

Original Research

Long-Term Developments and Biodiversity in Carabid and Staphylinid (Coleoptera: Carabidae and Staphylinidae) Fauna during the Application of Organic Fertilizers under Agroecosystem Conditions

Jana Ivanič Porhajašová*, Mária Babošová, Jaroslav Noskovič, Peter Ondrišík

Department of Environmentalism and Zoology, Faculty of Agrobiological and Food Resources,
Slovak University of Agriculture in Nitra, Nitra, Slovakia

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Abstract

The aim of this work was to ascertain the influence of applying various doses of organic fertilizers on the occurrence of the Carabidae and Staphylinidae families. The research was carried out in five treatments: 1) control treatment, 2) 25 t ha⁻¹ of farmyard manure, 3) 50 t ha⁻¹ of bio-sludge, 4) 50 t ha⁻¹ of farmyard manure, and 5) 100 t ha⁻¹ of bio-sludge. Coleoptera was represented by 87,324 individuals, Carabidae with a dominance of 80.53 to 86.28%, and Staphylinidae from 5.36 to 8.32%. Carabidae recorded the highest number for the 5th treatment, for 16,534 individuals, with the lowest number being for the 4th treatment, for 12,322 individuals. Staphylinidae recorded the highest number for the 4th treatment, with a frequency of 1,273 individuals, and the lowest number was for the 2nd treatment, with 934 individuals. When considering the crops grown that produce convenient individual conditions, crops producing shading, *Helianthus annuus* and *Zea mays* were preferred. The statistical evaluation did not confirm the effect of treatments, temperature, precipitation, and year of the occurrence of Carabidae. The effect of the treatment was not confirmed statistically in Staphylinidae, and the impact of the year, temperature, and precipitation were significant.

Keywords: agroecosystem, biodiversity, Carabidae, Staphylinidae, soil edaphon

Introduction

The occurrence of edaphic animals is significantly affected by the biotic and abiotic factors present in the given biotope. Agroecosystems are characterized by the influence of natural factors, but significantly are also applied to anthropogenic interventions, such as, for instance, growth structure, soil cultivation, bringing into and applying organic or inorganic fertilizers into the soil, and others. These interventions are often involved in reducing their number [1-2]. Soil communities represent a diversified component of soil fauna. Thanks to a wide range of taxonomic groups with specific adaptations to soil habitat and by a different sensitivity to environmental stress, they are suitable for studying the influence of natural and anthropogenic disturbances on the soil environment. They are an important component of soil fauna because they participate in decomposition processes, regulate the population of soil microorganisms, some forms are pests of plants, so they have a different functional status in the soil system [3]. Throughout the long history of agriculture, many species of soil zoofauna have been adapted to the high impact of disturbances, uniformity and intensive utilization of soil [4]. The dominant group among soil animals together with Collembola, Acarina, Heteroptera and others, is represented by coleoptero fauna with predominantly represented families of Carabidae and Staphylinidae. The most numerous families of Coleoptera, which occur in all terrestrial ecosystems, are the families of Carabidae and Staphylinidae [5].

Most Carabidae species are living on the surface of the soil, and some require shading or are heliophilic, occurring during the day on open habitats. These are hygrophilous species, with night activity. From the trophic point of view, they are omnivorous species, non-specialized carnivores, specialized vegetarian at the stage of a larva, but also imago. The development of the predominant majority is one year. Among factors underlying their occurrence belong moisture, temperature, shade, the type of vegetation present, and the nature of soil background [6]. There may be potential for the use of productivity and disturbance estimations in the provision of ecosystem services, especially in assessing the conditions required to optimize ground beetle activity for pest control [7]. Although soil Coleoptera represent a taxonomically diverse group and differ widely in size and ecological role, a lot of studies have focused on Carabidae and Scarabaeidae [8]. Biodiversity of Carabidae under the conditions of different types of farming was evaluated [9]. The organic system of management has shown a higher representation of Carabidae when compared with conventional management. In their work, they found a positive influence of the application of organic fertilizers on the occurrence of dominant families of Carabidae and Staphylinidae. The impact of applied doses of organic fertilizers can be evaluated positively in particular for the improvement of the soil

structure, increasing the vitality and density of the crops, with which to create more suitable conditions for the present fauna [10].

