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LOCAL CHANGES IN THE POPULATION OF WILD BEES
I. CHANGES IN THE FAUNA TEN YEARS LATER

LOKALNE ZMIANY ZASOBÓW DZIKO ŻYJĄCYCH PSZCZÓŁ
I. ZMIANY FAUNY PO DZIESIĘCIU LATACH

Józef BANASZAK

Department of Biology and Environmental Protection, Pedagogical University, 51 Chodkiewicza Str., 85-667 Bydgoszcz

Abstract: Changes in species diversity and density of *Apoidea* over a ten year period between the seventies and the eighties were investigated at six sites in western Poland (agricultural landscape and natural habitats). An increasing density trend was observed in the eighties, along with an increase in the number of species at the majority of sites. Only vegetation succession changes in xerothermic grasslands (tree overgrowth) caused a decrease in the number of species and density.

Key words: *Apoidea*, wild bees, diversity, density, changes in fauna, western Poland.

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Treść: W latach 70-tych i 80-tych badano zróżnicowanie gatunkowe i zagęszczenie *Apoidea* zbadano na 6 stanowiskach zlokalizowanych w krajobrazie rolniczym i na siedliskach naturalnych w Zachodniej Polsce. Po 10 latach stwierdzono wzrost zagęszczenia i zwiększenie liczby gatunków na większości stanowisk. Jedynie zmiany sukcesyjne na murawie kserotermicznej (zarastanie roślinnością drzewiastą) wywołały spadek liczby gatunków i ich zagęszczenia.

INTRODUCTION

Despite currently more frequent reporting on changes in fauna (also including *Apoidea*) (Wodziczko 1947; Ruszkowski et al. 1981; Leclerq 1982; Banaszak 1983, 1987; Rasmont et al. 1993; O'Toole 1994), this issue has not yet been sufficiently investigated. The general opinion is that human activities have a negative influence on fauna (Ryszkowski, Karg 1977; Wilkaniec, Wójtowski 1978; Ryszkowski 1981; Karg 1981, 1989; Starzyk, Kosior 1985; Kosior 1987; Kosior, Nosek 1987; De Bast et al., Jacob-Remacle 1987; Banaszak, Izdebska 1994). It is, however, not always the case. Generally, data on the degree and directions of possible changes in the fauna are scarce. A much broader analysis of this issue is provided by the recently published book *Changes of Wild Bees in Europe* edited by J. Banaszak (ed. J. Banaszak 1995). Previous fauna investigations of this group mainly covered species composition and did not allow the population numbers and densities to be estimated.

This paper presents the results of monitoring of pollinating insect species carried out in western Poland (the Wielkopolsko-Kujawska Lowland). The general plan was to be observation of the *Apoidea* over a sequence of three observation seasons, at ten-year intervals.

The first investigations of wild *Apoidea* were carried out in 1978–1980 (Banaszak 1983). Similar studies were repeated in 1988–1990. This article presents the results of the 1988–1990 study and attempts to track potential changes in the number of wild bee species (*Apoidea*) and their densities over a longer period of time.

STUDY AREA AND INVESTIGATION SITES

The studies were carried out at six sites (two types of landscape): 1) natural environment in the Wielkopolski National Park (15 kilometers south of Poznan) and 2) agricultural land around Turew and Kościan (50 kilometers south of Poznań). The farmland sites investigated have an extensive system of tree belts separating the fields, partially established in the 19th century by Poland's pioneer of modern agriculture Dezyderat Chłapowski (Chłapowski 1843). This area is currently part of the Agroecological Landscape Park which bears the name of General D. Chłapowski.

Three habitats were investigated in the Wielkopolski National Park:

1. Xerothermic grassland covering a sandy esker embankment of the Budzyńskie Lake (locally referred to as the „Szwedzkie Góry" – the Swedish Mountains). An advanced stage of vegetation succession can be observed at this site. The embankment is currently dominated by shrubby vegetation and trees because of an uncontrolled expansion of the ash-leafed maple (*Acer negundo*) – a species of foreign origin. Photographs of the embankment taken in the fifties demonstrate the basic changes in the structure of its vegetation cover (Figs 1 and 2). During the fifties, the southern slope-foot of the esker embankment was regularly ploughed. After ploughing it was abandoned, ash-leafed maple and pine started to appear spontaneously. In the sixties, well developed patches of the xerothermic grassland *Festuco-Silenetum otitis* Libb. 1993 (Celiński, Balcerkiewicz 1973) were still present at the site. Strong shading of the slope is causing regression of the grassland species. In spring of 1989, well preserved and typical grassland communities could hardly be found at this site. Individual xerothermic plants and grassland species were still present. At present the largest area is occupied by patches of *Arrhenatheretum mediaeuropaeum* (Br.-Bl. 1919) Oberd. 1919 with xerothermic and psammophytic species. The identified xerothermic species included: *Carex praecox, Euphorbia cyparissias, Medicago falcata, Pimpinella nigra, Galium verum, Centaurea rhenana, Potentilla arenaria, Artemisia campestris, Asparagus officinalis* and others. Only the south-western slope had well preserved fragments of psammophytic grassland (with a species composition similar to the one of *Diantho-Armeterium elongate* Kraush 1959, with *Festuca psammophila*). There were numerous species from the class *Rhamno-Prunetea*: *Crataegus monogyna, Rosa canina, Prunus spinosa, Evonymus europaea* and additionally *Prunus insititia* and *Acer negundo*. Among the herbaceous plants most frequently visited by the bees are (listed in order of blossoming): *Potentilla arenaria, Veronica chamaedrys, Senecio vernalis, Hieracium pilosella, Anchusa officinalis, Knautia arvensis, Coronilla varia, Echium vulgare, Centaurea rhenana, Senecio jacobaea, Thymus* sp., *Helichrysum arenarium, Arenaria elongata, Lotus corniuculatus, Trifolium arvense, Solidago virga aurea* and *Berteroa incana*.

