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Seasonality and habitat preferences of dung beetles (Coleoptera: Geotrupidae) attracted to moose *Alces alces* L. dung in the Kampinos National Park

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Abstract. Dung beetles (Coleoptera: Geotrupidae) are an extremely important element of many ecosystems. Their activity allows the incorporation of mineral compounds trapped in faeces into the nutrient cycle. Seasonality and habitat preferences are the most important factors shaping the beetle communities inhabiting dung. The present study compares beetle communities inhabiting moose dung Alces alces L. in various forest ecosystems quantitatively and qualitatively. Due to the beetle seasonality, field work was performed from the beginning of March until the end of October 2017 in three habitats: coniferous forest, oak-hornbeam forest and alder forest. The dung beetles were collected using three Barber traps on each site baited with moose dung (80 g ± 10 g) and the traps were emptied as well as rebaited every 15 days. Altogether, 2330 specimen of dung beetles representing three species were collected: Anoplotrupes stercorosus (2088), Trypocopris vernalis (154) and Geotrupes stercorarius (88). These three species were found in all of the studied habitats. The largest total number of individuals was captured in the alder forest (1132 individuals), followed by the broadleaved forest (712) and the smallest number was captured in the coniferous forest (486). In terms of individuals caught, each species was statistically significantly different between the habitats. The largest number of A. stercorosus was captured in the alder forest, followed by the broadleaved forest and the smallest number was caught in the coniferous forest. However, the reverse was observed in the case of T. vernalis and G. stercorarius, where the most individuals were caught in the coniferous forest, and fewer in the broadleaved and alder forests. This is most likely due to the various habitat preferences of each individual species. Furthermore, the seasonal dynamics of this beetle family showed some differences between habitats. These differences most probably resulted from different microclimatic and humidity conditions.

Keywords: *Anoplotrupes stercorosus*, *Geotrupes stercorarius*, *Trypocopris vernalis*, forest ecology, dung beetles, moose dung

1. Introduction

In Poland, the family Geotrupidae is represented by 9 species (Bunalski 2004). These are specialized coprophages, saprophages, and one herbivorous species (Stebnicka 1976). Up to date, in the Kampinos National Park, two Geotrupidae species, classified as coprophagous have been reported, that is, dung beetle Geotrupes stercorarius (Linnaeus 1758) and Geotrupes spiniger (Marsham 1802). Two other reported species are saprophagous, with a propensity for coprophagy: dor beetle Anoplotrupes stercorosus (Scriba 1791) and spring dor beetle Trypocopris vernalis (Linnaeus 1758) (Mroczyński, Marczak 2017). These insects are extremely important for both forest and meadow ecosystems. Due to a relatively large size of the body and high population numbers, they greatly contribute to the circulation of elements regained from dead organic matter (Rembiałkowska 1980, Rojewski 1980). The process increases soil fertility and aeration, which positively impacts the condition of environment (Borowski 1960).

The ecology of the species listed above has been known quite well. Up to date, these have been comprehensively stu-

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died: their role in forest and meadow ecosystems (Borowski 1960; Klemperer 1979; Rojewski 1980; Nervo et al. 2014), seasonality (Waβmer 1994; Bunalski 2006; Marczak 2013; Byk Węgrzynowicz 2015) and habitat preferences (Borowski 1960; Koch 1989; Tyk Semkiw 2010; Taurus 2011; Marczak 2013; Taurus, Rutkiewicz 2017). Food preferences of individual species, characterized by different degree of dung dietary specialization, were described by Stebnicka (1976), Koch (1989) and Bunalski (2006).

The aim of this study was to quantify and qualify the Geotrupidae communities attracted by moose droppings (the most easily available dung type in the Park and one of the least studied in terms of coprophagy in Europe) in the three types of forest ecosystems in the Kampinos National Park (different in terms of soil humidity, the amount of litter and a degree of its decomposition, as well as forest bottom exposure to sunlight).

