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ORIGINAL PAPER

Butterflies and bumblebees in greenways and sown wildflower strips in southern Sweden

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Abstract Greenways have recently been established in some intensively farmed areas of South Sweden in order to enhance recreation opportunities and biodiversity, but the effects of these green structures on biodiversity have not yet been determined. In this study, greenways and experimental sown wildflower strips were investigated for butterfly and bumblebee diversity. In total, 1,769 butterflies of 18 species and 1,216 foraging bumblebees of eight species were recorded. Sown wildflower strips proved to support much higher abundances and species numbers of butterflies and bumblebees than greenways, with 86% of all butterflies and 83% of all bumblebees being observed in the sown flower strips. However, in both types of green structure mostly common species were found. Counts of flower visits showed that *Knautia*, *Centaurea* and *Cirsium* were the most commonly visited plant species. The greenways studied did not seem to fulfil their function of enhancing biodiversity—at least not for butterflies and bumblebees. However, these greenways could easily be improved for common bumblebee and butterfly species by sowing wildflower strips along their margins.

Keywords Agri-environmental schemes · Enhancing biodiversity · Intensive agriculture · Green structure · Peri-urban

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Introduction

In many European countries there are now a variety of agri-environmental schemes to preserve and enhance biodiversity in field margins. In Sweden, however, a scheme for non-cropped field margins was only initiated very recently and is basically a compensation payment for not applying fertiliser, herbicides or pesticides in field margins (Government Offices of Sweden 2007). There are still no schemes to encourage farmers to establish sown wildflower strips. Such strips are usually sown with seed mixtures of wild flowers along field boundaries on arable land and have been introduced as agri-environmental measures in several European countries to enhance biodiversity (Aviron et al. 2007, Carvell et al. 2007, Woodcock et al. 2008). The impoverishment of biodiversity due to intensive agriculture has also become a severe problem in Sweden (e.g. Ockinger and Smith 2007; Rundlof and Smith 2006; Wretenberg et al. 2007). The landscape changes that have been caused by rationalisation and intensification of agriculture have simultaneously led to reduced accessibility for recreation (walking, horse riding) due to removal of farm tracks and boundaries (Hojring 2002). To improve recreational possibilities and also enhance biodiversity in peri-urban areas, several municipalities in the southernmost province of Sweden, Scania (*Skåne*), have started to establish greenways. These greenways, (in Swedish *beträdor*) are established on arable land by sowing a mixture of grass species and are managed (which basically means cut several times a year) by farmers. Farmers are not yet entitled to agricultural subsidies for this type of greenway and therefore the municipalities have made special agreements with these farmers to compensate them financially for loss of income and management costs.

Although the establishment of greenways in Sweden is comparatively expensive due to the high costs of leasing land, there have been very few, if any, studies in Sweden on the effects of these greenways on biodiversity or recreation. This study was therefore performed to investigate whether the greenways are fulfilling their function of enhancing biodiversity in the intensive agricultural region of south-west Sweden. The two species groups chosen for this study were butterflies and bumblebees, which have shown a considerable decline in agricultural areas and are known to be sensitive indicators of the habitat quality of grassland biotopes (e.g. Carvell et al. 2006; Van Swaay et al. 2006).

