RESEARCH INTO SCARAB BEETLES (SCARABAEOIDEA) IN KOPAČKI RIT NATURE PARK

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Research into the scarab beetle (Scarabaeoidae) fauna was done in Kopački rit Nature Park, one of the largest semi-natural floodplains in Europe. Research was conducted at three sampling sites: Tikveš Forest, Vemeljski Dunavac, and Sakadaš Lake, in the time periods July to November 2010 and April to July 2011. Continual sampling was done using the Barber pitfall trap method with attractants and the Flight Interception Trap (FIT) method. Animal excrement, pork liver, bananas and mushrooms were used as attractants. In total 1896 specimens were trapped and the presence of 23 species was determined. The most abundant species were: *Onthophagus coenobita* (554), *Sisyphus schaefferi* (478), *Onthophagus verticicornis* (291), and *Onthophagus vacca* (243). A larger number of specimens (70.3 %) were sampled using Barber pitfall traps, with excrement and pork liver attracting 81.7 % of individual insects.

Key words: scarab beetles, Kopački rit, Barber pitfall trap, Flight Interception Trap, attractants

K. KULUNDŽIĆ, N. TURIĆ, G. VIGNJEVIĆ i E. MERDIĆ: Istraživanje faune truležara (Scarabaeoidea) Parka prirode Kopački rit. Entomol. Croat. Vol. 18. Num. 1–2: 37–47

Istraživanje faune truležara (Scarabaeoidae) obavljeno je u Parku prirode Kopački rit, jednom od najvećih fluvijalno-močvarnih nizina u Europi. Istraživanje je provedeno na trima postajama, a to su Šuma Tikveš, Vemeljski dunavac i Obala Sakadaš, u razdoblju od srpnja do studenog 2010. godine te od travnja do srpnja 2011. godine. Kontinuirano uzorkovanje obavljeno je metodom Barberovih lovnih posuda uz atraktante i metodom prekinutog leta (FIT). Kao atraktanti korišteni su životinjski izmet, svinjska jetra, banana i gljiva. Uhvaćeno je ukupno 1 896 jedinki i utvrđena prisutnost 23 vrste. Vrste s najvećom brojnosti jedinki jesu: *Onthophagus coenobita* (554), *Sisyphus schaefferi* (478), *Onthophagus verticicornis* (291) i *Onthophagus vacca* (243). Veći broj jedinki (70,3 %) uzorkovan je Barberovim lovnim posudama, a u njima su atraktanti izmet i svinjska jetra privukli 81,7 % jedinki.

Ključne riječi: Truležari, Kopački rit, Barberova lovna posuda, metoda prekinutog leta, atraktanti

Introduction

Scarabaeoidea is of the largest superfamilies in the order Coleoptera and includes approximately 31,000 species worldwide (Endrödi 1985; Hanski and Cambefort 1991; Krikken 1984;Lawrence 1982; Machatschke 1972; Scholtz 1982). While some of the smaller groups are well known worldwide (e.g., Geotrupidae and Trogidae), some other groups (e.g., Scarabaeidae which comprises 91 % of the Scarabaeoidae) cannot be identified to even genus-level with reliability. The systematics within this superfamily is very complex and various scientists have different opinions about the systematics. According to Fauna Europaea, 17 families and 1201 species exist within Scarabaeoidae (www.faunaeur.org). In Croatia 11 families with 249 species were recorded in Fauna Europea within that superfamily and it is estimated that there are over 400 species (Mikšić, 1956; Mikšić, 1958; Mikšić, 1962a; Mikšić, 1962b; Mikšić, 1965).

Scarab beetles (Scarabaeoidea, Coleoptera) belong to a group considered distinctly thermophilic. The largest number of species can be found in the tropical region. The number of species of scarab beetles increases from the boreal forests in the north to the tropical forests around the equator. Scarab beetles have a significant position in every ecosystem. As they bury excrement, they act as secondary spreaders of plant seeds, increase the speed of the nutrient circulation cycle, contribute to the aeration of the soil, and participate in the decomposition of organic matter in nature. Scarab beetles are sensitive to various disturbances in nature, which leads to reduction in quantity, density, and biomass of the species. For that reason species from this family have recently been used as indicators to assess the condition of an ecosystem (Dortel et al., 2013).

