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Carabidae (*Coleoptera*) of pine forests in Poland

[With 5 tables and 3 figures in text]

Abstract. The paper contains the results of study of pine forest *Carabidae*, living in five areas: Babimost forest distr. near Poznań, Bory Tucholskie, Puszcza Białowieska, Puszcza Biała and Roztocze NP. The sample size was 39 000 pitfall per day, 16 647 *Carabidae* individuals of 52 species were collected. Ecological, zoogeographical and faunistical analyses were carried out. The analyses showed that the conditions of *Carabidae* communities changed for the worse. This situation concerns especially Babimost and Bory Tucholskie communities.

INTRODUCTION

The following paper is a part of a larger survey "Species composition and structure of pine forests fauna". The survey is the first attempt to comprehensively describe the fauna of pine forests in Poland. In addition to their scientific and cognitive value, studies of pine forest fauna are important in a more practical sense, since a threat exists that pine forest in almost the whole country may be severely damaged by noxious foliophagous insects, called "primary pests" by foresters. In order to show how grave the problem is, let us just mention that within the last ten years the total area of pine forest stands endangered by primary pests has reached 7200 thousand hectares (about 28 000 square mi.), which is roughly equal to the total area of all forests in Poland (ZWOLIŃSKA 1991).

The subject of this paper are ground beetles (*Carabidae*). These beetles play an important role in forest biocenoses — among other things they keep down larval stages of noxious foliophagous insects. *Carabidae* appear to be the most numerous epigeic animals of those caught in pit fall traps. The taxonomy of *Carabidae* has been well studied, and more and more data are collected concerning their ecology.

Many papers by Polish authors deal with the ecology of *Carabidae* of pine forests. The most comprehensive papers are those by GRÜM (1971, 1976), LEŚNIAK (1972, 1980) and SZYSZKO (1974, 1983). Besides theses in ecology and

faunistics have been written in recent years (HURUK 1989, MĘŻYK 1990, and PAJKERT 1989) concerning *Carabidae*, with chapters on *Carabidae* of pine forests. It should be stressed, however, that none of the papers mentioned above was a part of a complex research over the animals of pine forests. Therefore, the aim of this work is not only to examine the current situation of ground beetles in Polish coniferous forests, but also to estimate this taxon's role and significance to the fauna as a whole.

THE AREA AND METHODS OF RESEARCH

The researches were conducted continuously during the vegetational seasons in 1986 and 1987. The research areas comprised mature pine forest stands representing *Peucedano-Pinetum*-type forest (Puszcza Biała and Puszcza Białowieska) and *Leucobryo-Pinetum*-type forest (Roztocze NP, Bory Tucholskie and Babimost forest distr. near Poznań). In terms of forest typology, both units of vegetation belong to the pine forest type of habitat (MATUSZKIEWICZ, DEGÓRSKI, KOZŁOWSKA 1993).

The five areas mentioned above differ in terms of hylopathology. They are situated in different wholesomeness zones of forest stands. According to NUNBERG (1951), Babimost forest distr. and Bory Tucholskie are located in the zone of constant exposure to noxious pests insects, while Puszcza Biała, Puszcza Białowieska and Roztocze PN are resistant to pests. KOEHLER (1971) classifies only Bory Tucholskie in the zone of the greatest exposure. According to him Puszcza Białowieska belongs to the zone of low exposure to pests and the remaining three areas belong to moderate exposure zone.

The author's own studies on the monitoring of forest soil fauna and the occurrence of noxious insects during the last decade show Nunberg's classification to be more appropriate.

The catches were conducted in the following forest divisions:

Babimost forest district – 103, 105

Bory Tucholskie – 306, 340, 346

Puszcza Białowieska – 538, 667, 668

Puszcza Biała – 34, 38, 62

Roztocze NP – 38, 178, 198.

In order to provide as complete a description of the fauna of the analysed areas as possible, a couple of methods for collecting specimens were employed apart from Barber's pitfall traps; including soil sifting, Moericke's traps, and sweeping nets. However, the analysis of the collected materials of *Carabidae* proved once again that only Barber's pitfall traps (with ethylene glycol) can provide a vast and objectively diversified sample of this taxon.

Thirty traps worked continuously in each of the areas during the two-years-long research. A total of 39 000 pitfall trap per day were obtained (3000 in Babimost forest distr. and 9000 in each of the remaining objects). Only *Carabidae* caught from May to September were taken into consideration, since only few ground beetles can be collected during the rest of the year. Moreover, only data obtained in this way can be compared to the results of other studies. The

total number of collected *Carabidae* was 16 647 individuals of 52 species and 17 genera.

In order to determine the character of fluctuations in *Carabidae* communities of pine forests, species similarity indices and qualitative-quantitative similarity indices were calculated for each of the analysed areas. The former were obtained according to Jaccard's formula, the latter – Bekhlemishev's modification of Jaccard's formula.

