PATTERNS OF SECONDARY PRODUCTIVITY OF GROUND BEETLE COMMUNITIES (*COLEOPTERA, CARABIDAE*) IN NATURAL AND SEMINATURAL FOREST ECOSYSTEMS IN RELATION TO GEOLOGICAL SUBSTRATE AND VERTICAL ZONALITY OF CLIMATE

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Abstract

The secondary productivity of 48 carabid communities from natural forests on different geologic substrates and at different altitudes is compared. In spite of its great variability within individual trophic series and vegetation tiers (in sense of RAUŠER & ZLATNÍK 1966), it shows a decreasing trend from communities form habitats on alkaline or nitrophilous substrates to the acidic substrates and from low altitudes to the high altitudes. In communities in habitats on more fertile substrates, a considerable part of biomass is bound by large species occurring in a low number of individuals, whereas on the less fertile substrates the existing biomass tends to be split among a large number of little species, occurring sometimes in huge numbers of individuals. In some cases, the direct influence of the habitat trophicity or climatic factors is combined with indirect influence of liter structure or its continuous covering by mosses.

Introduction

Geological substrate and vertical zonality of climate represent important abiotic factors responsible of productivity of ecosystem. The geological substrate directly influences the soil fertility, which increases from the acid soils to the nitrophilous or alkali soils. It also indirectly influences the hydrological regime in ecosystems. In this way it influences humidity in the respective ecosystem and condition for its productivity and creates preconditions for occurrence of individual plant or animal species. Production of plant communities determines the food basis for herbivores and, secondarily, of carnivores and decomposers. Thus their occurrence and population size is directly dependent of the plant productivity.

The aim of this contribution is to show, how the productivity of ground-beetle communities varies along the geologic and climatic gradients in the natural or seminatural forest stands in Central Europe.

Material and methods

The material was pitfall trapped in 49 habitats in 17 localities (ŠUSTEK 1972, 1976, 1982, 1983, 1984, 1986, 1988, 2006, 2007, 2008 Tab. 1) in Bohemia, Moravia and Slovakia in 1970 – 2008: Malá Pleš 49°59'4"N, 13°49'32"E; Kohoutov 49°59'43"N, 13°50'29"E; Hřebínek 50°50'54"N, 15°16'2"E; Žákova hora 49°41'1"N, 16°1'15"E; Františkova Myslivna 50°3'27"N, 17°12'28"E; Pavlovské kopce 48°52'40"N, 16°39'33"E; Boleradice 48°58'23"N, 16°47'39"E; Buchlovice 49°5'57"N, 17°17'50"E; Kľačianska Magura 49°9'14"N, 18°57'40"E; Šrámková 49°11'13"N, 19°7'11"E; Zadná Javorová dolina 49°12'40"12N, 20°9'19"E., Kolová dolina49°10'14"N, 20°10'30"E, Zadné Meďodoly

49°14'10"N, 20°10'44"E, Vyšné Hágy 49°7'26.96"N, 20°6'4.06"E. More detailed characteristics of the localities are given in the papers cited above. In these papers the complete surveys of species and data on their abundance are given.

The ecological conditions in these habitats are characterized using the Zlatník's system of phytocoenological classification of natural forests in the Central Europe (ZLATNÍK & RAUŠER 1966, ZLATNÍK 1976). It distinguishes four trophic series (A – acidophilous, B – neutral, C – nitrophilous, D – alkaline) and three transition series (AB, BC and BD) in relation to the geological substrate and defines nine vegetation tiers, named according the dominant edificatory trees, in rapport to sequence of altitudinal and expositional changes in climate (1 – oak, 2 – beech-oak, 3 – oak-beech, 4 – beech (In Carpathians) or oak-pine (in Hercynicum), 5 – beech-fire, 6 – beech-fire-spruce, 7 – spruce, 8 – dwarf pine, 9 alpine meadows). This system is completely valid for territory of the former Czechoslovakia and closely adjacent territories, but can not be applied, for example, for the Alps, where other sequence of the vegetation has been developed in high altitudes.

