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GROUND BEETLES (CARABIDAE) IN INUNDATION AREA OF THE RIVER DANUBE

Changes in the structure of ground beetle communities indicate environmental stability or instability influenced by e.g., urbanization, agriculture, and forestry. Over the course of the year 2021, we used pitfall traps to record 504 individuals (185 ♂; 319 ♀) belonging to 26 species at ten localities. The predominance of macropterous species indicating the higher anthropogenic intervention was recorded in the habitats of meadows and pastures. We found an even representation of apterous, brachypterous and macropterous species in the habitat of forest stands, wetland reed communities, restored poplar forest with continued succession.

Keywords: Carabidae; Faunistics; bioindicators; floodplain areas; the Danube River.

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Introduction

There are only few floodplain forests in Europe, the majority is destroyed and of the remaining fragments are in a poor condition. They are among the most endangered natural ecosystems in Europe, therefore, it is important to record the current conditions in these habitats using bioindicators (Ábrahámová et al., 2014). For the needs of Bratislava Regional Conservation Association (BROZ), monitoring of Carabidae was performed in selected localities of the Danube floodplain. Floodplain forests have an irreplaceable self-regulatory role in the country function. If ceased to fulfill their bioregulatory function, it would mean the loss of not only some functions in the country, but also, for example, the potential loss of territory.

The research of beetles (Coleoptera) in that area intensified in the early 1990s in connection with the construction of the Gabčíkovo waterworks. The monitoring of the area was focused on the family of Curculionidae, where in 1991–1996 Majzlan (1995, 1997) found the occurrence of 136 species of beetles. Šustek (1995) studied the Carabidae of floodplain forests around the Danube River in 1986–1992, the Chrysomelidae of the Danube floodplain were mapped by Muránsky (1999). In the section of the Danube near Dobrohošť, they studied the family Chrysomelidae Lisický & Mucha (2003), where in 1993–1996 they recorded 168 species of hazelnuts in six localities. In the section of the projected R7 highway, Majzlan & Litavský (2015) recorded 150 species of beetles in five study areas in 2014.

For the bioindication and monitoring the quality of the environment, the Carabidae family (Coleoptera) is the most commonly used (Burgio et al., 2015). Carabidae inhabit different habitat types, respond sensitively to changes in habitat conditions (pH, soil moisture changes) as well as the presence of toxic substances including herbicides and insecticides. Changes in the species structure of the short-lived communities reflect various long-term environmental changes (Porhajašová et al., 2015, 2018; Langraf et al., 2020a, 2020b; Avtaeva et al., 2021; Brygadyrenko et al., 2021).

The aim of our monitoring is to evaluate the bioindicative family carabidae in selected localities of the Danube floodplain (solved within the LIFE project – Danube meadows).

Material and methods

Ground beetles were sampled in 2021 in 10 localities representing 6 types of biotopes, classified according to Ružičková et al. (1996) (tab. 1). We used pitfall traps (750 ml) (Novák et al., 1969) which were arranged at each biotope in a trap line, and each trap line consisted of five pitfall traps (at 10 m intervals). As a killing agent, 4% formaldehyde solution was used. We identified the collected material according to Hůrka (1996). The study areas were located in the Podunajská nížina lowland.

Ground beetles were divided into three bioindication classes according to Farkač et al. (2006):

Group R – relicts, stenotopic species, narrow ecological valence – mostly rare and endangered species of natural ecosystems;

Group A – adaptable species which colonize

Table 1. Location data of the study localities

Localities	C. a.*	Biotope	m.a.s.l	G.C.
1	Dobrohošť	Wetland reed communities (Phragmition)	121	47°58'42.8"N 17°22'02.4"E
2	Dobrohošť	Regenerated forest (poplar)	121	47°58'21.9"N 17°22'19.2"E
3	Baka	Willow-poplar lowland floodplain forest	114	47°53'32.6"N 17°30'27.5"E
4	Baka	Willow-poplar lowland floodplain forest	114	47°53'36.7"N 17°30'32.0"E
5	Baka	Willow-poplar lowland floodplain forest	114	47°53'41.6"N 17°29'10.4"E
6	Bodíky	Pasture	119	47°54'33.5"N 17°27'52.9"E
7	Bodíky	Regenerated forest (poplar)	118	47°53'52.3"N 17°27'23.0"E
8	Kľúčovec	Lowland meadow	110	47°47'07.2"N 17°44'11.4"E
9	Veľký Lél	Alluvial meadow	108	47°44'60.0"N 17°56'09.9"E
10	Veľký Lél	Regenerated forest (poplar)	108	47°44'48.3"N 17°55'20.2"E

