitat dampness (alder habitat, boggy habitat, moist habitat, fresh habitat) on the number of collected species. Fertility and dampness of habitats were considered as independent variables, and the number of individuals was considered as a dependent variable. The calculations were conducted with the help of Statistica software.

RESULTS

The number of collected specimens of the forest dung beetle in particular types of forest habitats in the Białowieża Forest was increasing in fresh habitats beginning with the fresh coniferous forest, through the fresh mixed coniferous forest and the fresh mixed broadleaved forest and, finally, the fresh broadleaved forest. Similarly, the abundance of the forest dung beetle was increasing in boggy habitats beginning with the boggy coniferous forest, through boggy mixed coniferous forest, boggy mixed broadleaved forest and, finally, even the ash-alder swamp forest. In moist habitats the number of the forest dung beetle individuals was increasing beginning with the moist coniferous forest, through the moist mixed broadleaved forest, and decreasing again in the moist broadleaved forest. In the course of the whole research period the largest number of the forest dung beetle specimens were collected into traps distributed over the fresh broadleaved forest habitat (ca. 2.9 thousand individuals), fresh mixed broadleaved forest habitat (ca. 2.6 thousand), fresh mixed coniferous forest habitat (ca. 2.2 thousand) moist mixed broadleaved forest habitat (2 thousand) and fresh coniferous forest habitat (ca. 1.7 thousand). The fewest beetles were collected in the habitats of boggy coniferous forest (94 individuals), alder swamp forest (125), boggy mixed coniferous forest (186), boggy mixed broadleaved forest (208) ash-alder swamp forest (318) and moist coniferous forest (359). An intermediate number of the forest dung beetle individuals was found in the habitats of moist mixed coniferous forest (ca. 1.1 thousand) and moist broadleaved forest (ca. 1.2 thousand). It was discovered that the share of the collected forest dung beetle specimens in fresh and moist habitats was very high when compared with the total number of collected specimens, and amounted to 63% and 31%, respectively.

The obtained results show disparities in the collectability of the forest dung beetle in various forest habitat types. An average efficiency of a trap in particular forest habitat types ranged from 4 to 146 specimens. The trap efficiency was definitely the highest in fresh habitats, ranging from 87 to 146 specimens, and in the habitat of moist mixed broadleaved forest – 98 specimens. It was the lowest in boggy habitats, ranging from 4 to 11 specimens, and in the alder swamp forest – 7 specimens. In the other moist habitats and in the ash-alder swamp forest the trap efficiency was neither exceedingly high nor exceedingly low and ranged from 15 to 62 specimens (Fig. 3).

The results of numerical data analysis showed statistical validity of disparities in the forest dung beetle abundance in coniferous habitats, broadleaved habitats and alder habitats (Table 2, Fig. 4).

The average trap efficiency in tree stands growing in broadleaved habitats was higher than that of coniferous habitats, and definitely higher than that of tree stands growing in alder habitats, and amounted to 89, 47 and 11 specimens, respectively.

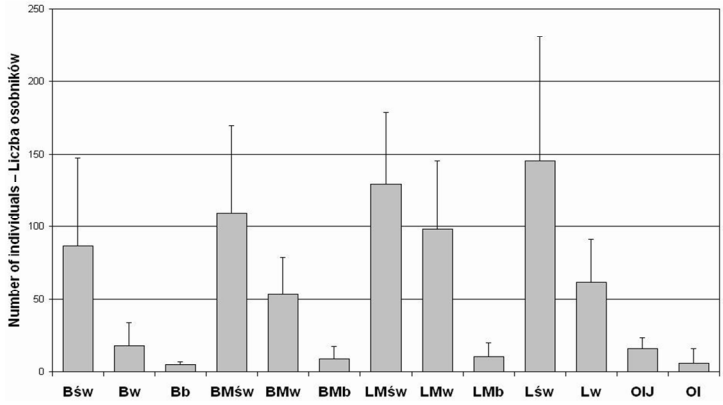

Fig. 3. Average number of *Anoplotrupes stercorosus* (Scriba) individuals collected in traps in particular habitat types of the Białowieża Forest: Bśw – fresh coniferous forest, Bw – moist coniferous forest, Bb – boggy coniferous forest, BMśw – fresh mixed coniferous forest, BMw – moist mixed coniferous forest, BMb – boggy mixed coniferous forest, LMśw – fresh mixed broadleaved forest, LMw – moist mixed broadleaved forest, LMb – boggy mixed broadleaved forest, Lśw – fresh broadleaved forest, Lw – moist broadleaved forest, OlJ – ash-alder swamp forest, Ol – alder swamp forest

Rys. 3. Średnia liczba osobników żuka leśnego *Anoplotrupes stercorosus* (Scriba) łowiona w pułapkę w poszczególnych typach siedliskowych w Puszczy Białowieskiej

Furthermore, the results of numerical data analysis showed statistical validity of disparities in the forest dung beetle abundance between fresh habitats and moist, boggy and alder habitats, as well as between moist habitats and fresh, boggy and alder habitats. On the other hand, no statistically valid disparities in the forest dung beetle abundance were discovered between boggy habitats and alder habitats (Table 3, Fig. 5).

