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INFLUENCE OF CLIMATIC FACTORS ON DISTRIBUTION OF THE BEETLES FROM FAMILIES *Curculionidae* AND *Carabidae* (Coleoptera)

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Abstract

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Relationships between climatic factors and occurrence of beetles (Coleoptera) belonging to families *Curculionidae* and *Carabidae* (forming respectively phytophagous and carnivorous guilds) have been investigated in southern part of Cracow-Częstochowa upland during three consecutive years 2001–2003. Thirty localities differing in features of natural environment have been chosen. Principal Component Analysis described of 57.2% of variation for *Carabidae* assemblages and 35.5% of variation for *Curculionidae* assemblages for the first two axes. Exposure and land use were main factors determining species variation between localities. Multiple Regression didn't show close relationships between insect richness and climatic factors. Usefulness of analyse small group in investigation of biodiversity is discussed.

Key words: diversity, climatic factors, *Carabidae*, *Curculionidae*

Introduction

Many hypotheses and empirical tests concerning geographic distribution of biological diversity have been published (Rhode, 1992; Rosenzweig, 1995). Most of them are trying to link climatic conditions (mainly measures of energy intake or climate stability) and species richness gradients. Currie (1991) in so-called species richness–energy hypothesis, predicted that, as heat and water availability increases, so does the species richness. Such point of view is strongly supported by empirical data on regional or continental scale (Currie, 1991; Linder, 1991; Birks, 1996; Wohlgemuth, 1998; Qian, 1998; O'Brien et al., 1998).

Unfortunately, the description of geographic trends in species number is accompanied by many methodological difficulties. First of all, it is unevenness of sampling effort in different regions. Casual relationships underlying multivariate environmental and spatial correlation are also important (Lobo et al., 2001). When we take into account mesoregional relationships, many global events (such as evapotranspiration) are not influential (Kerr, 2001). We must also remember that we always analyse only a small proportion of mostly uniform (in ecological requirements) group of species which does not describe the overwhelming diversity (Ricketts et al., 2002).

Invertebrates, the most diverse group of organisms play critical role in many ecosystem processes (Stork, Eggleton, 1992). As a good representatives of whole group two families (*Carabidae* and *Curculionidae*) of the order Coleoptera have been chosen. Carabid beetles are often used as a good indicators of environmental changes because they show different degrees of habitat selectivity (habitat specialists and generalists) (Niemela, 1990) and food requirements (Hengewelt, 1980). Weevils beetles, however are indicative of botanical composition (Witkowski, 1978) and management practices (Morris, 1967).

The objective of the current study was to identify which (if any) factor of mesoclimate is responsible for changes in community structure components of two beetles assemblages – *Carabidae* and *Curculionidae*. We suspect that if climatic theory is a paradigm these two groups independently should respond in the same way on climatic disproportion.

Material and methods

The study area consists of a small fragment of Cracow-Częstochowa upland's southern part, 10–15 km north-west of Cracow. It stretches 9 km from north to south and 5 km from east to west, and covers the area of 45 square km. In the physical-geographical division by Kondracki (2000), particular parts of the study area belong to three mesoregions going along the parallel of latitude:

- Olkusz upland in the north – an undulated surface of planation (400–420 m a.s.l.), with mogots reaching up to 468 m a.s.l., strongly dismembered by karst canyons 80–120 m deep
- Krzeszowice Through in the centre – a flat tectonic depression, filled with fluvio-glacial sediments forming a high plain. Its borders are marked with steep slopes reaching 60–100 m
- Tenczyn Ridge in the south – a horst with surface of planation on its top (350–360 m a.s.l.).

