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Evaluation of cultivated margin option effectiveness and exploration of their natural capital

Final Report

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Executive Summary

Cultivated margins (HF11/20 and AB11) and floristically enhanced grass margins (HE10 and AB8) were monitored in 2018 and 2019 to determine their relative value to arable plants, pollinators and natural enemies. The main aim of the project was to identify how habitat management influences the botanic composition of these two margin types and the influence of management and vegetation structure on use by associated invertebrate groups. The final aim of the project was to use the study results to develop management guidelines to improve the delivery of these habitats. Our results are summarised below.

Cultivated margins

- Of the 30 sites surveyed 25 included species that are used to define and evaluate "Important Arable Plant Areas" in the UK, highlighting the importance of cultivated margins for rare arable plants.
- 183 species of broad-leaved plants and grasses were found in the cultivated margins.
- Soil type along with the type and time of cultivation significantly influenced cultivated margin vegetation composition. Trends in invertebrate abundance were largely driven by relationships between margin management and vegetation structure.
- Five herbaceous plant species and two pernicious grass species were significantly more abundant when cultivations were conducted in the autumn compared with spring. Three of the broad-leaved species have forage value for wild bees.
- Margins cultivated by ploughing compared to minimum tillage had fewer grass weeds and a higher proportion of bare ground, with overall lower vegetation height and density. Margins cultivated by minimum tillage had more perennial plants, including dandelions that were favoured by wild bees and Syrphidae (hoverflies). Ploughed margins had fewer pollinators, solitary bees and natural enemies.
- Rotational cultivated margins were associated with fewer flower heads, lower broad-leaved species cover and lower vegetation heights which in turn negatively impacted bee abundance. Boundary type was only found to impact the abundance of *Bombus lapidarius* (red-tailed bumblebees) which were more commonly found on cultivated margins adjacent to hedgerows and woody habitats.
- Larger cultivated margin habitats had fewer pernicious grass weeds and although coverage of broad-leaved species was lower, this is because they were home to less competitive plant species. This resulted in fewer Staphylinidae but more Syrphidae (hoverflies) in those margins.

Floristically enhanced margins

- The most important factor affecting the composition of perennial vegetation was age since establishment, with vegetation in recently-established margins being characterised by a higher frequency of annual species typical of regularly cultivated arable land and early successional stages e.g. *Tripleurospermum inodorum* and *Bromus sterilis*.
- The vegetation characteristics were found to change over time, with older margins becoming dominated by grass and containing fewer flowerheads to support foraging pollinators.
- Compared to natural regeneration, sown margins were associated with increased bee and hoverfly abundance which is probably linked to the high flowerhead abundance and broad-leaved species coverage evident on sown plots.

- Our pollinator foraging data from 2019 showed that *Cirsium* vulgare (spear thistles) and *Lotus corniculatus* (bird's-foot trefoil) attracted the highest number of foraging bumblebees on floristically enhanced margins, whilst hoverflies were most commonly found foraging on *Crepis* species (hawk's-beard) and *Anthriscus sylvestris* (cow parsley).

Our results highlight that cultivated margins are functioning as they were originally conceived by providing space for rare arable plants on farmland. However, since rotational cultivated margins were associated with low flower abundance generally and in turn low bee abundance, we recommend against annually rotated margins and instead advise that cultivated margins are implemented on the same location over longer periods. For floristically enhanced margins we suggest that there is some scope for improvement in sown seed mixtures and that some arable weeds are tolerated as many pollinating invertebrates were seen foraging on them. We also recommend that the surveys be repeated in the future as our results were based on only two years of data, which both experienced extreme weather conditions, the first year was affected by a late period of extremely cold temperatures "the beast from the east" and was drier than usual, whilst the second year had some extremely high temperatures but also a series of heavy rainfall events in spring and early summer.

1 Introduction

Arable plants are the most threatened group of British flora with 10 species extinct and 57 classified as Near Threatened or Critically Endangered (IUCN categories: Cheffings & Farell (2005). In the past many of these species that were classified as crop weeds have declined following the development of modern intensive agricultural systems. Among the key practices that have caused their decline are: 1) the widespread use of herbicides that are both broad-spectrum and whose efficacy has improved overtime; 2) chemical fertilisers that both increase crop growth and thereby their competitiveness with the arable plants and create unfavourable soil conditions for the arable plants germination and growth; 3) crop varieties that are better able to respond to agrochemicals making them more competitive; 4) greater adoption of minimum tillage with less soil disturbance so that once existing arable plants have been depleted through use of herbicides they are not restored by returning buried seeds to the soil surface through deep cultivations; 5) earlier harvesting that reduces the time available for arable plants to set seed; 6) more efficient seed cleaning so that fewer arable plant seeds are returned to the soil; 7) simpler crop rotations with fewer spring-sown crops that reduce the opportunities for a diverse arable plant community to persist; 8) farmers and retailers dislike of untidy farms leading to a loss of unmanaged weedy habitats.

To conserve declining rare arable plants the agri-environment scheme habitat "uncropped cultivated margins for rare arable plants" (hereafter cultivated margins) was designed and tested on the Breckland ESA, it was subsequently included in the first Countryside Stewardship scheme in 1991 (Andrew Cooke, *pers. comm*), it remains in the new Countryside Stewardship scheme today. The effectiveness of cultivated margins for conserving scarce and declining annual plants is relatively well understood, with recent research further increasing our understanding of effective management for plant species (Defra Project BD5204). Cultivated margins for arable plants contribute directly towards Objective 1b in Bio2020 and are a key component of the Wild Pollinator and Farm Wildlife package. However, uptake of these options is still relatively low compared to other margin types and arable options. The Genrep and SITI Agri systems were recently used to track agri-environment scheme uptake and showed 71,000ha of key arable options have been lost against this Objective 1b target since 2013; some of this sum includes cultivated margins. There is now considerable urgency to understand where these option areas have been lost, which populations have been impacted and which options could be used to plug the gap. Cultivated margins for arable plants are massively underutilised options for a variety of reasons including land manager's dislike of their untidy appearance and agronomic concerns, including the perception of weed species being introduced onto farmland. However, they not only provide growing conditions for scarce arable plants, but also for more common annual plant groups too, all of which combine to provide a wide range (both physiologically and temporally) of foraging resources for farm wildlife, but in particular for wild pollinators.

Concerns over perceived declines in pollinators in the 1990s led to the introduction of options to provide flower-rich habitats on farmland e.g. "pollen and nectar mixes" which were initially introduced via the first Countryside Stewardship scheme in 1991. Floristically enhanced grass margins were added to the UK's agri-environment scheme programme in 2005 as part of the Environmental Stewardship Scheme, they aimed to provide benefits for both foraging pollinators and insectivorous farmland birds. Floristically enhanced grass margins are non-rotational sown or naturally regenerated field edge strips and comprise a mixture of grasses and perennial flowering plants such as *Leucanthemum vulgare* and *Lotus corniculatus*. Methods of establishment and subsequent management can substantially affect the survival of herbaceous plants within these margins and invasion by noxious weeds. Understanding which management factors are important in preserving their herb component is critical if these options are to deliver high value to wildlife, in particular their value to rare arable plants has receive little attention in scientific literature.

It is now recognised that cultivated margins, managed for arable plants could offer significant opportunities for wild pollinators. Monitoring use by pollinators and natural enemies across examples of cultivated margins in real agreements will help us to understand their environmental value relative to floristically enhanced grass margins and how the quality of delivery influences floral resource provision and subsequent benefits for these invertebrates. Many earlier studies in the UK have examined the value of margins sown with wildflowers for pollinators (e.g. Pywell et al., 2005, 2006; Carvell et al., 2007; Pywell & Nowakowski 2007) and three looked at annually cultivated areas: Kells et al., 2001; Pywell et al., 2005; Carvell et al., 2007. A more recent study examined floristically enhanced grass margins and annually cultivated margins managed according to the scheme guidelines (Holland et al., 2015). Studies of natural enemies in the two habitats are rarer, although see Holland et al. (2014; 2015).

Looking towards Natural England's Conservation Strategy C21, one of the key elements that is critical to successful delivery of cultivated margins is to empower and build the confidence of landowners to engage with and deliver management successfully. As one of the most variable interventions (assemblages and success rates show yearly variation) understanding what cultivated margins have in terms of plant and animal species and how to react to the very changeable nature of cultivated margin/plot management appropriately is essential for advisers, agronomists and land managers alike. It is hoped that the product of this research will help inform future publicity and guidance for arable plant conservation and potentially contribute to the development of measurable parameters for a payment by results approach.

The project aims were to:

- Monitor the abundance and diversity of two functional groups of invertebrates (pollinators and natural enemies) on 1) cultivated fallow plots or margins for arable plants, hereafter cultivated margins (HF11/20 and AB11), and 2) floristically enhanced grass margins (HE10 and AB8).
- Identify how management influences the botanical composition/structure of these habitats and use by associated invertebrate groups.
- Provide information on the relative value of cultivated margins and floristically enhanced margins to arable plants, pollinators and natural enemies.

2 Method

2.1 Study sites

Assessments were made across 15 farms per year for two years, providing a total of 30 farms, each with an example of a cultivated and floristically enhanced margin. Therefore 30 cultivated margins and 30 floristically enhanced margins were surveyed during the study In 2018, 15 farms were selected for surveys across three regions of England: South (Hampshire / Dorset), Midlands (Northamptonshire / Rutland / Nottinghamshire / Lincolnshire) and East (Norfolk). In 2019, 15 farms were selected for surveys across three regions of England: South (Hampshire / Dorset), Oxford (Oxfordshire) and East (Norfolk). The Midlands region was not surveyed in 2019 due to a lack of interest in participation by farmers in the area.

Sites were selected from a list of eligible farms supplied by Natural England. Sites which were situated within the study regions were selected at random Preliminary margin information was collected to determine the suitability of each margin for the project. Margins which were directly adjacent to another HLS option, such as a wild bird seed plot, were rejected. Additionally, where information on atypical management or margins characteristics (e.g. being subject to high public disturbance or being only partly cultivated or sown) was known these margins were rejected for inclusion in the study.
See appendix I for more information on site selection.

2.2 Cultivated margin and floristically enhanced management data

At the start of the project management data and information on other key attributes thought to influence plant and/or invertebrate communities were recorded for each margin type. For both margin types key attributes included age, width, soil type (chalk, heavy, medium or sandy) or soil fertility (extracted from the Soilscapes map, landis.org.uk), cereal crop adjacent (Yes/No), adjacent habitat type (hedgerow – including other woody habitats), year (2018 or 2019) and survey number if appropriate. Soil fertility was included in our models because soil that is fertile will supply essential nutrients and water to plants in adequate amounts and will influence plant growth and reproduction. We therefore expect soil fertility to impact the vegetative community of plots and in turn the number of invertebrates it can support.

For cultivated margins the management data collected also included cultivation type (plough or minimum/non-inversion tillage) and if the margin was rotational or non-rotational. Cultivated margins are ploughed to turn over the top layer of soil, thereby changing the soil structure and burying vegetation remains which are left to decompose in the soil. In contrast minimum tillage aims to minimise soil manipulation, it does not involve turning the soil over. Minimum tillage management on cultivated margins encompassed a wide range of descriptions including discing (e.g. sites M2, M3, O5), chisel tine drag followed by power harrow (M4), use of a specialised minimum cultivation tool (Horsch Tiger) by O2, shallow discing and pressing (S1) and the use of a tine cultivator (S5).

For floristically enhanced margins the management data also included information on plot establishment method (sown or natural regeneration) and if/when the margin was cut (not cut, Autumn/Winter or Spring/Summer).

2.3 Invertebrate monitoring

Three approaches were used to assess the invertebrates in each habitat.

2.3.1 Pitfall trapping

Pitfall traps were used to measure terrestrial invertebrate species, predominantly night active natural enemies (Coleoptera and Arachnida). The technique has limitations (e.g. capture is activity dependent) and therefore is more valuable for estimating species richness than abundance.

Pitfall traps comprised of a plastic sleeve, which held a plastic cup containing water and unscented detergent. A funnel was placed inside the cup to prevent entry by small mammals. Traps were placed in the ground and were level with the soil surface. Pitfall traps were deployed on three week-long occasions in May, July and September (Appendix II), six per plot, located 20m apart in a transect each plot, pitfall locations were marked with flexicanes between sampling rounds. On collection the trap contents were decanted into another plastic cup containing a label and stored in 70% alcohol. When sampling was not taking place, to prevent capturing wildlife, the pitfall sleeve contained a cup filled with stones or water (as a weight) and had a lid.

Invertebrates recorded were: Carabidae adults (identified to species in 2018), Staphylinidae, Linyphiidae and Lycosidae (identified to family level). Carabidae and Staphylinidae larvae were also counted.

2.3.2 D-Vac suction sampling

D-vac suction sampling was used to capture the smaller natural enemies that are difficult to observe (e.g. parasitic wasps important for biocontrol, some generalist predators (Araneae, Carabidae, Staphylinidae) and other pollinators that are difficult to observe on transect walks (predominantly Diptera).
In total four suction samples were collected along the middle of each margin; the first sample was taken 5 m from the transect start with 10 m intervals between samples (Figure 1). Each sample comprised 5 x 10 second sucks, moving 2 m between each suck in a line along the transect and corresponded to a sampling area of $0.5m^2$. At each location a “suck” had been taken, a white cane was dropped to mark where the associated vegetation survey should be completed. A twist of paper impregnated with Ethyl acetate was added to preserve samples that could not be frozen on the same day. Vegetation was removed and samples were stored in 80% alcohol.

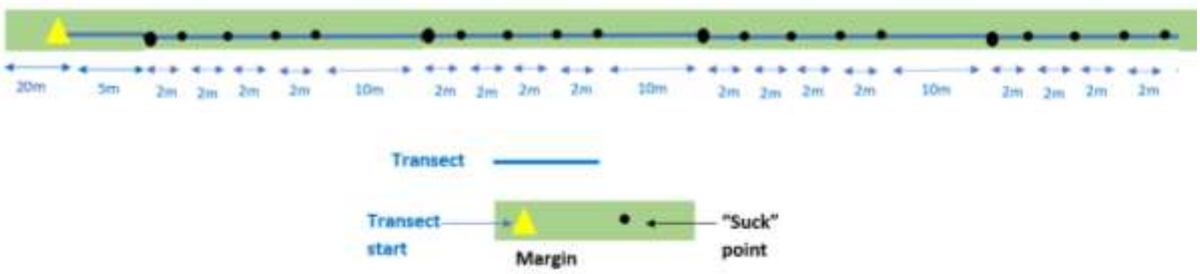

Figure 1. Diagram illustrating suction sampling along margin.

D-vac sampling was conducted in late-May and early-June each year because sampling at this time provides the best assessment of their invertebrate communities and covers the time when natural enemies are active in the habitats (Appendix III). Samples were identified under a binocular microscope and invertebrates were only recorded if they were a natural enemy or a pollinator (either to order, family or genus):

- Arachnids: Linyphiidae, Thomisidae, Lycosidae, Opililiones
- Coleoptera: Cantharidae, Carabidae, Coccinellidae, Elateridae, Mordellidae, Melyridae, Oedemeridae, Scydmaenidae, Staphylinidae
- Diptera: Bombyliidae, Calliphoridae, Conopidae, Dolichopodidae, Empididae, Fanniidae, Hybotidae, Lonchopteridae, Muscidae, Syrphidae, Sacrcophagidae, Scathophagidae, Stratiomyidae, Tachinidae
- Hempitera: Anthocoridae, Nabidae, Reduviidae, Saldiddae
- Hymenoptera: Parastica, Formicidae, Apidae (to genus), Vespidae
- Forficulidae
- Neuroptera

For analysis involving pest natural enemies we summed the following groups: Linyphiidae, Thomisidae, Lycosidae, Opililiones, other Araneae, Araneae juveniles, Cantharidae, Carabidae, Coccinellidae, Elateridae, Scydmaenidae, Staphylinidae, Forficulidae, Dolichopodidae, Empididae, Hybotidae, Lonchopteridae, Anthocoridae, Nabidae, Reduviidae, Saldiddae, Parastica, Formicidae and Neuroptera.

For analysis involving pollinating invertebrates we summed the following groups: Mordellidae, Melyridae, Oedemeridae, Bombyliidae, Calliphoridae, Conopidae, Fanniidae, Muscidae, Syrphidae, Sacrcophagidae, Scathophagidae, Stratiomyidae, Tachinidae, Andrenidae, Anthocoridae, Apidae, Colletidae, Halicidae, Megachilidae, Sphecidae, Vespidae.

Invertebrate diversity was also calculated for D-vac samples as a count of the taxa recorded at each sampling point.

2.3.3 Pollinator transects

A standard "bee walk" methodology (Prys-Jones and Corbet, 1991) was used to assess the numbers of bees and hoverflies using cultivated and floristically enhanced margins.

Surveys were conducted monthly, between 10:00 – 17:00hr, from April to September (Appendix IV). The order in which sites were visited was randomised on each round of visits. Surveys only took place when the temperature was above 10°c, wind levels were below 4 on the Beaufort scale and in the absence of heavy rain or thick fog. The observer walked at an even pace, of approximately 15-20 m per minute, along the middle of 100 m long transects. Due to the shape of some margins, however, it was necessary to adjust the transect into two parallel shorter lines which added up to 100m. The start and end transect coordinates were recorded using GPS to ensure the same transect was walked during each survey. A photograph was taken of each margin on each visit (a selection of photos are presented in Appendix V).

All bees seen foraging or actively nest searching within 2m of the observer were recorded. Hoverflies were only recorded when sitting on flowers, or hovering close to flowers, within 1 m of the observer. If necessary, bees were caught with a net and transferred to a transparent pot for identification. Bumblebees and honeybees were recorded to species and caste (worker, queen, male/drone). *Bombus terrestris* and *B. lucorum* were not differentiated due to the difficulty in doing this accurately in the field. Solitary bees were recorded to genus (Andrena, Anthophora, Colletes, Halictus, Hylaeus, Lasioglossum, Megachile, Nomada, Osmia, Panurgus, Sphecodes). Hoverflies were recorded to family level (Syrphidae). Additionally, the plant species on which they were foraging was recorded.

2.4 Vegetation assessments

Two methods were used to assess the plant community and their role in delivering ecosystem services.

2.4.1 Assessments of margin vegetative characteristics

Following monthly pollinator walks, observers completed vegetation assessments using a 1 m quadrat (Figure 2, Appendix IV). Starting at the beginning of the transect (0 m), and at 10m intervals, 10 quadrats were placed along the middle of the margin. Where there was a pitfall trap, the quadrat was placed with the pitfall trap in the corner of the quadrat to reduce trampling. If there was no pitfall trap, it was placed at random.

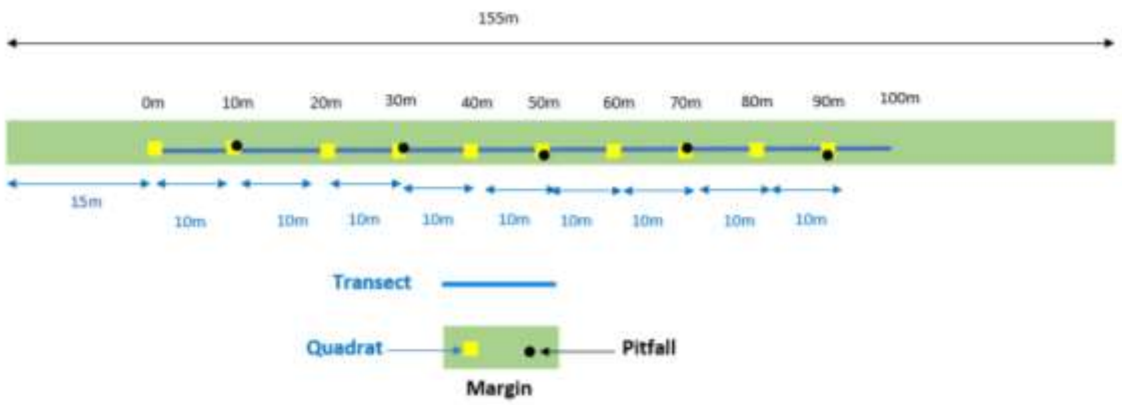

Figure 2. Diagram of quadrat and pitfall placement.

Within each quadrat, the number of flowering units were counted. Where the plant inflorescence consisted of many flowers they were counted as one flowering unit, such as Umbel-type plants like cow parsley *Anthriscus sylvestris*. Percentage cover of grass, broad-leaved species, bare soil and any other coverage (e.g. moss) was estimated. A drop disc and ruler were then placed in each corner and near the centre of the quadrat to record five measurements of vegetation density (using a 200-g drop disk with a 30cm diameter), height (cm) and height of the nearest plant (cm). This allowed assessment of average vegetation density and height, respectively.

