Stanisław HURUK[1, 2*], Alicja HURUK[1],
Arvīds BARŠEVSKIS[3], Grzegorz WRÓBEL[1]
and Anna DEGÓRSKA[4]

CARABIDAE (COLEOPTERA) SELECTED NATURAL ENVIRONMENTS IN PUSZCZA BORECKA

CARABIDAE (COLEOPTERA) WYBRANYCH ŚRODOWISK PRZYRODNICZYCH W PUSZCZY BORECKIEJ

Abstract: The paper presents the results of research on Carabidae of a mixed forest site and an oak-hornbeam forest site carried out between 2004 and 2011 within the Integrated Natural Environment Monitoring Base Station in Puszcza Borecka. Carabidae were captured into glycol-filled Barber pitfall traps between May and September every year in five one-month catch cycles. The aim of the study was to characterise assemblage structures of Carabidae in these two habitats with regard to selected abiotic environmental factors. A total of 13,227 individuals of Carabidae representing 31 species were captured. The total yield in the mixed forest was 8,023 individuals of 25 species, compared to 5,204 individuals of 26 species in the oak-hornbeam forest. Both habitats supported species associated with forest, open and forested areas, and open areas. The species represented all zoogeographical elements found in Poland. However, their proportions differed between the two habitats. There was also a difference in the pattern of activity, with peak activity of the mixed forest assemblage seen in August and in the oak-hornbeam forest, in July. Species diversity, measured with the Shannon-Wiener index (H'), and evenness, measured with the Pielou index (J'), were H' = 1.8981, J' = 0.5897 for the mixed mesic forest assemblage and H' = 2.1328, J' = 0.6546 for the oak-hornbeam forest site. Catch results were analysed with regard to such factors as air temperature, ground temperature, precipitation, relative air humidity, and air levels of SO_2 and NO_2. There was a statistically significant positive correlation between the Carabidae catch yield and air temperature at 2 metres in both habitats: for the mixed forest, r = 0.4, df = 38, p = 0.01; for the oak-hornbeam forest, r = 0.35, df = 38, p = 0.02; and between catch yield and ground temperature at a depth of 0.05 m: for the mixed forest, r = 0.49, df = 38, p = 0.001; for the

[1] Department of Zoology and Biological Didactics, Institute of Biology, The Jan Kochanowski University, ul. Świętokrzyska 15A, 25–406 Kielce, Poland, phone: +48 41 349 63 57.

[2] The Świętokrzyski National Park, ul. Suchedniowska 4, 26–010 Bodzentyn, Poland.

[3] Systematic Biology Institute, Daugavpils University, Vienibas Str. 13, Daugavpils, Latvia.

[4] Institute of Environmental Protection, ul. Krucza 5/11d, 00–584 Warszawa, Poland.

* Corresponding author: stanislawhuruk@ujk.edu.pl

oak-hornbeam forest, r = 0.42, df = 38, p = 0.007. Correlations between catch yield and the remaining factors were less marked and reached statistical significance only in three cases.

Keywords: Carabidae, nature monitoring, atmospheric factors, environmental pollution

Introduction

For several dozen years, base stations of the Integrated Natural Environment Monitoring System have been responsible for the measurement of environmental indices in the area where they are situated. The underlying methodological assumption behind Integrated Natural Environment Monitoring is that the field stations carry out focused stationary research on selected elements of the natural environment [1], including physical, chemical and biological factors. The monitoring of physical and chemical factors in conjunction with biological monitoring may be an important tool for analysing changes in the environment provided it is carried out over the long term and follows a unified methodology to allow for comparison of results obtained within one object as well as between objects [2]. The biological monitoring includes observations of epigeic fauna, including ground beetles (Carabidae, Coleoptera), as this taxon is eligible for monitoring [3–8].

In view of the above, the aim of the present study was to analyse Carabidae assemblage structures and correlations between structural indices (*ie* the number of species and individuals captured) and the following selected abiotic factors: air temperature at 0.05 m and 2 m above ground, ground temperature at a depth of 0.05 m; 0.1 m; 0.2 m; 0.5 m; and 1 m, mean monthly precipitation, mean monthly relative air humidity, and mean monthly air pollutant (SO_2, NO_2) levels. Correlations were verified with the t test and significance was assessed with Pearson's linear correlation coefficient. Assemblage diversity was also assessed with Shannon-Wiener's index of species diversity (H') [9], and assemblage evenness was measured with Pielou's index of evenness (J') [10].

Material and methods

The research was carried out between 2004 and 2011 within the Integrated Natural Environment Monitoring Base Station in Puszcza Borecka (catchment area of Lake Lekuk, located in the mesoregion of Pojezierze Elckie, macroregion of Pojezierze Mazurskie, subprovince of Pojezierze Wschodniobaltyckie – Fig. 1), in Borki Forest Inspectorate, Diabla Gora forest district, Przerwanki surveying section. Samples were collected in two habitat variants: a mixed forest site (variant I) and an oak-hornbeam forest site (variant II). (Fig. 1). The mixed forest grew on rusty pseudogley and rusty brown pseudogley soils. It was composed of hornbeam (30 %), spruce (20 %) and oak (20 %) trees, all aged 117 years, with admixtures of linden (10 %) and birch (10 %) aged 117 years and 24-year-old hornbeam (10 %). The oak-hornbeam forest was composed of spruce (30 %), oak (30 %) and hornbeam (30 %) aged 119 years growing on pseudogley soils, with admixtures of 39-year-old hornbeam trees (10 %). Three permanent study sites were established in both types of forest. Five Barber pitfall traps

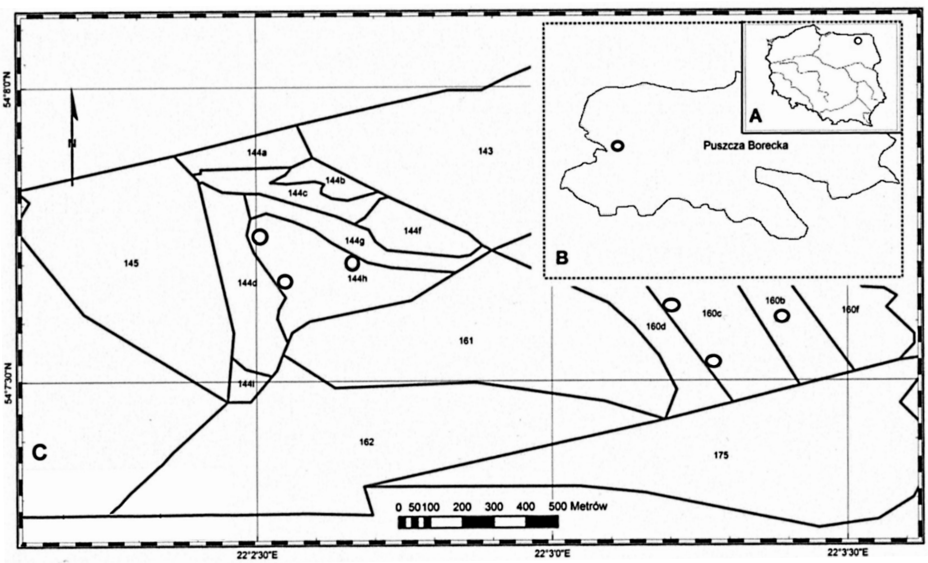

Fig. 1. Location of the study area (A, B) and permanent study sites (C) [□ – divisions, ○ – study sites]

were buried in the ground at 3-metre intervals at each site and filled with ethylene glycol to a third of their height. Carabidae were collected in five monthly catch cycles from May to October.

Abundance was determined on the basis of the catch yield of species and individuals, dominance patterns were represented by a dominance index [11], dominance distribution by Simpson's dominance index [12], constancy was characterised with a constancy index [13], and a fidelity index was used to study fidelity [13]. Carabidae were classified into particular ecological categories on the basis of papers by such authors as Koch [14], Larsson [15], Lindroth [16], Sarova [17, 18], Szyszko [19], and Aleksandrowicz [20].

