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Bees (Hymenoptera: Apoidea) as indicators of xerisation processes in the lower Vistula Valley

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Abstract. In the lower Vistula Valley, between the towns of Włocławek and Chełmno, 244 species were found, which makes ca. 56% of the total number of species found in Poland and 87% of that found in the Kujawy-Pomerania region. Locally, 86 to 144 bee species were reported. An important factor affecting the species diversity of bee communities in the environments of the lower Vistula Valley was the habitat differentiation of their nutrient vegetation, which was affected by the xerisation gradient (increasing from the river towards the valley edge). In nearly all the plots with south-exposed slopes, the numbers of species associated with the marginal zone (1), the slope zone (2) and the valley floor zone (3) were in the proportion 1 : 2 : 1. Studying the occurrence of the particular species in those valley zones, it was found that all of them nested or were associated with nesting sites in the slope zone, and from there they spread to the valley floor environments (51% of slope species) and to the nearby environments on a plateau (43%). On the opposite slopes exposed to the north, and therefore cooler, the bees nested in the vast sandy fields of the valley floor.

Key words: Hymenoptera, Apoidea, bees, bioindication, xerisation, Vistula Valley.

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I. INTRODUCTION

Bees are highly active, or potentially highly active, efficient fliers and specialized phytophages pollinating flowering plants. They form multispecies communities of populations competing for environmental resources in the biocenosis, or, most frequently, the complex of biocenoses of a given landscape. They occur in nearly all land environments including those extremely transformed by man, as long as they can find there nutrient flowering plants (MATHESON 1994, MATHESON et al. 1996, MICHENER 2000, SEELEY 1985).

Studying the bee fauna from the point of view of its richness in species in environments transformed by man can, in the first place, help assess the extent of xerisation of those environments. That is associated with the xerothermophilous character of the group of insects, which prefer for nesting dry and warm habitats grown with sward and herbaceous vegetation or dwarf shrubs with a low proportion of fruticose or arboreous plants. It has been found that among all types of habitats occupied by bees the richest in species are areas with xerothermic habitats (LINSLEY 1958). Nowadays, both in Poland and in other European countries, such habitats develop nearly exclusively as a result of all kinds of cultural activity. Studies of bee species resources in areas consisting mainly of xerotherms were conducted, among others, in the Pieniny mountains (DYLEWSKA 1962, DYLEWSKA & NOSKIEWICZ 1963), in Kampinos Forests (BANASZAK & PLEWKA 1981), in the Toruń Basin (PAWLIKOWSKI 1985, 1992), in the region of Zamość (KOSIOR & FIJAŁ 1992, PAWLIKOWSKI et al. 1993). Subject to study were also the xerothermic slopes near Chełmno in the so-called Unisław Valley Basin of the Vistula Valley (BANASZAK & CIERZNIAK 1994, PAWLIKOWSKI & KOWALEWSKA 1998) and the xerothermic environments in the lower Odra Valley (ENGEL 1938).

The object of the present study was to find out to what extent the variable hygroxeric conditions in the valley environments of the lower Vistula determined their choice and colonization by bees. Those relationships were investigated in the basic landscape types of the valley as well as in the area of the entire landscape profile (transect-catena model) of the valley between Włocławek and Chełmno.

II. STUDY AREA

Our studies were conducted mainly in the right-bank areas of the lower Vistula Valley between Włocławek and Chełmno. That area is situated within the administrative boundaries of the Kujawy-Pomerania region (Fig. 1) and separates the right-bank lands of the Chełmno Lake District and Dobrzyń Plateau from the left-bank Świecie Plateau and Kujawy. The valley slopes, which constitute the exact or approximate (owing to the eroded terrace slopes) boundaries between the moraine plateau and the sandy valley floor, in places rise steeply reaching up to 70 m above average river level. They are dissected by numerous segmented ravines facilitating the descent from the plateau down into the valley. Some fragments of the slope are flattened by sand blown up from the valley floor and by landslide and alluvial processes brought about by the waters of the contact zone of the landscape mesoregions.

Moreover, the valley floor and the adjoining environments are subject to progressive xerisation as a result of erosion of the valley floor. That process is particularly intensive down from the dam in Włocławek to Ciechocinek (BABIŃSKI 1992).

From the geobotanical point of view, the lower Vistula Valley and the adjoining plateau areas are part of the west-Pomeranian intermediate belt. The flora of that area is comparatively young, much younger than that of the south of Poland. It developed after the recession of the last glacier, i.e. About 12000 years ago. (Before the glaciation the area was covered with subtropical vegetation). It was characterized by great floristic richness due to diversity of relief, water conditions and climate (BOIŃSKI 1988).

The plateau areas abounded in fertile soils. That is why ever since the beginning of human activity the prevailing forest vegetation was gradually removed, and the deforested areas were turned into arable land or meadows. Even the riverside marshy forests were not spared. Substitute communities were developing: associations of crop-related weeds, of meadow plants, or ruderal vegetation.

The process of the forest decline and development of agricultural landscape in the plateau areas reflects the history of settlement development there. The lower Vistula Valley constituted an important trade track leading to the Baltic and inside the country. In the Middle Ages a large number of strongholds were erected in the area under study, eg. in Unisław (beginning of 11th c.), Płutowo (beg. of 12th c.), Starogród (beg. of 13th c.), Toruń (beg. of 13th c.) (CHUDZIAKOWA 1994). The economic activity of the residents of those cities resulted in the development of xerothermic grassland

