The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of Western and Central Europe

Andrzej Kosior, Waldemar Celary, Paweł Olejniczak, Jan Fijał, Wiesław Król, Wojciech Solarz and Piotr Płonka

Abstract The bumble and cuckooo bees (Hymenoptera: Apidae: Bombini; *Bombus* spp. and *Psithyrus* spp., respectively) are important plant pollinators and any decline in numbers or species constitutes a significant threat both to biological diversity and to whole economies. The distribution, status and factors threatening all 60 known taxa (species and subspecies) of Bombini of 11 countries of Western and Central Europe (Belgium, the Netherlands, Luxembourg, Denmark, Germany, Switzerland, Austria, Czech Republic, Slovakia, Hungary, Poland) were assessed from the beginning of the 20th century. The analysis was based on a literature review, unpublished data, personal communications, our own observations, and an expert review. The IUCN Red List categories were used for assessing the threat of extinction. Eighty per cent of taxa were threatened in at least one country of the region, and 30% of taxa were threatened throughout their range in the countries considered. More species went extinct per country in the second than in the first half of the 20th century, and four taxa went extinct in all 11 countries during 1951–2000. Amongst the factors adversely affecting the Bombini anthropogenic factors (particularly those associated with large-scale farming schemes) appear to be of greater importance than natural factors. To halt population declines and species extinctions it will be necessary to preserve aspects of traditional farming practices and for all Bombini to be afforded legal protection in all countries of the region. The implementation of the European Union's Common Agricultural Policy is likely to have the greatest single impact upon pollinators in the near future.

Keywords Agriculture, Apidae, bees, Bombini, *Bombus*, Europe, Hymenoptera, pollinator loss, *Psithyrus*, threats.

Introduction

Because of their role as pollinators the bumble and cuckoo bees (Hymenoptera: Apidae: Bombini; *Bombus* spp. and *Psithyrus* spp., respectively) have been receiving increasing attention, and a marked decrease in numbers has been noted worldwide (Williams, 1982, 1988, 1989, 2005; Corbet *et al.*, 1991; Monsevičius, 1995; Allen-Wardell *et al.*, 1998; Kearns *et al.*, 1998; Goulson, 2003; Goulson *et al.*, 2005). Pollinators play a key role in ecosystems, ensuring production value in crops, survival and maintenance of plant diversity, and trophic integrity (Herrera & Pellmyr, 2002). An estimated >80% of crops in the European Union directly depend upon biotic pollination (Williams, 1994). Similarly, >80% of all wild plant species depend on insect pollination and >60% of plant species show pollination limitation (Burd, 1994). The drop in the numbers of insect pollinators, particularly Bombini, constitutes a significant threat both to biological diversity and to whole economies.

In most regions of the world, however, there is a significant lack of data on the biology, distribution, status or causes of the decline of the Bombini. This is the case even in Europe with its relatively long tradition of entomological studies. Here we assess the distribution, status and factors threatening all known taxa of Bombini in 11 Western and Central European countries, and assess the implications of the decline in these taxa for agriculture and biodiversity.

Methods

We assessed the Bombini of Belgium, the Netherlands, Luxembourg, Denmark, Germany, Switzerland, Austria, Czech Republic, Slovakia, Hungary and Poland (Fig. 1). The evaluation of species composition and ranges were based on a literature review, unpublished data, and our own observations. A significant part of this information, as well as the degree of threat to individual species and the factors adversely affecting them, was obtained from

Andrzej Kosior (Corresponding author), **Paweł Olejniczak**, **Jan Fijał**, **Wiesław Król**, **Wojciech Solarz** and **Piotr Płonka** Institute of Nature Conservation, Polish Academy of Sciences, Mickiewicza 33, 31-120 Kraków, Poland. E-mail kosior@iop.krakow.pl

Waldemar Celary Institute of Systematics and Evolution of Animals, Sławkowska 17, 31-016 Kraków, Poland.

Received 19 November 2004. Revision requested 17 March 2005. Accepted 19 September 2005.

© 2007 FFI, *Oryx*, **41**(1), 79–88 doi:10.1017/S0030605307001597 Printed in the United Kingdom

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

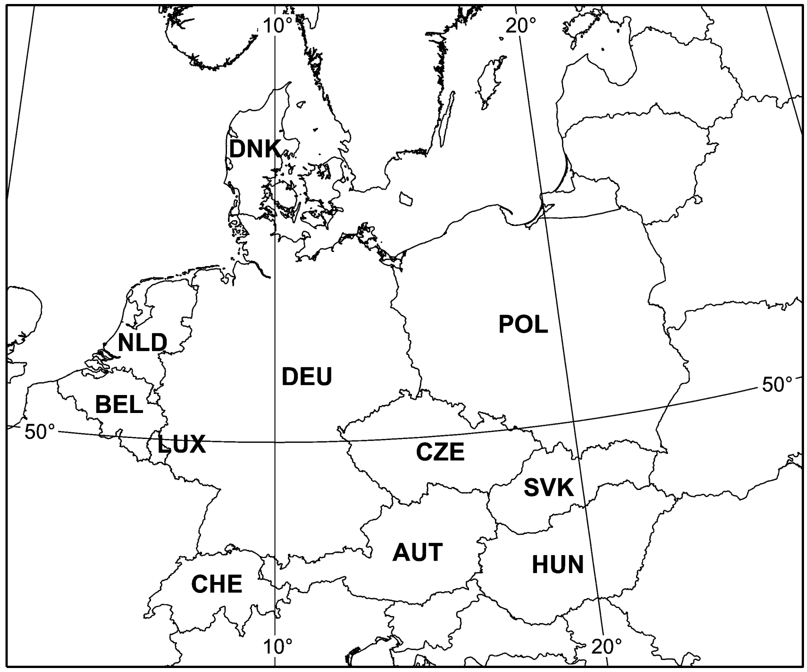

Fig. 1 The 11 countries of Western and Central Europe for which information on Bombini was collated: BEL, Belgium; NLD, the Netherlands; LUX, Luxembourg; DNK, Denmark; DEU, Germany; CHE, Switzerland; AUT, Austria; CZE, Czech Republic; SVK, Slovakia; HUN, Hungary; POL, Poland.

questionnaires completed by experts from the countries covered by the analysis.

For assessing the threat of extinction we used the IUCN Red List categories (IUCN, 2001). For each taxon (species or subspecies) an index of overall threat was also calculated by dividing the number of countries in which the species was in one of the Red List categories (EX, Extinct; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened) by the total number of countries in which the species was present.

