BEES (HYMENOPTERA: *Apiformes*) OF THE AGRICULTURAL AREAS IN THE LOWER VISTULA VALLEY*

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Summary

The research took place over a time span of two seasons. It was conducted in the Lower Vistula valley between the towns of Toruń and Chełmno. There 144 species were recorded, which is, ca. 33% of all the species recorded in Poland, as well as 58% of the species recorded in the Kujawy-Pomerania region. From 35 to 88 bee species were recorded at six research locations. Diversity of bee communities in marginal environments of agricultural areas of the Lower Vistula valley, was found. A significant factor influencing bee diversity was the process of habitat diversification of their nutritional vegetation. This factor remained under the influence of the xerisation gradient. A directly proportional relationship was revealed between the diversity of bee communities and the general diversity of marginal habitats in agricultural areas. Domination-species analysis according to the Renkonen index, described the structure at similar level to be two times higher (=more accurate) as compared to the species method according to the Marczewski-Steinhaus index.

Keywords: *Apiformes*, bee communities, agricultural areas, valley landscape, Lower Vistula.

INTRODUCTION

In agricultural areas, the main habitats of bees are marginal habitats. Marginal habitats include, such areas as grassland and herb communities on boundary strip or roadsides, bushes, strips of open land which is in the process of converting to forest, ecotone forest patches, parks etc. Such habitats provide bees with a place to forage, nests, develop and hibernate. Agrotechnical methods used on farmland include ploughing and crop rotation of, what are for bees, nutritionally unattractive plants. The chance for bees to have a full life cycle or hibernation are impossible or limited where agrotechnical methods have been used, e.g. on fodder crops of Fabaceae (Pawlikowski 1987, 1989).

Of particular significance for the functioning of agricultural areas is their distribution in the valley landscape of the Lower Vistula. One can find the most attractive local refugia of bees on the southern slopes of the marginal zone of the Vistula Valley. The research of Pawlikowski and Hirsch (2002) in the Lower Vistula valley between the towns of Włocławek and Chełmno revealed 244 species. That is about 56% of all the species recorded in Poland, as well as being 87% of all the species recorded in the Kujawy-Pomerania region. A significant

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factor influencing the species diversity of bee communities in environments of the Lower Vistula valley was the process of habitat diversification of their nutritional vegetation. The habitats remained at the same time under the influence of the xerisation gradient (increasing from the river towards the edge of the valley). On hillsides that had southern exposure; the moraine plateau near the marginal zone, the slope zone and the valley floor, the number of species run at the approximate ratio of 1:2:1. When analysing the occurrence of individual species in the zones for the whole studied section of the valley, it was found that all the species nested or were connected with nesting places in the slope zone. From there they spread to environments of the valley floor and to nearby environments of the moraine plateau.

The aim of the present paper was to describe the variability of the structure of bee communities. These were bee communities in agricultural areas which had diverse habitats distributed throughout the valley of the Lower Vistula.

STUDY AREA

The scientific studies were conducted mainly in the areas of the Lower Vistula valley between the cities of Toruń and Chełmno. This area divides the right-bank lands of the Chełmno Lake District and the Dobrzyń Upland from the left-bank Świecie Upland and the Kujawy Region. The hillsides of the valley are either clear or eroded borders between the moraine upland and the sandy bottom of the valley. The hillsides rise here and there distinctly and steeply. They eventually reach up to 70 m above the average water level of the river. The hillsides are cut by numerous, segmented ravines. These ravines make climbing down from the upland into the valley much easier. In some places the hillsides have been flattened by sands blown in from the bottom of the valley. In other places the hillsides have been flattened by landslides and alluvial processes with waters from the contact zone of the mesoregions.

In geobotanical terms, the Lower Vistula valley and the adjacent upland areas belong to the West-Pomeranian transitional strip. The vegetation cover of this area is relatively young. It is much younger than the vegetation cover of southern Poland. The vegetation developed after the last deglaciation, i.e. around 12000 years ago. There is rich amount of floral plants, which resulted from the diverse relief, water conditions and climate (Boiński 1988).

The good soils of the upland areas, caused humans, from the very beginning, to develop the land. The primary forest vegetation was gradually destroyed and the lands were converted into arable fields and meadows. Not even the riparian mixed forests at the bottom of the valley were spared. Substitute communities developed: communities of weeds connected with crops, communities of meadow plants and communities of ruderal plants. The history of the settlement of the upland areas is reflected in the process of forest extinction and the development of agriculture in that area. In the Middle Ages, numerous fortified settlements developed in the studied area (Chudziakowa 1994). With their economic activity, residents of those strongholds contributed to the development of xerothermic grasslands in the hillside zone of the valley. Until the present time, the subsequent societies maintained the xerothermic nature of the hillsides through grazing, burning of grasslands and destruction of thicket vegetation.