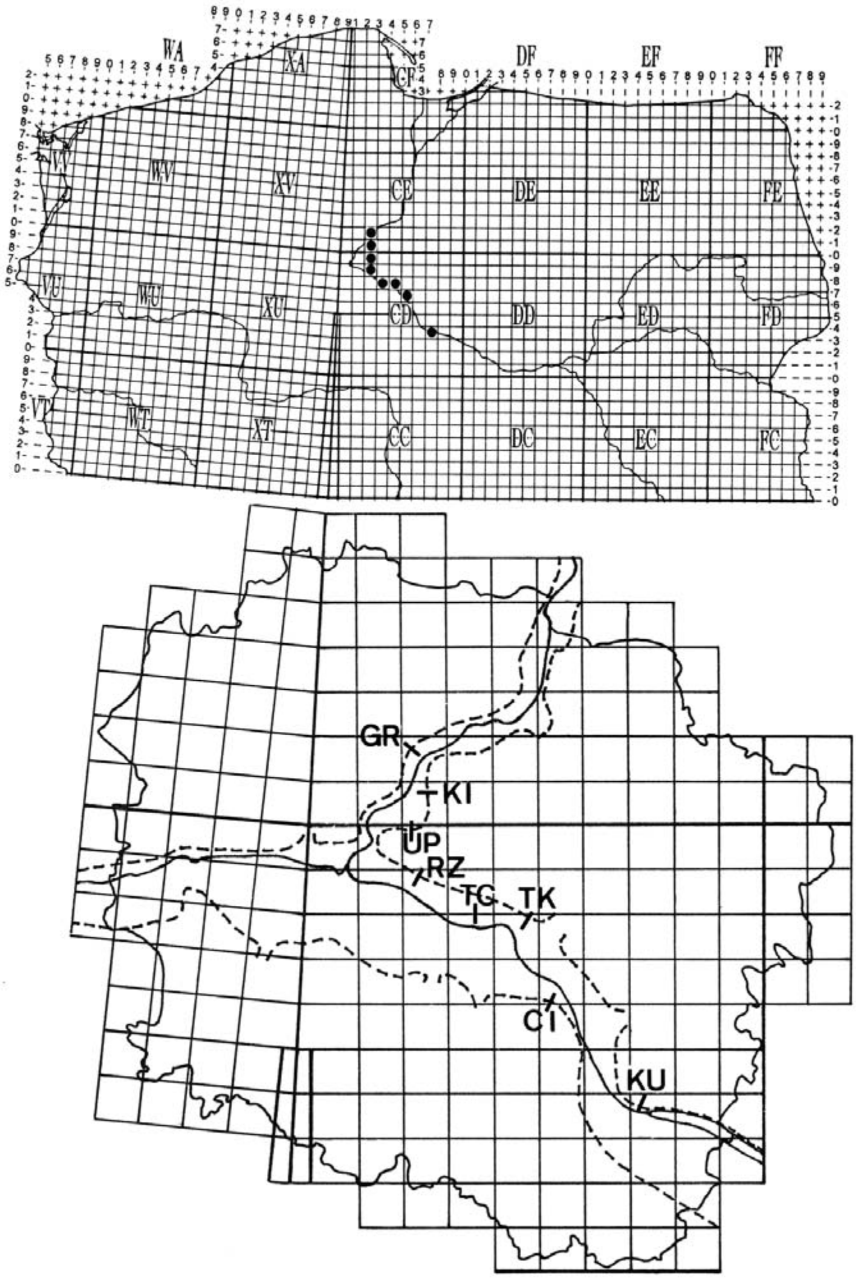

Fig. 1. Distribution of stands (transects) in the lower Vistula Valley with UTM grid system (North Poland): KU – Kulin, CI – Ciechocinek – Raciążek, TK – Toruń-Kaszczorek, TC – Toruń-Chełmińskie, RZ – Rzęczkowo, UP – Unisław Pomorski, KI – Kiełp – Starogród, GR – Gruczno.

in the slope zone of the valley. The subsequent communities until modern times sustained the xerothermic character of the slopes by grazing, burning down the sward and destroying the brushwood vegetation.

Nowadays, in the agricultural landscape of the lower Vistula plateau, natural (climactic) and paranatural (anthropoclimactic) plant communities cover a relatively small percentage of the area. Among all finds of swards, communities with steppe vegetation have subsisted in the closest to natural condition. According to CEYNOWA-GIEŁDON (1968, 1984) on the slopes of the lower Vistula proglacial stream valley occur the richest in northern Poland clusters of xero- and thermophilous vegetation. Those clusters constitute the northernmost relict stands of south-east European steppes. Xerothermic steppe swards occur mainly on south-exposed slopes: warm, very well insolated, with soils extremely rich in calcium carbonate. The first species of steppe plants migrated to the lower Vistula Valley in the preboreal age, ca 8000 B.C. The routes of their westward migrations are marked by still existing on the sides of the proglacial stream valley relict stands of steppe species, such as *Adonis vernalis* L. and *Stipa* sp. The rapid increase in density of the forest cover in later times impeded the development and migrations of the most shade-susceptible steppe species. Their renewed expansive development occurred only as a result of human agricultural activity. In 17^{th}-18^{th} c., in the deforested dune fields of the valley floor, monoculture pine forests were introduced.

In 1963 the swards of the marginal slopes between Płutowo Ravine and Starogród came under legal protection as steppe reserve „Zbocza Płutowskie" (CEYNOWA-GIEŁDON 1971). Since then the slopes of the reserve have been successively overgrown by fruticose and arboreous vegetation. Nowadays, xerothermic swards stil remain over 30-60% of the protected slope areas. Successive overgrowing of swords has been observed beyond the reserve, on the south slopes of Kiełp Ravine.

Well preserved natural communities of forest vegetation in the lower Vistula Valley are fragments of *Tilio-Carpinetum* forest. They grow over unarable, steep valley sides and the slopes of some of its ravines. One of the larger and oldest *Tilio-Carpinetum* forest areas in the slope zone is the forest of Płutowo Ravine. Since 1956 it has been legally protected as a forest reserve (CEYNOWA-GIEŁDON 1971).

An exceptional place on the high south-western valley slopes in Włocławek is occupied by a *Dictamnus albus* L. community in an open oak forest – *Potentillo albae Quercetum* – habitat. That stand is included in the area of the floristic reserve „Kulin", set up in 1967. In the reserve have been distinguished two steppe communities: *Potentillo-Stipetum* and *Adonio-Brachypodietum*, the thermophilous brushwood community *Peucedanum-Coryletum* and two forest communities: *Tilio-Carpinetum* i *Fraxino-Ulmetum*, as well as several plant communities (KĘPCZYŃSKI & ZAŁUSKI 1982).

The soils of the Vistula valley floor consist nearly exclusively of crypto-podzolic, podzolic lightly podzolized and rusty soils. They develop mainly in the vast dune fields of the Toruń Basin and the Płock Basin. Only near the slope zone brown and grey-brown soils penetrate in places from the plateau. The plateau areas are built mainly of boulder clays, on which have developed brown and grey-brown soils with a small percentage of black earths (BEDNAREK & PRUSINKIEWICZ 1984, PLICHTA & REGEL 1973).

Basing on KACZOROWSKA's (1962) and LORENC's (1998) climatic criteria, an assessment of the study years 1997-1999 has been made. The year 1997 has been estimated as average both in respect of precipitation and of mean annual temperature. It was characterized by a frosty winter, comparatively cool spring, warm summer and average autumn. The 1998 brought average precipitation, it was warm, with high temperatures in summer and autumn. The 1999 was wet, average in respect of temperature, with a warm winter and spring but cool and wet summer and autumn.

According to the division of Poland into climatic provinces (KONDRACKI, 1988), the lower Vistula Valley area belongs to the province of Bydgoszcz. It is transitional between the cool and fairly humid Pomeranian province and the drier and warmer central province. The annual mean temperature for this province is 7.9ºC, for January –3.5ºC, for July 18.5ºC. The total annual mean precipitation ranges from 500 mm (Włoclawek) to 450 mm (Toruń) and 467 mm (Chełmno), 65% of which falls in summer. The mean duration of the growing season (mean 24-h temperature ≥5°C) is 210 days. It usually starts in the second decade of April. Droughty months (with less precipitations than required for plant vegetation) in this region occur with comparatively high frequency; it amounts to 55%. The mean duration of the summer season (mean 24-h temperature ≥15°C) is 100 days (HOHENDORF 1952, TRAJKOWSKA 1982).

Eight plots were selected for study, most of which were situated on the south slopes of the valley and surrounded by arable fields. The list of plots, the location of the study areas and a characterization of the vegetation are presented in Tables 1 and 2. The study areas were demarcated within the landscape zones of the lower Vistula Valley profile. In each plot, and at the same in each slope transect, three landscape zones were considered: the plateau near the marginal zone, the slope zone and the valley floor (Fig. 2). The slope zone of six plots was adjacent to the marginal zone of the plateau, at of the two remaining ones (TK and TC) was in its vicinity.

Table 1

A list of stands and plots in landscape zones of the lower Vistula Valley (Fig.1) during 1997-1999 investigated: 1 – moraine plateau near marginal zone, 2 – slope zone, 3 – valley floor

Stand			Elevation [m asl.]	Plot (as in Tab. 2)	Years
Transect	UTM	Zone			
Kulin (KU)	CD73	1	105	s	1998
		2	80	r	
		3	65	p	
Ciechocinek – Raciążek (CI)	CD56	1	90	l	1998
		2	75	k	
		3	60	j, t	1999
Toruń-Kaszczorek (TK)	CD47	1	80	z	1999
		2	60	w	
		3	55	u	
Toruń-Chełmińskie (TC)	CD37	2	60	a	1997-1999
Rzęczkowo (RZ)	CD28	2	75	f	1997-1999
		3	40	e	
Unisław Pomorski (UP)	CD29	1	90	d	1997-1999
		2	60	c	
		3	40	b	
Kiełp – Starogród (KI)	CE20	1	90	o	1998
		2	60	n	
		3	35	m	
Gruczno (GR)	CE21	1	95	i	1997
		2	60	h	
		3	35	g	