The habitats belonging purely to the alkaline trophical series D were omitted in these comparisons, because the available material originates from the steppe-like formations with an extremely low occurrence of ground-beetles resulting from the extremely reduced humidity and , with some exceptions, from absence of species adopted to such type habitats. The floodplain ecosystems were also intentionally omitted in this study, because the possible direct influence of the geologic substrate is here strongly masked by a rich input of sediments from outside. Thanks to it, the conditions in such habitats converge to the nitrophilous series C. At the same time, the secondary production of ground-beetles in them is strongly subjected to natural fluctuations of hydrological regime and to its profound anthropogenic changes.

Number of traps (glass or plastic jars with diameter of 75 mm, filled with 4% formalin) installed in each habitat varied according to purposes of the respective investigations. In the earlier studies (ŠUSTEK 1972, 1976, 1983), 10 traps were installed in homogenous habitats in accordance with the experimental study of OBRTEL (1971), while in the later studies (ŠUSTEK 2006, 2007, 2008) it was reduced to 6, as it has been shown (BLAŽEK & PAVLÍČEK 1986, ŠUSTEK, 1994) that the suggested number of 10 traps was exaggerated by OBRTEL'S calculations because analyzing a rich material from a habitat with strong local differences in humidity and, as a consequence, in the local species assemblages. In the heterogeneous habitats (ŠUSTEK 1982, 1983, 1984; ŠUSTEK & ŽUFFA 1986, 1988), the trap number was adopted according to ecological gradients studied in these studies. In such cases, the homogenous segments of transects were selected.

The cumulative biomass was calculated by multiplying number of individuals standardized per one trap and ones vegetation period by average dry weight of species. It was established by weighting at last 20 individuals after desiccation in a thermostat at the temperature 80°C for 24 hours, with accuracy on four decimal digits. In the rare species, like *Licinus hoffmannsegi*, only the available specimens could be weighted (Tab. 2). This approach was adapted as a relatively simple way, evicting weighting of each specimen in the samples and, to certain degree, eliminating the individual differences in size and weight. The total weight of the one-year catch of ground-beetles, calculated in the above way, is taken as measure of productivity of their communities.

The nomenclature of Carabids is adopted according to JELÍNEK (1993). In this study, 97 species are taken in consideration. Most of them are mesohygrophilous stenotopic forests species, characteristic of the respective types of natural forest. A minor parts are euryecious species or heliophilous species of open landscape, which penetrate the forests due to their fragmentation, especially in the lowlands.

Results and discussion

The Central European carabids show large differences in size of individual species. Body length ranges from 1.6 mm (*Elaphropus parvulus* Dejean, 1831) to 40 mm (*Carabus coriaceus*). Hence the largest species is 25 times longer then the smallest species. These differences become still clearer if the body size is expressed by the body weight, which reaches from: about 0.001 g in the smallest species to 6,5 g in the largest *Carabus coriaceus*. Thus the largest species may be 6500 times heavier than the smallest species (Table 2, Fig. 1 and 2).

Distribution of body weight among the species examined is very unequal. *Carabus coriaceus* with its 6,5 g takes a clearly isolated position among the Central European ground beetles, being followed by 8 species with a weight of approximately 2 g, 10 species with a weight of about 1.5 g and 6 species weighting 0.5 – 1.0 g. The weight of next 72 species decreases almost linearly, from a value of about 0.5 g to 0.004 g, but even in this groups species an indication of a step-like decreasing pattern is evident. However, differences between these steps are minute (Fig. 2) and lay within the possible individual variability. The weight differences shown in Fig. 1 and 2, especially between the large species, and differences in occurrence of these species in individual habitats may essentially influence cumulative productivity of the respective communities, as shown bellow.