Classes of dominance and frequency were determined and the average biomass of all community members was counted for the sake of an ecological analysis (SZYSZKO 1983).

Classes of dominance – this ecological characteristic was determined according to the following criteria:

I class of dominance – individuals of a given species constitute more than 10% of the whole community
II class – the figures range from 5.1 to 10%
III class – from 1.1 to 5.0%
IV class – less than 1.0%.

Classes of frequency – the following classification was adopted:
class 1 – the species was registered in 75.1–100% of samples
class 2 – 25.1–75.0% of samples
class 3 – 10.1–25% of samples
class 4 – less than 10.0% of samples.

The specimens were also classified by their trophic type as large zoophages, small zoophages and hemizoophages, the last term comprising species whose larvae are predator and imagines are phytophagous.

PRESENTATION OF RESULTS AND DISCUSSION

Table I presents the data on the numbers of *Carabidae* collected.

Faunistical analysis.

The majority of the species collected are forms typical of pine forests. They have been registered in most of studies on *Carabidae* living in these habitats. Out of these species, the most interesting are: *Carabus intricatus* L., *Carabus cancellatus*, *Metabletus forveatus*, and *Microlestes minutulus*.

C. intricatus is now an extremely rare species, but as many as 72 individuals were collected in Puszcza Biała. This species is typical for mature deciduous forests. In the region of Podlasie it was recorded only in two studies – by JACOBSON in 1901 and by KAPUŚCIŃSKI and BORUSIEWICZ in 1950 (MROCZKOWSKI, BURAKOWSKI, STEFAŃSKA 1964). The fact that so many individuals of this species were found in Puszcza Biała seems to prove that these areas were afforested with deciduous trees during past cutting rotations. This hypothesis is strengthened by the analysis of soil types in these areas. The soils also have an influence, though an indirect one, on the more than double increase in the number of *Carabidae* collected.

Table I. Number of *Carabidae* (*Coleoptera*) caught in definite areas in 1986-1987.