Staphylinidae are characterized by their oval body and shortened wing sheaths, they prefer shadowed habitats, their activity is influenced by light intensity, their high migration ability is indicated by a strong human influence for biotopes. Their trophic relationships are more diverse than those of Carabidae. Some are predators or can be fed with organic residues, they are also mycofagous species, etc. [11-12]. The number of species and individuals of Staphylinidae is mostly higher in stable biotopes than in habitats affected by abiotic conditions (anthropogenic activity).

In general, it may be stated that the higher number of Carabidae and Staphylinidae may not always indicate its haleness and undisturbed state. The agroecosystems are often found to have higher species representation as, for example, in semi-natural habitats, since the ecological requirements of each species are decisive. Predominant in the agroecosystems are species of ubiquitous, in the undisturbed habitats predominate species with higher ecological demands and stenotop species. The species composition of the staphylinid fauna in apple and pear orchards could not be considered uniform. The environmental conditions and the soil together have a significant influence upon the richness of species, and the cumulative effects of these factors can modify even the dominant structures of the communities [12].

Since Carabidae and Staphylinidae play an indispensable role in natural and artificial biocenoses, they act as predators of many pests, they have the potential to integrate plant protection against pests, and they are applied in maintaining equilibrium and the cycle of substances and energy, and for this reason it is important to study the anthropogenic impact on the occurrence of these populations. The aim of this work is to ascertain conclusive evidence of the effect of applying specified doses of organic fertilizers (manure and bio sludge) in connection with microclimatic environmental factors and cultivated crops under agroecosystem conditions.

Materials and Methods

The collection of the epigeic component of the animals was carried out 2001-2009 on a field semi-operational experiment at the experimental station of the Slovak University of Agriculture in Nitra-Kolíňany, located 10 kms northeast of the town of Nitra. The elevation above sea level of the monitored location is 160-180 m, with the coordinates N 48°21'41"E 18°12'37". The soil type is brown soil, with an average humus content of 2.149% Hm. According to the morphogenetic soil classification system of the Slovak Republic, we classify Haplic luvisol as a subtype, with exchangeable soil reaction (pH/KCL) as strongly acidic or acidic (4.59 to 5.39 pH units). On this basis,

Table 1. The average monthly temperatures and total monthly rainfall 2001-2009.