To test whether there has been an increase in threats to the Bombini the 20th century was divided into pre- and post-1950 periods and the total number of extinction events in all countries compared for these two periods. A list of 21 anthropogenic and natural factors adversely affecting the Bombini was prepared from a literature review. The experts, to whom this list was sent, chose factors that they considered to be drivers of Bombini decline in their countries. Systematics of the Bombini followed Reinig (1981), von Hagen & Aichorn (2003), Přidal (2004) and NHM (2005).

Data were obtained from the following sources: Belgium: Rasmont & Mersch (1988), Rasmont *et al.* (1993), Rasmont (1995), Rasmont *et al.* (1995), P. Rasmont (pers. comm., 2002, 2004). Netherlands: Warncke (1986), Peeters *et al.* (1999), C. Achterberg (pers. comm., 2002). Luxembourg: Warncke (1986), Rasmont *et al.* (1995), P. Rasmont (pers. comm., 2002). Denmark: I. Calabuig (pers. comm., 2004), H.B. Madsen (pers. comm., 2004), H.B. Madsen & R. Mortensen. (unpubl. data). Germany: Riess *et al.* (1976), Wergin (1977), Warncke *et al.* (1984), Warncke (1986), Westrich (1990), Schwartz *et al.* (1996), Westrich *et al.* (1998), van der Smissen & Rasmont (1999), von Hagen & Aichhorn (2003). Switzerland: Warncke (1986), F. Amiet (pers. comm., 1994, 2004), Rasmont *et al.* (1995), von Hagen & Aichhorn (2003), S. Durrer (pers. comm., 2004). Austria: Aichorn (1983), Kosior (1992a), Schwartz *et al.* (1996), Neumayer & Paulus (1999), J. Neumayer (pers. comm., 2002), von Hagen & Aichhorn (2003). Czech Republic: May (1959), Tkalců (1974, 1999), Pagliano (1994), M. Pavelka (pers. comm., 2002), I. Valterova (pers. comm., 2002), Přidal & Tkalců (2003), Přidal (2004), A. Přidal (pers. comm., 2004). Slovakia: May (1959), Tkalců (1974), Beláková *et al.* (1979), Pagliano (1994), Lukas (2001), R. Chlebo (pers. comm., 2002, 2004), J. Slamecka (pers. comm., 2002), Přidal & Tkalců (2003), Pridal (2004), V. Ptáček (pers. comm., 2004), V. Smetana (pers. comm., 2004). Hungary: Móczár (1957), Rasmont (1983), K. Szauter (pers. comm., 2001), M. Sárospataki (pers. comm., 2002), Sárospataki *et al.* (2003). Poland: Kosior (1987, 1990, 1992c), Kosior & Nosek (1987), Banaszak (1993, 1996, 2002), Dylewska (1996), Kosior & Witkowski (1997), Celary *et al.* (2004), T. Pawlikowski (unpubl. data), Starzyk & Kosior (1985).

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Results

The earliest information on Bombini for the countires considered dates from the last half of the 19th century, from Poland (Siła-Nowicki, 1864; Wierzejski, 1868, 1874; Śnieżek 1893, 1899) and Austria (Müller, 1881). There are records for the first half of the 20th century from Belgium (Rasmont & Mersch, 1988), Denmark (H.B. Madsen & R. Mortensen, unpubl. data) and the Netherlands (C. Achterberg, pers. comm., 2002), and later from Hungary (Móczár, 1957), the area of the Czech Republic and Slovakia (May, 1959) and the remaining countries of Western and Central Europe considered here. The information pertained mainly to records of taxa, and only to a limited extent to distribution, numbers and habitats.

The 60 taxa (species and subspecies) of Bombini found to occur in the 11 countries since the beginning of the 20th century included 48 taxa of bumble bees and 12 taxa of cuckoo bees (Table 1). The least number of taxa (26–30) were found in small (Luxembourg) and lowland countries (the Netherlands and Denmark). Countries with diverse physical and geographical features (Germany, Switzerland, Austria, Czech Republic, Slovakia and Poland), had the most taxa (38–45). There was no relation between country area and the number of taxa.

The first intimation of threats to the Bombini, and of known extinctions, dates from the 1940s for Belgium (Rasmont *et al.*, 1993), Denmark (H.B. Madsen & R. Mortensen, unpubl. data), the Netherlands (C. Achterberg, pers. comm., 2002) and Poland (Banaszak, 2000). Extinctions also subsequently occurred in Austria (Aichhorn, 1983; J. Neumayer, pers. comm., 2002), Switzerland (Amiet, 1994), Hungary (M. Sárospataki, pers. comm., 2002), Germany (Riess *et al.*, 1976), and the Czech Republic (A. Přidal, pers. comm., 2004).

We were able to evaluate the status of most taxa in the 11 countries but were not able to evaluate 74% of the taxa occurring in Luxembourg. Data Deficient species accounted for <10% of taxa except for Poland (26.8%) and Slovakia (13.2%; Table 2). Of the taxa occurring in the whole study area, 16 (26.7%) were categorized as CR, 22 (36.7%) as EN, 38 (63.3%) as VU and 38 (63.3%) as NT in at least one country. Thirty-two taxa (53.3%) were categorized as EX, CR, EN, VU or NT in >75% of the countries in which they occurred. This includes 19 (31.7%) taxa threatened throughout their range in the 11 countries. Only 11 taxa (18.3%) were not categorized as EX, CR, EN, VU or NT in >75% of the countries in which they occurred. Our analysis may, however, underestimate the overall threat to those species that have only been recorded in one or two countries.

The greatest number of taxa categorized as EX, CR, EN, VU or NT were found in Switzerland (35), Czech Republic (29), Germany and Austria (28 each), and the lowest in Poland (15) and Slovakia (16). When the percentages of threatened taxa were considered, the most threatened are in Switzerland (79.5%), Hungary (78.1%), Czech Republic (74.4%) and Belgium (72.2%), and the least in Slovakia (42.1%) and Poland (36.6%). Correlations between the percentage of species categorized as EX, threatened (CR, EN, VU) or NT in each country, both separately and pooled, and country area were insignificant.

Six and 13 taxa, respectively, became extinct in at least one country in the periods 1901–1950 and 1951–2000 (Table 3). Four species became totally extinct in the 11 countries (*B. armeniacus*, *B. cullumanus*, *B. serrisquama* and *B. sidemii*) in 1951–2000. Of 29 country extinctions 21 (72.4%) occurred in 1951–2000, significantly more than in 1901–1950 ($\chi^2 = 5.533$, df = 1, $P < 0.05$). All first records of Bombini occurred in the second half of the 20th century (Table 3).

In the opinion of experts the reason for changes in composition and distribution of Bombini in the 11 countries can be attributed to the effects of a range of both anthropogenic and natural factors (Table 4). Of the anthropogenic factors, fragmentation and decrease in suitable habitats were considered to have adversely affected Bombini in 10 of the 11 countries, and homogenization of habitats due to agricultural practices and intensive use of chemical fertilizers, herbicides and pesticides, to have affected Bombini in nine countries. Pollution by heavy metals, mortality due to tourism and road traffic, and expansion of urban areas were considered to be important drivers of pollinator loss in approximately half of the countries examined.