Table 2

Vegetation in plots of the lower Vistula Valley

Plot		Vegetation
KU1	s	sward along highway near gardens, orchards and meadows: TXof, TAvu, CIin
KU2	r	slope (SW 60°) covered by *Potentillo albae-Quercetum* forest with *Dictamnus albus* and xerothermic swards in the area of „Kulin" Reserve – VEsp, SApr, STre, POar
KU3	p	inundation plain with *Salix* shrubs and patchs of herbs: TRpr, VIsp, Sose
CI1	l	sward along highway near gardens with dominated ruderal plants: TGsp, CLof, ALro, BAni, AHof, ECvu
CI2	k	slope (SW 45°) with herb-sward vegetation: Ahof, BAni, CHma, CIin, TRpr, SApr, MEfa
CI3	j	inundation plain with meadows and patchs of ruderal vegatation: BAni, TAvu, CHma, MEfa
	t	inundation plain, dam along river with shrubs (*Caragana* sp., *Lonicera* sp., *Spirea* sp., *Tamarix* sp.) and meadows: BEin, CAac, TAvu, MEfa
TK1	z	swards near shrubs in area of housing estate: TXof, BEin, TRre, Ecvu
TK2	w	slope (NE 45°) with *Sedo-Scleranthetea* sward: POar, SCoc, CErh, FRvi, Seac
TK3	u	inundation plain with ruderal vegetation and psammophilou sward: BAni, LEca, LOco, AHof, ECvu, ERpl, TXof, JAmo, CErh, TRpr
TC2	a	slope (S 30°) of uper terrace with *Sedo-Scleranthetea* sward near pine thickets: POar, POag, SEac, CErh
RZ2	f	slope (S 30-60°) with old mine of sand and clay covered by xerothermic swards: Poar, CErh
RZ3	e	sward along highway near fields and meadows: COar, GEpr, ECvu, CDac, Bein
UP1	d	sward along highway near gardens and orchards with ruderal vegetation: COar, GEpr, BAni, TXof
UP2	c	slope (S 45°) with *Festuco-Brometea* sward: ADve, POar, CAsy, Sapr
UP3	b	inundation plain with fields and *Artemisietea* community sward along roads: LAal, BAni, TAvu
KI1	o	sward along highway near farm buildings, gardens and fields with dominated ruderal-segetal vegetation
KI2	n	slope (SW i S 60°) with step swards and *Crategus* shrubs in area of „Zbocza Płutowskie" Reserve: ADve, SApr, OXpi, CAsy
KI3	m	inundation plain with fields, meadows and sward along roads: LAal, ANsi, AEpo, ARla, CRol, SYof, LYsa
GR1	i	sward along highway near fields and *Molinio-Arrhentheretea* meadows: LAal, TXof, TRpr, CErh
GR2	h	slope (SE 50°) with *Festuco-Brometea* sward: POar, CAsy, CErh, Sapr
GR3	g	inundation plain with fields and sward along roads, also with synanthropic vegetation near farm buildings: LAal, GEpr, ECvu, CDac, BEin

Explanations symbols of flowering plant species in Table 2:

ALro – *Althaea rosae* (L.), ADve – *Adonis vernalis* L., AEpo – *Aegopodium podagraria* L., AHof – *Anchusa officinale* L., ANsi – *Anthriscus silvestris* BIEB., ARla – *Arctium lappa* L. , BAni – *Ballota nigra* L., BEin – *Berteroa incana* (L.), CAsy – *Campanula sybirica* L., CAac – *Carduus acanthoides* L., CErh – *Centaurea rhenana* BOR., CHma – *Chelidonium maius* L., CIin – *Cichorium intybus* L., CLof – *Calendula officinalis* L., CRol – *Cirsium oleraceum* (L.), COar – *Convolvulus arvense* L., ECvu – *Echium vulgare* L., ERpl – *Eryngium planum* L., FRvi – *Fragaria viridis* DUCH., GEpr – *Geranium pratense* L., JAmo – *Jasione montana* L., LAal – *Lamium album* L., LEca – *Leonurus cardiaca* L., LOco – *Lotus corniculatus* L., LYsa – *Lythrum salicaria* L., MEfa – *Medicago falcata* L., OXpi – *Oxytropis pilosa* (L.), POar – *Potentilla arenaria* BORKCH., POag – *Potentilla argentea* L., SApr – *Salvia pratensis* L., SCoc – *Scabiosa ochroleuca* L., SEac – *Sedum acre* L., SOse – *Solidago serotina* AITON, STre – *Stachys recta* L., SYof – *Symphytum officinale* L., TAvu – *Tanecetum vulgare* L., TGsp – *Tagetes sp.*, TXof – *Taraxacum officinale* WIGG., TRpr – *Trifolium pratense* L., TRre – *Trifolium repens* L., VIsp – *Vicia spp*., VEsp – *Veronica spicata* L.

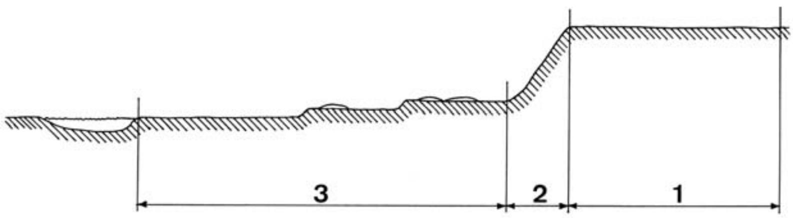

Fig. 2. Landscape zones accross a profile of the lower Vistula Valley: 1 – moraine plateau near marginal zone, 2 – slope zone, 3 – valley floor (with inundation plain and terraces partly covered by diunes).

III. MATERIAL AND METHODS

In the selected plots (Tab. 1) bees were observed and collected (only for species identification) from the end of April till the end of August 1997-1999. A sample consisted of the number of individuals counted, including some collected ones (to confirm the identification), in the course of a 30-min. passage (at 7-10 m /min. rate) over a belt 1 m in width, in a layer of grass and herbage, also some small clusters of shrubs (near nests, on flowers in nuptial flights) under optimal-flying conditions. The following have been adopted as optimal conditions: air temperature 18-22C, gentle or moderate wind, bright days, between 9:00 and 14:00 h, CET. In the slope zone the experimenter moved perpendicularly to the slope slant. An area of 300-400 m^2 was penetrated in one passage. Generally, on a given day one passage was carried out in each zone of each plot. To determine the mean density of bees (A) the number of individuals recorded was recalculated for a 200 m^2 area. The samples were taken every 7-10 days in each plot. A total of 37 thou. individuals were recorded in eight plots, the proportion of the number of bumblebees (*Bombus* LATREILLE) to the number of other wild bees to that of honey bee workers (*Apis mellifera* LINNAEUS) was 1 : 2.4 : 4 (Tab. 3). All the individuals were used to define the species diversity of the distinguished bee communities. A close analysis of the structure of the bee communities will be the object of a separate paper.

IV. RESULTS AND DISCUSSION

The principal factor affecting the species diversity of bees in the environments of the lower Vistula Valley was the process of habitat differentiation of their nutrient vegetation due to xerization gradient (increasing from the river to the plateau areas, Fig. 2). The number of bee species (S) in the valley environments under study and the number of flowering plant species visited by them (X) were found to be in very close correlation ($r = 0.998$ for $p<0.05$) at regression line equation $S = 8.9748 + 1.8480\ X$. If we assume that the diversity of the visited plant species was directly proportional to the diversity of the biocenoses of the environments under study, then the richness of species of the bee communities was dependent on the heterogenization of the area in the local scale. That regularity considerably contributes to the explanation of the phenomenon of differentiation of the structure of the biocenotic community system (Mac ARTUR & Mac ARTUR 1961). It must be remarked, however, that in the case of valley environments their heterogenization is mainly the result of historical and contemporary human activity.