Aside from the ecological importance for the ecosystem in which they live, it is important to note their place in human culture. As far back as Ancient Egypt people considered dung beetles to be symbols of survival and existence and they related them to the sun. The semicircular section of the head (*Scarabaeus sacer*) resembles the rising sun. In recent times there have been some interpretations which say that the dung beetle was the inspiration to the Egyptians for mummifying their deceased. A dung beetle nest resembles a tomb where a small ball, the mummy, awaits its solar resurrection (Hanski & Cambefort, 1991).

Kopački rit represents a specific and unique area along the Danube River; it is a natural depression where water enters and stays on average about one hundred days a year. Such an area is a unique habitat which is dependent on the fluviometric regime of the Danube. Due to its state of preservation as a rare wetland ecosystem with high biodiversity and its exceptional scientific and ecological value, Kopački rit is divided into two parts. The entire area is protected as a Nature Park because of its historical and ecological value and the most important area is protected as a Special Zoological Reserve. Kopački rit is listed as a RAMSAR site (No: 3HR002) and UNDP/GEF/WWF consider this area, together with the Danube Delta, to be the most important part of the River Danube due to its characteristics as an inland delta (Smart, 2000). Even though research into the insects in the area has been done for years, the entomofauna is still not sufficiently known due to the extreme diversity of insect groups. Scarab beetles have never been explored in this area and there is very little information about scarab beetle fauna (Mihaljević et al., 1999).

Therefore the main goal of this research was to establish the diversity of scarab beetles in Kopački rit Nature Park and compare sampling methods, with the emphasis on the efficiency and specifics of the attractants.

Materials and Methods

Research into scarab beetle fauna was done in the periods July to November 2010 and April to July 2011 at three localities in Kopački rit: Tikveš Forest, Vemeljski Dunavac, and Sakadaš Lake. The Tikveš Forest site (N 45° 41′ 52″ E 18° 49′ 55″) was located in the forest community of *Carpino betuli-Quercetum roboris*. The Vemeljski Dunavac site (N 25° 40′ 21″ E 18° 49′ 55″) was located in the forest community of *Genisto elate-quercetum roboris*. Those two sites were in an area out of reach of flood waters, while the Sakadaš Lake site (N 45° 36′ 43″ E 18° 48′ 14″) was located in the Special Zoological Reserve, under the significant influence of flood waters within a forest community of *Galio-salicetum albe*.

Sampling was done using two types of traps: the Barber pitfall trap and the Flight Interception Trap. The traps were set during the entire duration of the research, a sample was taken once a week and the attractants were replaced every two weeks. The following attractants were used in the Barber traps: excrement, pork liver, bananas and mushrooms (button mushrooms). There were sixteen Barber pitfall traps set at each site in a square arrangement - four sets of four traps. The distance between the sets of four set traps was 50 m. Each set contained four traps with different attractants and they were set about 1 m from each other. A Barber pitfall trap consisted of a plastic container about 10 cm in diameter and 20 cm high which was buried in the ground up to the edge. The container was filled with water up to one third of its height (ca 20 ml) and a small quantity of detergent was added to reduce surface tension. A 15 mm mesh net was placed over the opening of the container and an attractant was secured with a strong rope, the net also prevented larger animals from falling into the trap (snails, mice, frogs and similar). The container was protected with a lid which was raised above the trap so that the insects might pass under it and fall into the trap. The Flight Interception Trap was used at only two sites: Tikveš Forest and Vemeljski Dunavac. We could not obtain a licence to sample using this method at the Sakadaš Lake site due to the large number of tourists. A dense net sized 2x1 m was stretched and tied with a rope between two trees 10 cm above the ground. Shallow plastic containers which contained water with detergent were placed under the net. The traps were set near the Barber pitfall traps with attractants. Captured specimens were preserved in situ in 70 % ethanol. The sampled material was identified using Freude et al., (1969) and Mikšić (1958, 1962). An entomological collection with all the species is stored in the Department of Biology at Josip Juraj Strossmayer University in Osijek.