At present, natural (climax) and paranatural (anthropoclimax) plant communities cover a relatively small percentage of the agricultural area of the Lower Vistula uplands. From among the grasslands in the most natural conditions, communities with steppe vegetation were preserved (Ceynowa-Giełdon 1968, 1984).

In the 1960s, steppe reserves were created on grasslands of hillsides between the Płutowo Ravine and the village of Starogród – the Hillsides of Płutowo („Zbocza Płutowskie") reserve, and on the opposite bank between the villages of Topolinek and Gruczno – the Ravines with Stipa („Parowy Ostnicowe") reserve (Ceynowa-Giełdon 1971, 1984). Since then, as a result of succession, shrubs and tall vegetation have been encroaching on the reserves' hillsides. This growth has taken place despite the fact that Polish heath sheep ("wrzosówka") have been used to regularly cut and graze.

Cryptopodsols, podsol (slightly podsolized) and rusty soil are the main soils of the bottom of the Vistula River valley. This soil developed mainly on the extensive dune fields of the Toruń Valley and the Płock Valley. Only near the hillside zone, can brown and lessivés soil be seen penetrating here and there from the upland. Upland areas are built mainly of boulder clays, on which brown and lessivés soils developed, and to a lesser degree black earths (Bednarek and Prusinkiewicz

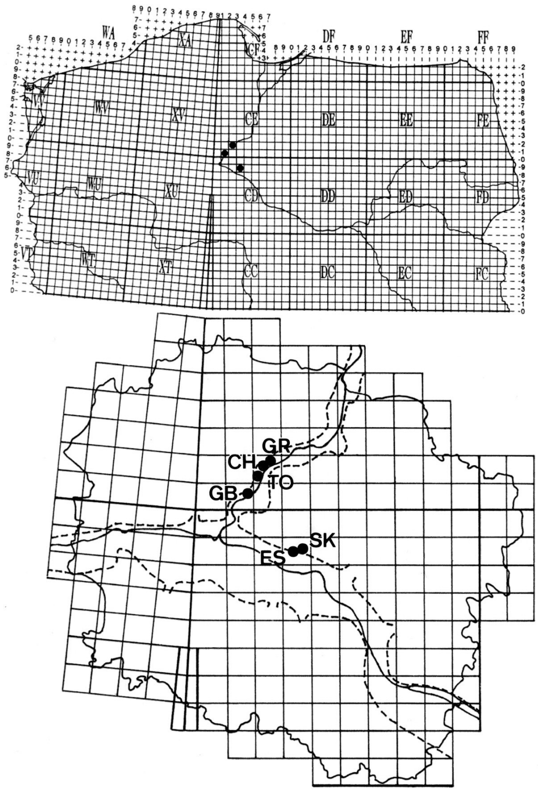

Fig. 1. Distribution of sites in the Lower Vistula valley (dashed line) with UTM grid system of North Poland: GR – Gruczno, CH – Chrystkowo, TO – Topolinek, GB – Grabówko, ES – Leszcz, SK – Świerczynki.

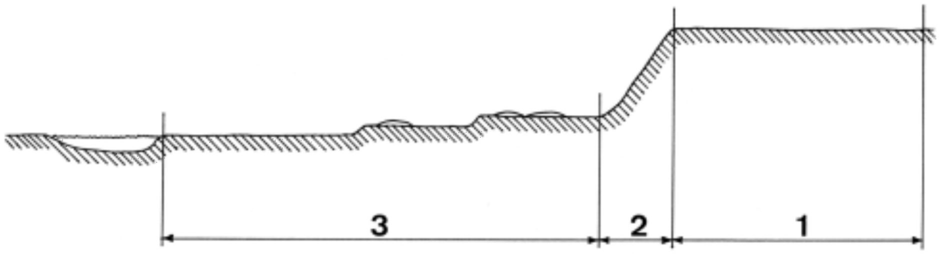

Fig. 2. Landscape zones accross a profile of the Lower Vistula valley:
1 – moraine plateau near marginal zone, 2 – slope zone, 3 – valley floor with inundation plain and terraces partly covered by diunes.

1984, Plichta and Regel 1973).

