MUSEUM AND INSTITUTE OF ZOOLOGY
POLISH ACADEMY OF SCIENCES

FRAGMENTA FAUNISTICA

Fragm. faun.	Warszawa, 30.06.2001	44	41-57

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Ground beetles (*Carabidae, Coleoptera*) of Świnia Góra Reserve in the Świętokrzyskie Mountains

Abstract: Between 1990 and 1992 field studies of epigeal communities of *Carabidae* were carried out in beech stand, fir stand, pine stands and on a forest meadows in Świnia Góra Reserve. The standard procedure of pitfall trapping modified by Szyszko was used and yielded in excess of 15,000 *Carabidae* individuals representing 33 species captured in a total of 72,000 day-traps. The collections were subsequently analysed in detail in terms of zoogeographical, ecological and faunistical features.

Key words: Carabid communities, zoogeographical analysis, ecological analysis, Świnia Góra Reserve

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INTRODUCTION

Over the past 20 years Poland has seen rapid increases in the number of various spatial forms of wildlife protection areas. Not only the number of National Parks has risen, but also of nature reserves, landscape parks, protected landscape areas and even so-called ecological cropland. It needs to be pointed out that Poland has now more national Parks than other European countries. Regrettably, identification of the natural resources of the protected areas, especially with regard to invertebrate fauna, leaves much to be desired, contravening international agreements ratified by Poland as part of a global strategy for nature protection developed by relevant UN agencies. The Division of Zoology at the Akademia Świętokrzyska University in Kielce has therefore undertaken statutory research over the fauna of protected areas in the Świętokrzyskie Mountain Region. Besides insects, the investigations are focussing on insectivorous mammals (the shrew and the bat), amphibians, reptiles and their parasites, terrestrial snails and certain aspect of palaeozoology of these areas.

The aim of this study was to investigate epigeal communities of carabid beetles in various biotopes of Świnia Góra Reserve and provide ecological, zoogeographical and faunistical descriptions thereof.

It needs to be stressed that no similar study of this area had been conducted before. Świnia Góra reserve is undoubtedly one of the most interesting protected areas in the Świętokrzyskie Mountain Region; owing to its charming primaevality, it has been compared to Białowieża National Park.

The study could not have been successfully completed without the invaluable help of MBiol students from the Division of Zoology: Ms Agata Mliczek-Bielat, MA, and Ms Jolanta Sojka, MA, and technicians Mr Jacek Matuszczyk, MA, and Mr Paweł Sidło, MA, to all of whom I address words of gratitude for their efforts.

METHODS AND SCOPE OF RESEARCH

The standard Barber pitfall trapping method, modified by SZYSZKO (1983), was used in the field study. Catches were carried out over 3 years (1990–1992) during periods of the highest activity of epigeal fauna, i.e. from May until the end of September. Series of 10 pitfalls were placed four times in each sampling area, which, according to BREYMAYER (1961) warrants a representative sample. Thus, sample size was 72,000 day-traps: 150 days × 3 years × 4 sites × 40 traps.

During the first year of the study it was also attempted to collect material from siftings, using a 25 × 25 cm steel corer. However, the "spoils" were so scant and non-representative that this method was eventually abandoned.

An ecological analysis of the sample utilized the following indices and features of species:

- **index of constancy** (C) was used as in SZUJECKI (1983): $C = \frac{q}{Q}100$ (q – number of samples containing a species, Q – total number of samples); four constancy classes were distinguished after GÓRNY, GRÜM (1981):
  class IV – euconstant species – species found in 75–100% of samples,
  class III – constant species – found in > 50% of samples,
  class II – accessory species – found in 25–50% of samples,
  class I – incidental species – found in less than 25% of samples;

- **index of dominance** ($D = \frac{n}{N}$, where n – number of individuals of a given species, total number of individuals); four dominance classes were distinguished after the following criteria for dominance index:
  class I – eudominant species, when D > 10.0% ,
  class II – dominant species, when 5.1% ≥ D ≥ 10.0%,
  class III – subdominant species, when 2.1% ≥ D ≥ 5.0%,
  class IV – recedent species, when D ≤ 2.0%;

- **Simpson's index of diversity**: $I = \sum p_i$, where p_i is the proportion of individuals in the *i*th species;

- **community effectiveness index** (CEI) was calculated for each community according to the following formula (LEŚNIAK 1999): $CEI = \sqrt{nxN}$, where: n - number of species, N - number of individuals;
- **developmental type**, after LARSON, 1941;
- **trophic type**, after GÓRNY, 1975;
- **occurrence pattern and moisture requirements**, after BURAKOWSKI *et al.* 1973, 1974.

The degree of similarity between communities was estimated according to Soerensen's (qualitative) and Beklenishev-Nefiedov's (quantitative-qualitative) formulae, after LEŚNIAK (1972).

The zoogeographical analysis employed the author's own classification (LEŚNIAK 1987).

A total of 15,404 *Carabidae* individuals representing 33 species were caught on the study sites in Świnia Góra Reserve. With a sample size of 72,000 day-traps, trapability was estimated at 0.21 individual per day-cylinder, which comes in between findings described in 1970's and 1980's (LEŚNIAK 1980, 1990) studies and in recent studies (LEŚNIAK 1999).