Lp.	Areas	Babimost forest distr.			Bory Tucholskie				Puszcza Białowieska				Puszcza Biała				Roztocze NP				Total
	division / species	103	105	sum	306	340	346	sum	538	667	668	sum	34	38	62	sum	38	178	198	sum	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	*Carabus coriaceus* L.	14	10	24	0	5	0	5	1	2	7	10	22	98	54	174	4	31	61	96	309
2	*C. intricatus* L.	0	0	0	0	0	0	0	0	0	0	0	20	44	8	72	0	0	0	0	72
3	*C. violaceus* L.	0	0	0	63	41	7	111	13	37	18	68	3	65	17	85	170	79	35	284	548
4	*C. convexus* FABR.	0	0	0	11	6	13	30	1	26	16	43	9	0	25	34	0	1	0	1	108
5	*C. nitens* L.	0	0	0	0	2	26	28	0	0	0	0	0	0	0	0	0	0	0	0	28
6	*C. granulatus* L.	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	2
7	*C. cancellatus* ILL.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	3	11	11
8	*C. arcensis* HERBEST.	1	0	1	465	230	223	918	65	250	94	409	791	1787	1682	4260	224	737	694	1655	7243
9	*C. nemoralis* O. F. MULLER	0	2	2	1	6	0	7	1	1	1	3	14	3	1	18	0	0	0	0	30
10	*C. hortensis* L.	2	0	2	8	4	4	16	76	66	196	338	2	0	33	35	5	30	2	37	428
11	*C. glabratus* PAYK.	0	0	0	0	0	0	0	7	45	40	92	0	0	0	0	2	13	0	15	107
12	*C. linnaei* DUFT.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	32	0	36	36
13	*Cychrus attenatus* (FABR.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
14	*C. caraboides* (L.)	0	0	0	0	0	0	0	1	6	13	20	3	2	1	6	11	11	5	27	53
15	*Leistus rufomarginatus* (DUFT.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3
16	*L. ferragineus* (L.)	139	14	153	0	12	3	15	0	0	0	0	1	1	0	2	0	0	0	0	170
17	*L. piceus* FROL.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
18	*Notiophilus aquaticus* (L.)	2	0	2	16	1	0	17	3	1	0	4	2	1	3	6	0	1	5	6	35
19	*N. biguttatus* (FABR.)	1	1	2	49	49	18	116	33	2	4	39	1	1	47	49	1	19	0	20	226
20	*N. palustris* (DUFT.)	3	0	3	4	1	0	5	5	2	2	9	0	0	1	1	0	0	0	0	18
21	*Loricera caerulescens* (L.)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
22	*Broscus cephalotes* (L.)	0	0	0	0	1	0	1	0	0	0	0	2	0	0	2	0	0	0	0	3
23	*Epaphius secalis* (PAYK.)	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	2
24	*Amara familiaris* (DUFT.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
25	*A. lunicollis* SCHIODTE	0	1	1	0	0	0	0	3	2	0	5	0	0	0	0	0	0	0	0	6
26	*A. erratica* (DUFT.)	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
26	*A. brunnea* (GYLL.)	0	0	0	0	0	1	1	24	11	13	48	0	0	0	0	0	0	0	0	49
28	*A. aulica* (PANZ.)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	3
29	*Pterostichus cupreus* (L.)	0	1	1	0	0	0	0	7	2	0	9	2	4	3	9	3	1	3	7	26
30	*Pt. virens* (O. F. MULLER)	0	0	0	1	0	1	2	1	0	0	1	0	8	7	15	0	0	3	3	21
31	*Pt. augustatus* (DUFT.)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	2
32	*Pt. oblongopunctatus* (FABR.)	20	6	26	62	131	273	4666	112	278	400	790	152	247	636	1035	62	223	131	416	2733
33	*Pt. niger* (SCHALL.)	45	116	161	162	32	18	212	9	68	97	174	29	168	278	475	92	42	44	178	1200
34	*Pt. vulgaris* (L.)	0	1	1	0	0	1	1	2	0	1	3	0	0	0	0	1	0	0	1	6
35	*Pt. nigrita* (FABR.)	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
36	*Pt. strennus* (PANZ.)	0	0	0	0	0	0	0	0	2	0	2	1	0	0	1	0	0	0	0	3
37	*Pt. aethiopis* (PANZ.)	0	0	0	0	0	0	0	0	39	29	68	15	57	105	177	182	127	83	392	637
38	*Abax carinatus* (DUFT.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
39	*A. parallelopideus* (PILL. et MITT.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
40	*Calathus erratus* (C. R. Sahl.)	43	0	43	7	4	4	15	1	0	0	1	2	12	13	27	0	1	1	2	88
41	*C. melanocephalus* (L.)	166	4	170	5	4	1	10	0	1	2	3	0	1	13	14	0	0	0	0	197
42	*C. micropterus* (Duft.)	169	54	223	751	269	295	1315	43	23	134	200	90	102	222	414	1	0	5	6	2158
43	*Synuchus nivalis* (Panz.)	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	2
44	*Agonum sexpunctatum* (L.)	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	2
45	*Ag. assimile* (Payk.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	2
46	*Ag. obscurum* (Herbst.)	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
47	*Harpalus rufipes* (de Geer.)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1
48	*H. latus* (L.)	0	5	5	0	1	0	1	5	7	4	16	16	0	0	19	0	3	1	4	45
49	*Metabletus foreatus* (Fourcr.)	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1
50	*Microlestes minutulus* (Goeze)	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
51	*Cymindis humeralis* (Fourcr.)	1	0	1	6	1	0	2	0	0	0	0	0	0	0	0	0	0	4	4	7
52	*C. vapovariorum* (L.)	5	0	5	1	1	0	7	0	0	0	0	0	0	0	0	0	0	0	0	12
Total		612	220	832	1613	801	889	3303	414	875	1073	2362	1177	2603	3154	6934	769	1365	1082	3216	16647

C. cancellatus, *M. foveatus* and *M. minutulus* are beetles of open areas that are found only in forests by chance. *M. foveatus* and *M. minutulus* are rare species and they were never registered in Puszcza Biała and Podlasie respectively.

16 out of 52 species recorded are forms very typical for pine forests. They were registered in all of the areas or in four of them. Their names are: *Carabus coriaceus*, *Carabus violaceus*, *Carabus convexus*, *Carabus arcensis*, *Carabus nemoralis*, *Carabus hortensis*, *Notiophilus aquaticus*, *Notiophilus biguttatus*, *Notiophilus palustris*, *Pterostichus oblongopunctatus*, *Pterostichus niger*, *Calathus erratus*, *Calathus melanocephalus*, *Calathus micropterus* and *Harpalus latus* (Tab. I).

Twenty species were noted in one area only. They fall into two categories. The first one comprises species like *Cychrus attenuatus* or *Carabus linnaei* that are found only in the mountains and plateau of southern Poland and not in the lowlands. The other group contains simply rare species that are recorded only accidentally. Most of the species registered in two areas only should also be included in this group.

The most widespread species are usually the most abundant ones. This is a self-evident regularity, but exceptions to this rule do exist. For instance, *Harpalus latus*, *N. aquaticus*, *N. palustris*, *Cychrus caraboides*, *Pterostichus cupreus*, *Pterostichus virens* are very widely spread, but they are not numerous species.