For measuring species diversity between sampling sites diversity indices (Margalef, Pielou, Shannon-Wiener, and Simpson) were used. Non-metric multidimensional scaling (nMDS) were used to determine the similarity of scarab beetle assemblages between four different attractants (Clarke & Warwick, 2001). Relative distances in a plot reflect the relative dissimilarity between samples or groups based on the Bray-Curtis distance matrix. The total abundance of scarab beetles were square-root transformed prior to the analysis. Multivariate statistical analysis was performed using the PRIMER 5.2.9. Software ® (2002 PRIMER-E Ltd., Plymouth, UK).

Results

During the research 1896 specimens of scarab beetles were collected and within this material 8 families, 12 genera, 6 tribes, and 23 species were identified. The largest number of collected species belongs to the genera *Onthophagus* (11) and *Trox* (2), while for all the other genera just one species was collected (Table 1). The largest number of scarab beetles was collected or sampled in Tikveš Forest with 1247 specimens (65.77 % of the overall scarab beetles sampled) and 18 species, 507 specimens (26.74 %) and 16 species at Vemeljski Dunavac and 142 specimens (7.49 %) with 12 species at Sakadaš Lake. Nine species were sampled at all three sites and five species only at the Tikveš Forest site (*Cetonia aurata*, *Copris lunaris*,*Onthophagus curticornis*, *Aphodius prodromus*,and *Trox sabulosus*). Even though the fewest scarab beetles were captured at the Sakadaš Lake site, two species: *Phylloperta horticola* and *Anoplotrupes stercorosus* were sampled only at that site (Table 1). During the research a great difference in the number of scarab beetles was recorded, so 1247 specimens (65.77 %) were captured at the Tikveš Forest site, 507 specimens (26.74 %) at the Vemeljski Dunavac site, and 142 specimens (7.49 %) at the Sakadaš Lake site (Figure 1). The number of captured scarab beetles per site during the season varied from 0 in the winter months to 491 in July 2010, which indicates their thermophilic nature. Four species account for as much as 85 % of the scarab beetle fauna and represent the eudominant species of scarab beetles in Kopački rit, those are *Onthophagus coenobita* (30 %), *Sisyphus schaefferi* (26 %),*Onthophagus verticicornis* (16 %), and *Onthophagus vacca* (13 %) (Figure 2). Other species are subdominant, recendent, and subrecendent.