2.4.2 Botanical characterisation of field margins

This survey forms the basis of the botanical characterisation of each field margin (Appendix VI).

In the area where each D-vac nozzle was placed the percentage cover of all vascular plant species was estimated in a 1m^2 quadrat centred on the sample point. Vegetation obviously trampled by the previous sampling was avoided. A total of 20 quadrats were therefore recorded in each field margin. Mean percentage occurrence of each species was calculated for analysis.

In addition to the quadrat recording, all plant species present in each margin were recorded. The abundance of each species (including those in the quadrats) was then estimated on the DAFOR scale (D=Dominant, A=Abundant, F=Frequent, O=Occasional, R=Rare). Frequencies and mean percentage covers of all species were calculated for each margin.

2.5. Statistical analysis

2.5.1 Identifying the impact of habitat management

Data analysis was conducted in R v.3.3.5 (R core Team 2017).

We explored the relationship between invertebrate abundance (measured using pitfall traps, D-vac suction sampling and pollinator transect surveys) and habitat management, and, the relationship between vegetation characteristics and habitat management on cultivated margins and floristically enhanced margins using generalised additive models (GAMs) or generalised additive mixed effects models (GAMMs), to account for pseudoreplication present in the data, depending on the number rounds of data collection. Pollinator transect and vegetation characteristics models were built as GAMMs where round was included as a random effect. Models of pitfall trap data included round as a fixed effect as the number of rounds, 3, did not meet the minimum requirement, of 5 rounds, to be included as a random effect. Round was therefore included a fixed effect in a GAM. The D-vac data was modelled as a GAM as only one round of data collection took place.

For cultivated margin models explanatory variables comprised plot age, plot width, soil fertility, adjacent cereal crop (yes/no), adjacent habitat type (hedgerow or other), cultivation type (plough/ minimum till), rotational/non-rotational, year (2018 or 2019) and survey number if appropriate (see appendix VII for a description of habitat characteristics by site). Plot age and width were log+1 transformed so that the residuals are approximately normally distributed with variance constant over the range of values.

For floristically enhanced margin models explanatory variables comprised plot age, plot width, soil fertility, adjacent cereal crop (yes/no), adjacent habitat type (hedgerow or other), margin establishment (sown or natural regeneration), time cut (not cut, Autumn/Winter or Spring/Summer), year (2018 or 2019) and survey number if appropriate (see appendix VII for a description of habitat characteristics by site). Plot age and width were log+1 transformed so that the residuals are approximately normally distributed with variance constant over the range of values.

Invertebrate abundance models were run using the poisson distribution and if overdispersion was evident were rerun using the quasipoisson distribution. Solitary and red-tailed bumblebee abundance were converted to presence/absence data due to the high number of absences in these datasets (cultivated margin solitary bees=67.2%, cultivated margin red-tailed bees=78.3%, floristically enhanced margin solitary bees=72.7%, floristically enhanced margin red-tailed bees=71.1%), they were therefore modelled with the binomial distribution. Models relating vegetation height and density to management variables used the gaussian distribution. For the DVac suction sampling data an additional analysis was conducted to identify if there was a relationship between pollinator and pest natural enemy abundance in cultivated margins or floristically enhanced margins.

To account for potential spatial autocorrelation the geographical position, a northings-eastings interaction term with a spatial smooth (K), was included in analyses (Wood, 2006). K was automatically selected for all models and we used basis dimension checking to ensure K wasn't too low (Wood 2011). In addition, normality and homogeneity of the residuals were visually checked using QQ plots and graphs of the model residuals versus fitted values.

2.5.2. Effect of environment and management on species composition

To investigate the effect of environmental variation on species composition of the ground flora community we used canonical correspondence analysis (CCA). For both cultivated and floristically enhanced margins the species average percentage cover was fitted as the response. For cultivated margins explanatory variables were year (2018/2019), region (north, south, east, midlands), rotational (yes/no), cultivation type (minimum till/plough), broad soil type (chalk, heavy, medium, sandy), broad adjacent habitat (hedge/other), adjacent cereal crop (Yes/No). For floristically enhanced margins explanatory variables were year (2018/2019), region (north, south, east, midlands), establishment (sown or natural regeneration), broad soil type (chalk, heavy, medium, sandy), broad adjacent habitat (hedge/other), adjacent cereal crop (Yes/No), cutting time (not, spring/summer or autumn/winter), cuttings removed (Yes/No), cut (Yes/No). Forward selection was used to identify the simplest model, containing only the significant predictors. Only species that occurred on over 5 out of 30 sites were used in analysis to avoid issues caused by the inclusion of rare species.

Frequencies and mean percentage covers of all species were calculated for each margin. An analysis of the frequency data was performed using Canonical Correspondence Analysis within the Canoco 5.1 package on a subset of the management data (ter Braak & Smilauer, 2018). For cultivated margins the following variables were used: time of cultivation (autumn/spring), soil type (chalk, clay/loam, sand), cultivation type (ploughing, minimum tillage), age of margin option, region (south, Norfolk, Midlands, Oxfordshire), presence of adjacent hedge, presence of adjacent cereal and rotational/permanent. The combination of variables that fitted best with the vegetation data was generated by forward selection, and the significance of each variable was tested using the Monte-Carlo permutation test with 499 permutations. Frequency and percentage cover data for individual species and the summed variables: rhizomatous weeds, *Bromus sterilis+diandrus*, perennial grasses, other perennial species and Important Arable Plant Areas (IAPA) scores (used to highlight arable farmland in the UK that are of county, national or European importance and are based on the presence of 1) specific threatened species 2) exceptional plant assemblages and 3) priority habitats) were examined in relation to time of cultivation (autumn/spring), soil type (chalk, clay/loam, sand), and cultivation type (ploughing, minimum tillage) in Minitab using the generalised linear model with Tukey tests between means. Only those 63 species with occurrences in more than five margins were included.

Similarly, for floristically enhanced margins restricted CCA's were constructed using Canoco 5.1. The following variables were used: soil type (a qualitative three point scale – chalky, sandy and loam/clay), cut time (autumn/winter, spring/summer, not cut), removal of cuttings, age since establishment, region (as for cultivated margins), presence of adjacent hedge, presence of adjacent cereal type of margin (floristically enhanced, naturally regenerated). The combination of variables that fitted best with the vegetation data was generated by forward selection and the significance of each variable was tested using the Monte-Carlo permutation test with 499 permutations. Frequency and percentage cover data for individual species and three summed variables, sown dicotyledonous species, sown grasses and annuals were analysed with respect to age since establishment and type of margin in

Minitab using the generalised linear model with Tukey tests between means. Only those with occurrences in more than five margins were included.

2.5.3 Community composition

To explore differences in the invertebrate (Carabidae in pitfall traps 2018 only, pollinators from transect walks and invertebrates from D-vac suction sampling) community composition between sites functions within Primer-e software were used. The Anosim function was used to test for the effect of year and region separately as the Midlands and Oxford region sites were only sampled in one year. Shade plots were used to depict the relative abundance of different taxa and the SIMPER function was used to identify which taxa were contributing most to any differences. To reduce the impact of very rare species, those only occurring once across all sites were excluded.

3 Results

3.1. Cultivated margin

3.1.1. Pitfall trapping

A total of 5166 Lycosidae (and average of 11.7 per pitfall trap), 3150 Linyphiidae (average 7.1), 19040 adult Carabidae (average 43.2) and 2986 adult Staphylinidae (average 6.8) were recorded on cultivated margins during the project. Carabidae and Staphylinidae larvae were respectively recorded 206 and 235 times, however they were present in less than 25% of pitfall traps, this data was therefore unsuitable for analysis (Figure 3).

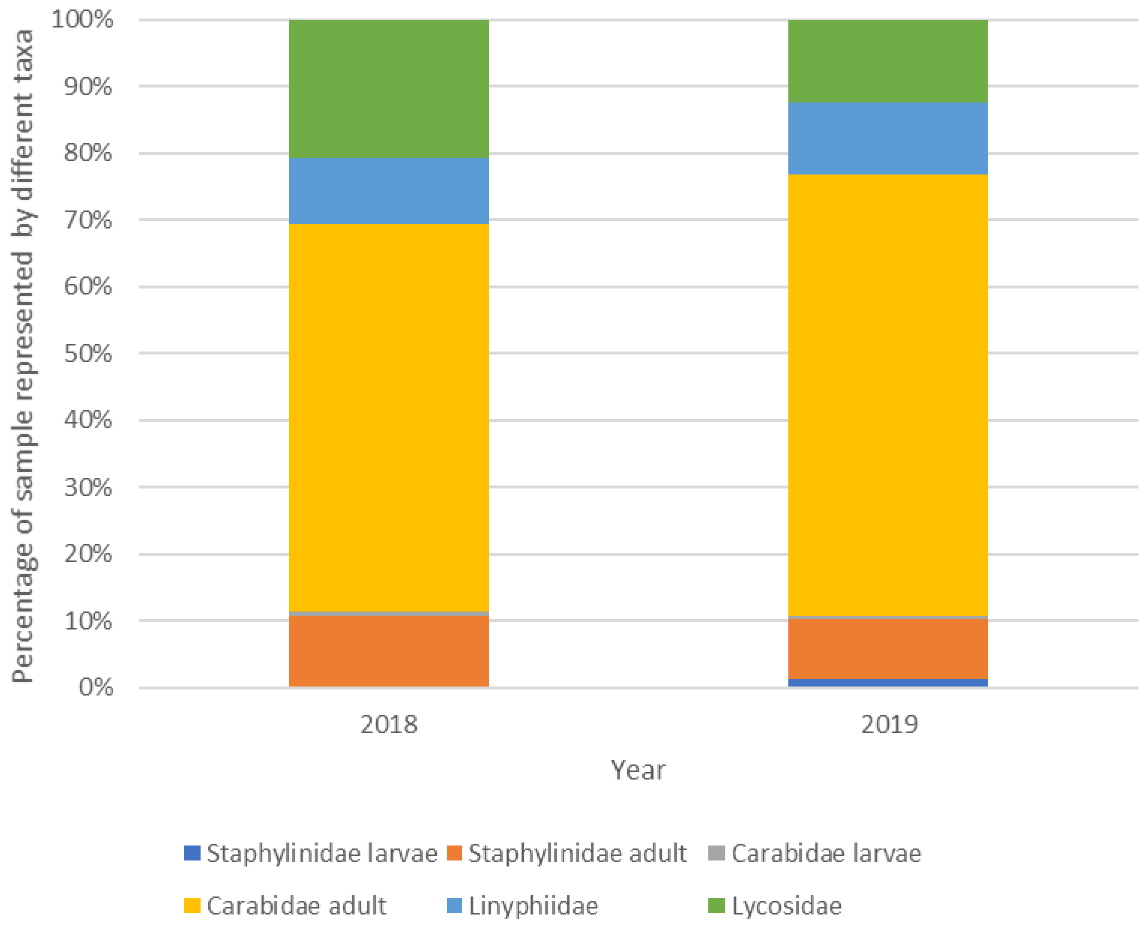

Figure 3. The proportion Staphylinidae larvae, Stapylinidae adult, Carabidae larvae, Carabidae adult, Linyphiidae and Lycosidae present in pitfall traps sampled on cultivated margins in 2018 and 2019.

In cultivated margins the abundance of Lycosidae, Linyphiidae and Staphylinidae declined over the survey period (Table 1), while Carabidae abundance increased over the same period. Staphylinidae abundance was also found to decrease with plot width (Table 1). We found significant non-linear relationships with location (Eastings, Northings) and abundance of all four species groups (Table 1).

In 2018, a total of 52 carabid species were found in the cultivated margins (Appendix VIII). A few common species were widespread across sites. These species are typically found in arable crops, notably *Bembion lampros*, *Ptersotichus melanarius*, *P. madidus*, *Nebria brevicollis* and *Harpalus rufipes*. However, the number of beetle species was much

*Table 1. GAMM model estimates for the effect of cultivated margin management measures on total bee abundance, total bees excluding honey bees (quasipoisson), Bombus species (quasipoisson), hoverflies (quasipoisson) and the occurrence of solitary (binomial) and red-tailed bumblebees (binomial) surveyed along pollinator transects. Survey was included as a random effect. S is used to represent covariates with smooth. K sets the upper limit on the degrees of freedom associated with an S. Equivalent degrees of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.*

	Total bee		**Bee-Honey**		**Bombus species**		**Solitary**		**Red-tailed**		**Hoverfly**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	2.06 ± 1.19	N.S	1.72 ± 1.19	N.S	**-2.09 ± 0.99**	*****	**-1.65 ± 0.64**	*****	**-2.89 ± 0.92**	******	**-1.77 ± 1.01**	*****
Age	-0.44 ± 0.29	N.S	**-0.60 ± 0.29**	*****	**0.56 ± 0.26**	*****	-0.10 ± 0.18	N.S	0.11 ± 0.23	N.S	-0.13 ± 0.18	N.S
Width	-0.01 ± 0.34	N.S	-0.01 ± 0.27	N.S	-0.04 ± 0.16	N.S	0.02 ± 0.13	N.S	0.27 ± 0.15	N.S	**0.50 ± 0.12**	*******
Soil fertility	-0.05 ± 0.42	N.S	0.18 ± 0.27	N.S	0.27 ± 0.17	N.S	0.18 ± 0.12	N.S	0.08 ± 0.15	N.S	-0.15 ± 0.11	N.S
Adjacent cereal (Y)	-0.37 ± 0.73	N.S	-0.74 ± 0.50	N.S	-0.25 ± 0.36	N.S	-0.34 ± 0.26	N.S	-0.88 ± 0.33	N.S	-0.19 ± 0.27	N.S
Boundary type (other)	-0.46 ± 0.55	N.S	-0.63 ± 0.56	N.S	0.54 ± 0.32	N.S	-0.36 ± 0.27	N.S	**-0.12 ± 0.31**	******	0.35 ± 0.28	N.S
Cultivation (Plough)	0.06 ± 0.56	N.S	0.14 ± 0.55	N.S	-0.22 ± 0.31	N.S	**-0.64 ± 0.30**	*****	-0.28 ± 0.33	N.S	0.31 ± 0.23	N.S
Rotational (Y)	**-1.27 ± 0.56**	*****	**-1.62 ± 0.59**	******	-0.26 ± 0.43	N.S	-0.24 ± 0.34	N.S	-0.62 ± 0.45	N.S	0.00 ± 0.29	N.S
Year (2019)	0.99 ± 0.71	N.S	0.72 ± 0.51	N.S	0.67± 0.34	N.S	**0.67 ± 0.26**	*****	0.36 ± 0.30	N.S	**2.78 ± 0.38**	*******
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings, Eastings)	**2**	******	**2**	******	2	N.S	2	N.S	2	N.S	2	**

more than typically found in arable crops, where approximately 20 species may be expected.

There was a significant difference (Figure 4; R=0.28, P=0.004) between the regions in the carabid species composition, with this being largest between the eastern sites and the midlands.

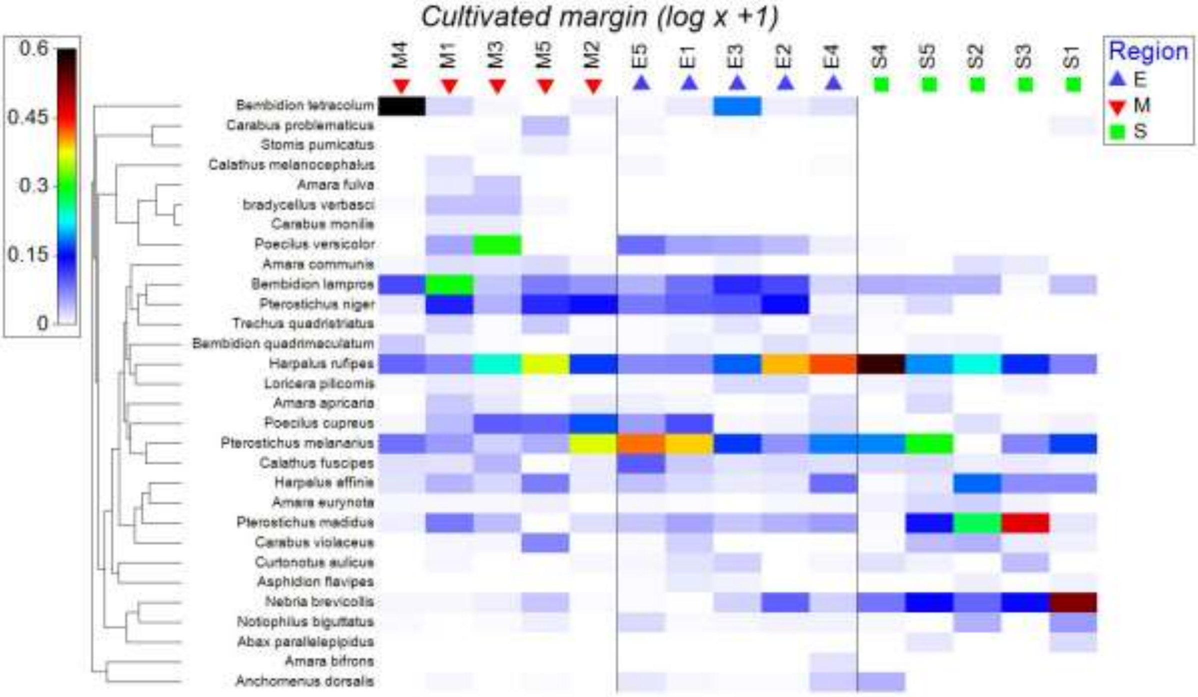

Figure 4. Composition of the carabid species in each cultivated margin site in 2018.

3.1.2. D-vac suction sampling

2562 invertebrates (average of 21.35 per sample) were collected using D-vac suction sampling. Natural enemies comprised 95% (2433) (average of 20.28 per sample, Figure 5) of which approximately 70% were Parasitica and 221 pollinators (average of 1.07, Figure 6). The average number of taxa per sample was 28.1. We summarise the DVac suction sampling results in Appendix IX. The Parasitica are predominantly comprised of parasitic wasps that parasitise other invertebrates, although it also includes those that are hyperparasitoids (parasites of the parasitic wasps) and the Cynipoidea (gall wasps) which are phytophagous. Parasitic wasps are one of the key natural enemies of most field crop pests, see AHDB, Encyclopaedia of pests and natural enemies.

The sum of invertebrates and natural enemies sampled increased with cultivated margin age, however, the abundance of the same two groups declined relative to soil fertility (Table 2). More invertebrates were also recorded on cultivated margins adjacent cereal crops (Table 2). The total number of pollinators recorded was found to significantly correlate with the total number of pest natural enemies recorded in the Dvac suction samples ($p<0.01$; Appendix X).

Cultivation impacted the abundance of three of our invertebrate groups, namely total invertebrates, natural enemies and pollinators, in all models cultivated margins that had been ploughed supported fewer invertebrates compared to minimum tillage (Table 2).

Temporal effects were also present in the data with the sum and diversity of invertebrates, in addition to the number of natural enemies being higher in 2019 compared to 2018. Significant non-linear relationships with location (Eastings, Northings) were present for the sum of invertebrates and natural enemies (Table 2; Appendix XI).