Changes adversely affecting the Bombini in the 11 countries have in some cases resulted in legal protection and some species have been included in Red Data lists (Table 5). In Germany, Switzerland, Czech Republic, Slovakia and Poland all or almost all Bombini taxa are legally protected. In Belgium, Austria and Hungary selected species are protected. The Bombini are not legally protected in the Netherlands, Luxembourg or Denmark.

Discussion

Although the use of a data set compiled by country is to some extent artificial (international boundaries generally being arbitrary rather than following natural landscape features) our analyses yielded some important insights for conservation and confirmed concerns about the conservation status of this group of pollinators. Only 20% of the 60 Bombini taxa were not threatened in some way in the 11 countries studied. The remaining 80% were threatened in at least one country, with more than

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Table 1 Red List categories (IUCN, 2001)[1] of the 60 Bombini taxa (species and subspecies) of 11 Western and Central European countries (Fig. 1), with their threat index (see text for further details).

Taxon	Countries											Threat index
	BEL	NLD	LUX	DNK	DEU	CHE	AUT	CZE	SVK	HUN	POL	
Bombus alpinus[2] L.					EX	EN	NT					1.00
Bombus argillaceus (Scop.)					EN	VU	VU		LC	VU		0.80
Bombus armeniacus (Rad.)							EX	EX				1.00
Bombus brodmannicus (Vogt)						NT						1.00
Bombus confusus Schenck	EX	EX	NE		EN	EX	CR	CR	EN	NT	VU	0.90
Bombus cryptarum Fabr.	VU		VU	NT	DD	VU	NT	VU	DD		DD	0.67
Bombus cullumanus (K.)	EX	EX		EX	EX							1.00
Bombus distinguendus Mor.	EX	CR		VU	EN	EX	EX	CR	CR	EX	VU	1.00
Bombus fragrans[2] Pall.							EX	EX	DD	EN	EX	0.80
Bombus gerstaeckeri[2] Mor.					VU	VU	NT			VU		1.00
Bombus haematurus (Kriech.)										VU		1.00
Bombus hortorum (L.)	VU	LC	NE	LC	LC	LC	LC	NT	LC	LC	LC	0.18
Bombus humilis Ill.	EN	NT	NE	NT	NT	VU	VU	EN	LC	LC	VU	0.73
Bombus hypnorum (L.)	LC	LC	NE	LC	LC	LC	LC	CR	VU	VU	LC	0.27
Bombus inexspectatus[2] (Tkalcu)						VU	EN					1.00
Bombus jonellus[3] (K.)	EN	NT	NE	NT	VU	EN	VU	VU	DD		VU	0.80
Bombus laesus mocsaryi[2] Kriechb.						NT	EX		CR	VU	VU	1.00
Bombus lapidarius (L.)	VU	LC	NE	LC	LC	LC	LC	LC	LC	LC	LC	0.09
Bombus lucorum (L.)	VU		VU	LC	LC	LC	LC	LC	LC	NT	LC	0.30
Bombus maculidorsis Skor.											VU	1.00
Bombus magnus Vogt	VU		VU	NT	EN	NT	NT	VU			DD	0.88
Bombus mendax[2] (Gerst.)					VU	VU	NT					1.00
Bombus mesomelas[2] Gerst.	NE				EN	VU	NT	CR	DD	EX	DD	0.63
Bombus monticola hypsophilus[2] (Skor.)					NT	NT	NT					1.00
Bombus mucidus[2] (Gerst.)					VU	VU	NT					1.00
Bombus muscorum (L.)	VU	NT	NE	NT	EN	NT	CR	CR	EN	NT	LC	0.82
Bombus pascuorum (Scop.)	LC	LC	NE	LC	LC	LC	LC	LC	LC	LC	LC	0.00
Bombus pomorum (Panz.)	EX	EX		EX	EN	EN	CR	CR	CR	NT	VU	1.00
Bombus pratorum (L.)	LC	LC	NE	LC	LC	LC	LC	LC	LC	NT	LC	0.09
Bombus pyrenaeus afasciatus Dyl.									LC		DD	0.00
Bombus pyrenaeus tenuifasciatus[2] Vogt					NT	NT	LC					0.67
Bombus ruderarius (Müll.)	VU	NT	NE	NT	VU	VU	VU	EN	LC	LC	LC	0.64
Bombus ruderatus ruderatus (Fabr.)	CR	CR		EX	NT	EN		CR	VU	NT	VU	0.50
Bombus ruderatus eurynotus (D. T.)			NE				NT					1.00
Bombus schrencki (Mor.)											DD	0.00
Bombus semenoviellus[4] Skor.					LC			DD			DD	0.00
Bombus serrisquama[2] (Mor.)										EX		1.00
Bombus sichelii sichelii (Rad.)								DD	DD		EX	0.33
Bombus sichelii alticola[2] (Kriechb.)					VU	VU	LC					0.67
Bombus sidemii (Rad.)								EX				1.00
Bombus soroeensis proteus Gerst.	EN	EN	NE	NT	NT	EN	LC	VU	VU	VU	VU	0.82
Bombus soroeensis soroeensis (Fabr.)	EN			NT	NT			VU	VU	VU	VU	1.00
Bombus subterraneus (L.)	CR	CR	NE	VU	NT	EN	CR	CR	EN	VU	VU	0.91
Bombus sylvarum (L.)	VU	EX	NE	NT	NT	VU	NT	CR	LC	LC	LC	0.64
Bombus terrestris (L.)	VU	LC	VU	LC	LC	LC	LC	LC	LC	LC	LC	0.18
Bombus veteranus (Fabr.)	EN	VU	NE	VU	VU	VU	EN	CR	CR		VU	0.90
Bombus wurflenii mastrucatus[2] Gerst.	DD				NT	EN	LC	VU	LC		DD	0.43
Bombus zonatus[2] (Smith)										CR		1.00
Psithyrus barbutellus (Kirby)	EN	EN	EN	VU	LC	NT	LC	CR	VU	NT	NT	0.82
Psithyrus bohemicus (Seidl.)	LC	LC	NE	LC	LC	NT	LC	LC	LC	VU	LC	0.18
Psithyrus campestris (Panz.)	VU	LC	NE	VU	LC	LC	LC	NT	LC	VU	LC	0.36
Psithyrus flavidus flavidus (Evers.)											DD	0.75
Psithyrus flavidus alpium[2] (Rich.)					NT	NT	NT				DD	0.00
Psithyrus maxillosus (Klug)						NT	VU	CR	VU			1.00
Psithyrus norvegicus Sp.–Schn.	DD	LC	NE	NT	LC	NT	NT	EN	VU		DD	0.50
Psithyrus quadricolor quadricolor Lep.	DD			EX	NT			CR	CR		DD	0.83
Psithyrus quadricolor meridionalis (Rich.)			DD		NT	NT	NT	CR	CR			0.67
Psithyrus rupestris (Fabr.)	EN	NT	EN	LC	LC	EN	LC	LC	LC	NT	LC	0.45