Table 2. An analysis conducted by means of the Kruskal-Wallis test, comparing the number of *Anoplotrupes stercorosus* (Scriba) individuals collected in habitats representing particular fertility variants (coniferous habitat, broadleaved habitat, alder habitat) in the Białowieża Forest (H (2, N = 260) = 64.08972, p = 0.0000)

Tabela 2. Analiza przeprowadzona za pomocą testu Kruskala-Wallisa, pomiędzy liczbą osobników *Anoplotrupes stercorosus* (Scriba) łowionych na siedliskach o różnej żyzności (siedlisko borowe, siedlisko lasowe, siedlisko olsowe) w Puszczy Białowieskiej (H (2, N = 260) = 64,08972, p = 0,0000)

Habitat Siedlisko	Coniferous habitat Siedlisko borowe R: 118.96	Broadleaved habitat Siedliko lasowe R: 171.22	Alder habitat Siedlisko olsowe R: 63.325
Coniferous habitat Siedlisko borowe		0.000001	0.000152
Broadleaved habitat Siedlisko lasowe			0.000000

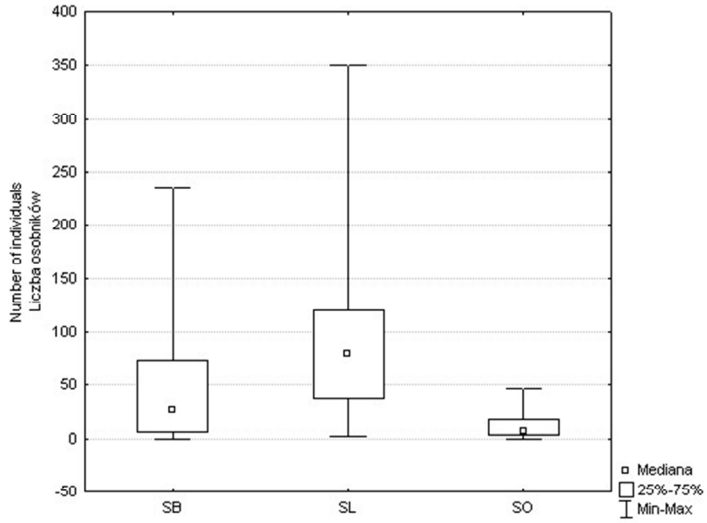

Fig. 4. The median and the range of typical values (lower and upper quartile) for the number of *Anoplotrupes stercorosus* (Scriba) individuals collected in traps in habitats representing particular fertility levels in the Białowieża Forest: SB – coniferous habitat, SL – broadleaved habitat, SO – alder habitat

Rys. 4. Mediana i przedziały wartości typowych (kwartyl dolny – kwartyl górny) dla liczebności żuka leśnego *Anoplotrupes stercorosus* (Scriba) odłowionego w pułapkę w poszczególnych wariantach żyzności siedlisk w Puszczy Białowieskiej: SB – siedliska borowe, SL – siedliska lasowe, SO – siedliska olsowe

Table 3. An analysis conducted by means of the Kruskal-Wallis test, comparing the number of *Anoplotrupes stercorosus* (Scriba) individuals collected in habitats characterised by various levels of dampness (alder habitat, boggy habitat, moist habitat, fresh habitat) in the Białowieża Forest (H (3, N = 260) = 174.4305, p = 0.000)

Tabela 3. Analiza przeprowadzona za pomocą testu Kruskala-Wallisa, pomiędzy liczbą osobników *Anoplotrupes stercorosus* (Scriba) łowionych na siedliskach o różnej wilgotności (siedlisko olsowe, siedlisko bagienne, siedlisko wilgotne, siedlisko świeże) w Puszczy Białowieskiej (H (3, N = 260) = 174,4305, p = 0,000)

Habitat Siedlisko	Alder habitat Siedlisko olsowe R: 63.325	Boggy habitat Siedliko bagienne R: 53.692	Moist habitat Siedlisko wilgotne R: 148.85	Fresh habitat Siedlisko świeże R: 203.34
Alder habitat Siedlisko olsowe		n.s.	0.000000	0.000000
Boggy habitat Siedlisko bagienne			0.000000	0.000000
Moist habitat Siedlisko wilgotne				0.000027

n.s. – result which is not statistically valid.
n.s. – wynik nieistotny statystycznie.