In the climatic division, the whole area is included in the region of upland climates, in the Silesia-Cracow subregion (Romer, 1949). The climate of the studied area is controlled mainly by the air masses advection. The polar maritime air masses dominate (60.2%). In summer, they bring cool and cloudy weather with showers, while in winter – warming and thawing. Polar continental air masses are less frequent (24.9%), but dominate in winter (Hess, 1969). They bring cold air from the Asiatic High in winter, while in summer they cause significant warming. Moreover, warm tropical air masses (7.9%) and cold arctic air masses (7%) reach the study area. The atmospheric fronts are observed during 42% days per year (Niedźwiedź, 1969). Dismemberment of the area and large differences in relative height influence to a large extent climatic conditions, mean annual air temperature varies from 7.2–7.6°C at the tops of flattened ridges to 7.8–8.2°C in the valleys (Nowak, 1968; Tlałka, 1970). Mean annual temperature in January is equal to –4.5°C, while in July it is about 17°C, therefore mean annual temperature range exceeds 21°C (Klein, 1974). The increase of continentality in the valleys' floors is worth noting (Nowak, 1966). It is documented by higher values of temperature range in the valleys than at the flattened ridge tops. Concave landforms warm and cool much faster, which results in higher maximum and lower minimum temperatures (Hess, 1966). Annual sums of precipitation vary from 600–650 mm in Krzeszowice

Table 1. Selective climatic factors in regions of southern part of Cracow–Częstochowa Upland

Region types	Air temperature [°C]		Annual sums of precipitation [mm]	Frequency of days with temperature			Number of days with fog	Relative insolation [%]
	mean maximum	mean minimum		max < 0°C	min < 0°C	max > 25°C		
The lowest part of Krzeszowice Trough to altitude 280 m a.s.l.	> 12.7	< 3.4	< 700	< 35	> 80	> 40	> 70	100
Higher part of Krzeszowice Trough at altitude 280 m a.s.l.	12.4–12.7	3.4–3.6	700–750	35–37	75–80	36–40	62–70	100–105
Depressions and slopes of karst canyons (altitude: 300–380 m a.s.l.)	10.9–12.7	3.6–4.4	750	37–47	52–75	22–36	40–62	105–110
Slopes of Krzeszowice Trough with southern exposure (altitude: 300–380 m a.s.l.)	10.9–12.7	3.6–4.4	700–800	37–47	52–75	22–36	40–62	> 120
Slopes of Krzeszowice Trough with northern exposure (altitude: 300–380 m a.s.l.)	11.3–12.4	3.4–3.7	700–800	35–44	60–80	23–40	46–70	< 95
Surface of planation of Tenczyn Ridge (above 360 m a.s.l.)	< 11.3	> 4.2	> 800	> 44	< 60	< 23	< 46	105–110
Surface of planation of Olkusz upland (above 360 m a.s.l.)	< 10.9	> 4.4	> 800	> 46	< 52	< 22	< 40	105–110

Source: Nowak (1966), modified

Through to 800–850 mm at Olkusz upland. However, the karst canyons located in the "precipitation shadow" receive less precipitation. Temperature inversions are a characteristic feature in the study area. They occur in the valleys of the Olkusz upland and in Krzeszowice Through (Nowak, 1968). The frequency of days with temperature inversions reaches 256 days per year, and the highest noted values were equal to 9–10°C (Nowak, 1966; Partyka, 1990). Temperature inversions are closely related to the fog formation. The fog occurs in Krzeszowice Through and little valleys up to 280–300 m a.s.l. The number of days with fog is the smallest at the top of the flattened ridge (< 40 per year) and the highest at the bottom of Krzeszowice Through and in the valleys of Olkusz upland (> 80 per year). Sometimes the karst canyons are filled with fog while the tops of the flattened ridges are exposed to sunshine. The variety of landforms influences to a large extent the snow cover duration. It lasts the longest in shaded valleys (over 100 days), while on the flattened ridges and isolated rocks it is present during only 55 days. The difference in snow cover duration between southern and northern slopes can reach 20 days. The main climatic features of the study area are presented in Table 1.

The material was collected during consecutive years 2001–2003 at 30 sites. Samples from the ground floor were collected using pitfall traps consisting of plastic cups (diameter 90 mm, 500 ml) containing glycerol (Thiele, 1977). On each locality row of five cups in regular line 7 m apart was placed. To estimate diversity in herb layer standard sizes (38 cm diameter) sweepnet was applied. Six sampling units (sweeps ca 30 minutes) on each locality were taken (Siemann et al., 1999; Duelli et al., 1999). The material was sorted in a laboratory and identified using identification keys (Smreczyński, 1965–1976; Hurka, 1996).

We analysed characteristic parameters of assemblage structure on each locality: cumulative total abundance (A), total species richness (S) and five nonparametric indexes of diversity- Shannon-Wiener (H') and its eveness (e), Simpson (D), Berger-Parker (B) and McIntosh (Q) (Magurran, 1988).

