Final Thesis

Bumblebee distribution in space and time in three landscapes in south eastern Sweden

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LiTH-IFM-Ex--07/1775--SE

Contents

1 Abstract

During the last decades, bumblebees (*Bombus* spp.) have declined in Europe, most likely as a result of agricultural practises. The aim of this study was to describe flower utilisation, landscape element utilisation and the phenology of different bumblebee species in three landscapes in south eastern Sweden. In one of the landscapes, the stability in landscape element utilisation between years was examined as well. The number of bumblebee species found in this study was higher than normally found in Western Europe. More species were observed in a heterogeneous landscape (14 spp.) compared to an intensively agricultural landscape (10 spp.) and a landscape dominated by forest (10 spp.). Most species were observed in semi-natural grasslands. This landscape element was also one of the most stable in bumblebee abundance and diversity between years, compared to leys and road verges that are disturbed by cutting. Bumblebees preferred several plant species, but flowers belonging to *Fabaceae* and particularly *Trifolium* seemed important for a majority of the bumblebees. Long-tongued species paid most visits to *Fabaceae* and short-tongued to *Asteraceae*. An earlier peak in bumblebee abundance (middle of July) was observed in the forested landscape compared to the heterogeneous and agricultural landscapes (beginning of August), most likely caused by lower amount of late flowering plant species in the forest landscape. This study shows the importance of heterogeneous landscapes for bumblebees. Flower-rich landscape elements need to be considered in conservation plans to preserve bumblebee species in heterogeneous landscapes.

Keywords: *Bombus*, conservation, heterogeneous landscape, interannual variation, plant preference, semi-natural grassland, species richness

2 Introduction

During the latter half of the twentieth century, the abundance and species richness of bumblebees have declined in Europe (Bäckman & Tiainen. 2002, Pywell et al. 2005) and North America (Goulson et al. 2002). In Europe, about 60 bumblebee species are found and 80 % of them are threatened in some way (Kosior et al. 2007). Nowadays, only six species are commonly seen in the UK (Carvell 2002, Carvell et al. 2004, Croxton et al. 2002), compared to 25 some decades ago (Benton 2006). This decline is alarming since the majority of the bumblebees are important pollinators and they are more effective compared to other bees because they are able to forage early in the morning, late in the evening and during bad weather (Benton 2006). Bumblebees pollinate both wild-flowers and crops and that makes them valuable both ecologically and economically (Allen-Wardell et al. 1998). Several plants are predominantly pollinated by bumblebees and sometimes of certain species (Goulson 2003). They are especially efficient pollinators of plants with deep corolla tube (Teräs 1985). If these services disappear, it may affect other organisms as well (Goulson 2003).

Bumblebees need continuous supply of nectar and pollen during the entire colony cycle (Alford 1975). Flower-rich patches in connection to the nests are therefore necessary to maintain bumblebee diversity. The foraging range differs between species; some are reported having forage distances up to 1750 m (Walther-Hellwig & Frankl 2000) and other as low as 250 m (Saville et al. 1997). Abandoned nests of small mammals are often used for nesting and they have to be located in undisturbed patches (Svensson et al. 2000). The amount of suitable habitats for bumblebees has declined due to the intensification of agricultural practices leading to habitat destruction and fragmentation (Stoate et al. 2001), and also the use of pesticides (Thompson & Hunt 1999). One of the most important effects of the agricultural intensification is the loss of semi-natural grasslands, 90% has been lost in the U.K. between 1932 and 1984 (Fuller 1987, Robinson & Sutherland 2002). The same process has occurred also in Sweden. During the last 60 years, semi-natural grasslands have declined severely in Sweden and in most landscapes only fragments remaining. The causes are, for example, abandonment and conversion to forest, plantation of coniferous forest and increasing field sizes, and this is expected to have effects on the flora and fauna (Ihse 1995), including the bumblebees. In Sweden, 40 bumblebee species are found and six of them are on the Swedish red list (Gärdenfors 2005). The changes in land use have resulted in strikingly different landscapes in different parts of Sweden. In the more fertile, agriculturally-dominated areas, fields have become larger and semi-natural patches have to a large extent disappeared. In more forested areas where small-scale farming were dominating, coniferous forests has become dominating since many of the small farms has been abandoned resulting in a large loss of semi-natural grasslands.

The aim of the study was to describe plant utilisation, landscape element utilisation and phenology of bumblebees in three landscapes with different amount of semi-natural grasslands, forests and arable fields. The stability in landscape element utilisation between years was investigated in one of the landscapes. Differences in bumblebee abundance and species richness were examined as well.

3 Materials and methods

3.1 Study period and area

The study was performed during the summer of 2006 in three landscapes with different amount of semi-natural grasslands, forests and arable fields (Table 1). The landscapes Sturefors (heterogeneous landscape), Bjälbo (agricultural landscape) and Bjäsätter (forested landscape), are all located in the county of Östergötland, south eastern Sweden (Table 1).