In the second half of the last century intensive studies were conducted of bee resources in the lower Vistula Valley between Włocławek and Chełmno. 244 species were found, ie about 56% of all species found in Poland. They also constituted 87% of all species recorded in the Kujawy-Pomerania region. Locally, in the area of an average valley transect (0.001 km^2) were recorded 86 to 144 bee species (Tab. 3). Between the recorded number of species (S) and the range of study area (X) in Poland was found a close correlation ($r = 0.83$ for $p<0.05$) at regression line equation $S = 146,90 + 0,00095 \log X$ (Tab. 4, Fig. 3 and 4).

Table 3

Number of specimens of bee species collected in stands of the lower Vistula Valley (as in Tab. 1) during 1997-1999: occupied zones (Fig. 2) are in uper index

Species	Stands (Transects)								
	KU 1998	CI 1998-1999	TK 1999	TC 1997-1999	RZ 1997-1999	UP 1997-1999	KI 1998	GR 1997	KU→GR 1997-1999
1	2	3	4	5	6	7	8	9	10
1. *Hylaeus angustatus* (SCHENCK)				1:^{2}					1
2. *Hy. annularis* (KIRBY)			3:^{23}	8:^{2}	4:^{23}	1:^{3}	2:^{3}		18
3. *Hy. bisinuatus* FÖRSTER	1:^{2}								1
4. *Hy. brevicornis* NYLANDER	7:^{12}	8:^{3}	2:^{3}	5:^{2}	6:^{23}	1:^{3}		1:^{2}	30
5. *Hy. cardioscapus* COCKERELL							5:^{23}		5
6. *Hy. communis* NYLANDER	4:^{123}	8:^{23}	11:^{123}	51:^{2}		2:^{23}	8:^{123}	5:^{13}	89
7. *Hy. confusus* NYLANDER	1:^{2}	1:^{3}			5:^{23}	1:^{2}	22:^{3}	2:^{1}	32
8. *Hy. difformis* (EVERSMANN)		1:^{3}				1:^{2}			2
9. *Hy. gibbus* SAUNDERS				9:^{2}	1:^{3}	3:^{13}			13
10. *Hy. gracilicornis* (MORAWITZ)					1:^{3}	1:^{3}		1:^{2}	3
11. *Hy. gredleri* FÖRSTER	1:^{2}	5:^{3}	1:^{3}	3:^{2}	2:^{3}				12
12. *Hy. hyalinatus* SMITH	1:^{1}	5:^{13}	5:^{2}		23:^{23}	15:^{123}	2:^{1}		51
13. *Hy. lepidulus* COCKERELL		1:^{3}				2:^{2}			3
14. *Hy. nigritus* (FABRICIUS)			7:^{23}						7
15. *Hy. pictipes* NYLANDER			1:^{2}						1
16. *Hy. punctulatissimus* SMITH						1:^{2}			1
17. *Hy. rinki* (GORSKI)		1:^{3}		1:^{2}					2
18. *Hy. sinuatus* (SCHENCK)			1:^{3}		7:^{23}				8
19. *Hy. styriacus* FÖRSTER		10:^{3}		1:^{2}			1:^{3}		12
20. *Colletes cunicularius* (L.)	2:^{123}	4:^{3}	19:^{123}	413:^{2}	12:^{23}	20:^{23}	17:^{2}	2:^{2}	489
21. *Co. daviesanus* SMITH	29:^{12}	26:^{123}	41:^{123}		107:^{23}	113:^{123}	11:^{123}	8:^{13}	335
22. *Co. fodiens* (FOURCROY)		9:^{3}	10:^{23}	37:^{2}	2:^{2}				58
23. *Co. nasutus* SMITH			1:^{2}						1
24. *Co. similis* SCHENCK			1:^{2}					1:^{1}	2
25. *Andrena alfkenella* PERKINS	6:^{2}		1:^{3}		10:^{23}			1:^{1}	18
26. *A apicata* SMITH			5:^{1}	1:^{2}					6
27. *A. argentata* SMITH		1:^{3}					1:^{2}		2
28. *A. barbilabris* (KIRBY)		3:^{23}	19:^{23}	83:^{2}		10:^{23}	5:^{3}	1:^{3}	121
29. *A. bicolor* FABRICIUS	1:^{1}	6:^{23}		3:^{2}	5:^{23}	8:^{123}			23
30. *A. bimaculata* (KIRBY)		3:^{3}	5:^{1}	1:^{2}		1:^{2}		2:^{23}	12
31. *A. chrysosceles* (KIRBY)		5:^{23}							5
32. *A. cineraria* (LINNAEUS)			2:^{12}	19:^{2}		2:^{23}			23
33. *A. combinata* (CHRIST)	1:^{1}			1:^{2}		7:^{2}		2:^{2}	11
34. *A. curvungula* THOMSON	1:^{2}					6:^{2}			7
35. *A. denticulata* (KIRBY)	7:^{2}								7
36. *A. dorsata* (KIRBY)		1:^{3}	1:^{1}		2:^{23}	10:^{123}		3:^{23}	17
37. *A. falsifica* PERKINS	6:^{12}	3:^{3}	4:^{2}	44:^{2}	7:^{23}	29:^{23}		8:^{12}	101
38. *A. flavipes* PANZER	38:^{12}	13:^{3}	22:^{123}	17:^{2}	236:^{23}	35:^{123}	27:^{23}		388
39. *A. florea* FABRICIUS	1:^{2}						1:^{1}		2
40. *A. floricola* EVERSMANN					4:^{23}				4
41. *A. fucata* SMITH				1:^{2}	1:^{2}	10:^{2}	1:^{2}		13

Table 3 cont.