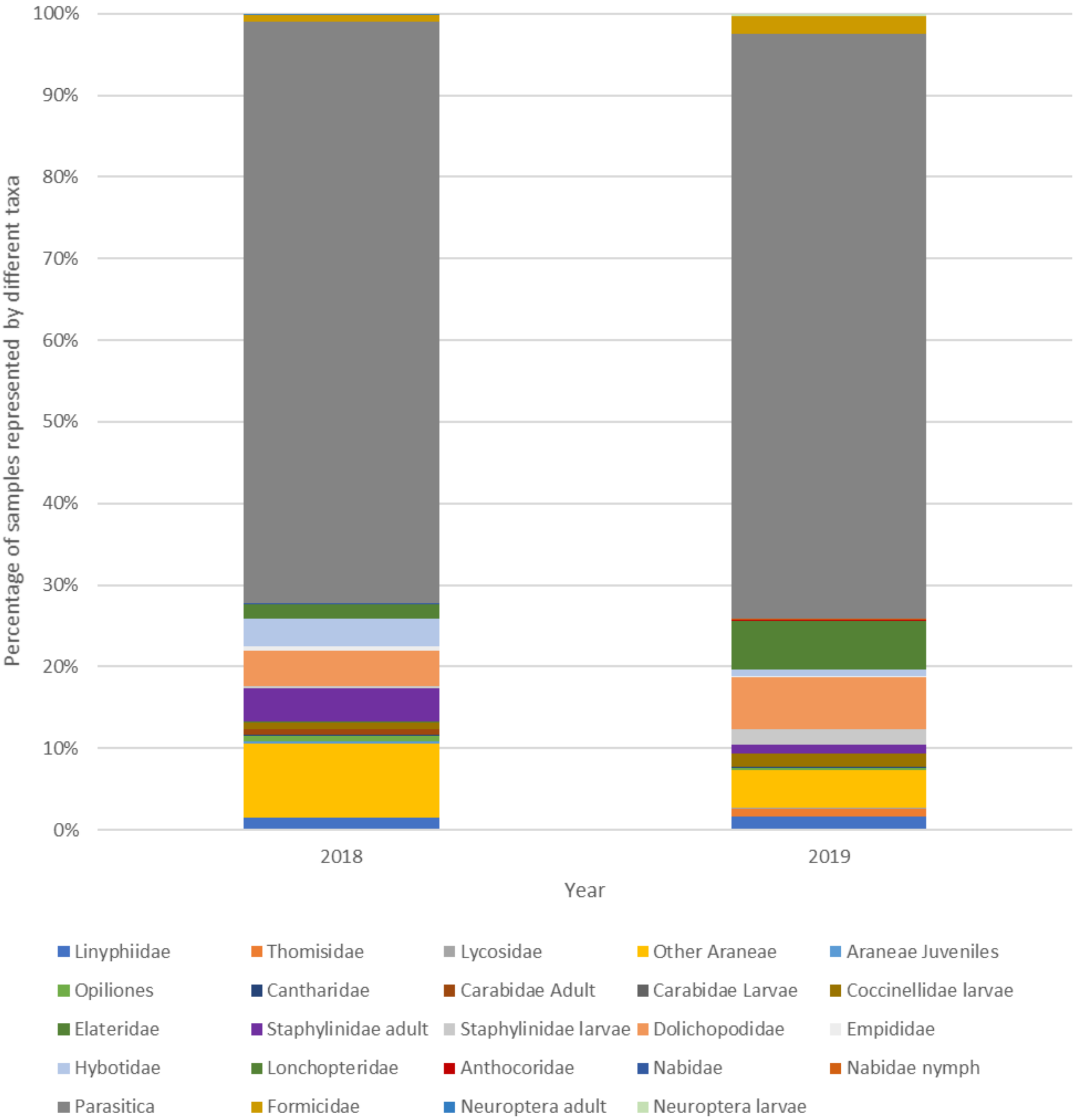

Figure 5. The proportion of each natural enemy taxa present in D-vac samples on cultivated margins in 2018 and 2019. The natural enemy taxa identified were Lyiphiidae, Thomisidae, Lycosidae, Other Araneae, Araneae Juveniles, Opiliones, Cantharidae, Carabidae adult, Carabidae larvae, Coccinellidae larvae, Elateridae, Staphylinidae adult, Staphylinidae larvae, Dolichopoidae, Empididae, Hybotidae, Lonchopteridae, Anthocoridae, Nabidae, Nabidae nymph, Parasitica, Formicidae, Neuroptera adult and Neuroptera larvae.

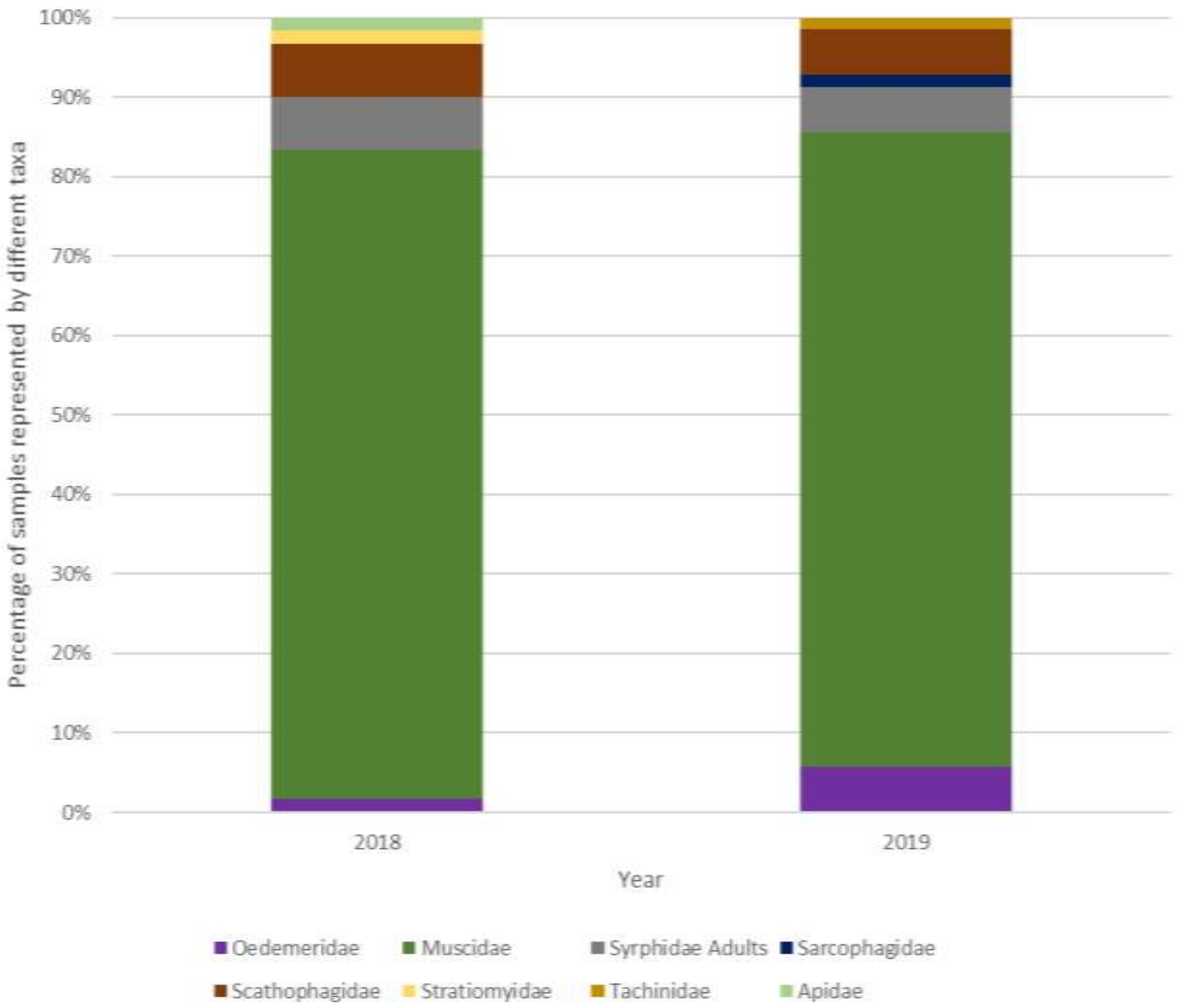

Figure 6. The proportion of each pollinating invertebrate taxa present in pitfall traps on cultivated margins in 2018 and 2019. The pollinators identified in pitfall trap samples were Oedemeridae, Muscidae, Syrphidae Adults, Sarcophagidae, Scathophagidae, Stratiomydae, Tachinidae and Apidae.

*Table 1. GAM model estimates for the effect of cultivated margin management measures on the sum of invertebrates (quasipoisson), diversity of invertebrates (poisson), abundance of natural enemies (quasipoisson) and pollinators (poisson) sampled using D-vac suction sampling. S is used to represent covariates with a smooth. K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model. Equivalent degrees of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.*

	Sum		**Diversity**		**Natural enemies**		**Pollinators**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	**2.28 ± 0.78**	**	**1.37 ± 0.12**	***	**2.25 ± 0.78**	**	-1.00 ± 1.97	N.S
Age	**0.70 ± 0.23**	**	0.05 ± 0.03	N.S	**0.69 ± 0.22**	**	0.81 ± 0.57	N.S
Width	0.24 ± 0.16	N.S	-0.00 ± 0.02	N.S	0.25 ± 0.16	N.S	-0.13 ± 0.39	N.S
Soil fertility	**-0.81 ± 0.24**	***	-0.00 ± 0.02	N.S	**-0.81 ± 0.24**	***	-0.70 ± 0.56	N.S
Adjacent cereal (Y)	**0.98 ± 0.39**	*	-0.02 ± 0.05	N.S	0.96 ± 0.39	N.S	1.28 ± 0.93	N.S
Boundary type (other)	0.13 ± 0.40	N.S	0.01 ± 0.05	N.S	0.11 ± 0.40	N.S	0.56 ± 0.95	N.S
Cultivation (Plough)	**-1.14 ± 0.28**	***	-0.03 ± 0.04	N.S	**-1.12 ± 0.28**	***	**-1.45 ± 0.67**	*
Rotational (Y)	-0.34 ± 0.35	N.S	-0.05 ± 0.05	N.S	-0.34 ± 0.35	N.S	-0.30 ± 0.83	N.S
Year (2019)	**1.69 ± 0.50**	***	**2.52 ± 0.07**	***	**1.66 ± 0.49**	**	1.92 ± 1.21	N.S
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings, Eastings)	**18.86**	***	2	N.S	**18.8**	**	17	N.S

The analysis using ANOSIM (Primer-e) showed that there was no significant difference between years or regions in the invertebrate community. Parasitica were by far the most abundant group of invertebrates at each site. Other abundant and widespread groups were Dolichopodidae (long-legged flies), the other Araneae (spiders), Staphylinidae and Coccinellidae (Figure 7). All of the aforementioned taxa are considered pest natural enemies and therefore capable of contributing to pest control. Muscidae (house flies) were also widespread and abundant.

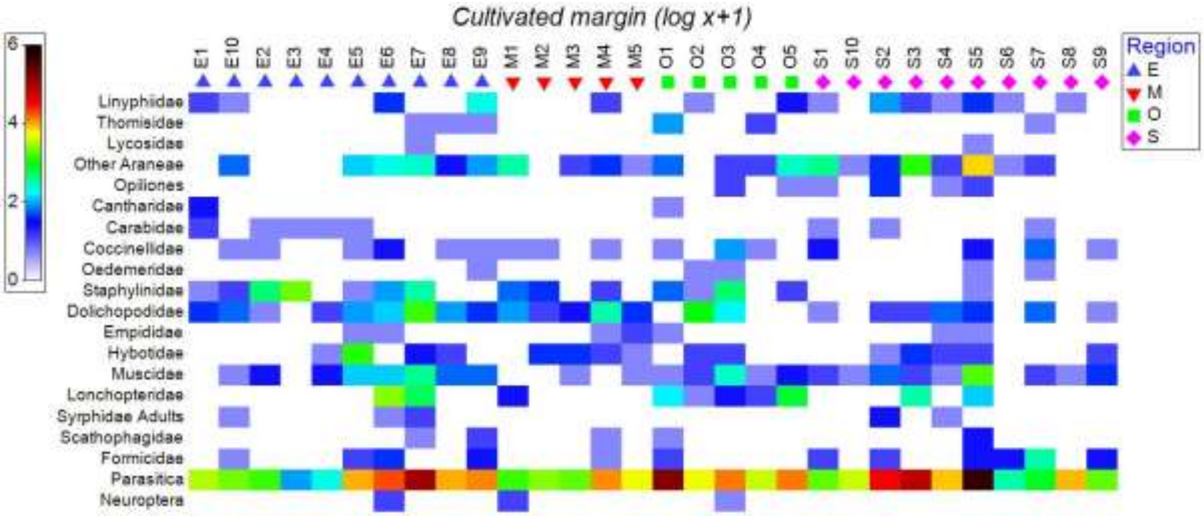

Figure 7. Composition of the invertebrate taxa in D-vac samples for each cultivated margin site in 2018 and 2019.

3.1.3. Pollinator transects

1070 bees were recorded on cultivated margins over the project, 10% (109) of which were honeybees. Of the wild bees 34% (322) were *Bombus* species (figure 8) and 66% (635) were solitary bees (figure 9). Syrphidae (hoverflies) were the most abundant taxa (1480) with an average of 8.2 per survey. The pollinator transect data is summarised in Appendix XII.The bumblebees were comprised of the six most common and widespread species, of which *Bombus pascuorum*, *B. terrestris/lucorum* and *B. lapidarius* were the most frequently observed. The cultivated margins were visited by a wide range of solitary bee families and comprised a greater proportion of the bee community compared to the floristic margins. The presence of the different families of solitary bee differs considerably over the monitoring period as workers are shorter lived and more seasonal in activity compared to bumblebees, typically activity period was 2-3 months.

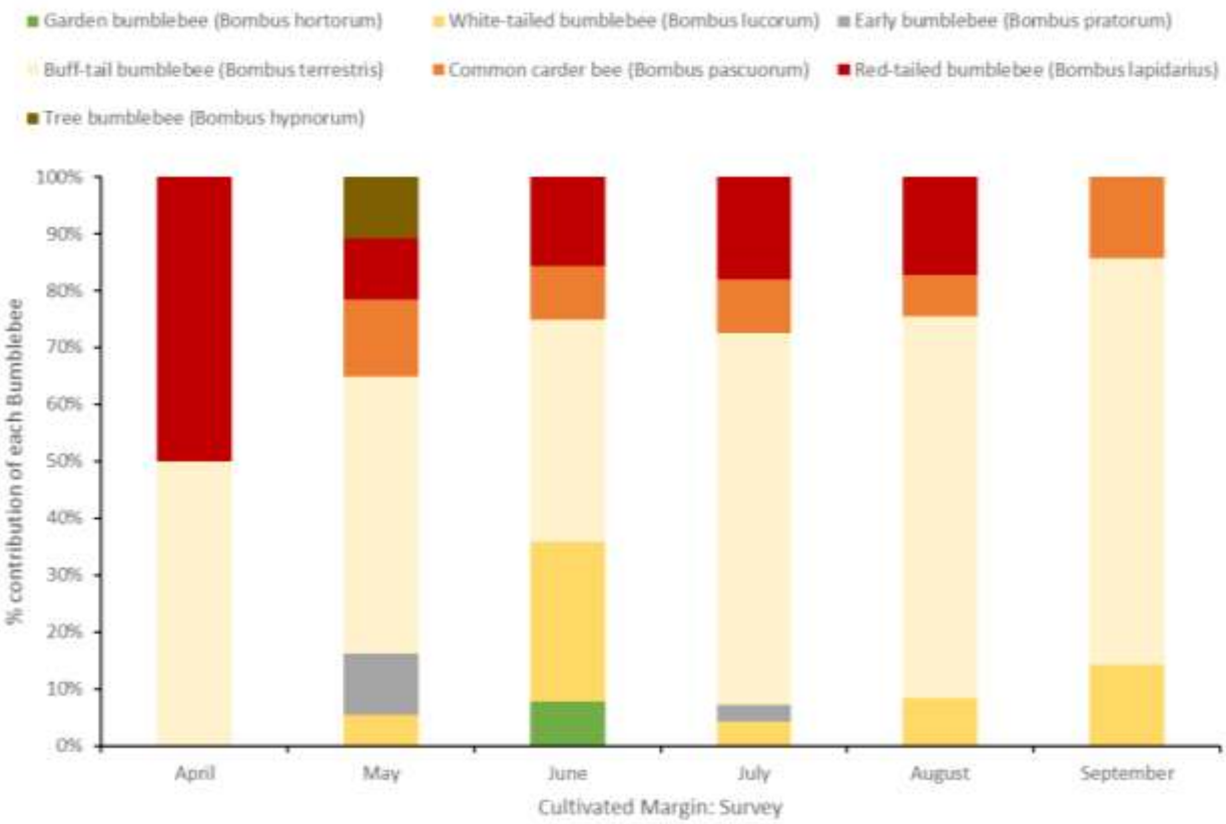

Figure 8. Average proportion of each bumblebee species present in during monthly pollinator walks (April – September) along cultivated margins. The bumblebee species recorded were garden bumblebee, white-tailed bumblebee, early bumblebee, buff-tail bumblebee, common carder bee, red-tailed bumblebee and tree bumblebee.

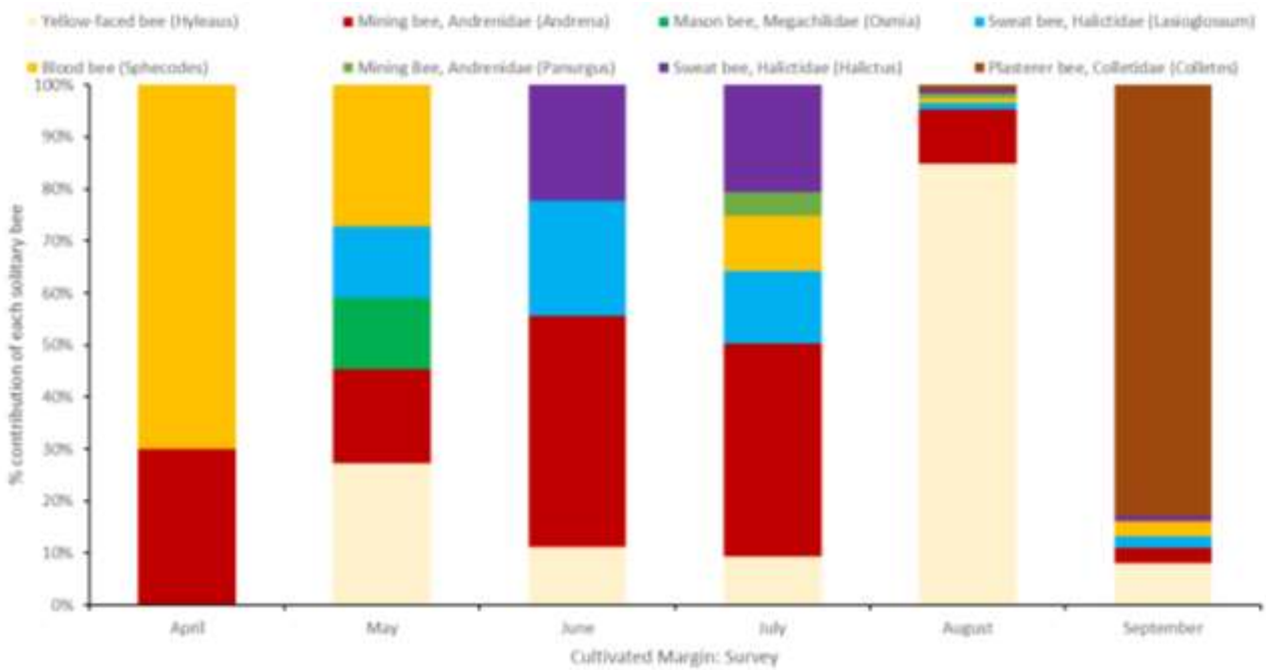

Figure 9. Average proportion of each solitary bee taxa present in during monthly pollinator walks (April – September) along cultivated margins. Solitary bee taxa recorded were Hyleaus, Andrena, Osmia, Lasioglossum, Sphecodes, Panurgus, Halicidae and Colletes.

The GAM analysis revealed opposing correlations with margin age for the total number of bees excluding honeybees and *Bombus* species, the former declined with margin age and the later increased (Table 3). The number of Syrphidae recorded on survey transects was found to increase relative to margin width (Table 3). *Bombus lapidarius* were significantly more likely to be present on margins adjacent to hedgerows (Table 3). Ploughing was negatively associated with the presence of solitary bees (Table 3). Compared to non-rotational margins, rotational margins supported significantly fewer bees and bees minus *Apis mellifera* (honeybees) (Table 3).

There was a significant impact of location on the abundance of bees excluding honeybees, *Bombus* species and hoverflies (Table 3). Temporal effects were only present for solitary bees, which were more abundant in 2019 compared to 2018 (Table 3).

There was a significant difference between years in the pollinator community (ANOSIM results R=0.36, P=0.001), but not between the regions. Syrphidae (hoverflies), *Andrena* spp. (mining bees), *B. terrestris/lucorum* (buff-tailed/white-tailed bumblebees), *B. lapidarius* (red-tailed bumblebee) and *B. pascuorum* (common carder bee) contributed to 72% of the difference between years. In 2019 compared to 2018, Syrphidae were 8x, *Andrena* spp. 20x, *B. terrestris/lucorum* 3x and *B. lapidarius* 3.2x more abundant while there were 1.4x more *B. pascuorom* in 2018.