The following climatic parameters were taken under consideration: annual sums of precipitation, minimum and maximum insolation in the vegetation period, relative sunshine duration, mean annual maximum and minimum air temperatures, frequency of days with maximum temperature below 0°C and above 25°C, and minimum temperature below 0°C, frequency of temperature inversions, frequency of days with fog, and duration of the snow-cover. Table 2 shows the correlation matrix of the mentioned climatic parameters, in order to find out their inter-correlation. In the correlation coefficient was higher than 0.9, only one chosen parameter was used for further analysis.

The relationship between community structure measures (dependent variables) and climatic factors (independent variables) were analysed using stepwise backward multiple regression analysis. In multiple regression method, the sum of squared residuals between the regression plane and the observed values of dependent variables are minimized. Backward elimination removes the least significant variables in the model until all remaining variables have individual p values smaller than 0.05 (Jongman et al., 1995).

Principal Component Analysis (PCA) was used to explain variation in composition and relative abundance of species between particular assemblages. In this data reduction technique allowing multivariate data sets to be represented to lower dimensional space. The method derives new axes of variation in data-sets which summarise as much variation as possible. The distance between assemblages is a measure of differences in species composition. Species abundances in analysed matrix were log (n+1) transformed to improve normality. All statistical computations were made using Statistica (2003).

Results and discussion

We found no correlation between ground beetles and weevils across 30 sites, using any of seven indices of assemblage structure (Fig. 1, Table 3). Them we may expect that also different abiotic factors, if any will be responsible for diversity pattern in local scale.

Results of stepwise backward multiple regression confirm these hypotheses. The minimal adequate models of climatic factors describing assemblage indices are shown in Table 4. Weevils diversity indices variability are explained by climatic factors in 30%. It is sig-

T a b l e 2. Correlation matrix of main climatic factors

Climatic factors	1	2	3	4	5	6	7	8	9	10	11	12	13
1		**0.97** **p = .000**	–0.46 p = .011	–0.04 p = .844	–0.16 p = .409	–0.10 p = .600	0.02 p = .900	0.18 p = .337	–0.04 p = .850	0.18 p = .351	0.07 p = .711	0.01 p = .951	0.38 p = .040
2	**0.97** **p = .000**		–0.52 p = .003	–0.15 p = .423	–0.25 p = .182	–0.03 p = .879	–0.11 p = .551	0.30 p = .104	–0.16 p = .408	0.29 p = .116	0.18 p = .333	0.10 p = .617	0.31 p = .091
3	–0.46 p = .011	–0.52 p = .003		0.58 p = .001	0.49 p = .006	–0.28 p =.135	0.56 p = .001	–0.63 p = .000	0.50 p = .005	–0.58 p = .001	–0.51 p = .004	–0.36 p = .054	–0.18 p = .341
4	–0.04 p=.844	–0.15 p=.423	0.58 p=.001		0.86 p=.000	–0.78 p=.000	0.84 p=.000	–0.84 p=.000	**0.91** **p=.000**	–0.48 p=.008	–0.91 p=.000	–0.86 p=.000	0.50 p=.005
5	–0.16 p=.409	–0.25 p=.182	0.49 p=.006	0.86 p=.000		–0.76 p=.000	0.77 p=.000	–0.93 p=.000	**0.92** **p=.000**	–0.62 p=.000	–0.92 p=.000	–0.87 p=.000	0.44 p=.016
6	–0.10 p=.600	–0.03 p=.879	–0.28 p=.135	–0.78 p=.000	–0.76 p=.000		–0.69 p=.000	0.62 p=.000	–0.78 p=.000	0.19 p=.321	0.80 p=.000	0.86 p=.000	–0.63 p=.000
7	0.02 p=.900	–0.11 p=.551	0.56 p=.001	0.84 p=.000	0.77 p=.000	–0.69 p=.000		–0.82 p=.000	0.84 p=.000	–0.56 p=.001	–0.83 p=.000	–0.72 p=.000	0.41 p=.023
8	0.18 p=.337	0.30 p=.104	–0.63 p=.000	–0.84 p=.000	–0.93 p=.000	0.62 p=.000	–0.82 p=.000		–0.92 p=.000	0.80 p=.000	**0.90** **p=.000**	0.74 p=.000	–0.28 p=.129
9	–0.04 p=.850	–0.16 p=.408	0.50 p=.005	**0.91** **p=.000**	**0.92** **p=.000**	–0.78 p=.000	0.84 p=.000	–0.92 p=.000		–0.53 p=.003	–0.99 p=.000	–0.92 p=.000	0.61 p=.000
10	0.18 p=.351	0.29 p=.116	–0.58 p=.001	–0.48 p=.008	–0.62 p=.000	0.19 p=.321	–0.56 p=.001	0.80 p=.000	–0.53 p=.003		0.49 p=.006	0.24 p=.207	0.19 p=.319
11	0.07 p=.711	0.18 p=.333	–0.51 p=.004	–0.91 p=.000	–0.92 p=.000	0.80 p=.000	–0.83 p=.000	**0.90** **p=.000**	–0.99 p=.000	0.49 p=.006		**0.93** **p=.000**	–0.59 p=.001
12	0.01 p=.951	0.10 p=.617	–0.36 p=.054	–0.86 p=.000	–0.87 p=.000	0.86 p=.000	–0.72 p=.000	0.74 p=.000	–0.92 p=.000	0.24 p=.207	**0.93** **p=.000**		–0.74 p=.000
13	0.38 p=.040	0.31 p=.091	–0.18 p=.341	0.50 p=.005	0.44 p=.016	–0.63 p=.000	0.41 p=.023	–0.28 p=.129	0.61 p=.000	0.19 p=.319	–0.59 p=.001	–0.74 p=.000	