2. Research area

Field research was conducted in Kampinos National Park, central Poland. Three forest types (sites) were examined: 1) fresh mixed coniferous forest (forest sub-district Lipków, section 223) with vegetation on sandy soils, characterized by low humus contents, low humidity, relatively low forest stand density and high sunlight exposure of the forest bottom, 2) oak -hornbeam forest (sub-district Lipków, section 269), growing on fertile brown soils with higher humidity than that in coniferous forest, characterized by relatively compact tree stands with forest bottom accessible to sunlight and large amounts of leaf litter, 3) alder-ash forest (sub-district Zaborów, section 270), growing on damp black soils – periodically flooded (in late autumn and spring), shaded after the formation of tree leaves, with sunlight hardly ever reaching the forest bottom.

3. Material and methods

Field observations were carried out in 2017, from the beginning of March to the end of October. Barber pitfall traps, lured with moose faeces (80 g ± 10 g) were used to capture dung beetles (Figure 1). The traps were filled with 200 ml of ethylene glycol, to preserve captured insects. Moose droppings were collected in the spring 2017 and stored in a frozen state until used as a bait in the traps. Three traps were set up about 50 m apart in each forest type examined. In all the forest sites, the traps were controlled at 15-day intervals. The species of captured insects were determined using a dedicated identification key (Stebnicka 1976).

In order to compare the examined forest sites, the numbers of captured specimens of a given species were ascertained, and the dominance indices were also calculated (percentage share in the community). The statistical significance of the differences obtained was tested by means of the Kruskal-Wallis test and post-hoc analysis ($p < 0.05$).

4. Results

In total, 2330 specimens of three Geotrupidae species were collected from the traps, that is, 2088 specimens of Anoplotrupes stercorosus, 154 specimens of Trypocopris vernalis and 88 specimens of Geotrupes stercorarius. All three species were found in each of the forest types examined. The highest number of Geotrupidae beetles were captured in the alder forest (1132), then in the oak-hornbeam forest (712) and the coniferous forest (486).

The dominant species in all the forest sites observed was A. stercorosus, with the total number accounting for 61% of the total number of beetles collected in the coniferous forest, 94% – in the oak-hornbeam forest and 99% – in the alder forest. T. vernalis numbers constituted 30% of all the beetles collected in the coniferous forest, 1% – of those collected in the oak-hornbeam forest and well below 1% – in the alder forest. The least numerous species observed was G. stercorarius, which constituted 8% of all the beetles collected in the coniferous forest, 5% – in the oak-hornbeam forest and 1% – in the alder forest (Figure 2).

The abundances of individual species indicated significant differences between the examined forest sites (Figure 3–5). The highest A. stercorosus numbers were captured in alder forest (1119), then in oak-hornbeam forest (672) and in coniferous forest (297). The differences between A. stercorosus numbers observed in coniferous forest and alder forest were statistically significant ($p = 0.0354$). In the case of T. vernalis, the highest number of specimens were captured in the coniferous forest (148), and much lesser – in the oak

Figure 1. Ground trap with bait for collecting dung beetles

-hornbeam forest (5) and the alder forest (1). Statistically significant differences were found between T. vernalis numbers in the coniferous forest and alder forest ($p = 0.0002$) and between the coniferous forest and oak-hornbeam forest ($p = 0.0037$). The highest G. stercorarius numbers were captured in the coniferous forest (41), then in the oak-hornbeam forest (35) and the lowest in the alder forest (12). Statistically significant differences were found between the coniferous forest and alder forest ($p = 0.0316$).

The seasonal dynamics of Geotrupidae beetles showed differences depending on the forest site examined. In coniferous forest, the first specimens were captured in the first half of April, in the oak-hornbeam forest – a single specimen was already trapped in the second half of March, and in the alder forest – in the first half of May. In all the forest types examined, the beetles under the study were captured until the last days of October.

In the examined coniferous forest, the seasonal dynamics of A. stercorosus population indicated three relatively evident peaks: in the first half of May, in the first half of July and then in the second half of September. In the oak-hornbeam forest, there were also observed three peaks: in the first half of May, in the first half of July and in the first half of August. A different situation was observed in the alder forest, where just one evident peak could be distinguished – in the second half of July, and two not as obvious peaks – in the first half of September and the first half of October.