Table 1. Amount of semi-natural grasslands, arable fields, forests and remaining vegetation within 4 km^2 in each landscape,

Vegetation type (%)	Heterogeneous landscape	Agricultural landscape	Forested landscape
Semi-natural grasslands	28	7	14
Arable fields	22	83	21
Forest	38	6	57
Remaining vegetation	12	4	8

Within each landscape, six different types of landscape elements were identified: semi-natural grassland, ley, uncropped field verge, wood verge and two kinds of road verges. The road verges were along smaller gravel roads and larger asphalt roads. Suitable semi-natural grasslands large enough to use in this study were not present in the agricultural landscape and grasslands that had been more or less fertilised were chosen instead (called semi-natural grasslands in this study). Each landscape element had three replicates, which gave a total of 18 sites in each landscape. The sites were located within an area of ca 4 km^2. The sites in the heterogeneous landscape were visited 15 times during the season. The sites in the agricultural- and forested landscape was visited five times each.

3.2 Bumblebee recording

The study was conducted from the 12th of June to the 13th of September. Bumblebees were monitored between 08.00 and 17.00 (Swedish summer time), when the temperature was >17^{o}C and when the wind speed were less than five according to the Beaufort scale.

Bumblebees (*Bombus*) were recorded using a line transect method described by Banaszak (1980). This method has been used in several other studies of bees (Mänd et al. 2002, Svensson et al. 2000). The transects were 400 m and were walked in a steady pace during 16 minutes. Bumblebees belonging to all castes and sexes (queens, males and workers) that were one meter forward or one meter to the sides were recorded and identified to species using their colouring. If the bumblebees were caught to be identified, the survey was paused and during that time no other bumblebees were recorded. Individuals that could not be identified in field were caught and analysed later. The activity of the bumblebees was recorded as feeding (collecting nectar or pollen) or flying. If they were feeding, the plant species was noted. The sites in the heterogeneous landscape were visited at least once a week. In the agricultural- and forested landscapes seven of the 18 sites were visited each week following a scheme. The reason why the sites were visited more frequently in Sturefors was that these data should be used to evaluate the variation in landscape element utilisation between years.

The sites were visited following a scheme where the sites were visited at different times of the day, to avoid possible bias due to within-day variation.

The nomenclature of the *Bombus* species followed Alford (1975). *Bombus terrestris* and *Bombus lucorum* are difficult to distinguish in the field and were therefore treated as *B. terrestris/lucorum* following Carvell et al. (2004).

The bumblebees were classified as either long-tongued or short-tongued according to the length of the proboscis (Benton 2006) (Appendix 1).

3.3 Nectar sources

To estimate the amount of forage resource available in different landscape elements at different times, the frequency of inflorescences was recorded as described by Jansson (2004). After each transect walk, a 0.2 m^2 square was placed every 20^{th} meter along the transect. Within the square, the number inflorescences of the flowering plants were recorded. They were quantified into three categories of inflorescence richness, 1: 1-5 inflorescences, 2: 6-15 inflorescences and 3: >15 inflorescences. The nomenclature of the plants followed Karlsson (1998).

3.4 Variation between years

The same sites at the heterogeneous landscape had been sampled, with identical methods during the summer of 2005 (Jansson 2006). These data were compared with the data from Sturefors in this study to evaluate the stability in landscape element utilisation between years.

3.5 Data analyses

Calculations and analyses of phenology, plant utilization and variation between years were carried out using STATISTICA 7 (Statsoft Inc. 2004). Multivariate analyses were made with Canoco for Windows 4.5 (ter Braak

& Smilauer 2002). When data from the three landscapes were compared, the data from the heterogeneous landscape was adjusted to comparable sample size by elimination.

Some of the bumblebee species were not abundant enough for statistical analyses. Totally eight species was included in the analyses in the heterogeneous landscape, six species in the forested landscape and five in the agricultural landscape. Differences in species richness and bumblebee abundance between landscapes and between landscape elements were made using General Linear Model (GLM).

The distribution of bumblebee species in relation to landscape elements was analysed in Principal components analyses (PCA). The square root transformed data were summed for each landscape. The transform was made to avoid abundant species to have bigger influence on the PCA outcome.

Differences in habitat utilization among species were evaluated using a Generalized Linear Model (GLZ) with Poisson distribution and log link function.

4 Results

A total of 1911 bumblebees belonging to 18 species were recorded during this study. Of these, 1089 bumblebees belonging to 17 species were recorded in the heterogeneous landscape (389 belonging to 14 species when adjusted to comparable sample size to the other landscapes), 414 bumblebees belonging to 10 species in the agricultural landscape and in the forested landscape 408 bumblebees belonging to 10 species. The most common species was *B. pascuorum* that accounted for more than one quarter of the observations.

4.1 Landscapes and landscape elements

The GLM showed no significant differences in species richness (P=0.10, $F_{(2,46)}$=2.40) and bumblebee abundance (P=0.97, $F_{(2,46)}$=0.03) between the landscapes (data from Sturefors had been adjusted to comparable sample size). There was significant differences in species richness between landscape elements when all sites were compared together (P=0.0075, $F_{(5,46)}$=3.63) but not in bumblebee abundance (P=0.5472, $F_{(5,46)}$=0.81).