1 – minimum insolation in the vegetation period, 2 – maximum insolation in the vegetation period, 3 – duration of the snowcover, 4 – annual sums of precipitation, 5 – region types of mesoclimate, 6 – frequency of temperature inversions, 7 – moisture regions, 8 – mean annual maximum air temperatures, 9 – mean annual minimum air temperatures, 10 – frequency of days with maximum temperature below 0°C, 11 – frequency of days with maximum temperature above 25°C, 12 – frequency of days with minimum temperature below 0°C, 13 – relative sunshine duration

nificant that total abundance and species richness is not significantly related to climatic factors. It means that species saturation in phytophagous insect communities as well as their reproductive success is not related to energy intake. Climatic variability changes only dominance structure among assemblages. Increase of Shannon-Wiener index of diversity (Fig. 2A) is significant when values of minimum insolation in the vegetation period, and frequency of temperature inversions grow up together. Shannon-Wiener index is especially sensitive to fraction of rare species in the community (Magurran, 1988). Such situation is characteristic for more disturbed communities. It is suspected that this disturbing factor may be of frequency of temperature inversions. What is more, this factor increase influence negatively a Simpson and McIntosh indices of diversity (Fig. 2B, C) which values are higher when fraction of dominant species is more abundant.

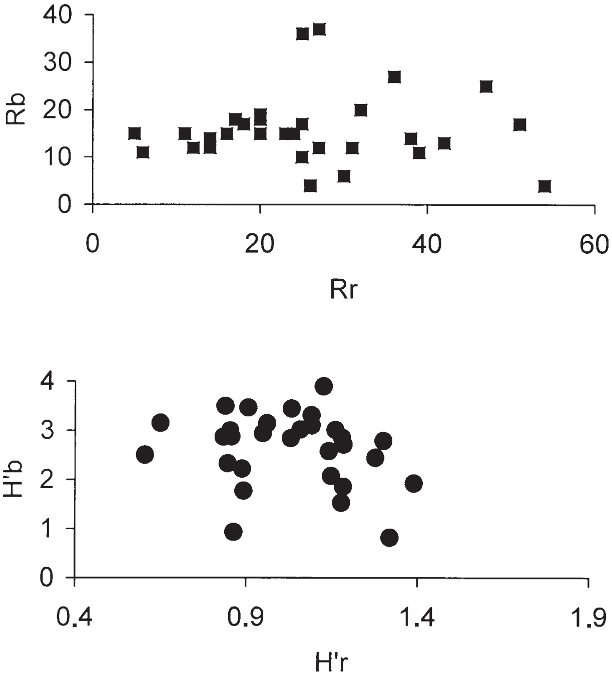

Fig. 1. Relationships between species richness of weevils (Rr) and ground beetles (Rb) and Shannon-Wiener index of diversity of weevils (H'r) and ground beetles (H'b).