Poland can be divided into climatic districts according to Kondracki (1988), the Lower Vistula valley belongs to the Bydgoszcz District. It has a transitional character. It is located between the rather cold and relatively humid Pomeranian district and the drier and warmer central district. The average annual temperature for this district is: 7.9°C, for January –3.5°C (of the range –2.7- 4.1°C), for July 18.5°C (18.0 - 18.6°C). Average annual precipitation ranges from 450 (Toruń) up to 467 mm (Chełmno), 65% of the total precipitation occurs during the summer period. The duration of the growing season (average daily temperature ≥5°C) amounts to 210 days. Usually it starts in mid-April. The frequency of drought months (months that do not have enough precipitation as required for the growth of plants) is relatively high in this area and amounts to 55%. The summer period (average daily temperature ≥15°C) lasts on average 100 days (Hohendorf 1952, Trajkowska 1982).

The years of the scientific study (1997-1998) were evaluated based on the climatic criteria of Kaczorowska (1962) and Lorenc (1998). The year 1997 was recognized as an average year, both in respect of precipitation and average annual temperature. It was characterized by a frosty winter, relatively chilly spring, warm summer and average autumn. The year 1998 received standard precipitation. It was a warm year, which was influenced by high summer and autumn temperatures.

Six sites were selected for the studies, whose location and vegetation description are presented in Table 1 and Fig. 1. The research sites were located within the landscape zones of the Lower Vistula valley (Fig. 2).

MATERIAL AND METHODS

At the selected locations (Table 1) bees were caught from mid May till mid September in 1997 and 1998. They were caught using Moericke's traps. White bowls with a diameter of 20 cm and a depth of 6 cm, were filled with an aqueous solution of 4.8% glycol (and 0.2% surfactant) up to 2/3 volume. Traps were distributed in selected biotopes on stakes above the herb layer or they were hung three at a time on shrubs at each location. They were emptied every 7-10 days. A sample consisted of the number of individuals collected at one emptying of the three traps at one location.

Altogether 1520 wild bees and 1066 workers of *Apis mellifera* L. were recorded in the study area (Table 2). They were included in the description of communities. The following parameters define the

Table 1.

Study sites of arable areas in the valley landscape of the Lower Vistula

Location [UTM]	Site	Arable area		
		Landscape zones	Marginal habitats	Diversity of wild vegetation
Gruczno [CE21]	GR	valley floor	bushes on a boundary strip	low
Chrystkowo [CE21]	CH	valley floor	a boundary strip with herb and shrub vegetation on a shallow drainage ditch	low
Topolinek [CE21]	TO	valley floor	a boundary strip with herb, grassland and shrub vegetation	low
Grabówko [CE10]	GB	valley floor	bushes on a flood boundary strip	low
Leszcz [CD38]	ES	SW-slope zone	fragments of shrub vegetation on a boundary strip with herb and grassland vegetation near ecotone-forest patches	high
Świerczynki [CD38]	SK	moraine plateau	a boundary strip with herb and grassland vegetation on the slope of a drainage ditch near an ecotone forest patch	moderate

community structure: the number of species (S), domination of each species (D), general species diversity (H').

Domination was defined according to the formula $\mathbf{D = n_i / N}$, where n_i is the number of individuals of the i^{th} species in a community with the total number of N individuals. The formula of the general species diversity index was accepted after Shannon (Shannon and Weaver 1963): $\mathbf{H' = \sum p_i \log_2 p_i}$, where $p_i = n_i / N$, which means a dominant fraction of the i^{th} species in a community that consists of S species.

For the qualitative comparison of the communities' structure, the index of Marczewski-Steinhaus (1959) was applied: $\mathbf{MS = w / (a + b - w)}$, where w – the number of species common in the compared communities, a – the number of species in the first compared community, b – the number of species in the second compared community. Also the Renkonen index of quantitative and qualitative similarity was applied (1938): $\mathbf{Re = \sum D_{min}}$, where D_{min} – the minimum domination value for a species from the compared communities. To define the similarity of the total species diversity of communities, the Liu index (1995) was applied, also called the community diversity index: $\mathbf{Q = H' / \sin\alpha}$, where the value of α was obtained from the formula $\mathrm{tg}\alpha = H' / H'_{max}$, with $H'_{max} = \log_2 S$.

RESULTS AND DISCUSSION

The main factor influencing the species diversity of bees in the Lower Vistula valley was the process of habitat diversification of nutritional vegetation.

Journal of Apicultural Science

Table 2.

Number of specimens of bees collected in sites of the Lower Vistula valley (as in Tab. 1) during the 1997-1998 seasons; n – number of samples.