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Table 1 (*Continued*)

Taxon	Countries BEL	NLD	LUX	DNK	DEU	CHE	AUT	CZE	SVK	HUN	POL	Threat index
Psithyrus sylvestris Lep.	LC	LC	NE	LC	LC	LC	LC	VU	LC	VU	LC	0.18
Psithyrus vestalis (Geoff. in Four.)	VU	LC	NE	LC	LC	VU	LC	LC	LC	NT	LC	0.27
Total no. of taxa	33	26	27	30	44	44	45	39	38	32	41	

[1]EX, Extinct; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient; NE, Not Evaluated. Note that LC is not actually a category on the Red List but signifies that the species has been assessed and found not to be threatened.
[2]Taxa with specific habitat requirements (alpine, mountain or steppe habitat)
[3]A glacial relict in the mountains of Central Europe
[4]Species expanding its range westwards

Table 2 Number and percentage (in parentheses) of Bombini taxa (Table 1) in each Red List Category (IUCN, 2001) of 11 Western and Central European countries (Fig. 1).

	Countries										
Category*	BEL	NLD	LUX	DNK	DEU	CHE	AUT	CZE	SVK	HUN	POL
EX	4(12.1)	4(15.4)	0	4(13.3)	2(4.5)	2(4.5)	4(8.9)	3(7.7)	0	3(9.4)	2(4.8)
CR	2(6.1)	3(11.5)	0	0	0	0	4(8.9)	14(35.9)	6(15.8)	1(3.1)	0
EN	7(21.2)	2 (7.7)	2(7.4)	0	7(15.9)	8(18.2)	2(4.4)	3(7.7)	3(7.9)	1(3.1)	0
VU	11(33.3)	1(3.8)	4(14.8)	5(16.7)	7(15.9)	13(29.5)	5(11.1)	7(17.9)	7(18.4)	11(34.4)	12(29.2)
NT	0	5(19.2)	0	10(33.3)	12(27.3)	12(27.3)	13(28.9)	2(5.1)	0	9(28.1)	1(2.4)
LC	5(15.2)	11(42.3)	0	11(36.7)	15(34.1)	9(20.5)	17(37.8)	8(20.5)	17(44.7)	7(21.9)	15(36.6)
DD	3(9.1)	0	1(3.7)	0	1(2.3)	0	0	2(5.1)	5(13.2)	0	11(26.8)
NE	1(3.0)	0	20(74.1)	0	0	0	0	0	0	0	0
Total	33	26	27	30	44	44	45	39	38	32	41

*See footnote to Table 1

Table 3 Extinctions and first records of Bombini taxa (Table 1) of 11 Western and Central European countries (Fig. 1).

	Extinction		First record	
Taxon	Before 1950	After 1951	Before 1950	After 1951
B. alpinus		DEU		
B. armeniacus		AUT, CZE		
B. confusus	NLD	BEL, CHE		
B. cryptarum				CZE, SVK
B. cullumanus	BEL, DNK	DEU, NLD		
B. distinguendus		AUT, BEL, CHE, DNK, HUN		
B. fragrans	POL	AUT, CZE		
B. laesus mocsaryi		AUT		
B. magnus				CZE
B. mesomelas		HUN		
B. pomorum	NLD, DNK	BEL		
B. ruderatus ruderatus		DNK		
B. semenoviellus				DEU, POL, CZE
B. serrisquama		HUN		
B. sichelii sichelii	POL			CZE, SVK
B. sidemii		CZE		
B. sylvarum		NLD		
P. quadricolor quadricolor	DNK			
Total no. of taxa	6	13	0	4
Total no. of extinctions/first records	8	21	0	8

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Table 4 Occurrence of 16 anthropogenic and five natural factors (see text for details) threatening the Bombini (Table 1) of 11 Western and Central European countries (Fig. 1), ranked by the number of countries in which the threats occur.

	Country											No. of countries
Factors	BEL	NLD	LUX	DNK	DEU	CHE	AUT	CZE	SVK	HUN	POL	
Anthropogenic												
Fragmentation & decrease in suitable habitats (including melioration of wetlands)	+	+		+	+	+	+	+	+	+	+	10
Homogenization of habitats due to agricultural practices	+	+		+	+	+	+	+	+		+	9
Intensive use of chemical fertilizers, herbicides & pesticides	+	+		+	+	+	+	+	+		+	9
Shortage of food due to frequent mowing of meadows	+			+	+	+	+	+	+			7
Shortage of food due to competition with honey bees	+			+	+		+		+		+	6
Pollution with heavy metals		+			+		+	+		+	+	6
Trampling due to tourism				+	+		+	+		+	+	6
Mortality caused by cars				+	+		+	+		+	+	6
Burning of old grass in the spring & stubble in summer				+			+		+	+	+	5
Afforestation on xerothermic swards, meadows & glades	+			+	+				+		+	5
Expansion of urban areas	+				+		+		+		+	5
Destruction of nests by heavy machines on meadows, fields & forests					+		+		+		+	4
Import of alien species for pollination					+		+		+		+	4
Pollution by acid rain					+		+	+	+			4
Building of dams								+			+	2
Collecting for museum & private collections											+	1
Natural												
Natural succession of forest glades, meadows & xerothermic swards				+	+			+	+		+	5
Sterilization of wintering females by *Sphaerularia bombi*				+	+		+		+		+	5
Parasitism or predation by Arachnidae, Lepidoptera, Diptera, Hymenoptera, & birds & mammals					+	+	+				+	4
Adverse weather conditions (long winters, drought)					+		+		+		+	4
Natural mortality of wintering females											+	1

half of all taxa threatened in most countries. This evidence of adverse changes in the species composition and distribution of the Bombini across this large area of Western and Central Europe corroborates the results of country-based studies in this region (Riess *et al.*, 1976; Wergin, 1977; Aichhorn, 1983; Warncke *et al.*, 1984; Starzyk & Kosior, 1985; Kosior, 1987, 1990, 1992c; Kosior & Nosek, 1987; Westrich, 1990; Kosior & Witkowski, 1997; Banaszak *et al.* 1998; C. Achterberg, pers. comm., 2002; R. Chlebo, pers. comm., 2002; J. Neumayer, pers. comm., 2002; P. Rasmont, pers. comm., 2002; M. Sárospataki, pers. comm., 2002; von Hagen & Aichhorn, 2003; Celary *et al.*, 2004; S. Durrer, pers. comm., 2004; H.B. Madsen, pers. comm., 2004; A. Přidal, pers. comm., 2004). Neither the total number of taxa nor the total number of threatened species of Bombini per country could be explained by country area or longitude.