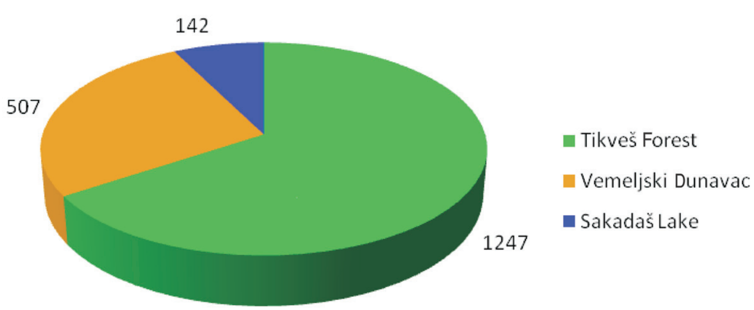

Figure 1. Proportion of specimens caught at three sampling sites

Table 1. List of Scarabaeoidae species in Kopački rit

Family Cetoniidae		
Tribus Cetonini		
Cetonia aurata Linneaus, 1761		
Family Scarabaeidae		
	Tribus Scarabaeini	
		Sisyphus schaefferi Linneaus, 1758
	Tribus Coprini	
		Copris lunaris Linnaeus, 1758
	Tribus Onthophagini	
		Onthophagus coenobita Herbst, 1783
		O. fracticornis Peyssler, 1790
		O. gibbulus Pallas, 1781
		O. grossepunctatus Reitter, 1905
		O. joannae Goljan, 1953
		O. ovatus Linnaeus, 1767
		O. similis Scriba, 1790
		O. vacca Linnaeus, 1767
		O. verticicornis Laicharting, 1781
		O. illyricus Scopoli, 1763
		O. curticornis Endrödi, 1955
Family Ochodaeidae		
	Tribus Ochodaeini	
		Ochodaeus chrysomeloides Schrank, 1781
Family Aphodidae		
	Tribus Aphodini	
		Aphodius prodromus Brahm, 1790
Family Trogidae		
	Tribus Trogini	
		Trox sabulosus Linnaeus, 1758
		Trox hispidus Pontoppidan, 1763
Family Valgidae		
	Tribus Valgini	
		Valgus hemipterus Linnaeus, 1758
Family Rutelidae		
	Tribus Anomalini	
		Phylloperta horticola Linnaeus, 1758
Family Geotrupidae		
	Tribus Geotrupini	
		Geotrupes niger Marsham, 1802
		Odontaeus (odonteus)armiger Scopoli, 1772
		Anoplotrupes stercorosus Scriba, 1791

The results of species diversity analysed using Margalef's Index and the Shannon-Wiener Index, as well as evenness and dominance analysed using Pielou's evenness index, and Simpson's Dominance index are presented in Table 3. Diversity indices showed that the most similarities exist between Tikveš Forest and Vemeljski Dunavac, while similarity is lowest between Vemeljski Dunavac and Sakadaš Lake. The Barber trap method with attractants was the more efficient sampling method since it was used to capture 1333 (70.30 %) specimens of scarab beetles, while the

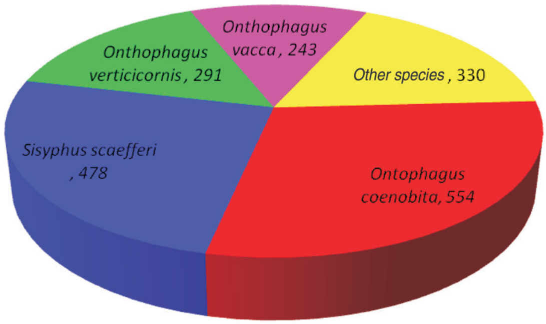

Figure 2. Proportion of the most abundant species of Scarabaeoidea in Kopački rit

flight interception method was used to capture 563 specimens (29.70 %). Almost all species were sampled using Barber traps except for the species *Onthophagus illyricus* which was sampled only using the flight interception method (Table 1).

Out of the total 1333 specimens sampled by Barber traps, the attractants which attracted the most scarab beetles were excrement (558; 41.86 %) and liver (531; 39.83 %). Those two attractants are more effective than bananas (129; 9.68 %) and mushrooms (115; 8.63 %) as attractants. Aside from the quantity, the traps captured samples of different species. All attractants were effective in sampling different species, out of 23, 10 species were captured using mushrooms, 13 species by using

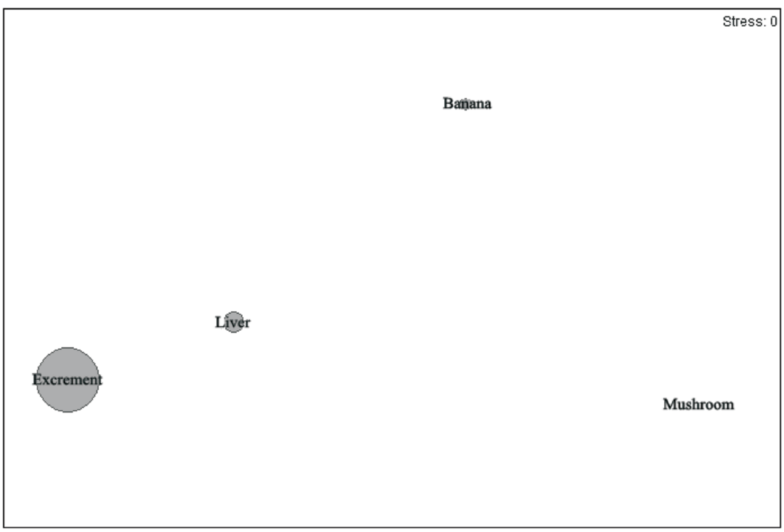

Figure 3. Non metric multimensional scaling (nMDS) ordination of samples using square- root transformed abundance data

