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**SPATIAL AND TEMPORAL DIFFERENTIATION
OF BEES (*APOIDEA*) IN THE FORESTS
OF WIELKOPOLSKI NATIONAL PARK, WESTERN POLAND**

**PRZESTRZENNE I CZASOWE ZRÓŻNICOWANIE *APOIDEA*
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Results of the investigations of spatial and temporal differentiations of *Apoidea* in the forests of Wielkopolski National Park were presented. It was shown that the both forest floor differ with the degree of species differentiation and domination's structure and total number of bees. In the herbaceous layer of the forests about twice as many species were found than in the crowns. Also the Shannon-Weaver's indices for bees communities of the herbs layer are higher in all three investigated forest ecosystems.

The curves of *Apoidea* numbers in tree crowns and forest floor were similar. The curves of *Apoidea* numbers in the deciduous forests have one peak in the first days of May. Whereas the curves of *Apoidea* numbers in the pine forest have multi peak course. It was proved that trees play an important role in feeding chain of bees inhabiting deciduous forests.

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1. INTRODUCTION

Annual cycle of the flora of deciduous forests of temperate zone is related mostly to the early spring and spring season, i.e. the period before appearance of leaves on trees. Also the fauna of pollinators of these communities appears mostly in spring deciding about reproduction success of the plants.

Most of the research carried out so far on pollination and forest plant pollinators concerns bottom floor of the forest – its vegetal cover. Traditionally the researchers concentrated on describing relations between one or few plant species and one or some species of bees which pollinated them. Comprehensive studies of the pollination dynamics of plant species and related to them pollinators can be found mostly in the works by Macior (1968 a, b, 1969, 1970 a, b). Pollination interrelationships of vernal, herbaceous angiosperms in a deciduous forest with particular emphasis on phenological integration of the bionomics of flowers and the annual colonies of *Bombus* pollinators were presented in another paper by Macior (1978). Pollination ecology of the spring wildflower community was studied by Motten (1986).

The pollinators of the vegetal cover of oak forest of Ukrainian forest steppe were investigated by Antonova (1979), and interactions between blooming time and pollination were studied by Schemske et al. (1978). A broad approach presenting seasonal dynamics of various *Apoidea* species on the background of blooming of herbaceous plants in Polish dry ground forests can be found in the works by Banaszak (1983, in press).

The least recognized layer of forest still remain tree crowns as a source of food for bees. It should be stressed here that the tree crowns environment is generally little known. The attempts in this direction are described by Denison (1973), Turnbull (1960) and Hesse (1940). A broad study on ecology and fauna of the arachnids of tree crowns was published in Poland by Dziabaszeński (1976). Banaszak (1991) gives introductory report of study on *Apoidea* of tree crowns. Concerning the bees it is generally known that some trees of the temperate zone such as lime, robinia and oders producing honey dew are a source of nectar flow for honey bee. However, we do not know to what degree the upper floor of a forest is penetrated by wild *Apoidea*. To answer this question was the main goal of this study. The research

concerned both deciduous and coniferous (pine) forests. The other problem was evaluation of phenological changes of *Apoidea* in the both examined kinds of forests.

2. STUDY SITE AND METHODS

In the years 1987 and 1988 *Apoidea* communities were studied on the area of the Wielkopolski National Park, western Poland. The field investigations were carried out from early April till October.

Three forest communities were studied:

- 1) low dry ground forest of natural character (oak-hornbeam forest – *Galio silvatici-Carpinetum*;
- 2) oak forest on *Galio silvatici-Carpinetum* site;
- 3) pine forest – *Leucobrio-Pinetum*.

Galio silvatici-Carpinetum (low dry ground forest on eastern bank on the Góreckie Lake). It is a fragment of a tree stand with well preserved natural character. It includes *Quercus robur* and *Carpinus betulus* as well as *Populus tremula* and individuals of *Tilia cordata* and *Fraxinus excelsior*. In the shrub layer *Corylus avellana* dominates. The herbaceous layer is well developed. Among the herbaceous plants the bee feeding species deserve attention: *Galeobdolon luteum*, *Ficaria verna* and *Convalaria maialis* cover commonly about 30% of the area of forest floor. Less numerous are: *Oxalis acetosella*, *Viola silvestris*, *Ajuga reptans*, *Alliaria officinalis*, *Maianthemum bifolium*, *Impatiens noli-tangere*, *Geranium robertianum*, *Pulmonaria obscura*, *Lathyrus vernus*, *Glechoma hederacea*.

Galio silvatici-Carpinetum (oak forest) near forester's lodge Górká. On dry ground site there is an artificial stand of 80–100 year old *Quercus robur* nad *Q. sessilis*. The stand is supplemented by individuals of birch *Betula verrucosa*, and by *Pinus silvestris*. In the undergrowth there is hornbeam (3–5 m tall). There are no shrubs. The vegetal cover plants of importance for bees are few, except for *Impatiens noli-tangere* which at its peak development stage covers up to 100% of the investigated area. On the borders of the area there are small patches (1–2 m²) of *Glechoma hederacea*, *Veronica chamaedrys* and *Ajuga reptans*. Beside it single plant of *Viola silvestris*, *Geranium robertianum*, *Stellaria palustris*, *Stellaria media*, *Mycellis muralis* and *Maianthemum bifolium* can be found.

Leucobrio-Pinetum (near the Piskorzewskie Meadows on the Dymaczewska Moraine). The investigated coniferous forest area (about 1 ha) is surrounded by mixed pine and oak forest. The stand includes almost exclusively 80 years old pine with single trees of oak *Quercus robur* and common birch. In the undergrowth layer are only single shrubs of alder buckthorn. The vegetal cover

has patches of *Vaccinium myrtillus* (about 10% of the area) and *Calluna vulgaris* (about 10% of the area). Beside it single specimens of *Linaria vulgaris*, *L. minor*, *Hypericum perforatum*, *Hieracium pilosella*, *Campanula rotundifolia*, *Viola silvestris*, *Euphorbia cyparissias* and *Impatiens noli-tangere* can be seen.

The material was caught using Moericke's colour traps (Moericke 1951). They were plastic bowls (dishes) of 20 cm diameter and 12 cm deep. They were filled with a liquid of the following composition: water 94.2%, ethylene glycol 5.6%, detergent 0.2%.

The bowls of 3 colours were used: white (natural colour of the plastic), yellow – inside and outside walls were painted with yellow (resembling rapeseed flower colour) phthalate paint, and blue (only in the second year of study). Application of the three colours was related to an attempt at evaluating the effect of trap colour on number and differentiation of caught bees. The results of that study are given in a separate paper (Banaszak, Cierznia, Szymański, 1994). The insects were removed from the traps at 7 day intervals, and the preserving liquid was supplement – at as required.

Two variants of trap locations were used to evaluate vertical distribution of bees in forest: 1) traps placed in herbs layer directly on the ground, three bowls of each colour, 2) traps hung in tree crowns (pine, oak, hornbeam), three bowls in each investigated community.

Each time when the researchers were in the forests they noted the plants that have blooming and visiting bees. In pre-spring and spring time, i.e. till the appearance of the leaves and shortly after the intensity of light reaching the forest bottom was observed. The measurements were made with actynometer. At describing each community the following parameters were considered: number of species, their relative size and Shannon and Weaver's index (H'). Statistical significance of differences between H' indices for different communities was estimated. The significance of the differences was assumed at the level $p = 0.05$.