Species	Sites						
	GR	CH	TO	GB	ES	SK	GR -> SK
	n=16+ 13	n=13+ 11	n=14+ 14	n=11+ 10	n=13+ 17	n=12+ 15	n=79+ 80
1	2	3	4	5	6	7	8
1. *Hylaeus annularis* (K.)	-	-	-	-	2	-	2
2. *Hy. brevicornis* Nyl.	5	-	1	1	-	-	7
3. *Hy. communis* Nyl.	1	7	-	6	5	15	34
4. *Hy. confusus* Nyl.	1	4	-	1	3	2	11
5. *Hy. difformis* (Eversmann)	-	1	-	-	1	-	2
6. *Hy. gibbus* Saunders	-	-	-	-	1	-	1
7. *Hy. gracilicornis* (Mor.)	-	-	-	-	2	-	2
8. *Hy. gredleri* Förster	-	-	1	-	2	-	3
9. *Hy. lepidulus* Cockerell	-	-	-	-	-	1	1
10. *Hy. pectoralis* Förster	-	1	1	-	-	-	2
11. *Hy. sinuatus* (Schenck)	3	1	-	-	-	-	4
12. *Hy. styriacus* Förster	1	-	-	-	-	-	1
13. *Colletes cunicularius* (L.)	-	-	-	-	1	1	2
14. *Co. daviesanus* Smith	-	9	3	-	-	1	13
15. *Co. fodiens* (Fourcroy)	-	-	-	-	1	-	1
16. *Co. similis* Schenck	-	-	-	-	-	1	1
17. *Co. succinctus* (L.)	-	-	-	-	-	1	1
18. *Andrena sp.*	-	-	-	-	2	1	3
19. *Andrena alfkenella* Perkins	-	-	-	-	5	1	6
20. *A. barbilabris* (K.)	-	-	-	-	-	1	1
21. *A. bicolor* F.	-	-	-	-	10	1	11
22. *A. bimaculata* (K.)	-	-	-	-	2	-	2
23. *A. chrysosceles* (K.)	-	1	-	-	-	-	1
24. *A. cineraria* (L.)	-	-	-	-	3	2	5
25. *A. clarkella* (K.)	-	-	-	-	-	1	1
26. *A. combinata* (Christ)	1	2	1	-	2	1	7
27. *A. dorsata* (K.)	2	-	3	1	-	-	6
28. *A. falsifica* Perkins	-	-	-	-	2	-	2
29. *A. flavipes* Pz.	-	-	-	-	-	1	1
30. *A. fucata* Smith	3	1	6	1	4	-	15
31. *A. fulva* (Műller)	1	-	1	-	11	1	14
32. *A. fulvida* Schenck	-	-	-	-	-	2	2
33. *A. gravida* Imhoff	-	-	-	-	1	-	1
34. *A. haemorrhoa* (F.)	8	9	3	5	92	16	133
35. *A. helvola* (L.)	5	1	6	1	100	9	122
36. *A. jakobi* Perkins	-	-	-	-	7	2	9

Table 2.

Number of specimens of bees collected in sites of the Lower Vistula valley (continued).