Ecological analysis

Table II presents data on the abundance of *Carabidae* in each analysed area, the number of species and the trapability of specimens caught. Compared with results of other studies on the *Carabidae* of Polish forests, the data show that the number of species falls between the existing standards, while the number of individuals is alarmingly low (with the exception of Puszcza Biała study areas). Similar data from 1978-1980 catches conducted in five national parks provide a good basis for comparison (LEŚNIAK 1980).

Table II. Number of *Carabidae* (*Coleoptera*) caught in definite studied area.

Area	Number of species	Average trpability
Babimost forest distr.	21	0.28
Bory Tucholskie	25	0.37
Puszcza Białowieska	30	0.26
Puszcza Biała	26	0.77
Roztocze NP	32	0.36
Total	52	0.43

Current average numbers of *Carabidae* caught per one pitfall trap per day turn out to be considerably lower that those of the 1978-1980 research. Following are the data from 1980:

Name of the area	The number of Carabidae specimens per pitfall trap per day
Roztocze NP	0.87
Wolin NP	0.75
Bieszczady NP	0.42
Karkonosze NP	0.34

A conclusion can be drawn from the above comparison that ten years ago more of these useful insects were collected even in Karkonosze NP – an area of a recognized ecological disaster – than today not only in sulphur-free Puszcza Białowieska as well. One can, of course, make assumptions that *Carabidae* are now a taxon "retrogradation" but the ecological and zoogeographical analysed provide further evidence for the worsening condition of *Carabidae* communities of pine forests.

Species similarity and qualitative-quantitative similarity indices were computed for *Carabidae* communities of each analysed area in order to determine the character of fluctuations in *Carabidae* communities in pine forests. The results are shown in detail in Table III. The indices, and especially the indices of species similarity were usually high, which proves that the areas were chosen appropriately. Puszcza Białowieska recorded the highest indices in relation to all the remaining areas, while the lowest – especially Bekhlemishev's index of qualitative-quantitative similarity – were computed for Babimost forest distr. This is probably due to the fact that in this area the analysed forest stands grow on formerly arable soil. On the other hand, it was very easy to account for the lowest species similarity indices noted for Roztocze NP in relation to all the remaining areas. In geobotanical terms this area belongs to the Pontic Division, and a number of mountain *Carabidae* species are found in this park and not in any of the remaining areas.

Table III. Similarity of *Carabidae* (*Coleoptera*) communities — quantitative by Jaccard and qualitative by Bekhlemieshev — in studied areas.

	Babimost forest distr	Bory Tucholskie	Puszcza Białowieska	Puszcza Biała	Roztocze NP
Babimost forest distr.	X	53.3 12.9	45.7 16.1	46.9 6.8	35.9 6.1
Bory Tucholskie		X	52.9 33.7	54.5 28.0	40.0 34.9
Puszcza Biała			X	55.6 25.4	62.5 29.3
Puszcza Białowieska				X	34.9 36.2
Roztocze NP					X

Table IV presents the detailed results of the ecological analysis of the materials collected. The following characteristics of *Carabidae* species are contained there: type of a phagous group, biomass, dominance index, frequency index.

Table IV. General comparison of ecological data 1986-1987). Founctional groups: Z – large zoophages, z –small zoophages, hz – hemizoophages. Zoogeographical elements. Explanation as in Tab. V. D – dominance (class I–IV), F – frequency (class 1–4)