1	2	3	4	5	6	7	8	9	10
42. *A. fulva* (Műller)	$2:^{1}$	$2:^{23}$		$9:^{2}$	$6:^{23}$	$8:^{2}$		$3:^{2}$	30
43. *A. fulvago* (Christ)				$25:^{2}$					25
44. *A. fuscipes* (Kirby)				$4:^{2}$					4
45. *A. gelriae* Vecht	$1:^{3}$			$19:^{2}$	$12:^{23}$	$5:^{12}$			37
46. *A. gravidae* Imhoff	$1:^{2}$		$1:^{2}$		$1:^{3}$	$1:^{3}$			4
47. *A. haemorrhoa* (Fabricius)	$18:^{12}$	$34:^{3}$	$39:^{123}$	$205:^{2}$	$18:^{23}$	$29:^{123}$	$50:^{123}$	$7:^{123}$	400
48. *A. hattorfiana* (Fabricius)	$2:^{2}$				$3:^{3}$	$17:^{23}$	$1:^{1}$		23
49. *A. helvola* (Linnaeus)		$1:^{3}$		$1:^{2}$	$1:^{3}$				3
50. *A. humilis* Imhoff								$1:^{2}$	1
51. *A. jakobi* Perkins	$1:^{1}$	$2:^{3}$			$1:^{2}$		$1:^{3}$		5
52. *A. labiata* Fabricius	$1:^{1}$	$11:^{3}$	$6:^{2}$	$3:^{2}$	$2:^{3}$				23
53. *A. lepida* Schenck		$5:^{23}$			$9:^{23}$	$3:^{23}$			17
54. *A. minutula* (Kirby)		$2:^{3}$	$5:^{12}$	$3:^{2}$	$7:^{3}$	$9:^{12}$	$1:^{3}$	$4:^{12}$	31
55. *A. minutuloides* Perkins	$16:^{12}$	$9:^{3}$	$1:^{1}$		$8:^{23}$	$8:^{123}$		$1:^{1}$	43
56. *A. mitis* Schmiedeknecht	$2:^{12}$								2
57. *A. nana* (Kirby)					$1:^{2}$				1
58. *A. nigriceps* (Kirby)				$3:^{2}$					3
59. *A. nigroaenea* (Kirby)			$1:^{1}$	$4:^{2}$	$1:^{2}$	$2:^{2}$		$1:^{2}$	9
60. *A. nitida* (Műller)	$9:^{12}$	$5:^{13}$	$1:^{3}$	$1:^{2}$	$16:^{23}$	$15:^{2}$	$2:^{2}$	$10:^{23}$	59
61. *A. niveata* Friese					$2:^{2}$				2
62. *A. nycthemera* Imhoff						$1:^{2}$	$5:^{2}$		6
63. *A. ovatula* (Kirby)		$1:^{3}$	$1:^{3}$	$5:^{2}$	$12:^{23}$	$5:^{2}$	$1:^{2}$	$2:^{3}$	27
64. *A. paucisquama* Noskiewicz	$1:^{2}$			$3:^{2}$		$2:^{2}$			6
65. *A. carbonaria* Fabricius		$4:^{3}$	$3:^{12}$		$15:^{3}$			$2:^{2}$	24
66. *A. potentillae* Panzer			$1:^{2}$	$11:^{2}$				$1:^{2}$	13
67. *A. praecox* (Scopoli)	$20:^{23}$	$1:^{3}$	$12:^{1}$	$7:^{2}$		$3:^{2}$	$4:^{2}$		47
68. *A. proxima* (Kirby)	$8:^{13}$	$12:^{23}$				$1:^{3}$	$5:^{23}$		26
69. *A. rosae* Panzer					$1:^{3}$			$2:^{12}$	3
70. *A. ruficrus* Nylander							$3:^{2}$		3
71. *A. similis* Smith								$1:^{2}$	1
72. *A. subopaca* Nylander	$5:^{123}$	$7:^{3}$			$2:^{3}$	$6:^{123}$	$24:^{3}$	$1:^{1}$	45
73. *A. symphyti* Schmiedeknecht						$1:^{1}$	$4:^{23}$		5
74. *A. tibialis* (Kirby)			$3:^{13}$	$5:^{2}$	$3:^{23}$	$2:^{23}$			13
75. *A. vaga* Panzer	$11:^{2}$		$11:^{123}$	$5:^{2}$	$2:^{23}$	$24:^{23}$	$10:^{2}$	$30:^{23}$	93
76. *A. varians* (Kirby)	$1:^{1}$						$20:^{23}$		21
77. *A. ventralis* Imhoff		$11:^{3}$	$5:^{1}$		$33:^{23}$	$9:^{123}$	$41:^{23}$		99
78. *Panurgus calcaratus* (Scop.)		$1:^{3}$	$2:^{23}$						3
79. *Halictus perkinsi* Blüthgen	$37:^{123}$	$3:^{23}$	$1:^{2}$	$39:^{2}$	$5:^{23}$	$3:^{2}$	$3:^{2}$	$1:^{1}$	92
80. *H. eurygnathus* Blüthgen	$1:^{2}$								1
81. *H. leucaheneus* Ebmer	$2:^{2}$		$5:^{13}$	$4:^{2}$	$5:^{23}$			$1:^{2}$	17
82. *H. maculatus* Smith	910^{123}	$20:^{3}$		$2:^{2}$	$432:^{23}$	109^{123}	$12:^{123}$	$9:^{123}$	1494
83. *H. quadricinctus* (Fabricius)			$2:^{13}$		$186:^{23}$	$22:^{2}$	$2:^{2}$		212
84. *H. rubicundus* (Christ)		$5:^{3}$	$4:^{13}$	$5:^{2}$	$6:^{3}$	$24:^{123}$	$4:^{12}$	$3:^{2}$	51
85. *H. sexcinctus* (Fabricius)	$29:^{2}$	$5:^{3}$	$3:^{23}$		$115:^{23}$	$17:^{23}$	$10:^{2}$	$6:^{23}$	185
86. *H. simplex* Blüthgen	$5:^{123}$		$2:^{1}$			$6:^{23}$	$1:^{2}$	$2:^{23}$	16
87. *H. subauratus* (Rossi)	$52:^{123}$	$2:^{3}$	$5:^{23}$	$4:^{2}$	$32:^{23}$		$1:^{1}$	$7:^{2}$	103
88. *H. tumulorum* (Linnaeus)	$58:^{123}$	$24:^{123}$	$49:^{123}$	$10:^{2}$	$49:^{23}$	$81:^{123}$	$5:^{2}$	$17:^{12}$	293
89. *Lasioglossum albipes* (F.)	$2:^{1}$	$2:^{23}$	$5:^{13}$	$8:^{2}$	$12:^{3}$		$1:^{2}$	$1:^{3}$	31

Table 3 cont.

1	2	3	4	5	6	7	8	9	10
90. *L. brevicorne* (SCHENCK)			3:^{12}	5:^{2}		2:^{12}			10
91. *L. calceatum* (SCOPOLI)	9:^{13}	31:^{123}	18:^{123}	24:^{2}	83:^{23}	12:^{123}	10:^{123}	13:^{123}	200
92. *L. convexiusculum* (SCHENCK)	1:^{3}					5:^{2}		1:^{2}	7
93. *L. fulvicorne* (KIRBY)						41:^{123}	2:^{23}		43
94. *L. intermedium* (SCHENCK)	1:^{2}								1
95. *L. laevigatum* (KIRBY)	20:^{2}					1:^{2}		6:^{13}	27
96. *L. laticeps* (SCHENCK)	2:^{12}	2:^{23}			13:^{23}	30:^{123}	20:^{123}	3:^{3}	70
97. *L. lativentre* (SCHENCK)					1:^{2}				1
98. *L. leucopum* (KIRBY)				1:^{2}					1
99. *L. leucozonium* (SCHRANCK)		6:^{3}	8:^{13}	12:^{2}	3:^{3}	13:^{123}	1:^{2}	3:^{13}	46
100. *L. limbellum* (MORAWITZ)		1:^{3}	2:^{2}	6:^{2}					9
101. *L. lucidulum* (SCHENCK)	2:^{2}								2
102. *L. malachurum* (KIRBY)	151:^{2}					2:^{2}			153
103. *L. minutissimum* (KIRBY)								3:^{2}	3
104. *L. morio* (FABRICIUS)	246^{123}	19:^{13}	18:^{123}	6:^{2}	205:^{23}	270^{123}	40:^{12}	23:^{123}	827
105. *L. nitidiusculum* (KIRBY)	3:^{2}					8:^{2}			11
106. *L. eaneidorsum* (ALFKEN)		1:^{3}				6:^{12}			7
107. *L. parvulum* (SCHENCK)		1:^{2}		1:^{2}	51:^{2}	7:^{12}	15:^{23}		75
108. *L. pauxillum* (SCHENCK)	224:^{12}	17:^{23}	20:^{123}	12:^{2}	107:^{23}	84:^{123}	13:^{12}	14:^{123}	491
109. *L. politum* (SCHENCK)	39:^{123}								39
110. *L. punctatissimum* (SCHENCK)	1:^{2}			2:^{2}					3
111. *L. quadrinotatulum* (SCHCK.)		2:^{3}			2:^{3}	14:^{2}			18
112. *L. quadrinotatum* (KIRBY)	1:^{2}					1:^{2}			1
113. *L. rufitarse* (ZETTERSTEDT)				1:^{2}					1
114. *L. semilucens* (ALFKEN)				1:^{2}					1
115. *L. setulosum* (STRAND)	1:^{2}								1
116. *L. sexnotatum* (KIRBY)	60:^{123}	6:^{123}	6:^{123}	1:^{2}	4:^{3}	5:^{123}	8:^{23}	2:^{13}	92
117. *L. sexstrigatum* (SCHENCK)		2:^{3}	3:^{2}	4:^{2}	4:^{23}	3:^{23}			16
118. *L. subfasciatum* (IMHOFF)						1:^{2}			1
119. *L. tarsatum* (SCHENCK)	119:^{2}	1:^{3}		2:^{2}				1:^{1}	123
120. *L. villosulum* (KIRBY)		2:^{23}		1:^{2}	2:^{3}	1:^{2}	2:^{2}		8
121. *L. xanthopum* (KIRBY)	1:^{2}	4:^{2}			1:^{3}	5:^{2}	2:^{2}	2:^{12}	15
122. *L. zonulum* (SMITH)	2:^{12}						1:^{3}		3
123. *Sphecodes albilabris* (F.)	1:^{2}		20:^{123}	114:^{2}	12:^{23}	8:^{23}	11:^{2}	4:^{2}	170
124. *Sp. crassus* (THOMSON)		1:^{3}	1:^{1}		4:^{2}	3:^{12}			9
125. *Sp. croaticus* MEYER	2:^{2}				26:^{2}		2:^{2}		30
126. *Sp. ephippius* (LINNAEUS)	2:^{2}			10:^{2}	2:^{2}	1:^{3}			15
127. *Sp. geofrellus* (KIRBY)	2:^{23}				27:^{23}	10:^{2}			39
128. *Sp. ferruginatus* HAGENS	23:^{2}	1:^{3}	1:^{2}	3:^{2}	50:^{23}	26:^{23}	10:^{2}	4:^{2}	118
129. *Sp. gibbus* (LINNAEUS)	28:^{23}			2:^{2}	18:^{2}	10:^{2}	1:^{2}		59
130. *Sp. hyalinatus* HAGENS				1:^{2}	124:^{2}	3:^{2}		1:^{2}	129
131. *Sp. longulus* HAGENS				1:2					1
132. *Sp. marginatus* HAGENS	1:^{2}					4:^{23}			5
133. *Sp. miniatus* HAGENS	1:^{2}		1:^{2}		3:^{2}	1:^{2}			6
134. *Sp. monilicornis* (KIRBY)				2:^{2}	5:^{23}	4:^{23}			11
135. *Sp. niger* HAGENS					1:^{2}				1
136. *Sp. pellucidus* SMITH		1:^{3}	11:^{13}	31:^{2}	3:^{23}	1:^{2}			47
137. *Sp. puncticeps* THOMSON	2:^{2}				31:^{2}	4:^{2}			37