The apparently greater number of species extinctions in the second half of the 20th century could be affected by the fact that earlier data may have been less precise. However, a similar trend in increasing extinctions has been noted for butterflies in Poland (Razowski, 1985) and bumble bees in Britain (Williams, 1982). In the second half of the 20th century more species also expanded their ranges than in the pre-1950 period. These expansions do not seem to be facilitated by weaker competition from declining species, as they do not share the same niche, and the species expanding their ranges are probably more tolerant of anthropogenic pressures.

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Table 5 Legal protection accorded to the Bombini of 11 Western and Central European countries (Fig. 1), with their coverage in Red Books and Red Lists of threatened species.

Country	Legal protection	Red Book*	Red List*
BEL	Only 6 species of *Bombus*, since 2002 (P. Rasmont, pers. comm., 2002)		
NLD			Peeters & Reemer (2003; does not include *Bombus*)
LUX			
DNK			
DEU	All Bombini species since 1980 (Gauld *et al.*, 1990; von Hagen & Aichhorn, 2003)	Blab *et al.* (1984)	Blab *et al.* (1984), Westrich & Schmidt (1985), Winter (1994), Westrich *et al.* (1998), Dathe & Saure (2000)
CHE	Only the Vaud Canton protects all useful insects, including bumble bees (Gauld *et al.*, 1990)		Amiet, 1994
AUT	None, except for Burgenland, where catching any useful insects, including Bombini, is prohibited by law	J. Gepp (1983; includes only *B. inexpectatus* in Carinthia)	Aichorn (1983), von Hagen & Aichorn (2003) (bumble bees & threats thereto are only referred to in a comment)
CZE	All *Bombus* (Czech Republic, 1992; V. Ptáček, pers. comm., 2002)	Škapec (1992; does not include *Bombus*)	
SVK	All *Bombus* (Slovak Republic, 1999; R. Chlebo, pers. comm., 2002)	Škapec (1992; does not include *Bombus*)	
HUN	Only *B. argillaceus* (K. Szauter, pers. comm., 2001; M. Sárospataki, pers. comm., 2002)	Rakonczay (1989; includes only *B. argillaceus* & *B. fragrans*)	
POL	All *Bombus* & 2 species of *Psithyrus* (Minister of Environment, 2004)	Kosior (1992b; includes only *B. jonellus*)	Banaszak (2002)

*Red List, a list of species with their Red List categories; Red Book, a comprehensive Red List assessment of each species.

The assessment of factors threatening the Bombini was based largely on expert opinion. Whilst there are disadvantages to the use of such subjective judgement it was, however, the only way to obtain proxy information of drivers of Bombini decline in the region. Although experts' opinions on the importance of factors such as hiking or road kills were diverse, they were consistent on the importance of the impacts of various aspects of large-scale farming schemes, similar to findings regarding the role of agricultural intensification (Banaszak, 1995) and habitat fragmentation and isolation (Steffan-Dewenter & Tscharntke, 2002) in Bombini declines.

In the opinion of the experts surveyed the importation of alien pollinators is not important in the decline of the Bombini, although they noted the important role of competition with honey bees *Apis* spp.. Competition for floral resources occurs between Bombini and several introduced bee species (Goulson, 2003), and between wild bees and managed pollinators (Butz-Huryn, 1997; Steffan-Dewenter & Tscharntke, 2000). Competition with honey bees has been identified as one of the factors contributing to the extinction or decline of bumble bee species in central England, along with predation, parasites, pesticides, and changes in vegetation structure (Williams, 1982). The latter was largely a result of intensification of agriculture: an acceleration of mechanization, drainage of pastures, and the increase in the size of fields by the removal of hedges. Intensification of agricultural practices are regarded as contributing to the decline of Bombini in the former East Germany, Belgium and Northern France (Williams, 1982).

Species richness amongst British bumble bees is influenced by the availability of food plants (Williams, 1989), and long-tongued and therefore more specialized bumble bees are more likely to have exhibited a decline (Goulson *et al.*, 2005). For this reason introduction of non-native flowering plants may also contribute to pollinator loss (Brown & Mitchell, 2001; Chittka & Schürkens, 2001). There may be a synergistic effect of pressure from natural mortality factors and the increasing impact of anthropogenic effects on the Bombini. For example, the spread of diseases and parasites of Bombini has been identified as an important driver of pollinator loss (Watanabe, 1994). It is known that the nematode *Sphaerularia bombi* is capable of sterilizing gonads in 35–90% of wintering bumble bee females (Pouvreau, 1974).

The general conclusion from our analysis is that to halt population declines and species extinctions of Bombini it will be necessary, above all, to preserve aspects of traditional farming practices. The maintenance

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

of habitat patchiness and limiting use of chemical preparations and heavy machinery are of key importance for the Bombini. Approaches to the conservation of Bombini differ significantly between countries, and in some countries of the region the protection afforded to this economically important group of insects is inadequate. Given their importance as pollinators it would be appropriate for all Bombini taxa to be afforded legal protection in all countries of the region, and for threatened taxa to be assessed for inclusion in the relevant national and regional Red Lists.

The growing evidence of pollinator loss in Europe has resulted in a number of initiatives to protect the Bombini. A recent European Union funded project, ALARM (Assessing LArge scale environmental Risks for biodiversity with tested Methods; Settele *et al.*, 2005), focuses on risks consequent, amongst others, on loss of pollinators. As changes in agricultural practices are probably the main single factor affecting Bombini in the region, and as the majority of the countries are EU members, the implementation of the EU's Common Agricultural Policy is likely to have the greatest single impact upon pollinators in the near future. A prerequisite to halt pollinator loss in Europe is for this Policy to follow advice provided by results of scientific research. Unfortunately, pollinator loss is rarely perceived as a serious threat to biodiversity by the general public, and an increase in awareness of this issue is therefore also of great importance.

Acknowledgements

We thank the following specialists who made available their unpublished data: J. Neumayer (Austria), P. Rasmont (Belgium), M. Pavelka, A. Přidal, V. Ptáček and I. Valterova (Czech Republic), I. Calabuig, H.B. Madsen and R. Mortensen (Denmark), C. van Achterberg (Netherlands), M. Sárospataki and K. Szauter (Hungary), P. Westrich (Germany), R. Chlebo, J. Slamecka and V. Smetana (Slovakia), F. Amiet and S. Durrer (Switzerland), and T. Pawlikowski (Poland). We also thank three anonymous reviewers for their invaluable comments on an earlier version of this article. W. Król and W. Solarz were partly funded by EU project ALARM, No. GOCE-CT-2003-506675.