Correlations were investigated between the following combinations of catch yield (abundance) data and selected abiotic factors: a) catch yield (abundance) of Carabidae individuals in particular months of the growing season in a given year vs. mean monthly values of a given factor (separately for each year in the period 2004–2011); b) overall catch yield in particular months of the growing season in consecutive years of study vs. the value of a given factor in a given month (Table 1); c) catch yield in a given year vs. mean value of a given factor in the growing season; d) catch yield in a given year vs. mean value of a given factor in that year. The analyses were then replicated with regard to species classified as dominants (eudominants, dominants, subdominants) collectively and separately for each species of that group. The t test was used to determine the significance of Pearson's linear correlation coefficient. Correlations were also assessed with canonical correspondence analysis (CCA) [21]. Assemblage diversity was also investigated, using Shannon-Wiener's index of species diversity (H') [9], while assemblage evenness was evaluated with Pielou's index of evenness (J') [10].

Table 1

Correlation between Carabidae abundance and selected abiotic environmental factors in the years 2004–2011

Factor		TP [°C]		TG [°C]					RH	PR	S-SO_2	N-NO_2
		2 m	0.05 m	0.05 m	0.1 m	0.2 m	0.5 m	1 m	[%]	[mm]	[μg/m^3]	[μg/m^3]
Mixed forest	r	0.403	0.494	0.486	0.486	0.468	0.400	0.265	0.112	0.279	0.004	0.061
	p	0.0099	0.0012	0.0015	0.0015	0.0023	0.0105	0.0980	0.5082	0.0817	0.9783	0.7099
Oak-hornbeam forest	r	0.355	0.356	0.417	0.417	0.391	0.294	0.126	0.018	0.187	–0.012	0.010
	p	0.0247	0.0240	0.0074	0.0074	0.0125	0.0651	0.4403	0.9164	0.2489	0.9395	0.9518

Key to symbols: r – Pearson's linear correlation coefficient, p – level of significance, RH – air humidity, TG – ground temperature, TP – air temperature, PR – precipitation.

Results

The total catch yield during the study was 13.227 individuals of Carabidae representing 31 species (Table 2). In the mixed forest the total abundance was 8.023 individuals representing 25 species (Table 3). The figures varied over time, but displayed a general growing trend (Fig. 2). As regards dominance patterns, *P. niger* accounted for a constantly high proportion of the assemblage.

It was clearly the dominant species and maintained a eudominant rank throughout the study period (Table 7), with annual contributions from 18.01 % in 2004 to 59.51 % in 2009. Another species that was also a eudominant in individual years of the study period was *P. melanarius*, whose contribution to the assemblage ranged from 11.90 % in 2007 to 39.88 % in 2004, falling into the dominant range only once (5.37 % in 2006). The abundance of the remaining 22 species varied considerably, placing them into the recendent, subdominant, dominant or eudominant bracket depending on the particular species and year. The distribution of individuals between species was assessed with Simpson's index. These figures are presented in Table 7 and reveal the greatest evenness for the assemblage of the year 2005. The only species in the highest constancy class of euconstant species was *P. niger* (92.5 %) (Table 9), while three species: *P. melanarius* (72.5 %), *C. hortensis* (61 %) and *P. oblongopunctatus* (53 %), were classified as constant species. The accessory species group comprised *C. granulatus* (48 %), *N. brevicolis* (44.2 %), *A. assimile* (40.8 %), *C. caraboides* (37.5 %), *C. violaceus* (36 %), *C. coriaceus* (32 %) and *C. cancellatus* (25 %). The remaining 14 species (56 % of all species recorded in the mixed forest) were classified as accidental. An analysis of fidelity revealed 16 characteristic species, of which 6 were selective and 10 were preferential. Unique exclusive species (100 %) comprised *Carabus convexus, C. glabratus, A. plebeja, A. ater,* and *A. viduum*, with exclusive species including also *P. nigrita* (80.28 %). Selective characteristic species comprised *C. caraboides* (74.01 %), *P. aethiops* (70 %), *P. melanarius* (69.45 %), *N. brevicolis* (65.41 %), *C. violaceus* (64.11 %), *P. niger* (64.01 %), *C. granulatus* (63.61 %), *C. hortensis* (52.04 %), *C. coriaceus* (50.99 %), *H. latus* (50 %).

Overall peak activity of the carabid assemblage from the mixed forest site during the entire period of study was noted in August (Fig. 3). As regards ecological indices, the dominant habitat preference of the constituent species was for forest habitats (Table 5), while in terms of humidity preferences the dominant type was mesohygrophilous species, with large zoophages dominating with regard to feeding habits and spring breeders being the dominant breeding type.

A variety of zoogeographic elements were noted (Table 6), with the Palaearctic element dominant among the 8 types recorded. Species diversity, measured as Shannon-Wiener's index (H'), and evenness, measured as Pielou's index (J'), were H' = 1.8981 (H' max = 3.2189) and J' = 0.5897, respectively, in the mixed forest assemblage.

The total abundance of ground beetles in the oak-hornbeam site was 5,204 individuals representing 26 species (Table 4). Abundance varied between years of study, but as with the mixed forest habitat, a clear tendency towards increasing catch yield was noted (Fig. 2).

Table 2

Zoogeographic and ecological characteristics of Carabidae and overall species abundance in the entire study period in both habitat variants

No.	Species	Ecological category				Zoogeo-graphic element	Abundance
		Habitat	Feeding habits	Humidity preferences	Breeding type		
1	*Carabus coriaceus* L.	F	Lz	Mh	A	Efp	151
2	*C. violaceus* L.	F	Lz	Mh	S	Pal	170
3	*C. convexus* Fabr.	OFa	Lz	Mh	S	Esb	1
4	*C. granulatus*L.	OFa	Lz	Hg	S	Esb	742
5	*C. cancellatus* Ill.	OFa	Lz	Mh	S	Esb	210
6	*C. arcensis* Herbst	F	Lz	Mh	S	Pal	250
7	*C. nemoralis* O. F. Müller	F	Lz	Mh	S	Efp	155
8	*C. hortensis* L.	F	Lz	Mh	A	Efp	513
9	*C. glabratus* Payk.	F	Lz	Mh	S	Ear	2
10	*Cychrus caraboides* (L.)	F	Lz	Mh	S	Ear	153
11	*Leistus piceus* Frol.	F	Sz	Hg	S	Efpm	11
12	*Nebria brevicollis* (Fabr.)	OFa	Sz	Hg	A	Emd	1064
13	*Patrobus atrorufus* (Stroem)	F	Sz	Hg	S	Esb	58
14	*Amara plebeja* (Gyll.)	Oa	Hz	Hg	S	Pal	2
15	*Pterostichus oblongopunctatus* (Fabr.)	F	Sz	Mh	S	Pal	674
16	*P. niger* (Schall.)	F	Lz	Mh	S	Esb	5460
17	*P. melanarius* (L.)	OFa	Lz	Mh	A	Esb	2239
18	*P. nigrita* (Fabr.)	OFa	Sz	Hg	S	Pal	142
19	*P. strenuus* (Panz.)	F	Sz	Mh	S	Pal	4
20	*P. aethiops* (Panz.)	F	Sz	Mh	S	Eca	10
21	*Abax carinatus* (Duft.)	F	Sz	Mh	S	Efpm	8
22	*A. ater* (Pill. et Mitt.)	F	Sz	Mh	A	Efp	1
23	*Calathus micropterus* (Duft.)	F	Sz	Mh	A	Pal	3
24	*Agonum muelleri* (Herbst)	OFa	Sz	Mh	S	Hol	57
25	*A. viduum (*Panz.)	Oa	Sz	Hg	S	Esb	1
26	*A. assimile* (Payk.)	F	Sz	Hg	S	Pal	1084
27	*A. obscurum* (Herbst)	F	Sz	Hg	S	Hol	1
28	*A. gracile* Sturm	Oa	Sz	Hg	S	Pal	3
29	*Harpalus rufipes* (De Geer)	Oa	Hz	Mh	A	Pal	1
30	*H. latus* (L.)	F	Hz	Mh	S	Pal	56
31	*H. guadripunctatus* Dej.	F	Hz	Mh	S	Pal	1
	Total						13227

Key: F – Forest (species), Oa – open-area, OFa – open and forested area; Lz – Large zoophage, Sz – Small zoophage, Hz – Hemizoophage; Hg – Hygrophilous, Mh – Mesohygrophilous; S – Spring breeder, A – Autumn breeder; Hol – Holarctic; Pal – Palaearctic, Esb – Euro-Siberian, Eca – Euro-Central Asian, Ear – Euro-Arctic, Emd – Euro-Mediterranean, Efp – European Forest Province, Efpm – European Forest Province (montane).