A number of studies have been carried out on the species richness of butterflies and bumblebees in field margins, including the role of plant diversity on insect abundance. The majority of these studies have been carried out in unsown field margins (Backman and Tiainen 2002; Croxton et al. 2002; Dover et al. 2000; Dramstad and Fry 1995; Feber et al. 2007; Kells et al. 2001; Kuussaari et al. 2007; Meek et al. 2002; Ockinger and Smith 2007). However, some studies have investigated butterflies (Aviron et al. 2007; Feber et al. 1996) and bumblebees (Carvell et al. 2004; Critchley et al. 2006; Pywell et al. 2005; Pywell et al. 2006) in sown wildflower strips. Pywell et al. (2006) concluded that the most effective way to improve habitat quality for bumblebees in intensively managed farmland is sowing simple mixtures of pollen- and nectar-rich plants, as a cheaper and better solution than wildflower mixtures. Margins with pollen- and nectar-rich plants consisted in this study of at least four nectar rich dicots (e.g. *Trifolium* species, *Lotus corniculatus*, *Medicago lupulina*) and four grasses. The wildflower strips could include other plant species as well as for example *Leucanthemum vulgare* and *Achillea millefolium*. Sown grass margins are better than normally cropped margins and have more butterfly and bumblebee species (Critchley et al. 2006). Carvell et al. (2004) found that wildflower seed mixtures combined with grassy species can distinctly improve habitat quality for bumblebees. Naturally regenerated field margins can be of great value for bumblebees due to their nectar supply through *Cirsium* spp., but with ongoing succession and disappearance of *Cirsium* the value of these margins for bumblebees decreases again (Carvell et al. 2004). Feber et al. (1996) studied different field margins in relation to butterfly species numbers and abundance. Margins sown with a mixture of wildflower and grass seeds attracted more butterfly numbers and butterfly species than unsown margins. Aviron et al. (2007) compared butterfly diversity and abundance between wildflower strips, conventional grassland and wheat fields and found both diversity and abundance to be higher on average in wildflower strips than in the other two habitats.

The aim of this study was to investigate the species richness and abundance of butterflies and bumblebees in greenways. In addition, sown wildflower strips were studied to explore potential possibilities to improve biodiversity in intensively used agricultural areas by this measure. Since there are currently no agri-environmental schemes for sown wildflower strips in Sweden, the study had to be confined to experimental strips established on arable land around the campus of the Swedish University of Agricultural Sciences (SLU) at Alnarp. A secondary aim of the study was to identify factors influencing species diversity and abundance in the two types of green structures studied.

Methods

Study area

The study was carried out at four different sites all located in the area around Malmö and Lund in Scania, south-west Sweden (Fig. 1). Greenways were studied at three sites and sown wildflower strips at one site. All greenways and wildflower strips studied had been established on arable land in intensive agricultural areas with large arable fields. Only a few of the greenways and strips were adjacent to woodlands but some contained planted trees and one contained planted trees and shrubs.

The first site was near SLU at Alnarp, north of Malmö. Here, wild flower strips were sown in the mid-1990s using a seed mixture of wildflowers and grasses (species typically occurring in meadows) bought from a commercial producer (Väståkra ängsfrö, Linné mixture). However, in two cases wildflower strips were established by using hay from a nearby meadow. The strips were created as experimental strips for other research projects, to enhance amenity around the university campus or for demonstration purposes. The sown wildflower strips were cut once a year, at the end of July and the grass is removed afterwards.

The second site was near Staffanstorp, close to the village of Tottarp, where a farmer established a system of greenways around his fields in the 1990s. These greenways were established by sowing a seed mixture of grasses and are cut several times a year. Some have planted trees, mostly *Salix*. The greenways are primarily intended to be used for recreation (walking and horse riding), but have also been identified as an opportunity to increase biodiversity by implementing green structures. The farmer is paid subsidies by the municipality.

The third site was east of Lund, near a village called Arendala where greenways were established by sowing a mixture of grassy species. No other plantings have been done.The greenways were established in 2005 and are cut several times a year.