No	Species	Functional groups	Zoogeographical elements	Average biomass of indyviduals g	Areas															
					Babimost forest distr.		Puszcza Biała				Puszcza Białowieska				Bory Tucholskie				Roztocze NP			
					D	F	D		F		D		F		D		F		D		F	
					87	87	86	87	86	87	86	87	86	87	86	87	86	87	86	87	86	87
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	*Carabus coriaceus*	Z	Epl	1.742	III	3	III	III	4	4	IV	IV	2	2	IV	IV	–	–	III	III	3	3
2	*C. intricatus*	Z	Epl	0.611	–	–	IV	III	3	3	–	–	–	–	–	–	–	–	–	–	–	–
3	*C. violaceus*	Z	P	0.75	–	–	III	III	3	3	III	III	4	3	III	III	4	3	II	II	4	3
4	*C. convexus*	Z	ES	0.27	–	–	IV	IV	3	3	III	III	3	3	IV	IV	3	3	II	II	–	1
5	*C. nitens*	Z	EA	0.191	–	–	–	–	–	–	–	–	–	–	IV	IV	2	2	–	–	–	–
6	*C. granulatus*	Z	ES	0.185	–	–	–	–	–	–	IV	–	1	–	–	–	–	–	IV	IV	1	–
7	*C. cancellatus*	Z	ES	0.317	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	IV	2	2
8	*C. arcensis*	Z	P	0.219	II	1	I	I	4	4	I	I	4	4	I	I	4	4	I	I	4	4
9	*C. nemoralis*	Z	Epl	0.4	II	1	IV	IV	2	3	IV	IV	1	1	IV	IV	1	2	–	–	–	–
10	*C. hortensis*	Z	Epl	0.548	II	1	IV	IV	3	3	I	I	4	4	IV	IV	2	3	III	IV	3	2
11	*C. glabratus*	Z	WA	0.704	–	–	–	–	–	–	III	III	3	3	–	–	–	–	IV	IV	2	2
12	*C. linnaei*	Z	Eplg	0.201	–	–	–	–	–	–	–	–	–	–	–	–	–	–	III	III	3	3
13	*Cychrus attenatus*	Z	Eplg	0.17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	IV	1	1
14	*C. caraboides*	Z	EA	0.214	–	–	–	–	2	–	IV	IV	2	3	–	–	–	–	IV	IV	3	3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
15	*Leistus rufomarginatus*	z	Epl	0.036	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	IV	1	–
16	*L. ferrugineus*	z	EA	0.025	I	4	IV	IV	1	1	–	–	–	–	IV	IV	2	2	–	–	–	–
17	*L. piceus*	z	Eplg	0.031	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	IV	1	–
18	*Notiophilus aquaticus*	z	H	0.007	IV	1	IV	IV	1	1	IV	IV	1	1	IV	IV	1	3	IV	IV	1	2
19	*N. biguttatus*	z	P	0.007	IV	1	III	IV	3	2	III	III	3	3	III	III	3	4	IV	IV	2	2
20	*N. palustris*	z	P	0.007	IV	2	IV	–	1	–	IV	IV	2	2	–	IV	–	1	–	–	–	–
21	*Loricera caerulescencens*	z	H	0.027	–	–	–	IV	–	1	–	–	–	–	–	–	–	–	–	–	–	–
22	*Broscus cephalotes*	Z	ES	0.281	–	–	IV	–	1	–	–	–	–	–	–	IV	–	1	–	–	–	–
23	*Epaphius secalis*	z	P	0.003	–	–	–	–	–	–	IV	IV	1	1	–	–	–	–	–	–	–	–
24	*Amara familiaris*	hz	P	0.013	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	IV	–	–
25	*A. lunicollis*	hz	P	0.019	IV	1	–	–	–	–	IV	IV	–	1	–	–	–	–	–	–	–	–
26	*A. erratica* (DUFT.)	hz	H	0.013	–	–	–	–	–	–	–	IV	1	1	I	I	1	1	I	I	1	1
27	*A. brunnea* (GYLL.)	hz	H	0.013	–	–	–	–	–	–	III	III	3	3	IV	–	1	–	–	–	–	–
28	*A. aulica* (PANZ.)	hz	P	0.033	IV	1	–	–	–	–	–	–	–	–	–	–	–	–	IV	IV	1	–
29	*Pterostichus cupreus* (L.)	z	P	0.078	IV	1	IV	IV	2	2	IV	IV	1	2	–	–	–	–	IV	IV	1	2
30	*Pt. virens* (O. F. MULLER)	z	ES	0.084	–	–	IV	IV	3	2	IV	–	1	–	–	IV	–	1	IV	IV	1	1
31	*Pt. augustatus* (DUFT.)	z	Epl	0.057	–	–	–	IV	–	1	–	–	–	–	–	–	–	–	–	–	–	–
32	*Pt. oblongopunctatus* (FABR.)	z	P	0.057	III	3	I	I	4	4	I	I	4	4	I	I	4	4	I	I	4	4
33	*Pt. niger* (SCHALL.)	Z	ES	0.22	I	4	II	III	4	4	II	III	4	3	III	II	3	4	II	II	3	4
34	*Pt. vulgaris* (L.)	Z	ES	0.134	IV	1	–	–	–	–	IV	–	1	–	–	IV	1	–	IV	–	1	–
35	*Pt. nigrita* (FABR.)	z	P	0.004	–	–	–	–	–	–	–	–	–	–	IV	–	1	–	–	–	–	–
36	*Pt. strennus* (PANZ.)	z	P	0.013	–	–	–	IV	–	1	–	IV	–	1	–	–	–	–	–	–	–	–