* C. a. – Cadastral area; m a.s.l. – metres above sea level; G.C. - geographic coordinates

semi-natural habitats, they occur in secondary, good regenerating biotopes and its ecotones;

Group E – eurytopic species without special requirements on the character and quality of environment. They occur in unstable and changing biotopes with strong anthropogenic influence.

Database quality

The data obtained by the research has been saved in Microsoft SQL Server 2017 database program (Express Edition), including frequency tables for collections, measured environmental variables. The database also consisted of code tables for study sites and their variables (habitat, locality name, cadastral area, altitude, coordinates of localities). Matrices for statistical calculations were programmed.

Statistical analyses

Multivariate analysis (Cannonical Correspondence Analysis – CCA) to determine the dependencies between objects (Carabidae and enviromental variables) was used. We tested the statistical significance of forest stands, meadows and pastures, restored poplar forest, wetland reed communities using the Monte Carlo permutation test in the Canoco5 program (Ter Braak, Šmilauer, 2012).

Results and discussion

In the study area of the Podunajská nížina lowland we recorded 504 individuals (185 ♂; 319 ♀) belonging to 26 species. The species of Carabus granulatus Linnaeus, 1758 (36.71%), Nebria brevicollis (Fabricius, 1792) (14.88%), Calathus fuscipes (Goeze, 1777) (12.9%), Pterostichus niger (Schaller, 1783) (11.9%) had a eudominant representation of individuals (tab. 2). Based on the division of the Carabidae into flight ability (A, B, M), we recorded the highest species distribution in the localities in group M species (18 species; 69.23%). To a lesser extent, groups A (4 species; 15.38%) were represented B (4 species; 15.38%).

Multivariate analysis of the Carabidae in 2021 was determined using the Cannonical Correspondence Analysis (CCA, SD = 4 on the first ordination axis). The explained variability of taxonomic data values was 54.12% on the first ordination axis and 61.01% on the second cumulative ordination axis. The variability of the species set explained by environment variables was represented in the first ordination axis 73.05% and in the 2nd cumulative axis 89.41%. Using the Monte Carlo permutation test, we identified the statistically significant effect of forest stands (p-value = 0.034), meadows and pastures (p-value = 0.041), restored poplar forest (p-value = 0.014) and wetland reed communities (p-value = 0.037). The selected variables were not mutually correlated with the maximum value of the inflation factor = 3.5187.

The ordination graph of the (biplot) analysis has species ordained into 4 clusters (fig.). The first cluster (I) consisted of apterous, brachypterous