3. RESULTS AND DISCUSSION

3.1. STRUCTURE OF *APOIDEA* COMMUNITIES IN THE FOREST ECOSYSTEMS

3.1.1. Oak-hornbeam forest

Forest floor. The *Apoidea* community has relatively high index of species differentiation – 3 bits. In the herbs layer 32 *Apoidea* species were observed ($n = 121$ insects) (Tab. I and III). This number is almost three times greater

then the one noted earlier in the same plant community using the „stalking” method and linear transect (Banaszak 1983). This proves great usefulness of colorful traps in catching bees which can catch the insects non-stop throughout the season.

Among the found species dominate the representatives of the *Andrenidae* family (Fig. 1) with dominating *Andrena haemorrhoa* (14.6%) and *A. lapponica* (13%), but with relatively high proportion of bumblebees *Bombus pascuorum* (9.8%) and *B. lucorum* (8.9%). The participation of honey bee in this community was very slight (2.4%).

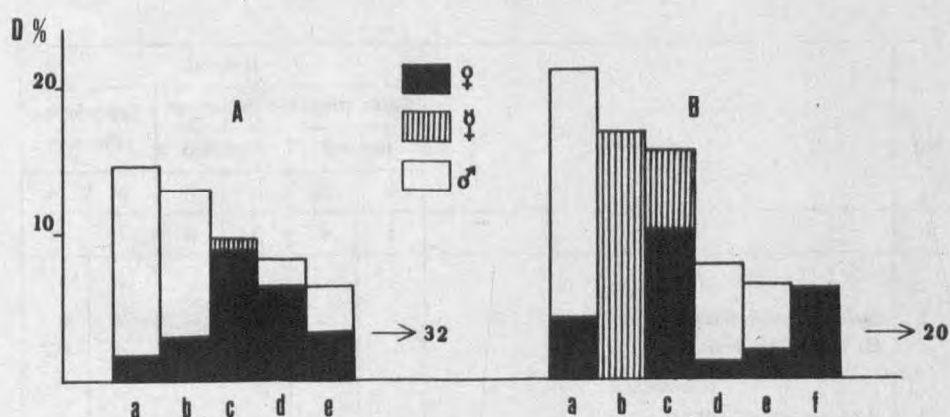


Fig. 1. Dominance structure of *Apoidea* in the oak-hornbeam forest

A – herbs layer: a – *Andrena haemorrhoa*, b – *A. lapponica*, c – *Bombus pascuorum*, d – *B. lucorum*, e – *Nomada leucophtalma*; B – tree crowns: a – *Andrena haemorrhoa*, b – *Apis mellifera*, c – *Bombus lucorum*, d – *Andrena lapponica*, e – *A. helvola*, f – *Lasioglossum subfasciatum*. 32, 20 – number of species in the biotope

Tree crowns. The upper floor of the forest growing of the dry ground, different than the herbs layer, have lesser differentiation of *Apoidea* and smaller number of them. The coefficient of differentiation of species in the tree crowns in these forests is 2.42, and the difference between the investigated forest layers is statistically significant at $p = 0.05$. The traps hung in tree crowns caught 20 species ($n = 89$). Also the domination structure is different in this community where though *Andrena haemorrhoa* predominates (21.3%) but with subdomination of *Apis mellifera* (16.9%) and *Bombus lucorum* (15.7%) (Fig. 1).

3.1.2. Oak forest

Forest floor. The herbs layer of the oak forest proved to be equally rich as a typical dry ground forest and it had Shannon Weaver index of 3.12 bites. In all 35 species were found in this layer with total number of 121 specimens (Tab. I, III). Though a considerable part of the found species represent the family *Andrenidae* (14) but this forest is dominated by *Apis mellifera* (13.0%) also in

Table I

Species composition, numbers and dominance structure of *Apoidea* communities in the deciduous and pine forests of the Wielkopolski National Park

No	Species	Habitat					
		<i>Galio silvatici-Carpinetum</i>				<i>Leucobryo-Pinetum</i>	
		natural		modified			
		n	%	n	%	n	%
1	2	3	4	5	6	7	8
	<i>Colletidae</i>						
1	<i>Hylaeus brevicornis</i> Eversmann	—	—	—	—	1	0.2
2	<i>H. communis</i> Nylander	—	—	—	—	1	0.2
	<i>Andrenidae</i>						
3	<i>Andrena tibialis</i> (Kirby)	—	—	2	0.8	2	0.4
4	<i>A. subopaca</i> (Nylander)	5	2.5	15	5.7	23	4.6
5	<i>A. falsifica</i> Perkins	—	—	—	—	1	0.2
6	<i>A. minutula</i> (Kirby)	—	—	1	0.4	1	0.2
7	<i>A. haemorrhoa</i> (Fabricius)	38	18.8	21	8.0	42	8.4
8	<i>A. grvida</i> Imhoff	1	0.5	—	—	—	—
9	<i>A. cineraria</i> (Linnaeus)	—	—	2	0.8	9	1.8
10	<i>A. vaga</i> Panzer	5	2.5	—	—	—	—
11	<i>A. nitida</i> Müller	1	0.5	2	0.8	2	0.4
12	<i>A. nigroaenea</i> (Kirby)	—	—	—	—	3	0.6
13	<i>A. carantonica</i> Perkins	1	0.5	1	0.4	2	0.4
14	<i>A. barbilabris</i> (Kirby)	4	2.0	3	1.1	—	—
15	<i>A. helvola</i> (Linnaeus)	11	5.4	21	8.0	17	3.4
16	<i>A. praecox</i> (Scopoli)	2	1.0	—	—	1	0.2
17	<i>A. lapponica</i> (Zetterstedt)	1	10.4	13	5.0	67	13.4
18	<i>A. fucata</i> Smith	5	2.5	8	3.0	1	0.2
19	<i>A. armata</i> (Gmelin)	2	1.5	7	2.7	12	2.4
20	<i>A. clarkella</i> (Kirby)	2	1.0	2	0.8	3	0.6
	<i>Halictidae</i>						
21	<i>Halictus tumulorum</i> (Linnaeus)	1	0.5	1	0.4	—	—
22	<i>Lasioglossum subfasciatum</i> (Imhoff)	6	3.0	10	3.8	6	1.2

Table I (contd.)