STUDY AREA

Świnia Góra Reserve is situated in the Świętokrzyskie Mountain Region on the border of the Łysogóry and Końskie districts, in Region VI - Central Poland Uplands, the province of Świętokrzyskie Mountains (MROCZKIEWICZ 1952), about 7 km south-west of the village of Bliżyn, in division 137 of the Wilczy Bór forest inspectorate (Suchedniów forest range). The forest reserve Świnia Góra was founded in 1938 and occupies an area of 51 ha (ADAMCZYK 1965). The reserve extends over a part of Świnia Góra hill. Height difference between the highest (350 m above sea level) and lowest point of the reserve is about 25 m. However, the reserve itself is plain, with the inclination angles of local depressions rarely exceeding 5 degrees. The north-eastern part of the reserve is drained by two small streams flowing northwards into the river Kamienna. A part of the reserve is waterlogged (ADAMCZYK 1965). Besides streams, water-heads and bog-springs, there are former mining pits of various sizes which are constantly or periodically filled with water. These are the remainder of iron ore and fire-clay quarrying in the past (KOŹMIŃSKI 1955). These practices, which continued for several hundred years, had a significant impact on soil conditions.

ADAMCZYK (1965) has distinguished in the reserve two series of rock formations: marly-siliceous and quartz-siliceous. The former gave rise to slightly acidic or neutral meso- and eutrophic soils with a highly saturated sorption complex. The carbohydrate-free quartz-siliceous basis gave rise to acidic oligotrophic soils. Soils of different type, fertility and moisture level support distinct plant associations (FABIJANOWSKI, ZARZYCKI 1965), including coniferous forests, riverside carrs or linden-oak-hornbeam forests. The climate of the area is typical of uplands in Central Poland. According to FABIJANOWSKI, ZARZYCKI (1965), mean annual air temperature

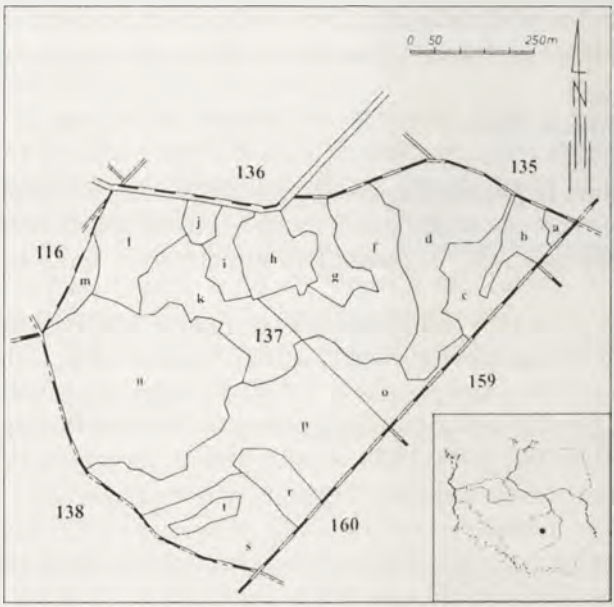

Fig. 1. Świnia Góra Reserve in the Świętokrzyskie Mountains.

was 7.3°C, with a total precipitation of 832 mm. The vegetative period is 210 days long and snow cover is present for 63 days.

According to PIEKOŚ (1971), the climate of Świnia Góra, compared to adjacent regions, was characterised by higher precipitation, longer-lasting snow cover and a shorter vegetation period.

The location of the reserve on a map of Poland and the placement of permanent study sites are shown in Fig. 1. Study sites included the following:

1. Fir stand site (subdivision 137n)

A *Pino-Quercetum* coniferous forest with fir. The forest stand is composed of fir, common oak and pine with an admixture of beech and Polish larch. A poor ground cover is characteristic of coniferous forests, with dominant *Vaccinium myrtillus* and also some *Majanthemum bifolium, Pteridium aquilinum* and with a large proportion of the mosses *Dicranum scoparium, Entodon Schreberi* and *Polytrichum attenuatum.*

The soils are sandy-clayey and moderately moist podzols.

2. Forest meadow site (subdivision 137j)

A waterlogged meadow with swamp-related vegetation (*Phragmition*). There are species characteristic of swamps: *Phragmites communis, Rumex hydrolaputum, Iris sibirica, Caltha palustris.* These species are concentrated in periodically waterlogged areas. Elevated areas within the meadow are penetrated by tree species: maple, beech, oak and various shrubs.

The soils are leached brown soils.

3. Pine stand site (subdivision 137s)

A *Pino-Quercetum* mixed coniferous forest where the stand is composed mainly of pine and some larch, fir and oak. The ground cover is composed of *Pteridium aquilinum, Vaccinium myrtillus, Majanthemum biforlium* and the mosses *Dicranum scoparium, Entodon Schreberi, Hylocomium splendens.*

The soils are sandy-clayey podzols.

Table I. Results of catches of ground beetles (*Carabidae*) in Świnia Góra Reserve by study sites and years.