2. Leafy oak-hornbeam forest (belonging to *Galio silvatici-Carpinetum* Oberd. 1957) on the eastern bank of the Górecke Lake. This is a fragment of a well preserved natural tree stand (Fig. 3). It is composed of *Quercus robur* and *Carpinus betulus* and also *Populus tremula* and individual specimens of *Tilia cordata, Fraxinus excelsior* and recessing *Pinus silvestris*. The shrub layer is dominated by *Corylus avellana*. Bee feeding species particularly worth mentioning among the herbaceous plants are: *Galeobdolon luteum* and *Ficaria verna*, accounting for a total of 30% of the

Phot. Z. Pniewski

Fig. 1. Southern slopes of the Budzyńskie Lake embankment in the Wielkopolski National Park. Photograph taken in the fifties.

Ryc. 1. Południowe stoki wału ozowego nad jeziorem Budzyńskim w Wielkopolskim Parku Narodowym. Fotografia wykonana w latach 50.

Phot. Z. Pniewski

Fig. 2. Overgrowth on the Budzyńskie Lake embankment. Status in 1978.

Ryc. 2. Zarastający wał ozowy nad Jeziorem Budzyńskim. Stan z roku 1978

Phot J Banaszak

Fig. 3. *Galio silvatici-Carpinetum stachyetosum* near the Góreckie Lake.

Ryc. 3. Las grądowy *Galio silvatici-Carpinetum stachyetosum* nad jeziorem Góreckim.

forest floor vegetation cover. The summer appearance is due to *Impatiens parviflora*, accounting in some areas for 80% of the cover. This is a xenophytic species which has been expanding over the entire Wielkopolski National Park area for a dozen years or so. Other species such as *Oxalis acetosella, Viola silvestris, Ajuga reptans, Allaria officinalis, Maianthemum bifolium, Impatians noli-tangere, Geranium robertianum, Pulmonaria obscura, Lathyrus vernus* and *Glechoma hederacea* were less numerous.

3. *Calmagrosti-Quercetum petraeae* (Hartm. 1934) Scam 1959. The tree stand is composed of *Quercus petraea* and *Pinus silvestris*. The expansion of sessile oak is particularly significant (it dominates the shrub layer). Other species found in the undergrowth are *Corylus avellana, Fagus silvatica, Sorbus acuparia* and *Frangula alnus*. The herb-layer has a significant cover (approx. 70–80%). It contains both acidiphilic coniferous forest species and plants which are specific of leafy forests. The dominant species are *Vaccinium myrtillis* and *Convallaria maialis*. Other, less frequent species are: *Calamagrostis arundinacea, Festuca ovina, Lusula pilosa, Millium effusum, Pteridium aquilinum, Impatiens parviflora, Dryopteris spinulosa, Melica nutans, Rubus saxatilis, Vaccinium vitis-idaea, Moehringia trinervia, Hieracium lachenalii, Hieracium murorum, Solidago virga-aurea, Viola sylvestris, Mycelis muralis, Campanula rotundifolia* and *Polygonatum odoratum*.

The following types of sites were investigated in the agricultural landscape areas:

4. Field track shoulder in Rogaczewo (Fig. 4) with abundant herbaceous and shrub vegetation. The following shrub associations were observed on the investigated stretches

Phot. J. Banaszak

Fig. 4. Field track shoulders with rich herbaceous and shrub vegetation.

Ryc. 4. Pobocza drogi polnej z bogatą roślinnością zielną i krzewiastą.

(400 x 2 or 4 meters): *Urtico-Sambucetum* (Doing 1962), Olsson 1978, the initial stage of *Pruno-Crataegetum* Hueck 1931 and an association with *Rubus caesius* along with herbaceous plant associations: *Tanaceto-Artemisietum* Br.-Bl (1931) 1949, *Convolvulo-Agropyretum* Felf 1943, *Anthriscetum silvestris* Hadač 1978, *Arrhenatheretum medioeuropaeum*, associations with *Chenopodium album* and truncated forms of plant communities in xerophilous fringes of *Trifolio-Geranietea*. The herbaceous plants which are the most frequently visited by bees are (listed in order of blossoming): *Trifolium repens, Rubus caesius, Anchusa officinalis, Knautia arvensis, Linaria vulgaris, Cirsium arvense, Thymus* sp., *Lotus corniculatus, Trifolium pratense, Centaurea jacea, Leonthodon hispidus* and *L. autumnalis*.

5. A poplar alley in Turew (Fig. 5). The road shoulders (width 2 m) are covered with meadow and ruderal vegetation, and a row of poplars (*Populus* sp.) grows along the axis of each of these bands. They were established in the fifties.

Phot. J. Banaszak

Fig. 5. Poplar alley (*Populus* sp.) with shoulders covered by meadow and ruderal-type vegetation.

Ryc. 5. Aleja topolowa (*Populus* sp.) z ciagami przydroży pokrytych roslinami o charakterze łąkowo-ruderalnym.

There are individual occurrences of poplar undergrowth and shrubs (*Crataegus monogyna* and *Sambucus nigra*). The dominant herbaceous plant communities are *Convulvulo-Agropyretum, Tanaceto-Artemisietum* (with *Artemisia vulgaris*), patches of a truncated form of *Arrhenateretum medioeuropaeum* (with *Dactylis glomerata*) and, on the edges of the road *Lolio-Plantaginetum* (Lincola 1921; Berger 1930; Siss 1966, 1969). Among the apparently poor herbaceous vegetation eleven bee feeding species were identified (listed in order of blossoming): *Veronica hederifolia, Viola arvensis, Taraxacum officinale, Geranium* sp., *Consolida regalis, Centaurea cyanus, Achillea millefolium, Convolvulus arvensis, Cichorium intybus, Medicago sativa* and *Pimpinella saxifraga*. For the local bee populations, the most important species is *Cichorium intybus*.

6. Tree belts of (approx. 1500 x 15 m), stretching east-west near Turew (Fig. 6). The tree stand is dominated by *Quercus robur*, with the addition of *Robinia pseudacacia, Fraxinus excelsior* and *Pirus communis*. The shrub layer contains *Robinia pseudacacia* and numerous specimens of *Sambucus nigra* and *Crataegus monogyna, Syringa vulgaris, Rosa canina* and *Rubus caesius*. The tree belt communi-

Phot. J. Banaszak

Fig. 6. Mid-field tree belt.