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
37	*Pt. aethiopis* (PANZ.)	z	Epl	0.093	–	–	III	III	4	4	III	III	3	3	–	–	–	–	I	I	4	4
38	*Abax carinatus* (DUFT.)	Z	Eplg	0.158	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	–	1	–
39	*A. parallelopideus* (PILL. et MITT)	Z	Epl	0.28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	–	1	–
40	*Calathus erratus* (C. R. SAHL)	z	P	0.046	II	3	IV	IV	3	3	IV	–	1	–	IV	IV	2	3	–	IV	–	1
41	*C. melanocephalus* (L.)	z	P	0.019	I	3	IV	IV	2	2	IV	–	1	–	IV	IV	1	3	–	–	–	–
42	*C. micropterus* (DUFT.)	z	P	0.019	I	4	II	II	4	4	II	I	4	4	I	I	4	4	IV	IV	1	1
43	*Synuchus nivalis* (PANZ.)	z	ES	0.019	–	–	I–	–	–	–	–	–	–	–	–	–	–	–	IV	–	1	–
44	*Agonum sexpunctatum* (L.)	z	P	0.027	–	–	–	–	–	–	–	–	–	–	–	IV	–	1	IV	–	–	1
45	*Ag. assimile* (PAYK.)	z	P	0.061	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	IV	–	1
46	*Ag. obscurum* (HERBST.)	z	H	0.013	IV	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	*Herpalus rufipes* (DE GEER.)	hz	P	0.126	–	–	IV	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
48	*H. latus* (L.)	hz	P	0.045	IV	1	IV	IV	1	2	IV	IV	2	2	IV	IV	–	1	IV	IV	2	1
49	*Metabletus foreatus* (FOURCR.)	z	P	0.002	–	–	–	–	–	–	–	IV	1	–	–	–	–	–	–	–	–	–
50	*Microbites minutulus* (GOEZE)	z	P	0.002	–	–	–	–	–	–	IV	–	–	1	–	–	–	–	–	–	–	–
51	*Cymindis humeralis* (FOURCR.)	z	ESr	0.048	IV	1	–	–	–	–	–	–	–	–	IV	IV	–	1	IV	IV	1	1
52	*C. vapovariorum* (L.)	z	P	0.027	IV	2	–	–	–	–	–	–	–	–	IV	IV	1	2	–	–	–	–

The trophic type functional group

As far as trophic type is concerned, *Carabidae* fall into three categories:

– large zoophages – forms preying on large epigean invertebrates like larvae of noxious foliophages, snails, etc.

– small zoophages – predator forms that regulate the abundance of smaller invertebrates in the saprotrophic sub-system

– hemizoophages – species whose larvae are carnivorous and imagines are phytophagous.

Fig. 1 shows the percentages of the mentioned above functional groups in *Carabidae* communities of the studied objects.

Fig. 1. Contribution of the functional groups in *Carabidae* (*Coleoptera*) communities in 1986-87. Z – large zoophages, z – small zoophages, hz – hemizoophages

The author's former studies of *Carabidae* living in areas of the gradation of foliophages and in National Parks have shown that with decreasing soil fertility large zoophages would become less abundant in a community and the number of small zoophages would grow. Where the habitat was seriously damaged by man, the number of hemizoophages would also rise. The current data intriguing: the total abundance of *Carabidae* communities has decreased, but the structure of phagous groups has improved (the percentage of large zoophages has increased). This may result from large-scale changes taking place in Polish forests: once solid coniferous forest stands have been considerably thinned (as a result of industrial pollution, decreasing underground water levels, pest damage).

Owing to this, deciduous plants could enter the brushwood as well as the second floor of the forest stand. These changes might have resulted in better conditions for large zoophages.

The diagrams show that Babimost forest distr. and Bory Tucholskie display a different pattern of proportions between the functional groups than the remaining three areas. Small zoophages are the dominant group in the two areas, which is indicative of worse environmental conditions for *Carabidae* communities. This is also an indirect indication that forest's health conditions in these stands are bad. The data for Puszcza Białowieska *Carabidae* community are also alarming – the proportions of large and small zoophages are equal there and the proportion of hemizoophages is the highest for all areas. This is indicative of the presence of some intensive stressor. One possible explanation may be disturbances of water balance in Puszcza Białowieska.

The average biomass of individuals of all *Carabidae* species in a given community (Szyszko 1983).

The materials collected were sufficient to count the average individual biomass for the communities of each area. The figures are a good indication of whether a given environment is fit for ground beetles. One can also make estimations about the forest stand's potential for growth using these figures since they correlate with soil fertility. They are also closely correlated with the afore-mentioned structure of phagous groups. The following figures were obtained:

The name of the area	The average dry mass of one individual
Babimost forest distr.	0.114 g
Bory Tucholskie	0.127 g
Puszcza Białowieska	0.211 g
Puszcza Biała	0.227 g
Roztocze NP	0.278 g

Compared with other characteristics, these figures seem to be good estimations of the state of the environment. In the above chart, living conditions for *Carabidae*, state of health of forest stands and their potential for growth have been grouped progressively from the worst to the best.

Dominance and frequency in *Carabidae* communities

The analysis of the data on dominance and frequency structures shows *Carabidae* communities to possess a high degree of organization and stability. The studied species have usually not changed their dominance of frequency classes over time. A more detailed analysis shows that the rare changes that do occur are actually inconsiderable. It is normally "border-case" species that change their dominance or frequency classes. The stability of *Carabidae* communities proves once again that this taxon is a prime object for bioindicative studies. Less stable structures are not that useful for that purpose, especially when the habitat conditions are rapidly changing.