No	Sites	Fir stand				Forest meadow				Pine stand				Beech stand				Total
	Species	1990	1991	1992	Total	1990	1991	1992	Total	1990	1991	1992	Total	1990	1991	1992	Total	
1	*Carabus coriaceus* L.	17	51	121	189	8	21	177	206	61	104	268	433	34	38	136	208	1036
2	*C. violaceus* L.	120	107	102	329	40	56	273	369	92	124	94	310	123	168	185	476	1484
3	*C. auronitens* FABR.	–	–	1	1	–	–	–	0	–	5	8	13	–	–	–	0	14
4	*C. convexus* FABR.	–	–	–	0	–	–	–	0	–	–	1	1	–	–	–	0	1
5	*C. granulatus* L.	–	–	–	0	–	–	2	2	–	–	–	0	–	–	–	0	2
6	*C. cancellatus* ILL.	–	–	–	0	–	–	–	0	–	–	–	0	–	1	–	1	1
7	*C. arcensis* HERBST	5	14	16	35	11	57	108	176	26	55	31	112	–	17	24	41	364
8	*C. hortensis* L.	13	6	14	33	14	14	16	44	1	–	–	1	17	26	30	73	151
9	*C. glabratus* PAYK.	34	44	60	138	3	7	36	46	19	26	23	68	17	11	12	40	292
10	*C. linnaei* DUFT.	398	404	482	1284	128	77	191	396	193	289	202	684	220	267	430	917	3281
11	*Cychrus rostratus* (L.)	53	41	46	140	8	19	30	57	15	52	22	89	27	42	30	99	385
12	*Leistus piceus* FROL.	–	5	1	6	–	–	–	0	–	–	–	0	–	–	–	0	6
13	*Nebria brevicollis* (FABR.)	1	1	–	2	22	6	1	29	8	–	–	8	–	8	7	15	54
14	*Patrobus atrorufus* (STROEM)	–	–	3	3	–	–	2	2	–	–	–	0	–	–	1	1	6
15	*Pterostichus caerulescens* (L.)	–	–	–	0	–	–	–	0	–	–	–	0	–	–	1	1	1
16	*Pt. cupreus* (L.)	–	–	–	0	–	–	–	0	–	1	–	1	–	–	–	0	1
17	*Pt. oblongopunctatus* (FABR.)	90	105	271	466	57	98	91	246	95	206	129	430	23	102	333	458	1600
18	*Pt. niger* (SCHALL.)	217	336	313	866	222	324	794	1340	133	312	113	558	226	496	443	1165	3929
19	*Pt. vulgaris* (L.)	22	33	19	74	69	109	105	283	–	–	–	0	73	105	171	349	706
20	*Pt. anthracinus* (ILL.)	–	–	–	0	–	–	2	2	–	–	–	0	–	–	–	0	2
21	*Pt. nigrita* (FABR.)	–	–	3	3	–	5	21	26	–	–	–	0	–	8	9	17	46
22	*Pt. strenuus* (PANZ.)	–	1	–	1	–	1	–	1	–	–	–	0	–	5	–	5	7
23	*Pt. aethiops* (PANZ.)	–		–	0	–	–	–	0	–	–	–	0	–	–	1	1	1
24	*Pt. burmeisteri* HEER	31	51	39	121	26	28	16	70	36	36	29	101	32	115	115	262	554
25	*Abax carinatus* (DUFT.)	149	152	141	442	43	76	67	186	3	2	1	6	55	278	324	657	1291
26	*A. ovalis* (DUFT.)	13	24	8	45	2	–	–	2	–	5	–	5	3	3	–	6	58
27	*Calathus fuscipes* (GOEZE)	–	–	–	0	–	–	1	1	–	–	–	0	–	–	–	0	1
28	*C. micropterus* (DUFT.)	1	–	4	5	–	–	–	0	–	2	–	2	–	–	1	1	8
29	*Synuchus nivalis* (PANZ.)	–	–	–	0	–	2	–	2	–	2	–	2	–	–	–	0	4
30	*Agonum viduum* (PANZ.)	–	–	–	0	–	–	2	2	–	–	–	0	–	–	–	0	2
31	*Ag. assimile* (PAYK.)	–	7	5	12	–	12	7	19	–	–	–	0	6	20	55	81	112
32	*Harpalus rufipes* (DE GEER)	–	–	–	0	–	–	1	1	–	–	–	0	–	–	–	0	1
33	*H.latus* (L.)	–	1	–	1	–	–	1	1	–	–	–	0	–	–	1	1	3
	Total	1164	1383	1649	4196	653	912	1944	3509	682	1221	921	2824	856	1710	2309	4875	15404
	Number of species				22				25				18				21	33

4. Beech stand site (subdivision 137k)

Mountain beech wood stand (*Dentario glandulosae-Fagetum*). Forest stand composed predominantly of beech with some fir and maple. Shrub layer has *Rubus hirtus* as the most frequent species. Ground cover includes: *Alium ursinum, Mercurialis perennis, Dentarium bulbifera*, less frequently *Anemone nemorosa, Asperula odorata, Hepatica nobilis, Dryopteris spinulosa, Oxalis acetosella.*

The soil is a very fertile proper brown soil.

RESULTS

Ecological characteristics of *Carabidae* communities

Species composition. The study sites in Świnia Góra Reserve yielded 33 carabid species, which is indicative of a relatively high biodiversity of the area under study (Table I). The largest number of species (25) was registered at the forest meadow, and the smallest (18 species) in the pine forest, with 22 species found in the fir stand and 23 species recorded in the beech wood. The finding of a high species richness of *Carabidae* at the meadow site can be accounted for by the meadow's small size, which allowed it to be occupied by both heliophilous open-area species and forest species, which would have found it easy to penetrate there from the forest. On the other hand, a low species richness in the pine forest stand would have been related to the much less fertile soil at that site.

Of all species registered at Świnia Góra reserve, 10 (all of the species of the genus *Carabus*) are legally protected species.

Four species, namely *Pterostichus caerulescens, Pt. vulgaris, Pt. anthracinus* and *Pt. aethiops*, according to a Catalogue of Polish Fauna (MROCZKOWSKI *et al.* 1974), had not been previously recorded from the Świętokrzyskie MTS However, these are by no means rare species and have been found in adjacent areas and in the Małopolska Uplands. The author wishes to point out that typical montane species (*Carabis linnaei, Leistus piceus* and *Pterostichus burmeisteri*) were among those found in the reserve.