Ryc. 6. Śródpolne zadrzewienie pasowe.

ties may be classified as dry-ground *Galio-Carpinetum*. Clusters of *Robinia pseudacacia* mostly occur in the patches of *Chelidonio-Robinietum*. The herb-layer is dominated by grasses: *Agrostis vulgaris, Agropyron repens, Dactylis glomerata* and *Festuca rubra*. Species such as *Moechringia trinervia, Urtica dioica, Galeopsis pubescens, Chelidonium majus, Stachys sylvatica* have also been observed. The edges of this belt are mainly occupied by a few patches of *Urtico-Sambucetum nigri*, the fringe communities are dominated by grass species. These are *Convolvulo-Agropyretum* communities and patches of *Bromus sterilis, Urtica dioica* and *Balloto-leonuretum* R. Tx. et Roch. 1942 em. Pas. 1955. Specimens of *Euphorbia cyparissias* were found on southern-exposed sites. Among herbaceous plants visited by the bees, fourteen feeding species have been identified (listed in order of blossoming): *Euphorbia cyparissias, Taraxacum officinale, Glechoma hederacea, Ribes grossularia, Lamium purpureum, Linaria vulgaris, Convolvulus arvensis, Chelidonium maius, Achillea millefolium, Torilis japonica, Campanula* sp., *Cichorium intybus, Galeopsis pubescens* and *Stachys silvatica*.

METHODS

The investigation method applied to evaluate the density of bees during the experiment carried out in the eighties was similar to the one applied in the seventies (band or linear transects – Banaszak 1980). In this method the insects are caught with an entomological net along a 1 x 200 m band of land and counted. The sampling procedure lasts 20–30 minutes. The samples were collected in similar conditions (sunny and windless weather, ambient temperature over 20°C).

During all the field studies, the feeding conditions of the bees were also investigated by scoring the numbers of flowering plants and the bee species visiting these plants.

The basic factors of potential impact on the changes in fauna composition (such as the use of chemical fertilizers and pesticides in farmland areas, ambient temperature and precipitation levels and the structure of crops in areas adjacent to the sites investigated) were also assessed and compared.

The Shannon-Weaver domination and species diversity index (H') was applied to evaluate the structure of the groups investigated. Deviation from maximum theoretical diversity was assessed using the Pielou equivalency coefficient (J') (1975). The significance of differences between average densities of particular species was estimated using the Student's t-test and the differences between species diversities using Hutcheson's formula (Hutcheson 1970).

RESULTS

CHANGES IN FAUNA DIVERSITY AND DOMINATION STRUCTURE

In the seventies, at the six sites investigated, 89 wild species of *Apoidea* were identified. Ten years later the number of species reached 91. A total of 122 species were found in the investigated area (Table 1). In the eighties, the presence of 31 species was not confirmed (25.4%), but on the other hand, 31 new species were observed (which were not identified the previous time).

Comparison of numbers of species in particular habitats after ten years can provide more information (Table 2, Fig. 7). Species diversity in the *Calamagrosti-Quercetum petraeae* community and the poplar avenue did not change significantly over the decade. A slightly higher number of species was observed during the eighties in the dry-ground forest and the tree belts. The most significant differences were observed in the xerothermic grasslands in the Wielkopolski National Park and on the field track shoulders in Rogaczów.

In the eighties, a significant decrease in the number of species was observed in the xerothermic grassland (from 70 to 47). In the case of the field track shoulders in Rogaczów the number of species increased from 30 to 45. The above findings are also confirmed by the species diversity indexes of Shannon-Weaver, calculated for bee populations in

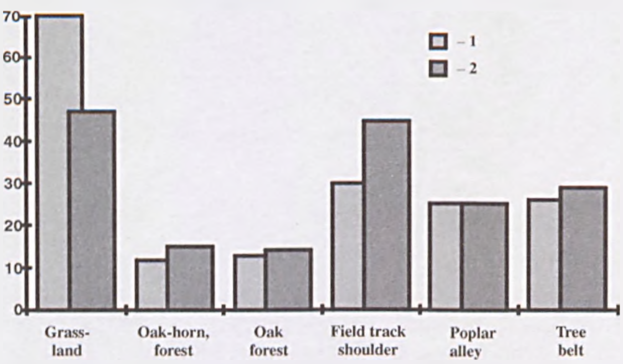

Fig. 7. Comparison of the number of *Apoidea* species observed in particular ecosystems in the seventies (1) and eighties (2).

Ryc. 7. Porównanie liczby gatunków *Apoidea* wykazanych w poszczególnych ekosystemach w latach 70-tych (1) i 80-tych (2).

Table 1. Comparison of species composition and density of *Apoidea* in six investigated ecosystems in the seventies and eighties. Biotopes: a – leafy forest, b – *Calmagrosti-Quercetum petraeae* community, c – xerothermic grassland, d – tree belts, e – poplar alley, f – field track shoulder; q – species identified by additional qualitative investigation of fauna. Degree of significance: * – 0.05>p>0.01, ** – p<0.01, ns – not significant.

Tabela 1. Porównanie składu gatunkowego i zagęszczenia pszczół *(Apoidea)* w sześciu badanych ekosystemach w latach 70-tych i 80-tych. Biotopy: a – las liściasty, b – kwaśna dąbrowa, c – murawa kserotermiczna, d – zadrzewienie pasowe, e – aleja topolowa, f – pobocze drogi polnej; q – gatunek stwierdzony w wyniku dodatkowych ocen jakościowych fauny. Poziom istotności: * – 0,05>p>0,01, ** – p<0,01, ns – nie istotny statystycznie.