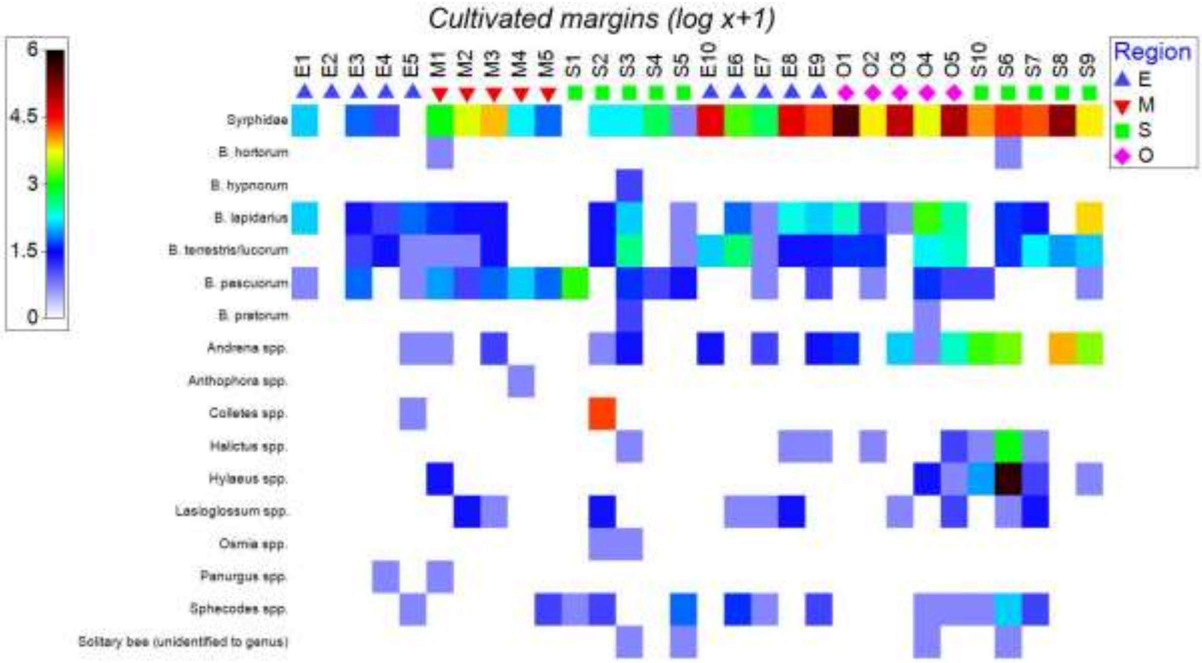

Figure 10. Composition of the pollinator taxa at each cultivated margin site in 2018 (sites 1-5) and 2019 (sites 6-10).

In 2018, 286 plant forage visits undertaken by *Bombus* spp. were recorded, representing 6 species, although only three taxa were common (Figure 11). *Cirsium vulgare* (spear thistles) and *Crepis vesicaria* (beaked hawk's-beard) were the most commonly used plants, representing 60, 52, 32 and 27 foraging visits respectively. Other well foraged plants were *Lotus corniculatus* (bird's-foot trefoil), *Taraxacum* species (dandelions) and *Chrysanthemum segetum* (corn marigold). Species-specific preferences were also evident (Figure 11). Only single individuals of *B. pratorum* and *hortorum* were observed. 1310 foraging visits by Syrphidae were recorded on cultivated margins in 2018 (Figure 12). The plants more frequently foraged on were *Taraxacum* spp. (dandelions) (328 visits), *Leucanthemum vulgare* (ox-eye daisy) (235 visits) and *Glebionis segetum* (corn marigold) (174 visits). 509 foraging visits by solitary bees were recorded in 2018. Although 278 of these visits were to *Sonchus oleraceus* (common sowthistle) by yellow-faced bees on a survey on farm S6. *D*andelions were the next most visited plants by solitary bees (n=82), followed by beaked hawk's-beard (n=44, Figure 13).

*Table 2. GAMM model estimates for the effect of cultivated margin management measures on total bee abundance, total bees excluding honey bees (quasipoisson), Bombus species (quasipoisson), hoverflies (quasipoisson) and the occurrence of solitary (binomial) and red-tailed bumblebees (binomial) surveyed along pollinator transects. Survey was included as a random effect. S is used to represent covariates with smooth. K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model. . Equivalent degrees of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.*

	Total bee		**Bee-Honey**		**Bombus species**		**Solitary**		**Red-tailed**		**Hoverfly**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	2.06 ± 1.19	N.S	1.72 ± 1.19	N.S	**-2.09 ± 0.99**	*****	**-1.65 ± 0.64**	*****	**-2.89 ± 0.92**	******	**-1.77 ± 1.01**	*****
Age	-0.44 ± 0.29	N.S	**-0.60 ± 0.29**	*****	**0.56 ± 0.26**	*****	-0.10 ± 0.18	N.S	0.11 ± 0.23	N.S	-0.13 ± 0.18	N.S
Width	-0.01 ± 0.34	N.S	-0.01 ± 0.27	N.S	-0.04 ± 0.16	N.S	0.02 ± 0.13	N.S	0.27 ± 0.15	N.S	**0.50 ± 0.12**	*******
Soil fertility	-0.05 ± 0.42	N.S	0.18 ± 0.27	N.S	0.27 ± 0.17	N.S	0.18 ± 0.12	N.S	0.08 ± 0.15	N.S	-0.15 ± 0.11	N.S
Adjacent cereal (Y)	-0.37 ± 0.73	N.S	-0.74 ± 0.50	N.S	-0.25 ± 0.36	N.S	-0.34 ± 0.26	N.S	-0.88 ± 0.33	N.S	-0.19 ± 0.27	N.S
Boundary type (other)	-0.46 ± 0.55	N.S	-0.63 ± 0.56	N.S	0.54 ± 0.32	N.S	-0.36 ± 0.27	N.S	**-0.12 ± 0.31**	******	0.35 ± 0.28	N.S
Cultivation (Plough)	0.06 ± 0.56	N.S	0.14 ± 0.55	N.S	-0.22 ± 0.31	N.S	**-0.64 ± 0.30**	*****	-0.28 ± 0.33	N.S	0.31 ± 0.23	N.S
Rotational (Y)	**-1.27 ± 0.56**	*****	**-1.62 ± 0.59**	******	-0.26 ± 0.43	N.S	-0.24 ± 0.34	N.S	-0.62 ± 0.45	N.S	0.00 ± 0.29	N.S
Year (2019)	0.99 ± 0.71	N.S	0.72 ± 0.51	N.S	0.67± 0.34	N.S	**0.67 ± 0.26**	*****	0.36 ± 0.30	N.S	**2.78 ± 0.38**	*******
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings, Eastings)	**2**	******	**2**	******	2	N.S	2	N.S	2	N.S	2	**

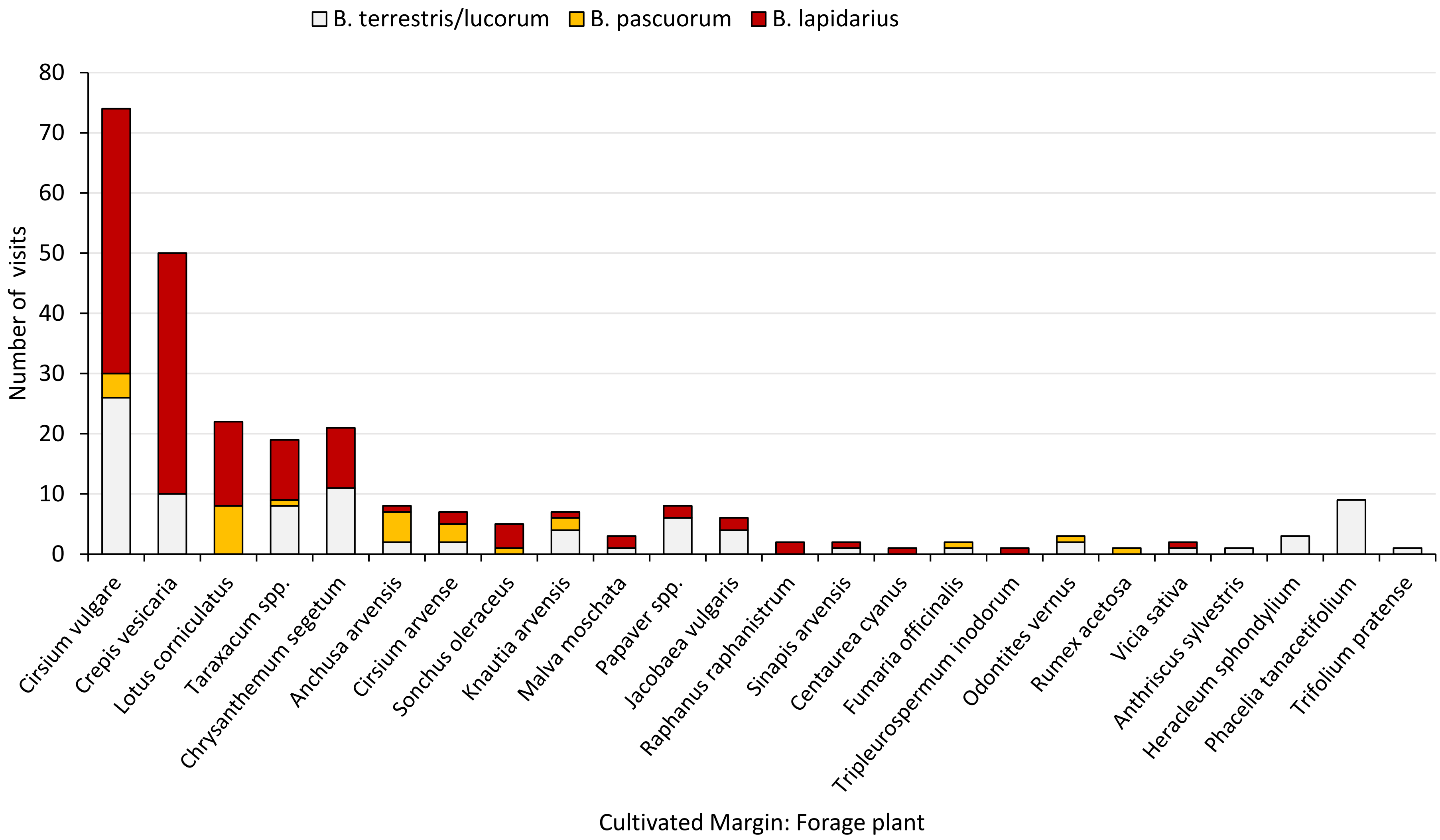

Figure 11. Total number of observed visits by *Bombus terrestris/lucourum, B. pascuorum, B. pratorum* and *B. lapidarius* to each plant species in cultivated margins in 2018 and 2019.

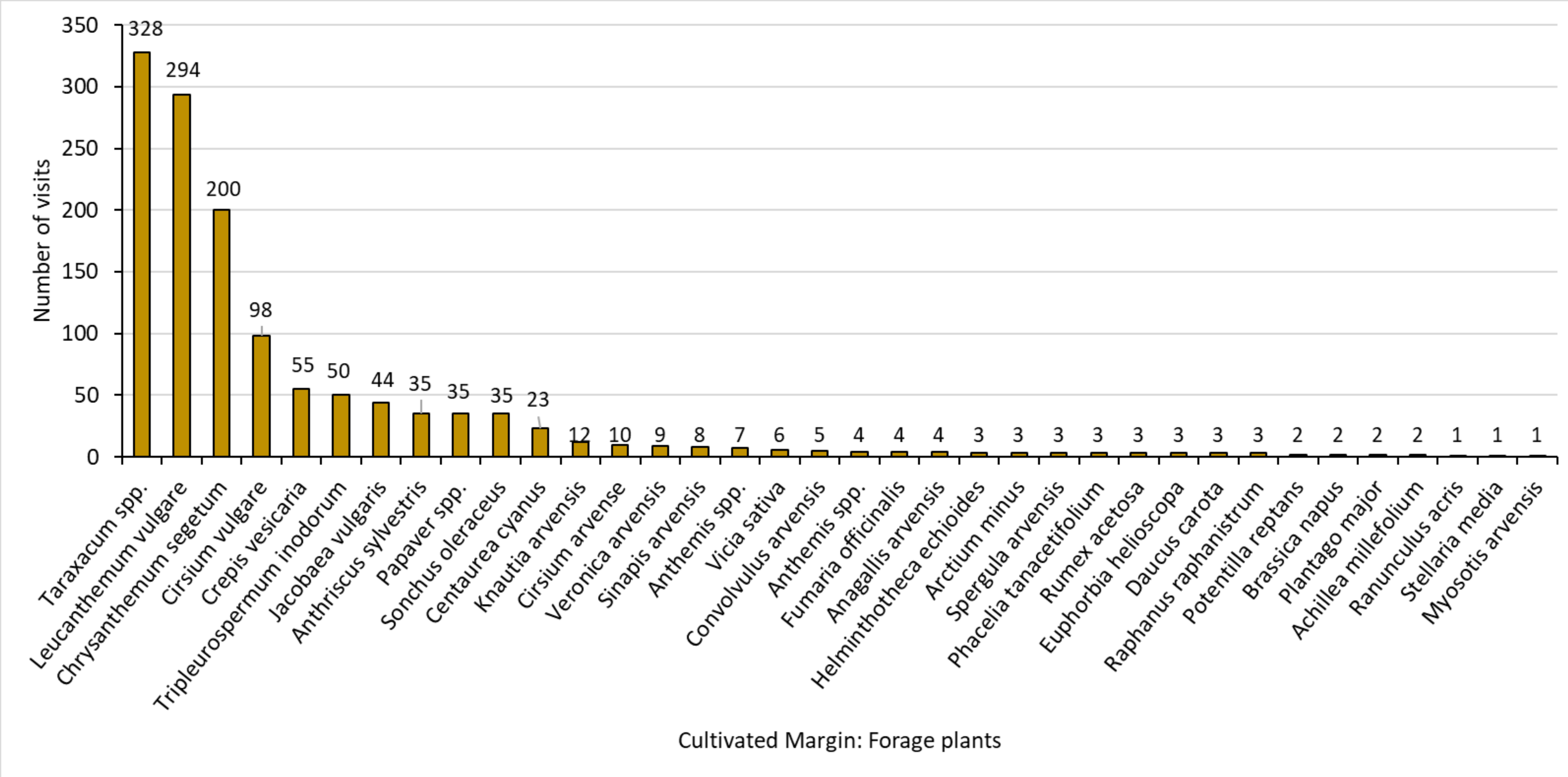

Figure 12. Total number of observed visits by hoverflies to each plant species in cultivated margins in 2018 and 2019.

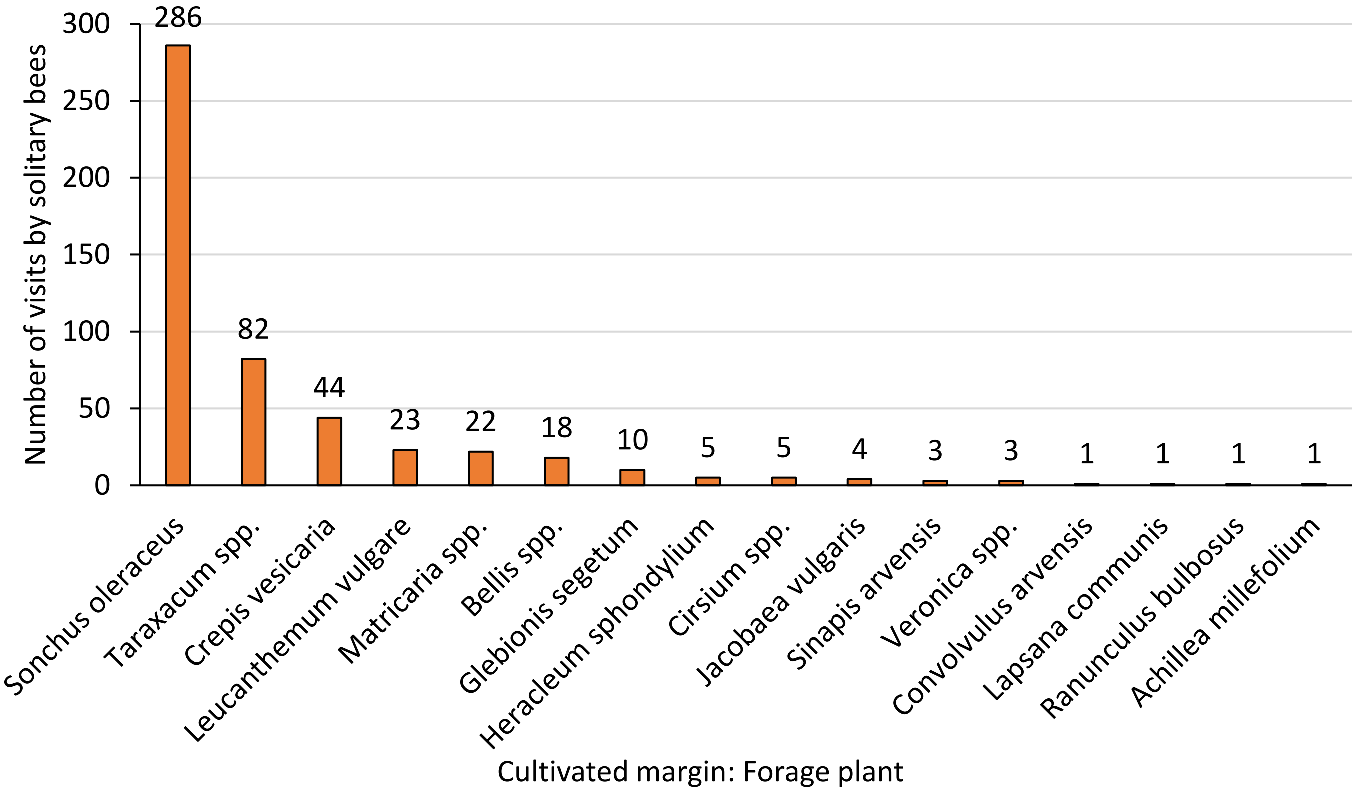

Figure 13. Total number of observed visits by solitary bees to each plant species in cultivated margin in 2018 and 2019.

3.1.4. Vegetation characteristics

A range of management measures and habitat characteristics were found to influence the vegetative characteristics of cultivated margins. Cultivation by ploughing had lower grass cover, vegetation height and vegetation density but had higher bare ground cover (Table 4). Rotational margins were characterised by having fewer flower heads, lower broad-leaved species cover and shorter vegetation height compared to non-rotational margins (Table 4)

Vegetation density was found to increase with margin age and bare ground cover declines (Table 4). A negative correlation was evident between broad leaved species cover and cultivated margin width (Table 4).

Annual variance was evident in a number of the vegetation characteristics measured. The number of flower heads and vegetation density was higher in 2019 than in 2018. The majority of vegetative characteristics, all bar the number of flower heads and vegetation height, showed significant non-linear relationships with location (Eastings, Northings) (Table 4).

Table 3. GAMM model estimates for the effect of cultivated margin management measures on the number of flower heads (quasipoisson), grass cover (quasipoisson), broad leaved species cover (quasipoisson), bare ground cover (quasipoisson), height cover (gaussian) and density (gaussian) surveyed along pollinator transects. Survey was included as a random effect. Height and density were log+1 tranformed. S is used to represent covariates with smooth K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model.. Equivalent degrees of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.