Structure of dominance. The following species were found most frequently at all study sites in Świnia Góra reserve: *Pterostichus niger, Carabus linnaei* i *Pterostichus oblongopunctatus*, and were classified in the first class of dominance (Table II). The second class of dominance comprised *Carabus coriaceus, C. violaceus, Pterostichus burmeisteri* i *Abax carinatus*, the third class was composed of *C. arcensis, C. glabratus* i *Cychrus rostratus*, while the remaining 22 species were included in the fourth class since they were represented in the collections by single individuals.

The dominants (1st class of dominance) had, however, different dominance indices across sites. These figures are shown in detail in Table III.

Patterns of occurrence. Three patterns of occurrence could be distinguished:

1. forest species – F
2. open-area species – OA
3. eurytopic species – E

Table II. Ecological characteristics of ground beetle species (*Carabidae, Coleoptera*) collected in the years 1990–1992 in Świnia Góra Reserve; F – forest species, OA – open-area species, Eu – eurytopic species, X – xerophilous sp., H – hygrophilous, M – mesophilous, A – autumnal species, S – spring species, Z – zoophages, Hz – hemizoophages, P – Palaearctic, E – European, EA – Euroarctic, ES – Eurosiberian, EPS – European Silvan Province, M – Mountaine, Em – Euro-Mediterranean.

No	Species	Number of individuals	Pattern of occurrence	Moisture requirements	Trophic type	Developmental type	Zoogeographical element	Dominance class	Constancy class
1	*Carabus coriaceus* L.	1036	F	X	Z	A	E	II	IV
2	*C. violaceus* L.	1484	F	H	Z	A	P	II	IV
3	*C. auronitens* FABR.	14	F	H	Z	S	P	IV	IV
4	*C. convexus* FABR.	1	OA	X	Z	S	ES	IV	IV
5	*C. granulatus* L.	2	F	X	Z	S	EPS	IV	IV
6	*C. cancellatus* ILL.	1	OA	X	Z	S	ES	IV	IV
7	*C. arcensis* HERBST	364	F	X	Z	S	P	III	IV
8	*C. hortensis* L.	151	F	H	Z	A	E	IV	III
9	*C. glabratus* PAYK.	292	F	H	Z	A	EA	III	IV
10	*C. linnaei* DUFT.	3281	F	H	Z	A	Eg	I	IV
11	*Cychrus rostratus* (L.)	385	F	H	Z	A	EA	III	IV
12	*Leistus piceus* FROL.	6	F	H	Z	A	M	IV	I
13	*Nebria brevicollis* (FABR.)	54	F	H	Z	A	Em	IV	II
14	*Patrobus atrorufus* (STROEM)	6	F	H	Z	A	ES	IV	I
15	*Pterostichus caerulescens* (L.)	1	OA	M	Z	S	ES	IV	I
16	*Pt. cupreus* (L.)	1	OA	H	Hz	S	P	IV	I
17	*Pt. oblongopunctatus* (FABR.)	1600	F	H	Z	S	P	I	IV
18	*Pt. niger* (SCHALL.)	3929	F	H	Z	A	ES	I	IV
19	*Pt. vulgaris* (L.)	706	Eu	X	Z	A	ES	II	III
20	*Pt. anthracinus* (ILL.)	2	Eu	H	Z	A	P	IV	I
21	*Pt. nigrita* (FABR.)	46	Eu	H	Z	S	P	IV	I
22	*Pt. strenuus* (PANZ.)	7	F	H	Z	S	P	IV	I
23	*Pt. aethiops* (PANZ.)	1	F	H	Z	S	E	IV	I
24	*Pt. burmeisteri* HEER	554	F	H	Z	S	M	II	IV
25	*Abax carinatus* (DUFT.)	1291	F	H	Z	A	M	II	IV
26	*A. ovalis* (DUFT.)	58	F	H	Z	A	M	IV	II
27	*Calathus fuscipes* (GOEZE)	1	OA	M	Z	A	P	IV	I
28	*C. micropterus* (DUFT.)	8	F	H	Z	A	P	IV	I
29	*Synuchus nivalis* (PANZ.)	4	Eu	X	Z	A	ES	IV	I
30	*Agonum viduum* (PANZ.)	2	Eu	H	Z	S	ES	IV	I
31	*Ag. assimile* (PAYK.)	112	F	H	Z	S	P	IV	II
32	*Harpalus rufipes* (DE GEER)	1	OA	X	Hz	A	P	IV	I
33	*H. latus* (L.)	3	OA	X	Hz	A	P	IV	I
	Total	15404							

Table III. Percentages of individuals of a given species in the entire collection material - dominance.