Month/ Year	The average monthly temperatures (°C)									
	Normal 1951-80	2001	2002	2003	2004	2005	2006	2007	2008	2009
I.	-1.7	0.4	-1.2	-1.9	-3.1	-0.1	-4.1	4.4	1.4	-1.3
II.	0.5	2.0	3.5	-1.8	1.6	-2.7	-1.6	5.0	2.7	1.2
III.	4.7	6.0	6.3	5.1	4.7	2.7	3.5	7.5	5.5	5.5
IV.	10.1	10.4	9.9	10.7	11.7	11.0	11.4	12.2	11.0	14.0
V.	14.8	17.0	17.4	18.8	14.3	15.2	14.0	16.6	16.0	15.5
VI.	18.3	18.0	19.6	21.3	17.9	18.0	19.2	21.1	19.9	17.1
VII.	19.7	21.9	22.1	21.2	20.0	20.5	22.6	22.3	20.4	20.6
VIII.	19.2	23.1	20.8	22.7	20.1	19.1	16.7	21.2	20.5	21.0
IX.	15.4	14.8	14.9	15.8	14.7	16.3	16.6	13.7	15.3	18.1
X.	10.1	14.1	9.7	7.9	11.7	10.7	12.2	9.9	11.2	10.3
XI.	4.9	3.9	8.0	7.0	5.5	4.2	7.5	3.6	6.7	6.7
XII.	0.5	-5.1	-0.4	0.9	0.8	0.4	3.2	-1.1	3.0	1.3
Average	9.7	10.5	10.9	10.6	9.9	9.6	10.1	11.4	11.1	10.8
Month/ Year	Total monthly rainfall (mm)									
	Normal 1951-80	2001	2002	2003	2004	2005	2006	2007	2008	2009
I.	31	22.9	11.9	33.0	55.9	31.0	57.4	66.3	25.5	41.7
II.	32	19.0	35.7	0.7	31.1	53.0	39.0	32.9	20.2	57.3
III.	33	50.9	28.7	2.3	52.8	3.4	35.2	58.0	62.7	53.6
IV.	43	20.0	44.5	27.0	36.3	78.7	48.1	0.0	36.4	10.1
V.	55	49.1	62.3	44.5	36.9	60.9	95.6	106.7	55.4	38.1
VI.	70	18.0	68.5	6.5	93.8	31.5	63.9	36.0	86.2	79.4
VII.	64	72.0	50.9	92.0	33.8	59.0	23.7	35.6	90.0	69.8
VIII.	58	23.8	90.0	24.0	19.4	94.5	84.0	78.9	9.8	49.8
IX.	37	101.5	62.1	16.0	35.4	47.1	12.7	91.2	51.5	13.4
X.	41	8.3	78.2	66.0	45.3	12.1	15.3	31.6	30.2	65.3
XI.	54	32.6	42.0	33.0	45.7	43.2	24.4	50.2	33.1	55.4
XII.	43	17.1	37.7	24.0	26.8	113.2	7.8	19.0	68.0	47.4
Σ	561	435.2	612.5	369.0	513.2	633.0	507.1	606.4	569.0	581.3

the soil can be evaluated as strongly influenced by anthropogenic activity [13-14].

The territory belongs to the climatic region MT2 (slightly warm, slightly humid, with a mild winter), the sum of temperatures is 2,200-2,500°C, with a probability of dry vegetation periods of 15-30%. The model territory belongs to the maize production area with a flat terrain, share of arable land of 87%, and a permanent grassland of 8% [15].

The average annual air temperature and average rainfall over the monitored period were elaborated upon on the basis of the characteristics of the agro-climatic

conditions of the area (Table 1). The average annual temperature during the monitored period was 10.5°C and the average of total rainfall was 563.3 mm. The tables also show the climatic standard over the period 1951-1980 [16-20].

The experiment was carried out in Koliňany using the earth traps method (the method is based on the location of the open glass jar into the soil - 1L filled up to 1/3 by fixative solution of 4% formaldehyde, earth traps were exposed within the crops and treatments during the growing season: April to October, obtained biological material was taken off in monthly intervals,

earth traps were subsequently renewed and in terms of the department was this material determinate), which were exposed in the five treatments: the 1st treatment was control, 2nd treatment was 25 t ha^{wasl} of farmyard manure, 3rd treatment was 50 t ha^{wasl} of biosludge, 4th treatment was 50 t ha^{wasl} of farmyard manure, and 5th treatment was 100 t ha⁻¹ of biosludge. The total area of the model was 9,000 m², and each treatment had a surface area of 1,800 m² (size of one treatment was 100 x 18 m). Biosludge is the residual after production of biogas and the fall was applied to the soil.

Each year the traps were exposed in different crops: 2001 - *Hordeum vulgare*, 2002 - *Beta vulgaris*, 2003 - *Zea mays*, 2004 - *Helianthus annuus*, 2005 - *Beta vulgaris*, 2006 - *Zea mays*, 2007 - *Beta vulgaris*, 2008 - *Hordeum vulgare*, and 2009 - *Helianthus annuus*.