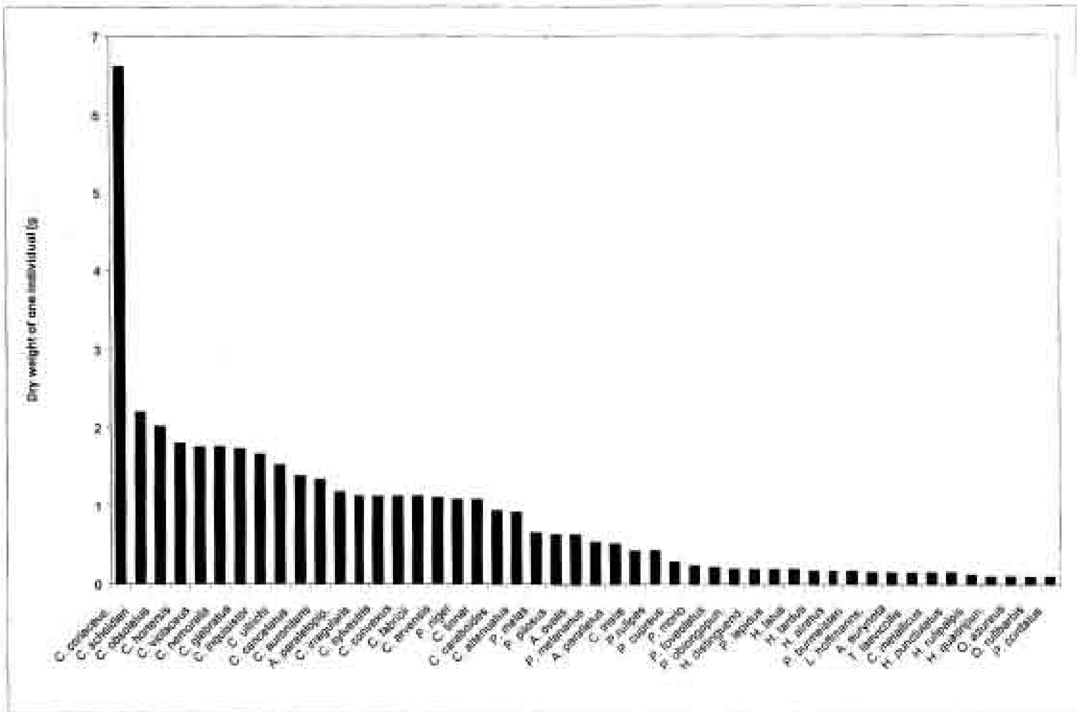

Fig. 1. Average weight of Carabids species with the weight above 0.1 g.
Fig. 1. Greutatea medie a speciilor de carabidele depasindu 0,1 g.

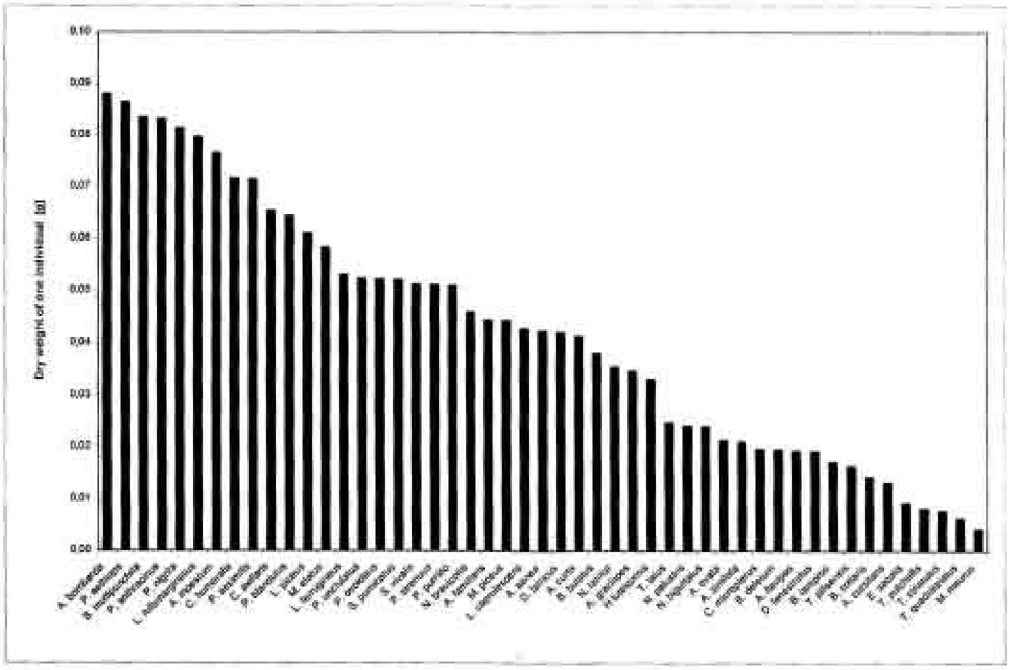

Fig. 2. Average weight of Carabids species with the weight bellow 0.1 g.
Fig. 2. Greutatea medie a speciilor de carabidele dedesubtul de 0,1 g