Table 3

Abundance of Carabidae species collected in mixed forest by year of study

No.	Species	Number of individuals								
		Mixed forest (Variant I)								
		2004	2005	2006	2007	2008	2009	2010	2011	Total
1	*C. coriaceus* L.	3	5		24	15	11	7	12	77
2	*C. violaceus* L.		4	9	32	19	18	24	3	109
3	*C. convexus* Fabr.					1				1
4	*C. granulatus* L.	139	115	57	85	54	22			472
5	*C. cancellatus* Ill.	16	22	2	1		5	38	2	86
6	*C. arcensis* Herbst							25	87	112
7	*C. nemoralis* O. F. Müller	15	11	18	14	6	1	3	7	75
8	*C. hortensis* L.	14	25	66	54	30	30	29	19	267
9	*C. glabratus* Payk.								2	2
10	*Cychrus caraboides* (L.)	11	6	7	35	18	12	11	14	114
11	*Leistus piceus* Frol.					3		1		4
12	*Nebria brevicollis* (Fabr.)	20	55		68	238	101	90	124	696
13	*Patrobus atrorufus* (Stroem)				5	5	6	2	4	22
14	*Amara plebeja* (Gyll.)						2			2
15	*Pt. oblongopunctatus* (Fabr.)	96	67	68	31	14	18	22	20	336
16	*P. niger* (Schall.)	154	220	208	640	439	741	712	381	3495
17	*P. melanarius* (L.)	341	87	272	141	75	161	226	252	1555
18	*P. nigrita* (Fabr.)	3				9	102			114
19	*P. aethiops* (Panz.)	7								7
20	*A. ater* (Pill. et Mitt.)			1						1
21	*Calathus micropterus* (Duft.)	1								1
22	*Agonum muelleri* (Herbst)						2	1		3
23	*A. viduum* (Panz.)						1			1
24	*A. assimile* (Payk.)	35	49	41	54	4	11	167	82	443
25	*H. latus* (L.)		1	25		1	1			28
	Total	855	667	774	1184	931	1245	1358	1009	8023
	Number of species collected	14	13	12	13	16	18	15	14	25

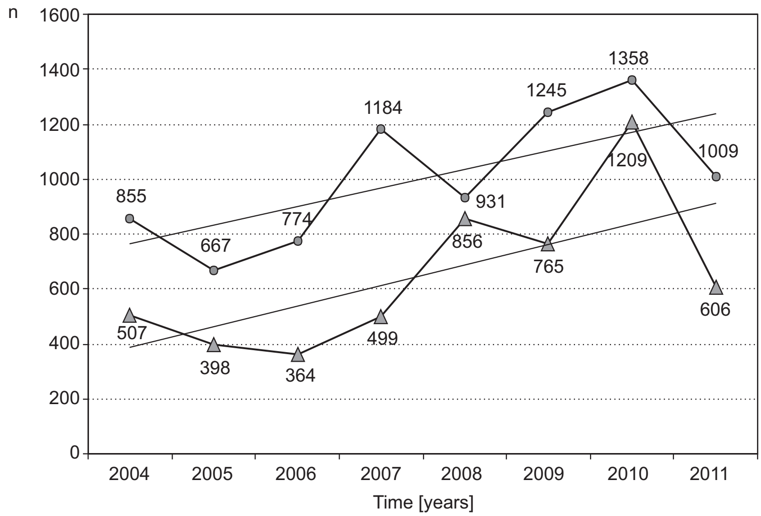

Fig. 2. Carabid abundance in oak-hornbeam forest and mixed forest by year of study (● – mixed forest, ▲ – oak-hornbeam forest)

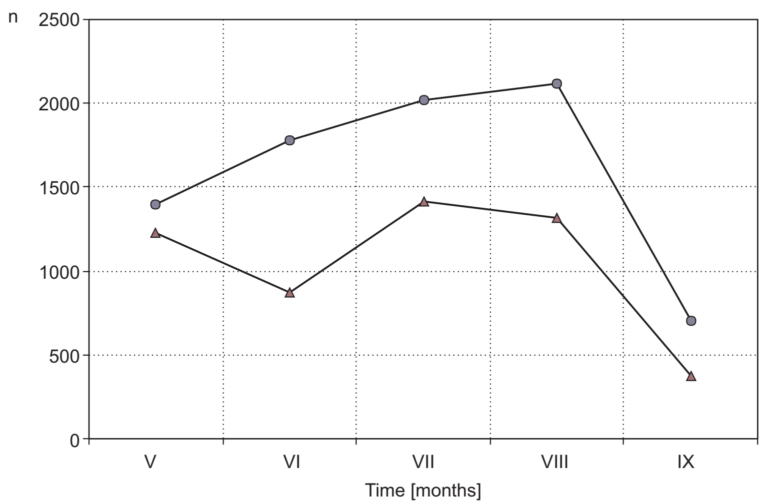

Fig. 3. Activity of Carabid assemblages in oak-hornbeam forest and mixed forest in years 2004–2011 (from May (V) to September (IX), ● – mixed forest, ▲ – oak-hornbeam forest)

Also in this variant, *P. niger* was a eudominant throughout the study period, with contributions to assemblage abundance from 11.39 % in 2005 to 55.42 % in 2009. *P. melanarius* was a eudominant in almost every year of the study period (except 2008 and 2010), as was *A. assimile* (except 2005 and 2009, when it was a subdominant). *N. brevicollis* and *C. granulatus* also had constantly high contributions to overall abundance. The dominance patterns of the remaining 21 species demonstrated con-

Table 4

Abundance of Carabidae species collected in the oak-hornbeam forest by year of study

No.	Species	Number of individuals								
		Oak-hornbeam forest (Variant II)								
		2004	2005	2006	2007	2008	2009	2010	2011	Total
1	*Carabus coriaceus* L.	7	11	10	12	15	13	1	5	74
2	*C. violaceus* L.	2		8	20	14	8	6	3	61
3	*C. granulatus*L.	32	88	40	40	43	27			270
4	*C. cancellatus* Ill.	12	13	3			4	81	11	124
5	*C. arcensis* Herbst							37	101	138
6	*C. nemoralis* O. F. Müller	26	8	16	11	5	4	4	6	80
7	*C. hortensis* L.	17	4	17	27	53	47	53	28	246
8	*Cychrus caraboides* (L.)	5	1	7	9	10	4		3	39
9	*Leistus piceus* Frol.	1				1		5		7
10	*Nebria brevicollis* (Fabr.)	6	11		8	201	64	46	32	368
11	*Patrobus atrorufus* (Stroem)	15			4	1	8	2	6	36
12	*Pt. oblongopunctatus* (Fabr.)	76	56	68	31	16	13	41	37	338
13	*P. niger* (Schall.)	140	45	88	203	388	424	474	203	1965
14	*P. melanarius* (L.)	75	130	53	67	46	108	104	101	684
15	*P. nigrita* (Fabr.)	27				1				28
16	*P. strenuus* (Panz.)		1				3			4
17	*P. aethiops* (Panz.)	2	1							3
18	*Abax carinatus* (Duft.)		8							8
19	*Calathus micropterus* (Duft.)	2								2
20	*Agonum muelleri* (Herbst)	20			13	16		5		54
21	*A. assimile* (Payk.)	37	19	40	49	44	37	346	69	641
22	*A. obscurum* (Herbst)	1								1
23	*A. gracile* Sturm	3								3
24	*Harpalus rufipes* (De Geer)					1				1
25	*H. latus* (L.)		2	14	5	1	1	4	1	28
26	*H. guadripunctatus* Dej.	1								1
	Total	507	398	364	499	856	765	1209	606	5204
	Number of species collected	21	15	12	14	17	15	15	14	26

siderable variability between species and between years. The distribution of individuals between species was evaluated with Simpson's index. These data are presented in Table 8 and show that the most uniform distribution of species was noted in 2010 and also in 2004 and 2006.