Species	Sites						
	GR	CH	TO	GB	ES	SK	GR -> SK
1	2	3	4	5	6	7	8
37. *A. labialis* (K.)	2	-	-	-	-	-	2
38. *A. lepida* Schenck	-	-	-	-	1	-	1
39. *A. minutula* (K.)	1	2	-	-	-	-	3
40. *A. minutuloides* Perkins	2	-	-	1	4	1	8
41. *A. nanula* Nyl.	-	-	-	-	3	-	3
42. *A. nigroaenea* (K.)	1	-	-	-	7	2	10
43. *A. nitida* (Műller)	1	-	-	-	2	1	4
44. *A. nycthemera* Imhoff	-	-	-	-	2	-	2
45. *A. ovatula* (K.)	-	-	-	-	-	1	1
46. *A. carbonaria* F.	-	-	-	-	-	2	2
47. *A. polita* Smith	-	-	-	-	4	-	4
48. *A. praecox* (Scop.)	1	-	3	-	5	-	9
49. *A. proxima* (K.)	2	-	-	-	-	-	2
50. *A. ruficrus* Nyl.	-	-	-	-	-	1	1
51. *A. subopaca* Nyl.	1	2	2	1	9	-	15
52. *A. suerinensis* Friese	-	-	-	-	2	1	3
53. *A. symphyti* Schmiedekn.	-	-	-	-	-	1	1
54. *A. vaga* Pz.	-	-	2	1	-	-	3
55. *A. varians* (K.)	-	-	-	-	1	-	1
56. *A. ventralis* Imhoff	5	-	5	12	-	-	22
57. *Panurgus calcaratus* (Scop.)	-	-	1	-	-	-	1
58. *Halictus perkinsi* Blüthgen	1	1	1	-	2	-	5
59. *H. maculatus* Smith	-	7	12	1	1	10	31
60. *H. quadricinctus* (F.)	1	-	-	-	2	-	3
61. *H. rubicundus* (Christ)	1	2	2	-	-	-	5
62. *H. simplex* Blüthgen	1	-	-	-	-	-	1
63. *H. subauratus* (Rossi)	7	-	-	-	-	-	7
64. *H. tumulorum* (L.)	21	3	17	4	59	13	117
65. *Lasioglossum albipes* (F.)	-	-	1	3	5	2	11
66. *L. brevicorne* (Schenck)	1	-	-	-	-	-	1
67. *L. calceatum* (Scop.)	1	5	8	11	20	7	52
68. *L. fulvicorne* (K.)	2	-	-	-	-	1	3
69. *L. intermedium* (Schenck)	-	-	-	-	1	-	1
70. *L. laevigatum* (K.)	-	-	1	-	-	-	1
71. *L. laticeps* (Schenck)	4	2	2	32	3	1	44
72. *L. lativentre* (Schenck)	-	2	5	6	4	2	19

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Table 2.

Number of specimens of bees collected in sites of the Lower Vistula valley (continued).

Species	Sites						
	GR	CH	TO	GB	ES	SK	GR -> SK
1	2	3	4	5	6	7	8
73. *L. leucozonium* (Schranck)	1	1	6	-	8	3	19
74. *L. lineare* (Schenck)	-	-	1	-	-	-	1
75. *L. lucidulum* (Schenck)	-	-	-	-	2	-	2
76. *L. majus* (Nyl.)	3	3	15	-	2	-	23
77. *L. minutissimum* (K.)	-	-	-	-	-	1	1
78. *L. morio* (F.)	81	1	23	9	20	40	174
79. *L. parvulum* (Schenck)	-	-	1	1	2	-	4
80. *L. pauxillum* (Schenck)	13	9	17	17	4	11	71
81. *L. prasinum haem.* (Schenck)	-	-	2	-	-	-	2
82. *L. quadrinotatulum* (Schenck)	-	-	-	-	1	-	1
83. *L. quadrinotatum* (K.)	-	1	-	2	3	4	10
84. *L. rufitarse* (Zett.)	-	-	-	-	4	-	4
85. *L. sexnotatum* (K.)	5	-	4	3	1	1	14
86. *L. sexstrigatum* (Schenck)	5	-	2	-	14	8	29
87. *L. villosulum* (K.)	-	-	3	1		1	5
88. *L. zonulum* (Smith)	-	-	-	-	1	-	1
89. *Sphecodes albilabris* (F.)	-	-	-	-	-	1	1
90. *Sp. crassus* (Thomson)	-	-	-	-	2		2
91. *Sp. ephippius* (L.)	1	-	-	-	1	1	3
92. *Sp. ferruginatus* Hagens	1	-	-	-	-	-	1
93. *Sp. gibbus* (L.)	-	-	-	-	-	2	2
94. *Sp. hyalinatus* Hagens	-	1	-	-	-	-	1
95. *Sp. longulus* Hagens	-	1	-	-	-	1	2
96. *Sp. miniatus* Hagens	-	-	-	-	1	-	1
97. *Sp. niger* Hagens	-	1	-	-	1	-	2
98. *Sp. pellucidus* Smith	-	-	-	1	1	-	2
99. *Sp. puncticeps* Thomson	-	-	-	1	4	1	6
100.*Rophites quinquespinosus* Sp.	-	1	-	-	-	-	1
101.*Melitta haemorrhoidalis* (F.)	-	-	-	-	1	-	1
102.*Dasypoda altercator* (Harris)	-	53	26	-	5	18	102
103.*Macropis europaea* Warncke	-	1	-	-	-	-	1
104.*Heriades truncorum* (L.)	1	1	-	-	1	-	3
105.*Chelostoma rapunculi* (Lep.)	-	-	-	1	-	-	1
106.*Osmia fulviventris* (Pz.)	-	-	-	-	1	-	1
107.*O. rufa* (L.)	-	1	-	-	4	-	5
108.*Megachile alpicola* Alfken	-	-	1	-	-	-	1

Table 2.