No	Sites / Species	Fir stand	Forest meadow	Pine stand	Beech stand	Average
1	*Carabus coriaceus* L.	4.5	5.87	15.34	4.27	6.73
2	*C. violaceus* L.	7.84	10.51	10.98	9.76	9.63
3	*C. auronitens* FABR.	0.02	-	0.5	-	0.1
4	*C. convexus* FABR.	-	-	0.04	-	0.01
5	*C. granulatus* L.	-	0.06	-.	.-	0.01
6	*C. cancellatus* ILL.	-	-	-	0.02	0.01
7	*C. arcensis* HERBST	0.83	5.02	3.97	0.84	2.36
8	*C. hortensis* L.	0.79	1.25	0.04	1.5	0.98
9	*C. glabratus* PAYK.	3.29	1.31	2.41	0.82	1.9
10	*C. linnaei* DUFT.	30.62	11.29	24.21	18.82	21.27
11	*Cychrus rostratus* (L.)	3.34	1.62	3.15	2.03	2.5
12	*Leistus piceus* FROL.	0.14	-	-	-	0.04
13	*Nebria brevicollis* (FABR.)	0.05	0.83	0.28	0.31	0.35
14	*Patrobus atrorufus* (STROEM)	0.07	0.06	-	0.02	0.04
15	*Pterostichus caerulescens* (L.)	-	-	-	0.02	0.01
16	*Pt. cupreus* (L.)	-	-	0.04	-	0.01
17	*Pt. oblongopunctatus* (FABR.)	11.11	7.01	15.23	9.39	10.39
18	*Pt. niger* (SCHALL.)	20.64	38.24	19.77	23.9	25.51
19	*Pt. vulgaris* (L.)	1.76	8.06	-	7.16	4.58
20	*Pt. anthracinus* (ILL.)	-	0.06	-	-	0.01
21	*Pt. nigrita* (FABR.)	0.07	0.74	-	0.35	0.3
22	*Pt. strenuus* (PANZ.)	0.02	0.03	-	0.1	0.05
23	*Pt. aethiops* (PANZ.)	-	-	-	0.02	0.01
24	*Pt. burmeisteri* HEER	2.88	1.99	3.58	5.37	3.6
25	*Abax carinatus* (DUFT.)	10.53	5.3	0.21	13.48	8.38
26	*A. ovalis* (DUFT.)	1.07	0.06	0.18	0.12	0.38
27	*Calathus fuscipes* (GOEZE)	-	0.03	-	-	0.01
28	*C. micropterus* (DUFT.)	0.12	-	0.07	0.02	0.05
29	*Synuchus nivalis* (PANZ.)	-	0.06	-	-	0.01
30	*Agonum viduum* (PANZ.)	-	0.06	-	-	0.01
31	*Ag. assimile* (PAYK.)	0.29	0.54	-	1.66	0.73
32	*Harpalus rufipes* (DE GEER)	-	0.03	-	-	0.01
33	*H. latus* (L.)	0.02	0.03	-	0.02	0.02

Species classified as forest species were found to be clear dominants at all study sites in Świnia Góra reserve, while eurytopic species made up less than 5% of the respective communities, and open area species represented as little as 0.1% of the study collections (Table II). Table IV presents percentages of the three types (numbers of individuals) collected at individual sites.

Moisture requirements. Three groups of species: hygrophilous, mesohygrophilous and xerophilous were distinguished with respect to their moisture requirements (Table II).

The Table V shows that the greatest proportions of xerophilous species were observed at sites meadow and pine forest. This is an interesting finding as these sites, particularly meadow, represent extremely moist habitats, subject to periodical flooding.

Table IV. Percentages of *Carabidae* representing different patterns of occurrence at individual study sites

Site / Species	Fir stand	Forest meadow	Pine stand	Beech stand	All sites (on an average)
forest	98.2	90.9	99.8	92.4	95.0
open-area	-	0.1	0.1	0.1	0.1
eurytopic	1.8	9.0	0.1	7.5	4.9

The most abundantly represented category at all sites was hygrophilous species, while mesohygrophilous species were practically absent (2 individuals out of the total number of more than 15,000 individuals collected). The percentages of xero- and hygrophilous species at individual sites are presented in table V. It may be supposed that the division into hygro- and xerophilous species posited in literature is probably the result of the use of inadequate criteria, and specifically, the placement of heliophilous forms among xerophilous species.

Table V. Percentages of species with different moisture requirements at the study sites.

Site / Species	Fir stand	Forest meadow	Pine stand	Beech stand	All sites (on an average)
Xerophilous	7.1	19.1	19.3	12.3	13.8
Hygrophilous	92.9	80.9	80.7	87.7	86.2

Trophic type. The percentages of different trophic types among *Carabidae* at different study sites in Świnia Góra reserve are shown in Table VI, referring both to species (numerator values) and individuals (denominator values).

Table VI. Percentage shares of trophic groups of *Carabidae* at different sites in Świnia Góra Reserve.

Trophic groups / Sites	Large zoophages	Small zoophages	Hemi-zoophages
Fire stand	45.6 42.8	9.1 6.6	4.5 0.07
Forest meadow	48 70.3	8 2.9	16 0.2
Pine stand	35.3 50.1	11.8 5.6	5.9 0.04
Beech stand	43.6 53.2	8.7 2.9	13 0.06

When the overall proportion of individuals at all sites is considered, the large zoophage group (species with a body length exceeding 20 mm) comes out as dominant. The proportion of the large zoophage group species is also higher than that of small zoophages, with the smallest difference observed for forest meadow, where the proportion of hemizoophages was also the largest.

Developmental type. It was assumed, after LARSON (1941) that *Carabidae* are divided into two developmental types, namely, a spring type (wintering as imagines) and an autumn type (wintering as larvae). The latter was distinctly dominant at all the sites studied. The percentages of the two developmental types at individual sites are shown in the table VII:

Table VII. Percentages of developmental types of *Carabidae* at individual sites.

Site / Developmental type	Fir stand	Forest meadow	Pine stand	Beech stand	All sites (on an average)
Autumnal	84.8	84.6	76.7	82.2	82.4
Spring	15.2	15.4	23.3	17.8	17.6

The above table shows that the *Carabidae* community from the pine forest stand was the most different from the others and was characterised by the highest percentage of the spring developmental type.