4.1.1 Bumblebee species in relation to landscape elements

The number of individual bumblebee species recorded varied significantly between the landscape elements when the landscapes were analysed separately (Table 2). The highest amounts of both bumblebees and bumblebee species in the heterogeneous landscape were recorded in the semi-natural grasslands, wood verges and field verges and these patterns were the same for both long- and short-tongued species (Table 2). In the agricultural landscape, field verges were harbouring most individuals followed by semi-natural grasslands and gravel road verges. The long-tongued species were most frequent in the semi-natural grasslands, field verges and wood verges while the short-tongued were most abundant in gravel road verges and field verges. In the forested landscape, both short- and long-tongued species were most frequent in the leys (Table 2).

4.1.2 Landscape element utilisation

When evaluating species composition in the PCA semi-natural grassland and wood verges were the landscape elements where most of the bumblebee species were found in the heterogeneous landscape (data from the heterogeneous landscape had been adjusted to comparable sample size) (Figure 1a). In the agricultural landscape, semi-natural grasslands were important as well, together with field verges (Figure 1b). In the forested landscape, the leys clearly were the most visited by the majority of bumblebees (Figure 1c).

Table 2. The mean number of bumblebees per 10 km transect, summed over the season, in the heterogeneous landscape (S) (all visits), the agricultural landscape (BB) and the forested landscape (BS). P-values and Wald statistic from Generalized linear model with Poisson distribution and log link function (not possible to conduct for all species when there were too many zeros in some of the landscape elements).

Species (N)	Land-scape	Asphalt road Verge	Gravel road Verge	Semi-Natural grassland	Wood verge	Ley	Field verge	Wald	P
B. pascuorum									
(340)	S	62	103	155	132	35	80	57.5	0.0000
(56)	BB	45	5	85	130	0	15	-	-
(109)	BS	75	75	90	25	185	95	26.2	0.0001
B. lapidarus									
(90)	S	10	10	85	18	12	15	77.8	0.0000
(24)	BB	20	60	15	5	5	15	15.7	0.0078
(51)	BS	15	85	45	10	100	0	19.6	0.0015
B. ruderarius									
(127)	S	5	2	133	23	5	43	111.7	0.0000
(76)	BB	15	40	190	60	0	75	-	-
(15)	BS	-	-	-	-	-	-	-	-
B. sylvarum									
(112)	S	48	13	32	5	37	52	26.3	0.0001
(109)	BB	110	70	115	25	10	215	43.5	0.0000
(50)	BS	45	45	45	0	55	60	0.31	0.9973
B. hortorum									
(103)	S	27	23	32	58	0	32	-	-
(6)	BB	-	-	-	-		-	-	-
(42)	BS	10	60	10	20	80	30	18.9	0.0020
B. soroeensis									
(47)	S	7	7	25	35	0	5	-	-
(0)	BB	-	-	-	-	-	-	-	-
(78)	BS	15	35	15	25	290	10	102.6	0.0000
B. pratorum									
(26)	S	10	7	12	7	0	8	-	-
(5)	BB	-	-	-	-	-	-	-	-
(4)	BS	-	-	-	-	-	-	-	-
B. terrestris/lucorum									
(155)	S	37	27	63	70	20	42	25.7	0.0001
(116)	BB	70	180	35	30	105	160	35.1	0.0000
(42)	BS	5	5	15	25	150	10	51.0	0.0000
Short-tongued species									
(339)	S	70	53	195	138	35	73	102.8	0.0000
(153)	BB	95	255	55	45	110	205	48.5	0.0000
(176)	BS	70	125	80	80	545	30	169.4	0.0000
Long-tongued species									
(686)	S	142	142	357	218	77	208	133.3	0.0000
(248)	BB	170	120	390	215	15	330	63.0	0.0000
(217)	BS	135	200	175	45	325	205	40.1	0.0000
Total no. of bumblebees									
(1089)	S	230	207	577	372	113	317	233.2	0.0000
(414)	BB	270	375	470	260	125	570	67.7	0.0000
(408)	BS	205	335	255	140	870	235	179.1	0.0000
Total no. of species									
(17)	S	1.9	1.6	3.3	2.4	0.8	2.4	7.91	0.1611
(10)	BB	1.7	0.9	2.6	1.2	0.4	2.9	14.2	0.0143
(10)	BS	1.8	2.5	2.1	1.1	2.7	1.5	2.14	0.8290