P. niger (79.2 %) was the sole member of the group of the most constant species (euconstant), while *P. melanarius* (61.2 %) was classified as a constant species. Accessory species were represented by *N. brevicolis* (42.5 %), *P. oblongopunctatus* (42.5 %), *C. hortensis* (40.8 %), *C. granulatus* (38.3 %), *A. assimile* (36.7 %), *C. nemoralis* (33.3 %), *C. cancellatus* (29.1 %), and *C. coriaceus* (28.3 %) (Table 9). The remaining 16 species (61 % of all species captured in the oak-hornbeam habitat) were classified as accidental. A fidelity analysis revealed 16 characteristic species, including 7 exclusive and 9 preferential species. Unique exclusive (100 %) species comprised *P. strenuus, A. carinatus, A. obscurum, A. gracile, H. rufipes*, and *H. guadripunctatus*. *A. müelleri* (94.73 %) was classified as exclusive, while the group of preferential characteristic species comprised *C. micropterus* (66.66 %), *L. piceus* (63.63 %), *P. atrorufus* (62.06 %), *A. assimile* (59.13 %), *C. cancellatus* (59.04 %), *C. arcensis* (55.2 %), *C. nemoralis* (51.61 %), *P. oblongopunctatus* (50.14 %), and *H. latus* (50 %).

The highest activity of this assemblage was noted in July (Fig. 3). The dominant ecological elements were the same as in the mixed forest assemblage, with the exception of ranking by feeding habits, as it was small zoophages which were the dominant element in this dimension in qualitative analysis (Table 5), accounting for 50 % of the assemblage, while the proportion of large zoophages was 38.5 %.

Table 5

Ecological characteristics of Carabid assemblages

Ecological category	Ecological element	Variant I (Mixed forest)				Variant II (Oak-hornbeam forest)			
		M	[%]	N	[%]	M	[%]	N	[%]
Habitat	F	16	64.0	5093	63.480	18	69.231	3672	70.561
	OFa	7	28.0	2927	36.483	6	23.077	1528	29.362
	Oa	2	8.0	3	0.037	2	7.692	4	0.077
Feeding habits	Lz	12	48.0	6365	79.334	10	38.462	3681	70.734
	Sz	11	44.0	1628	20.292	13	50.000	1523	29.266
	Hz	2	8.0	30	0.374	3	11.538	30	0.576
Humidity requirements	Hg	8	32.0	1754	21.862	8	30.769	1354	26.018
	Mh	17	68.0	6269	78.138	18	69.231	3850	73.982
Breeding type	S	19	76.0	5426	67.631	20	76.923	3829	73.578
	A	6	24.0	2597	32.369	6	23.077	1375	26.422

Key: F – Forest (species), Oa – open-area, OFa – open and forested area; Lz – Large zoophage, Sz – Small zoophage, Hz – Hemizoophage; Hg – Hygrophilous, Mh – Mesohygrophilous; S – Spring breeder, A – Autumn breeder; M – number of species, N – number of individuals, % – percentage of assemblage.

Zoogeographic variety in the oak-hornbeam site assemblage was at the same level (8 elements) and the dominant element was also Palaearctic (Table 6). The indices of species diversity and evenness amounted to H’ = 2.1328 (H’ max = 3.2581) and J’ = 0.6546, respectively.

Table 6

Contribution of zoogeographic elements to Carabidae abundance

Zoogeographic element	Variant I (Mixed forest)				Variant II (Oak-hornbeam forest)			
	M	[%]	N	[%]	M	[%]	N	[%]
Holarctic	1	4.0	3	0.037	2	7.692	55	1.057
Palaearctic	8	32.0	1145	14.271	11	42.308	1245	23.924
Euro-Siberian	7	28.0	5632	70.198	5	19.231	3079	59.166
Euro-Arctic	2	8.0	116	1.446	1	3.846	39	0.749
Euro-Central Asian	1	4.0	7	0.087	1	3.846	3	0.058
Euro-Mediterranean	1	4.0	696	8.675	1	3.846	368	7.071
European Forest Province	4	16.0	420	5.235	3	11.538	400	7.686
Euro. Forest Province (montane)	1	4.0	4	0.050	2	7.692	15	0.288

Key: M – number of species, N – number of individuals, % – percentage of assemblage.

There was a statistically significant positive correlation between the number of carabids captured in particular months during the growing season and mean monthly air temperature at 2 m in both habitat variants: for the mixed forest ($r = 0.4$, $df = 38$, $p = 0.01$) and for the oak-hornbeam forest ($r = 0.35$, $df = 38$, $p = 0.02$); and also between the number of carabids captured in particular months during the growing season and mean monthly ground temperature at a depth of 0.05 m: for the mixed forest ($r = 0.49$, $df = 38$, $p = 0.001$) and for the oak-hornbeam forest ($r = 0.42$, $df = 38$, $p = 0.007$). Data from different years of study show that in 2010 there was a strong positive correlation between carabid abundance in the mixed forest and mean monthly values of the following indices: air temperature at 2 m ($r = 0.95$, $df = 3$, $p = 0.012$) and at 0.5 m ($r = 0.95$, $df = 3$, $p = 0.013$), and ground temperature at a depth of 0.05 m ($r = 0.96$, $df = 3$, $p = 0.008$), 0.1 m ($r = 0.96$, $df = 3$, $p = 0.011$) and 0.2 m ($r = 0.95$, $df = 3$, $p = 0.015$).

With regard to SO_2 and NO_2 levels in the air, a significant negative correlation was noted between carabid abundance and mean monthly SO_2 levels in the air in the mixed forest in 2004 ($r = –0.89$, $df = 3$, $p = 0.043$), while a positive correlation with regard to this index was noted in 2008 ($r = 0.95$, $df = 3$, $p = 0.013$). Of note is also a positive and significant correlation between carabid abundance and mean monthly NO_2 levels in the air in the mixed forest in 2006 ($r = 0.95$, $df = 3$, $p = 0.015$).

An analysis of correlations between the capture rates of dominant species and the abiotic factors revealed that changes in the abundance of *Pterostichus niger* in both

Table 7

Dominance patterns in Carabidae assemblages in mixed forest by year of study

No.	Species	Dominance [%]							
		Mixed forest							
		2004	2005	2006	2007	2008	2009	2010	2011
1	*Carabus coriaceus*	0.35	0.75		2.03	1.61	0.88	0.52	1.19
2	*C. violaceus*		0.60	1.16	2.70	2.04	1.45	1.77	0.30
3	*C. convexus*					0.11			
4	*C. granulatus*	16.26	17.24	7.36	7.18	5.80	1.77		
5	*C. cancellatus*	1.87	3.30	0.26	0.08		0.40	2.80	0.20
6	*C. arcensis*							1.84	8.62
7	*C. nemoralis*	1.75	1.65	2.33	1.18	0.64	0.08	0.22	0.69
8	*C. hortensis*	1.64	3.75	8.53	4.56	3.22	2.41	2.14	1.88
9	*C. glabratus*								0.20
10	*Cychrus caraboides*	1.29	0.90	0.90	2.96	1.93	0.96	0.81	1.39
11	*Leistus piceus*					0.32		0.07	
12	*Nebria brevicollis*	2.34	8.25		5.74	25.56	8.11	6.63	12.29
13	*Patrobus atrorufus*				0.42	0.54	0.48	0.15	0.40
14	*Amara plebeja*						0.16		
15	*Pt. oblongopunctatus*	11.23	10.04	8.79	2.62	1.50	1.45	1.62	1.98
16	*P. niger*	18.01	32.98	26.87	54.05	47.15	59.52	52.43	37.76
17	*P. melanarius*	39.88	13.04	35.14	11.91	8.06	12.93	16.64	24.98
18	*P. nigrita*	0.35				0.97	8.19		
20	*P. aethiops*	0.82							
22	*A. ater*			0.13					
23	*Calathus micropterus*	0.12							
24	*Agonum muelleri*						0.16	0.07	
25	*A. viduum*						0.08		
26	*A. assimile*	4.09	7.35	5.30	4.56	0.43	0.88	12.30	8.13
30	*H. latus*		0.15	3.23		0.11	0.08		
	λ*	0.23	0.18	0.23	0.32	0.30	0.39	0.32	0.23

* Simpson's dominance index.