Number of specimens of bees collected in sites of the Lower Vistula valley (continued).

Species	Sites						
	GR	CH	TO	GB	ES	SK	GR -> SK
1	2	3	4	5	6	7	8
109.*M. centuncularis* (L.)	-	2	-	1	-	-	3
110.*M. circumcincta* (K.)	1	-	-	-	-	-	1
111.*M. ligniseca* (K.)	-	1	-	5	3	1	10
112.*M. versicolor* Smith	-	1	-	-	1	1	3
113.*M. willughbiella* (K.)	-	-	-	-	-	1	1
114.*Nomada fabriciana* (L.)	-	1	-	-	3	-	4
115.*N. flavoguttata* (K.)	-	-	-	-	4	-	4
116.*N. fulvicornis* F.	-	1	-	-	-	-	1
117.*N. goodeniana* (K.)	-	-	-	-	4	-	4
118.*N. marshamella* (K.)	-	-	-	-	-	1	1
119.*N. ochrostoma* Zett.	2	2	1	-	2	-	7
120.*N. panzeri* Lep.	-	-	-	-	11	-	11
121.*N. ruficornis* (L.)	-	-	-	-	7	-	7
122.*N. signata* Jurine	-	-	-	-	1	-	1
123.*N. striata* F.	-	-	-	-	-	2	2
124.*Tetralonia macroglossa* Ill.	2	-	1	2	-	1	6
125.*Athophora plumipes* (Pallas)	-	-	-	1	-	-	1
126.*At. retusa* (L.)	-	-	-	-	1	-	1
127.*Ceratina cyanea* (K.)	-	-	1	-	-	-	1
128.*Bombus hortorum* (L.)	-	-	-	1	1		2
129.*B. hypnorum* (L.)	1	1	-	-	1	2	5
130.*B. jonellus* (K.)	-	-	-	-	-	1	1
131.*B. lapidarius* (L.)	1	2	-	-	4	5	12
132.*B. lucorum* (L.)	-	4	2	-	8	19	33
133.*B. pascuorum* (Scop.)	-	2	1	-	9	1	13
134.*B. pratorum* (L.)	-	-	-	1	1	-	2
135.*B. ruderarius* (Müller)	-	2	-	1	3	1	7
136.*B. ruderatus* (L.)	-	-	-	-	-	1	1
137.*B. semenoviellus* Skor.	-	1	-	-	-	3	4
138.*B. sylvarum* (L.)	2	6	-	-	1	-	9
139.*B. terrestris* (L.)	-	2	1	1	6	6	16
140.*B.(Ps.) bohemicus* (Seidl)	-	-	-	-	4	4	8
141.*B.(Ps.) campestris* (Pz.)	-	-	-	-	1	-	1
142.*B.(Ps.) rupestris* (F.)	-	-	1	-	1	3	5
143.*B.(Ps.) vestalis* (Fourcroy)	-	-	-	-	-	3	3
144.*Apis mellifera* L.	14	90	144	28	552	238	1066
Total number of specimens (N)	221	256	341	165	1109	494	2586
Number of species (S)	46	48	44	35	88	68	144

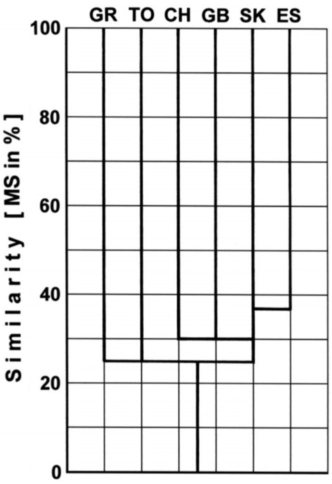

Fig. 3. Species similarity (according to the Marczewski-Steinhaus index, MS) of bee comunities in sites of the Lower Vistula (sites as in Tab. 1).

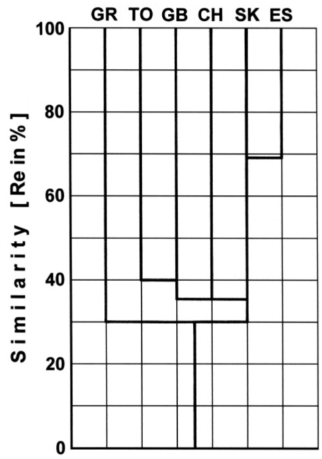

Fig. 4. Quantity-qualitity similarity (according to the Renkonen index, Re) of bee comunities in sites of the Lower Vistula (sites as in Tab. 1).