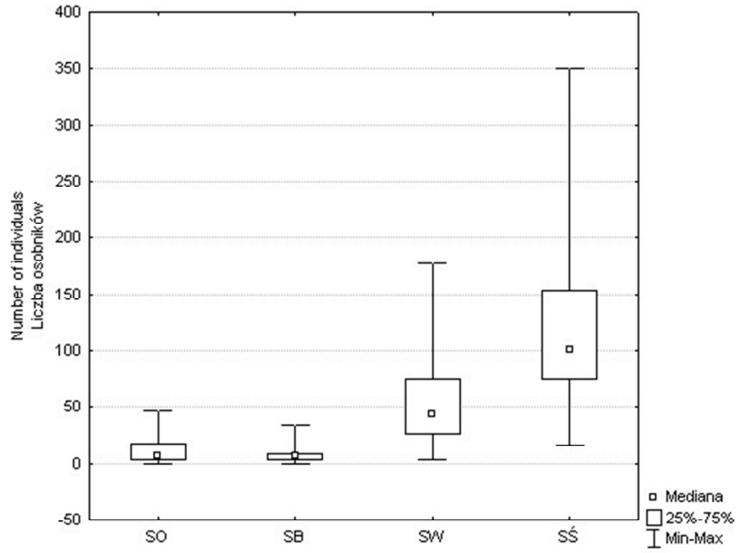

Fig. 5. The median and the range of typical values (lower and upper quartile) for the number of *Anoplotrupes stercorosus* (Scriba) individuals collected in traps in habitats representing particular dampness levels in the Białowieża Forest: SO – alder habitat, SB – boggy habitat, SW – moist habitat, SŚ – fresh habitat

Rys. 5. Mediana i przedziały wartości typowych (kwartyl dolny – kwartyl górny) dla liczebności żuka leśnego *Anoplotrupes stercorosus* (Scriba) odłowionego w pułapkę w poszczególnych wariantach uwilgotnienia siedlisk w Puszczy Białowieskiej: SB – siedliska bagienne, SO – siedliska olsowe, SŚ – siedliska świeże, SW – siedliska wilgotne

The average trap efficiency in tree stands growing in fresh habitats was considerably higher than in tree stands growing in moist habitats (118 and 58 specimens, respectively), and definitely higher than in tree stands growing in boggy and alder habitats (8 and 11 specimens, respectively).

DISCUSSION

On the basis of the collected entomofaunistic material there has been proved the statistical validity of disparities in the abundance of the forest dung beetle in coniferous, broadleaved and alder habitats of Białowieża Forest. The average trap efficiency in tree stands growing in broadleaved habitats was higher than in coniferous habitats and considerably higher than in tree stands growing in alder habitats. This indicates that the forest dung beetle finds the best conditions for living and developing in broadleaved and coniferous habitats of Białowieża Forest, and tends to avoid alder habitats. There has also been proved the statistical validity of disparities in the abundance of the forest dung beetle in fresh vs. moist, boggy and alder habitats, as well as moist habitats vs. fresh,

boggy and alder habitats. No statistically valid disparities have been discovered in the abundance of the forest dung beetle in boggy habitats and alder habitats. This indicates that the living conditions of the forest dung beetle are better in fresh habitats of the Białowieża Forest.