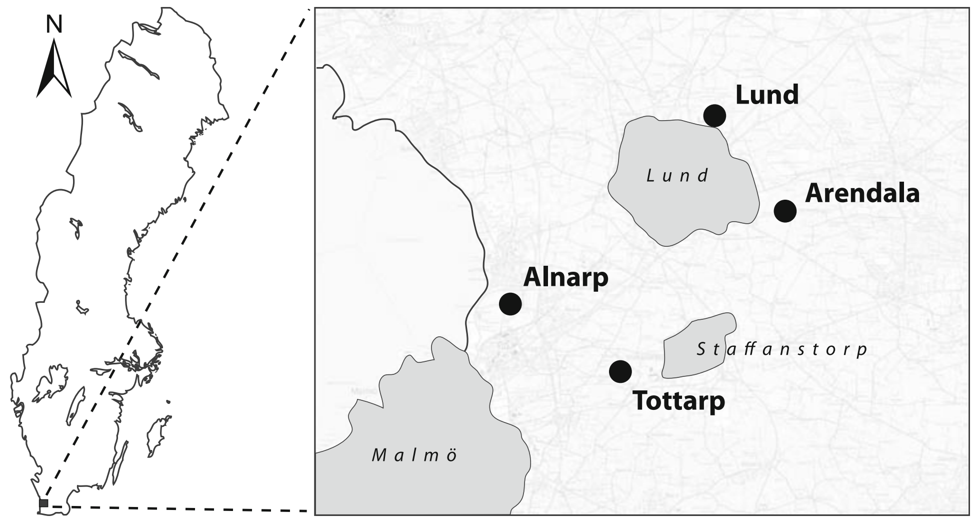

Fig. 1 Location of study area in Scania, southern Sweden

The fourth site was situated north of Lund (Ladugårdsmarken), directly adjacent to new housing areas. Here the municipality of Lund established in 2004 greenways for walking and horse riding to enhance possibilities for recreation near the new housing areas. A mixture of grassy species was sown here. A particular feature of these greenways is that in addition to trees, bushes were also planted to improve conditions for recreation and biodiversity. The greenways are cut several times a year but a very small margin containing weeds (*Cirsium, Matricaria*) is left unmanaged between greenway and arable land.

Site variables

The following variables were recorded for each greenway and sown strip:

- Abundance of flowering plant species on each recording occasion on a scale of 1–3, where 1 = rare, 2 = spread, more or less thinly distributed over the whole area, 3 = very abundant
- Plantings of trees or bushes
- Management system (number of cuts)
- Width
- Adjacent land use
- Age (number of years since establishment)

Greenway systems at each site were recorded along transect sections, with a new section being started each time vegetation, plantings, management, width or adjacent land use changed. At Alnarp six transect sections were investigated, at Tottarp seven, at Arendala five and at Lund two. The length of each greenway or wildflower strip section was calculated in the geographical information system (GIS) ArcView. The source of the spatial data was an orthophotograph from the year 2005 provided from the Swedish mapping, cadastral and land registration authority.

Butterfly and bumblebee recording

Butterflies and bumblebees were recorded along transects by walking in the middle of the greenway or wildflower strip. Butterfly recording was carried out according to the transect method described by Pollard and Yates (1993), which means in suitable weather conditions, but only in 2 m on each side of the recorder, since most greenways were only 4 m wide. One exception was made where the greenway was 8 m wide and almost all flowering plants were situated at the outer margins. Here, the two outer margins of the greenway were recorded instead. Foraging bumblebees were counted at the same time as the butterfly recording was carried out, also 2 m on each side of the recorder. The species *Bombus lucorum* and *B. terrestris* were combined due to difficulties in field identification. For both butterflies and bumblebees, the flower visited was noted. Recordings were carried out on five occasions between June and end of August/beginning of September, 2007.

Flower index

A flower index was calculated for plant species that were most often visited by butterflies and bumblebees. The index is the sum of the abundance class (1–3) at all five visits divided by the number of visits (= 5). This flower index was used in a multiple regression analysis.

Statistical analysis

Multiple regressions were carried out using Statistica (Statsoft 1997) to analyse the relationships between the environmental variables recorded and butterfly and bumblebee individual numbers and diversity. Canocoo (ter Braak and Šmilauer 2002) was used to analyse differences in species composition between greenways and the sown wildflower strips (Correspondence analysis, CA). One-way ANOVA was used to analyse differences in butterfly and bumblebee abundances among study sites, using the statistical package Minitab (Minitab Inc. 2007).