Species Gatunek	Habitat Siedlisko						Mean desities inds/ha Średnie zagęszczenie os./ha		Degree of significance Poziom istotności różnic
	a	b	c	d	e	f	1970s	1980s	
1	2	3	4	5	6	7	8	9	10
Colletes daviesanus Smith							0.27	–	ns
Colletes fodiens (Fourcroy)			+				1.10	0.29	ns
Hylaeus annularis (Kirby)			+				–	0.29	ns
Hylaeus brevicornis Nylander				+		+	0.27	0.58	ns
Hylaeus communis Nylander	+		+			+	1.92	4.09	ns
Hylaeus confusus Nylander			+			+	0.27	0.88	ns
Hylaeus difformis (Eversmann)							q	–	–
Hylaeus gracilicornis (Morawitz)			+			+	–	1.17	ns
Hylaeus pfankuchi(Alfken)						+	–	0.29	ns
Hylaeus styriacus Foster				+			–	0.29	ns
Hylaeus pectoralis Foster							q	–	–
Andrena albofasciata					+	+	0.27	0.29	ns
Andrena bicolor Fabr.							0.27	–	ns
Andrena falsifica Perkins							0.82	–	ns
Andrena flavipes Pancer							0.27	–	ns
Andrena floricola Eversm.							–	q	–
Andrena fucata Smith	+						–	0.89	ns
Andrena fulva (Muller)		+	+			+	0.75	0.89	ns
Andrena gerliae v.d. Vecht							0.27	–	ns
Andrena gravida Imhoff							0.75	–	ns
Andrena haemorrhoa (Fabr.)	+	+	+	+	+	+	1.90	3.80	ns
Andrena helvola (L.)	+			+			3.00	0.58	ns
Andrena humilis Imhoff							0.27	–	ns
Andrena jakobi Perkins						+	–	0.29	ns
Andrena labiata Fabr.				+		+	0.60	1.17	ns
Andrena lapponica Zett.		+					0.80	0.58	ns
Andrena minutula (Kirby)						+	–	0.89	ns
Andrena minutuloides Perk.			+			+	0.60	1.46	ns
Andrena nanula Nylander							q	–	–
Andrena nigroaenea (Kirby)				+	+	+	2.45	1.14	ns
Andrena nitida (Muller)							2.27	–	ns
Andrena saxonica Stoeckhert						+	–	0.29	ns
Andrena subopaca Nylander	+	+	+			+	1.10	4.97	*
Andrena synadelpha Perkins							–	q	–
Andrena tibialis (Kirby)						+	0.27	0.29	ns
Pangurus calcalatus (Scopoli)							q	–	–
Halictus confusus Smith			+				–	0.58	ns
Halictus eurygnathus Büthgen			+				–	0.58	ns
Halictus maculatus Smith							0.75	–	ns
Halictus rubicundus (Christ)						+	3.57	0.29	ns
Halictus sexcinctus (Fabr.)							3.85	0.29	*
Halictus tumulorum (L.)			+	+	+	+	7.40	2.92	*
Lasioglossum aeratum (Kirby)							0.27	–	ns

Table I cont.

1	2	3	4	5	6	7	8	9	10
Lasioglossum albipes (Fabr.)			+				4.40	0.29	**
Lasioglossum brevicorne (Schenck)			+	+			–	0.29	ns
Lasioglossum calceatum (Scopoli)			+	+	+	+	26.65	36.26	ns
Lasioglossum laeve (Kirby)							0.27	–	ns
Lasioglossum laticeps (Schenck)							0.27	–	ns
Lasioglossum lativentre (Schenck)				+			1.90	0.29	ns
Lasioglossum leucopum (Kirby)			+				–	0.29	ns
Lasioglossum leucozonium (Schr.)			+				1.90	0.58	ns
Lasioglossum lucidulum (Schenck)						+	–	0.29	ns
Lasioglossum minutissimum (Kirby)							–	q	–
Lasioglossum morio (Fabr.)					+	+	2.45	0.88	ns
Lasioglossum nitidiusculum (Kirby)			+	+	+		4.10	1.75	ns
Lasioglossum parvulum (Schenck)					+	+	1.35	1.46	ns
Lasioglossum pauxillum (Schenck)	+	+		+	+		1.35	2.34	ns
Lasioglossum punctatissimum (Schenck)					+		0.27	0.29	ns
Lasioglossum quadrinotatulum (Schenck)			+	+		+	2.45	2.92	ns
Lasioglossum quadrinotatum (Kirby)			+	+			4.40	0.88	*
Lasioglossum semilucens (Alfken)							2.27	q	ns
Lasioglossum sexnotatum (Kirby)			+			+	1.50	1.17	ns
Lasioglossum sexstrigatum (Schenck)			+				0.87	0.88	ns
Lasioglossum subfasciatum (Imhoff)			+	+	+	+	2.45	6.14	*
Lasioglosssum villosulum (Kirby)							–	q	–
Lasioglossum xanthopus (Kirby)							0.27	–	ns
Sphecodes ephippius (L.)			+			+	0.55	0.88	ns
Sphecodes gibbus (L.)			+				–	0.29	ns
Sphecodes marginatus v. Hagens						+	–	0.29	ns
Sphecodes miniatus v. Hagens							0.27	–	ns
Sphecodes monilicornis (Kirby)						+	0.27	0.88	ns
Sphecodes puncticeps Thomson							0.27	–	ns
Sphecodes reticulatus Thomson							0.27	–	ns
Melitta haemorrhoidalis (Fabr.)							–	q	–
Dasypoda altercator (Harris)							1.10	–	ns
Anthidiellum strigatum (Panzer)			+				0.55	0.29	ns
Proanthidium oblongatum Latreille							–	q	–
Heriades truncorum (L.)							0.27		ns
Chelostoma florisomne (L.)			+				0.27	0.29	ns
Chelostoma fuliginosum (Panzer)					+		–	0.88	ns
Hoplitis adunca (Panzer)							0.27	–	ns
Hoplitis leucomelana (Kirby)							–	q	–
Hoplitis parvula (Duf. Per.)			+			+	–	1.46	ns
Osmia rufa (L.)							0.37	–	ns
Osmia ventralis (Panzer)			+				–	0.29	ns
Megachile centuncularis (L.)			+				0.27	0.58	ns
Megachile circumcincta (Kirby)							0.55	–	ns
Megachile ligniseca (Kirby)						+	0.27	1.17	ns
Megachile versicolor Smith			+				0.55	0.29	ns
Megachile villughbiella (Kirby)							0.82	–	ns
Nomada alboguttata Herr.-Scaff.	+						–	1.17	ns
Nomada furva Panzer							–	q	–
Nomada flavoguttata (Kirby)							2.27	–	ns
Nomada goodeniana (Kirby)				+	+		0.27	0.88	ns
?*Nomada guttulata* Schenck					+	+	–	1.46	ns

Table 1 cont.