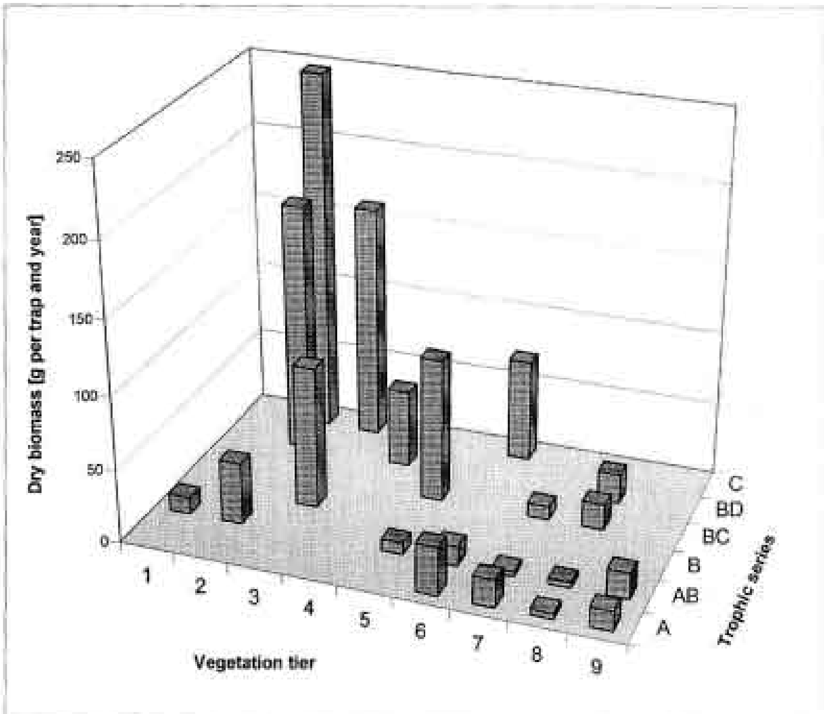

Fig. 3. Average weight of dry biomass of carabid communities in different vegetation tiers and trophic series (1 – 9: oak vegetation tier – veg. tier of alpine meadows; A – acidophilous trophic series, B – neutral trophic series, C – nitrophilous trophic series, D –alcaline trophic series, AB, BD and BD – transitory trophic series)
Fig. 3. Greutatea medie a biomasei sece de cenozele Carabideor în diferite zone de vegetaţie şi serii trofice (1 – 9: zona de vegetaţie a stejarului -- zona de vegetaţie a pajiştilor alpine; A – serie trofică acidofilă, B – serie trofică neutrală, C – serie trofică nitrofilă, D – serie trofică alcalică, AB, BC şi BD – serii trofice de tranziţie).

The productivity of carabid communities in the individual trophic series and vegetation tiers is obviously very variable, as between these two categories (Fig. 3), as within them (Fig. 5). The extreme values are 300 g per trap and season (Pavlovské kopce, beech-oak vegetation tier, neutral-alkaline trophic series, *Querci Fageta*) and 0,9 g per trap and season (High Tatra, spruce vegetation tier, acid – alkaline series, *Sorbi abieti piceeta*). However, there are evident two clear tendencies: A decrease two directions – from the average values of almost 220 – 250 g per trap and year in the nitrophilous trophic series and in the beech-oak or oak-beech vegetation tier to average values of about 5 – 30 g per trap and year in the acidophilous trophic series and in the vegetation tiers of dwarf pines and alpine meadow. There exists a relatively high correlation between trophic series and cumulative dry biomass of the community (r = 0,68), while correlation between trophic series and number of individuals is lower (r = 0.55). The dry biomass of some communities, especially of those in higher altitudes is, however, in a contradiction (r = 0.47) with cumulative number of individuals (Fig. 4). It is due to huge amounts of small species, especially *Pterostichus pumilio, Pterostichus unctulatus* and species of the genus *Trechus* in acidophilous spruce forests and a low quantitative representation or even absence of large species. In such cases, the low secondary production does not result only from little fertile substrate and, as a consequence, low food offer, but also from character of the liter or covering the ground surface or from a continuous growth of mosses, which make difficult movement or burying activity of large Carabids. On the contrary, in the most productive communities in low vegetation tiers and in the trophic series BD, BC and C, the high productivity and a relatively reduced number of individuals (Fig. 4) is caused by predominance of *Carabus coriaceus* and/or of the species with average weight of one individual of 1.5 – 2.0 g (Tab. 1). Especially in the habitats on the limestone or dolomitic limestone substrates (they do not mostly belong to the alkaline trophic series D, but in dependence of the terrain relief they belong to the nitrophilous series C or to the transitory series BD), the high productivity often results from a high levels of carbonates in the soil making favorable conditions for mollusks. Their high abundance represents a rich food offer for large *Carabus* species. Within the material examined in this study it is particularly the case of all habitats in the Pavlovské kopce hills. On the contrary, the mollusks are almost absent on the acidophilous substrates, especially in the mountain forests of High Tatras of Malá Fatra.