	Flower heads		**Grass cover**		**Broad leaved species**		**Bare ground**		**Height**		**Density**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	**2.76 ± 0.80**	*******	2.44 ± 1.67	N.S	**4.00 ± 0.46**	*******	**3.47 ± 0.58**	*****	**3.34 ± 0.52**	*******	**1.53 ± 0.51**	******
Age	-0.33 ± 0.21	N.S	0.61 ± 0.48	N.S	-0.13 ± 0.13	N.S	**-0.36 ± 0.18**	*****	0.12 ± 0.13	N.S	**0.29 ± 0.14**	*****
Width	-0.10 ± 0.14	N.S	0.11 ± 0.35	N.S	**-0.21 ± 0.09**	*****	-0.07 ± 0.12	N.S	-0.14 ± 0.08	N.S	0.50 ± 0.12	N.S
Soil fertility	-0.02 ± 0.13	N.S	-0.54 ± 0.51	N.S	0.11 ± 0.08	N.S	0.21 ± 0.15	N.S	-0.09 ± 0.10	N.S	-0.09 ± 0.12	N.S
Adjacent cereal (Y)	-0.17 ± 0.26	N.S	0.31 ± 0.83	N.S	0.05 ± 0.16	N.S	0.22 ± 0.26	N.S	0.19 ± 0.18	N.S	0.17 ± 0.21	N.S
Boundary type (other)	0.18 ± 0.19	N.S	-1.33 ± 0.86	N.S	0.21 ± 0.17	N.S	0.23 ± 0.26	N.S	0.09 ± 0.19	N.S	-0.12 ± 0.21	N.S
Cultivation (Plough)	0.13 ± 0.28	N.S	**-2.16 ± 0.59**	*******	-0.31 ± 0.17	N.S	**0.54 ± 0.22**	*****	**-0.73 ± 0.16**	*******	**-0.82 ± 0.17**	*******
Rotational (Y)	**-0.76 ± 0.37**	*****	0.53 ± 0.76	N.S	**-1.00 ± 0.22**	*******	0.37 ± 0.28	N.S	**-0.46 ± 0.20**	*****	-0.30 ± 0.22	N.S
Year (2019)	**0.72 ± 0.26**	******	1.43 ± 1.05	N.S	0.29± 0.15	N.S	-0.20 ± 0.32	N.S	0.48 ± 0.22	N.S	**0.73 ± 0.26**	******
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings, Eastings)	2	N.S	**19.62**	*******	**2**	*****	**11.95**	******	2	N.S	**2**	******

3.1.5. Species composition

Region (p<0.001) and year (p<0.01) were identified as significant factors in explaining cultivated margin ground flora composition. The first ordination separated species occurring in Oxford (positive scores) from species in the Midlands (negative scores), whist the second ordination separated species occurring in the South (negative scores) from species in the East (positive score). Species which occurred in 2019 (Yearb) were best described by positive scores for CAA1 and CAA2, while species which occurred in 2018 were best described by negative scores for CAA2 and CAA2 (figure 14). The grass and dicot species recorded in each region are summarised in Appendix XIII and XIV.

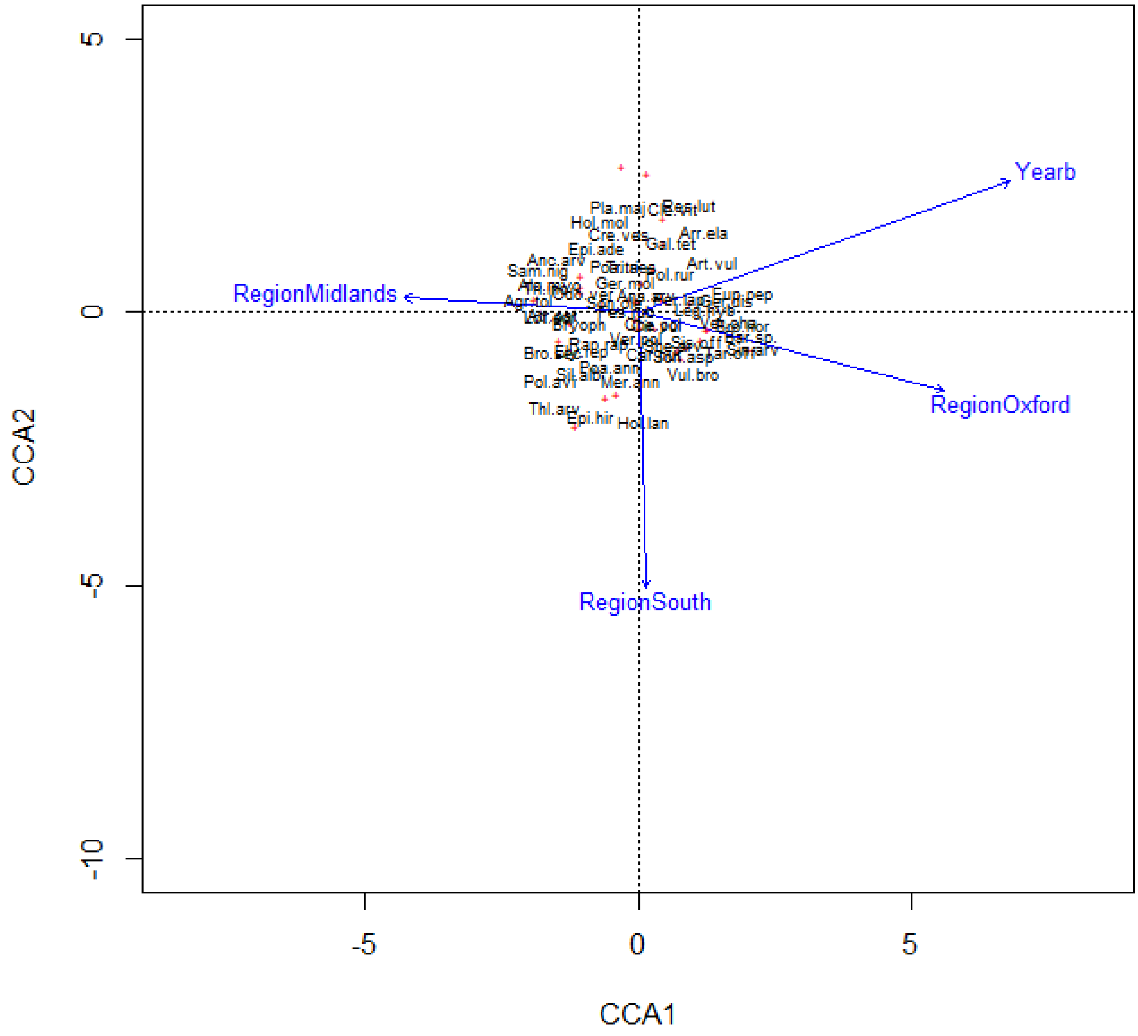

Figure 14. CAA ordinations for cultivated margins; site = red crosses; codes refer to scientific names of species; year (a/b), region (north, south, east, midlands), rotational (yes/no), cultivation type (minimum till/plough), broad soil type (chalk, heavy, medium, sandy), broad adjacent habitat (hedge/other), adjacent cereal crop (Y/N) are superimposed as vectors.

3.1.6. Uncommon arable plant species

Species included on the list for evaluating Plantlife's Important Arable Plant Areas (IAPAs; Byfield & Wilson, 2005) were found at 25 of the 29 farms where cultivated margins were surveyed (Table 5). The IAPA scoring system is based on a synthesis of measures of conservation value for rare and uncommon plants, including IUCN status (critically endangered, endangered, vulnerable, near threatened), Nationally Rare (Wigginton, 1999), Nationally Scarce (Stewart et al, 1994) and other declining species (Preston et al, 2002). Species scores range from one to nine, and can be added to give a site score which can then be evaluated in a regional, national of international context. This system is subject to occasional review, and a current updated version can be found at https://www.plantlife.org.uk/application/files/4515/1784/3813/IAPA_List_and_Scores_GB-Wales-England.pdf. Scores for species recorded in this survey are given in Appendix ……

Of these, farm O4 is of European importance, O5 is of national importance and ten further margins are of regional importance. One species, *Galeopsis angustifolium*, is listed on Section 41 of the NERC Act (2007) and is considered to be Critically Endangered in the Vascular Plant Red List, while *Valerianella dentata* is Endangered (Cheffings & Farrell, 2004). Both of these species were present on O4.

Table 4. Important Arable Plant Area species recorded in cultivated margins on the surveyed farms. Species in brackets not recorded in quadrats.

Site code	***IAPA species***	***IAPA score***
E1	*Raphanus raphanistrum, Spergula arvensis (Papaver argemone)*	15
E10	*Silene noctiflora*	7
E2	*Anchusa arvensis, Geranium pusillum, Spergula arvensis*	10
E3	*Glebionis segetum, Raphanus raphanistrum, (Filago vulgaris)*	14
E4	*Anchusa arvensis, Geranium pusillum, Silene noctiflora, Spergula arvensis*	17
E5	*Anchusa arvensis*	1
E6	*Filago vulgaris, Geranium pusillum, Raphanus raphanistrum*	9
E7	*Raphanus raphanistrum (Anchusa arvensis)*	2
E8	*Anchusa arvensis, Geranium pusillum, Silene noctiflora, Spergula arvensis*	17
E9	*Filago vulgaris*	6
M1	*Anchusa arvensis, Glebionis segetum, Erodium cicutarium, Geranium pusillum, Lamium amplexicaule, Spergula arvensis*	19
M2	*Chenopodium polyspermum*	2

M3	*Anchusa arvensis, Erodium cicutarium, Lamium amplexicaule, Spergula arvensis (Filago vulgaris, Lamium hybridum)*	16
M4	*Anchusa arvensis, Erodium cicutarium, Geranium pusillum, Lamium amplexicaule (Spergula arvensis)*	12
M5		0
O1	*Raphanus raphanistrum*	1
O2	*Anthriscus caucalis, Apera spica-venti, Geranium pusillum, Papaver hybridum, Torilis nodosa*	17
O3	*Glebionis segetum, Silene noctiflora, Spergula arvensis, Chaenorhinum minus, Sherardia arvensis (Raphanus raphanistrum). Sown species Centaurea cyanus, Agrostemma githago*	21
O4	*Euphorbia exigua, Kickxia spuria, Legousia hybrida, Papaver dubium ssp lecoquii, Sherardia arvensis, Silene noctiflora, Valerianella dentata, Galeopsis angustifolia, Geranium columbinum, Kickxia elatine)*	44
O5	*Glebionis segetum, Geranium pusillum, Raphanus raphanistrum, Silene noctiflora, Stachys arvensis (Euphorbia exigua, Sherardia arvensis)*	30
S1		0
S10		0
S2	*Anthemis cotula, Euphorbia exigua, KIckxia spuria, Sherardia arvensis*	17
S3	*Euphorbia exigua, Scandix pecten-veneris, Sherardia arvensis, (Orobanche minor)*	18
S4	*(Chenopodium ficifolium, Chaenorhinum minus)*	3
S5		0
S6	*Anthemis cotula, Chaenorhinum minus, Chenopodium polyspermum, Kickxia spuria, Legousia hybrida, Sherardia arvensis, (Polygonum rurivagum, Fumaria densiflora)*	23
S7	*Lamium amplexicaule, Legousia hybrida, Polygonum rurivagum, Sherardia arvensis, Veronica polita, (Kickxia elatine)*	12
S9	*Lamium amplexicaule, Sherardia arvensis*	2

3.1.7. Species Detrimental to Field-margin Condition

Potentially competitive (Grime et al, 2008) species, including many widely considered by agronomists and farmers to be agricultural problems, were a feature of most of the field margins surveyed. The principal species are listed in Table 6. The most frequently recorded species (with more than 1% cover in a margin) were *Cirsium arvense* (14 margins), *Sonchus arvensis* (9 margins), *Sonchus asper/oleraceus* (8 margins), *Bromus diandrus*, *Holcus lanatus*, *Agrostis stolonifera* and *Artemisia vulgaris* (6 margins; Table 7).

Total cover of detrimental species ranged from <5% at three sites which had been cultivated very late in the spring, to more than 70% at two sites. There was no association between the presence of rare species and the frequency or cover of detrimental species, Spearman's rank correlation test gave an S value of 4036.4 with P=0.98.

Table 5. Species potentially detrimental to the botanical species-richness of cultivated margins recorded during this project. Life form and Ellenberg N (fertility) Index (Hill et al, 1999).

Species	***Life form***	***Ellenberg N value***
Arrhenatherum elatius	*Tussock-forming/bulbous perennial*	*7*
Avena fatua	*Annual grass*	*7*
Agrostis gigantea	*Rhizomatous perennial*	*7*
Arctium minus	*Tap-rooted perennial*	*8*
Alopecurus myosuroides	*Annual grass*	*6*
Agrostis stolonifera	*Stoloniferous perennial*	*6*
Artemisia vulgaris	*Rhizomatous perennial*	*7*
Bromus diandrus	*Annual grass*	*4*
Bromus hordaceus	*Annual grass*	*4*
Bromus sterilis	*Annual grass*	*7*
Cirsium arvense	*Rhizomatous perennial*	*6*
Convolvulus arvensis	*Rhizomatous perennial*	*6*
Dactylis glomerata	*Tussock-forming perennial*	*6*
Equisetum arvense	*Rhizomatous perennial*	*6*
Elymus repens	*Rhizomatous perennial*	*7*
Galium aparine	*Annual*	*8*
Helminthotheca echioides	*Tap-rooted perennial*	*6*
Heracleum sphondylium	*Tap-rooted perennial*	*7*
Lolium multiflorum	*Crop relic*	*7*
Lolium perenne	*Crop relic*	*6*
Ranunculus repens	*Stoloniferous perennial*	*7*

Sonchus arvensis	*Rhizomatous perennial*	*6*
Sonchus asper	*Annual*	*6*
Sonchus oleraceus	*Annual*	*7*
Taraxacum spp.	*Tap-rooted perennial*	*6*
Trifolium repens	*Stoloniferous perennial*	*6*

Table 6. Species potentially detrimental to the botanical species-richness of cultivated margins recorded in the 2018 and 2019 surveys. Ac Agrostis capillaris, Ae Arrhenatherum elatius, Af Avena fatua, Ag Agrostis gigantea, Ami Arctium minus, Amy Alopecurus myosuroides, As Agrostis stolonifera, Av Artemisia vulgaris, Bd Bromus diandrus, Bh Bromus hordaceus, Bs Bromus sterilis, Bsy Brachypodium sylvaticum, Ca Cirsium arvense, Car Convolvulus arvensis, Cv Cirsium vulgare, Dg Dactylis glomerata, Ea Equisetum arvense, Er Elymus repens, Fr Festuca rubra, Ga Galium aparine, He Helminthotheca echoides, Hl Holcus lanatus, Hr Hypochaeris radicata, Hs Heracleum sphondylium, Lp Lolium perenne and multiflorum, Pl Plantago lanceolata, Rc Rumex crispus, Ro Rumex obtusifolius, Rr Ranunculus repens, Sar Sonchus arvensis, Sas Sonchus asper and oleraceus, Sj Senecio jacobaea, Ta Taraxacum spp., Tr Trifolium repens.

	Undesirable species	***Total % cover of undesirable species***
E1	*Ca*	*16.5*
E10	*Sas, Ca, Sar,*	*8.4*
E2		*2.1*
E3		*0.9*
E4	*Sa, Ca*	*4.0*
E5	*Av, Sar, Er, As, Ca, Bs, Bd*	*68.0*
E6	*Hl, As, Ea, Cv, Ae*	*27.9*
E7	*Car, Hl, Er, Ca, Ae, Pl, Fr, As*	*66.6*
E8	*Ae, Hl, Fr, Ca, Dg, Ac*	*34.0*
E9	*Hl, Ac, Bd, As, Hr, Sj*	*43.7*
M1	*As, Ag, Tr, Av, Ca*	*72.9*
M2	*Bh, Ta, Sar, Hl, Ac, Rr, Ca, Ro, Dg, As, Tr*	*46.0*
M3	*Tr, Av, Ca, Hl, As, Sar, Ami,*	*53.0*
M4	*Ag, Hl, Bh, Lp, Av, Ca, Sas, Bs*	*61.6*
M5	*Am*	*29.1*
O1	*Ae, Af, Hl, Rr, He*	*38.5*

O2	*Bd, Af, Ga*	*74.6*
O3	*Av*	*5.2*
O4	*Er, Sar, Av*	*30.2*
O5	*Ca, Sar*	*15.9*
S1		*0.6*
S10	*Sas*	*8.4*
S2	*Ca, Ta, Lp, Amy, Bd, Sar, Rr*	*52.8*
S3	*Bd, Ca, Tr, Sar, Ami, Sas, Bs, Rr*	*55.1*
S4	*Sas, Lp,*	*11.7*
S5	*Tr, Bsy, Ae, As, Bs, Hs, Rr, Bh, Lp, Dg*	*54.6*
S6	*Bd, Sar, Sas,*	*24.2*
S7	*Sas*	*5.1*
S8		*0*
S9	*Bs, Sar, Ca, Rc*	*54.7*

3.1.8. Relationships between vegetation and environmental factors in cultivated margins

Analysis of vegetation composition with respect to the following variables: time of cultivation (autumn/spring), soil type (chalk, clay/loam, sand), cultivation type (ploughing, minimum tillage), age of margin option, rotational/permanent, year of survey (2018, 2019), geographical location (Norfolk, Southern England, Oxfordshire, Midlands), presence of an adjacent hedge and presence of an adjacent cereal crop. The Canonical Correspondence Analysis in the Canoco 5.1 (ter Braak & Smilauer, 2018) package showed that the only statistically significant relationships were with geographical location (Southern England $P<0.01$; Norfolk $P<0.01$; Oxfordshire $P<0.05$), soil type (sand $P<0.01$; chalk $P<0.01$) and year ($P<0.05$). These relationships are illustrated in Figures 15 - 18

Figure 15 shows separation of polygons including Plantlife IAPA species typical of chalky soils from those typical of sandy soils. Figure 16 shows separation of polygons enclosing perennial species (Grime et al, 1988), typically autumn-germinating species and typically spring-germinating species.

Figures 17 and 18 show relationships between sites and environmental variables. Figure 17 separates polygons of sites on chalky and sandy soils. Anomalous sites are indicated. These include E9 where there was a strong maritime influence, O2 where the soil was calcareous sand and S1 where the site had been treated with herbicide. Figure 18 shows field margins cultivated in autumn and spring.

Frequencies of species were analysed with respect to the environmental variables: time of cultivation (autumn/spring), soil type (chalk, clay/loam, sand), and cultivation type (ploughing, minimum tillage). Only those 63 species with occurrences in more than five margins were included. Composite measures of frequency including rhizomatous weeds, *Bromus sterilis* + *diandrus*, perennial grasses, other perennial species and IAPA score were also examined. Tables 8, 9 and 10 include significant results only (probabilities; * P<0.05, **P<0.01, ***P<0.001).

Of those species for which results were significant, all seven were more frequent in autumn cultivated margins than in spring-cultivated margins and of these two were pernicious grass weeds (*Alopecurus myosuroides and Bromus sterilis* + *diandrus*) (Table 8). The perennials *Taraxacum* spp. and *Agrostis stolonifera* were more frequent after minimum tillage, while the annuals *Atriplex patula, Fumaria officinalis, Lamium hybridum, Persicaria maculosa* and *Silene noctiflora* were more frequent after ploughing. The summed frequency of all perennial grass species was also significantly higher in minimum-tilled margins (Table 9). Only four species showed significant soil preferences (Table 10). *Agrostis stolonifera* was most frequent on sandy soils, *Helminthotheca echioides* was most frequent on clay/loam soils and *Sherardia arvensis* and *Sinapis arvensis* were more frequent on chalky soils.

Table 7. Frequency of species in cultivated margins after spring and autumn cultivations (Probabilities* P<0.05, **P<0.01, ***P<0.001).

Species	***Spring cultivated***	***Autumn cultivated***	***P***
Alopecurus myosuroides	1.37	5.20	*
Arenaria serpyllifolia	0.63	4.00	*
Crepis capillaris	0.05	3.60	*
Medicago lupulina	0.63	5.10	*
Trifolium dubium	0.26	1.10	*
Veronica arvensis	1.26	8.10	**
Bromus sterilis+diandrus	1.51	7.47	*

Table 8. Frequency of species in cultivated margins under minimum tillage (including power-harrowing) and conventional ploughing (Probabilities* P<0.05, **P<0.01, ***P<0.001).

Species	***Minimum tillage***	***Ploughed***	***P***
Agrostis stolonifera	5.00	0.88	*
Atriplex patula	0.67	3.50	*
Fumaria officinalis	1.71	5.13	*
Lamium hybridum	0.24	3.50	*
Persicaria maculosa	0.81	8.13	***
Silene noctiflora	0.38	3.56	*
Taraxacum spp.	2.95	0	*
Perennial grasses	15.77	4.44	**

Table 9. Frequency of species in cultivated margins on chalk, clay/loam and sandy soils (Probabilities* P<0.05, **P<0.01, ***P<0.001). Means with the same superscript letter are not significantly different.

Species	***Chalk***	***Clay/loam***	***Sand***	***P***
Agrostis stolonifera	1.33[a]	1.75[ab]	5.81[b]	*
Picris echioides	0.22[a]	2.50[b]	0.25[a]	*
Sherardia arvensis	4.33[a]	1.20[b]	0.13[b]	**
Sinapis arvensis	5.62[a]	1.25[b]	2.00[ab]	*

3.1.8. Relationships between vegetation and environmental factors in cultivated margins

Analysis of vegetation composition with respect to the following variables: time of cultivation (autumn/spring), soil type (chalk, clay/loam, sand), cultivation type (ploughing, minimum tillage), age of margin option, rotational/permanent, year of survey (2018, 2019), geographical location (Norfolk, Southern England, Oxfordshire, Midlands), presence of an adjacent hedge and presence of an adjacent cereal crop. The Canonical Correspondence Analysis in the Canoco 5.1 (ter Braak & Smilauer, 2018) package showed that the only statistically significant relationships were with geographical location (Southern England P<0.01; Norfolk P<0.01; Oxfordshire P<0.05), soil type (sand P<0.01; chalk P<0.01) and year of survey (P<0.05). These relationships are illustrated in Figures 15 – 18. The significant effect due to "year of survey" may be due to different regional effects in the two years, and without a longer run of data is difficult to interpret.