1	2	3	4	5	6	7	8	9	10
Nomada marshamella (Kirsby)					+		0.27	0.29	ns
Nomada moeschlerei Alfken		+	+	+			0.55	0.88	ns
Nomada panzeri Lepeletier	+				+		8.70	5.50	ns
Nomada signata signata Jurine		+	+			+	0.87	0.58	ns
Epeolus cruciger (Panzer)							–	0.29	ns
Nomada marshamella (Kirsby)					+		0.27	0.29	ns
Nomada moeschlerei Alfken		+	+	+			0.55	0.88	ns
Nomada panzeri Lepeletier	+				+		8.70	5.50	ns
Nomada signata signata Jurine		+	+			+	0.87	0.58	ns
Epeolus cruciger (Panzer)							–	0.29	ns
Epoleus variegatus (L.)							0.55	–	ns
Anthophora bimaculata (Panzer)							–	q	–
Anthophora furcata (Panzer)	+		+				–	1.17	ns
Anthophora plumipes (Pallas)				+	+	+	0.27	3.80	*
Ceratina cyanea (Kirby)			+			+	0.80	1.46	ns
Bombus cryptarum (Fabr.)	+		+			+	–	2.34	*
Bombus hortorum (L.)			+	+	+		1.64	1.17	ns
Bombus hypnorum (L.)		+	+				3.02	0.58	*
Bombus lapidarius (L.)			+	+	+	+	38.18	19.23	*
Bombus lucorum (L.0	+	+	+	+	+	+	15.11	21.34	ns
Bombus magnus Vogt				+			–	0.29	ns
Bombus muscorum (L.)			+	+	+	+	1.65	4.97	*
Bombus pascuorum (Scopoli)	+	+	+	+	+	+	30.50	79.82	**
Bombus pratorum (L.)	+	+	+			+	1.10	6.14	*
Bombus ruderarius (Muller)			+	+	+	+	6.50	3.80	ns
Bombus subterraneus (L.)							q	–	–
Bombus sylvarum (L.)				+		+	1.25	2.05	ns
Bombus terrestris (L.)		+	+	+	+	+	34.00	4.70	**
Psithyrus bohemicus (Seidl)		+	+		+	+	1.10	2.63	ns
Psithyrus campestris (Panzer)							0.60	–	ns
Psithyrus rupestris (Fabr.)						+	1.35	0.29	ns
Psithyrus vestalis (Geoffr.)							1.35	–	ns
Apis mellifera L.	+	+	+	+	+	+	138.25	159.36	ns

Table 2. Species diversity (H') and density of bees in the investigated biotopes. Significance: *** – < 0.001; J' – eveness.

Tabela 2. Zróżnicowanie gatunkowe (H') i zagęszczenie *Apoidea* w badaniach biotopach. Istotność: *** – < 0,001; J' – równomierność.

Biotopes Siedliska	Number of species Liczba gatunków		H'			J'		Density ind/ha Zagęszczenie	
	1970	1980	1970	1980	signifi-cance	1970	1980	1970	1980
Natural (naturalne):									
Oak-hornbeam forest Las dębowo-grabowy	11	15	1.70	2.32	***	0.68	0.85	87.5	140.6
Oak forest Kwaśna dądrowa	13	14	2.04	2.32	ns	0.80	0.88	74.5	58.9
Grassland Murawa	70	47	3.69	2.18	***	0.64	0.57	1088.5	807.6
Anthropogenic (antropogeniczne):									
Tree belt Zadrzewienie pasowe	26	29	2.83	1.82	***	0.91	0.55	122.0	494.7
Poplar alley Aleja topolowa	24	25	2.56	2.20	ns	0.81	0.67	272.0	366.7
Field track shoulder Pobocze drogi polnej	30	45	1.80	2.21	***	0.53	0.59	591.0	867.0

particular habitats (Table 2). Statistically significant differences between the two periods occurred at most of the sites, with exception of the *Calamagrosti-Quercetum petraeae* community and poplar alley.

The domination structure of the *Apoidea* in particular habitats is also quite interesting. Over the ten year interval the domination structures in natural environments changed at all three sites (Figs 8–10). On the xerothermic grassland overgrown by trees, the percentage of *Bombus pascuorum* normally linked with tree stands increased, and the numbers of *Bombus lapidarius* and *B. terrestris* (normally linked with open habitats) decreased. In the oak-hornbeam forest, the observed numbers of bumble-bees *Bombus pascuorum*, *B. pratorum* and *B. lucorum* increased along with a decrease in the number of representatives of *Andrena* and their parasite species *Nomada ruficornis*. In the *Calmagrosti-Quercetum petraeae* community the of *B. lucorum* decreased significantly along with an increase in the population of *B. pratorum*. The changes in bumble-bee species numbers observed in both associations (oak-hornbeam forest and the *Calamagrosti-Quercetum petraeae* community) can not easily be interpreted, despite the fact that they may result from periodic fluctuation caused by varying weather conditions in particular years. Contrarily to expectations, the species composition of the bee population in agricultural areas was found to be the most stable (Figs 11–13). On the Rogaczew road shoulder and tree belts the same species of bees were dominant (only in the poplar rows the numbers of the main representatives of *Halictus* decreased, giving way to bum-

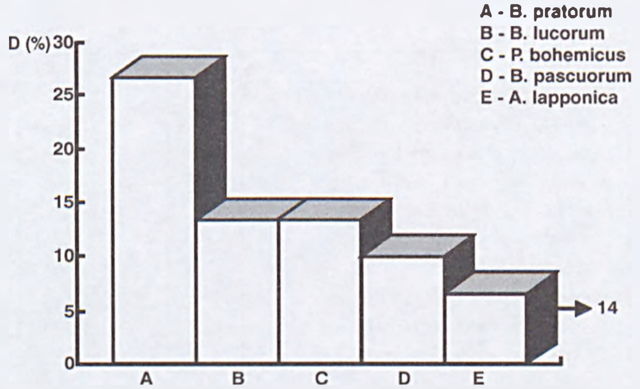

Fig. 10. Domination structure of the *Apoidea* in the *Calmagrosti-Quercetum petraeae* community of the Wielkopolski National Park.