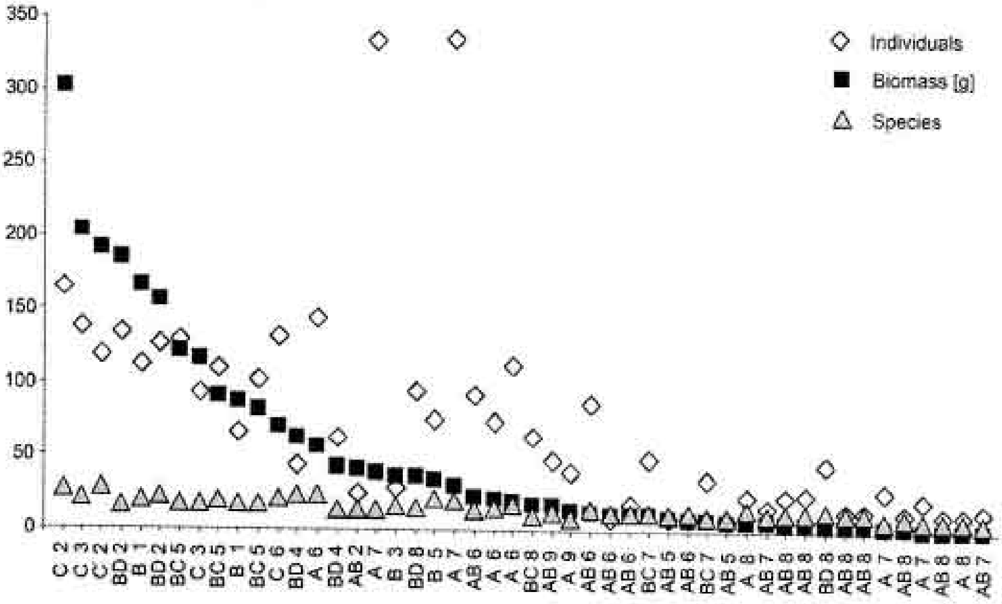

Fig. 4. Dry biomass in grams, number of individuals and number of species of carabid communities in different vegetation tiers and trophic series, (abbreviations as in fig. 3).
Fig. 4. Greutatea medie a biomasei sece în grame, numărul indivizilor şi a speciilor în cenozele de Carabidae în diferite zone de vegetaţie şi serii trofice (abrevierii ca în fig. 3).