Constancy. The constancy of individual species of *Carabidae* in Świnia Góra reserve and at the different study sites is presented in Table VIII. Significant differences in constancy, exceeding 25% at different sites, were found in the case of 13 species. Table VIII also shows mean constancy per site values, with the highest mean recorded for the beech stand, and the lowest figure obtained for the forest meadow. There is also a lack of complete overlap between the number of individuals collected and mean constancy, as shown by the figures obtained for meadow and pine stand.

Zoogeographical characteristics of the communities of *Carabidae*

Detailed results of a zoogeographical analysis based on a classification proposed by the present author (LEŚNIAK 1987) are presented in Table IX. The table presents the characteristics at fraction, wherein the numerator refers to species and the denominator corresponds to individuals (quantitative aspect). The Palaearctic element and the European silvan province element (montane species) were found to be dominant at all study sites both qualitatively and quantitatively. The share of the latter element was by far the highest in the beech and fir stands.

In terms of individual abundance-based percentages of the respective zoogeographical elements, the forest meadow site community stands out from the rest, with the highest share of the Palaearctic element and the lowest share of the European silvan province element. This site also had the comparatively highest share of species

representing the Euroarctic element and the lowest share of species representing the European silvan province element.

Table VIII. Constancy of Carabid species at different sites in Świnia Góra Reserve in the years 1990-1992. A – fir stand, G – forest meadow, P – pine stand, F – beech stand.

No	Sites / Species	% constancy				Average
		A	G	P	F	
1	*Carabus coriaceus* L.	100	91.7	100	100	97.9
2	*C. violaceus* L.	100	100	100	100	100.0
3	*C. auronitens* FABr.	8.3	–	66.7	–	18.8
4	*C. convesus* FABR.	–	–	8.3	–	2.1
5	*C. granulatus* L.	–	8.3	–	–	2.1
6	*C. cancellatus* ILL.	–	–	–	8.3	2.1
7	*C. arcensis* HERBST	83.3	91.7	100	66.7	85.4
8	*C. hortensis* L.	91.7	58.3	8.3	91.7	62.5
9	*C. glabratus* PAYK.	100	75	100	83.3	89.6
10	*C. linnaei* DUFT.	100	100	100	100	100.0
11	*Cychrus rostratus* (L.)	100	75	100	100	93.8
12	*Leistus piceus* FROL.	16.7	–	–	–	4.2
13	*Nebria brevicollis* (FABR.)	16.7	50	8.3	33.3	27.1
14	*Patrobus atrorufus* (STROEM.)	16.7	8.3	–	8.3	8.3
15	*Pterostichus caerulescens* (L.)	–	–	–	8.3	2.1
16	*Pt. cupreus* (L.)	–	–	8.3	–	2.1
17	*Pt. oblongopunctatus* (FABR.)	100	91.7	100	91.7	95.9
18	*Pt. niger* (SCHALL.)	100	100	100	100	100.0
19	*Pt. vulgaris* (L.)	66.7	91.7	–	91.7	62.5
20	*Pt. anthracinus* (ILL.)	–	8.3	–	–	2.1
21	*Pt. nigrita* (FABR.)	16.7	41.7	–	33.3	22.9
22	*Pt. strenuus* (PANZ.)	8.3	8.3	–	16.7	8.3
23	*Pt. aethiops* (PANZ.)	–	–	–	8.3	2.1
24	*Pt. burmeisteri* HEER.	91.7	66.7	100	100	89.6
25	*Abax carinatus* (DUFT.)	100	100	33.3	91.7	81.3
26	*A. ovalis* (DUFT.)	66.7	16.7	25	16.7	31.3
27	*Calathus fuscipes* (GOEZE)	–	8.3	–	–	2.1
28	*C. micropterus* (DUFT.)	25	–	8.3	8.3	10.4
29	*Synuchus nivalis* (PANZ.)	–	8.3	8.3	–	4.2
30	*Agonum viduum* (PANZ.)	–	8.3	–	–	2.1
31	*Ag. assimile* (PAYK.)	58.3	58.3	–	75	47.9
32	*Harpalus rufipes* (DE GEER)	–	8.3	–	–	2.1
33	*H. latus* (L.)	8.3	8.3	–	8.3	6.2
	Number of species	22	25	18	23	33
	Constancy (average)	62.5	51.3	59.7	72.3	61.5
	Number of individuals	4196	3509	2824	4875	15404

Similarity of ground beetle communities from the study sites

There is a high degree of (qualitative) similarity between individual carabid communities inhabiting the study sites in Świnia Góra reserve, with mean similarity amounting to 62.4% (Table X). The similarity value obtained for the meadow site and pine forest site *Carabidae* communities (44.6%) is the most distant from this mean. Mean similarity expressed as a measure accounting for both species composition and the abundance of individual species (species & abundance-based similarity) is lower, at 54.3%, than the qualitative similarity measure (Table X). The lowest species and abundance-based similarity was also established for the meadow site and pine forest site *Carabidae* communities. It is currently not possible to provide an explanation for this finding, which is all the more surprising as the two sites are more similar to one another than to any others in terms of the penetration of light to the forest floor and also with respect to repeated flooding in spring - and a much higher level of underground water than at the other sites.

Table IX. Percentage shares of zoogeographical elements at different sites in Świnia Góra Reserve.