Ryc. 10. Struktura dominacyjna *Apoidea* w kwaśnej dąbrowie Wielkopolskiego Parku Narodowego.

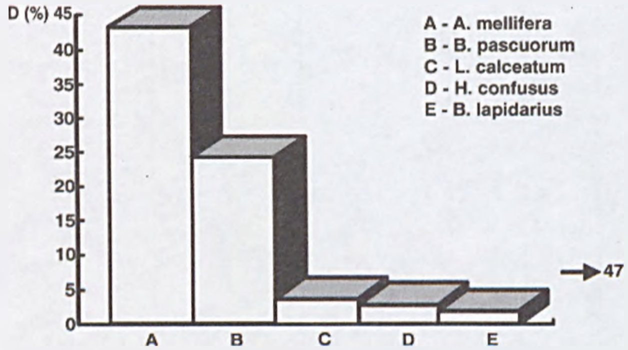

Fig. 8. Domination structure of the *Apoidea* on the xerothermic grassland in the Wielkopolski National Park.

Ryc. 8. Struktura dominacyjna *Apoidea* na murawie kserotermicznej w Wielkopolskim Parku Narodowym.

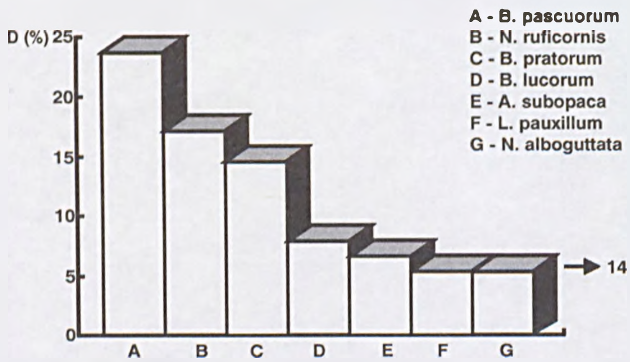

Fig. 9. Domination structure of the *Apoidea* in the oak-hornbeam forest at Wielkopolski National Park.

Ryc. 9. Struktura dominacyjna *Apoidea* w lesie grądowym w Wielkopolskim Parku Narodowym.

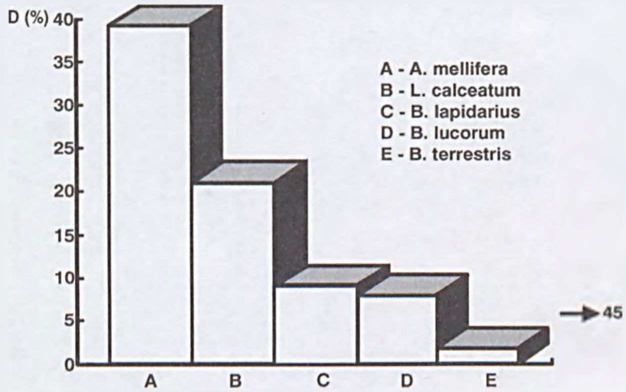

Fig. 11. Domination structure of the *Apoidea* on the field track shoulder.

Ryc. 11. Struktura dominacyjna *Apoidea* na poboczach drogi polnej.

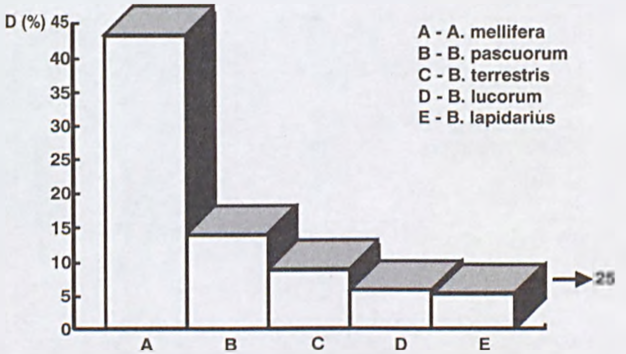

Fig. 12. Domination structure of the *Apoidea* in the poplar alley.

Ryc. 12. Struktura dominacyjna *Apoidea* w przydrożach alei topolowej.

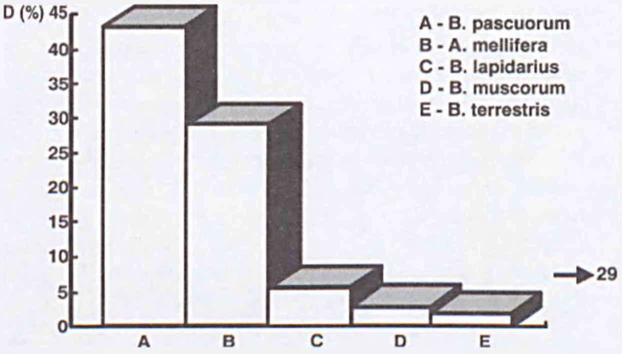

Fig. 13. Domination structure of the *Apoidea* in the tree belts.

Ryc. 13. Struktura dominacyjna *Apoidea* w zadrzewieniu pasowym.

ble-bees (more particularly to *Bombus pascuorum* and *B. lucorum*). The increase in the numbers of bumble-bees was most probably caused by the establishment of a nearby lucerne plantation - an attractive feeding plant for this group of *Apoidea*.

CHANGES IN WILD BEES NUMBERS

The comparison of the average densities of wild bees in the particular ecosystems investigated indicates general increasing tendencies similar to those of the species diversity analysed above. In most of the habitats a slight increase in the density of wild bees was observed after ten years at most of the sites. The most important increase (almost 500%) – from an average of 100 specimens/hectare during the season to almost 500 specimens/hectare was observed in the tree belts. Only in the xerothermic grassland in the Wielkopolski National Park a significant decrease in the number of wild *Apoidea* was observed in the eighties (from approx. 1,100 specimens/hectare to 807.6 specimens/hectare (Fig. 14).

Among the 122 wild species observed in both research periods there were no statistically significant changes in populations of 109 (89.3%) species, seven species (5.7%) increased and the remaining six decreased in numbers (Table 1).