1	2	3	4	5	6	7	8
23	<i>L. quadrinotatum</i> (Kirby)	1	0.5	—	—	1	0.2
24	<i>L. lativentris</i> (Schenck)	1	0.5	1	0.4	2	0.4
25	<i>L. sextrigatum</i> (Schenck)	—	—	1	0.4	—	—
26	<i>L. punctatissimum</i> (Schenck)	1	0.5	—	—	5	1.0
27	<i>L. minutum</i> (Kirby)	1	0.5	1	0.4	—	—
28	<i>L. laticeps</i> (Schenck)	—	—	1	0.4	—	—
29	<i>L. albipes</i> (Fabricius)	1	0.5	2	0.8	3	0.6
30	<i>L. calceatum</i> (Scopoli)	1	0.5	2	0.2	9	1.8
31	<i>L. rufitarse</i> (Zetterstedt)	1	0.5	2	0.8	9	1.8
32	<i>Sphecodes reticulatus</i> Thomson	1	0.5	—	—	1	0.2
33	<i>S. divisus</i> (Kirby)	1	0.5	—	—	1	0.2
<i>Megachilidae</i>							
34	<i>Osmia rufa</i> (Linnaeus)	—	—	5	1.9	1	0.2
<i>Anthophoridae</i>							
35	<i>Nomada marshamella</i> (Kirby)	—	—	1	0.4	1	0.2
36	<i>N. ruficornis</i> Linnaeus	5	2.5	2	0.8	4	0.8
37	<i>N. signata</i> Jurine	1	0.5	2	0.8	5	1.0
38	<i>N. leucophtalma</i> (Kirby)	3	1.5	1	0.4	8	1.6
39	<i>N. ferruginata</i> (Linnaeus)	—	—	—	—	1	0.2
40	<i>N. bifida</i> Thomson	1	0.5	1	0.4	2	0.4
41	<i>N. moeschleri</i> Alfken	3	1.5	3	1.1	11	2.2
42	<i>N. alboguttata</i> Her.-Schaf.	2	1.0	—	—	4	0.8
43	<i>N. flavoguttata</i> Kirby	—	—	1	0.4	1	0.2
44	<i>N. fabriciana</i> (Linnaeus)	—	—	—	—	1	0.2
45	<i>N. furva</i> Kirby	—	—	—	—	1	0.2
46	<i>Anthophora plumipes</i> (Pallas)	1	0.5	—	—	1	0.2
<i>Apidae</i>							
47	<i>Bombus lucorum</i> (Linnaeus)	26	12.9	12	4.6	41	8.2
48	<i>B. terrestris</i> (Linnaeus)	5	2.5	2	0.8	8	1.6
49	<i>B. pratorum</i> (Linnaeus)	8	4.0	2	0.8	8	1.6
50	<i>B. lapidarius</i> (Linnaeus)	4	2.0	2	0.8	5	1.0
51	<i>B. muscorum</i> (Linnaeus)	—	—	—	—	1	0.2
52	<i>B. pascuorum</i> (Scopoli)	9	4.4	3	1.1	9	1.8
53	<i>B. hortorum</i> (Linnaeus)	1	0.5	—	—	1	0.2
54	<i>Psithyrus bohemicus</i> (Seidl)	2	1.0	2	0.8	5	1.0
55	<i>Apis mellifera</i> Linnaeus	17	8.4	104	39.7	161	32.2

the herbs layer. However, the proportion of *Andrena subopaca* (11.4%) and *A. helvola* (8.9%) (Fig. 2 A) was lower.

Tree crowns. Species differentiation of *Apoidea* in the crowns of oak forest is considerably lower ($H = 1.61$) than in its herbs layer. This difference

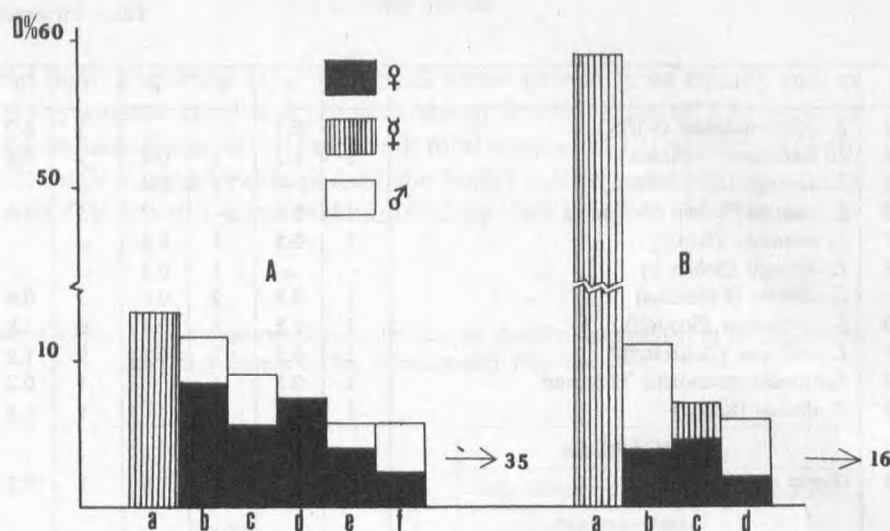


Fig. 2. Dominance structure of *Apoidea* in the oak forest
 A – herbs layer: a – *Apis mellifera*, b – *Andrena subopaca*, c – *A. helvola*, d – *Lasioglossum subfasciatum*, e – *Andrena haemorrhoa*, f – *A. lapponica*; B – tree crowns, a – *Apis mellifera*, b – *Andrena haemorrhoa*, c – *Bombus lucorum*, d – *Andrena helvola*. 35, 16 – number of species in the biotope

is statistically significant. Only 16 *Apoidea* species were found in oak crowns though the traps caught a large number of specimens ($n = 152$). The cause is very large proportion of workers of honey bee which constituted 58.6% of the caught insects. The proportion of wild bees was significantly lower: *Andrena haemorrhoa* – 11.2, *Bombus lucorum* – 7.2% and *A. helvola* – 5.6% (Fig. 2 B).

3.1.3. Pine forest

Forest floor. The herbs layer of pine forest is the richest in *Apoidea* species. The Shannon Weaver's index is 3.03 bits. Forty six species ($n = 392$) were found (Tab. I, III). Among them clearly dominated *Apis mellifera* constituting 34.8% of all collected specimens with subdomination of *Andrena lapponica* 15.7% (Fig. 3).

Tree crowns. Differentiation of *Apoidea* in pine crowns was considerably lower ($H' = 2.53$) than in the herbs layer of this forest. This difference is statistically significant. In the crowns of pine forest a total of 23 species ($n = 107$) were found with domination of *Apis mellifera* (17.4%) and *Bombus lucorum* (12.8%) (Fig. 3 B).

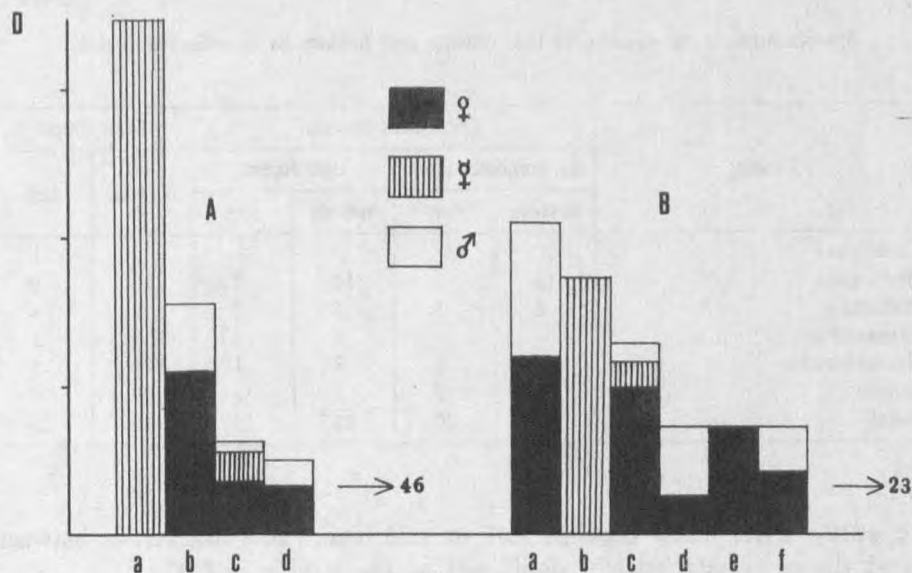


Fig. 3. Dominance structure of *Apoidea* in the pine forest

A – herbs layer: a – *Apis mellifera*, b – *Andrena lapponica*, c – *Bombus lucorum*, d – *Andrena haemorrhoa*; B – tree crowns: a – *Andrena haemorrhoa*, b – *Apis mellifera*, c – *Bombus lucorum*, d – *Andrena helvola*, e – *A. fulva*, f – *Lasioglossum rufitarse*. 46, 23 – number of species in the biotope

3.2. VERTICAL DIFFERENTIATION OF BEES

From the above characteristics of the *Apoidea* communities the results are clear that both forest floors differ with respect to the degree of species differentiation and structure of domination and total number of bees. It should be emphasized that these differences are equally marked in all forest types, both on deciduous and coniferous forests. The presence of wild *Apoidea* in the herbs layer is related to: a) nesting of the most of these insects in soil, b) variability and abundance of herbaceous plants (see chapter 2), c) mating flights. The cause of the presence of bees in tree crowns can be: a) blooming and honey dew production and, b) mating flights.