Table 8

Dominance patterns in Carabidae assemblages in oak-hornbeam forest by year of study

No.	Species	Dominance [%]							
		Oak-hornbeam forest							
		2004	2005	2006	2007	2008	2009	2010	2011
1	*Carabus coriaceus*	1.38	2.76	2.75	2.40	1.75	1.70	0.08	0.83
2	*C. violaceus*	0.39		2.20	4.01	1.64	1.05	0.50	0.50
3	*C. granulatus*	6.31	22.11	10.99	8.02	5.02	3.53		
4	*C. cancellatus*	2.37	3.27	0.82			0.52	6.70	1.82
5	*C. arcensis*							3.06	16.67
6	*C. nemoralis*	5.13	2.01	4.40	2.20	0.58	0.52	0.33	0.99
7	*C. hortensis*	3.35	1.01	4.67	5.41	6.19	6.14	4.38	4.62
8	*Cychrus caraboides*	0.99	0.25	1.92	1.80	1.17	0.52		0.50
9	*Leistus piceus*	0.20				0.12		0.41	
10	*Nebria brevicollis*	1.18	2.76		1.60	23.48	8.37	3.80	5.28
11	*Patrobus atrorufus*	2.96			0.80	0.12	1.05	0.17	0.99
12	*Pt. oblongopunctatus*	14.99	14.07	18.68	6.21	1.87	1.70	3.39	6.11
13	*P. niger*	27.61	11.31	24.18	40.68	45.33	55.42	39.21	33.50
14	*P. melanarius*	14.79	32.66	14.56	13.43	5.37	14.12	8.60	16.67
15	*P. nigrita*	5.33				0.12			
16	*P. strenuus*		0.25				0.39		
17	*P. aethiops*	0.39	0.25						
18	*Abax carinatus*		2.01						
19	*Calathus micropterus*	0.39							
20	*Agonum muelleri*	3.94			2.61	1.87		0.41	
21	*A. assimile*	7.30	4.77	10.99	9.82	5.14	4.84	28.62	11.39
22	*A. obscurum*	0.20							
23	*A. gracile*	0.59							
24	*Harpalus rufipes*					0.12			
25	*H. latus*		0.50	3.85	1.00	0.12	0.13	0.33	0.17
26	*H. guadripunctatus*	0.20							
	λ*	0.14	0.19	0.14	0.21	0.27	0.34	< 0.01	0.19

* Simpson's index of dominance.

Table 9

Fidelity and constancy of occurrence of Carabidae species in the two habitat variants

No.	Species	Fidelity [%]		Constancy [%]	
		Mixed forest	Oak-hornbeam forest	Mixed forest	Oak-hornbeam forest
1	*Carabus coriaceus*	50.99	49.01	32.21	28.32
2	*C. violaceus*	64.12	35.88	36.72	21.63
3	*C. convexus*	100.00		0.81	
4	*C. granulatus*	63.61	36.39	48.11	38.31
5	*C. cancellatus*	40.95	59.05	25.32	29.13
6	*C. arcensis*	44.80	55.20	11.06	15.82
7	*C. nemoralis*	48.39	51.61	27.03	33.33
8	*C. hortensis*	52.05	47.95	61.26	40.83
9	*C. glabratus*	100.00		1.73	
10	*Cychrus caraboides*	74.51	25.49	37.52	19.26
11	*Leistus piceus*	36.36	63.64	2.51	2.54
12	*Nebria brevicollis*	65.41	34.59	44.24	42.54
13	*Patrobus atrorufus*	37.93	62.07	11.72	7.53
14	*Amara plebeja*	100.00		0.81	
15	*P. oblongopunctatus*	49.85	50.15	53.23	42.52
16	*P. niger*	64.01	35.99	92.58	79.28
17	*P. melanarius*	69.45	30.55	72.51	61.26
18	*P. nigrita*	80.28	19.72	4.23	5.84
19	*P. strenuus*		100.00		1.62
20	*P. aethiops*	70.00	30.00	4.23	2.53
21	*Abax carinatus*		100.00		1.62
22	*A. ater*	100.00		0.81	
23	*Calathus micropterus*	33.33	66.67	0.81	1.62
24	*Agonum muelleri*	5.26	94.74	2.51	7.53
25	*A. viduum*	100.00		0.81	
26	*A. assimile*	40.87	59.13	40.83	36.72
27	*A. obscurum*		100.00		0.81
28	*A. gracile*		100.00		1.62
29	*Harpalus rufipes*		100.00		0.81
30	*H. latus*	50.00	50.00	6.66	11.73
31	*H. guadripunctatus*		100.00		0.81

habitat variants correlated significantly with changes in mean monthly air temperatures at the height of 2 m in the mixed forest (r = 0.585, df = 38, p = 0.0001) and in the oak-hornbeam forest (r = 0.622, df = 38, p = 0.0001), and at the height of 0.05 m in the mixed forest (r = 0.669, df = 38, p = 0.0001) and in the oak-hornbeam forest (r = 0.634, df = 38, p = 0.0001). There was also a correlation with changes in mean monthly

Table 10

Trophic structure of Carabidae assemblages in the years 2004–2007

T	2004				2005				2006				2007			
	M	[%]	N	[%]	M	[%]	N	[%]	M	[%]	N	[%]	M	[%]	N	[%]
Mixed forest																
Lz	8	0.57	693	0.81	9	0.69	495	0.73	8	0.67	639	0.83	9	0.69	1026	0.87
Sz	6	0.43	162	0.19	3	0.23	171	0.26	3	0.25	110	0.14	4	0.31	158	0.13
Hg					1	0.08	1	0.01	1	0.08	25	0.03				
Oak-hornbeam forest																
Lz	9	0.43	316	0.62	8	0.53	300	0.75	9	0.75	242	0.66	8	0.57	389	0.78
Sz	11	0.52	190	0.37	6	0.40	96	0.24	2	0.17	108	0.30	5	0.36	105	0.21
Hg	1	0.05	1	0.01	1	0.07	2	0.01	1	0.08	14	0.04	1	0.07	5	0.01

Key: T – feeding habits, Lz – large zoophage, Sz – small zoophage, Hg – hemizoophage, M – number of species, N – number of individuals, % – percentage of assemblage.

Table 11

Trophic structure of Carabidae assemblages in the years 2008–2011

T	2008				2009				2010				2011			
	M	[%]	N	[%]	M	[%]	N	[%]	M	[%]	N	[%]	M	[%]	N	[%]
Mixed forest																
Lz	9	0.56	657	0.71	9	0.50	1001	0.80	9	0.60	1075	0.79	10	0.71	779	0.77
Sz	6	0.38	273	0.28	7	0.39	241	0.19	6	0.40	283	0.21	4	0.29	230	0.23
Hg	1	0.06	1	0.01	2	0.11	3	0.01								
Oak-hornbeam forest																
Lz	8	0.47	574	0.67	9	0.60	639	0.84	8	0.53	760	0.63	10	0.71	493	0.81
Sz	7	0.41	280	0.32	5	0.33	125	0.15	6	0.40	445	0.36	3	0.21	112	0.18
Hg	2	0.12	2	0.01	1	0.07	1	0.01	1	0.07	4	0.01	1	0.07	1	0.01

Key: T – feeding habits, Zd – large zoophage, Zm – small zoophage, Hg – hemizoophage, M – number of species, N – number of individuals, % – percentage of assemblage.