Table 2. Distribution of the Carabids based on flight ability in the study areas

Species	Flight ability	Localities										∑ individuals
		1	2	3	4	5	6	7	8	9	10	
Carabus granulatus Linnaeus, 1758	B	1	5	1	1	5	-	163	1	6	2	185
Nebria brevicollis (Fabricius, 1792)	M	30	1	-	11	12	2	16	-	1	2	75
Calathus fuscipes (Goeze, 1777)	M	-	-	-	4	7	8	-	46	-	-	65
Pterostichus niger (Schaller, 1783)	M	7	5	8	-	8	4	13	3	11	1	60
Anchomenus dorsalis (Pontoppidan, 1763)	M	-	-	-	4	1	-	16	1	2	1	25
Pseudoophonus rufipes (DeGeer, 1774)	M	3	-	-	1	5	8	-	-	-	-	17
Brachinus crepitans (Linnaeus, 1758)	M	-	-	-	1	-	11	-	-	-	-	12
Poecilus versicolor (Sturm, 1824)	M	-	-	-	1	1	6	1	-	-	2	11
Carabus coriaceus Linnaeus, 1758	A	2	-	7	-	-	-	-	-	-	-	9
Platynus assimilis Paykull, 1790	M	1	2	-	1	-	-	1	-	-	-	5
Amara aenea (De Geer, 1774)	M	-	-	1	3	1	-	-	-	-	-	5
Cychrus caraboides (Linnaeus, 1758)	A	-	1	-	-	-	-	-	-	4	-	5
Harpalus affinis (Schrank, 1781)	M	-	-	-	1	-	4	-	-	-	-	5
Platyderus rufus (Duftschmid, 1812)	B	-	-	-	-	-	-	-	-	-	3	3
Brachinus explodens Duftschmid, 1812	M	-	-	-	-	1	1	1	-	-	-	3
Amara saphyrea Dejean, 1828	M	-	-	-	1	-	-	-	-	-	-	1
Poecilus cupreus (Linnaeus, 1758)	M	-	-	-	3	-	-	-	-	-	-	3
Carabus ullrichi Germar, 1824	A	-	-	-	-	-	-	-	3	-	-	3
Harpalus rubripes (Duftschmid, 1812)	M	2	-	-	-	-	-	-	-	-	-	2
Abax parallelus (Duftschmid, 1812)	B	2	-	-	-	-	-	-	-	-	-	2
Callistus lunatus (Fabricius, 1775)	M	-	-	1	-	-	1	-	-	-	-	2
Chlaenius nigricornis (Fabricius, 1787)	M	-	-	-	-	-	-	2	-	-	-	2
Carabus cancellatus Illiger, 1798	A	-	-	-	-	-	-	-	1	-	-	1
Calathus melanocephalus (Linnaeus, 1758)	B	-	-	-	1	-	-	-	-	-	-	1
Drypta dentata (Rossi, 1790)	M	-	-	-	-	-	-	1	-	-	-	1
Cicindela germanica Linnaeus, 1758	M	-	-	-	1	-	-	-	-	-	-	1
∑ individuals	-	48	14	18	34	41	45	214	55	24	11	504

and macropterous species with a connection to reed and forest stands. The presence of apterous and brachypterous species indicated a more stable environment with lower anthropogenic intervention. The second cluster (II) was mainly represented by apterous and brachypterous species, indicating a more stable environment and pointing to increasing succession in the renewed poplar forest. The third cluster (III) consisted only of macropterous species correlating with meadows and pastures. Macropterous species indicated an unstable environment exposed to cyclical changes and higher anthropogenic intervention. The fourth cluster (IV) also had a predominance of macropterous species indicating environmental instability and high anthropogenic intervention, but brachypterous species indicated a more stable environment with low anthropogenic intervention are also present. The fourth cluster was between cluster I (forest stands) and cluster III (meadows and pastures) due to the occurrence of brachypterous species found in forest stands.

Ground beetles living in anthropogenic environments have a wider environmental tolerance than species of natural habitats (Kotze et al., 2011). They achieve high local density due to anthropogenic activities such as urbanization, forestry, or agriculture