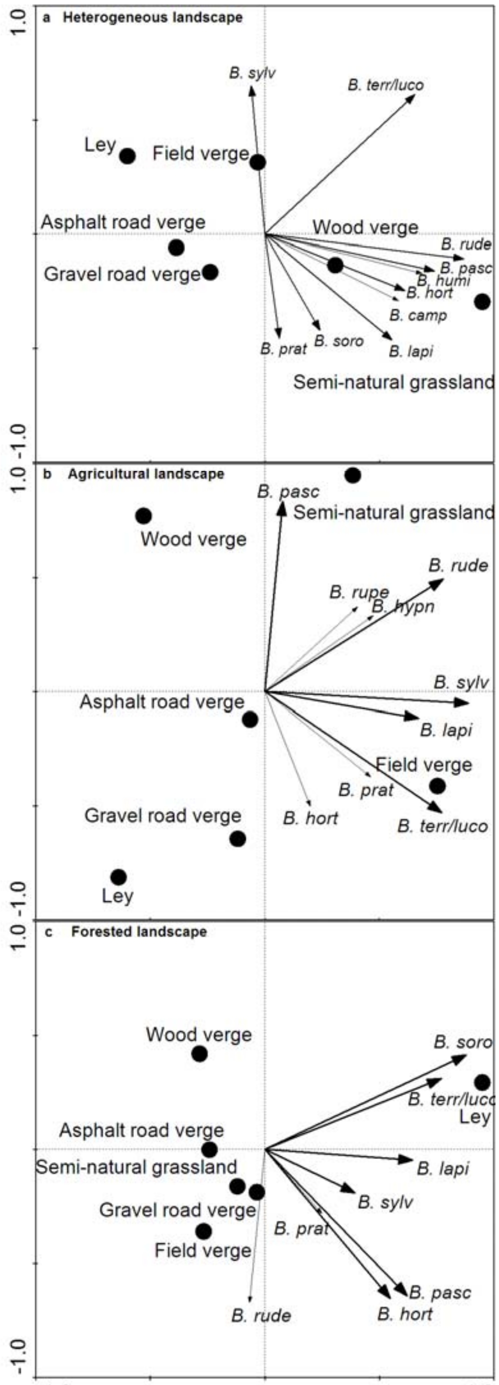

Figure 1. Principal component analyses with the first two components plotted. Species that had >20 recordings have thick arrows and species with <20 recordings have thin arrows. Separate analyses were conducted for: (a) the heterogeneous landscape (data adjusted to comparable sample size), eigenvalue first axis: 0.342, second axis: 0.179, (b) the agricultural landscape, eigenvalue first axis: 0.464, second axis: 0.247 and (c) the forested landscape, eigenvalue first axis: 0.413, second axis: 0.194.

4.2 Flower patterns and preferences

Of the 88 plant species recorded, 34 were observed in all three landscapes (Table 3). Seventeen plant species were utilised in all landscapes, and these plant species accounted for 842 bumblebee visits, 79% of the total amount of the flower visits.

Table 3. The number of plant species (N) available and used by bumblebees per landscape (the data from the heterogeneous landscape was adjusted to comparable sample size) and all landscapes combined. The number of bumblebee visits to flowers in each landscape and to those common to all landscapes (Nv).

Landscape	Available (N)	Used (N)	Flower visits (Nv)
Heterogeneous landscape	65	37	305
Forested landscape	56	26	388
Agricultural landscape	60	27	370
Data for plants that were present at all three landscapes	34	17	842
Total	88	46	1063

The plant utilization differed between bumblebee species and between landscapes (Table 4). In all landscapes, plant species belonging to *Fabaceae* and especially *Trifolium* had many visits. In the heterogeneous landscape, *Trifolium medium*, *Trifolium pratense*, *Leontondon autumnalis* and *Centaurea jacea* had most visits; in the forested landscape *T. pratense* and *T. repens* and in the agricultural landscape *T. pratense*, *Centaurea scabiosa*, *Rubus caesius* and *Cirsium vulgare* (Table 4).

Long-tongued species paid most visits to *Trifolium* in all landscapes, but in the agricultural landscape *Asteraceae* and *Rosaceae* had a high percentage of visits as well. Short-tongued bumblebees preferred *Asteraceae* in the heterogeneous- and agricultural landscapes while they preferred *Trifolium* in the forested landscape.

A number of plant species were utilised by single bumblebee species or in only one of the landscapes. In the heterogeneous landscape, *B. soroeensis* almost only paid visits to *Campanula* species and in the agricultural landscape, *C. scabiosa* and *R caesius* had a large amount of visits from a number of species (Table 4)

Table 4. The percentage of the total amount of visits for the bumblebee species in Sturefors (S)(all visits), Bjälbo (BB) and Bjäsätter (BS). The two most visited plant species for the bumblebee species in each landscape are shown.