Table 3. Spearman rank-correlation coefficients between weevil and ground beetle assemblage indices

Assemblage structure parameters	R	t(N-2)	p level
Total abundance (A)	–0.155	–0.828	0.415
Species richness (R)	–0.002	–0.009	0.993
Shannon-Wiener index (H')	–0.304	–1.689	0.102
equitqbility (e)	0.131	0.699	0.490
Simpson index (D)	–0.232	–1.260	0.218
Berger-Parker index (B)	–0.108	–0.574	0.570
McIntosh index (Q)	–0.232	–1.260	0.218

Ground beetle indices of diversity are not described significantly by climatic variation (Table 4). Minimum insolation in the vegetation period described 35% of total abundance variance among localities, meanwhile mean annual temperature don't change values of the parameter (Fig. 2D). Species richness of ground beetles relay on two parameters: mean annual minimum temperature and frequency of days with minimum temperature

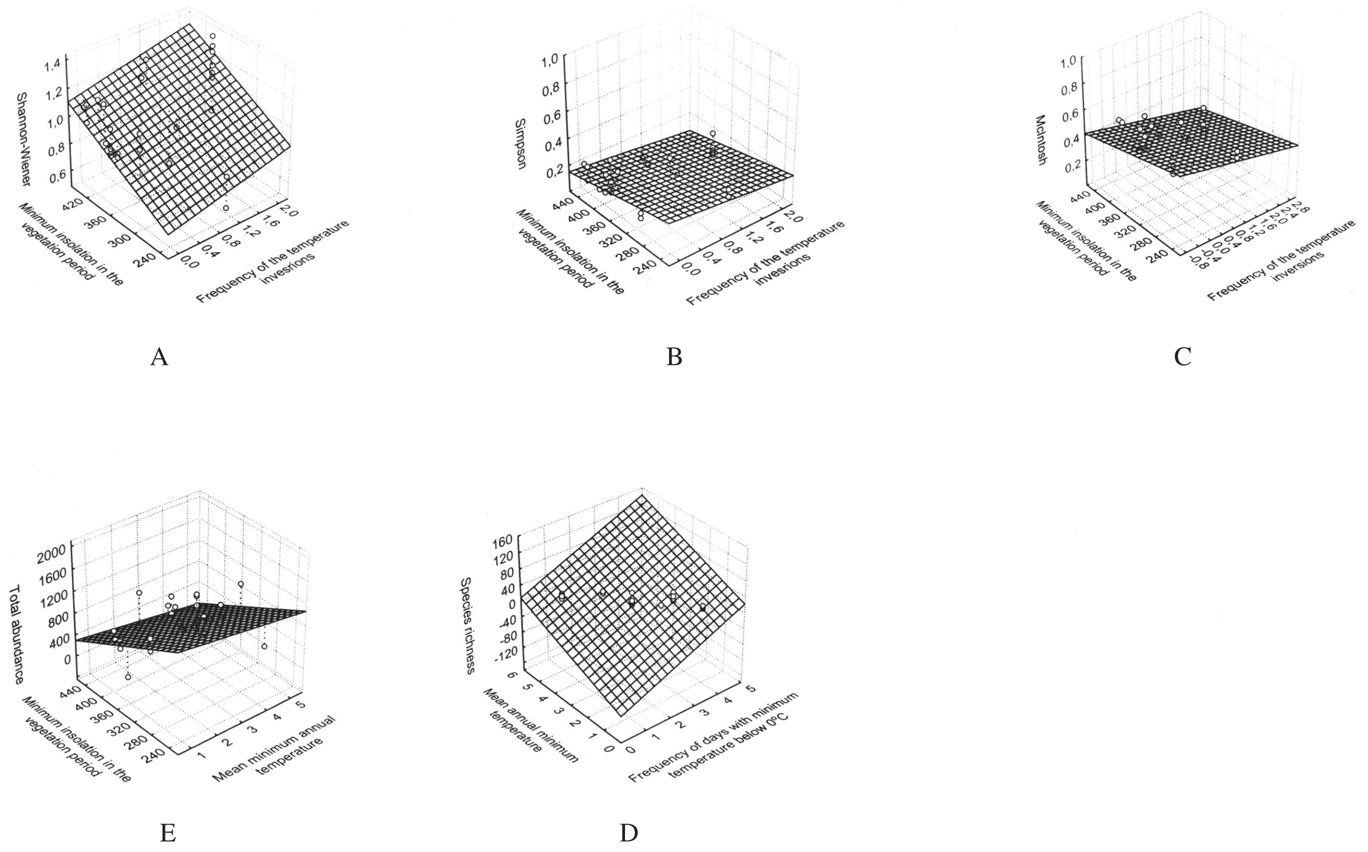

Fig. 2. Influence of climatic factors on assemblage structure indices of weevils (A–C) and ground beetles (D, E) derived from stepwise backward multiple regressions.

Table 4. Summary of the stepwise backward multiple regression for climatic factors to build the models for assemblage indices of weevils and ground beetles

Assemblage structure parameters		Confidence of regression		Explained variation	Climatic factors	BETA	SE BETA	B	SE B	t(27)	p
Weevils assemblages	Shannon-Wiener index	F(2.27) = 7.33	p < .002	$R^2 = 0.35$	Intercept			0.265	0.31	1.148	0.261