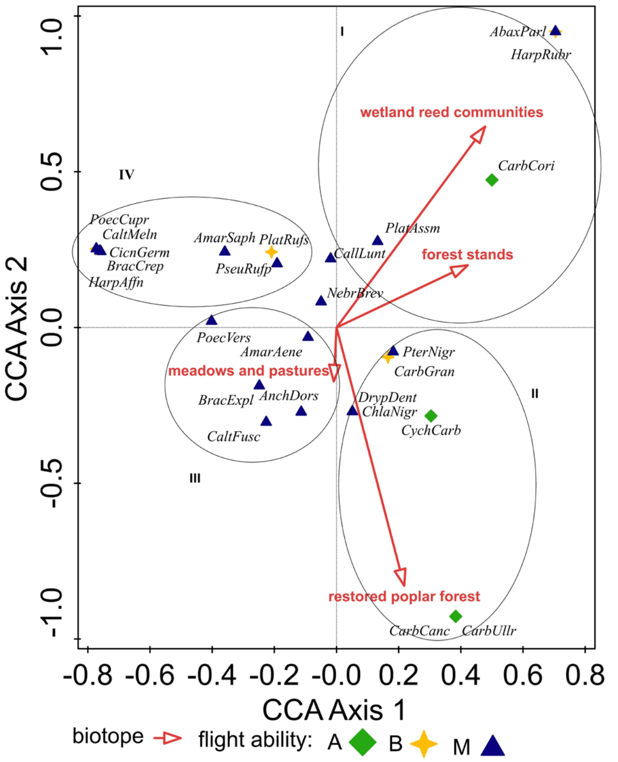

Fig. CCA analysis of Carabidae with environmental variables

(Vician et al., 2011). Several works (Turin, 2000; Gelashvili et al., 2011; Shibuya et al., 2014; Rouabah et al., 2015) reported the predominance of apterous and brachypterous species in less frequently disturbed ecosystems. Macropterous species are predominant in ecosystems exposed to cyclical changes, which indicates instability. The less frequently disturbed environment can be identified based on the predominance of apterous and brachypterous species. The rural landscape is characterized by cover forestry and with a predominance of apterous and brachypterous species (Gobbi et al., 2007). During forest development, the number of apterous species increased (Gaublomme et al., 2008). Those species were characterized by lower dispersing ability, and their presence indicated the less frequent disruption of the habitat (Den Boer et al., 1990). On the contrary, the macropterous species showed high dispersion in the settlement of anthropogenically disturbed habitats. Studies (Jelaska, Durbešić, 2009) confirmed the decrease in apterous and brachypterous species with increasing habitat disturbance and an increase in the number of macropterous species.

Conclusions

In order to preserve European important forest biotopes, it is necessary to know the ecological niches between species and biotopes, with the help of spatial distribution appliction. An appropriately used bioindicator group is the Carabidae family, which points to significant anthropic disturbance, and thus we can set the management of forests for their preservation according to it. Our data confirmed previous studies where the presence of certain groups of carabids pointed to anthropogenic disturbance. And multivariate scaling tecknique contributed into that task greatly.

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References

1. Avtaeva T.A., Sukhodolskaya R.A., Brygadyrenko V.V. Modeling the bioclimating range of Pterostichus melanarius (Coleoptera, Carabidae) in conditions of global climate change // Biosystems diversity. 2021. 29(2). P. 140–150. doi:10.15421/012119.

2. Ábrahámová A., Kollár J., Žarnovičan H.. Vegetation of the Váh River Inundation in the Part Nové Mesto nad Váhom – Šaľa. Comenius University, Bratislava, 2014. 50 p.

3. Brygadyrenko V., Avtaeva T., Matsyura A.. Effect of global climate change on the distribution of Anchomenus dorsalis (Coleoptera, Carabidae) in Europe // Acta Biologica Sibirica. 2021. 7. P. 237–260. doi: 10.3897/abs.7.e72409.

4. Burgio G., Campanelli G., Lateo F., Ramilli F., Depalo L., Fabbri R., Sgolastra F. Ecological Sustainability of an Organic Four-Year Vegetable Rotation System: Carabids and Other Soil Arthropods as Bioindicators // Agroecology and sustainable food systems. 2015. 39(3). P. 295–316. doi: 10.1080/21683565.2014.981910/

5. Den Boer P.J. Density limits and survival of local populations in 64 carabid species with different powers of dispersal // Journal of evolutionary biology. 1990. 3. P. 19–48. https://doi.org/10.1046/j.1420-9101.1990.3010019.x

6. Farkač J., Kopecký T., Veselý P. Využití střevlíkovitých brouků (Coleoptera, Carabidae) fauny Slovenska k indikaci kvality prostředí // Ochrana Přírody. 2006. 25. P. 226–242.