References

Aichorn, A.A. (1983) Zur Gefährdungssituation der Hummeln in Österreich (*Bombus*, Hymenoptera). In *Rote Listen gefährdeter Tiere Österreichs. 1* (ed. J. Gepp), pp. 3–242. Im Auftrag des Bundes–ministeriums für Gesundheit und Umweltschutz, Wien, Austria.

Allen-Wardell, G., Bernhardt, T., Bitner, R., Burquez, A., Cane, J., Cox, P.A., Dalton, V., Feinsinger, P., Ingram, M., Inouye, D., Jones, C.E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G.P., Pavlik, B., Tepedino, V., Torchio, P. & Walker, S. (1998) The potential consequences of pollinator declines on the conservation of biodiversity and stability of crop yields. *Conservation Biology*, **12**, 8–17.

Amiet, F. (1994) Rote Liste der gefährdeten Bienen der Schweiz. In *Rote Listen der gefährdeten Tierarten der Schweiz* (ed. P. Duelli), pp. 38–44. Hrsg. Bundesamt für Umwelt, Wald und Landschaft, BUWAL-Reihe Rote Listen, Bern, Switzerland.

Banaszak, J. (1993) *Trzmiele Polski*. WSP, Bydgoszcz, Poland.

Banaszak, J. (1995) *Changes in Fauna of Wild Bees in Europe*. Pedagogical University, Bydgoszcz, Poland.

Banaszak, J. (1996) Import trzmieli do Polski – korzyści i zagrożenia. *Chrońmy Przyrodę Ojczystą*, **52**, 110–116.

Banaszak, J. (2000) A checklist of the bee species (Hymenoptera, Apoidea) of Poland, with remarks on their taxonomy and zoogeography: revised version. *Fragmenta Faunistica*, **43**, 135–193.

Banaszak, J. (2002) Apoidea. In *Red List of Threatened Animals in Poland* (ed. Z. Głowaciński), pp. 80–87. Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland.

Banaszak, J., Michalik, S., Fijał, J. & Kosior, A. (1998) Wpływ sukcesji zbiorowisk nieleśnych na pszczołowate Apoidea rezerwatu leśno-stepowego Skołczanka. *Prądnik Prace i Materiały Muzeum Im. Prof. Władysława Szafera*, **11–12**, 223–250.

Beláková, A., Smetana, V. & Valenčík, M. (1979) Výskyt niektorých zástupcov podčeladí Bombinae a Psithyrinae (Hymenoptera, Apoidea) na Slovensku. *Biológia*, **34**, 637–644.

Blab, J., Nowak, E., Trautmann, W. & Sukopp, H. (eds) (1984) *Rote Liste der gefährdeten Tiere und Pflanzen in der Bundesrepublik Deutschland. 4. Erweiterte und bearbeitete Auflage*. Kilda-Verlag, Greven, Germany.

Brown, B.J. & Mitchell, R.J. (2001) Competition for pollination: effects of pollen of an invasive plant on seed set of a native congener. *Oecologia*, **129**, 43–49.

Burd, M. (1994) Bateman's principle and plant reproduction: the role of pollen limitation in fruit and seed set. *Botanical Review*, **60**, 83–139.

Butz-Huryn, V.M. (1997) Ecological impacts of introduced honey bees. *The Quarterly Review of Biology*, **72**, 275–296.

Celary, W., Fijał, J., Kosior, A., Król, W., Solarz, W. & Witkowski, Z. (2004) Changes in the species composition and range of Bombini (Apidae) in Cracow since the mid 1850s. Unpublished Report. Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland.

Chittka, L. & Schürkens, S. (2001) Successful invasion of a floral market. *Nature*, **411**, 653.

Corbet, S.A., Williams, I.H. & Osborne, J.L. (1991) Bees and the pollination of crops and wild flowers in the European Community. *Bee World*, **72**, 47–59.

Czech Republic (1992) *Law No. 114/1992 and Edict No. 395/1992*. Praha, Czech Republic.

Dathe, H.H. & Saure, C. (2000) Rote Liste und Artenliste der Bienen des Landes Brandenburg (Hymenoptera: Apidae). Beilege zum Heft 1. *Naturschutz und Landschaftspflege in Brandenburg*, **9**, 1–35.

Dylewska, M. (1996) *Nasze trzmiele*. ODR, APW, Karniowice, Polska.

Gauld, I.D., Collins, N.M. & Fitton, M.G. (1990) The biological significance and conservation of Hymenoptera in Europe. *Nature and Environment Series*, **44**, 3–47.

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Gepp, J. (1983) *Rote Listen gefährdeter Tiere Österreichs. 1*. Im Auftrag des Bundes–ministeriums für Gesundheit und Umweltschutz, Wien, Austria.

Goulson, D. (2003) Effects of introduced bees on native ecosystems, *Annual Review of Ecology, Evolution and Systematics*, **34**, 1–26.

Goulson, D., Hanley, M.E., Darvill, B., Ellis, J.S. & Knight, M.E. (2005) Causes of rarity in bumble bees. *Biological Conservation*, **122**, 1–8.

Herrera, C. & Pellmyr, O. (eds) (2002). *Plant-Animal Interactions*. Blackwell Science, Malden, USA.

IUCN (2001) *2001 Categories and Criteria (version 3.1)*. IUCN, Gland, Switzerland [http://www.redlist.org/info/categories_criteria2001.html, accessed 18 October 2004].

Kearns, C.A., Inouye, D.W. & Waser, N.M. (1998) Endangered mutualisms: the conservation of plant-pollinator interactions. *Annual Review of Ecology and Systematics*, **29**, 83–112.

Kosior, A. (1987) Impact of economic activity upon bumblebee *Bombus* Latr. population in the West Bieszczady Mts. *Ochrona Przyrody*, **45**, 239–262.

Kosior, A. (1990) The bumble bees *Bombus* Latr. of the selected glades of the Tatra National Park. *Studia Naturae, A*, **34**, 113–123.

Kosior, A. (1992a) Bumble bees (*Bombus* Latr.) and cuckoo bees (*Psithyrus* Lep.) in selected areas of the Hohe Tauern (Central Alps, Austria). *Ochrona Przyrody*, **50**, 153–171.

Kosior, A. (1992b) *Bombus jonellus* (Kirby, 1802). Trzmiel tajgowy. In *Polish Red Data Book of Animals* (ed. Z. Głowaciński), pp. 300–302. PWRiL, Warszawa, Polska.

Kosior, A. (1992c) The influence of anthropogenic factors on the decline of bumble bees (*Bombus* Latr.) in Poland. In *Natural Resources of Wild Bees in Poland* (ed. J. Banaszak), pp. 145–152. Pedagogical University, Bydgoszcz, Poland.