Generally, in the herbaceous layer of the forests about twice as many species were found than in the crowns (Tab. II). As a result also the Schannon-Weaver's indices for bee communities of the herbs layer are higher in all three investigated forest ecosystems and reach the values of 3 bits. The indices for species differentiation of the *Apoidea* communities in tree crowns

Table II

Species number of *Apoidea* in tree crowns and bottom in investigated forests

Family	Deciduous forests				Pine forest	
	oak-hornbeam forest		oak forest		bottom	top
	bottom	top	bottom	top		
<i>Colletidae</i>	—	—	—	—	2	1
<i>Andrenidae</i>	12	8	14	7	13	9
<i>Halictidae</i>	6	5	5	5	9	4
<i>Megachilidae</i>	—	—	1	1	—	1
<i>Anthophoridae</i>	6	2	8	1	11	1
<i>Apidae</i>	8	5	7	2	9	7
Total	32	20	35	16	44	23

are within lower limits between 1.61 to 2.53 bits. These differences between forest floors are statistically significant at the level $p = 0.05$.

A question arises here whether there are species which occur exclusively in the lower layer of a forest and never, or very rarely reach its upper floor. Or, are there species feeding only or more willingly, in tree crowns. Naturally there is quite large number of species caught only into the traps in herbs layer and not found in the crowns. But they are not numerous species and it is difficult to draw any more general conclusions. However, one groups of species was caught and observed quite numerously on the bottom of the forests despite the fact that the traps in tree crowns revealed only single individuals or none. This concerns mostly bumblebees: *Bombus pascuorum* (forest floor 24 specimens, tree crowns 2 specimens), *B. pratorum* (16:4), *B. terrestris* (13:2) and *B. lapidarius* (9:4). However, *Bombus lucorum* is an exception equally frequently caught into ground (43 specimens) and crowns (39) traps. Females, males and workers were equally numerous. This species makes both feeding and mating flights to tree crowns. This observation confirms the earlier observation that *B. lucorum*, in contrast to *B. terrestris*, clearly prefers forest ecosystems (Banaszak 1983). The females of this species appearing very early use the food gathered from tree flowers. The group distinguished by its occurrence almost only in the forest floor are the representatives of the *Nomada* but this is related to their parasitic search for the nests of their hosts (mainly *Andrena*). A marked relation to forest floor can be also observed in case of *Andrena subopaca*. Small body size of this species probably prevent long distance flights. This concerns both the feeding and mating flights. *Andrena lapponica* is clearly related to herbs layer and is at the same time among the most numerous species in the studied forests, particularly in the pine forest.

It is interesting to analyse the proportion of sexes in the collected species in both forest layers. Generally, in the vegetal cover layer females are more numerous and their proportion to males is 2:1, while in tree crowns the proportion are closer (1:1). The balanced proportion of sexes of wild bees suggests that their presence in tree crowns is mainly related to mating flights there. Only the presence of *Apis mellifera* in a given layer should be related exclusively to search for food. Comparison of the number of *Apis mellifera* workers in the both layer of the oak-hornbeam and oak forests indicates competitiveness of tree crowns for vegetal cover plants in this ecosystem. The presence of honey dew or oak pollen was particularly important for *Apis* in the oak stand where honey bee only sporadically went to the bottom layer, despite a great number of abundantly blooming vegetal cover plants. In contrast, in the pine forest more important for honey bee was cover layer with its blooming patches of *Calluna vulgaris*.

Analysis of sexes proportion in the dominant species indicates biocenotic role of each species in an ecosystem. This is clearly illustrated by the Fig. 1-3. For instance: though generally *Andrena haemorrhoa* and *A. lapponica* dominate in the oak-hornbeam forest due to small proportion of females the decisive role in pollination of vegetal cover plants have bumblebees – *Bombus pascuorum* and *B. lucorum* (Fig. 1 A)

In case of wild bees the same factors which decide about species differentiation probably the general size of vegetal cover and tree crown communities. The differences in the number of wild *Apoidea* between the investigated forest floors were statistically significant. It should be stressed that

Table III

Comparison of total numbers and diversity of *Apoidea* communities in investigated forests

Plant association	Number of individuals			Number of species	H'
	<i>Apis mellifera</i>	wild bees	total		
Oak-hornbeam forest					
herbs layer	3	118	121	32	3.00
tree crowns	15	74	89	20	2.44
Oak forest					
herbs layer	16	105	121	35	3.12
tree crowns	89	63	152	16	1.61
Pine forest					
herbs layer	138	254	392	46	3.03
tree crowns	19	86	107	23	2.53

differentiation in the numbers was greater in the pine forest and smaller in deciduous one. In the herbs layer of the pine forest three times more wild *Apoidea* were caught than in pine crowns. Whereas in the deciduous forest the herbaceous layer contained 1.5 times more bees. This index proves a certain feeding attractiveness (greater than in pine forest) of the crowns of deciduous trees for wild bees (Tab. III).

The bee communities of the two investigated forest layers have also different domination structure. These differences mostly deal with various participation of the same dominant species in the two compared layers, which is particularly well seen in the oak and pine forests (Fig. 2, 3). Whereas in the dry ground forest, besides the differences in dominant groups, there is also different proportion of females and males of wild bees (Fig. 1).

3.3. PHENOLOGY OF BEES

Descriptions of the structure of *Apoidea* communities (cf. chapter 3.1) are based on absolute number of the insects caught during vegetative season (absolute number of the caught specimens are given for the whole year). This is impossible in case of analysing the changes in bee numbers in shorter periods. The impossibility is due to elimination of some traps caused by the factors beyond the authors control (breaking the line by the wind, destruction of the traps by tourists etc.). The differences in the number of caught insects due to elimination of traps were slight during the whole year span and amounted to 3.7% (statistically not significant). In the analysis presented below the number of bees from each day and week were converted into 1 trap and 1 day (so called day/bowls).