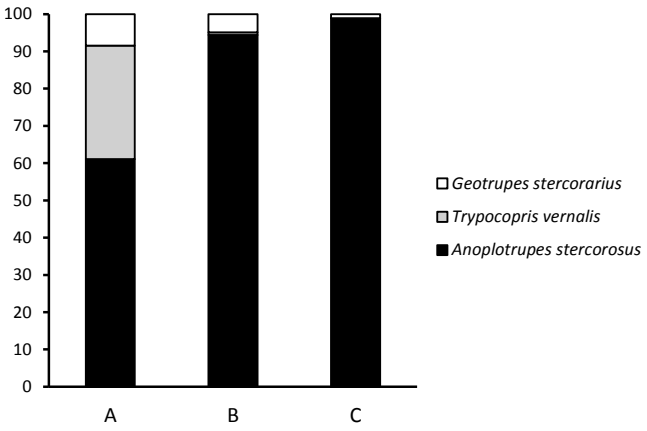

Figure 2. The domination structure of dung beetle (Geotrupidae) communities in: A) coniferous forest, D) oak-hornbeam forest, C) alder forest in Kampinos National Park

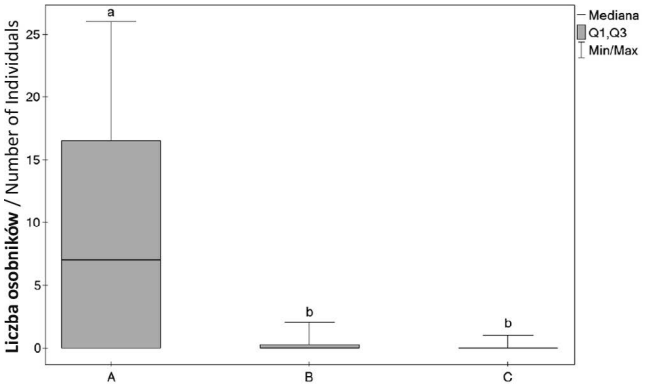

Figure 4. Comparison of descriptive statistics for *Trypocopris vernalis* comprising all sampling periods in: A) coniferous forest, D) oak-hornbeam forest, C) alder forest in Kampinos National Park. Different letters indicate statistically significant differences between forest types ($p<0.05$).

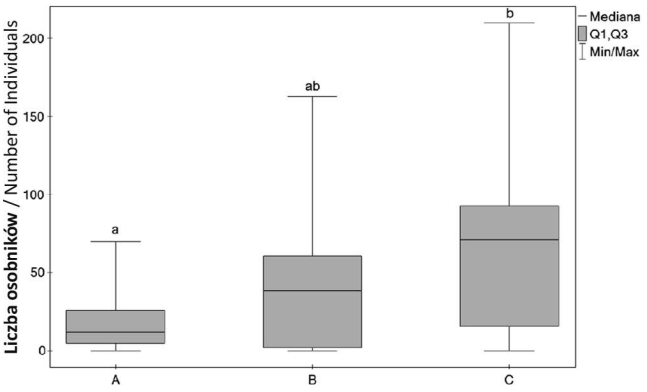

Figure 3. Comparison of descriptive statistics for *Anoplotrupes stercorosus* comprising all sampling periods in A) coniferous forest, D) oak-hornbeam forest, C) alder forest in Kampinos National Park. Different letters indicate statistically significant differences between forest types ($p<0.05$).