Plant species (% of total visits) SS(%) BB (%) BJ (%)	Land- scape	*B. pasc* N=312 N=53 N=100	*B. lapi* N=79 N=21 N=46	*B. rude* N=112 N=51 N=15	*B. sylv* N=102 N=105 N=44	*B. hort* N=97 N=6 N=41	*B. soro* N=45 N=0 N=75	*B. prat* N=24 N=5 N=4	*B. terr /luco* N=138 N=109 N=41	Total N=909 N=370 N=387	Short- tongued N=226 N=135 N=166	Long- tongued N=623 N=215 N=200
T. pratense (12)	S	20	3	4	30	12		4	3	12	2	17
(13)	BB	15	10	12	8				19	13	16	10
(38)	BS	70	22		55	56	12		15	38	15	61
T. medium (16)	S	19	8	10	10	63	2		3	16	4	22
(0)	BB											
(6)	BS	5			5	27				6		11
L. autumnalis (12)	S	6	37	21	10		4	4	18	12	20	8
(1)	BB				1				1	1	1	
(3)	BS		15		2				2	3	5	1
C. jacea (8)	S	4	15	25	5	1	11	21	3	8	9	8
(0)	BB											
(0)	BS											
C. rotundifolia (1)	S						22			1	4	
(0)	BB											
(1)	BS						4			1	2	
C .persicifolia (1)	S						22			1	4	
(0)	BB											
(0)	BS											
S. tinctoria (5)	S	5	3	9	4		2	21	1	5	4	5
(7)	BB	8		22	2				4	7	3	8
(0)	BS											
H. sphondylium (4)	S						4		20	4	10	
(0)	BB											
(0)	BS											
M. pratense (1)	S	1				1				1		1
(5)	BB	32			2				1	5	1	9
(0)	BS											
C. scabiosa (0)	S											
(24)	BB		43	29	17				37	24	39	15
(0)	BS											
G. tetrahit (0)	S											
(6)	BB	2		4	17					6		11
(0)	BS											
R. caesius (0)	S											
(15)	BB	4	10	12	16				20	15	18	12
(0)	BS											
C. vulgare (0)	S											
(8)	BB		10	6	10				9	8	10	7
(0)	BS											
T. repens (4)	S	5	8	3	2	2		8	7	4	6	4
(2)	BB	11	5		1					2	1	4
(31)	BS	9	46		9	10	72		54	31	59	10
T. hybridum (1)	S	1		3	3	2				1		2
(0)	BB											
(4)	BS				10	7	3		12	4	4	4

4.3 Phenology

The largest amount of bumblebees was recorded at the agricultural- and heterogeneous landscape (data adjusted to comparable sample size) during August while the peak at the forested landscape came a few weeks earlier (Figure 2a). In all landscapes, the number of bumblebees increased slightly during the first part of the season and then decreased.

The peak of bumblebee species coincided at the forested- and heterogeneous landscape (Figure 2b). This was the same time as the peak in bumblebee abundance in the forested landscape but earlier than the heterogeneous landscape. In the agricultural landscape, no clear peak in species richness could be seen, only a slow decrease over the study period.

Even though there were no significant differences in bumblebee species richness, the mean number of observed species was higher in Sturefors over the entire season (Figure 2b).

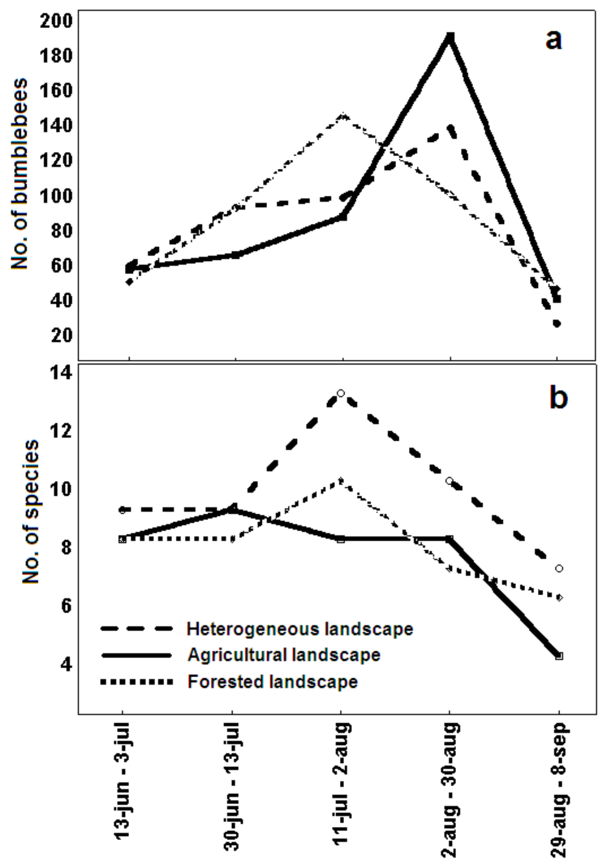

Figure 2. Trend lines (fitted according to lowess with the stiffness 0) over the change in a) total number of bumblebees (data from Sturefors adjusted to comparable sample size) and b) total number of bumblebee species over the season 2006 (data from the heterogeneous landscape adjusted to comparable sample size).

4.4 Variation between years

In the season of 2005, 1053 bumblebees belonging to 17 species were recorded in the heterogeneous landscape (Jansson 2006). The number of bumblebees in 2006 was 1089 belonging to 16 species. Fourteen of the species were recorded both years. The variation in the total bumblebee abundance and number of species between the years of 2005 and 2006 was relatively small (Figure 3). In general the abundance of individuals and species in the landscape elements were lower in the beginning of the season in 2006. Semi-natural grassland and wood verges had the most equal patterns in both species richness and bumblebee abundance during the years. Field verges and leys had the same patterns during parts of the season, but varied greatly in others. Gravel road verges and asphalt road verges showed the greatest variation between the seasons.