Kosior, A. & Nosek, A. (1987) Species composition and number of bumble bees *Bombus* Latr. in the areas influenced by the emissions from non-ferrous metal works in the Silesian Upland. *Studia Naturae, A*, **31**, 81–99.

Kosior, A. & Witkowski, Z. (1997) Stan przyrody ożywionej w rejonie zespołu zbiorników wodnych Czorsztyn-Niedzica i Sromowce Wyżne w trakcie piętrzenia (w 1997 r.). In *Fauna trzmieli (*Bombus *Latr.) i trzmielców (*Psithyrus *Lep.) obszaru zbiornika Czorsztyńskiego na tle fauny obszarów sąsiadują cych (Pieniny Centralne, Pieniny Spiskie i pasmo Lubania)* (ed. Z. Witkowski), pp. 1–2. Unpublished Report. Institute of Nature Conservation, Polish Academy of Sciences, Krakow, Poland.

Lukas, J. (2001) Cerveny (ekosozologicky) zoznam blanokridlovcov (Hymenoptera) Slovenska. In *Cerveny zoznam rastlin a zivocichov Slovenska* (eds D. Balaz, K. Marhold & P. Urban), *Ochrana Prirody*, **20**, 129–133.

May, J. (1959) *Čmeláci v ČSR, jejich bionomie, chov a hospodářský význam*. Sborník Akademie zemědělských věd ČSFR, Praha, Čechoslovakia.

Minister of Environment (2004) Decree on strictly protected animal species, 28 October. *Dziennik Ustaw*, **220**, 15570–15582.

Móczár, M. (1957) Méhfélék Apidae. Hymenoptera 3. *Fauna Hungariae*, **19**, 1–76.

Monsevičius, V. (1995) A check-list of wild bee species (Hymenoptera, Apoidea) of Lithuania with data to their distribution and bionomics. *New and Rare for Lithuania Insect Species. Records and Descriptions of 1994–1995*: 7–144.

Müller, H. (1881) *Alpenblumen, ihre Befruchtung durch Insekten und ihre Anpassungen an dieselben*. W. Engelmann, Leipzig, Germany.

Neumayer, J. & Paulus, H.F. (1999) Ökologie alpiner Hummelngemeinschaften: Blütenbesuch, Ressourcenaufteilung und Energiehaushalt. *Stapfia*, **67**, 5–246.

NHM (Natural History Museum) (2005) Bombus *Bumblebees of the World*. Http://www.nhm.ac.uk/research-curation/projects/bombus/ [accessed 10 August 2006].

Pagliano, G. (1994) Catalogo degli Imenotteri Italiani. IV. (Apoidea: Colletidae, Andronidae, Megachilidae, Anthophoridae, Apidae). *Memorabilia Societatis Entomologica Italiana*, **72**, 331–467.

Peeters, T.M.J., Raemakers, I.P. & Smit, J. (1999) *Voorlopige atlas van de Nederlandse bijen (Apidae)*. EIS, Leiden, Nederland.

Peeters, T.M.J. & Reemer, M. (2003) *Bedreigde en verdwenen bijen in Nederland (Apidae s.l.). Basisrapport met voorstel voor de Rode lijst*. EIS-Nederland, Leiden, Netherlands.

Pouvreau, A. (1974) Les ennemis des bourdons. II. Organismes affectant les adultes. *Apidologie*, **5**, 39–62.

Přidal, A. (2004) Checklist of the bees in the Czech Republic and Slovakia with comments on their distribution and taxonomy. (Insecta: Hymenoptera: Apoidea). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, **52**, 29–65.

Přidal, A. & Tkalců, B. (2003) Records of two bumblebee species new for the Czech Republic and Slovakia (Hymenoptera: Apoidea: Bombini). *Entomofauna*, **24**, 317–329.

Rakonczay, Z. (1989) *Red Data Book of Animals in Hungary*. Akadémia Kiadó, Budapest, Hungary.

Rasmont, P. (1983) Catalogue commenté des Bourdons de la région ouest-paléarctique (Hymenoptera, Apidae, Bombinae). *Notes fauniques de Gembloux*, **7**, 1–72.

Rasmont, P. (1995) How to restore the Apoid diversity in Belgium and France? Wrong and right ways, or the end of protection paradigm! In *Changes in Fauna of Wild Bees in Europe* (ed. J. Banaszak), pp. 53–63. Pedagogical University, Bydgoszcz, Poland.

Rasmont, P., Ebmer, A., Banaszak, J. & van der Zanden, G. (1995) Hymenoptera Apoidea Gallica. Liste taxonomique des abeilles de France, de Belgique, de Suisse et du Grand-Duché de Luxemburg. *Bulletin de la Société Entomologique de France*, **100**, 1–98.

Rasmont, P., Leclercq, J., Jacob-Remacle, A., Pauly, A. & Gaspar, C. (1993) The faunistic drift of Apoidea in Belgium. In *Bees for Pollination* (ed. E. Bruneau), pp. 65–87. Commission of the European Communities, Brussels, Belgium.

Rasmont, P. & Mersch, P. (1988) Première estimation de la dérive faunique chez les bourdonsde la Belgique (Hymenoptera: Apidae). *Annales de la Société Royale Zoologique de Belgique*, **118**, 141–147.

Razowski, J. (1985) Changes in the Lepidopterous fauna of Cracov, Poland. *Nota Lepidopterologica*, **8**, 65–68.

Reinig, W.F. (1981) Synopsis der in Europa nachgewiesenen Hummel- und Schmarotzerhummelarten. *Spixiana*, **4**, 159–164.

Riess, W., Roth, H.M. & Nitsche, G. (1976) Rote Liste bedrohter Tiere in Bayern (Wirbeltiere und Insekten). Fassung 1. *Bayerisches Landesamt für Umweltschutz. Schriftenreihe für Naturschutz und Landschaftspflege*, **7**, 5–38.

Sárospataki, M., Novák, J. & Molnár, V. (2003) Hazai poszméh – és álposzméhfajok (Hymenoptera: Apidae, *Bombus* és *Psithyrus*) UTM térképezése és az adatok természetvédelmi felhasználhatósága. *Állattani Közlemények*, **88**, 1–24.

Schwartz, M., Gusenleitner, F., Westrich, P. & Dathe, H.H. (1996) Katalog der Bienen Österreichs, Deutschlands und der Schweiz (Hymenoptera, Apidae). *Entomofauna*, **Supplement 8**, 1–398.