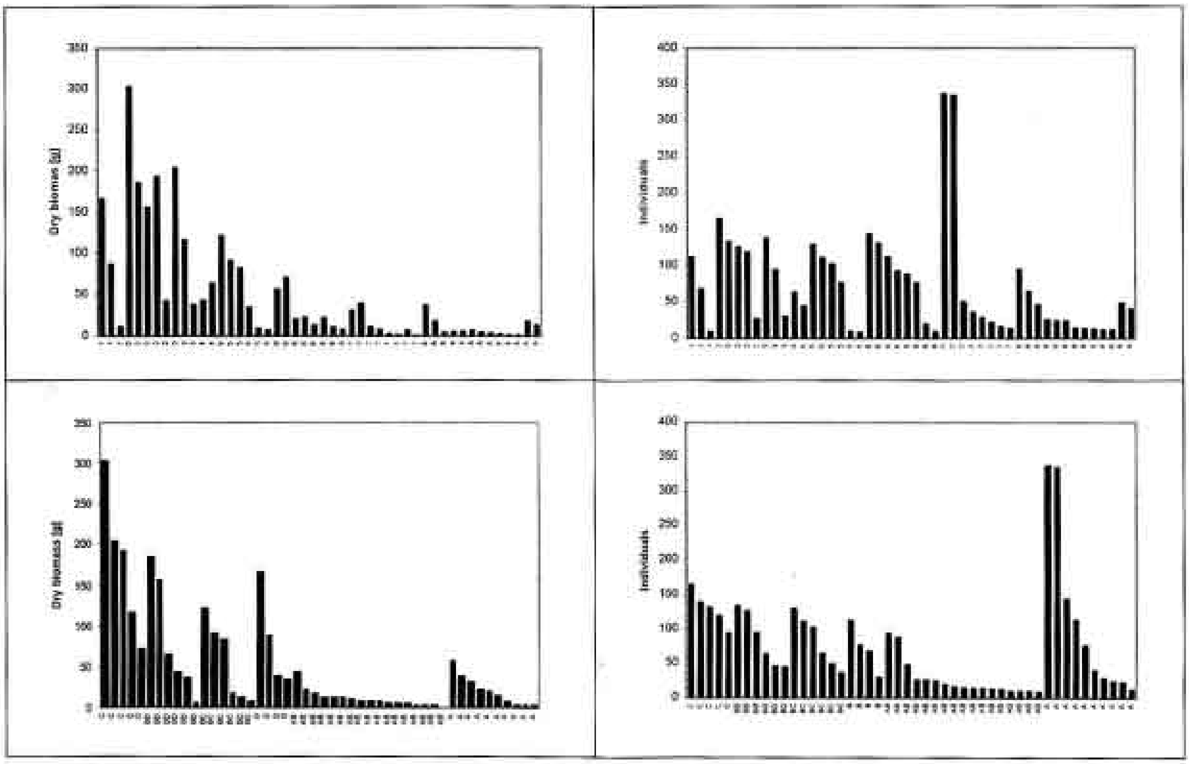

Fig. 5. Variability of dry biomass and number of individuals with each trophical series and vegetation tier (abbreviations as in fig. 3).
Fig. 5. Variabilitatea biomasei sece şi a numărului de indivizii în cadrul fiecărei serii trofice şi a zonei de vegetaţie (abrevierii ca în fig. 3).

Influence of the geological substrate o the secondary productivity and species composition of Carabids is not evident only from comparison of samples from remote localities, but can be directly observed in some parts of West Carpathians, where a mosaic of acid or alkaline substrates exists on a small territory and their boundaries can be observed in the terrain ŠUSTEK 2006; ŠUSTEK Z. & ŽUFFA, 1986, 1988).

Conclusions

The maximum productivity of Carabid communities reaches 300 g per trap and vegetation season, while the minimum productivity drops to 1.6 g per trap and vegetation season. It is very variable, as within individual trophic series and vegetation tiers, as between them. The variation ranges within individual trophic series or vegetation tiers overlap mutually. But there is a general tendency of decreasing of productivity from the average values of 220 – 280 g per trap and vegetation season in the nitrophilous or transitory neutral – alkaline trophic series and lower vegetation tiers to 5 – 30 g per trap and vegetation season in the acid trophic series and mountain vegetation tiers. The average values of productivity in a richer trophic series are mostly visibly higher then those in the next poorer series. The secondary productivity expressed by the dry biomass is freely correlated with the productivity expressed by the cumulative number of individuals. In the more productive communities, a lower number of individuals of large species bind the major part of biomass, whereas in the less productive communities the existing biomass is split among a large number of individuals of small species. This relation is, however, strongly biased by character of litter and covering of soil surface by mosses, which create conditions for movement of individual species through the litter and hiding in it. Number of individuals can be generally used as an indicator of secondary productivity of Carabid communities, but it is to be always interpreted in regard with body size structure of the communities. Otherwise it can lead to misinterpretations

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