Results

Butterfly and bumblebee numbers in sown wild flower strips and greenways

During the study, 2.9 km sown wildflower strips (at Alnarp) and 6.8 km greenway (3.5 km at Tottarp, 1.4 km at Arendala and 1.9 km at Lund) were surveyed. In total, 1,769 butterflies of 18 species (including one day flying moth) were recorded. A total of 1,216 foraging bumblebees were observed and eight different species could be identified. 86% of all butterflies observed and 83% of all bumblebees observed were recorded in the sown flower strips at Alnarp. The numbers of butterflies and bumblebees at the different sites are shown in Fig. 2. The mean number of butterflies was about 20 times higher in sown wild flower strips than in greenways typical of the region (Fig. 2a). The greenways north of Lund with tree and bush plantings had slightly higher numbers, but still had far less than the sown wildflower strips. Bumblebees were virtually absent from the typical greenways sown with grasses (Fig. 2b).

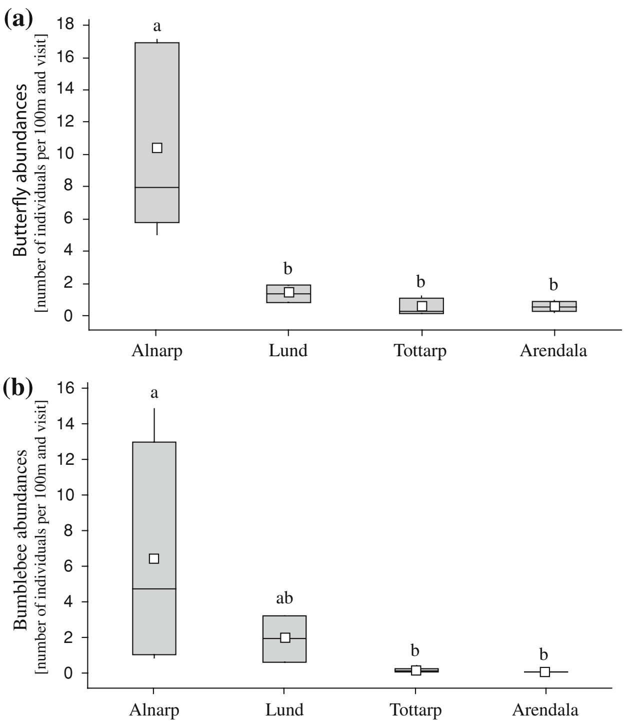

Fig. 2 Boxplots showing results of one-way ANOVA for (a) butterfly and (b) bumblebee abundances per 100 m transect section and visit at the four study sites. Alnarp = sown wildflower strip, Lund, Tottarp, Arendala = greenways. For (a): $F = 13.59$, $P = 0.000$, and (b): $F = 4.74$, $P = 0.015$. Post-hoc analyses (Tukey's HSD) showed significant differences ($P < 0.05$) between sites marked "a" and "b", whereas "ab" did not differ from the others

Butterfly and bumblebee species

Almost all butterfly species recorded in both the sown wildflower strips and the greenways were very common species. They included species typical for agricultural areas such as the whites (*Pieris napi*, *P. rapae*) or typical grassland species such as *Thymelicus lineola*, *Aphantopus hyperantus*, *Maniola jurtina*, *Coenonympha pamphilus*, *Lycaena phlaeas* and *Polyommatus icarus*. In addition, there were ubiquitous species such as *Aglais urticae*, *Cynthia cardui*, *Gonepteryx rhamni*, *Inachis io* and *Vanessa atalanta*. *Ochlodes venatus* and a few individuals of *Araschnia levana*, *Argynnis paphia* and *Cupido minimus* were found only in the sown wildflower strips. A list of all species recorded is given in Appendix 1.

The bumblebee species recorded were also all common in southern Sweden. Most abundant were the species *Bombus lapidarius* and *B. terrestris/lucorum*. The correspondence analysis of the butterfly species composition demonstrated a clear separation in species composition between sown wildflower strips and greenways (Fig. 3).