excrement and bananas, and 15 species by using liver (Table 2). With all the attractants, the most numerous species were: *Sisyphus schaefferi, Onthophagus coenobita, Onthophagus verticicornis,* and *Onthophagus vacca.* The species *Sisyphus schaefferi* was the most numerous for three attractants: excrement, bananas and mushrooms, while for liver the most numerous species was *Onthophagus coenobita* (Table 2). NDMs analysis shows significant differences among the attractants and confirms excrement and liver as the best attractants. (Figure 3).

Table 2. List of scarab beetles captured with attractants at three sampling sites

Species/ Sampling site/ Atractant	Forest Tikveš	Vemeljski Dunavac	Sakadaš lake	Excrement	Liver	Banana	Mushroom
Cetonia aurata	+						+
Sisyphus scaefferi	+	+	+	+	+	+	+
Copris lunaris	+					+	
Onthophagus coenobita	+	+	+	+	+	+	+
O. fracticornis	+	+	+	+	+	+	+
O. gibbulus	+	+		+	+		
O. grossepunctatus	+	+	+	+	+	+	+
O. joannae	+	+	+	+	+	+	
O. ovatus	+	+	+	+	+	+	+
O. similis	+	+	+	+	+	+	+
O. vacca	+	+	+	+	+	+	+
O. verticicornis	+	+	+	+	+	+	+
O. illyricus *	+						
O. curticornis	+	+			+		
Ochodaeus chrysomeloides		+				+	
Aphodius prodromus	+						+
Trox sabulosus	+			+	+		
Trox hispidus	+	+			+		
Valgus hemipterus	+	+		+		+	
Phylloperta horticola			+	+			
Odontaeus armiger		+	+			+	
Geotrupes niger		+			+		
Anoplotrupes stercorosus			+		+		

* species sampled only with Flight Interception Trap

Table 3. Values of diversity indices at three sampling sites in Kopački rit

Sampling station	Number of species	Number of individuals	Margalef index	Pielou index	Shannon-Wiener index	Simpson index
Tikveš Forest	18	1247	2.385	0.6129	1.772	0.783
Vemeljski Dunavac	16	507	2.408	0.6439	1.785	0.7748
Sakadaš Lake	12	142	2.22	0.8105	2.014	0.8393

The flight interception method was used to capture specimens flying near the Barber traps (and attractants) the largest number of specimens belonging to the species *Onthophagus coenobita* 193 (34.28 %).

Discussion

In the area of NP Kopački rit 23 species of scarab beetles were sampled, which represents a high abundance of species on such a small area and during only one season of sampling. When this abundance of scarab beetles is added to the already known entomofauna of Kopački rit, the fact that it is an exceptional area considering the biodiversity of insect fauna is confirmed. In its two sections (flooded and forest) Kopački rit offers various ecological conditions for life, and faunas in these areas are significantly different (Merdić, 1993; Merdić & Sudarić, 2003; Perović et al., 2006; Krčmar, 2005) this diversity being confirmed in this research, in both quantity and quality, with a considerably larger number of scarab beetles being captured in the forest sites Tikveš Forest and Vemeljski Dunavac. Scarab beetles are mostly insects which move along the and accordingly it is to be expected that there should be more species in the section of the park that is rarely flooded. Furthermore, in that area there are significantly more large ruminants and wild hogs which leave their excrement and in such a way enable the survival of many scarab beetles. In the northern section of Kopački rit, the forest community of *Genisto elate-quercetum roboris*is is dominant where the soil is soft so the scarab beetles can easily bury dung. Significantly fewer scarab beetles were captured at a site within the flooded area (Sakadaš Lake), the reasons for which could be: the influence of flood waters, lower density of vegetation, easier dispersal of odour, significantly lower number of big game which results in the lower quantity of excrement. Eudominant species in all three sites were: *Onthophagus coenobita, Sisyphus schaefferi, Onthophagus verticicornis,*and *Onthophagus vacca* (eol.org). These species are actually widely present throughout Central Europe (faunaeur. org). These species usually live in hot, dry and sunny areas (Dortel et al., 2013), which corresponds to the fact that most scarab beetles were captured during the warmest months (July and August). All of the stated species are coprophagous and clearly have sufficient quantities of excrement in Kopački rit.