As can be seen, the contributions of the most abundant species (the first class of dominance) to the communities are very high (Fig. 2). A high contribution of eudominant species is indicative of environmental conditions that are unfavourable for the forest and its epigic components (LEŚNIAK 1979). This holds true especially for Babimost forest distr. and Bory Tucholskie, which corresponds with the results of other analyses.

Fig. 2. Contribution of dominance classes in *Carabidae* (*Coleoptera*) communities in 1986-87
I, II, III, IV — dominance classes.

Figure 3 presents data on dominance for the 5 most abundant species in each area. The following species appear to be the most abundant in the five areas (in the descending order of total contributions of the species to the communities of various areas): *Carabus arcensis*, *Pterostichus oblongopunctatus*, *Calathus micropterus*, *Pterostichus niger*, *Carabus hortensis*, *Carabus violaceus*, *Leistus ferrugineus*, *Pterostichus aethiops*, *Calathus melanocephalus*, *Notiophilus biguttatus*, *Calathus erratus*. These species are the most typical representatives of pine forest *Carabidae* communities.

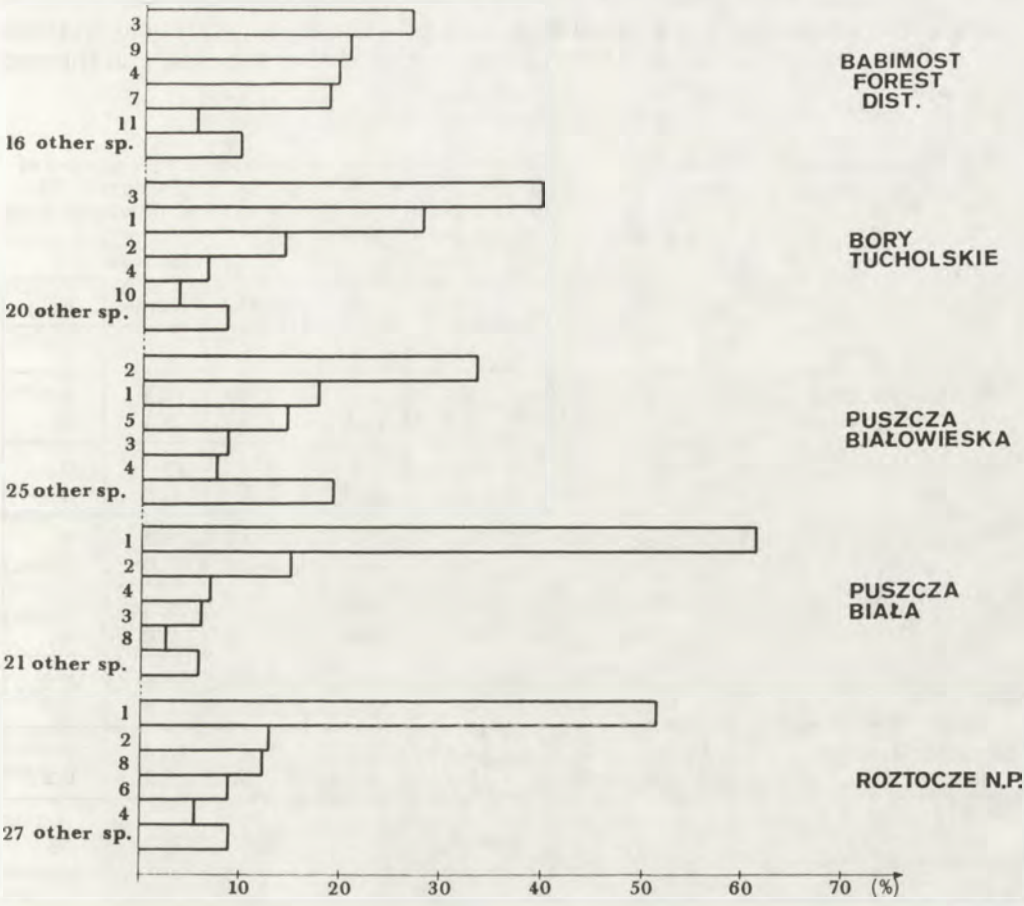

Fig. 3. Contribution of 5 the most abundant species in *Carabidae* (*Coleoptera*) communities in 1986-87. 1 – *Carabus arcensis*, 2 – *Pterostichus oblongopunctatus*, 3 – *Calathus micropterus*, 4 – *Pterostichus niger*, 5 – *Carabus hortensis*, 6 – *Carabus violaceus*, 7 – *Leistus ferrigineus*, 8 – *Pterostichus aethiops*, 9 – *Calathus melanocephalus*, 10 – *Notiophilus biguttatus*, 11 – *Calathus erratus*