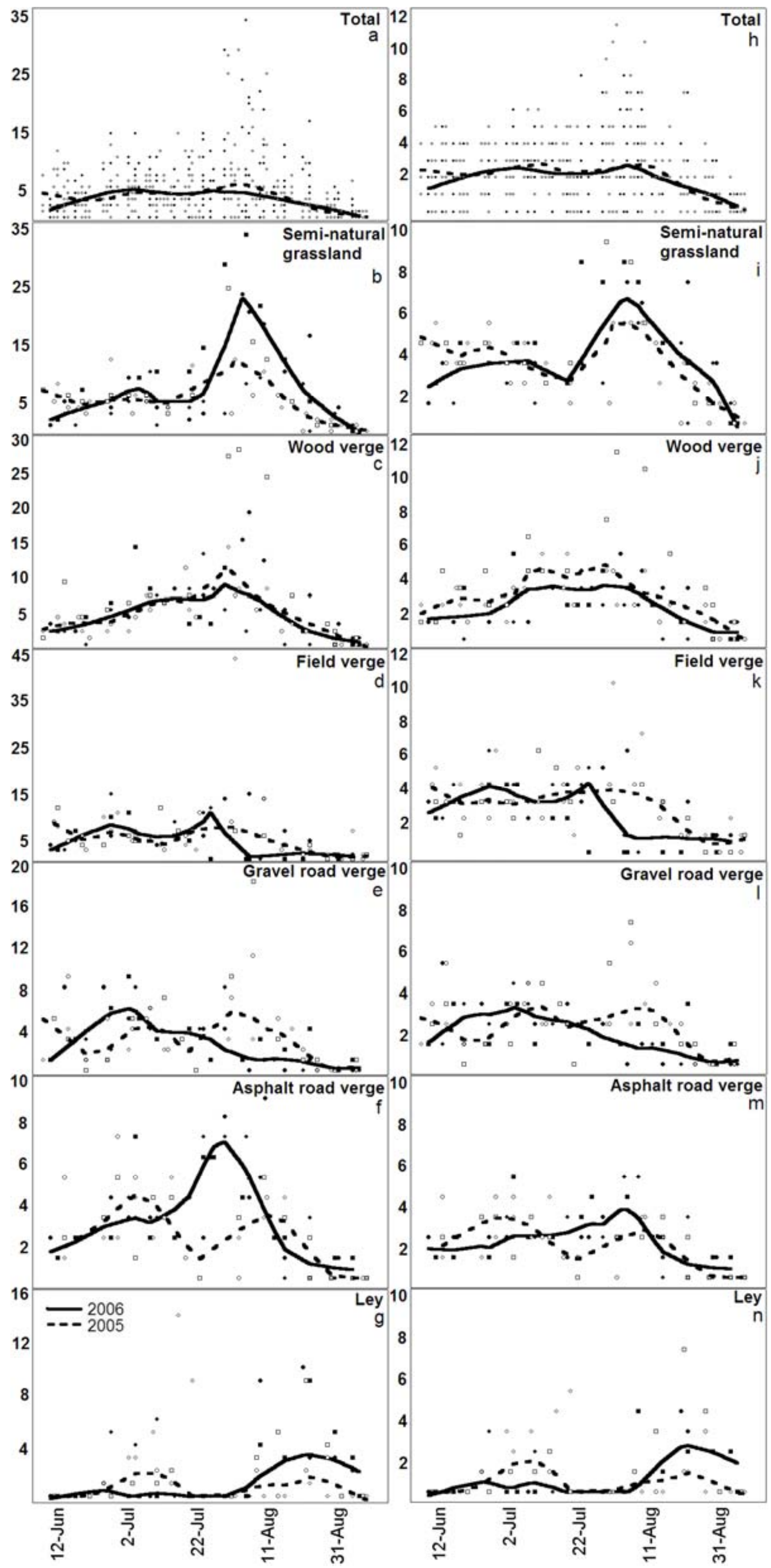

Figure 3. The amount of bumblebees (left column) and number of species (right column) recorded during the seasons 2005 and 2006.The trend lines were fitted according to Lowess with the stiffness 0.25.

5 Discussion

5.1 Landscape element utilisation and plant utilisation

The number of bumblebee species found in all landscapes was considerably higher than found in many studies in Western Europe (Benton 2006, Carvell et al. 2004, Westphal et al. 2006, Kleijn & van Langevelde 2006). In this study 14 spp were found in the heterogeneous landscape, 10 spp. in the agricultural landscape and 10 spp in the forested landscape (differences were not significant; P=0.1). The species that were missing in the latter landscapes are to some extent also declining in Europe. Examples are *Bombus humilis, B. soroeensis* and *B. ruderarius* that have disappeared from most of their range in e.g. the U.K. (Goulson 2003). *Bombus soroeensis*, which were missing in the agricultural landscape, is known to be connected to forest (Teräs 1985, Benton 2006), and these landscape elements were not very abundant in this landscape. *Bombus pratorum* were only found frequently in the heterogeneous landscape. This species seems to be less capable of surviving in agricultural areas (Benton 2006), explaining the scarcity in the agricultural landscape. The low frequency in the forested landscape was most likely the effect of low number of flowers belonging to *Asteraceae*, which they favour (Alford 1975).