7. Gaublomme E., Hendrickx F., Dhuyvetter H., Desender K. The effects of forest patch size and matrix type on changes in carabid beetle assemblages in an urbanized landscape // Biological conservation. 2008. 141(10). P. 2585–2596. doi: 10.1016/j.biocon.2008.07.022.

8. Gelashvili D.B., Soltzev L.A., Yakimov V.N., Sukhodolskaya R.A., Khabibullina N.R., Iudin D.I., Snegiryova M.S. Fractal analysis of the specific structure of Carabidae complexes in urbanized territories // Povolzhskiy journal of ecology. 2011. 4. P. 407–420.

9. Gobbi M., Rossaro B., Vater A.E., De Bernardi F., Pelfini M., Brandmayr P. Environmental features infl uencing Carabid beetle (Coleoptera) assemblages along a recently deglaciated area in the Alpine region // Ecological entomology. 2007. 32(6). P. 682–689. https://doi.org/10.1111/j.1365-2311.2007.00912.x.

10. Hůrka K. Carabidae České a Slovenské republiky. Kabourek, Zlin, 1996. 565 p.

11. Jelaska L., Durbešić P. Comparison of the body size and wing form of carabid species (Coleoptera: Carabidae) between isolated and continuous forest habitats // Annales - Societe Entomologique de France. 2009. 45(3). P. 327–338. doi: 10.1080/00379271.2009.10697618.

12. Kotze D.J., Brandmayr P., Casale A., Dauffy-Richard E., Dekoninck W., Koivula M., Brandmayr T.Z., Noordijk J.,

Paarmann W., Pizzolotto R., Saska P., Schwerk A., Serrano J., Szyszko J., Taboada A., Turin H., Venn S., Vermeulen R., Zetto T. Forty years of carabid beetle research in Europe-From taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation // ZooKeys. 2011. 100. P. 55–148. doi: 10.3897/zookeys.100.1523.

13. Langraf V., David S., Babosová R., Petrovičová K., Schlarmannová J. Change of Ellipsoid Biovolume (EV) of Ground Beetles (Coleoptera, Carabidae) along an Urban–Suburban–Rural Gradient of Central Slovakia // Diversity. 2020a.12(12). 475. https://doi.org/10.3390/d12120475.

14. Langraf V., Petrovičová K., David S., Svoradová A., Schlarmannová J. Prediction of Ecological Importance of Carabidae Biotopes Using Community Index of The Ground Beetles (Iks) in The Southern Part of Central Slovakia // Applied ecology and environmental research. 2020b. 18(1). P. 1197–1210. doi: 10.15666/aeer/1801_11971210

15. Lisický M.J., Mucha I. Optimalizácia vodného režimu ramennej sústavy v úseku Dunaja Dobrohošť – Sap z hľadiska prírodného prostredia. Prírodovedecká fakulta Univerzity Komenského, Bratislava, 2003. 205 p.

16. Majzlan O. The changes of weevil taxocoenoses (Coleoptera, Curculionidae) in forest soil of the association Salici-Populetum in the Danube river floodplain // Gabčíkovo part of the Hydroelectric power project. PrifUK, Bratislava, 1995. P. 275–281.

17. Majzlan O. Monitoring nosáčikov (Coleoptera, Curculionoidea) v pôde lesov Salici-Populetum pri Dunaji (Južné Slovensko) // Acta environmentalica Universitatis Comenianae. 1997. 9. P. 79–93.

18. Majzlan O., Litavský J. Bezstavovce (Evertebrata) – indikátory zmien v krajine // Entomofauna carpathica. 2015. 27(1). P. 63–68.

19. Microsoft SQL Server, 2017. (RTM) - 14.0.1000.169 (X64) Aug 22 2017 17:04:49 Copyright (C) 2017 Microsoft Corporation Express Edition (64-bit) on Windows 10 Home 10.0 <X64> (Build 18362:).

20. Muránsky P. Liskavky (Coleoptera: Chrysomelidae) inundačného pásma Dunaja // Folia faunistica Slovaca. 1999. 4. P. 121–128.