Zoogeographical elements / Sites	Palaearctic	Euroarctic	Eurosiberian	European silvan province	Montane	Euro-medyterranean
Fir stand	45.6 42.8	9.1 6.6	4.5 0.07	13.6 5.3	22.7 45.2	4.5 0.04
Forest meadow	48 70.3	8 2.9	16 0.2	8 7.1	16 18.7	4 0.8
Pine stand	35.3 50.1	11.8 5.6	5.9 0.04	17.6 15.9	23.5 28.1	5.8 0.3
Beech stand	43.6 53.2	8.7 2.9	13 0.06	13 5.8	17.4 37.8	4.3 0.3

Table X. Species similarity and combined species-based and quantitative similarity of ground beetle communities from different sites in Świnia Góra Reserve in the years 1990-1992.

Sites	Fir stand	Forest meadow	Pine stand	Beech stand
Fir stand	×	67.9 49.5	62.5 54.7	80 66.7
Forest meadow		×	44.8 46.8	65.5 60.5
Pine stand			×	53.8 47.6
Beech stand				×

Figures 2 and 3 show seasonal dynamics for the most abundant, dominant species: *Carabus coriaceus, Carabus violaceus, Carabus linnaei, Pterostichus niger, Pterostichus oblongopunctatus* and *Abax carinatus*. The data indicate that the seasonal dynamics of these species exhibited differences across years of study and that no substantial similarities could be seen between species with regard to this parameter. Also, the replacement of species abundance over time observed by KARPIŃSKI (1952) could hardly be observed in this study.

Trapability of *Carabidae* at the study sites in Świnia Góra reserve also exhibits marked variations, as shown in figure 4. This figure also presents the values of Simpson's index of biodiversity and the proposed community effectiveness index (CEI) (LEŚNIAK 1999) as well as the numbers of species registered at individual sites.

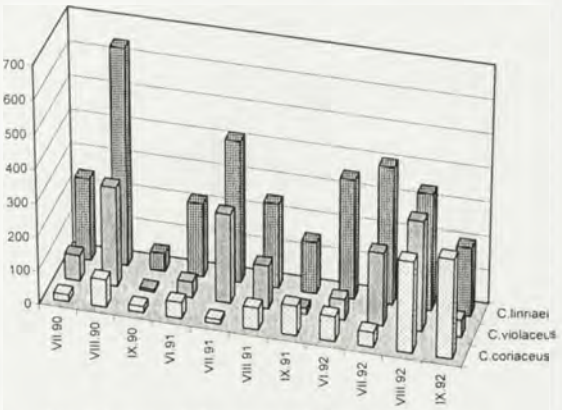

Fig. 2. Seasonal dynamics of dominant species.

An analysis of the essential indices used to describe the collected *Carabidae* demonstrates that the richest *Carabidae* fauna inhabits the beech stand, which had the greatest number of individuals and almost the highest number of species (Fig. 4). Following it in this classification is sites fir stand and forest meadow, while the pine forest is the poorest.

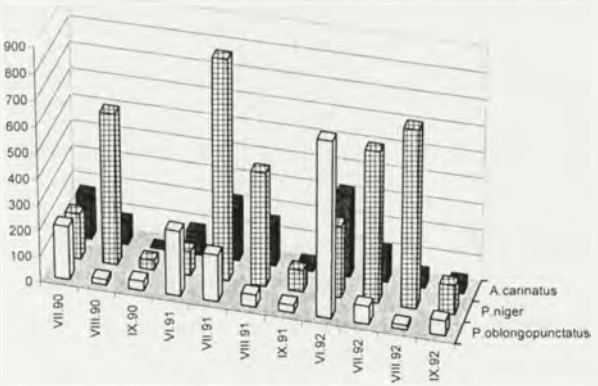

Fig. 3. Seasonal dynamics of dominant species.

However, Simpson's index of biodiversity is not an appropriate measure as it has produced similar results for three distinctly different sites. Hence, a proposed community effectiveness index (LEŚNIAK 1999) has been employed and apparently reflects the reality adequately. This measure is based on the product rather than the quotient of the number of species and individuals. Quotient-based measures produce erroneous results as the number of species changes much more slowly than the number of individuals. When the beetles' living conditions get worse, with both the number of species and individuals falling, but with the latter decreasing more abruptly, both Shannon-Wiener's and Simpson's indices will register an improvement, which is obviously absurd. For instance, if we are studying a site at two dates and a first collection yields 10 species represented by 100 individuals, while a second one registers 7 species and

50 individuals, Simpson's measure will increase from 30% to 35%, while the effectiveness measure, based on the square root of the product of the number of species and individuals will be decreased from 31.6 to 18.7, which definitely better reflects reality.

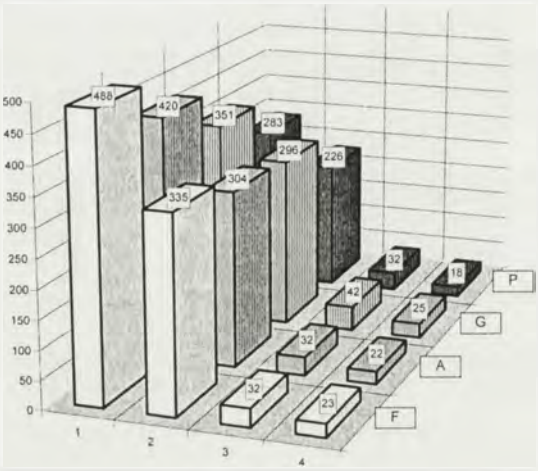

Fig. 4. Basic indices describing captured carabid beetles at 4 study sites in Świnia Góra reserve; F - beech stand, A - fir stand, G - forest meadow, P - pine stand, 1- individual abundance/10; 2 - community effectiveness index - CEI; 3 - Simpson's index/100, 4 - number of species.