A large amount of research regarding scarab beetles was done in the area of former Yugoslavia in the middle of the last century (Mikšić, 1956, 1958, 1962a, 1962b, 1965). In recent years in Croatia beetle fauna research was done in Gorski Kotar (Durbešić, 1984), on the islands of Kornat, Lavsa, and Žut (where 20 species from the superfamily Scarabaeoidae were recorded, Koren et al., 2010) and mountain Biokovo (Ozimec et al., 2011). Considering that a recent scarab beetle research in Serbia revealed the list of 178 species (Gavrilović & Čurčić, 2010) it can be assumed that this determined number of scarab beetle species in Kopački rit is not final.

The best way to analyse insect diversity is to use different sampling methods. This research confirms the different effectiveness of the two methods and four attractants. Methods used in this research (Barber pitfall trap and FIT) are used to sample scarab beetles that seek food on the ground and those that are just flying through. The species of *Onthophagus illyricus* which was sampled using only the flight interception method confirms that, regardless of the lower quantitative efficiency, the use of this method is essential for the reliable determination of biodiversity.

The selection of attractants for insect sampling has been the subject of many investigations, and such research has been done in Kopački rit previously (Krčmar et al., 2005; Merdić et al., 2007). Excrement as an attractant in sampling scarab beetles was used by many authors with excellent results. Excrement can originate from various animals: elephant (Sabu et al., 2006), cow (Fiene et al., 2011), pig (Flechtmann et al., 2009). Human excrement has also been used. Humans with various dietary habits were tested in Costa Rica and excrement from vegetarians was more attractive to scarab beetles than that of omnivores (Trierweiler & Madigan, 2005).

Other attractants used in this research (liver, bananas, and mushrooms) were used in order to determine other possible organic attractants for sampling scarab beetles. Similar research was done in Borneo (Davis, 1998). The most effective attractants, excrement (558 specimens) and liver (531 specimens) show that most of the sampled scarab beetles belong in the coprophagous group and that they find excrement and carrion equally attractive. Fruit and mushrooms are significantly less attractive to scarab beetles in Kopački rit probably because these items are not widely available in the area and so cannot be the natural source of scarab beetles' food.

The ratio of the four most numerous species to four attractants indicates the different affinities of individual species. The species *Sisyphus schaefferi* dominates with respect to all attractants except liver, where *Onthophagus coenobite* is the most numerous species .Aside from the species *Onthophagus coenobite*, the species *Onthophagus vacca* also shows significant affinity to carrion. Fruit as an attractant is significantly less attractive to the species *Onthophagus verticicornis.*

Conclusion

This is the first Scarabaeoidea systematical research in the Kopački rit Nature Park. Total of 1896 specimens of scarab beetles (Scarabaeoidea) were collected in Kopački rit. Within this material, 8 families, 12 genera, 6 tribes and 23 species were determined. The collected sample contained four eudominant species for the study area: *Onthophagus coenobita Sisyphus schaefferi, Onthophagus verticicornis and Onthophagus vacca.* A larger number of specimens were sampled using Barber pitfall traps than FIT method, among attractants excrement and pork liver showed better results.

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