Figure 15 shows separation of polygons including Plantlife IAPA species typical of chalky soils from those typical of sandy soils. Figure 16 shows separation of polygons enclosing perennial species (Grime et al, 1988), typically autumn-germinating species and typically spring-germinating species.

Figures 17 and 18 show relationships between sites and environmental variables. Figure 17 separates polygons of sites on chalky and sandy soils. Anomalous sites are indicated. These include E9 where there was a strong maritime influence, O2 where the soil was calcareous sand and S1 where the site had been treated with herbicide. Figure 18 shows field margins cultivated in autumn and spring.

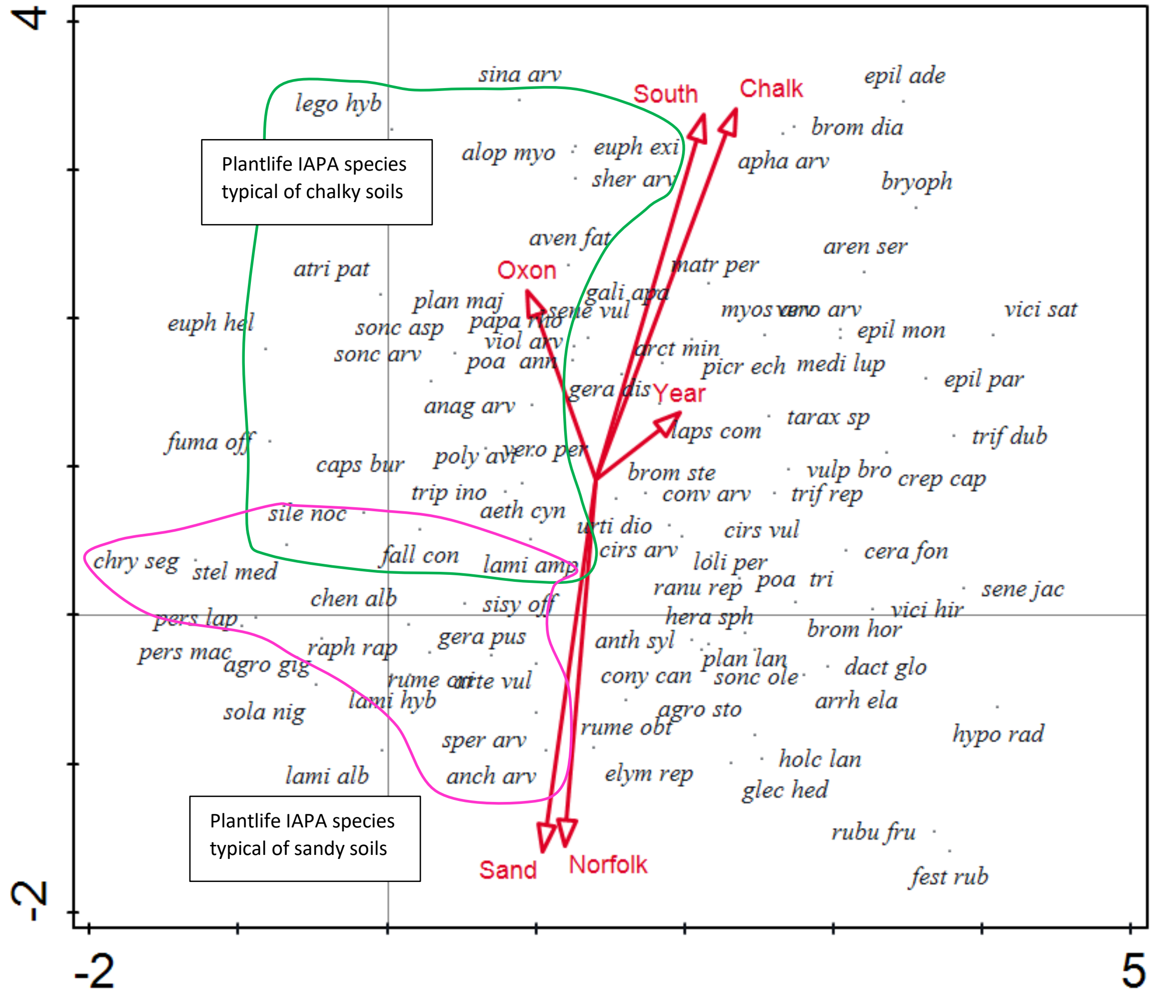

Figure 15. Scatterplot of species on Axes 1 and 2 of a CCA ordination of vegetation data from cultivated margins. Unconstrained analysis with superimposed environmental variable vectors (significant at P<0.05).

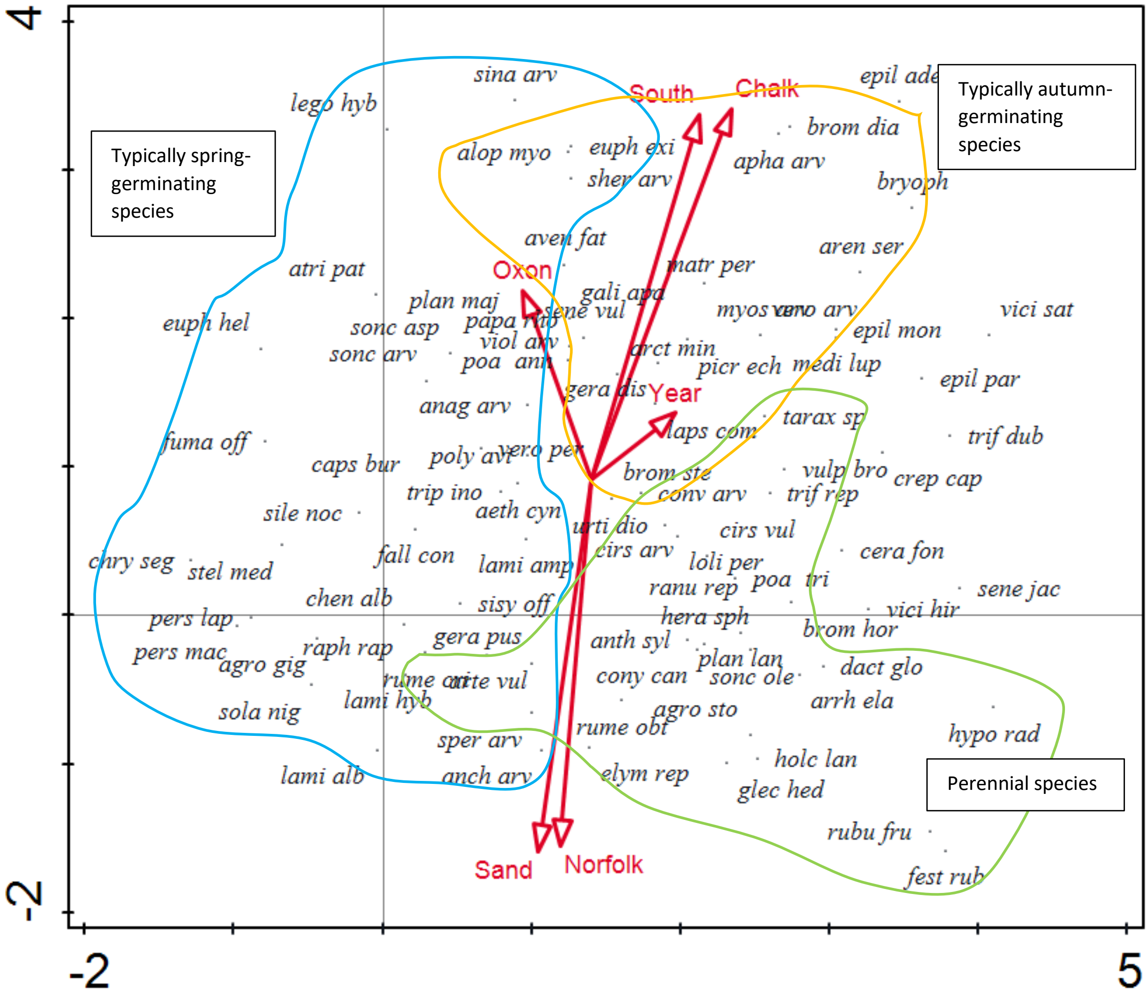

Figure 16. Scatterplot of species on Axes 1 and 2 of a CCA ordination of vegetation data from cultivated margins. Unconstrained analysis with superimposed environmental variable vectors (significant at P<0.05).

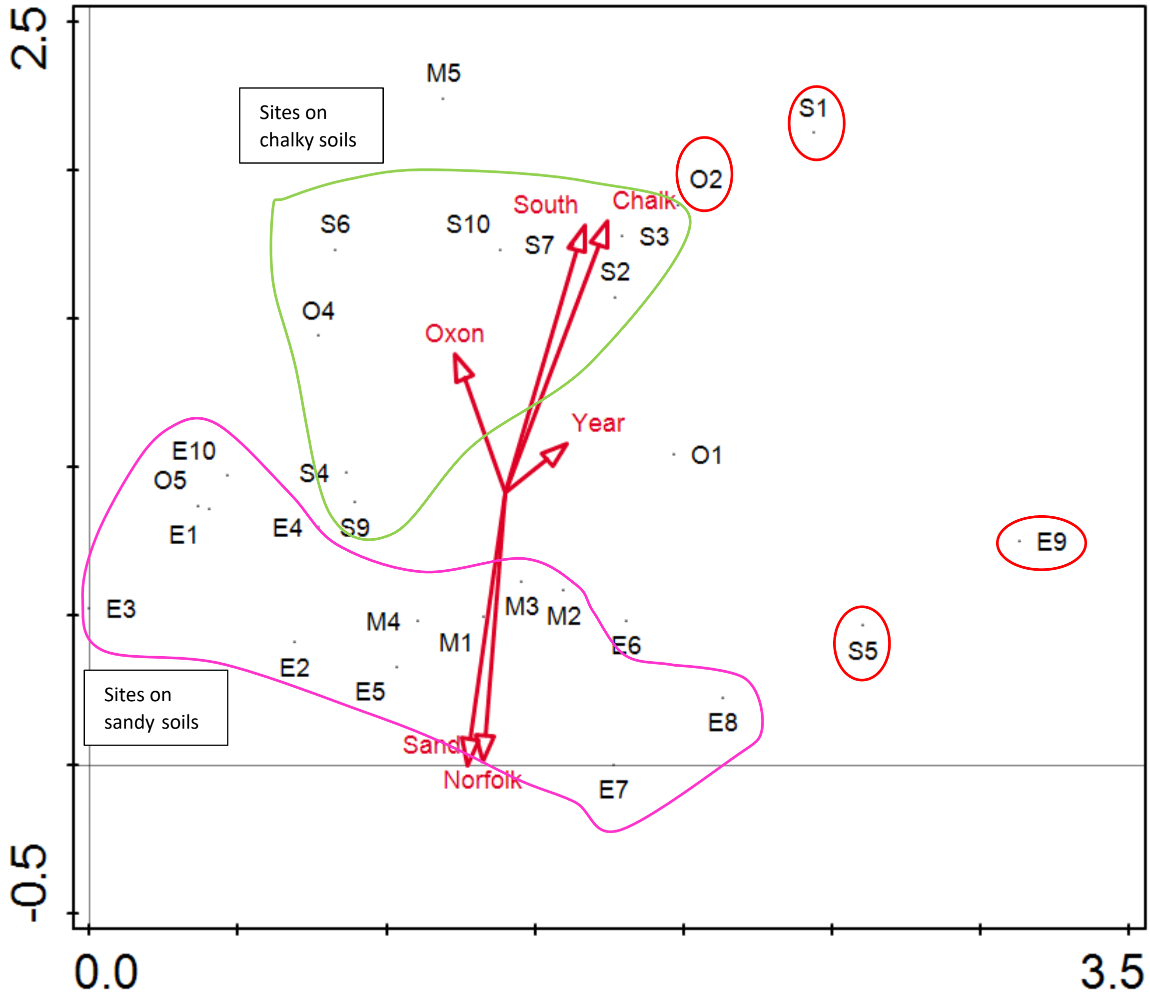

Figure 17. Scatterplot of sites on Axes 1 and 2 of a CCA ordination of vegetation data from cultivated margins. Unconstrained analysis with superimposed environmental variable vectors (significant at P<0.05). Anomalous sites in red circles: S5 uncultivated, S1 herbicide sprayed, E9 maritime, O2 sand/limestone soil.

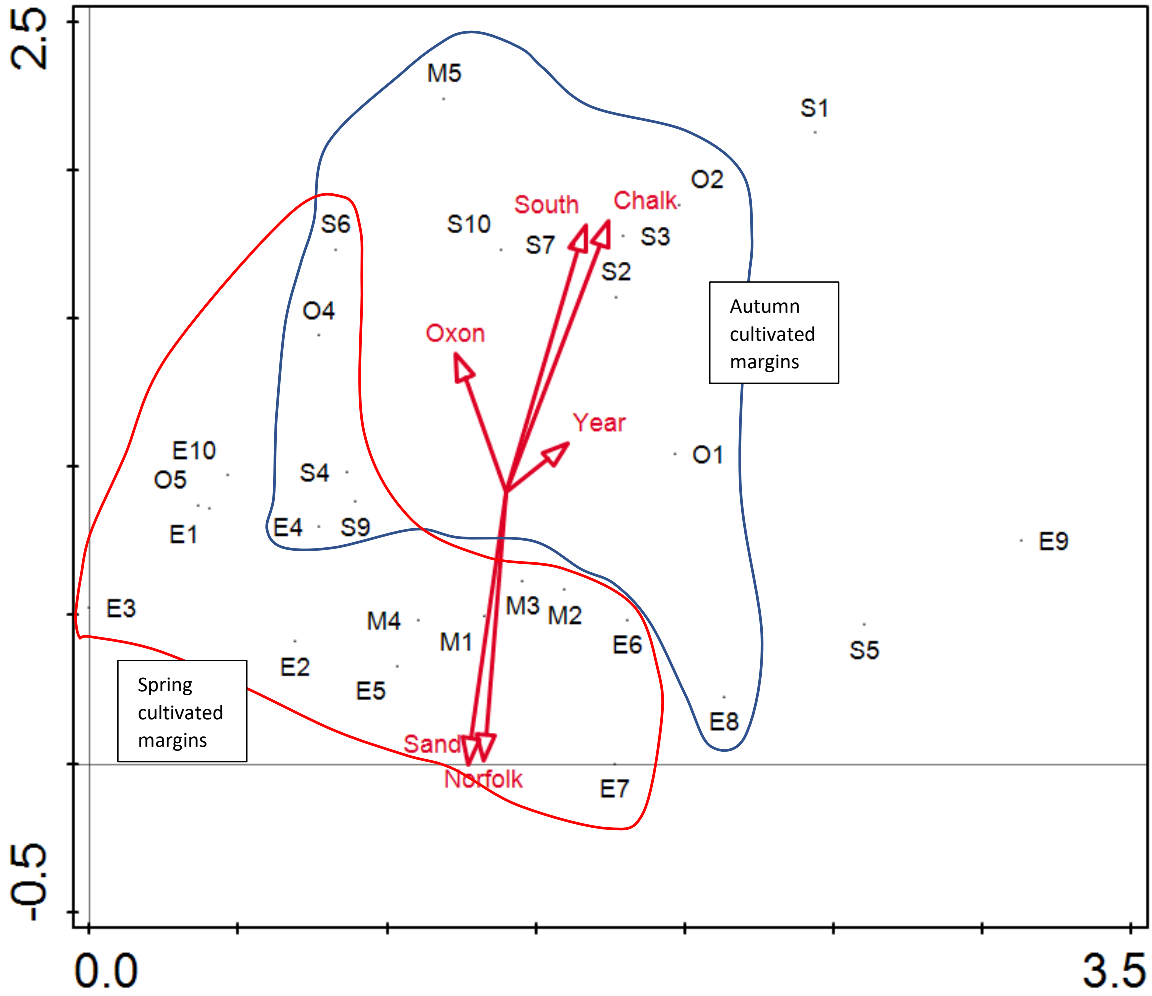

Figure 18. Scatterplot of sites on Axes 1 and 2 of a CCA ordination of vegetation data from cultivated margins. Unconstrained analysis with superimposed environmental variable vectors (significant at P<0.05).

3.2. Floristically enhanced margin

3.2.1. Pitfall trapping

A total of 8855 Lycosidae (and average of 19.9 per pitfall trap), 3090 Linyphiidae (average 6.9), 8377 adult Carabidae (average 18.8) and 1999 adult Staphylinidae (average 4.5) were recorded on floristically enhanced margins during the project (figure 18). Carabidae and Staphylinidae larvae were respectively recorded 267 and 338 times, however they were present in less than 31% of pitfall traps, this data was therefore unsuitable for analysis. The proportion of families and life stages was relatively similar in each year (figure 19).

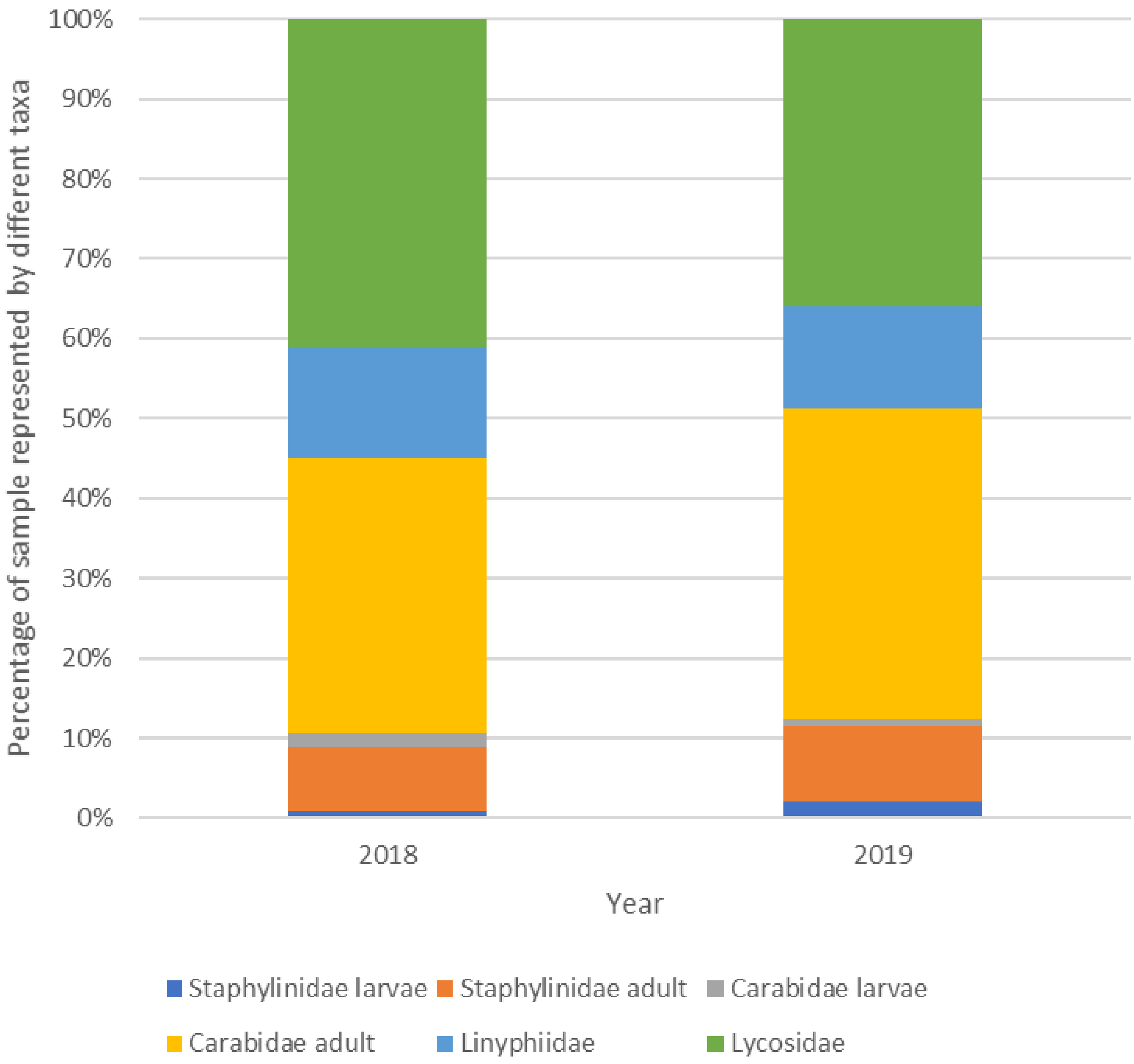

Figure 19. Proportion of each family and life stage present in pitfall traps in floristically enhanced margins each year.