21. Novák K., Balát F., Bartoš E., Bouček Z., Daniel M., Dlabola J., Doskočil J., Holman J., Hrbáček J., Agemann E., Kunst M., Landa V., Lang J., Mařan J., Miller F., Nosek J., Novák K., Obenberger J., Obr S., PelikánJ., Raušer J., Rosický B., Rusek J., Schwarz J., Skuhravý V., Slouková M., Šilhavý V., Štys P., Teyrovský V., Vondráček K., Zahradník J., Zelený J. Metody sběru a preparace hmyzu. Academia, Praha, 1969. 243 p.

22. Porhajašová J., Noskovič J., Rakovská A., Babošová M., Čeryová T. Biodiversity and Dynamics of Occurence of Epigeic Groups in Different Types of Farming // Acta Horticulturae et Regiotecturae. 2015. 18(1). P. 5–10. https://doi.org/10.1515/ahr-2015-0002.

23. Porhajašová J., Bartošová L.M., Noskovič J., Ondrišík P. Long-Term Developments and Biodiversity in Carabid and Staphylinid (Coleoptera: Carabidae and Staphylinidae) Fauna during the Application of Organic Fertilizers under Agroecosystem Conditions // Polish journal of environmaental studies. 2018. 27(5). P. 2229–2235. https://doi.org/10.15244/pjoes/77072.

24. Rouabah A., Villerd J., Amiaud B., Plantureux S., Lasserre F. Response of Carabid beetles diversity and size distribution to the vegetation structure with indifferently managed field margins // Agriculture, ecosystems and environment. 2015. 200. P. 21–32. doi: 10.1016/j.agee.2014.10.011.

25. Ružičková H., Halada Ľ., Jedlička L., Kalivodová E. Biotopy Slovenska. Príručka k mapovaniu a katalóg biotopov. Ústav krajinnej ekológie Slovenskej akadémie vied, Bratislava, 1996. 192 p.

26. Shibuya S., Kikvidze Z., Toki W., Kanazawa Y., Suizu T., Yajima T., Fujimori T., Mansournia M.R., Sule Z., Kubota K., Fukuda K. Ground beetle community in suburban Satoyama — A case study on wing type and body size under small scale management // Journal of Asia-Pacific entomology. 2014. 17(4). P. 775–780. https://doi.org/10.1016/j.aspen.2014.07.013.

27. Šustek Z. Diversity and Survival of Carabid communities in the area affected by the Barrage system Gabčíkovo // Gabčíkovo part of the hydroelectric power project. PrifUK, Bratislava, 1995. P. 261–264.

28. Ter Braak C.J.F., Šmilauer P. Canoco reference manual and user's guide: software for ordination, version 5.0, Microcomputer Power, 2012. 496 p.

29. Turin H. De Nederlandse Loopkevers: Verspreiding Enoecologie (Coleoptera: Carabidae). KNNV Uitgeverij, Utrecht, 2000. 666 p.

30. Vician V., Stašiov S., Kočík K., Hazuchová L. Structure of the Carabids (Coleoptera: Carabidae) associations on variously managed agricultural land of Podpoľanie area and their bioindication // Acta facultatis ecologiae. 2011. 24–25. P. 123–131.

Ланграф В., Петровикова К., Жларманнова Дж. **Структура сообществ жужелиц (Carabidae) в пойменных биотопах р. Дунай**.

Изменения в структуре сообществ жужелиц указывают на стабильность или нестабильность среды обитания, на которую оказывают влияние урбанизация, сельское и лесное хозяйство. В течение 2021 г. в затапливаемых биотопах поймы р. Дунай с использованием ловушек Барбера на десяти участках получена выборка жужелиц из 504 особей ((185 ♂; 319 ♀), принадлежащих 26 видам. На лугах и пастбищах доминировали макроптеры, что свидетельствует о повышенном антропогенном прессе. В лесных биотопах, тростниковых зарослях и сукцессионном тополевнике были зарегистрированы бескрылые виды, брахиоптеры и макроптеры.

Ключевые слова: Carabidae; жужелицы; фауна; биоиндикаторы; пойма; Дунай.

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