The following indicators were evaluated in the populations obtained:

- Total amount of epigeic material (abundance).
- Determining the line coleoptera aimed at the carabidae and staphylinidae families.
- Species identity (ij), according to jaccard [21], diversity degree (d), according to Shannon-Weaver, modified according to Schwerdtfeger [22].
- Overall evaluation of the occurrence of populations and their biodiversity.
- Statistical evaluation of the results in the STATGRAPHICS 5.1 PLUS program and – since the set did not have a uniform distribution even after using transformations – the nonparametric Kruskal-Wallis test [23] was used.

Results and Discussion

The epigeic material obtained presents collections of biological material during the 9-year research period (2001-2009) using the ground traps method. From the point of view of evaluation of agroecosystems homeostasis, the Coleoptera population was selected, with model families of Carabidae and Staphylinidae, which by their presence indicate topical and trophic environmental conditions, acting as part of the mechanisms of transport of substances and energy flow and reaction sensitively to changes carried out in the agroecosystems. Owing to their biodiversity, they are suitable for detecting the effects of natural and anthropogenic disturbances [24].

The frequency of colleopterofauna for the period under investigation represented 87,324 individuals. Concerning the objective of the work, attention was directed to the dominant Carabidae family, which during the years and treatments showed the representation from 80.53 to 86.28% and Staphylinidae from 5.36 to 8.32%. Both families are trophic and ecologically diverse groups occurring in all types of terrestrial ecosystems that are applied in natural biocenoses and agroecosystems due to their diversity and abundance in maintaining equilibrium in the circulations of substances and energy [12, 25].

On the basis of a summary evaluation of the collections during the monitored years and treatments, it can be stated that the occurrence and representation of the present families was uneven, which is related to the microclimatic conditions at the monitored locality over a longer period of time, the vegetation present, and the habitat requirements of the species present (Figs 1-5). The frequency of individuals during the period under review varied as follows:

- 1st treatment: control treatment family Carabidae from 612 individuals to 3,832 individuals (dominance of Coleoptera 86.28%), family Staphylinidae from 0 individuals to 188 individuals (dominance of Coleoptera 5.36%).
- 2nd treatment: 25 t ha⁻¹ of the farmyard manure family Carabidae from 1,080 individuals to 3,228 individuals (dominance of Coleoptera 84.24%), family Staphylinidae from 4 individuals to 280 individuals (dominance of Coleoptera 5.44%).
- 3rd treatment: 50 t ha⁻¹ of bio-sludge family Carabidae from 323 individuals to 4,440 individuals (dominance of Coleoptera 83.19%), family Staphylinidae from 28 individuals to 432 individuals (dominance of Coleoptera 7.26%).
- 4th treatment: 50 t ha⁻¹ of the farmyard manure family Carabidae from 372 individuals to 3,520 individuals (dominance of Coleoptera 80.53%), family Staphylinidae from 16 individuals to 388 individuals (dominance of Coleoptera 8.32%).
- 5th treatment: 100 t ha⁻¹ of bio-sludge family Carabidae from 404 individuals to 3,474 individuals, (dominance of Coleoptera 83.93%), family Staphylinidae from 12 individuals to 339 individuals (dominance of Coleoptera 5.59%) (Figs 1-5).

Based on the cumulative abundance of the effect of the treatment on the occurrence of the Carabidae family, as treatment with the highest occurrence of the 5th treatment with 100 t ha⁻¹ of biosludge (16,534 individuals) can be evaluated, and with the lowest occurrence of the 4th treatment with 50 t ha⁻¹ of the manure 12,322 individuals. The family Staphylinidae have recorded the highest frequency in the 4th treatment – 50 t ha⁻¹ of the farmyard manure (1,273 individuals) and the lowest representation was recorded by the second treatment of 25 t ha⁻¹ of farmyard manure (934 individuals; Fig. 6). The relationships of communities in individual fertilization treatments and years, respectively, in crops are represented by the above graphs, high abundance values are correlated mainly with climatic factors and the vegetation present, in the case of Carabidae also by the maximum dose of biosludge, in Staphylinidae they are correlated by the application of 50 t ha⁻¹ of biosludge and 50 t ha⁻¹ of farmyard manure. On the contrary, the lowest values are related to Carabidae with the application of 50 t ha⁻¹ of the manure and in family of Staphylinidae with the application of 25 t ha⁻¹ of farmyard manure.