3.3.1. Oak-hornbeam forest

Among the earliest blooming plants visited by bees in the oak-hornbeam forest were *Ficaria verna*, *Oxalis acetosella* and *Viola silvestris*. In 1988 *Ficaria* bloomed already at the beginning of April and it was blooming to the end of month. Other plants bloomed in the middle of April in the both years. In April first bees were caught into the ground traps: in the first decade – *Andrena clarkella*, *A. subopaca*, *Bombus pascuorum* and *B. pratorum*; in the second decade – *Andrena haemorrhoa*, *A. helvola*, *A. praecox*, *Lasioglossum minutum*, *Bombus lucorum* and *B. hortorum*; in the third decade – *Andrena lapponica*, *A. barbilabris*, *Halictus tumulorum*, *Lasioglossum subfasciatum*, *L. albipes*, *Bombus terrestris*, *B. lapidarius*. *Galeobdolon luteum* started blooming at the

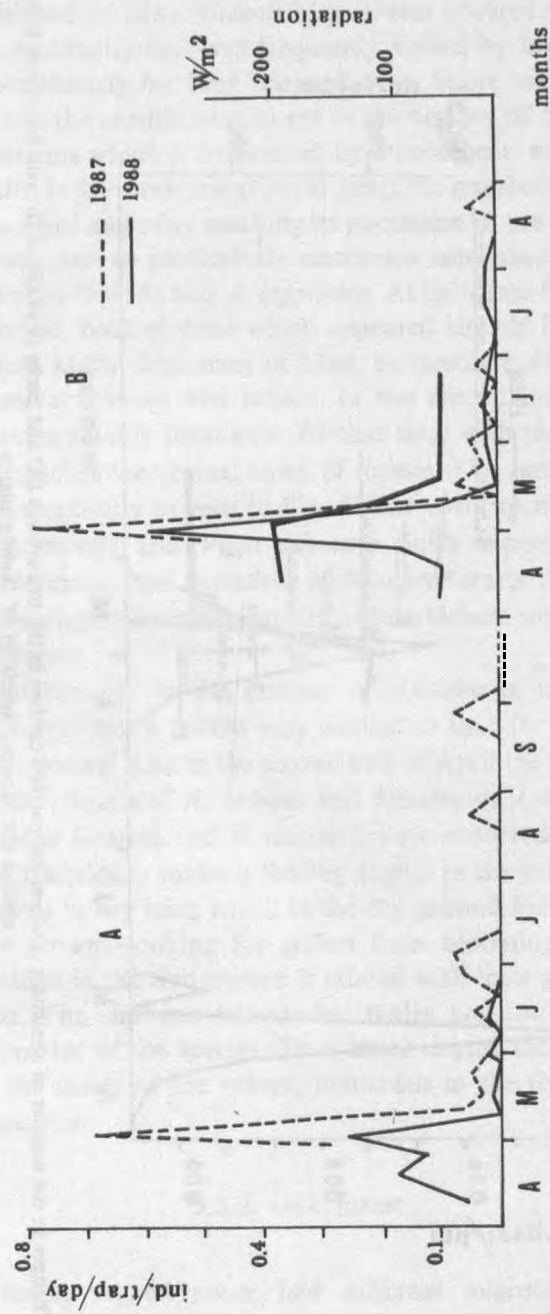


Fig. 4. Changes in the number of bees caught in tree crowns (A) and herbs layer (B) of the oak-hornbeam forest in 1987-1988

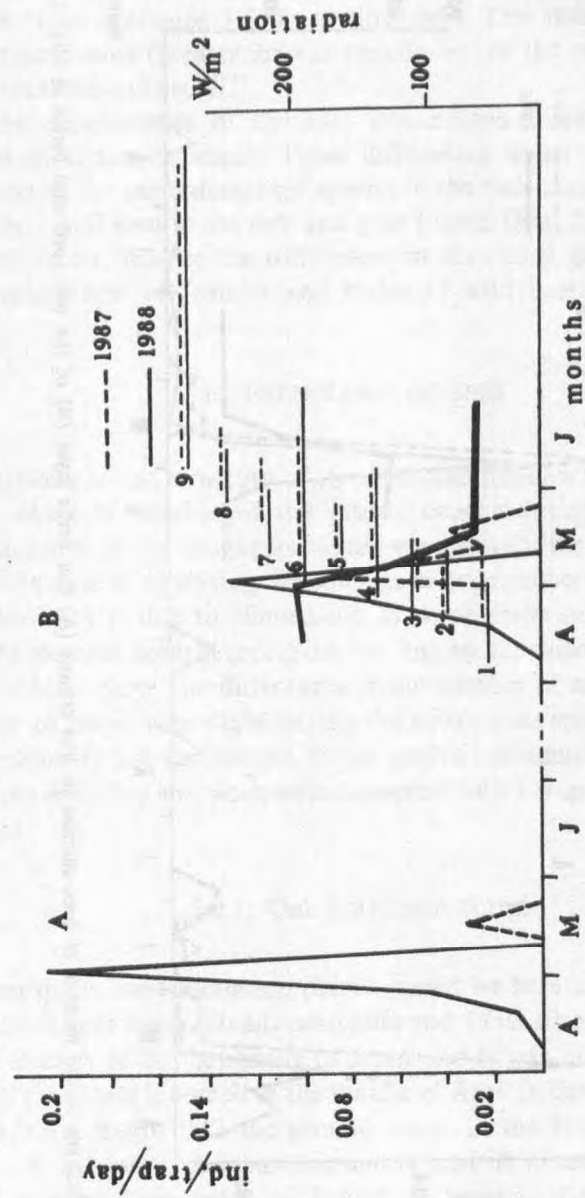


Fig. 5. Changes in the number of specimens *Andrena haemorrhoa* caught in the tree crowns (A) and herbs layer (B) of the oak-hornbeam forest against the blossom spectrum of feeding plants
 1 - *Ficaria verna*, 2 - *Oxalis acetosella*, 3 - *Viola silvestris*, 4 - *Galeobdolon luteum*, 5 - *Ajuga reptans*, 6 - *Alliaria officinalis*, 7 - *Convallaria maialis*, 8 - *Impatiens noli-tangere*

beginning of May in 1987 and in the third decade of April next year. It was blooming till the end of May. *Galeobdolon luteum* covered the greatest area, was blooming abundantly and was frequently visited by bees. It is the main feeding plant particularly for long tongued bees. Short tongued bumblebees and honey bee bite the corolla base to get to the nectary of this plant. In May *Ajuga reptans* blooms which is frequented by bumblebees, and more available *Alliaria officinalis*. In the both investigated years the numbers of bees increases rapidly between April and May reaching its maximum in the first week of May (Fig. 4). This was due to particularly numerous emergence of the males of *Andrena haemorrhoa* (Fig. 5) nad *A. lapponica*. At that time flights of most bee species are observed, both of these which appeared already in April and those leaving their nests at the beginning of May, particularly *Andrena helvola*, *A. vaga*, *Anthophora acervorum* and others. In the second decade of May the number of *Apoidea* rapidly decreases. At that time with the development of leaves less light reaches the vegetal cover of forests. The curve describing light intensity falls dramatically as seen in Fig. 5. The early spring species: *Ficaria verna*, *Oxalis acetosella* and *Viola silvestris* finish blooming. *Galeobdolon luteum* is still blooming and *Impatiens noli-tangere* starts the process. From that time on only single specimens, mostly of bumblebees were observed in the oak-hornbeam forest.