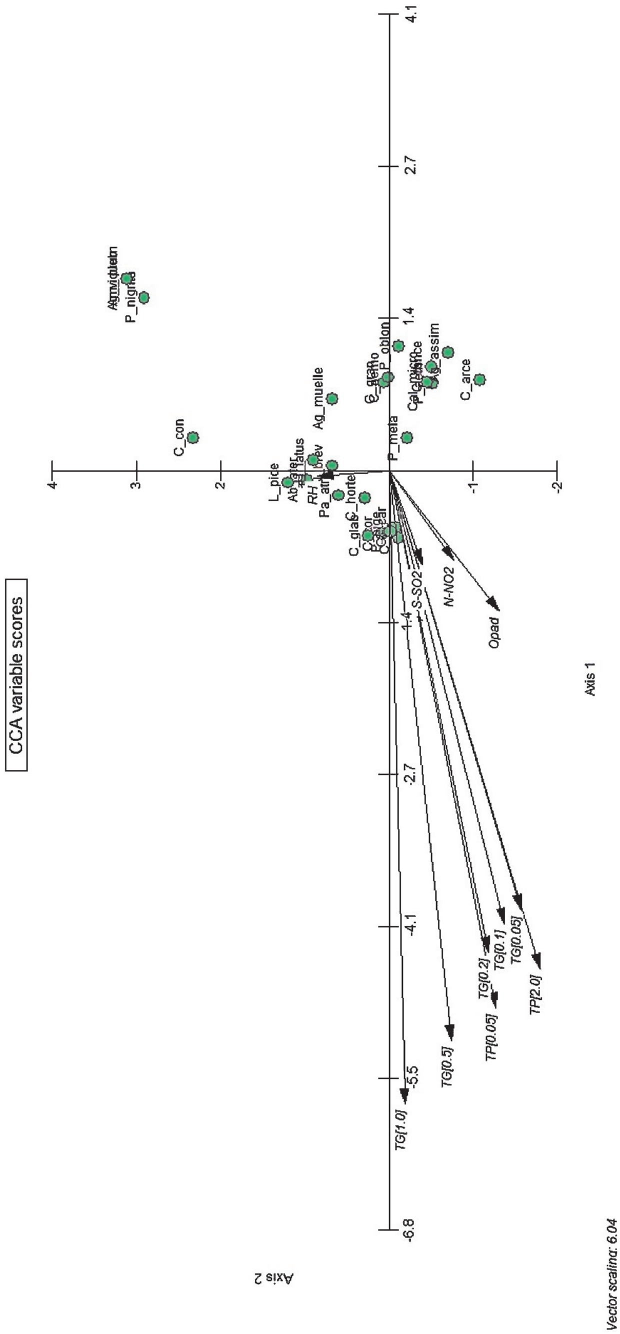

Fig. 4. Canonical correspondence analysis (CCA) diagram for Carabidae assemblages from the mixed forest

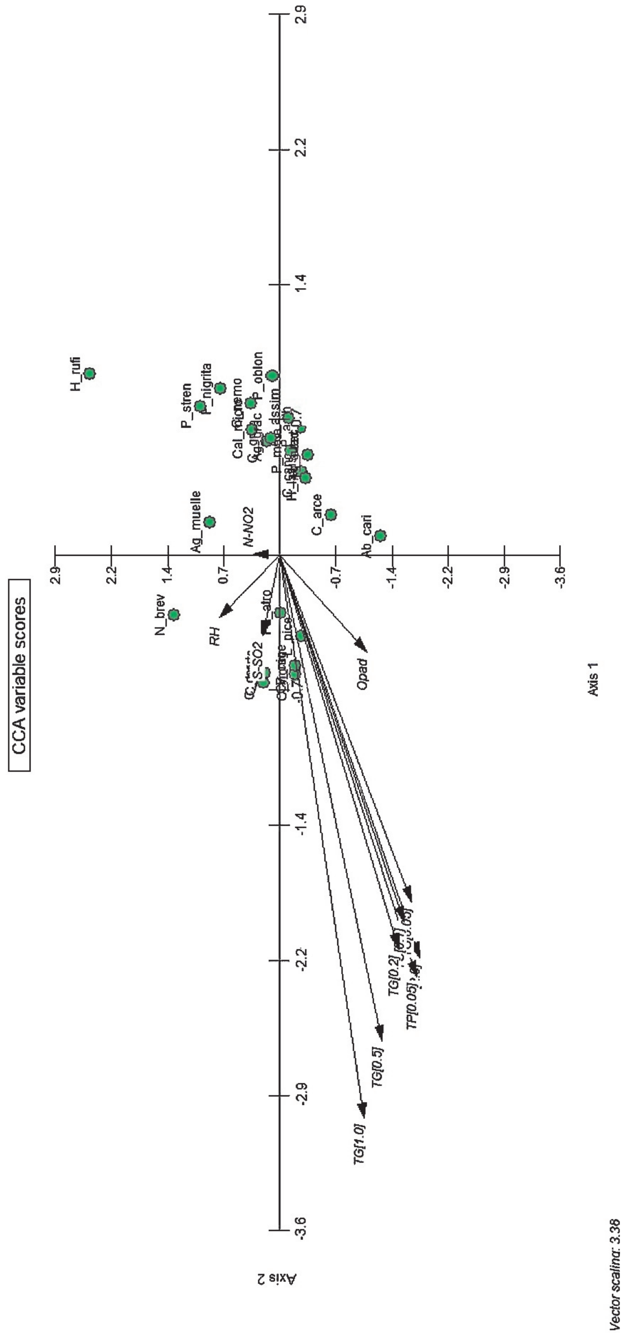

Fig. 5. Canonical correspondence analysis (CCA) diagram for Carabidae assemblages from the oak-hornbeam forest

temperatures of the ground at various depths: at 0.05 m (mixed forest: r = 0.579, df = 38, p = 0.0001; oak-hornbeam forest: r = 0.611, df = 38, p = 0.0001), 0.1 m (mixed forest: r = 0.584, df = 38, p = 0.0001; oak-hornbeam forest: r = 0.621, df = 38, p = 0.0001), 0.2 m (mixed forest: r = 0.601, df = 38, p = 0.0001; oak-hornbeam forest: r = 0.636, df = 38, p = 0.0001), 0.5 m (mixed forest: r = 0.631, df = 38, p = 0.0001; oak-hornbeam forest: r = 0.661, df = 38, p = 0.0001), 1 m (mixed forest: r = 0.593, df = 38, p = 0.0001; oak-hornbeam forest: r = 0.609, df = 38, p = 0.0001). *Carabus arcensis* also merits a note as the only dominant species to demonstrate a positive and significant correlation between its abundance and mean monthly precipitation in the oak-hornbeam forest in the study period 2004–2011 (r = 0.329, df = 38, p = 0.038).

Canonical correspondence analysis (CCA), whose results reflect correlations between the presence of a particular species and environmental factors [21], revealed, for both forest habitat variants studied, that the greatest effect on the Carabidae assemblages was exerted by ground temperature (Fig. 4, Fig. 5).

Discussion

The 8 years of research yielded quite abundant Carabidae material representing a variety of species, ecological categories and zoogeographic elements. The trapability index (number of Carabidae individuals captured daily into one trap) reached medium values similar to those reported from other studies [22, 23].

The Carabidae assemblage inhabiting the oak-hornbeam forest site demonstrated greater variety than its counterpart from the mixed forest site. The index of similarity for the two assemblages was 0.645. The assemblages differed distinctly with regard to peak activity, with the mixed forest assemblage displaying one peak in August and the oak-hornbeam forest assemblage showing two peaks of activity: a minor one in May and a major one in July. Ecological analysis showed a predominance of the same ecological elements in both assemblages with regard to the various categories, except for feeding habits. Representatives of 8 zoogeographic elements were found, *ie* all elements listed by Lesniak [24, 25].