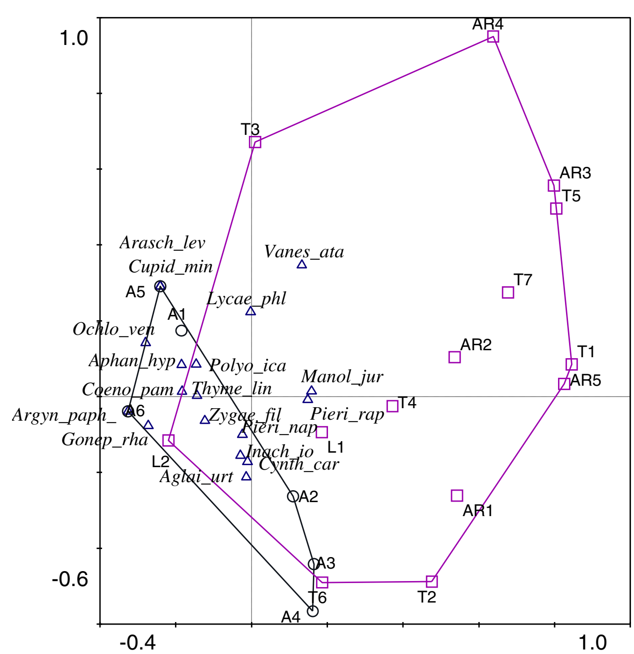

Fig. 3 Correspondence analysis of butterfly species composition in greenway and sown wildflower strips; *squares* greenway sites, *circles* sites with sown wildflower strips, *triangles* butterfly species

Factors influencing butterflies and bumblebees in greenways and wildflower strips

The results of the multiple regression analysis (stepwise forward) showed that the type of green structure (sown wildflower strip or greenway) explained a large proportion of the variation in butterfly and bumblebee abundance and species numbers (Table 1a). For butterflies the presence of bushes was another important factor explaining variations in abundance and species numbers. Variation in bumblebee species numbers was additionally influenced by the logarithmic length of the transect section and bumblebee individual numbers by the presence of trees.

Removing the variable TYPE from the analysis resulted in a large reduction in the R^2 values. Other variables, such as number of flowering plants, could not explain variations to a similar extent as for example green structure type. Inclusion of the abundance of the most visited flowering species—instead of green structure type—indicated that the flower index for *Knautia* explained most of the variation in abundance and species numbers of butterflies, while the flower index of *Centaurea* explained most of the variation of bumblebee abundance and diversity (Table 1b).

Flower visits

Of the 1,769 butterfly observations, 347 (20%) were made while the butterfly was visiting a flower. Two-thirds of all flower visits by butterflies were observed on *Knautia arvensis* (44%) and *Centaurea* spp. (*C. jacea* and *C. scabiosa*, 20%; Table 2a). *Cirsium arvense*, *Senecio* spp. and *Trifolium* spp. were other commonly visited plants. For bumblebees, visits on *Centaurea* spp. were totally dominant (72%), while 14% of all visits were recorded on *Knautia arvensis*, 5% on *Trifolium* ssp. and 4% on *Cirsium arvense* (Table 2b).

Table 1 Multiple regression results (stepwise forward) with independent variables included in analysis