The curve of changes in the number of *Apoidea* in the crowns of the oak-hornbeam forest has a course very similar to that for the vegetal cover layer (Fig. 4). No sooner than in the second half of April the males and females of *Andrena haemorrhoa* and *A. helvola* and females of *Lasioglossum subfasciatum* and *Bombus lucorum* and *B. terrestris* were observed. The latter group of females was doubtlessly making feeding flights in the crowns of the trees. The same concerns honey been which in the dry ground forest was practically penetrating the crowns looking for pollen from blooming trees. The peak number of *Apoidea* in the tree crowns is related with their greatest number in the forest floor. The *Andrena haemorrhoa* males are dominant with a few specimens of females of the species. To a lesser degree the tree crowns were penetrated by the males of the others, numerous in the forest floor, species – *Andrena lapponica*.

3.3.2. Oak forest

The oak forest vegetal cover had different microclimatic and flora conditions than that of the dry ground forest. The differences are the following:

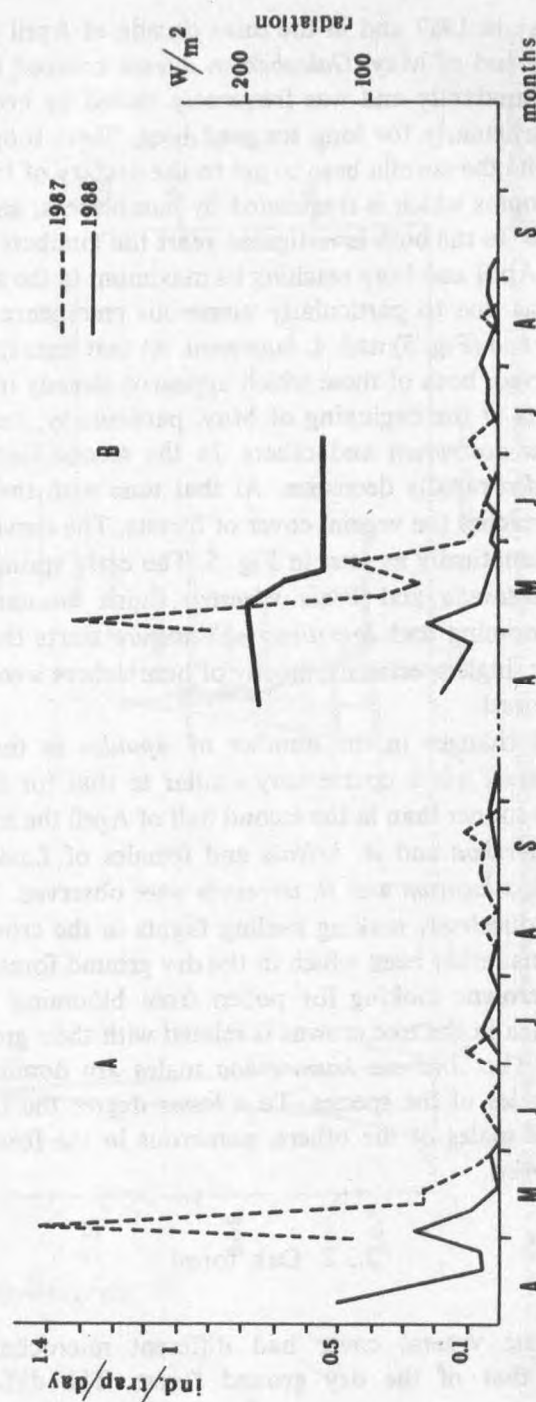


Fig. 6. Changes in the number of bees caught in tree crowns (A) and herbs layer (B) of the oak forest in 1987–1988

1. More light reaches the floor of the oak forest after leaves have developed. In the period from 10 to 15 May, when leaves appeared on the trees, the light intensity fell from 200 to only 150 W/m² and remained at the same level (Fig. 6). The light intensity in the dry ground forest after development of leaves was about 50 W/m² so three times more light reaches the oak forest floor than the investigated oak-hornbeam one. This must affect the development speed and composition of herbaceous plants.

2. The feeding plants bloom later than in a typical oak-hornbeam forest. The shift in the plant blooming spectrum was about 10 days, i.e. the first – *Viola silvestris* and *Glechoma hederacea* were blooming at the beginning of May. Hence, the source of food honey flow in April could be only blooming (or honey dewing by the end of month) trees – *Quercus robur*, *Betula verrucosa* and *Carpinus betulus*.

3. Different composition of the main feeding plants was observed (see chapter 2). In the oak forest among the most numerous and frequently visited by bees plants were *Veronica chamaedrys*, *Glechoma hederacea* and *Mycelis muralis*.

Common for the both investigated ecosystems were only *Alliaria officinalis* and *Impatiens noli-tangere*.

Despite different conditions in the both ecosystems general course of the curves of changes in numbers of *Apoidea* in the forest floor and tree crowns of the oak forest has dynamics similar to those for a typical oak-hornbeam one (Fig. 4, 6). They have one, marked numerical peak at the beginning of May with quite obvious occurrence of bees also in April. The spring peak ends with a rapid fall in *Apoidea* number already in the second decade of May. However, oak forest has clearly higher proportion of spring honey flow of the tree crowns (practically *Quercus robur*). This was seen frequent flights of *Apis mellifera* in the tree crowns.

As an typical oak-hornbeam forest also in the oak forest half of the wild bees of the cover appeared in April:

- the first decade: *Andrena helvola*, *A. subopaca*, *Lasioglossum albipes*,
- the second decade: *Andrena clarkella*, *A. minutula*, *Bombus lucorum*,
- the third decade: *Andrena cineraria*, *A. vaga*, *A. lapponica*, *A. barbilabris*, *Halictus tumulorum*, *Lasioglossum subfasciatum*, *L. minutulum*, *Bombus lapidarius*, *B. pratorum*.

The other spring species were caught into the traps between April and May. At the beginning of May the curve reaches its peak (Fig. 6). This first of all related to numerous appearance of *Andrena haemorrhoa* and *A. subopaca*. Considering the blooming spectra of feeding plants (herbaceous plants and trees) the *Apoidea* maximum in the oak forest should be related to tree

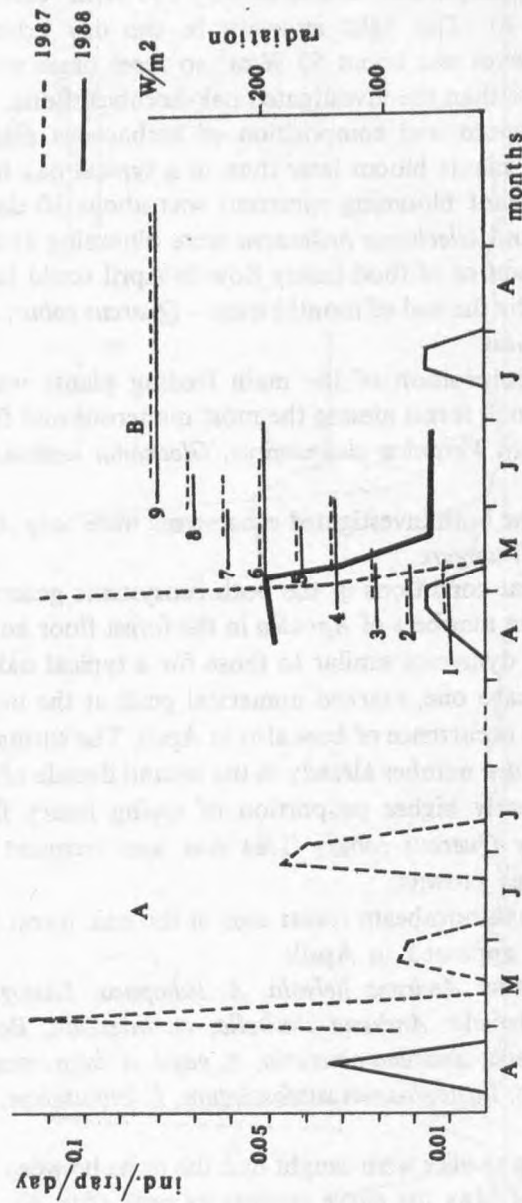


Fig. 7. Changes in the number of specimens *Bombus lucorum* caught in tree crowns (A) and herbs layer (B) of the oak-hornbeam forest against the blossom spectrum of feeding plants. For plants symbol see Fig. 5