The forest dung beetle has been the most abundant in the habitats of the fresh broadleaved forest, fresh mixed broadleaved forest, fresh mixed coniferous forest, moist broadleaved forest and fresh coniferous forest, while it tended to avoid the boggy coniferous forest, boggy mixed coniferous forest, boggy mixed broadleaved forest, ash-alder swamp forest and alder swamp forest. The impossibility of beetle multiplying in alder swamp forests and boggy coniferous forests has been pointed out by Borowski [1960]. The larvae of the forest dung beetle develop in the provision mass buried ca. 15-35 cm deep in the soil, and in alder swamp forest this would be impossible due to the high level of ground water. At the same time Borowski [1960] discovered that the forest dung beetle could be encountered in the largest numbers in coniferous forests and in comparatively large numbers in broadleaved forests. What is more, the author stated that the specimens of the forest dung beetle inhabiting coniferous forests had longer pronotums than the specimens inhabiting broadleaved forests and hence submitted a proposition that the beetle in question found better living conditions in coniferous forests than in broadleaved forests. However, the results obtained in the course of the field research conducted in the Białowieża Forest seem not to confirm this proposition. According to the results of the present study, the forest dung beetle has been collected in the greatest numbers in the habitats of fresh mixed broadleaved forest and fresh broadleaved forest rather than in the coniferous forest. Furthermore, Klimaszewski and Strużyński [2005] observed greater level of trap efficiency in mixed tree stands than in coniferous ones. The most important factor seems to be not the fertility of the habitat but its dampness and the accumulation of organic waste, i.e. the thickness of litter and humus layer. The fact that both the larvae and the imagoes of the forest dung beetle feed on mouldy plant litter was already pointed out by Goljan [1953], while Gilarov [1953] observed that the beetles in question fed also on litter overgrown with mycelium. However, it was Borowski [1960] who exhaustively studied and presented the nutritional spectrum of the forest dung beetle. An analysis of the provision mass conducted by the author showed that it was composed of leaf fragments, including conifer needles, bark fragments and mouldy moss. Neither fruiting bodies of mushrooms nor mouldy wood were discovered. However, it cannot be questioned that the feaces of large animals and the fruting bodies of umbrella mushrooms constitute the most attractive food for the imago forms of the forest dung beetles. Plewińska [2007] pointed out the attractiveness of rodent feaces for the forest dung beetles, which exceeded the attractiveness of cow or horse feaces. The author observed a considerable share of rodent feaces in the beetles' diet. Hence, it can be postulated that the forest habitats preferred by the forest dung beetle are those with large amounts of mouldy litter, animal feaces and mushrooms.

The specimens of the forest dung beetle encountered in fresh coniferous forests have larger body sizes than their counterparts encountered in fresh broadleaved forests, but are less numerous. Fresh broadleaved forests are inhabited by beetles which are smaller, but more abundant. Thus, the forest dung beetle has two different life strategies in the two groups of preferred habitat types, but the biomass of beetle assemblages inhabiting coniferous and broadleaved habitats is similar. The conditions for development found by the forest dung beetle in fresh coniferous forests and fresh broadleaved forests are comparable, and hence both types of habitats are equally popular.

CONCLUSIONS

The forest dung beetle is more abundant in the forests of fresh habitats than in the forests of moist, boggy or alder habitats. Optimal living conditions for the beetle can be found in habitats of the fresh broadleaved forest, fresh mixed broadleaved forest, moist broadleaved forest and fresh coniferous forest. On the other hand, the forest dung beetle tends to avoid exceedingly damp habitats, such as the boggy coniferous forest, boggy mixed coniferous forest, boggy mixed broadleaved forest, ash-alder swamp forest, and alder swamp forest, where it finds unfavourable conditions for its larvae because of a high level of ground water.

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PREFERENCJE SIEDLISKOWE ŻUKA LEŚNEGO *ANOPLOTRUPES STERCOROSUS* (SCRIBA, 1791) (COLEOPTERA: GEOTRUPIDAE) W PUSZCZY BIAŁOWIESKIEJ

Streszczenie. Celem pracy było poznanie preferencji siedliskowych żuka leśnego *Anoplotrupes stercorosus* (Scriba, 1791). W czasie badań założono 52 powierzchnie badawcze, po cztery na 13 typach siedliskowych lasu obecnych w Puszczy Białowieskiej. Na każdej

powierzchni badawczej założono pięć zmodyfikowanych pułapek Barbera. Pułapki funkcjonowały od 1 czerwca do 10 listopada w 1999 roku. Owady wybierano co 40 dni. W czasie badań odłowiono 14 980 żuków leśnych. Żuk leśny liczniej zasiedla lasy rosnące na siedliskach świeżych niż siedliskach wilgotnych, bagiennych czy olsowych. Optymalne warunki bytowe znajduje na siedliskach lasu świeżego, lasu mieszanego świeżego, boru mieszanego świeżego oraz lasu wilgotnego i boru świeżego. Unika siedlisk nadmiernie uwilgotnionych – borów bagiennych, borów mieszanych bagiennych, lasów mieszanych bagiennych, olsów jesionowych i olsów – na których ze względu na wysoki poziom wody gruntowej nie znajduje dogodnych warunków w stadium larwalnym.

Słowa kluczowe: Geotrupidae, *Anoplotrupes stercorosus,* typ siedliskowy lasu, Puszcza Białowieska

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