					Minimum insolation in the vegetation period	0.483	0.156	0.002	0.001	3.100	0.004
					Frequency of temperature inversions	0.396	0.156	0.088	0.035	2.544	0.017
	Simpson index	F(2.27) = 5.08	p < .013	$R^2 = 0.27$	Intercept			0.450	0.110	4.108	0.000
					Minimum insolation in the vegetation period	–0.388	0.165	–0.001	0.000	–2.351	0.026
					Frequency of temperature inversions	–0.392	0.165	–0.039	0.017	–2.378	0.025
	McIntosh index	F(2.27) = 5.35	p < .011	$R^2 = 0.28$	Intercept			0.730	0.128	5.703	0.000
					Minimum insolation in the vegetation period	–0.387	0.164	–0.001	0.000	–2.362	0.026
					Frequency of temperature inversions	–0.407	0.164	–0.048	0.019	–2.486	0.019
Ground beele assemblages	Total abundance	F(1.28) = 15.28	p < .0005	$R^2 = 0.35$	Intercept			2334.014	471.779	4.947	0.000
					Minimum insolation in the vegetation period	–0.594	0.152	–4.879	1.248	–3.908	0.001
	Species richness	F(2.27) = 2.80	p < .07	$R^2 = 0.17$	Intercept			–12.482	55.522	–2.026	0.053
					Mean annual minimum temperature	3.360	1.475	20.024	8.792	2.277	0.031
					Frequency of days with minimum temperature below 0°C	3.451	1.475	26.872	11.488	2.339	0.027

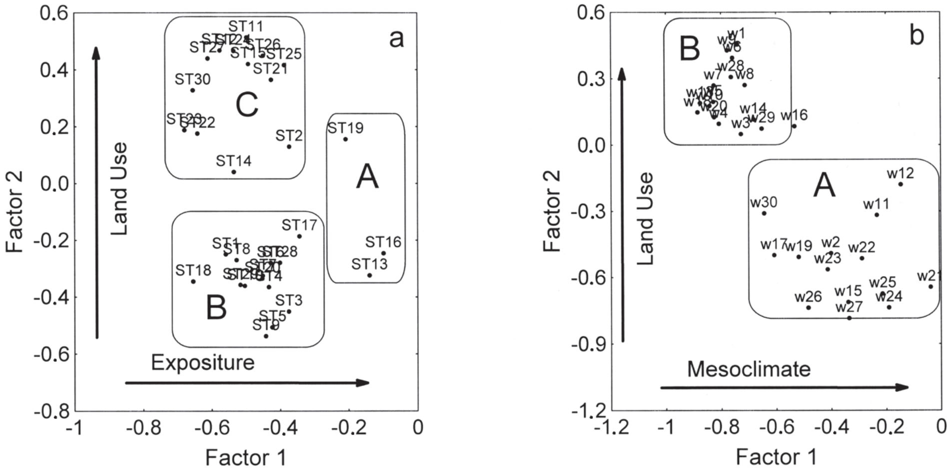

Fig. 3. Principal Component Analysis (PCA) for (A) - weevils assemblages (ST1-ST30) and (B) ground beetle assemblages (W1-W30) for the first two axes.

below 0°C. Increase of these two factors, which extend vegetation season, significantly enriches assemblages.