Table 3 cont.

1	2	3	4	5	6	7	8	9	10
138. *Sp. rufiventris* (PANZER)					3:^{2}				3
139. *Sp. scabricollis* WESMAEL					1:^{2}				1
140. *Rophites canus* EVERSMANN	4:^{2}	9:^{3}			14:^{23}	18:^{123}			45
141. *Ro. quinquespinosus* SPINOLA	34:^{2}	9:^{13}				26:^{23}		10:^{123}	79
142. *Melitta haemorrhoidalis* (F.)							1:^{2}		1
143. *Me. leporina* (PANZER)	13:^{123}	14:^{23}	9:^{123}	11:^{2}	74:^{23}	30:^{123}	2:^{2}	18:^{123}	171
144. *Me. nigricans* ALFKEN					7:^{23}				7
145. *Dasypoda altercator*(HARRIS)	4:^{23}	19:^{23}	11:^{13}	9:^{2}	23:^{23}	24:^{123}	2:^{12}	15:^{123}	107
146. *Trachusa byssina* (PANZER)								1:^{2}	1
147. *Anthidium manicatum* (L.)	5:^{23}	13:^{13}	5:^{123}	4:^{2}	5:^{23}	29:^{123}	1:^{1}		62
148. *Proanthidium oblongatum* (I.)			1:^{3}		1:^{2}				2
149. *Anthidiellum strigatum* (PZ.)			1:^{2}	10:^{2}					11
150. *Stellis punctulatissima* (K.)		1:^{3}	1:^{3}	1:^{2}	2:^{2}	3:^{2}			8
151. *Heriades crenulatus* NYL.		2:^{2}	16:^{123}	1:^{2}	2:^{3}				21
152. *He. truncorum* (LINNAEUS)	4:^{1}	16:^{13}	6:^{3}		2:^{3}	5:^{2}			33
153. *Chelostoma florisomne* (L.)		2:^{3}			3:^{23}				5
154. *Ch. foveolatum* (MORAWITZ)				1:^{2}		1:2			2
155. *Ch. maxillosum* (LINNAEUS)		26:^{3}	4:^{3}		1:^{3}	6:^{1}		1:^{2}	38
156. *Ch. rapunculi* (LEPELETIER)	2:^{12}			1:^{2}	3:^{23}	10:^{123}	3:^{12}		19
157. *Osmia aurulenta* (PANZER)	8:^{23}								8
158. *O. brevicornis* (FABRICIUS)			1:^{2}						1
159. *O. coerulescens* (LINNAEUS)					1:^{3}	1:^{2}			2
160. *O. confusa* (MORAWITZ)				1:^{2}	2:^{2}	1:^{1}			4
161. *O. emarginata* LEPELETIER			2:^{12}		1:^{3}				3
162. *O. fulviventris* (PANZER)		3:^{3}			10:^{23}				13
163. *O. rufa* (LINNAEUS)		6:^{3}	17:^{1}	3:^{2}	27:^{23}	9:^{123}	3:^{1}	1:^{3}	66
164. *Anthocopa papaveris* (LATR.)	1:^{2}				26:^{23}	4:^{23}	1:^{2}		32
165. *Hoplitis adunca* (PANZER)		26:^{13}	19:^{123}	5:^{2}	13:^{23}	14:^{123}	1:^{2}		78
166. *Ho. anthocopoides* (SCHCK.)			3:^{12}	2:^{2}					5
167. *Ho. leucomelaena* (KIRBY)		1:^{2}			1:^{2}				2
168. *Ho. parvula* (DUF.et PERRIS)				1:^{2}					1
169. *Ho. spinulosa* (KIRBY)						1:^{2}			1
170. *Ho. tridentata* (DUF. et PERRIS)			1:^{2}						1
171. *Megachile alpicola* ALFKEN	1:^{3}				2:^{2}		1:^{2}		4
172. *M. apicalis* SPINOLA	1:^{2}				1:^{3}				2
173. *M. argentata* (FABRICIUS)	1:^{2}		1:^{2}						2
174. *M. centuncularis* (LINNAEUS)				17:^{2}		1:^{2}	3:^{23}		21
175. *M. circumcincta* (KIRBY)	12:^{12}	2:^{3}	1:^{3}	4:^{2}	8:^{23}				27
176. *M. ericetorum* LEPELETIER		1:^{1}			1:^{2}	3:^{12}			5
177. *M. lagopoda* (LINNAEUS)		3:^{23}							3
178. *M. ligniseca* (KIRBY)				2:^{2}				2:^{13}	4
179. *M. maritima* KIRBY	1:^{3}		2:^{2}	12:^{2}	5:^{3}			2:^{23}	22
180. *M. pilidens* ALFKEN	1:^{2}								1
181. *M. versicolor* SMITH				6:^{2}	5:^{23}	1:^{1}		1:^{2}	13
182. *M. willughbiella* (KIRBY)		4:^{3}	2:^{23}	3:^{2}					9
183. *Coelioxys brevis* EVERSMANN				1:^{2}					1
184. *Cx. conoidea* (ILLIGER)			2:^{2}	22:^{2}		2:^{3}		1:^{2}	27
185. *Cx. elongata* LEPELETIER			5:^{23}	5:^{2}	1:^{2}		1:^{2}		12

Table 3 cont.