Correlations were also studied between abundance and selected abiotic factors. With regard to temperature, which ranks among the most important ecological factors, it was revealed that higher catch yields correlated positively and significantly with temperature in both habitat variants throughout the study period. Szujecki [26] points out that every insect species has an optimal temperature range where its basic life functions are at their best and most efficient. A The existence of a strong correlation between the activity of epigeic Carabidae and changes in soil temperature has been indicated by [27], Saska and Honek [28] and Tuf et al [29]. Williams and Gormally [30], in a study involving continuous monitoring of ground temperature, found a positive correlation between the abundance of *Carabus clatratus* and ground temperature (with higher temperatures being associated with increased abundance of that species). In a 4-year study, Olszewski [31] found a highly positive correlation between Carabidae abundance and air temperature. At the same time, Gutowski [32] failed to observe significant correlations between Carabidae catch counts and meteorological indices including mean air temperature during the growing season in Puszcza Białowieska in the years 1988–1999. The same authors indicate (Olszewski [31], Gutowski [32]) the absence of a correlation between the amount and distribution of precipitation in a given year and the year before vs. the number of Carabidae captured into Barber's traps. Still another study failed to show an association between Carabidae catch yield and precipitation [23, 33]. Besides temperature, humidity is also a very important abiotic factor that plays a major role in the development of soil-dwelling insects and influences these animals in a complex and multifaceted manner [34]. A positive correlation between soil humidity and the activity of selected species of Carabidae was shown by Nčve [35], with increased soil humidity causing an increase in the abundance of species preferring such habitat conditions. The present study did not analyse the correlation between soil humidity and abundance of Carabidae since soil humidity data were not available. However, we studied the link between relative air humidity and Carabidae catch yield, finding no significant correlations between these factors. This finding is partially attributable to the fact that, while air humidity is an important factor in insect life [26], the association between this factor and abundance is more difficult to grasp.

As regards SO_2 and NO_2 content in the air, only three instances of significant correlations between these factors and Carabidae catch yield were identified. These findings appear quite explicable in view of the fact that daily air concentrations of SO_2 and NO_2 did not exceed levels considered harmless to human health [36]. It might be speculated that air levels of sulphur dioxide and nitrogen dioxide that pose no harm to humans are also not harmful to plants or animals, which may explain the lack of significant correlations between these factors and catch yield for most analytical pairs. Other studies have revealed a strong negative correlation between Carabidae abundance and SO_2 and NO_2, concentrations, which were, however, determined in the soil (ground beetle abundance fell with increasing levels of these compounds in the soil) [31, 37–40].

Faunal monitoring within the system of INEM Base Stations aims also to assess the condition of the environment by evaluating a particular taxon or a group of taxa. In the case of Carabidae, indices serving to evaluate environmental health include abundance, dominance patterns, contributions of particular zoogeographic elements to an assemblage, trophic structure [3–8], geographical ranges of particular species [41] or mean individual biomass [42]. The monitoring of Carabidae by the INEM Base Stations involves such indices as the number of individuals and species, trapability, dominance, trophic structure, diversity and evenness. Of these, dominance patterns (Tables 7 and 8) and trophic structure (Tables 10 and 11) were found to be most useful for environmental monitoring. It is believed that good environmental conditions are paralleled by balanced dominance relations, with no species showing excessive quantitative advantage over the others. As regards the feeding habits of species in a community, it is believed that good environmental health is accompanied by a predominance of zoophagous species, especially large zoophages, while progressive destruction of a forest ecosystem shifts this index in favour of hemizoophages [7]. Our data (Tables 7 and 8 and Tables 10 and 11) allow the conclusion that the pressure of negative factors in the study habitats may not be high, as indicated by low values of Simpson's index and a predominance of zoophages in the two assemblages.

Conclusions

Studies of Carabidae assemblages conducted by INEM Base Stations are of considerable value owing to the continuity of data and the determination of abiotic factors at the site of collection of Carabidae, which affords unique possibilities for studying the correlation between a given factor and the catch yield. There are not many opportunities for carrying out such studies outside the base station network.

References

[1] Kostrzewski A. Zintegrowany Monitoring Środowiska Przyrodniczego – cele zamierzenia, zadania. In: A. Kostrzewski, editor. ZMŚP, Propozycje programowe. Warszawa: Biblioteka Monitoringu Środowiska; 1995;7-22.
[2] Kostrzewski A, Mazurek M, Stach A. Zintegrowany Monitoring Środowiska Przyrodniczego. Zasady organizacji, system pomiarowy, wybrane metody badań. Warszawa: Biblioteka Monitoringu Środowiska; 1995;15-23.
[3] Arndt E. Carabidae as monitoring subject in the light of EU Natura 2000 (Habitats Directive), In: Penev L, Erwin T, Assmann T, editors. Back to the Roots and Back to the Future. Towards a New Synthesis amongst Taxonomic, Ecological and Biogeographical Approaches in Carabidology. Blagoevgrad; 2008;373-384.
Available at: http://f3.tiera.ru/1/genesis/570-574/574000/1356f72c0490e42487d2a6b9d42e0eeb.
[4] Rainio J, Niemelä J. Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodivers. Conserv. 2003;12:487-506. DOI:10.1023/A:1022412617568.
[5] New TR. The role of ground beetles (Coleoptera: Ground beetleae) in monitoring programmes in Australia. Annales Zoologici Fennici. 1998;35:163-171.
Available at: http://www.sekj.org/PDF/anzf35/anzf35-163p.pdf
[6] Meitzner V, Schmidt J, Schultz R. Wald-Monitoring im Müritz-Nationalpark: Status-Quo-Erfassung der Laufkäfer (Coleoptera: Carabidae) in den Jahren 2001 und 2002. Angewandte Carabidologie. 2006;7:1-12.
Available at: http://www.laufkaefer.de/gac/pdf/GAC-Bd7/GAC-Bd7-S1-12-Meitzner_et_al.pdf
[7] Leśniak A. Metody analizy zgrupowań biegaczowatych (Carabidae, Col) w zooindykacji procesów ekologicznych. In: Waloryzacja ekosystemów leśnych metodami zooindykacyjnymi. Warszawa: Wyd. SGGW; 1997;29-41.
[8] Leśniak A. Studies on the terrestial entomofauna of the sod and shrubbs tiers of industriogenous vegetation. Spr. IBL dla US Dep. of Agricult. Warszawa; 1977;150-171.
[9] Shannon CE, Weiner W. The Mathematical Theory of Communication. University of Illinois Press Urbana. Illinois. 1963;117-118.
[10] Pielou, EC. Ecological diversity. New York: John Wiley and Sons; 1975;165-166.
[11] Balogh J. Lebensgemeinschaften der Landtiere ihre Erforschung unter besonderer berücksichtigung der Zoozönologischen Arbeitmethoden. Berlin: Akademie-Verlag; 1958;560.
[12] Weiner J. Życie i ewolucja biosfery. Warszawa: PWN; 1999;591.
[13] Kasprzak K, Niedbała W. Wskaźniki biocenotyczne stosowane przy porządkowaniu i analizie danych w badaniach ilościowych. In: M. Górny, L. Grüm, editors. Metody stosowane w zoologii gleby. Warszawa: PWN; 198;397-416.
[14] Koch K. Die Käfer Mitteleuropas. Ökologie. Krefeld: Goecke & Evers Verlag; 1989;413.
[15] Larsson SG. Entwicklungstypen und Entwicklungszeiten der dänischen Carabiden. Entomol Medd. 1939;20:277-560.
[16] Lindroth CH. Die fennoskandichen Carabidae. Eine tiergeographisce Studie. 3. Allgemeiner Teil. Zuglelh eine biogeographische Prinzipdiskussion. Goteborgs Kungl. Vetenskaps-och Vitterhets-Samhälles, Slätte Följden. 1949;Bd 4(3)911.
[17] Šarova ICh. žiznennye formy žuželic (Coleoptera, carabidae). Moskva: Izd-vo Nauka; 1981;359.
[18] Šarova I. Morfo-ekologičeskie tipy ličinok žuželic (Carabidae). Zool ž. 1960;39:691-708.