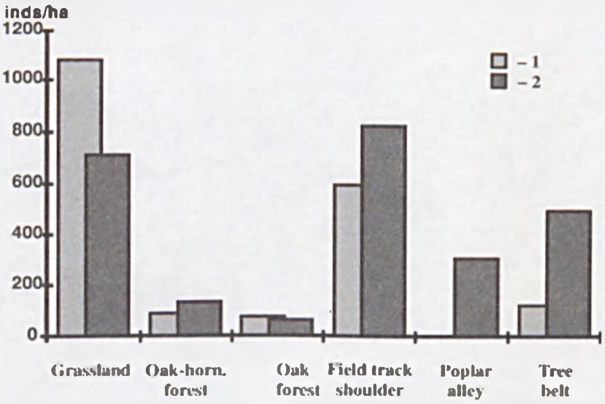

Fig. 14. Comparison of the densities of the *Apoidea* in particular ecosystems in the seventies (1) and eighties (2).

Ryc. 14. Porównanie zagęszczeń *Apoidea* w poszczególnych ekosystemach w latach 70-tych (1) i 80-tych (2).

Looking at the above population changes in particular taxonomic groups, the only conclusion to be drawn is that the most significant changes were observed in bumble-bees; over 50% of the species in this group decreased (*Bombus terrestris*, *B. hypnorum*, *B. lapidarius*) or increased (*B. cryptarum*, *B. pratorum*, *B. muscorum*, *B. pascuorum*) in numbers. These changes are probably linked with the changes in structure of the adjacent crop cultures or with the natural succession of plant species (grasslands overgrown by trees).

DISCUSSION

The comparison of species lists from the seventies and eighties indicates that the total number of species in the investigated ecosystems did not change. The monitoring of the same biotopes after ten years indicated a very similar number of species (89 versus 91 species observed earlier). Both lists differ significantly in species composition (25%). It should be said that the differences in both fauna compositions apply to the species which were not numerous in the investigated areas. Their observation could thus be a random event. The identification of such species often requires years of research. Therefore in the case of rare species, drawing general conclusions on their appearance or disappearance is risky. Independent of this reservation, the research carried out also demonstrated obvious cases of changes in the composition and population numbers of species present at particular investigation sites. This is demonstrated by the populations of particular species and the average density of the *Apoidea* in particular ecosystems over the entire vegetation season. These changes mainly consisted of the withdrawal of species from some of the biotopes and of the decrease (or increase) in populations of particular species. During the eighties 23 species disappeared from the xerothermic grasslands (a part of them withdrew because of natural successional changes in the vegetation). This particularly applies to *Andrenidae* (decrease from 11 to 4) and *Halictidae* (from 21 to 17). An excessive expansion of the ash-leafed maple caused shading of the slopes of the investigated embankment (formerly very well insolated).

A general increase in the number of *Apoidea* was observed in the remaining ecosystems (both in the natural landscape of the Wielkopolski National Park and the agricultural areas). The best example in this case is the tree belts and field track shoulders. Analysis of variations in the numbers of particular species indicated an increase in the number of species linked with forests and tree belts (such as *Andrena subopaca*, *Lasioglossum subfasciatum*, *Anthophora plumipes*, *Bombus cryptarum*, *B. muscorum*, *B. pascuorum* and *B. pratorum*). A statistically significant decrease in population numbers was observed in the case of a group of species linked with agricultural areas, mainly belonging to the *Halictidae* (*Halictus sexcinctus*, *H. tumulorum*, *Lasioglossum albipes*, *L. quadrinotatum*) and some bumble-bees linked with farmland environments (*Bombus terrestris* and *B. lapi-*

darius). In the eighties Cierzniak (1995) investigated the density and diversity of *Apoidea* on adjacent cultivated fields with a less variable landscape structure. He observed a 50% decrease in the populations of species linked with open environments with no tree growth (these can be considered as more threatened by agricultural activity-related pressures).

The analysis of factors which may have an impact on the numbers of *Apoidea* in the investigated types of landscape indicated that the seventies and eighties differed in terms of precipitation levels and the average ambient temperature (Fig. 15), the level of chemicals applied by adjacent agricultural activities (Table 3) and to a certain extent by a change in land use patterns. The weather conditions in the second period of investigation were characterized by a higher average ambient temperature along with a decrease in precipitation levels (Fig. 15). The second half of the eighties was characterized by a general warming of the climate in Poland (Kędziora 1993; Kocoń 1993; Trepińska 1993). Such weather conditions are considered to be favorable to the viability of mature specimens, larvae and eggs (Wilson 1979; Alford 1975, Pawlikowski 1989). More favorable weather conditions may be a partial explanation for the increase in numbers of certain wild bee species during the second period of research. The winters at the end of the eighties were milder and springs warmer, which accelerated blossoming of plants and appearance of the bees. For example in 1988–90 *Adrena fulva* in Poznań appeared 10–20 days earlier than a decade before (Banaszak 1994). The following factor which could potentially cause an increase in the numbers of certain *Apoidea* (bumble-bees in particular) in the agricultural landscape environment is changing land cultivation patterns in the investigated area. In the seventies the investigated sites were not adjacent to lucerne cultures, during the next decade several plantation of this crop species were established. Lucerne fields neighbored the tree belts, poplar alley and road shoulders in Rogaczewo, and the most significant increases in population numbers of *Apoidea* were observed there. Plantations of lucerne and perennial papilionaceous plants provide a rich seasonal feeding base and ensure appropriate breeding conditions, thus contributing to the qualitative and quantitative enrichment of the local fauna (Śnieżek 1894; Majewski 1963, 1989).

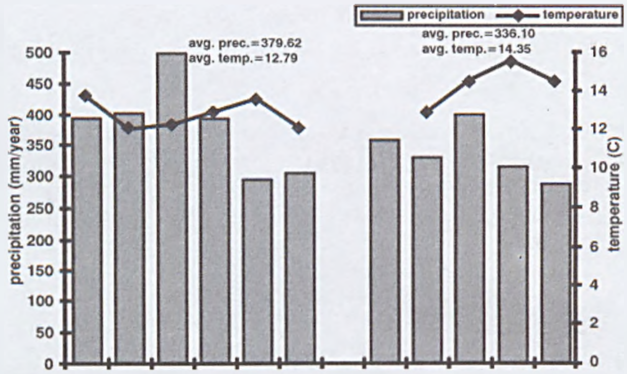

Fig. 15. Distribution of the average precipitation levels and temperatures during the vegetation season (March–August) in the investigated area in the seventies and eighties (after Cierzniak 1995).