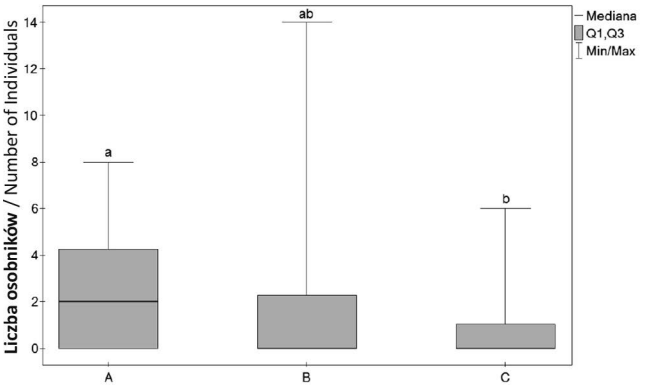

Figure 5. Comparison of descriptive statistics for *Geotrupes stercorarius* comprising all sampling periods in: A) coniferous forest, D) oak-hornbeam forest, C) alder forest in Kampinos National Park. Different letters indicate statistically significant differences between forest types ($p<0.05$).

T. vernalis seasonal dynamics in coniferous forest showed four indefinite peaks: in the second half of May, in the first half of July, in the first half of August and in the second half of September. The numbers of specimens captured in oak-hornbeam forest and those in alder forest were negligible, hence, reliable analyses of T. vernalis seasonal dynamics in the latter forest types were not possible.

In G. stercorarius seasonal dynamics observed in the coniferous forest, there were distinguished three population peaks: in the first half of May, in the first half of July and at the turn of September and October. The seasonal dynamics of this species in oak-hornbeam forest was alike, and population peaks were recorded in the second half of May, the second half of August and the first half of October. In the alder forest, the first G. stercorarius specimen was captured in the first half of May, then individual specimens were captured in the period from the first half of July to the second half of August, whereas the largest numbers of this species were found in the traps examined in the first half of October (Figure 6).

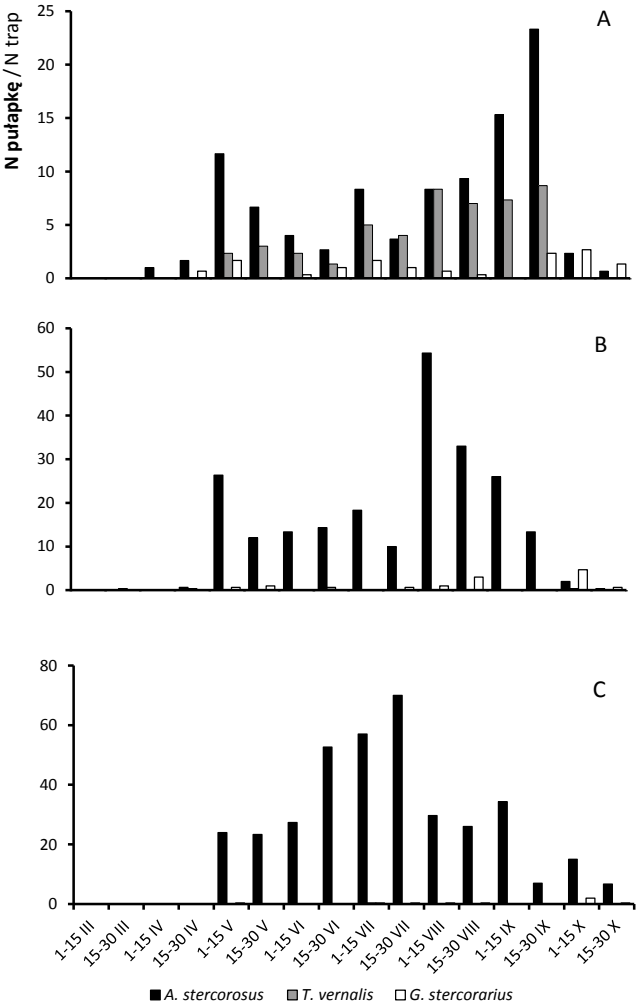

Figure 6. Seasonal dynamics of each dung beetle (Geotrupidae) species in: A) coniferous forest, D) oak-hornbeam forest, C) alder forest in Kampinos National Park