[19] Szyszko J. State of Carabidae (Col) fauna in fresh pine forest and tentative valorization of this environment. Warszawa: Warsaw Agricultural Unoversity Press; 1983:1-80.
[20] Aleksandrowicz OR. Biegaczowate (Carabidae). In: Bogdanowicz W, Chudzicka E, Pilipiuk I, Skibińska E, editors. Fauna Polski – charakterystyka i wykaz gatunków. Warszawa: MiIZ PAN; 2004;1:28-31. Available at: http://www.biologia.apsl.edu.pl/pracownicy/aleksandrowiczaleh/publikacje/71.pdf
[21] Piernik A. Metody numeryczne w ekologii na przykładzie zastosowań pakietu MVSP do analiz roślinności. Toruń: Wyd. Nauk. Uniwersytetu Mikołaja Kopernika; 2008;62-88.
[22] Huruk S, Huruk A. Zgrupowania biegaczowatych (Coleoptera, Carabidae) borów sosnowych oraz jodłowych w Górach Świętokrzyskich. Wiad Entomol. 2010;29(4):247-258. Available at: http://pte.up.poznan.pl/we/2010/29_huruk.pdf
[23] Huruk S. Analiza struktur i aktywności polnych zgrupowań biegaczowatych (Carabidae, Coleoptera) na wybranych typach gleb. Kielce: Wyd. Akademii Świętokrzyskiej; 2007;183.
[24] Huruk S, Huruk A. Struktura zgrupowań biegaczowatych w uroczysku Serwis Świętokrzyskiego Parku Narodowego w dwu odległych okresach badawczych. Regionalny Monitoring Środowiska, Kielce: KTN; 2002;3:75-81. Available at: http://www.ujk.edu.pl/ios/wydawnictwa/z3/Huruk.pdf
[25] Leśniak A. Zoogeografical analysis of the Carabidae (Coleoptera) of Poland. Fragm Faun. 1987;30(17):297-312.
[26] Szujecki A. Ekologia owadów leśnych. Warszawa: PWN; 1980;44-50.
[27] Honek A. The effect of temperature on the activity of Carabidae (Coleoptera) in a fallow field. Eur J Entomol.1997;94(1):97-104. Available at: http://www.eje.cz/pdfs/eje/1997/01/10.pdf
[28] Saska P, Honek A. Temperature development of central European species of Amara (Coleoptera, Carabidae). Eur J Entomol. 2003;100:509-515. DOI: 10.14411/eje.2003.078.
[29] Tuf IH, Dedek P, Veselý M. Does the diurnal activity pattern of carabid beetles depend on season, ground temperature and habitat? Arch Biol Sci, Belgrade. 2012;64(2):721-732. DOI:10.2298/ABS1202721T.
[30] Williams CD, Gormally, MJ. The effects of blanket bog management on ground beetles (Carabidae) with particular reference to the threatened *Carabus clatratus* L. Irish Wildlife Manuals, No 47. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland; 2010;25-28. Available at: http://www.npws.ie/publications/irishwildlifemanuals/IWM47.pdf
[31] Olszewski JL. Catches of Carabidae (Coleoptera) and *Geotrupes stercorosus* (Sc) (Scarabeidae, Coleoptera) in the Białowieża National Park, and the ecoclimatic parameters. Ecol Pol. 1979;27:437-447.
[32] Gutowski JM. Bezkręgowce jako obiekt monitoringu biologicznego w Puszczy Białowieskiej. Leśne Prace Badawcze. 2004;1:39-46. Available at: http://www.ibles.pl/web/lesne-prace-badawcze/-/lesne-prace-badawcze-2004-nr-1
[33] Moraes RM, de Souza Mendonça M, Ott R. Carabid beetle assemblages in three environments in the Araucaria humid forest of southern Brazil. Revista Brasileira de Entomologia, São Paulo. 2013;57(1):67-74. Available at: http://dx.doi.org/10.1590/S0085-56262013000100011.
[34] Thiele HU. Carabid beetles in their environments. Berlin: Springer-Verlag; 1977;1-370.
[35] Néve, G. Influence of temperature and humidity on the activity of three Carabus species. In: Desender K et al, editors. Carabid Beetles: Ecology and Evolution. Dordrecht: Kluwer Academic Publishers; 1994;189-192. DOI:10.1007/978-94-017-0968-2_29.
[36] Śnieżek T, editor. Ocena stanu środowiska Stacji Bazowej ZMŚP Puszcza Borecka w roku hydrologicznym 2008. Warszawa: Instytut Ochrony Środowiska; 2008;29-30. Available at: http://www.ios.edu.pl/pol/zaklady/puszcza/raport%20zmsp_2008.pdf
[37] Rybak J. Effect of sulphur contaminants on macroinvertebrates in the Karkonosze Mountains (Sudeten,Poland*)*. Environ Protect Eng. 2009;35(1):111-119. Available at: http://epe.pwr.wroc.pl/2009/Rybak_1-2009.pdf
[38] Cárcamo HA, Parkinson D, Volney JWA. Effects of sulphur contamination on macroinvertebrates in Canadian pine forests, Applied Soil Ecology. 1998;9:459-464. Available at: http://nofc.cfs.nrcan.gc.ca/bookstore_pdfs/18742.pdf
[39] Paoletti MG, Bressan M. Soil Invertebrates as bioindicators of Human Disturbance. Critical Reviews in Plant Science. 1996;15(1):21-62. DOI:10.1080/07352689609701935.
[40] Puszkar T. Zmiany wybranych elementów zoocenoz w agroekosystemach poddawanych silnej presji emisji przemysłowych. Puławy: IUNG; 1981;157:78.
[41] Odum EP. Ekologia. Warszawa: PWN; 1969;219.

[42] Skłodowski J. Interpreting the condition of the forest environment with use of the SCP/MIB model of carabid communities (Coleoptera: Carabidae). Baltic J Coleopterol. 2009;9:89-100. Available at: http://www.bjc.sggw.pl/arts/2009v9n2/294.pdf

CARABIDAE (COLEOPTERA) WYBRANYCH ŚRODOWISK PRZYRODNICZYCH W PUSZCZY BORECKIEJ

[1] Zaklad Zoologii i Dydaktyki Biologii, Instytut Biologii, Uniwersytet Jana Kochanowskiego w Kielcach
[2] Świętokrzyski Park Narodowy, Bodzentyn
[3] Instytut Biologii Systematycznej Uniwersytet w Daugavpils
[4] Instytut Ochrony Środowiska w Warszawie

Abstrakt: W pracy przedstawiono wyniki badań nad Carabidae lasu mieszanego oraz grądu prowadzonych w latach 2004–2011 w obrębie Stacji Bazowej ZMŚP w Puszczy Boreckiej. Celem pracy była charakterystyka struktur zgrupowań Carabidae funkcjonujących w wymienionych środowiskach na tle wybranych abiotycznych czynników środowiska. Podczas badań odłowiono łącznie 13227 osobników Carabidae należących do 31 gatunków. W lesie mieszanym odłowiono łącznie 8023 osobniki należące do 25 gatunków, w grądzie 5204 osobniki należące do 26 gatunków. Różnorodność gatunkowa mierzona wskaźnikiem Shannona-Wienera (H') oraz równomierność mierzona wskaźnikiem Pielou (J') wyniosły w przypadku lasu mieszanego H' = 1,8981; J' = 0,5897 a dla grądu odpowiednio H' = 2,1328; J' = 0,6546. Wyniki odłowów analizowano na tle takich czynników, jak temperatura powietrza, gruntu, opady atmosferyczne, wilgotność względna powietrza, zawartość w powietrzu SO_2, NO_2. Stwierdzono istotną statystycznie, dodatnią korelację między liczebnością odłowów Carabidae a temperaturą powietrza na wysokości 2 m w obydwu badanych środowiskach: las mieszany – r = 0,4, df = 38, p = 0,01, grąd – r = 0,35, df = 38, p = 0,02; jak również między liczebnością odłowów biegaczowatych a temperaturą gruntu na głębokości 0,05 m, odpowiednio: dla lasu mieszanego – r = 0,49, df = 38, p = 0,001 oraz grądu – r = 0,42, df = 38, p = 0,007. Zależności między liczebnością odłowów, a wartością pozostałych czynników były słabo wyrażone, tylko w trzech przypadkach istotne statystycznie.

Słowa kluczowe: Carabidae, monitoring przyrodniczy, czynniki atmosferyczne, temperatura, opady, SO_2, NO_2