Despite the above given, we can say that no significant difference in the occurrence of individuals has been found. The higher number of individuals found

in these treatments can be explained by the application of maximum doses of organic fertilizers, which have a positive influence on the soil structure and increase the vitality and density of growth, which is clearly related to the creation of more convenient conditions for the fauna present, mainly from the the point of view of shadowing. Many authors are of the opinion that the influence of the fertilizer variation on the occurrence of soil fauna is insignificant, and are of the opinion that the species present naturally migrate in agroecosystems, as has been

confirmed by our findings, too [26-27]. The occurrence of species is primarily influenced by the microclimatic conditions of the environment. The presence of other, lower-represented families only adds to the richness of the zoocenosis spectrum [28-29].

Based on the cumulative abundance and dominance of the monitored populations, we can conclude that the maximum occurrence of species of the Carabidae family was recorded in 2009, in the crop *Helianthus annuus*, with frequency of 17,844 individuals, suitable conditions from the point of view of shadowing and moisture have also been created by *Hordeum vulgare*

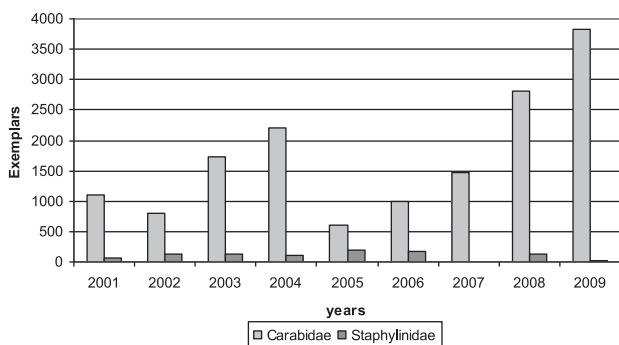


Fig. 1. 1st treatment - control treatment: abundance the family Carabidae and Staphylinidae on the location Koliňany in 2001-2009.

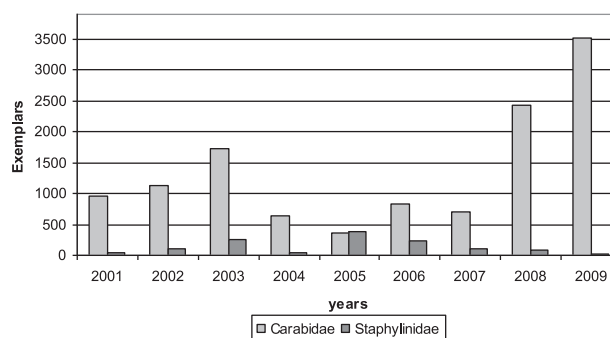


Fig. 4. 4th treatment - 50 t ha⁻¹ of farmyard manure: abundance the family Carabidae and Staphylinidae on the location Koliňany in 2001-2009.

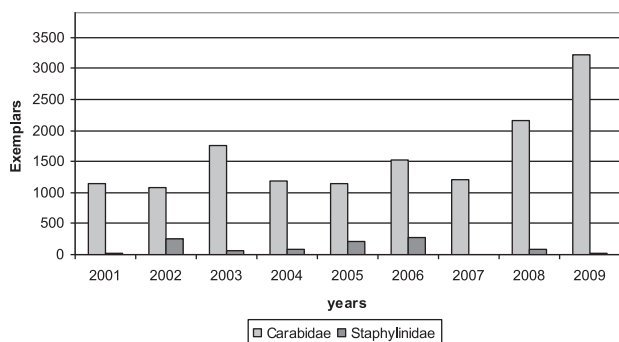


Fig. 2. 2nd treatment - 25 t ha⁻¹ of farmyard manure: abundance the family Carabidae and Staphylinidae on the location Koliňany in 2001-2009.