1	2	3	4	5	6	7	8	9	10
186. *Cx. quadridentata* (L.)	2:^{2}				4:^{23}				6
187. *Cx. rufescens* LEP. et SERVILLE		1:^{2}							1
188. *Cx. rufocaudata* SMITH					2:^{2}				2
189. *Nomada armata* HER.-SCHÄF.						1:^{2}			1
190. *N. atroscutellaris* STRAND						1:^{2}			1
191. *N. bifasciata* OLIVIER		1:^{3}				6:^{23}			7
192. *N. bispinosa* (MOCSARY)						1:2			1
193. *N. conjugens* HER.-SCHÄF.	1:^{2}				1:^{2}				2
194. *N. fabriciana* (LINNAEUS)	2:^{2}				1:^{2}				3
195. *N. flava* PANZER	1:^{2}					1:^{3}			2
196. *N. flavoguttata* (KIRBY)	11:^{2}			1:^{2}	2:^{2}	4:^{2}			18
197. *N. flavopicta* (KIRBY)					3:^{2}	3:^{23}			6
198. *N. fucata* PANZER	67:^{23}				119:^{23}	4:^{23}	38:^{2}	3:^{23}	231
199. *N. fulvicornis* FABRICIUS	5:^{2}			7:^{2}	1:^{2}	3:^{2}		1:^{2}	17
200. *N. goodeniana* (KIRBY)	31:^{2}	4:^{3}				7:^{2}	3:^{2}	4:^{2}	49
201. *N. lathburiana* (KIRBY)	44:^{2}		2:^{2}		2:^{23}	23:^{2}	29:^{2}	8:^{2}	109
202. *N. marshamella* (KIRBY)	6:^{12}		1:^{3}			3:^{12}	3:^{2}		13
203. *N. moeschleri* ALFKEN	1:^{2}	1:^{3}		2:^{2}		3:^{13}	6:^{23}		13
204. *N. ochrostoma* ZETTERSTEDT	6:^{23}		1:^{3}	34:^{2}	2:^{2}	5:^{23}	34:^{123}	2:^{2}	82
205. *N. panzeri* LEPELETIER				1:^{2}			21:^{23}		22
206. *N. roberjeotiana* PANZER					1:^{2}				1
207. *N. ruficornis* (LINNAEUS)	12:^{2}	5:^{3}		43:^{2}	7:^{23}	1:^{2}			68
208. *N. sheppardana* (KIRBY)	1:^{2}								1
209. *N. signata* JURINE			1:^{2}	6:^{2}		1:^{2}		3:^{2}	11
210. *Ammobates punctatus* (F.)			4:^{13}	4:^{2}					8
211. *Epeolus variegatus* (L.)	7:^{2}	1:^{3}	4:^{23}	5:^{2}					17
212. *Tetralonia macroglossa* I.		20:^{23}				5:^{13}	3:^{23}	172:^{23}	200
213. *Eucera longicornis* (L.)						18:^{12}	5:^{23}		23
214. *Clisodon furcatus* PANZER	2:^{2}	8:^{13}					3:^{3}	1:^{3}	14
215. *Anthophora acervorum* (L.)	12:^{123}	43:^{13}	15:^{123}		25:^{23}	57:^{123}	60:^{123}	15:^{123}	227
216. *At. aestivalis* (PANZER)	2:^{23}				33:^{23}		4:^{2}		39
217. *At. parietina* (FABRICIUS)						1:2			1
218. *At. pubescens* (FABRICIUS)		1:^{2}					6:^{12}		7
219. *At. quadrimaculata* (PANZER)						3:^{23}			3
220. *At. retusa* (LINNAEUS)	2:^{2}			17:^{2}		1:^{2}	3:^{12}		23
221. *Heliophila bimaculata* (PZ.)	30:^{23}	32:^{13}	206^{123}	340:^{2}	2:^{3}		3:^{1}	1:^{2}	614
222. *Melecta luctuosa* (SCOPOLI)					1:^{2}				1
223. *Mc. punctata* (FABRICIUS)	1:^{2}			1:^{2}	5:^{23}	26:^{123}	3:^{12}		36
224. *Ceratina cyanea* (KIRBY)			2:^{23}	3:^{2}	1:^{2}	4:^{2}		1:^{2}	11
225. *Bombus hortorum* (L.)	5:^{123}	17:^{123}	34:^{123}	11:^{2}	39:^{3}	37:^{123}	15:^{123}	5:^{13}	163
226. *B. humilis* ILLIGER								2:^{12}	2
227. *B. hypnorum* (LINNAEUS)		14:^{3}	15:^{123}	5:^{2}	3:^{3}	14:^{13}	3:^{1}	5:^{13}	59
228. *B. lapidarius* (LINNAEUS)	41:^{123}	156^{123}	67:^{123}	151:^{2}	178:^{23}	85:^{123}	54:^{123}	42:^{123}	774
229. *B. lucorum* (LINNAEUS)	7:^{12}	98:^{13}	61:^{123}	106:^{2}	49:^{23}	15:^{123}	19:^{123}	8:^{23}	363
230. *B. muscorum* (FABRICIUS)		2:^{3}	4:^{123}	4:^{2}	3:^{3}	4:^{23}	2:^{1}		19
231. *B. pascuorum* (SCOPOLI)	29:^{123}	197^{123}	198^{123}	261:^{2}	176:^{23}	261^{123}	60:^{123}	85:^{123}	1267
232. *B. pratorum* (LINNAEUS)	9:^{2}	3:^{1}	10:^{123}	5:^{2}	14:^{23}	19:^{13}	4:^{13}	1:^{3}	65
233. *B. ruderarius* (MÜLLER)	18:^{123}	82:^{123}	66:^{123}	81:^{2}	212:^{23}	94:^{123}	34:^{123}	22:^{123}	609

Table 3 cont.

1	2	3	4	5	6	7	8	9	10
234. *B. ruderatus* (LINNAEUS)	1:[1]	2:[13]	3:[2]	2:[2]	9:[3]	6:[13]	12:[13]		35
235. *B. subterraneus* (LINNAEUS)	1:[2]				1:[3]				2
236. *B. sylvarum* (LINNAEUS)	6:[123]	18:[3]	26:[123]	7:[2]	185:[23]	130[123]	17:[123]	8:[123]	397
237. *B. terrestris* (LINNAEUS)	76:[123]	289[123]	168[123]	215:[2]	242:[23]	119[123]	131[123]	36:[123]	1276
238. *Psithyrus barbutellus* (KIRBY)			1:[2]						1
239. *Ps. bohemicus* (SEIDL)	3:[2]	14:[3]	2:[13]	15:[2]	8:[23]			1:[2]	43
240. *Ps. campestris* (PANZER)	2:[23]	3:[3]	1:[3]	1:[2]		1:[2]			8
241. *Ps. norvegicus* SPARRE-SCHN.				1:[2]					1
242. *Ps. rupestris* (FABRICIUS)		2:[3]	1:[2]	23:[2]	8:[23]	5:[123]	4:[12]	4:[123]	47
243. *Ps. vestalis* (FOURCROY)		2:[13]			1:[2]				3
244. *Apis mellifera* LINNAEUS [123]	3643	5527	713	1371	1617	6257	982	450	20560
Total number of specimens (N)	**6428**	**7085**	**2158**	**4163**	**5417**	**8702**	**2032**	**1162**	**37147**
Number of species (S)	**117**	**102**	**105**	**117**	**136**	**144**	**82**	**84**	**244**

The numbers of species recorded in areas of selected valley transects are listed in Tab. 5. In nearly all plots containing south-exposed slopes the numbers of species associated with the marginal zone (1), the slope zone (2) and the valley floor zone (3) were in the proportion 1 : 2 : 1 . The percentage of species in the particular zones of the Toruń-Kaszczorek (TK) and Rzęczkowo (RZ) plots was fairly even. That was probably due to the similarity of habitat differentiation between the valley floor and the slope zone areas and to the lessening of the slope slant by sand deposits.