The abundance of Carabidae showed negative associations with sown floristically enhanced margins compared to those under natural regeneration (Table 11). Cutting regime had a significant impact on Staphylinidae abundance with lower abundances being recorded when

Table 10. GAM model estimates for the effect of floristically enhanced margin management measures on the abundance of Lycosidae, Linyphiidae, Carabidae and Staphylinidae sampled using pitfall traps. S is used to represent covariates with smooth. *K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model.*. Equivalent degrees of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.

	Lycosidae		**Linyphiidae**		**Carabidae**		**Staphalylinidae**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	0.51 ± 5.24	N.S	**3.95 ± 1.97**	*	6.35 ± 3.38	N.S	5.95 ± 3.21	N.S
Age	1.06 ± 0.87	N.S	-0.13 ± 0.32	N.S	-0.88 ± 0.53	N.S	-0.50 ± 0.54	N.S
Width	0.60 ± 1.23	N.S	-0.23 ± 0.48	N.S	0.09 ± 0.76	N.S	-1.49 ± 0.79	N.S
Soil fertility	0.13 ± 0.43	N.S	0.02 ± 0.17	N.S	-0.07 ± 0.29	N.S	0.29 ± 0.29	N.S
Adjacent cereal (Y)	-0.16 ± 0.78	N.S	-0.08 ± 0.30	N.S	-0.43 ± 0.50	N.S	-0.88 ± 0.49	N.S
Boundary type (other)	-0.71 ± 0.65	N.S	0.45 ± 0.26	N.S	0.56 ± 0.39	N.S	0.07 ± 0.45	N.S
Establishment (sown)	-0.10 ± 0.81	N.S	-0.40 ± 0.31	N.S	**-1.57 ± 0.50**	**	-0.16 ± 0.52	N.S
Cut (A/W)	0.56 ± 0.88	N.S	-0.10 ± 0.35	N.S	-0.16 ± 0.62	N.S	-0.63 ± 0.62	N.S
Cut (Sp/Su)	-0.22 ± 1.27	N.S	0.05 ± 0.50	N.S	0.08 ± 0.84	N.S	**-1.82 ± 0.83**	*
Cuttings removed (Y)	0.83 ± 1.44	N.S	0.25 ± 0.52	N.S	1.26 ± 0.87	N.S	1.53 ± 0.86	N.S
Year (2019)	-0.77 ± 0.90	N.S	-0.09 ± 0.37	N.S	-0.90 ± 0.57	N.S	**-1.27 ± 0.64**	*
Round	**-0.70 ± 0.05**	***	**-0.55 ± 0.05**	***	-0.05 ± 0.05	N.S	**0.18 ± 0.09**	*
	EDF	**p**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings, Eastings)	**18.34**	***	15.73	N.S	**17.06**	***	**14.91**	**

margins were cut during the spring/summer, compared to those that had not been cut that year (Table 11).

Temporal effects were strongest for Lycosidae, which were lower in 2019 and declined over the survey period. But Linyphiidae were also found to decline over the survey period (Table 11).

We found significant non-linear relationships with location (Eastings, Northings) and abundance of Lycosidae, Carabidae and Staphylinidae (Table 11).

In 2018, a total of 46 carabid species were found in the floristically enhanced margins. There was a more even distribution of species compared to the cultivated margins with less dominance by a few species.

There was a significant difference (Figure 20; R=0.45, P=0.001) in the communities between the regions, with this being highest between the southern and eastern regions.

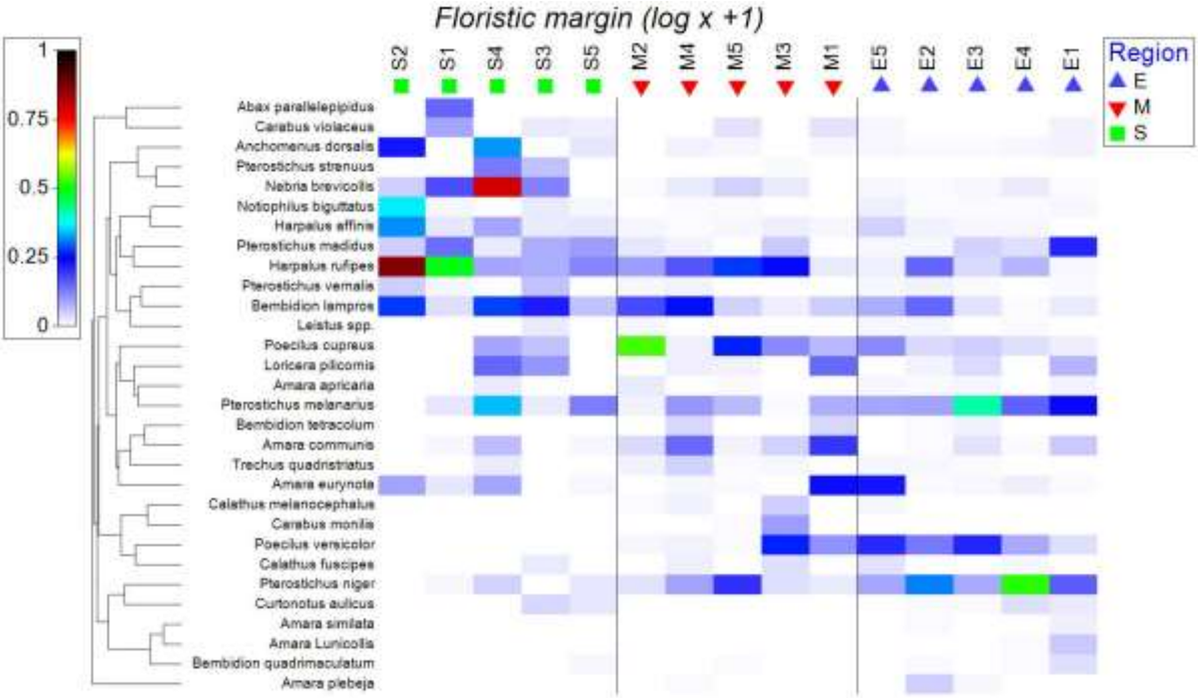

Figure 20. Composition of the carabid species at each floristically enhanced margin site in 2018.

3.2.2. D-vac suction sampling

A total of 6955 invertebrates and an average of 75.59 invertebrates per sample were collected by D-vac suction sampling. 95% (6643) of these invertebrates were classified as natural enemies, although approximately 80% were Parasitica (average 72.2, figure 21) and 312 as pollinators (average 2.29, figure 22). We summarise the DVac suction sampling results in Appendix XV. This represented an average diversity score of 22.4 invertebrate taxa per sample. Approximately 50% more invertebrates were collected in 2019 than 2018.

The abundance of these groups were not found to vary relative to floristically enhanced margin management (Table 12). Invertebrate diversity was higher in 2019 compared to 2018 (Table 12). We found no significant relationship between pollinator and pest natural enemy abundance in our Dvac data (P=0.40; Appendix XVI). We found significant non-linear relationships with location (Eastings, Northings) and all groups under investigation (Table 12; Appendix XVII).

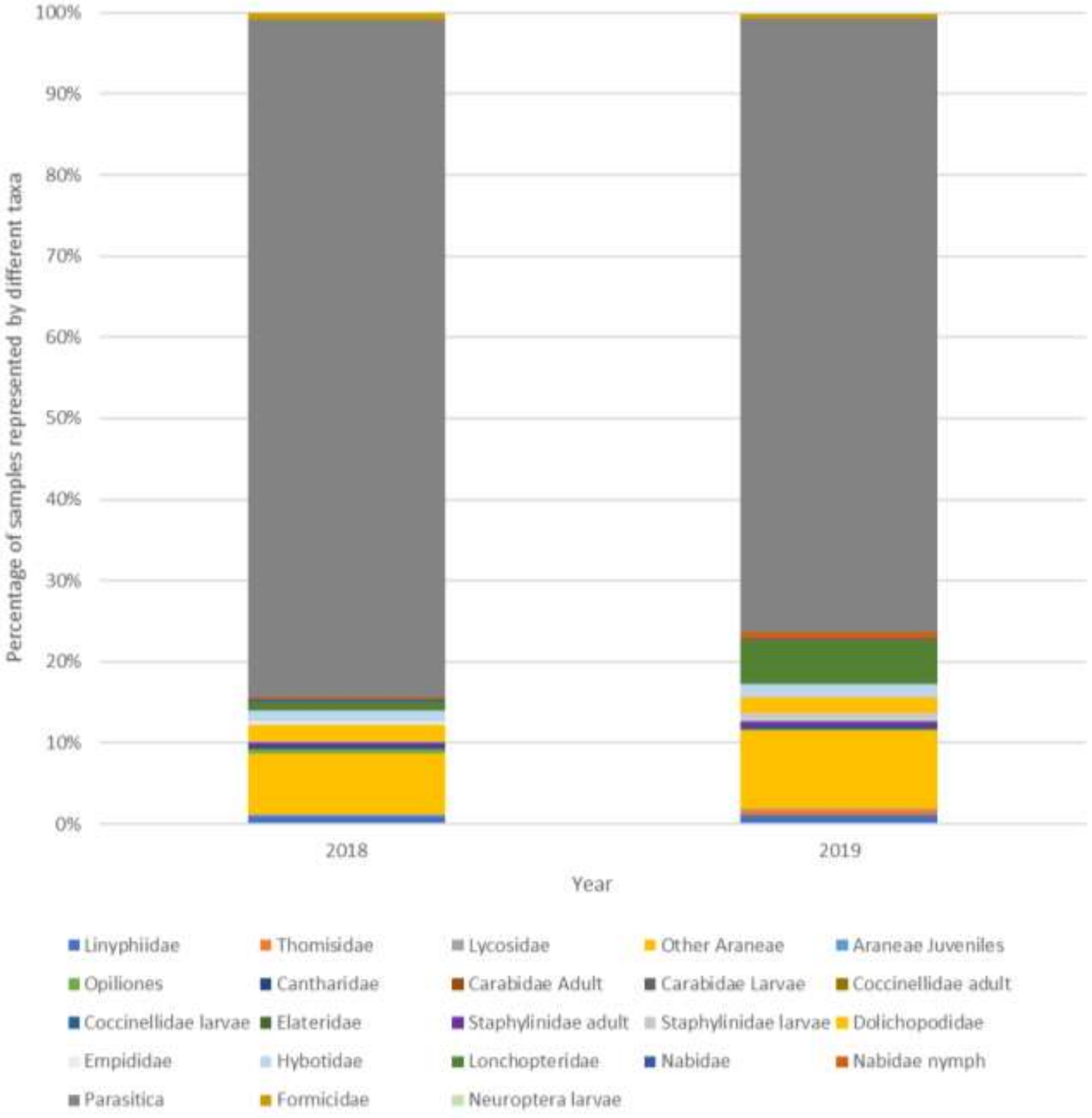

Figure 21. Proportion of each natural enemy taxa present in D-vac samples in floristically enhanced margins in 2018 and 2019. The natural enemy taxa identified were Liyphiidae, Thomisidae, Lycosidae, Other Araneae, Araneae Juveniles, Opiliones, Cantharidae, Carabidae adult, Carabidae larvae, Coccinellidae larvae, Elateridae, Staphylinidae adult, Staphylinidae larvae, Dolichopoidae, Empididae, Hybotidae, Lonchopteridae, Anthocoridae, Nabidae, Nabidae nymph, Parasitica, Formicidae, Neuroptera adult and Neuroptera larvae.

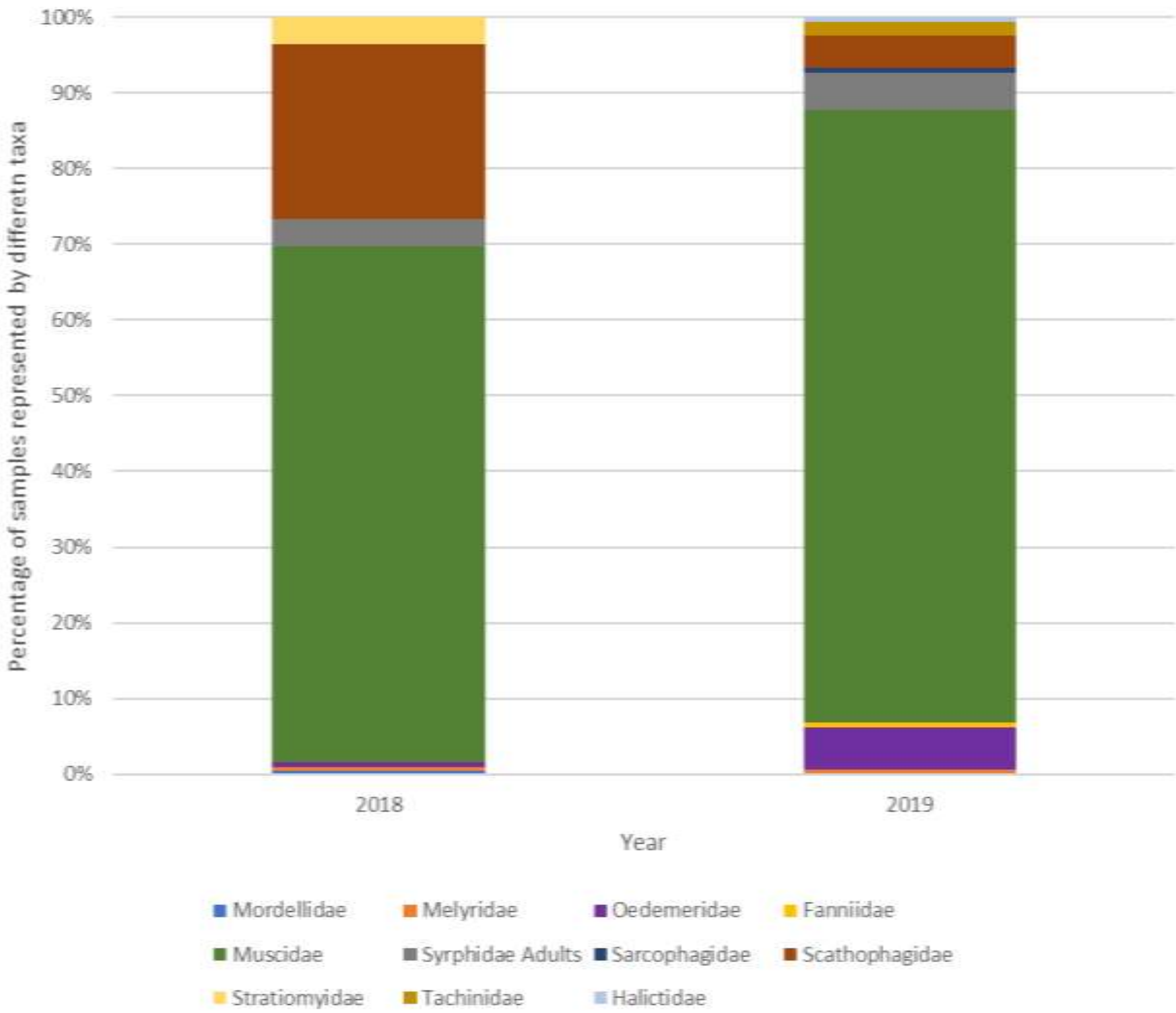

Figure 22. Proportion of each pollinating invertebrate taxa present in D-vac samples in floristically enhanced margins in 2018 and 2019. The pollinators identified in pitfall trap samples were Oedemeridae, Muscidae, Syrphidae Adults, Sarcophagidae, Scathophagidae, Stratiomydae, Tachinidae and Apidae.

Table 11. GAM model estimates for the effect of floristically enhanced margin management measures on the sum of invertebrates sampled, the diversity of invertebrate families recorded, total number of predators and total number of pollinators sampled using D-vac suction sampling. S is used to represent covariates with smooth. *K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model.* Equivalent degree of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.

	Sum		**Diversity**		**Predators**		**Pollinators**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	-0.05 ± 3.94	N.S	**1.59 ± 0.23**	***	-0.45 ± 4.12	N.S	2.18 ± 2.72	N.S
Age	1.06 ± 0.65	N.S	0.03 ± 0.03	N.S	1.06 ± 0.67	N.S	0.81 ± 0.44	N.S
Width	0.51 ± 0.92	N.S	0.11 ± 0.07	N.S	0.62 ± 0.97	N.S	-0.92 ± 0.66	N.S
Soil fertility	0.05 ± 0.33	N.S	0.02 ± 0.03	N.S	0.10 ± 0.34	N.S	-0.49 ± 0.26	N.S
Adjacent cereal (Y)	0.43 ± 0.59	N.S	0.04 ± 0.06	N.S	0.46 ± 0.62	N.S	-0.05 ± 0.43	N.S
Boundary type (other)	-0.32 ± 0.48	N.S	-0.04 ± 0.07	N.S	-0.29 ± 0.50	N.S	-0.48 ± 0.41	N.S
Establishment (sown)	0.19 ± 0.62	N.S	-0.09 ± 0.09	N.S	0.23 ± 0.65	N.S	-0.12 ± 0.43	N.S
Cut (A/W)	0.65 ± 0.65	N.S	0.13 ± 0.09	N.S	0.62 ± 0.69	N.S	0.57 ± 0.54	N.S
Cut (Sp/Su)	-1.17 ± 0.96	N.S	-0.02 ± 0.11	N.S	-0.23 ± 1.01	N.S	0.01 ± 0.73	N.S
Cuttings removed (Y)	-1.02 ± 1.09	N.S	-0.06 ± 0.07	N.S	-1.13 ± 1.14	N.S	0.44 ± 0.74	N.S
Year (2019)	0.20 ± 0.67	N.S	**1.98 ± 0.07**	***	0.22 ± 0.71	N.S	-0.25 ± 0.53	N.S
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings, Eastings)	**18.31**	***	**2**	***	**18.31**	***	**13.5**	*

There was a significant difference between years in the invertebrate community (ANOSIM results R=0.15, P=0.01) and also between the regions (Figure 23: R=0.12, P=0.05), although pairwise tests were not significant and along with the low R value suggest the differences were small. Eleven taxa made up 74% of the difference between years which included the most abundant and widespread taxa: Parasitica, Lonchopteridae (spear-winged flies), Dolichopodidae (long-legged flies), the other Araneae (spiders) and Hybotidae (dance flies). These taxa, with the exception of Parasitica, were also forming most of the differences between the regions.

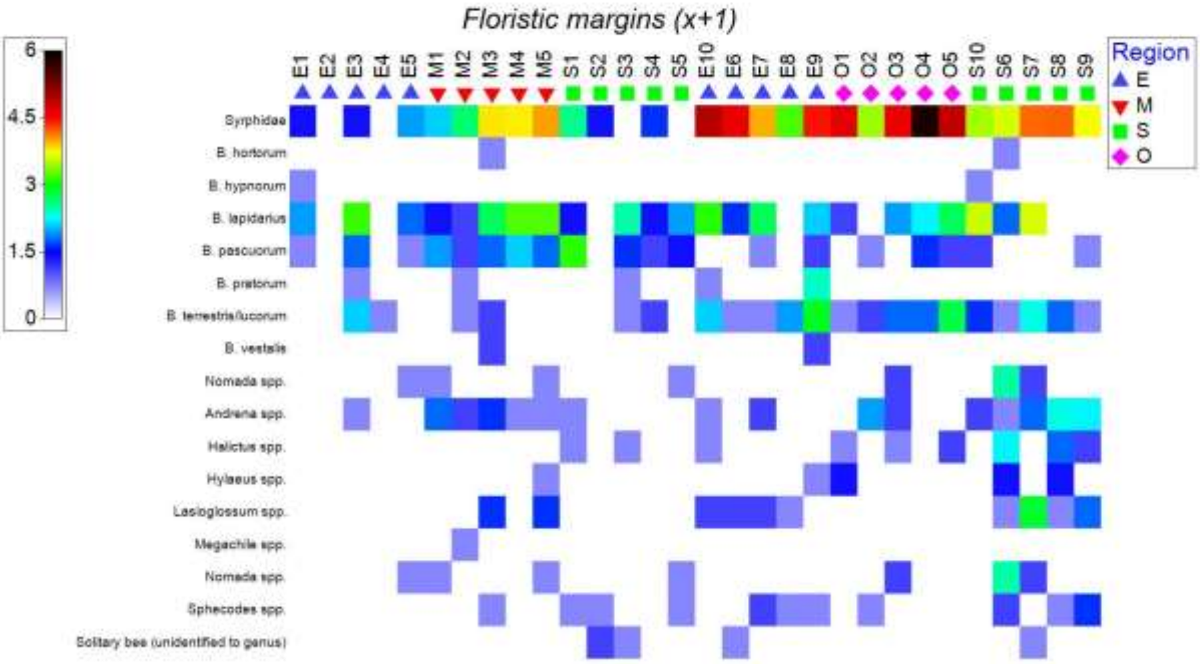

Figure 23. *Composition of the invertebrate taxa in D-vac samples for each floristically enhanced margin site in 2018 and 2019.*

3.2.3. Pollinator transects

879 bees were recorded on floristically enhanced margins over the project, 22% (188) of which were honeybees. Of the wild bees 76% (528) were *Bombus* spp. (Figure 24) and 24% (158) were solitary bees (Figure 25). 1503 Syrphidae were recorded, an average of 8.3 per survey. For a data summary see Appendix XVII. The margins were visited more by bumblebees than solitary bees, which was the opposite to that of the cultivated margins. The bumblebees were comprised of the four most common and widespread species: *Bombus pascuorum*, *B. terrestris/lucorum* and *B. lapidarius*. The margins were visited by a wide range of solitary bee families, especially Andrena species early and late season. Most families were found visiting the margins over 4-6 months.