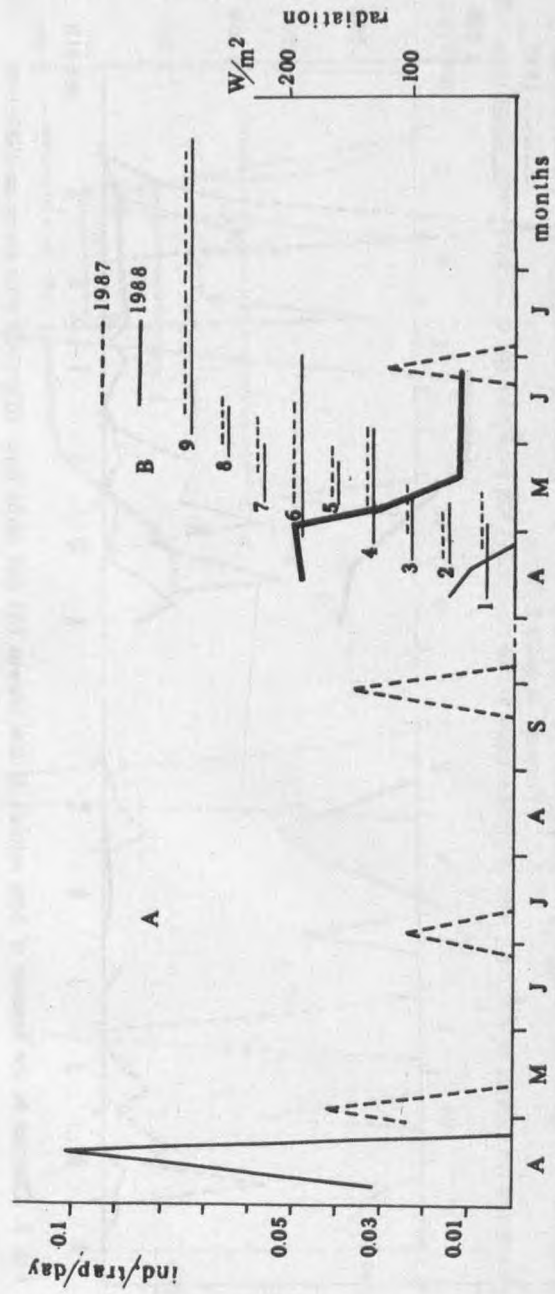


Fig. 8. Changes in the number of specimens *Apis mellifera* caught in tree crowns (A) and herbs layer (B) of the oak-hornbeam forest against the blossom spectrum of feeding plants. For plants symbol see Fig. 5



Fig. 9. Changes in the number of bees caught in tree crowns (A) and herbs layer (B) of the pine forest in 1987-1988

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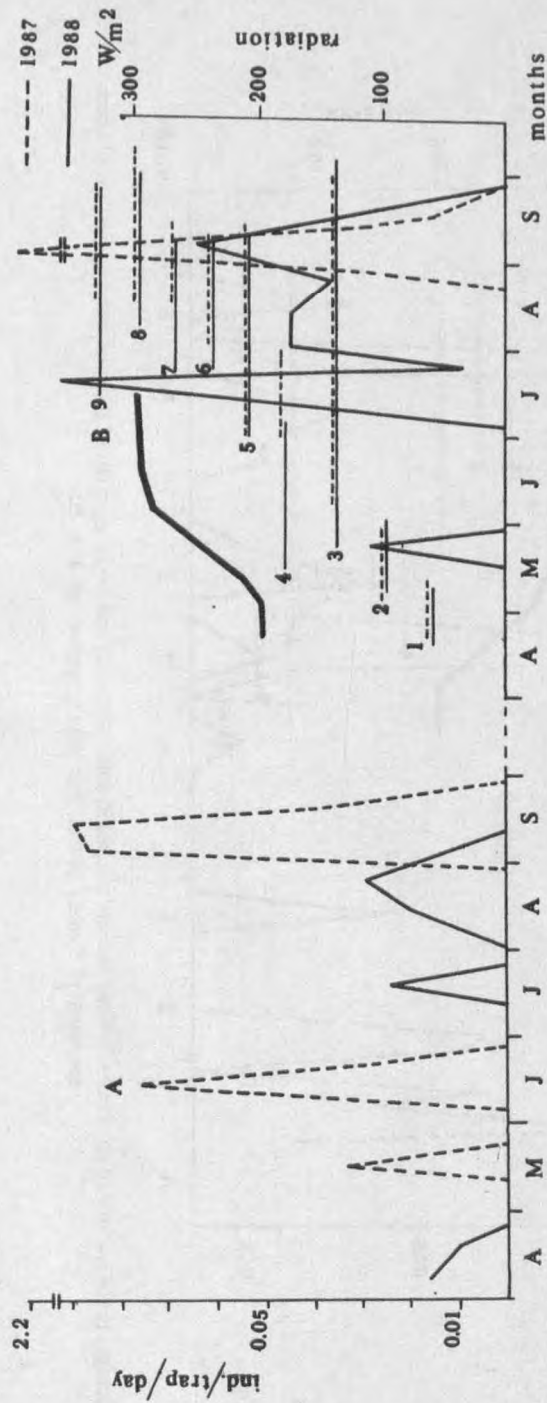


Fig. 10. Changes in the number of specimens *Apis mellifera* caught in tree crowns (A) and herb layer (B) of the pine forest against the blossom spectrum of feeding plants

1 - *Viola silvestris*, 2 - *Vaccinium myrtillus*, 3 - *Hieracium* sp., 4 - *Frangula alnus*, 5 - *Campanula rotundifolia*, 6 - *Linaria vulgaris*, 7 - *L. minor*, 8 - *Calluna vulgaris*, 9 - *Impatiens noli-tangere*