5. Discussion

A. stercorosus specimens evidently dominated in the total number of collected Geotrupidae beetles. This species is the most common and abundant representative of the family Geotrupidae reported in Poland's forests (Stebnicka 1976; Burakowski et al. 1983; Szwałko 1995). Somewhat lower A. stercorosus population numbers are observed in young forest plantations and clear-cut areas (Byk 2004; Marczak 2013). In the present study, comparatively lower population numbers were observed in the case of T. vernalis, which was most probably due to habitat preferences of this species. It avoids old, shaded forests and chooses young stands (Byk 2004; Marczak 2013). In the total number of captured beetles, G. stercorarius was the least abundant. The latter occurs in forests, nonetheless, shows a preference for open areas (pastures, wastelands, field roads). G. stercorarius commonly occurs throughout Poland and favours cattle and horse dung (Stebnicka 1976; Burakowski et al. 1983; Bunalski 2006). These factors could be the cause of the relatively low numbers of G. stercorarius observed in the traps set up in the studied forests.

The highest numbers of A. stercorosus specimens were captured in the alder forest, then in the oak-hornbeam forest, and the lowest – in the coniferous forest. Different results were reported by Borowski (1960), who observed the highest abundance of this species in the Białowieża Forest's coniferous stands (coniferous forest, mixed coniferous forest), then in the oak-hornbeam forest (wet oak-hornbeam and fresh oak-hornbeam forests), whereas the lowest A. stercorosus numbers were found in the alder forests and bog woodlands. The same author, however, noted the relatively low numbers of A. stercorosus in pine forest – a type similar to coniferous forest where the present study was carried out. According to Karpiński (1955), "pine forest" is a forest growing on sandy, dry and poor sites – overgrown by heather, grass, lingonberry and covered by patches of moss -like lichens. In the present study, particularly noteworthy is high abundance of A. stercorosus in the examined alder forest. The studies carried out in the Białowieża Forest – by Borowski (1960), as well as Byk and Semkiw (2010) – proved that alder forest was one of the least suitable habitats for this species. This is due to high groundwater levels in the alder forest sites that prevent A. stercorosus reproduction and larval development. On the other hand, the alder forest examined in the present study grows on the site with a relatively low groundwater level (the area is flood-prone only in

the periods of late autumn and early spring) and no water infiltration was observed in the ground where the experimental traps were set up (at approx. 20 cm depth). Besides, the presence of a thick litter layer (decaying leaves) could constitute an attractive and bulky A. stercorosus food base. It is possible that in the summer, when a decrease in the numbers of captured specimens was observed because of high temperatures and reduced humidity, alder forest could provide optimal conditions for A. stercorosus endurance. This is confirmed by the results presented in Figure 6, showing that in the period from the second half of June to the end of July, A. stercorosus population was the most abundant in alder forest – in contrast to the two other forest types examined.

The analysis of T. vernalis occurrence in the studied forest sites evidently showed that this species had different habitat preferences than A. stercorosus. Undoubtedly, the most T. vernalis specimens were captured in the coniferous forest, and just a few – in the oak-hornbeam forest and alder forest. Consistent with subject literature (Byk 2004; Marczak 2013), T. vernalis prefers clear cut areas and young forest plantations, hence – environments with a relatively high degree of insolation. In the present study, the examined coniferous forest constituted the site with the most plentiful sunlight, and this could positively influence T. vernalis population numbers (Klimaszewski, Szyszko 2000). Furthermore, evidence suggests different food preferences of this species when compared to A. stercorosus. Larvae of the latter species feed mainly on the decomposed litter – buried by adults (Borowski 1960; Bull 2004), whereas animal droppings predominate in diet of T. vernalis larvae and adults (Szwałko 1995; Klimaszewski and Szyszko 2000; Bunalski 2006). Hence, large litter amounts in oak-hornbeam forest and alder forest would rather not affect T. vernalis population numbers observed in these forest sites.