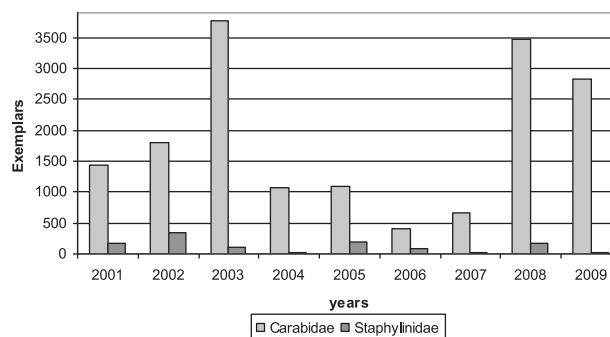


Fig. 5. 5th treatment - 100 t ha⁻¹ of bio-sludge: abundance the family Carabidae and Staphylinidae on the location Koliňany in 2001-2009.

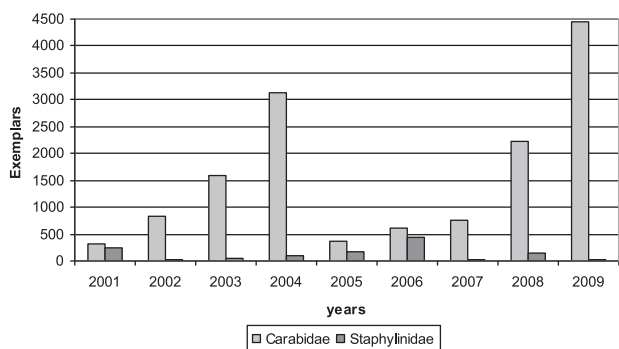


Fig. 3. 3rd treatment - 50 t ha⁻¹ of bio-sludge: abundance the family Carabidae and Staphylinidae on the location Koliňany in 2001-2009.

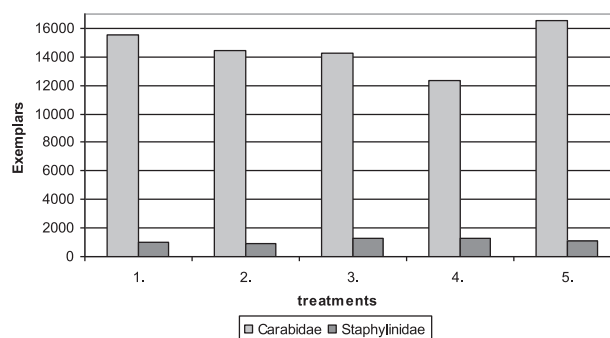


Fig. 6. abundance the family Carabidae and Staphylinidae on the location Koliňany in 2001-2009, on individual treatments.

and *Zea mays*. The lowest frequency (3,572 individuals) was found in the crop *Beta vulgaris*. This confirms that the most important factors determining the occurrence of Carabidae are moisture, temperature, shadowing, and vegetation, which has also been confirmed by our findings [6-7]. Besides the microclimatic conditions and vegetation type, it is worth mentioning the objective of our work – namely to ascertain the influence of the application of organic fertilizers, which in our case has positively influenced the number of individuals despite the fact that the statistical evaluation has not been confirmed. On the basis of the Kruskal-Wallis statistical evaluation test for the dependence of the occurrence of families on individual factors, it was found that the dependence of occurrence of the Carabidae family on year (0.12493), treatment (0.40151), temperature (0.12493), and precipitation (0.12493) were insignificant ($P > 0.05$). Based on the above it can be stated that the observed factors did not have a significant impact on the occurrence of the Carabidae.