Zoogeographical analysis

The basis for classifying *Carabidae* as different zoogeographical elements was the author's own classification (LEŚNIAK 1987). The data in Tab. V concerning the percentages of *Carabidae* species and individuals classified as different zoogeographical elements provide yet further evidence for the hypothesis that the situation in Polish forest is deteriorating. A considerable increase in the percentage of palearctic species is a sign of this alarming process. Compared with the results of a similar zoogeographical analysis carried out only ten years ago, the current results show that severe unfavourable changes have been taking

place. In Roztocze NP, for instance, the mountain element amounted to 31.8% of the community; now it only amounts to 12.5%. The zoogeographical analysis also points to Babimost forest distr. and Bory Tucholskie as the most endangered regions.

Table V. Contribution of zoogeographical elements of the *Carabidae* communities (% number of species/% number of specimens). Zoogeographical elements: H – Holarctic, P – Palearctic, ES – Euro-Siberian, EA – Euroarctic, ESr – Euro-Mediterranean, Epl – European forest provinces, Eplg – European forest provinces-mountain.

Zoogeogaphical elemements	H	P	ES	EA	ESr	Epl	Eplg
Area							
Babimost forest distr.	9.5 0.8	57.1 57.8	9.5 19.5	4.8 18.4	4.8 0.1	14.3 3.4	0 0
Bory Tucholskie	8 0.5	48 89.9	20 7.4	8 1.3	4 0.1	12 0.8	0 0
Puszcza Białowieska	10 2.2	50 65.9	20 9.4	6.7 4.7	0 0	13.3 17.8	0 0
Puszcza Biała	3.1 0.2	46.1 85.3	15.4 7.6	7.7 0.1	0 0	23.1 6.9	0 0
Roztocze NP	3.1 0.2	37.6 74.6	21.9 6.1	6.2 1.3	3.1 0.1	15.6 16.5	12.5 1.2
Total	9.6 0.5	42.3 80.2	15.4 8.1	7.7 2.1	1.9 0	15.4 8.5	7.7 0.2

SUMMARY

The following conclusions can be drawn from the analysis of the data obtained:

1. Comparing the current data to the results obtained in 1980, we can say that the abundance of the *Carabidae* has fallen, but the number of species has not changed.

2. A distinct (more than double) increase in the abundance of *Carabidae* in Puszcza Biała, as compared to other areas is due to more fertile soil.

3. The structure of trophic type groups has also changed – the contribution of small zoophages has increased.

4. The observed high contribution of eudominant species is due to currently unfavourable environmental conditions.

5. The contribution of zoogeographical elements of the European forest province has decreased, while the contribution of the palearctic element has increased.

6. All the analyses show the communities of Babimost forest distr. and Bory Tucholskie to be in the worst condition. Both of these areas are situated in the zone of constant exposure to noxious insects.

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STRESZCZENIE

[Tytuł: *Carabidae* (*Coleoptera*) borów sosnowych Polski.]

W latach 1986 i 1987 badano skład gatunkowy i struktury zgrupowań *Carabidae* sosnowych borów świeżych.

Odłowy wykonano przy użyciu standardowej metody pułapek Barbera z glikolem etylenowym. Wielkość próby wynosiła 39 tys. dobocylindrów. W pięciu badanych obiektach: nadleśnictwo Babimost, Bory Tucholskie, Puszcza Białowieska, Puszcza Biała, Roztoczański Park Narodowy odłowiono 16 647 osobników *Carabidae* należących do 52 gatunków. Materiał ten poddano analizie faunistycznej, ekologicznej i zoogeograficznej.

Uzyskano następujące ważniejsze wyniki:

1. Znacznie spadła liczebność łowionych *Carabidae* (w stosunku do rezultatów uzyskiwanych w badaniach sprzed dziesięciu laty), ale nie zmniejszyła się liczba gatunków.

2. Wyraźnie wyższa była liczebność zgrupowań *Carabidae* w obiekcie Puszcza Biała, co jest związane z wyższą żyznością gleb.

3. Zmieniła się też struktura grup fagicznych – wzrósł udział dużych zoofagów.

4. Stwierdzono wysoki udział eudominantów w zgrupowaniach, co wiąże się z niekorzystnymi obecnie warunkami środowiskowymi.

5. Stwierdzono zmniejszenie udziału elementu zoogeograficznego europejskiej prowincji leśnej na korzyść elementu palearktycznego.

6. Najgorszy stan zgrupowań *Carabidae* – potwierdzony wszystkimi analizami stwierdzono w obiektach: nadleśnictwo Babimost i Bory Tucholskie, to jest w strefie stałego zagrożenia naszych lasów przez szkodliwe owady.

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