In the case of G. stercorarius, the most specimens were captured in the coniferous forest, then in the oak-hornbeam forest and the alder forest. In line with the latest knowledge, G. stercorarius occurs in forests as often as in open areas (Bunalski 2006). The basic diet of this species consists of animal dung (cattle, horses, sheep). The results of this study suggest that this dung beetle species also likes wild animal faeces. The decreasing number of captured specimens in the gradient of increasing site humidity (and a degree of shading) in the environments examined may indicate G. stercorarius preference for permeable soils, of low or medium humidity, with at least temporary sunlight exposure. On the other hand, the G. stercorarius specimens captured in the alder forest indicate a relatively wide range of tolerance of this species to habitat factors.

Differences in dung beetle seasonal dynamics between the types of forests examined most probably resulted from dissimilar microclimatic and humidity conditions. Alder forest – relatively the wettest habitat and largely flooded until the beginning of May – was characterized by a relatively late emergence of Geotrupidae specimens. In addition, there was observed just one explicit population peak – in the warmest and driest period of the year. In the two other types of forests observed, Geotrupidae populations showed three peaks, of which the second one was the least obvious. In the oak-hornbeam forest, the third population peak was observed in the first half of August, and in the coniferous forest – in the second half of September. Significant differences in the seasonal dynamics of the observed populations found between the forest types could be caused by both different humidity conditions in the examined forest sites all through the year and different sun exposure – consequently, by the average daily temperature. In the coniferous forest lit by sunlight, daily temperature was most likely higher, which encouraged high population numbers of the examined Geotrupidae beetles until the end of September.

6. Conclusions

1. In all the types of forests examined, the most abundant was Anoplotrupes stercorosus – the most common and numerous dung beetle (Geotrupidae) occurring in Poland's forests.

2. The highest A. stercorosus numbers were captured in the alder forest, then in the oak-hornbeam forest, and the lowest – in the coniferous forest. Contradictory, in the case of T. vernalis and G. stercorarius, the highest specimen numbers were captured in the coniferous forest, whereas in the oak-hornbeam forest and alder forest, there were captured just a few beetles of these species. Most probably, the results obtained were due to different habitat preferences of Geotrupidae species under the study.

3. The seasonal dynamics of A. stercorosus, T. vernalis and G. stercorarius populations differed between the examined forest types. In all probability, the differences observed resulted from microclimatic conditions and humidity patterns shaped at a given forest site during the year, as well as – from specific preferences of the studied dung beetle species.

Conflict of interest

The author declares no potential conflicts of interest.

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References

Borowski S. 1960. Geotrupes stercorosus (Sc.) (Coleoptera, Scarabaeidae) w Białowieskim Parku Narodowym. Fragmenta Faunistica 8(23): 337–365.

Bunalski M. 1996. Żuki koprofagiczne (Coleoptera, Scarabaeoidea) okolic Szamotuł. Cz. II. Wiadomości Entomologiczne 15(4): 217–224.

Bunalski M. 2004. Scarabeiformia [139-145]. In: Fauna Polski – Charakterystyka i wykaz gatunków (W. Bogdanowicz, E. Chudzicka, I. Pilipiuk, E. Skibińska, editors). Muzeum i Instytut Zoologii PAN, Warszawa, PL.

Bunalski M. 2006. Żuki (Coleoptera: Scarabaeoidea) wschodnich rubieży Polski. Studium faunistyczno-ekologiczne części północnej i środkowej. Akademia Rolnicza im. Augusta Cieszkowskiego w Poznaniu, Rozprawy Naukowe 376: 1–133.

Burakowski B., Mroczkowski M., Stefańska J. 1983. Chrząszcze – Coleoptera. Scarabaeoidea, Dascilloidea, Byrrhoidea i Parnoidea. Katalog Fauny Polski, XXIII, 9: 1–294.

Byk A. 2004. Zmiany liczebności żuka leśnego Anoplotrupes stercorosus (Hartm.) pod wpływem zalesień. Sylwan 3: 28–34.

Byk A. 2005. Zmiany liczebności żuka wiosennego Trypocopris vernalis (L.) (Coleoptera: Geotrupidae) pod wpływem zalesień. Leśne Prace Badawcze 3: 51–59.