The amount and spatial configuration of preferred landscape elements is likely to be important for bumblebees. Forest edges and semi-natural grasslands serve as places for hibernation, nests and they are also major foraging habitats (Svensson et al. 2000). Reduction and fragmentation of these may have serious impacts on the bumblebee abundance and species richness (Stoate et al. 2001). Semi-natural grasslands were also the landscape element harbouring most species when all landscapes were analysed together (P=0.0075). Semi-natural grasslands and wood verges harboured most bumblebees in the heterogeneous landscape, field verges and semi-natural grasslands in the agricultural and leys in the forested landscape

Even though field verges were important floral patches in the agricultural landscape and leys in the forested landscape, they may not be suitable places for nesting. Leys are disturbed by haying and field verges by cutting machinery and the use of herbicides in the nearby fields. Since at least some bumblebees are known foraging relatively near their nests (Saville et al. 1997), the distribution and amount of landscape elements as semi-natural grasslands and wood verges are likely to be important. These landscape elements harbouring rocks, burrows and corners where nests can be established. Morandin et al. (2007) showed that the amount of bumblebees as well as other bees in fields increased when 15% of pastureland was within 800 m of field edges and Öckinger & Smith (2007) found that bumblebee abundance and species richness in linear habitat elements in agricultural areas is higher in the presence of semi-natural grasslands. The high abundance of bumblebees in the flower-rich leys in Bjäsätter is supported by Walther-Helwig & Frankl (2000), who found "super abundant" resources to entice bumblebees to fly longer distances, in particular *B. terrestris/lucorum*.

Almost all species were recorded in all landscape elements. This is supported by Goulson et al. (2006) and Teräs (1985), and point out that all landscape elements had some importance for the bumblebees. They seem to utilise patches where food plants are abundant, and these patches might switch throughout the season. However, some species as *B. sylvarum* in Sturefors, seemed more frequently in a certain landscape element (field verges) compared to the other species (Figure 1a).

In this study, 17 plant species used in all landscapes accounted for 79% of the flower visits. The number of visits to and the abundance of these plant species varied greatly between the landscapes but plant species belonging to *Fabaceae* and especially *Trifolium* species were visited to high extent as in Goulson & Darvill (2004) and Goulson et al. (2005). In the forested landscape, *Trifolium* species accounted for 75% of the flower visits, in the heterogeneous landscape 32% and in the agricultural landscape 15%. Long-tongued species were most frequently recorded on *Fabaceae* in the heterogeneous and the forested landscapes but in the agricultural landscape, where these flowers were not as abundant, they seemed to visit flowers like *C. scabiosa* to a higher extent. Short-tongued bumblebees were mostly recorded on flowers as *T. repens* and *L. autumnalis* that have short corolla tubes. However, short-tongued species, especially *B. terrestris/lucorum* and *B. lapidarius*, paid visits to *T. pratense* to some extent in all landscapes. Both these bumblebee species are known to rob nectar from plant species with long corolla tubes, and nectar robbing is most common among short-tongued species (Alford 1975; Stout et al. 2000; Teräs 1985).

The leys were the landscape element that differed most in preference between the landscapes. Most of the difference seems to be due to the incidence of two plant species, *T. pratense* and *T. repens.* The leys in the forested landscape were rich in these plant species and had a high frequency of bumblebees the whole season since the leys were not cut simultaneously. In the heterogeneous landscape, the hot weather and low precipitation caused low flowering in the leys until the end of the season when flowering of *T. pratense* become more frequent and the resource then were used by the remaining bumblebees. Only one of the leys that were surveyed in the agricultural landscape contained *T. pratense*, and this ley was the only ley really used by the bumblebees when flowering.

Few individuals of the long-tongued *B. hortorum* were recorded in the agricultural landscape and the reason may be the lower amount of *Trifolium* plant species. It has been proposed that some bumblebee species have specialized diets and especially so long-tongued species (Goulson et al. 2005). The long-tongued species, *B. ruderarius* and *B sylvarum,* have decreased dramatically in the UK, probably as a result of changing agricultural practises (Goulson et al. 2006). These species are still abundant in the agricultural landscape of Bjälbo, but if the intensification continuous, they may become rare in southern Sweden as well.

Even though *Fabaceae* had most visits, plants belonging to *Asteraceae* were visited to high extent in the heterogeneous and agricultural landscapes*. Centaurea jacea, C, scabiosa, S. tinctoria* and *C. vulgare* received more visits per inflorescence than those belonging to *Fabaceae* in these landscapes. This point out that plant species that are not very abundant may be important for bumblebees and especially certain species. Some of these plant species seemed to be particularly important for bumblebees in the later part of the season.

5.2 Phenology

The peak in bumblebee abundance occurred in August in the heterogeneous and the agricultural landscapes and in July in the forested landscape. Directly after the peak, the number of bumblebees decreased until the end of the season when only a few individuals were observed. The peak in bumblebee abundance takes place when the reproductive individuals emerge and the decline occurs soon after, when the workers start to decrease (De La Hoz 2006).