Ryc. 15. Rozkład średnich wartości opadów i temperatury w sezonie wegetacyjnym (marzec-sierpień) na badanym terenie w latach 70. i 80 (wg Cierzniaka 1995).

Table 3. Use of plant protecting chemicals (pesticides and herbicides) in the investigated landscape (after Cierzniak 1995).

Tabela 3. Zużycie środków ochrony roślin (pestycydy i herbicydy) na badanym terenie (wg Cierzniaka 1995).

Year Rok	Average use (kg/ha) – Średnie zużycie			
	Plant protecting chemicals Środki ochrony roślin	Fertilizers Nawozy N	P	K
1976	0	50	72	150
1978	3	153	92	150
1979	0	27	92	120
1980	4	170	115	240
Mean Średnia	1.7	100	93	165
1986	1.5	93	81	120
1987	5.5	85	82.2	135
1988	2.7	71	77.5	114
1989	6.7	77.5	82	120
1990	6.5	131	103.5	180
Mean Średnia	4.58	91.5	85.3	134

There is also a quite large group of species which decreased in terms of population numbers or which were not observed in the second phase of the experiment. The reasons for such situations are not easy to interpret. The withdrawal of several species due to the overgrowing of xerothermic grasslands is evident. Bee species from agricultural environments are more exposed to the direct effects of chemical pesticides and herbicides. The road shoulders and balks are more often contaminated during the application of chemicals over adjacent fields than the tree belts. In the eighties more herbicides and insecticides were applied near Turew (Table 3), which could have contributed to the decrease in numbers of some of the bee species in this area.

SUMMARY OF THE RESULTS

1. The assessment of species diversity and density of wild bees (*Apoidea*) in six ecosystems of natural and agricultural landscape was repeated at a ten year interval.

2. Although the total number of species did not change significantly (89 and 91 species respectively), the species composition was different. In the eighties the occurrence of 31 previously observed species was not confirmed (25.4%), though a similar number of new species (not observed in the seventies) was found.

3. A general increase in numbers and species diversity at some of the sites was observed after ten years. A significant decrease in numbers and diversity of the *Apoidea* was observed in the xerothermic grasslands. This was due to the natural succession changes such as overgrowth of the grassland by the ash-leafed maple.

4. The analysis of population changes in particular species indicated an increase in numbers of species linked with forests and tree belts (*Andrena subopaca, Lasioglossum subfasciatum, Anthophora plumipes, Bombus cryptarum, B. muscorum, B. pascuorum* and *B. pratorum*). A statistically significant decrease in population was observed in the group of species linked with open space and agricultural landscapes, mainly belonging to *Halictidae* (*Halictus sexcinctus, H. tumulorum, Lasioglossum albipes, L. quadrinotatum*) and some bumble-bees linked with agricultural habitats (*Bombus terrestris, B. lapidarius*) which are more exposed to pressure from human activity.

5. Tree belts and forests in the agricultural landscape which ensure the preservation and stabilization of the fauna of pollinating insects.

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STRESZCZENIE

W latach 70-tych i 80-tych badano zróżnicowanie gatunkowe i zagęszczenie *Apoidea* na 6 stanowiskach w krajobrazie naturalnym i rolniczym Polski Zachodniej (ryc. 1–6). Krajobraz naturalny reprezentowały: murawa kserotermiczna, las liściasto-grabowy i kwaśna dąbrowa, zlokalizowane na terenie Wielkopolskiego Parku Narodowego, a krajobraz rolniczy: pobocze drogi polnej, aleja topolowa oraz śródpolne zadrzewienie pasowe na terenie Agroekologicznego Parku Krajobrazowego w okolicy miejscowości Turew pod Kościanem, 50 km na południe od Poznania.

Badania obejmowały ocenę zagęszczenia pszczołowatych metodą transektów liniowych, określenie warunków pokarmowych, a także czynników mogących mieć wpływ na stosunki liczebne w tej grupie owadów (warunki mikroklimatyczne, strukturę zasiewów w sąsiedztwie badanych powierzchni oraz zużycie nawozów chemicznych i pestycydów na obszarach rolniczych).

W obu okresach badań na wszystkich stanowiskach stwierdzono podobną liczbę gatunków (89 i 91), zaobserwowano jednak różnice w składzie gatunkowym. W latach 80. nie potwierdzono występowania 31 taksonów (25,4%), a jednocześnie wykazano taką samą liczbę gatunków nie notowanych wcześniej. Łącznie zidentyfikowano 122 gatunki (tab. 1).

Po dziesięciu latach na większości stanowisk nastąpił ogólny wzrost liczebności *Apoidea* (ryc. 7), a na niektórych powierzchniach wzrost ich zróżnicowania gatunkowego (tab. 2). Wyraźny spadek zróżnicowania i liczebności *Apoidea* na murawie kserotermicznej (ryc. 7 i 8) był skutkiem zmian suksesyjnych, polegających na zarastaniu muraw, głównie przez klon jesionolistny.

Analiza zmian liczebności poszczególnych gatunków wykazała wzrost liczebny taksonów związanych z lasami i zadrzewieniami śródpolnymi, jak *Andrena subopaca, Lasioglossum subfasciatum, Anthophora plumipes, Bombus cryptarum, B. muscorum, B. pascuorum* i *B. pratorum*. Istotny statystycznie spadek liczebności zanotowano w grupie gatunków związanych z obszarami bezleśnymi, rolniczymi, znajdującymi się pod silniejszą presją gospodarczą. Grupę tę reprezentują głównie *Halictidae* (*Halictus sexcintus, H. tumulorum, Lasioglossum albipes, L. quadrinotatum*) i niektóre trzmiele zwiazane ze środowiskiem rolniczym (*Bombus terrestris, B. lapidarius*).

Zadrzewienia śródpolne i lasy są ważnymi elementami krajobrazu rolniczego, podtrzymującymi i stabilizującymi faunę owadów zapylających.