Principal component analysis for abundance matrix transformed as log (n+1), describing variability of species composition and its relative abundances between assemblages, describes 35.5% and 57.2% of total variance for the first two axes of weevil and ground beetle assemblages respectively. Results are shown on Fig. 3. Among weevil assemblages three groups can be derived. Group A consist of assemblages of natural meadows occurring on strongly insolated slopes on southern exposure. In group B concentrate assemblages of forests in different degree of management, whereas in group C are located assemblages of anthropogenic meadows and fields. Analysing distribution of assemblages along first axis, exposure describes 23% of species variation. Second axis (12% of variance) is strongly related to land use changes. No relationships with climatic factors is characteristic.

Ground beetles assemblages creates two, not clear groups (Fig. 3b): A - consist of assemblages from cold territories, mainly forests and B - assemblages of dry, anthropogenic ecosystems. Axis 1, describing 38.5% of variation ordinate assemblages along mesoclimatic gradient, whereas axis 2 (18.7% of variance) along gradient of land use intensity.

Our results show that climatic factors don't describe biological diversity in local and regional scale as it was suggested by many authors (Richerson, Lum, 1980; Currie, 1991; O'Brien et al., 1998). In both analysed groups species richness variability wasn't explained by energy intake. Such results were confirmed by Lobo et al. (2001). Climate related variables appear significant when we consider small, mostly homogeneous group of species.

Conclusions

- Mostly predaceous ground beetles are unlikely to be useful indicators of phytophagous weevils.
- Only diversity indices of weevil assemblages were significantly explained by minimum insolation in the vegetation period, however in different way.
- Increase in species richness depends on length of vegetation period. Land use and exposure were main factors describing in greatest degree of species composition in beetle assemblages. Climatic factors had only marginal significance.

Translated by the authors

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References

Birks, H.J.B., 1996: Statistical approaches to interpreting diversity patterns in the Norwegian mountain flora. Ecography, *19*, p. 332–340.

Currie, D.J., 1991: Energy and large-scale patterns of animal and plant species richness. Am. Nat., *137*, p. 27–49.

Duelli, P., Martin, K., Obrist, D., Schmatz, R., 1999: Biodiversity evaluation in agricultural landscapes: aboveground insects. Agric. Ecosyst. Environ. *74*, p. 33–64.

Gaston, K.J., 2000: Global patterns in biodiversity. Nature, *405*, p. 220–227.

Hengeveld, R., 1980: Polyphagy, oligophagy and food specialisation in ground beetles (Coleoptera, *Carabidae*). Netherlands Journal of Zoology, *30*, p. 564–584.

Hess, M., 1966: On mesoclimate on convex and concave landforms in south Poland (in Polish). Przegląd Geofizyczny, *11*, 1, p. 23–35.

Hess, M., 1969: The climate of the city of Cracow subregion (in Polish). Folia Geographica, ser. Geogr. Phys., *3*, p. 5–66.

Hurka, K., 1996: Carabidae of Czech and Slovak Republics. Kabourek, Zlin, 565 pp.

Huston, M.A., 1994: Biological Diversity: the Coexistence of Species on Changing Landscapes, Cambridge University Press.

Jongman, R.H.G., ter Braak, C.J.F., Van Tongeren, O.F.R. (eds), 1995: Data Analysis in Community and Landscape Ecology. Cambridge University Press, 298 pp.

Kerr, J., 2001: Global biodiversity patterns: from description to understanding. TREE, *16*, p. 424–425.

Klein, J., 1974: Meso- and microclimate of the Ojcow National Park. Studia Naturae A, 8, 105 pp.

Knoch, K., 1963: Die Landesklimaaufnahme, Wessen und Methodik. Berichte des DWD. Offenbach am Main.

Kondracki, J., 2000: Regional Geography of Poland (in Polish). PWN, Warszawa, 441 pp.

Linder, H.P., 1991: Environmental correlates of patterns of species richness in the south-western Cape Province of South Africa. Journal of Biogeography, *18*, p. 509–518.