The same dependence of the number of species on the habitat attractiveness of the zone most probably affected the species distribution in the zones of the Ciechocinek-Raciążek (CI) transect containing a north-exposed slope zone. In that transect the proportion of numbers of species in the particular zones was 1 : 1 : 4 respectively. That shows that the habitat attractiveness of the valley floor was four times that of the remaining zones of the transect. The distribution of species number in that place of the valley particularly emphasizes the xerothermic character of the valley floor in contrast to its hygric-cool northern slope. It must be assumed, however, that similar habitat at-

Table 4

Number of bee species recorded in different territories of the lower Vistula Valley, Kujawy-Pomerania region and Poland

Territory	Area [km^2]	Investigations	Number of species	Resources
Kulin	0.001	1998	117	HIRSCH 2002
Toruń-Kaszczorek	0.001	1999	105	
Unisław Pomorski	0.001	1997-1999	144	
Gruczno	0.001	1997	84	
Kiełp – Płutowo	0.002	1975-1994	91	PAWLIKOWSKI et al. 1997
Ciechocinek – Raciążek	0.01	1998-1999	102	HIRSCH 2002
Toruń Valley	1500	1982-1986	183	PAWLIKOWSKI 1992
Kulin – Gruczno valley	2000	1997-1999	244	HIRSCH 2002
Kujawy-Pomerania region	17970	1951-2000	280	computer data base
Poland	312685	1951-2000	436	PAWLIKOWSKI 2001
		1901-2000	463	

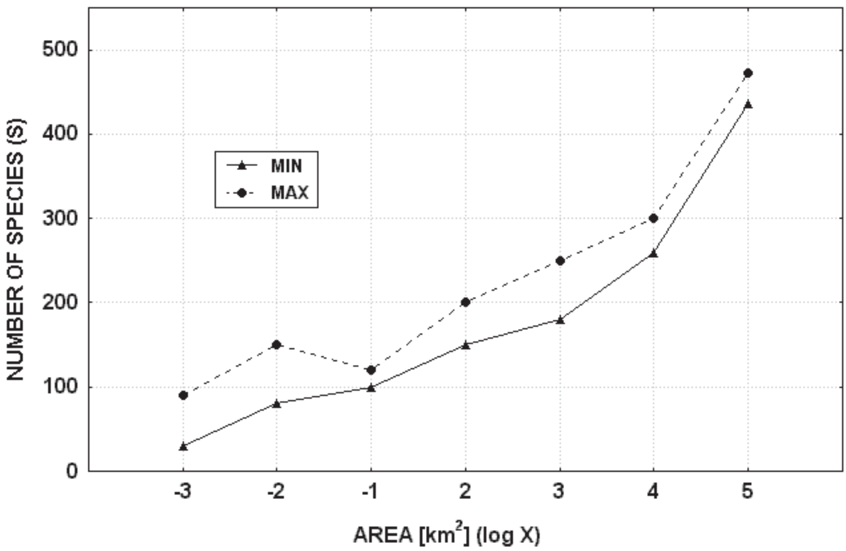

Fig. 3. Range of fluctuations of a number of species (S) to gradient of investigation areas (X) of Poland in 1901-2000 (according to HIRSCH 2002., PAWLIKOWSKI et al. 1997, PAWLIKOWSKI 1992, 2001).

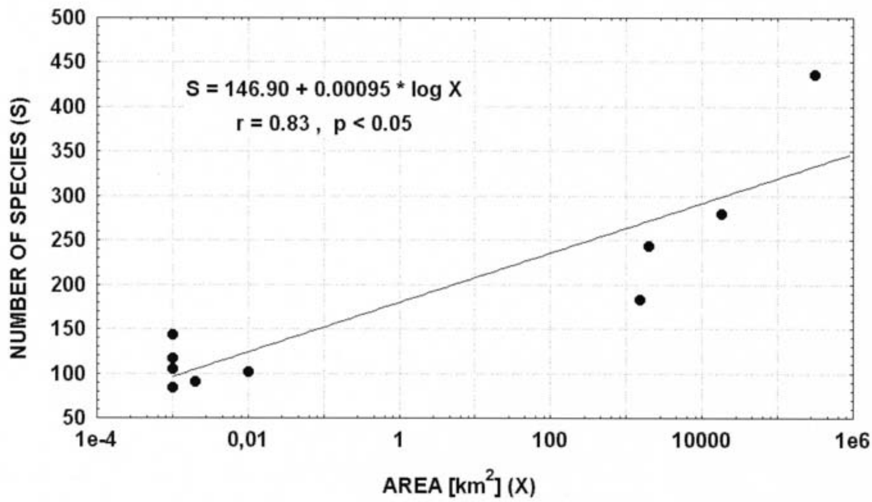

Fig. 4. Influence a size of investigation areas (X) on a number of bee species (S) in Poland during 1951-2000.

tractiveness is a natural property of those zones. It follows that the increase in attractiveness of the valley floor to xerothermophilous organisms revealed an adequate of degradation of its natural hygric conditions.

Studing the occurrence of the particular species in the landscape zones of the valley (Tab. 5), it was found that all species nested or were associated with nesting sites (clepto-parasites) in the slope

Table 5

Number of species (S) recorded in plot areas (as in Tab. 2) of transects (1+2+3) in the lower Vistula Valley (according to HIRSCH 2002)

Plot areas	Years of investigations											
	1997			1998			1999			1997-1999		
	S	%S 1-3	%S 2	S	%S 1-3	%S 2	S	%S 1-3	%S 2	S	%S 1-3	%S 2
KU1	–	–	–	48	41.0	54.2	–	–	–	48	41.0	54.2
KU2	–	–	–	98	83.8	100	–	–	–	98	83.8	100
KU3	–	–	–	38	32.5	50.0	–	–	–	38	32.5	50.0
KU(1+2+3)	–	–	–	117	100	–	–	–	–	117	100	–
CI1	–	–	–	24	36.9	29.0	–	–	–	24	23.5	29.0
CI2	–	–	–	31	47.7	100	–	–	–	31	30.4	100
CI3	–	–	–	49	75.4	58.1	86	100	–	96	94.1	83.9
CI (1+2+3)	–	–	–	65	100	–	86	100	–	102	100	–
TK1	–	–	–	–	–	–	56	53.3	54.7	56	53.5	54.7
TK2	–	–	–	–	–	–	64	61.0	100	64	61.0	100
TK3	–	–	–	–	–	–	69	65.7	59.4	69	65.7	59.4
TK(1+2+3)	–	–	–	–	–	–	105	100	–	105	100	–
TC2	55	100	100	53	100	100	61	100	100	117	100	100
RZ2	55	61.1	100	53	63.9	100	61	65.6	100	101	74.3	100
RZ3	64	71.1	54.5	62	74.7	58.5	64	68.8	57.4	104	76.5	66.3
RZ(2+3)	90	100	–	83	100	–	93	100	–	136	100	–
UP1	32	36.8	27.3	35	39.3	33.3	41	43.6	34.2	60	41.7	40.7
UP2	66	75.9	100	63	70.8	100	73	77.7	100	113	78.5	100
UP3	38	43.7	39.4	47	52.8	42.9	53	56.4	50.7	81	56.3	54.9
UP(1+2+3)	87	100	–	89	100	–	94	100	–	144	100	–
KI1	–	–	–	38	46.3	36.8	–	–	–	38	46.3	36.8
KI2	–	–	–	68	82.9	100	–	–	–	68	82.9	100
KI3	–	–	–	41	50.0	39.7	–	–	–	41	50.0	39.7
KI (1+2+3)	–	–	–	82	100	–	–	–	–	82	100	–
GR1	37	44.0	29.0	–	–	–	–	–	–	37	44.0	29.0
GR2	58	69.0	100	–	–	–	–	–	–	58	69.0	100
GR3	42	50.0	37.7	–	–	–	–	–	–	42	50.0	37.7
GR(1+2+3)	84	100	–	–	–	–	–	–	–	84	100	–

zone, and from there spread to environments in the valley floor zone and to the nearby environments on the plateau. In the valley floor zone were recorded 51% of the species from the slopes (ranging from 38 to 66%), and in the plateau environments 43% (ranging from 29 to 55%). The bees' preference for habitats in the slope zones exposed to the south is confirmed by the comparison of the percentages of species found in the particular landscape zones in relation to the total number of species recorded in the transects. Thus, in the marginal zones were recorded 41-53%, in the slope zones 61-82%, and in the valley floor zones 33-77% of the total number of species.

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