Summary of results

It is rather difficult to discuss the findings of this study for three reasons. Firstly, there had been no other studies of the *Carabidae* of this reserve and secondly, the reserve represents a highly unique natural formation. Thirdly, when attempting to compare results of studies from different areas, one should at least choose projects relating to the same period. The results of numerous studies of *Carabidae* in Poland indicate that the time factor plays an important role with respect to variability of many ecological structures in *Carabidae* communities. This having been said, a comparison of qualitative shares of the zoogeographical elements in Świnia Góra reserve, in the Łysogóry mountain ridge and generally in the Świętokrzyskie Mountains, has been undertaken and is presented in Table XI (BURAKOWSKI *et al.* 1973, 1974).

Table XI. Comparison of the zoogeographical makeup of *Carabidae* communities of different areas in percentages. *Includes Świnia Góra data for 1992

Area / Zoogeographical elements	Świnia Góra* Reserve	Łysogóry mountain ridge	Świętokrzyskie Mountains
Holarctic	-	0.03	7.2
Palaearctic	26.6	12.9	46.1
Eurosiberian	28.0	8.5	11.2
Euroarctic	3.7	1.7	2.4
Euromediterranean	0.1	0.04	8.0
European silvan province	12.6	1.7	20.8
European silvan province (montane species)	28.2	75.1	4.0

The above table shows that the percentages obtained for Świnia Góra reserve come in between the finding for the other two areas. Catches in pine forest stands situated near the reserve have revealed much smaller numbers of species and individuals, which is secondary to their poorer habitats. Another exploration by the present author - of Białe Ługi reserve and adjacent pine forest stands (LEŚNIAK, from a monograph on Białe Ługi reserve, in press) - produced a higher number of species and individuals outside of the reserve, which was due to more fertile habitats. Thus, the granting of a legally protected status alone is not sufficient to induce noticeable changes in the quality of *Carabidae* communities.

To sum up the finding, the following can be posited:

1. The study material is of moderate size and the species richness of *Carabidae* in it is rather high. 33 species were found at the 4 sites in the reserve, including 3 species *Pterostichus caerulescens, Pt. vulgaris* i *Pt. aethiops* according to the catalogue of Polish Fauna never previously recorded from the Świętokrzyskie Mountains, while *Pt. burmeisteri* had never been registered from the Małopolska Upland.

2. A zoogeographical analysis showed that the Palaearctic and European silvan province elements were dominant, both qualitatively and quantitatively at all study sites. Montane species were most abundantly represented at the more fertile sites (beech and fir forest stands).

3. Three species were established as dominants in *Carabidae* communities in Świnia Góra reserve, namely *Carabus linnaei, Pterostichus oblongopunctatus* and *Pt. niger.*

4. Approximately 95% of the collections was made up of forest species.

5. In terms of moisture requirements, the largest group was that of hygrophilous species (over 80%). A high proportion (> 19%) of species regarded to date as xerophilous was found in biotopes subject to periodical inundation in spring, which suggests that they should rather be classified as heliophilous species.

6. Species classified in large zoophages were most abundant at the study sites, with hemizoophages occurring hardly at all.

7. More than 80% of all *Carabidae* individuals collected in Świnia Góra reserve belonged to the autumnal developmental type.

8. *Carabidae* species occurred with the greatest constancy in the beech forest stand, which was the most fertile.

9. The communities under study were characterised by a high degree of quantitative (60%) and combined species-based and quantitative (> 50%) similarity. The forest meadow community and pine stand communities were the most different.

10. Seasonal dynamics of the dominant species of *Carabidae* showed differences between species and across years of study.

11. The beech forest stand supported the richest *Carabidae* community.

12. A new indicator, the community effectiveness index, is proposed which describes a community better than Simpson's index.

13. Constancy analyses indicate that spatial organisation is different in open-area and forest-dwelling communities of *Carabidae*.

The results of this study of *Carabidae* communities of Świnia Góra reserve may form a basis for further investigations. It seems that these explorations need to be

continued with marked changes, both qualitative and, particularly, quantitative, taking place now in epigeal beetle communities that play a major role in the process of litter breakdown, which is also of economic importance.

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STRESZCZENIE

[Tytuł: Biegaczowate (*Carabidae, Coleoptera*) Rezerwatu Świnia Góra w Górach Świętokrzyskich]

W latach 1990-92 przeprowadzono w lasach bukowych, jodłowych i sosnowych oraz na łące śródleśnej w rezerwacie Świnia Góra badania naziemnych zgrupowań *Carabidae*. Stosowano standardową metodę odłowów metodą pułapek Barbera modyfikacji Szyszko. Odłowiono ponad 15 000 osobników *Carabidae* należących do 33 ga-

tunków. Zebrany materiał poddano szczegółowej analizie zoogeograficznej, ekologicznej i faunistycznej. W wyniku przeprowadzonych prac stwierdzono, że na obszarze badanych powierzchni rezerwatu dominowały:

- elementy zoogeograficzne palearktyczny i europejskiej prowincji leśnej
- gatunki leśne (ca 95%)
- gatunki higrofilne (> 80%)
- duże zoofagi
- gatunki zaliczane do jesiennego typu rozwojowego (> 80%).

Ponadto stwierdzono najbogatszą (największą liczbę gatunków i osobników) faunę *Carabidae* w drzewostanie bukowym oraz wysokie podobieństwo ilościowe i gatunkowo-ilościowe zgrupowań *Carabidae* na badanych powierzchniach.