The earlier abundance peak in the forested landscape was most likely caused by lower amount of late flowering plant species as *S. tinctoria, C. jacea* and *C. scabiosa*. These flowers accounted for a large amount of visits in both the agricultural and heterogeneous landscapes. In landscapes with few resource-rich patches like the agricultural landscape, the result may be a more pronounced peak or a missed peak, due to increased risk for sampling error compared to the heterogeneous landscape that had many resources scattered throughout the landscape. In the forested landscape and the heterogeneous landscape, the later part of July was the most species-rich period. This is the period when one is most likely to observe a majority of the bumblebee species. The seasonal patterns of bumblebee species in the UK have been examined by (Alford 1975 and Benton 2006). In the

U.K., *B. pascuorum* and *B. terrestris/lucorum* may be observed frequently from May to September. *Bombus sylvarum, B. ruderarius* and *B. soroeensis* are most abundant from late July until early August and *B. hortorum* and *B. pratorum* in the first part of July.

In this study *B. pascuorum* were numerous over the whole season, *B. hortorum* were most abundant in July and *B. ruderarius*, *B. sylvarum* and *B. terrestris/lucorum* in August. *Bombus soroeensis* were most frequent earlier than expected in the forested landscape, this probably because of the lack of late flowering plant species. In the agricultural landscape no peak in species richness could be seen, only a slightly decrease during the season (Figure 2).

5.3 Stability in landscape element utilisation between years

Differences might occur in species composition, abundance as well as in the temporal patterns within a season (Wiens 1981). In the present study, the heterogeneous landscape had been sampled, with identical methodology, during two consecutive years. The most evident differences between the years were the weather impacts and the timing of management of road verges, leys and wood verges. The summer of 2006 was very hot with little precipitation causing drought in some of the sites while the summer of 2005 had more precipitation.

The interannual stability was most evident in semi-natural grasslands and wood verges making “key habitats” for bumblebees (Kozakiewicz 1995). Landscape elements like these are heterogeneous and undisturbed, and offer resources continuously every year even though the weather impacts as temperature and precipitation vary. Leys and road verges might be flower-rich at periods of the season, but when they are cut all resources disappear immediately.

Some of the variation in the leys and field verges between these seasons were most likely the consequence of the warm and dry summer 2006. There was almost no growth in the leys during June and July and that ended up with very few flowering plants until the end of the season. The field verges had roughly the same pattern during half the seasons. The fall of both bumblebee abundance and diversity in the field verges in the middle of the season of 2006 was a consequence of the warm and dry weather which made plants withers (Figure 3 d, k).

5.4 Conservation implications

This study showed the importance of a heterogeneous landscape with flower-rich patches for bumblebees, in particular semi-natural grasslands and wood verges. Due to serious fragmentation in the intensive agricultural landscapes, conservation efforts should be directed to preserve semi-natural grasslands and wooded edges and other flower-rich landscape elements. Even small patches of flower-rich undisturbed habitats are valuable to protect since more bumblebee species are found when distances between landscape elements are short (Morandin et al. 2007, Öckinger & Smith 2007), as in the heterogeneous landscape.

Timing and management of road verges and leys should also be considered. These landscape elements contain plants that are preferred by bumblebees and should be managed in a manner so that all plants do not disappear immediately when they are cut. It is not only the plants that disappear when they are cut, surface nest building species might also have their nest destroyed (Benton 2006). These landscape elements should be cut in a way that allows flowering during the entire season, and at least some areas should be left undisturbed for nests to survive.

More leys containing *T. pratense* should provide bumblebees, and in particular long-tongued species, with an important resource in agricultural areas. Long-tongued species are reported to decline in Europe (Goulson et al. 2005), raising the importance of conservation efforts for those species.

6 Acknowledgements

I would like to thank my supervisors Karl-Olof Bergman and Per Milberg for all support. I would also like to thank Björn Cederberg for help with species identification and all farmers involved for allowing access to their land.

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Appendix

Appendix 1. The number of bumblebees for each species that were observed in the heterogeneous landscape (all visits), the agricultural landscape, the forested landscape and in all landscapes together. L = long-tongued species. S = short-tongued species

Bumblebee species	Tongue-length	Abbreviation	Hetero-geneous landscape	Agricult-ural landscape	Forested landscape	All landscapes
Bombus pascuorum	L	*B. pasc*	340	56	109	505
Bombus humilis	L	*B. humi*	4	-	-	4
Bombus muscorum	L	*B. musc*	-	4	-	4
Bombus hypnorum	S	*B. hypn*	21	8	-	29
Bombus rupestris	S	*B. rupe*	2	9	-	11
Bombus lapidarius	S	*B. lapi*	89	24	51	164
Bombus ruderarius	L	*B. rude*	127	76	16	219
Bombus sylvarum	L	*B. sylv*	111	109	50	270
Bombus distinguendus	L	*B. dist*	5	-	-	5
Bombus hortorum	L	*B. hort*	102	7	42	151
Bombus jonellus	S	*B. jone*	2	-	-	2
Bombus barbutellus	S	*B. barb*	35	-	5	40
Bombus camperstris	S	*B. camp*	4	-	-	4
Bombus terrestris/lucorum	S	*B. terr/luco*	155	116	42	313
Bombus soroeensis	S	*B. soro*	47	-	78	125
Bombus pratorum	S	*B. prat*	26	5	5	36
Bombus bohemicus	S	*B. bohe*	16	-	10	26
Bombus sylvestris	S	*B. sylve*	3	-	-	3
Total no. of bumblebees			1089	414	408	1911
Total no. of species			17	10	10	18