Dependent variables	Variables included in model	Multiple R^2	F – to entr/rem	P-level
(a)[a]				
Butterfly individual numbers	TYPE	0.55	22.3	>0.001***
	BUSH	0.69	7.8	0.013*
Butterfly species numbers	TYPE	0.48	16.4	0.0012**
	BUSH	0.84	40.0	>0.001***
Bumblebee individual numbers	TYPE	0.37	10.4	0.0081**
	LOG LENGTH	0.45	2.8	0.12 n.s.
	TREE	0.61	6.2	0.024*
Bumblebee species numbers	TYPE	0.57	24.0	>0.001***
	LOG LENGTH	0.84	27.6	>0.001***
(b)[b]				
Butterfly individual numbers	KNAUTIA	0.74	51.3	>0.001***
Butterfly species numbers	KNAUTIA	0.49	17.5	>0.001***
	BUSH	0.71	12.2	0.003**
	CENTAUREA	0.78	5.9	0.029*
	TRIFOLIUM	0.84	5.6	0.033*
Bumblebee individual numbers	CENTAUREA	0.83	86.6	>0.001***
	TREE	0.89	16.2	0.007**
Bumblebee species numbers	CENTAUREA	0.69	40.6	>0.001***
	WIDTH	0.78	6.8	0.022*
	LOG LENGTH	0.86	9.6	0.009**

[a] Type of green structure (sown wildflower strip or greenway, TYPE); presence of bushes (BUSH) or trees (TREE); logarithmic length of transect section (LOG LENGTH); adjacent land use: either both sides arable or not (ADJ_LAND); width of greenway section (WIDTH); times cut (CUT); number of flowering plant species (NUM_FLOW); age (AGE). Number of transect sections analysed = 20

[b] Multiple regression results (stepwise forward) with independent variables included in analysis: flower index [sum of abundance class (1–3) of each of the five visits divided by number of visits (5)] of the species Knautia arvensis (KNAUTIA), Centaurea spp. (CENTAUREA), Cirsium arvense (CIRSIUM), and Trifolium spp. (TRIFOLIUM); presence of bushes (BUSH) or trees (TREE); adjacent land use: either both sides arable or not (ADJ_LAND); logarithmic length of transect section (LOG LENGTH); width of greenway section (WIDTH); times cut (CUT); number of flowering plant species (NUM_FLOW); age (AGE). Number of transect sections analysed = 20

Table 2 Number of observed visits by (a) butterflies ($n = 347$) and (b) bumblebees ($n = 1216$) to different flower species

Plant species	Number of observed flower visits	% flower visits
(*a*)		
Knautia arvensis	151	44
Centaurea spp.	68	20
Cirsium arvense	32	9
Senecio spp.	30	9
Trifolium spp.	29	8
Lotus corniculatus	13	4
Medicago lupolina	6	2
Crepis biennis	5	1
Others	13	4
Total	347	100
(*b*)		
Centaurea spp.	879	72
Knautia arvensis	171	14
Trifolium spp.	56	5
Cirsium arvense	46	4
Senecio spp.	23	2
Cichorium intybus	12	1
Ballota nigra	10	1
Others	19	2
Total	1,216	100

Discussion

The results of this study show firstly that the most common type of greenway currently being established in south-western Sweden is not enhancing biodiversity particularly well, at least regarding butterflies and bumblebees. Even if these greenways were primarily created to facilitate recreation, they are also assumed—according to many policy documents—to support or even enhance biodiversity in intensive agricultural regions. However, the results of this survey on butterflies and bumblebees on the greenways rather emphasise the impoverishment of biodiversity of these areas. Looking at the methods of establishment (sowing grass species) and the management regimes of the greenways, which involves cutting the entire greenway several times a year, this might not be surprising. On the other hand, the results of this study also clearly indicate that even in intensive agricultural areas, wildflower strips can support high numbers of bumblebees and butterflies, albeit mostly very common species. Plantings of bushes can influence butterfly numbers positively.