The Staphylinidae family was represented in a lower frequency, but still at the level of dominant occurrence, where the maximum incidence was recorded in 2006 with a frequency of 1,184 individuals (crop *Zea mays*) and in 2005 with a frequency of 1,124 individuals (crop *Beta vulgaris*). The lowest frequency was recorded in 2009 with a frequency of 132 individuals (crop *Helianthus annuus*). Staphylinidae are species mostly active during the day, they prefer rather shadowed habitats, and their activity is influenced by light intensity. The high frequency of species with good migratory possibilities indicates a strong human impact on the habitats [6-7].

On the basis of the Kruskal-Wallis statistical evaluation test it may be stated that the effect of the variant on the occurrence of Staphylinidae was not manifested (0.68154). The influence of climatic conditions such as year (0.01873), temperature (0.01873), and precipitation (0.01873) was significant ($P = 0.05-0.01$).

On the basis of correlative relationships, the Carabidae and Staphylinidae families are in mutually negative correlation, which may be explained by similar requirements on environmental conditions. The high number of Carabidae and Staphylinidae species found on the monitored locality may not always indicate the preservation and lack of disturbance of the environment. In agroecosystems the frequency is many times higher than in natural habitats, because the ecological requirements of the species present are decisive, in agroecosystems prevail ubiquitous species, while in undisturbed habitats there are species with increased ecological demands and stenotop species [12].

The occurrence of Carabidae and Staphylinidae species is closely related with their migratory capacity, especially at the time of reproduction and flexibility in searching for new habitats, habitat requirements,

and cenological properties. In their absence, in our case, the family of Staphylinidae in the 1st and 2nd treatments (years 2007), we cannot draw conclusions about the given site. On the contrary, from its presence in other variants we follow the direct proportionality of the migratory capacity of the given species. For a reason of the hidden way of life of the Carabidae and Staphylinidae populations, they are not affected by applied insecticides, which is to be considered because, according to other authors, these two families are an example of resistance to anthropogenic effects [29]. The Staphylinidae family does not react negatively to the agronomic practices in agroecosystems [30].

The values of Jaccard index of species identity in individual years and treatments varied from 73.68 to 84.21%, with the average of 79.76%. Low values appeared mainly in the variants that were accompanied by a high dominance of both families. In general, it may be stated that lower values are a reflection of ecosystems that are heavily influenced by human activity [31-32].

The index diversity values calculated according to Shannon-Weaver reached 0.73829, which is a real value considering the character of the biotope that is significantly affected by human activity. When compared to the calculated value within the Alúvium Žitava Nature reserve ecosystem, the value reached 2.12188 and is evidence of ecosystem stability [33-34]. In general, we can state that the presence of the edaphic groups is associated with a number of relatively complex relationships taking place in ecosystems.

Conclusions

The occurrence of edaphic groups of animals is dependent on the abiotic and biotic factors that are characteristic for a given habitat. Agroecosystems include, in addition to natural, anthropogenic factors (soil cultivation, crops, application of organic and inorganic fertilizers, and pesticides). All these interventions represent a risk for the edaphone present, which can be manifested mainly by decreasing the frequency.

The model epigeic groups of Coleoptera, with emphasis on the Carabidae and Staphylinidae families, can be used in detecting changes in biodiversity in ecosystems. In our case, it concerned the agroecosystem in which in the individual treatments are dominated by applied organic fertilizers, namely farmyard manure and bio-sludge at precisely specified doses, and present vegetative cover, taking into account the given microclimatic conditions of the given biotope. We can state that no significant differences have been found in connection with organic fertilizer doses, which play an important role in cultivated crops, especially in favor of crops that have generated shadowing of migration areas and have created suitable topical and trophic conditions for the given environment.

Acknowledgements

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