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press

Settele, J., Hammen, V.C., Hulme, P.E., Karlson, U., Klotz, S., Kotarac, M., Kunin, W.E., Marion, G., O'Connor, M., Petanidou, T., Peterson, K., Potts, S.G., Pritchard, H., Pysek, P., Rounsevell, M., Spangenberg, J., Steffan-Dewenter, I., Sykes, M.T., Vighi, M., Zobel, M. & Kuhn, I. (2005) ALARM: Assessing LArge scale environmental Risks for biodiversity with tested Methods. *GAIA - Ecological Perspectives in Science, Humanities, and Economics*, **14**, 69–72.
Siła-Nowicki, M. (1864) *Przyczynek do owadniczej fauny Galicyi*. Drukarnia Uniwersytecka, Kraków, Poland.
Škapec, L. (1992) *Ĉervení Kniha ochrozených a vzácnych druhov rastlin a živočichov ĈSFR. 3. Bezstavovce*. Príroda, Bratislava, Slovakia.
Slovak Republic (1999) *Supplement of the Edict 93/1999*. Bratislava, Slovakia.
Starzyk, J.R. & Kosior, A. (1985) Effect of hiking on the entomofauna of the Bieszczady National Park and the surrounding area. *Parki Narodowe i Rezerwaty Przyrody*, **6**, 93–100.
Steffan-Dewenter, I. & Tscharntke, T. (2000) Resource overlap and possible competition between honey bees and wild bees in central Europe. *Oecologia*, **122**, 288–296.
Steffan-Dewenter, I. & Tscharntke, T. (2002) Insect communities and biotic interactions on calcareous grasslands – a mini review. *Biological Conservation*, **104**, 275–284.
Śnieżek, J. (1893) O krajowych gatunkach trzmieli. *Sprawozdanie Komisji Fizjograficznej*, **29**, 1–22.
Śnieżek, J. (1899) O krajowych gatunkach trzmielców. *Sprawozdanie Komisji Fizjograficznej*, **34**, 86–95.
Tkalců, B. (1974) Bemerkenswerte Bienenfunde in der Tsc hechoslowakei (Hymenoptera: Apoidea). *Acta Entomologica Bohemoslovaka*, **71**, 205–208.
Tkalců, B. (1999) Two species of bumblebees new for the Czech Republic (Hymenoptera: Apoidea). *Sborník Přírodovědného klubu v Uh. Hradišti*, **4**, 121–123.
van der Smissen, J. & Rasmont, P. (1999) *Bombus semenoviellus* Skorikov 1910 eine für Westeuropa neue Hummelart (Hymenoptera: *Bombus*, *Cullumanobombus*). *Bembix Bielefeld*, **13**, 21–24.
von Hagen, E. & Aichhorn, A.A. (2003) *Hummeln: bestimmen, ansiedeln, vermehren, schützen*. Fauna Verlag, Nottuln, Germany.
Warncke, K. (1986) Die Wildbienen Mitteleuropas, ihre gültigen Namen und ihre Verbreitung. *Entomofauna*, **Supplement 3**, 1–128.
Warncke, K., Westrich, P., Preuss, G. & Riemann, H. (1984) Rote Liste der Bienen (Apoidea). In *Rote Liste der gefährdeten Tiere und Pflanzen in der Bundesrepublik Deutschland. 4. erweiterte und bearbeitete Auflage* (eds J. Blab, E. Nowak, W. Trautmann & H. Sukopp), pp. 50–52. Kilda-Verlag, Greven, Germany.
Watanabe, M.E. (1994) Pollination worries rise as honey bees decline. *Science*, **265**, 1170.
Wergin, J. (1977) Tiere in Gefahr. *Naturschutz und Naturparke*, **85**, 40–42.
Westrich, P. (1990) *Die Wildbienen Baden-Württembergs. Spezieller Teil: Die Gattungen und Arten*. Verlag Eugen Ulmer, Stuttgart, Germany.
Westrich, P. & Schmidt, K. (1985) Rote Liste der Stechimmen Baden-Württembergs (Hymenoptera Aculeata ausser Chrysididae) (Stand 01. 01. 1985). *Arbeitsblätter zum Naturschutz*, **5**, 35–42.
Westrich, P., Schwenninger, H.R., Dathe, H.H., Riehmann, H., Saure, C., Voith, J. & Weber, K. (1998) Rote Liste der Bienen (Hymenoptera: Apidae) Deutschlands (Bearbeitungsstand: 1997). In *Rote Liste gefährdeter Tiere Deutschlands* (eds M. Binot, R. Bless, P. Boye, H. Gruttke & P. Pretscher). *Schriftenreihe für Landschaftspflege und Naturschutz*, **55**, 119–129.
Wierzejski, A. (1868) Przyczynek do fauny owadów błonkoskrzydłych (Hymenoptera). *Sprawozdanie Komisji Fizjograficznej*, **2**, 108–120.
Wierzejski, A. (1874) Dodatek do fauny owadów błonkoskrzydłych (Hymenoptera). *Sprawozdanie Komisji Fizjograficznej*, **8**, 253–273.
Williams, P.H. (1982) The distribution and decline of British bumble bees (*Bombus* Latr.). *Journal of Apicultural Research*, **21**, 236–245.
Williams, P.H. (1988) Habitat use by bumble bees (*Bombus* spp.). *Ecological Entomology*, **13**, 23–237.
Williams, P.H. (1989) Why are there so many species of bumble bees at Dungeness? *Botanical Journal of the Linnean Society*, **101**, 31–44.
Williams, P.H. (1994) The dependence of crop pollination within the European Union on pollination by honey bees. *Agricultural Zoology Reviews*, **6**, 229–257.
Williams, P.H. (2005) Does specialization explain rarity and decline among British bumble bees? A response to Goulson *et al.*. *Biological Conservation*, **122**, 33–43.
Winter, R. (1994) Rote Liste der Wildbienen (Hymenoptera, Apoidea) Thueringens. *Landschaftspflege und Naturschutz in Thueringen*, **31**, 86–90.

Biographical sketches

Andrzej Kosior's long-term interest in pollinators has resulted in an extensive database on the distribution and biology of bumble bees, cuckoo bees and butterflies, and he has a particular interest in the ecology and conservation of insect pollinators.

Waldemar Celary has studied the systematics of the wild bees of Central Europe for almost 20 years, and since 1998 he has also been conducting research on their biology.

Paweł Olejniczak is interested in the mathematical modeling of plant-insect relations.

Jan Fijał has studied the distribution of Hymenoptera, amphibians and reptiles in Poland, and has contributed to the Polish Red Data Books of vertebrates and invertebrates.

Wiesław Król's main interests are in database design and geographical information system analysis of species distributions.

Wojciech Solarz studies alien species invasions and the population ecology of birds.

Piotr Płonka is interested in the biology of ants and the management of protected areas.

https://doi.org/10.1017/S0030605307001597 Published online by Cambridge University Press