Previous studies comparing butterfly and bumblebee diversity in different linear features established within agri-environmental schemes also showed that grassy margins generally have a rather poor butterfly and bumblebee diversity (Carvell et al. 2007; Field et al. 2007; Pywell et al. 2006). However in these studies the grassy margins were cut less often than in Sweden and can therefore be assumed to have a greater value for wildlife than the Swedish greenways. Pywell et al. (2006) came to the conclusion that rather cheap seed mixtures with a variety of *Leguminosae* provide the most valuable foraging habitat for bumblebees. In our study the wildflower strips supported high bumblebee numbers and a more diverse flora at the same time. It is generally acknowledged that the presence of bushes in margins and lanes increases butterfly numbers (e.g. Dover et al. 2000). That the presence of trees has a positive impact on bumblebee numbers is less obvious. Probably this can be explained with the fact that this variable is positively correlated with the index for number of flowering plant species (Spearman Rank 0.67, $P < 0.01$) and the presence of *Trifolium* spp. (Spearman Rank 0.77, $P < 0.001$).

Regarding flower visits, *Centaurea* spp. and *Knautia arvensis* were dominant among the plant species visited. *Cirsium arvense* and *Trifolium* spp., which are other two well-known foraging plants for bumblebees, played a comparatively minor role. Nevertheless *Cirsium* is an important foraging source where other wildflower species are absent.

Due to the very few existing wildflower strips in the region, the number of strips studied here was small. The results of this study are nevertheless important for the further implementation of greenways in the region. The first greenways were established on the initiative of an individual farmer, while subsequent greenways were established where municipalities managed to reach agreement with farmers, but not necessarily where they were most suitable from either a recreational or biodiversity perspective. Some municipalities in Sweden are currently investing a lot of money in leasing or even buying farmland to ensure recreational opportunities and at the same time enhance biodiversity in peri-urban areas. Negotiations with farmers bring additional very high time costs. Under these circumstances, it is important to optimise the results of such efforts.

For the design of the greenways, we suggest that in addition to the grassy margins, wildflower strips be sown at the edge of the greenway. These strips should be at least 0.5 m width, 1 m width would be better. Greenways tend to be 4 m wide, which would leave 2–3 m grass-dominated greenway in the middle for recreation purposes. The wildflower strips should not be cut more than once a year, preferably in late summer (mid-August at the earliest). The grassy strips can be cut as often as it deemed suitable for recreational purposes. Where bush and tree plantings are possible, these are very beneficial for overall wildlife diversity but it is not necessarily desirable to have plantings along all greenways. The seed mixture used at Alnarp seems to be very suitable for the task, since about 10 years after establishment the wildflower strips have a diverse flora including typical grassland species that have declined. The seed mixture works even on the very fertile soils of the region. There are few problems with weed species unwanted by farmers. In comparison to land lease costs, seed mixture expenses appear to be justifiable. Regarding the location of greenways combined with wildflower strips, it would be most beneficial to place these either along existing field borders where there is no margin with any semi-natural vegetation (which is very common). Another option would be in the middle of large existing fields, as done at Alnarp, but this is probably unrealistic on land that is not owned by the municipality. A third possibility is along farm borders, where there is also often no margin of semi-natural vegetation.

Conclusions

The current establishment of greenways in south-west Sweden does not appear to have promoted biodiversity, though this an important goal of these greenways, together with recreation. The existing greenways could be improved comparatively easily by sowing wildflower mixtures at the margins. Tree and bush plantings tend to improve overall diversity. Municipalities that spend a comparatively large amount on land leasing and time-consuming negotiations with farmers so as to establish greenways must ensure that these greenways are optimal for improving biodiversity.

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Appendix 1

List of butterfly species observed (including one day flying moth, *Zygaena filipendula*).

Aglais urticae
Aphantopus hyperantus
Araschnia levana
Argynnis paphia
Cupido minimus
Coenonympha pamphilus
Cynthia cardui
Goneptery rhamni
Inachis io
Lycaena phlaeas
Maniola jurtina
Ochlodes venatus
Pieris napi
Pieris rapae
Polyommatus icarus
Thymelicus lineola
Vanessa atalanta
Zygaena filipendulae

List of bumblebee species observed.

Bombus hortorum
Bombus lapidarius
Bombus pascuorum
Bombus subterraneus
Bombus terrestris/lucorum
Psithyrus bohemicus
Psithyrus norvegicus
Psithyrus rupestris

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