Lobo, J.M., Castro, I., Moreno, J.C., 2001: Spatial and environmental determinants of vascular plant species richness distribution in the Iberian Peninsula and Balearic Islands. Biological Journal of the Linnean Society, *73*, p. 233–253.

Magurran, A.E., 1988: Ecological Diversity and its Measurements. Croom Helm Ltd., London-Sydney, 179 pp.

Morris, M.G., 1967: Differences between the invertebrate fauna of grazed and ungrazed chalk grasslands. I Responses of some phytophagous insects to cessation of grazing. Journal of Applied Ecology, *4*, p. 459–474.

Niedźwiedź, T., 1969: Synoptic Weather Situations in Southern Poland and Their Effects on some Elements of the Climate (in Polish). Zesz. Nauk. UJ, Prace Geogr., *23*, p. 63–98.

Niemela, J., 1990: Effect of changes in the habitat on Carabid assemblages in a wooded meadow on the Aland Islands. Notule Entomologica, *69*, p. 169–174.

Nowak, A., 1966: The Mesoclimate of Krzeszowice Graben (in Polish). Praca magisterska w Arch. Zakł. Klim. IGiGP UJ, Kraków, 81 pp.

Nowak, A., 1968: The Mesoclimate of Krzeszowice Graben (in Polish). Zesz. Nauk. UJ, Prace Geogr., *18*, p. 87–103.

O'Brien, E.M., Whittaker, R.J., Field, R., 1998: Climate and woody plant diversity in southern Africa: relationships at species, genus and family levels. Ecography, *21*, p. 495–509.

Partyka, J., 1990: The Climate. In Jurassic Landscape Parks (in Polish). Partyka, J. (ed.), Karpaty, Kraków, p. 10–11.

Petryszak, B., 1987: Qualitative and quantitative investigations of weevils (Coleoptera, Curculionidae) in chosen communities of Pieniny National Park (in Polish). Ochrona Przyrody, *45*, p. 157–178.

Qian, H., 1998: Large-scale biogeographic patterns of vascular plant richness in North America: an analysis at the generic level. Journal of Biogeography, *25*, p. 829–836.

Richerson, P.J., Lum, K.-L., 1980: Patterns of plant species diversity in California: relation to weather and topography. American Naturalist, *116*, p. 504–536.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R., 2002: Does butter?y diversity predict moth diversity? Biological Conservation, *103*, p. 361–370.

Romer, E., 1949: The Climatic Regions of Poland (in Polish). Prace Wrocławskiego Tow. Nauk, B, 16, Wrocław, p. 1–26.

Rosenzweig, M.L., 1995: Species Diversity in Space and Time, Cambridge University Press.

Rhode, K., 1992: Latitudinal gradient in species diversity the search for the primary cause. Oikos, *65*, p. 314–327.

Siemann, E., Tilman, D., Haarstad, J., 1999: Abundance, diversity and body size: patterns from a grassland arthropod community. Journal of Animal Ecology, *68,* p. 824–835.

Smreczyński, S., 1965-1976: Weevils-Curculionidae, Keys for identification of Polish insects (in Polish). XIX, 98a-f, PWN, Warszawa.

Statistica, 2003: Data analysis software system. Version 6.0. statsoft, Inc., www.statsoft.com

Stork, N., Eggleton, P., 1992: Invertebrates as determinants and indicators of soil quality. American J. Alternative Agric, *7*, p. 38–47.

Thiele, H.U., 1977: Carabid Beetles in Their Environments. Springer Verlag, Berlin, 369 pp.

Tlałka, A., 1970: The Circulation of Water in an Upland Fault Region Illustrated by the Example of the Rudawa Basin (in Polish). Zesz. Nauk. UJ Prace Geogr., *24*, Kraków, p. 1–148.

Whittaker, R.H., 1975: Communities and Ecosystems. Macmillan Publishing, New York, 378 pp.

Witkowski, Z., 1978: Correlates of stability and diversity in weevil communities. Oecologia (Berl.), *37*, p. 85–92.

Wohlgemuth, T., 1998: Modelling floristic species richness on a regional scale: a case of study in Switzerland. Biodiversity and Conservation, 7, p. 159–177.

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