Byk A. 2011. Abundance and composition of Geotrupidae (Coleoptera: Scarabaeoidea) in the developmental cycle of pine stands in Człuchów Forest (NW Poland). Baltic Journal of Coleopterology 11(2): 171–186.

Byk A., Rutkiewicz A. 2017. Liczebność i skład gatunkowy koprofagicznych poświętników w cyklu odtworzeniowym drzewostanów sosnowych w Lasach Człuchowskich (Pojezierze Pomorskie). Sylwan 161(9): 781–792.

Byk A., Semkiw P. 2010. Habitat preferences of the forest dung beetle Anoplotrupes stercorosus (Scriba, 1791) (Coleoptera: Geotrupidae) in the Białowieża Forest. Acta Scientarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria 9(3–4): 17–28.

Byk A., Węgrzynowicz P. 2015. The structure and seasonal dynamics of coprophagous Scarabaeoidea (Coleoptera) communities in later developmental stages of pine stands in NW Poland. Journal of the Entomological Research Society 17(3): 39–57.

Karpiński J.J. 1955. Wycieczka do Puszczy. Państwowe Zakłady Wydawnictw Szkolnych, Warszawa: 1–164.

Klemperer H.G. 1979. An analysis of the nesting behaviour of Geotrupes spiniger Marsham (Coleoptera, Scarabaeidae). Ecological Entomology 4(2): 133–150. DOI 10.1111/j.1365-2311.1979.tb00569.x.

Klimaszewski K., Szyszko J. 2000. Żukowate (Coleoptera, Scarabaeidae) negatywnych drzewostanów sosnowych. Sylwan 10: 39–44.

Koch K. 1989. Die Käfer Mitteleuropas. Ökologie. Band 2. Goecke & Evers, Krefeld. 1–440.

Marczak D. 2013. Wybiórczość siedliskowa żuka leśnego Anoplotrupes stercorosus (Scriba) i żuka wiosennego Trypocopris vernalis (L.) (Coleoptera: Geotrupidae) w borze sosnowym świeżym w zależności od wieku drzewostanu. Leśne Prace Badawcze 74(3): 227–232.

Mroczyński R., Marczak D. 2017. Coprophagous beetles (Coleoptera) found in moose (Alces alces L.) feces in Kampinos National Park. World Scientific News 86(3): 376–381.

Nervo B., Tocco C., Caprio E., Palestrini C., Rolando A. 2014. The Effects of Body Mass on Dung Removal Efficiency in Dung Beetles. PLOS ONE 9(9): 1–9. DOI 10.1371/journal.pone.0107699.

Rembiałkowska E. 1980. Rola chrząszczy koprofagicznych z rodziny Scarabaeidae w ekosystemach łąkowych i leśnych strefy umiarkowanej. Wiadomości Ekologiczne 26: 253–263.

Rojewski C. 1980. Znaczenie żuków gnojowych w przyrodzie i gospodarce człowieka. Przegląd Zoologiczny 24(4): 431–438.

Shannon C.E., Weaver W. 1949. The mathematical theory of communication. Urbana, University of Illinois Press, 1–17.

Stebnicka Z. 1976. Żukowate – Scarabaeidae. Grupa podrodzin: Scarabaeidae laparosticti. Klucze do oznaczania owadów Polski. Warszawa, PWN, XIX, 28a: 1–139.

Szwałko P. 1995. Chrząszcze żukowate (Coleoptera: Scarabaeidae) Puszczy Białowieskiej w aspekcie dotychczasowych wyników badań monitoringowych na terenie północno-wschodniej Polski. Prace Instytutu Badawczego Leśnictwa, Seria A 794: 108–128.

Waβmer T. 1994. Seasonality of coprophagous beetles in the Kaiserstuhl area near Freiburg (SW-Germany) including the winter months. Acta Oecologica 15(5): 607–631.

Authors' contribution

D.M. – article concept, work on the study results, writing the text, field work; R.M. – article concept, work on the study results, writing the text, laboratory work, statistical analysis

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