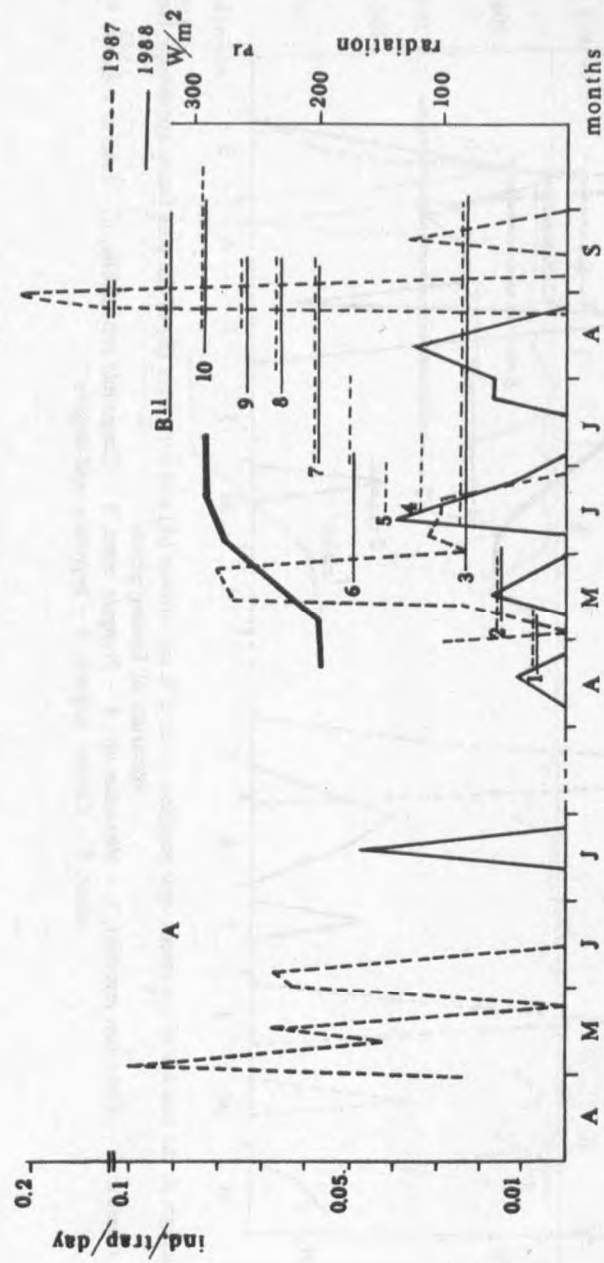


Fig. 11. Changes in the number of specimens *Bombus lucorum* caught in tree crowns (A) and herbs layer (B) of the pine forest against the blossom spectrum of feeding plants. For plants symbol see Fig. 10

blooming. It should be emphasized here that despite the fact that in this ecosystem much more light reaches the floor than in case of oak-hornbeam forest, honey bee was penetrating mostly tree crowns. Few workers of this species were found in the vegetal cover layer, perhaps due to small number of the cover plants.

3.3.3. Pine forest

In contrast to oak-hornbeam forests the coniferous ecosystem has continuous of blooming of bee feeding plants. Though subsequently blooming plants have various importance for bees but they secure greater or smaller amounts of food throughout the season. Supplementary role play also singly growing trees at blooming: *Quercus robur*, *Betula verrucosa* or eventually pine. However the greatest importance for bees have *Vaccinium myrtillus*, *Frangula alnus*, and *Calluna vulgaris* (Fig. 7, 8).

Therefore also the *Apoidea* dynamics curves have mult peak course, what is particularly clearly seen in 1987 since next year was less favorable for bee feeding (Fig. 9).

In springtime the curve of *Apoidea* dynamics in the vegetal cover of pine forest had two peaks. The first peak of the community size (beginning of May) should be related to blooming of oak and birch. It is equally clear for the bees caught in the tree crown traps. Mostly the males of *Andrena lapponica* and *A. subopaca* were caught.

The third numerical peak in September 1987 was very clearly connected with the blooming of *Calluna vulgaris* (L.). This plant attracts mostly *Apis mellifera* to the vegetal cover of pine forest (Fig. 10). It is interesting that at the same time large number of the workers of this species were caught into the traps in pine crowns (Fig. 10). Most probably this results from the direction of flight of *Apis mellifera* onto heather patches, i.e. from the height downwards. The workers flying near the traps get caught attracted by colour.

An illustration of almost continuous presence of feeding plants in the forest cover is multipeak course of the curve presenting flight dynamics of *Bombus lucorum* in this part of the forest (Fig. 11).

The curve demonstrating changes in the number of *Apoidea* in tree crowns of the pine forest reflects the flight dynamics of *Apoidea* in the forest floor. The comparison of the diagrams for tree crowns and vegetal cover (Fig. 9) illustrates well this observation. The number of peaks and the periods in which the most *Apoidea* were caught into traps overlap.

3.4. TROPHIC CONNECTIONS OF BEES

Location of colourful traps both in the herbs layer and tree crowns enabled demonstration of active penetration of the upper floor of forests by bees looking for food. This study provides some explanation of the problem of trophic relations of particularly wild bees in forest ecosystems. This fact was observed earlier in the work concerning *Apoidea* of dry ground and light oak forests in the Eastern part of the Polish Lowland – the Mazovian Lowland (Banaszak, 1991). In the previous chapter (3.3) the concurrence of maximal occurrence of wild bees living in deciduous forests with tree blooming, hence in the period of phenological early spring. At that time the following trees are blooming: *Carpinus betulus*, *Quercus robur*, *Quercus sessilis* and *Betula verrucosa*. The traps were placed in the crowns of oaks, hornbeam, lime and pine. All these produce pollen and dew. In all tree crown traps gave 35% of insect material. However, it should be emphasized that this percentage was very different in each forest type what generally proves considerable attractiveness of tree crowns in comparison to forest floor but also difference in this attractiveness. The traps hung in the crowns of oak tree caught as much as 55.3% of the material and in oak-hornbeam forest 42.0% while in the pine forest only 21.6. These numbers indicate that trees play an important role in feeding chain of bees, particularly those inhabiting deciduous forests. The source of food can be both pollen and honey dew. Among the trees which bloom later is lime additionally providing nectar. Since on lime the most species were caught before blooming it can be supposed that the insects were present there to collect honey dew. Other causes for frequent flight of bees into upper floor of these forests, e.g. mating flights should be excluded in many cases due to numerous presence of the females of social species, e.g. *Lasioglossum fulvitarse* (no males at that time), bumblebees and *Apis mellifera* workers. In case of the workers of honey bee the cause of flights and catches by the traps in tree crowns of pine and other species can be the direction of approaching flight – a bees flies over tree tops and from there reaches the forest floor.

In turn, a detailed analysis of the material according to tree species indicates that the number of the collected insects is very different on various trees. At the first sight it could be related to different attractiveness of each tree species in oak-hornbeam forests where the traps were hung. Perhaps it has some importance what indicated the earlier work (Banaszak, 1991). However, similar difference were noted for the traps placed only on pines in the pine forest. Hence, some other factor is involved which makes different numbers of insects to be caught by each trap. Perhaps an appropriate configuration and stand density, appropriate clearances between trees are responsible.

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5. SUMMARY

Przedstawiono wyniki dwuletnich badań nad pionowym (dno lasu – korony drzew) i czasowym zróżnicowaniem *Apoidea* w lasach grądowych i w borze sosnowym strefy umiarkowanej. Wykazano, że oba piętra lasów odmienne są pod względem zróżnicowania gatunkowego struktury dominacji oraz ogólnej liczebności. W warstwie zielnej lasów stwierdzono dwukrotnie większą liczbę gatunków. Również wskaźniki Shannona–Weavera zgrupowań pszczoł

warstwy zielnej są wyższe we wszystkich badanych zespołach leśnych. Przebieg krzywych zmian liczebności *Apoidea* w koronach drzew i w warstwie ziół jest zbliżony we wszystkich typach lasów. Krzywe liczebności w lasach liściastych miały przebieg jednowierzchołkowy, ze szczytem w pierwszych dniach maja, natomiast krzywe dynamiki pszczół w borze sosnowym są wielowierzchołkowe. Udowodniono, że drzewa odgrywają poważną rolę w szeregu pokarmowym pszczół zamieszkujących lasy liściaste.

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