The xerisation gradient from the river up to the upland areas was very influential. It was also proved that there is a very close correlation between the number of bee species in the valley environments and the number of visited species of flower plants (Pawlikowski and Hirsch 2002). One should also emphasize that in the case of valley habitats, their heterogenization resulted mainly from historical and present-day human activities. In reference to agricultural areas, heterogenization was connected with the development of their marginal habitats.

The study took place during two research seasons. It was a study on bee resources in agricultural areas of the Lower Vistula valley. This valley is between the towns of Toruń and Chełmno, 144 species were recorded. That is ca. 33% of all the species recorded in Poland, as well as being 58% of all the species recorded in the Kujawy-Pomerania region. At each location, between 35 and 88 bee species were being caught (Table 2). One should emphasize that the method of traps, applied for the estimation of the local species number, revealed 40% fewer species as compared to the transect method applied in the studies of Pawlikowski and Hirsch (2002). Generally, however, the trap method helped establish the real structure of bee communities in individual environments.

When comparing the occurrence of individual species in the landscape zones of the valley in relation to research by Pawlikowski and Kowalewska (1997), as well as Pawlikowski and Hirsch (2002), it was found that all recorded species nested in the slope zone. They therefore spread into habitats within the valley floor zone and nearby moraine plateau habitats. The analysis of the similarity of species in the structure of bee communities (according to the Marczewski-Steinhaus index) revealed that communities from areas with high (ES) and moderate (SK) diversity of marginal habitats were distinctly isolated

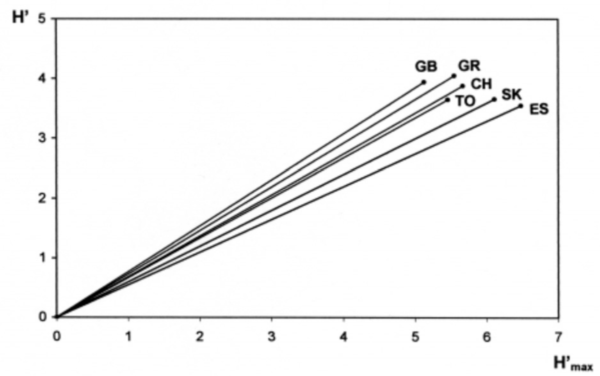

Fig. 5. Biodiversity similarity (according to the Liu index, Q) of bee comunities in sites of the Lower Vistula (sites as in Tab. 1).

from other groups of habitats at the level of 37% (Fig. 3). Whereas, domination and species similarity (according to the Renkonen index) of ES and SK communities with other communities remained at the level of 69% (Fig. 4). It appears from this that the domination-species analysis better describes the differences in the structure of communities in connection with vegetation diversity of marginal habitats. In the case of communities from more diversified habitats, those differences are described as almost twice as high as compared to the species analysis. Domination and species similarity of communities from marginal habitats with low vegetation diversity was only 10% higher than species similarity.

High similarity of communities from ES and SK habitats in relation to other communities was also emphasized by biodiversity analysis based on the commonly applied Shannon index (Fig. 5).

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REFERENCES

Barczak T., Bennewicz J., Kaczorowski G., Krasicka-Korczyńska E. (2000) – Znaczenie zarośli śródpolnych jako rezerwuarów naturalnych wrogów mszyc. [Role of midfield thickets as reservoirs of aphid natural enemies]. Wydawnictwo Uczelniane ATR, Bydgoszcz.

Bednarek R., Prusinkiewicz Z. (1984) – Gleby. In: Województwo toruńskie. Galon R. (Ed.), PWN, Warszawa-Poznań-Toruń. Pp: 189-205.

Boiński M. (1988) – Przewodnik przyrodniczy po województwie toruńskim. PWN, Warszawa-Poznań-Toruń.

Ceynowa M. (1968) – Zbiorowiska roślinności kserotermicznej nad dolną Wisłą. *Studia Societatis Scientiarum Toruniensis*, Sec.D, 8: 1-156.

Ceynowa-Giełdon M. (1971) – Osobliwości florystyczne i rezerwaty Ziemi Chełmińskiej. PWN, Toruń.

Ceynowa-Giełdon M. (1984) – Roślinność. In: Województwo toruńskie. Galon R. (Ed.), PWN, Warszawa-Poznań-Toruń. Pp: 207-239.

Chudziakowa J. (Ed.) (1994) – Wczesnośredniowieczne grodziska Ziemi Chełmińskiej. Katalog źródeł. UMK, Toruń.

Hohendorf E. (1952) – Klimat Ziemi Chełmińskiej w świetle potrzeb rolnictwa. *Studia Societatis Scientiarum Toruniensis*, Sec.C, 1(4): 51-88.

Kaczorowska Z. (1962) – Opady w Polsce w przekroju wieloletnim (tendencja, okresowość, oraz prawdopodobieństwo występowania niedoboru i nadmiaru opadów). *Prace Geograficzne*, 33: 71-90.

Liu Q. (1995) – A model for species diversity monitoring at community level and its aplications. *Environ. Monit. Assess*., 34: 271-287.

Lorenc H. (1998) – Ocena stopnia realizacji programu „Obserwacje meteorologiczne i badania klimatyczne w systemie zintegrowanego monitoringu środowiska przyrodniczego" oraz synteza uzyskanych wyników badań za okres 1994-1997. *Biblioteka Monitoringu Środowiska*, Warszawa.

Marczewski E., Steinhaus H. (1959) – O odległości systematycznej biotopów. [Systematical distance of biotopes.] *Zastosowania Matematyczne,* 4: 195-203.

Pawlikowski T. (1987) – Wpływ systemu gospodarowania na dzikie pszczołowate (Hymenoptera, Apoidea) w krajobrazie rolniczym. [Influence of farming system on wild bees (Hymenoptera, Apoidea) in agricultural landscape]. *Acta Universitatis Nicolai Copernici*, Biol. 35, 72: 153-167.

Pawlikowski T. (1989) – Struktura zgrupowań dzikich pszczołowatych (Hymenoptera, Apoidea) z obszarów rolnych o różnych typach parcelacji powierzchni uprawnej. [The structure of wild bee (Hymenoptera, Apoidea) communities from farming areas of different field sizes]. *Acta Universitatis Nicolai Copernici*, Biol. 33, 70: 31-46.

Pawlikowski T., Hirsch J. (2002) – Local faunas of bees (Hymenoptera: Apoidea) status as indicator of xeric conditions in the lower Vistula Valley. *Acta Zoologica Cracoviensia*, 45(4): 321.

Pawlikowski T., Kowalewska B. (1997) – Atrakcyjność środowisk krawędziowych dla pszczół (Hymenoptera: Apoidea) na Zboczach Płutowskich koło Chełmna. [Atractiveness of plateau marginal slope environments for bees (Hymenoptera: Apoidea) in slopes Zbocza Płutowskie near Chełmno (N Poland)]. *Wiadomości Entomologiczne*, 16(3-4): 165-176.

Plichta W., Regel S. (1973) – Gleby okolic Torunia. *Acta Universitatis Nicolai Copernici*, Geogr. 10, 32: 145-159.

Renkonen O. (1938) – Statistisch-ökologische Untersuchungen über die terrestische Käferwelt der finnischen Bruchmoore. *An. Zool. Soc. Zool.-Bot*. 6.

Shannon C.E., Weaver W. (1963) – The mathematical theory of communication. University of Illinois Press, Urbana.

Trajkowska M. (1982) – Klimat. In: Województwo Włocławskie – Monografia regionalna. Uniw. Łódzki, Łódź-Włocławek. Pp: 51-58.

PSZCZOŁY (HYMENOPTERA: *Apiformes*) OBSZARÓW ROLNICZYCH W KRAJOBRAZIE DOLINNYM DOLNEJ WISŁY

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Streszczenie

W trakcie dwusezonowych badań w dolinie dolnej Wisły między Toruniem a Chełmnem wykazano 144 gatunki, czyli około 33% ogółu gatunków stwierdzonych w Polsce, a równocześnie 58% stanu gatunków odnotowanych w regionie kujawsko-pomorskim. Na sześciu stanowiskach wykazywano od 35 do 88 gatunków pszczół. Istotnym czynnikiem kształtującym różnorodność zespołów pszczół w środowiskach marginalnych obszarów rolniczych doliny dolnej Wisły był proces siedliskowego różnicowania ich roślinności pokarmowej, zarazem pozostający pod wpływem gradientu kseryzacji. Wykazano wprost proporcjonalną zależność różnorodności zespołów pszczół od ogólnej różnorodności siedlisk marginalnych na obszarach rolniczych. Analiza dominacyjno-gatunkowa (indeks Renkonena) opisywała strukturę na dwa razy większym (=dokładniejszym) poziomie podobieństwa niż metoda gatunkowa (indeks Marczewskiego-Steinhausa).

Słowa kluczowe: Apiformes, zespoły pszczół, obszary rolnicze, krajobraz dolinny, dolna Wisła.