The abundance of Syrphidae was found to increase as the age of floristically enhanced margins increased. Syrphidae abundance was also higher on floristically enhanced margins that were sown compared to those under natural regeneration, this trend was also significant for the total number of bees recorded (Table 13).

The habitats adjacent to the floristically enhanced margins caused significant changes in the occurrence and abundance of multiple pollinator groups. *Bombus lapidarius* for example were more likely to occur on floristically enhanced margins adjacent to cereal crops compared to all other crop types (Table 13).The total number of bees and the total number of bees without honey bees was lower on margins adjacent hedgerows compared to other field edge habitats (Table 13).

Annual variation was evident for the total number of bees and hoverflies, with higher numbers being recorded in 2019 for both groups (Table 13). We found significant non-linear relationships with location (Eastings, Northings) and the total abundance of bees and hoverflies (Table 13).

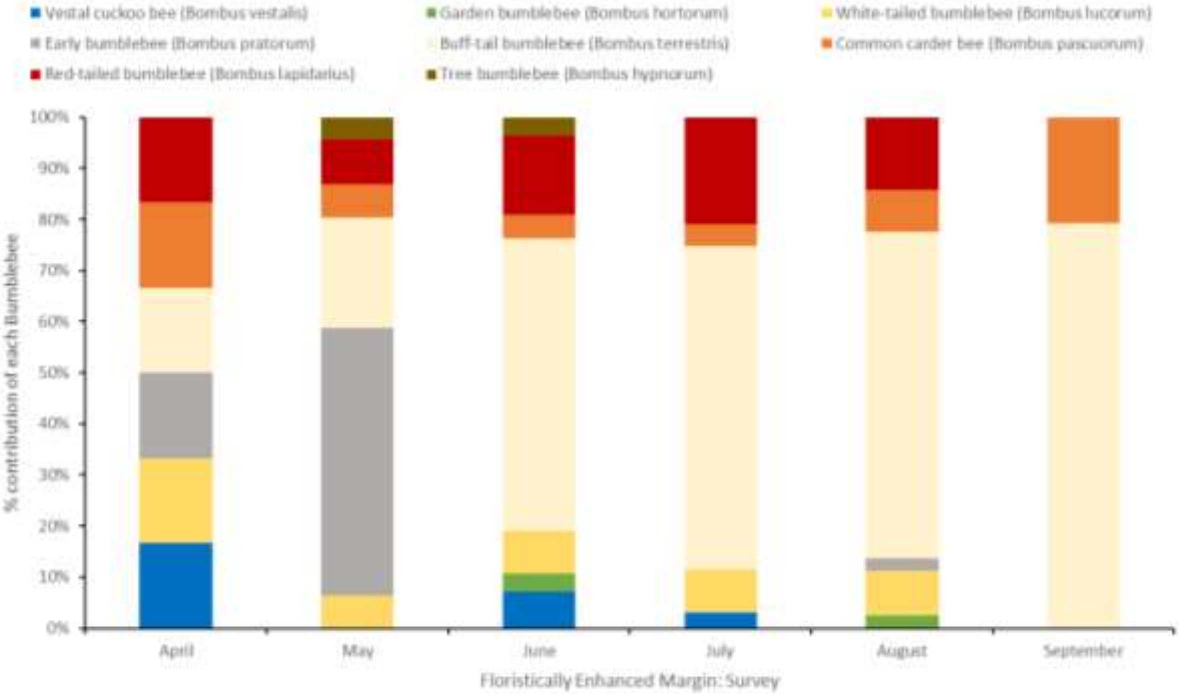

Figure 24. Average proportion of each bumblebee species present in during monthly pollinator walks (April – September) along floristically enhanced margins. The bumblebee species recorded were vestal cuckoo bee, garden bumblebee, white-tailed bumblebee, early bumblebee, buff-tail bumblebee, common carder bee, red-tailed bumblebee and tree bumblebee.

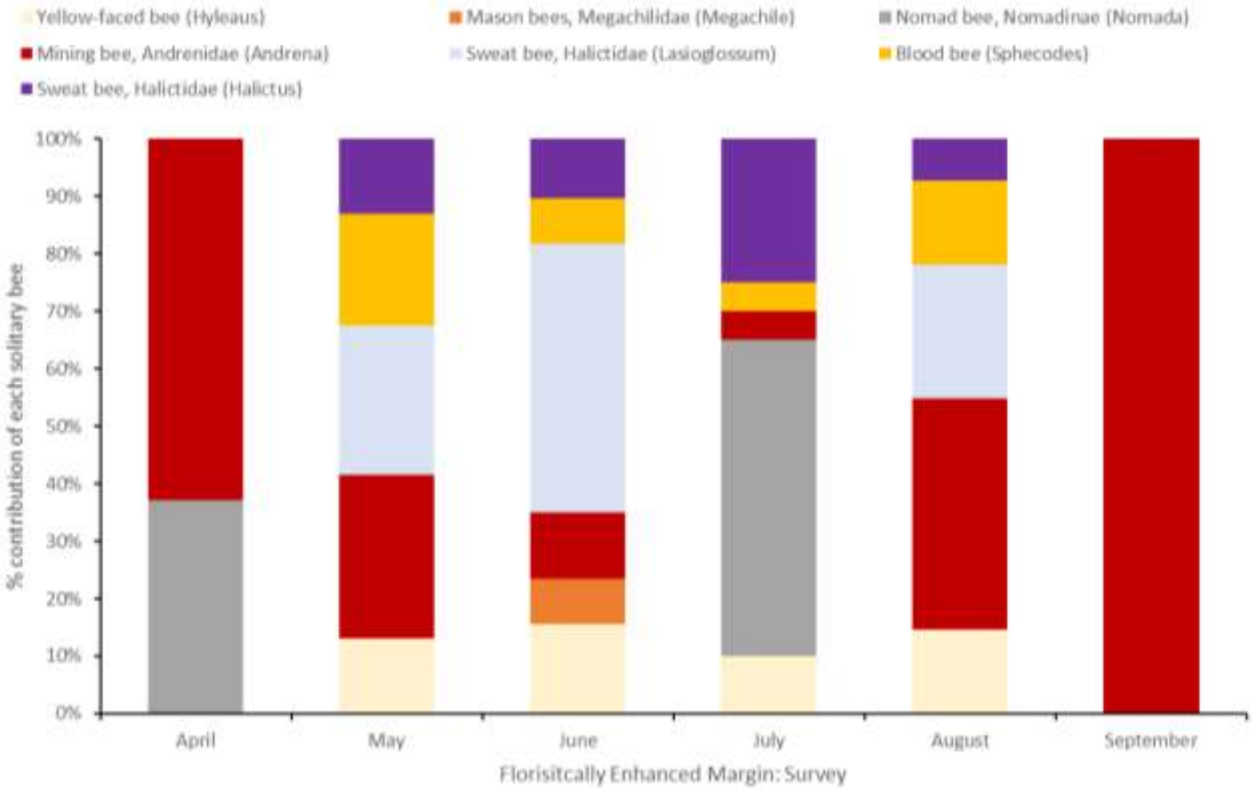

Figure 25. Average proportion of each solitary bee taxa present in during monthly pollinator walks (April – September) along floristically enhanced margins. The solitary bee taxa recorded were Hyleaus, Megachilidae, Nomada, Andrena, Lasioglossum, Sphecodes and Halicitus.

Table 12. GAMM model estimates for the effect of floristically enhanced margin management measures on total bee abundance, total bees excluding honey bees (quasipoisson), Bombus species (quasipoisson), hoverflies (quasipoisson) and the occurrence of solitary (binomial) and red-tailed bumblebees (binomial) surveyed along pollinator transects. Survey was included as a random effect. S is used to represent covariates with smooth. K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model. Equivalent degree of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.

	Total bee		**Bee-Honey**		**Bombus species**		**Solitary**		**Red tail**		**Hoverfly**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	-0.80 ± 1.25	N.S	0.01 ± 1.12	N.S	-1.51 ± 1.29	N.S	0.65 ± 2.38	N.S	**-8.86 ± 3.11**	**	**-4.35 ± 1.62**	**
Age	-0.04 ± 0.19	N.S	-0.09 ± 0.17	N.S	-0.13 ± 0.19	N.S	-0.24 ± 0.37	N.S	0.67 ± 0.47	N.S	**0.59 ± 0.25**	*
Width	0.11 ± 0.36	N.S	-0.05 ± 0.32	N.S	0.37 ± 0.12	N.S	-1.11 ± 0.81	N.S	1.60 ± 0.93	N.S	0.53 ± 0.42	N.S
Soil fertility	0.10 ± 0.12	N.S	-0.07 ± 0.11	N.S	0.01 ± 0.12	N.S	0.02 ± 0.24	N.S	0.27 ± 0.29	N.S	-0.05 ± 0.17	N.S
Adjacent cereal (Y)	0.34 ± 0.29	N.S	0.38 ± 0.25	N.S	0.39 ± 0.27	N.S	0.00 ± 0.51	N.S	**1.50 ± 0.67**	*	0.66 ± 0.41	N.S
Boundary type (other)	0.31 ± 0.30	N.S	**0.53 ± 0.27**	*	**0.82 ± 0.28**	**	-0.45 ± 0.59	N.S	1.06 ± 0.68	N.S	0.37 ± 0.43	N.S
Establishment (sown)	**1.14± 0.49**	*	0.67 ± 0.44	N.S	0.84 ± 0.49	N.S	0.48 ± 0.72	N.S	1.29± 0.96	N.S	**1.36 ± 0.62**	*
Cut (A/W)	-0.21 ± 0.57	N.S	0.05 ± 0.53	N.S	0.08 ± 0.59	N.S	0.23 ± 0.86	N.S	-0.68 ± 0.99	N.S	0.19 ± 0.87	N.S
Cut Sp/Su)	0.14 ± 0.60	N.S	0.31 ± 0.56	N.S	0.37 ± 0.62	N.S	0.31 ± 0.98	N.S	-0.64 ± 1.13	N.S	0.13 ± 0.97	N.S
Cuttings removed (Y)	-0.30 ± 0.39	N.S	0.41 ± 0.35	N.S	0.27 ± 0.40	N.S	-0.03 ± 0.68	N.S	-1.25 ± 0.91	N.S	-0.52 ± 0.48	N.S
Year (2019)	**0.78 ± 0.36**	*	0.55 ± 0.32	N.S	0.36 ± 0.34	N.S	0.53 ± 0.61	N.S	1.38 ± 0.75	N.S	**2.86 ± 0.55**	***
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings,Eastings)	**2**	*	2	N.S	2	N.S	2	N.S	2	N.S	**2**	**

There was a significant difference between years in the pollinator community (ANOSIM results R=0.34, P=0.001), but not between the regions (Figure 26). Syrphidae, *B. lapidarius, B. terrestris/lucorum*, *B. pascurom*, *Andrena* spp. and *Lasioglossum* spp. contributed to 74% of the difference in the pollinator community between years. In 2019 compared to 2018, Syrphidae were 6.8x more abundant, *B. lapidarius* 1.2x*, B. terrestris/lucorum* 6.3x, *Andrena* spp. 2.4x and *Lasioglossum* spp. 3.8x more abundant, whereas there were 4.8x fewer *B. pascurom*.

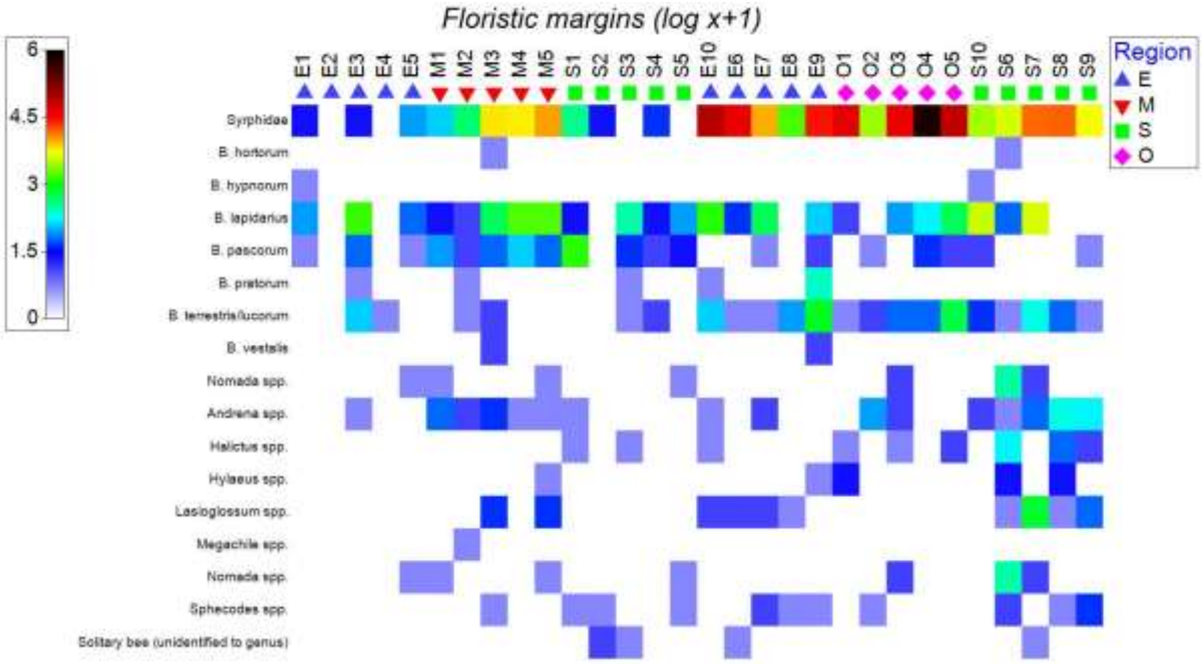

Figure 26. Composition of the pollinator taxa at each floristically enhanced margin site in 2018 and 2019.

In 2018, 289 plant forage visits by *Bombus* spp. were recorded, representing 8 species (Figure 27). *Cirsium vulgare* (spear thistle) and *Lotus corniculatus* (bird's-foot trefoil) and *Leucanthemum vulgare* (ox-eye daisy) were most commonly used, representing 115 and 52 visits respectively. Species specific differences were also evident with 62% of visits to thistles and 71% of foraging visits to bird's-foot trefoil being undertaken by *B. lapidarius*. Thistles were visited by the widest range of *Bombus* spp. with 6 species being recorded. Five *B. hypnorum* were observed foraging on *L. corniculatus*, *C. vulgare* and *P. spinosa.* Only three Bombus vestalis were seen, foraging on *C. nigra*.

1211 foraging visits by Syrphidae were recorded on floristically enhanced margins in 2018 (Figure 28). The plants more frequently foraged on were *Crepis vesicaria* (hawk's-beard) 338 visits, *Anthriscus sylvestris* (cow parsley) 295 visits, *Leucanthemum vulgare* (Ox-eye daisy) 124 visits, and *Taraxacum* species (dandelions) 111 visits. Solitary bees foraged most frequently on cow parsley in 2018, representing 59 of the 127 foraging visits recorded (Figure 29).

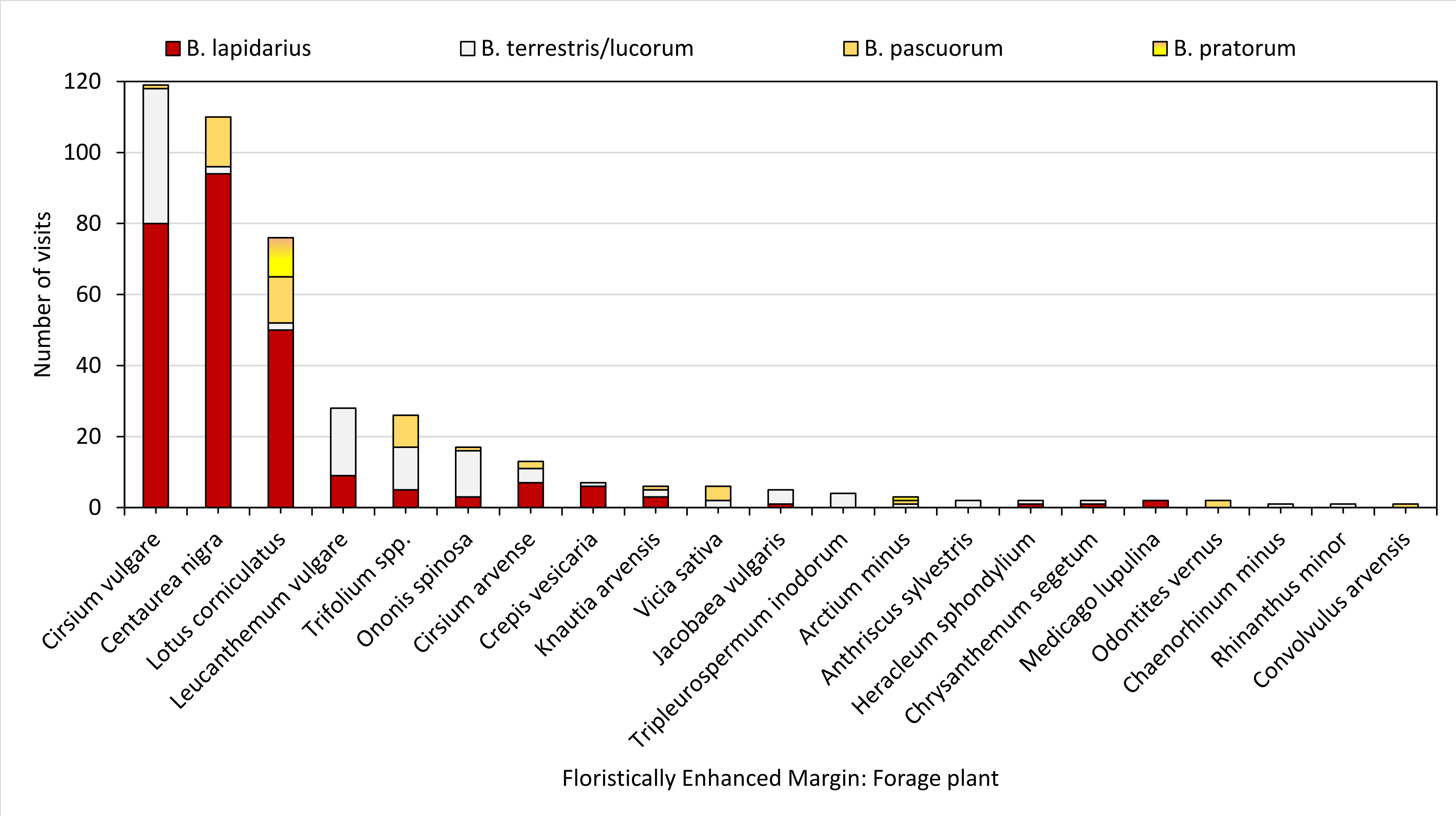

Figure 27. Total number of observed visits by by *B. lapidarius, B. terrestris/lucourum, B. pascuorum* and *B. pratorum* to each plant species in floristically enhanced margins in 2018 and 2019.

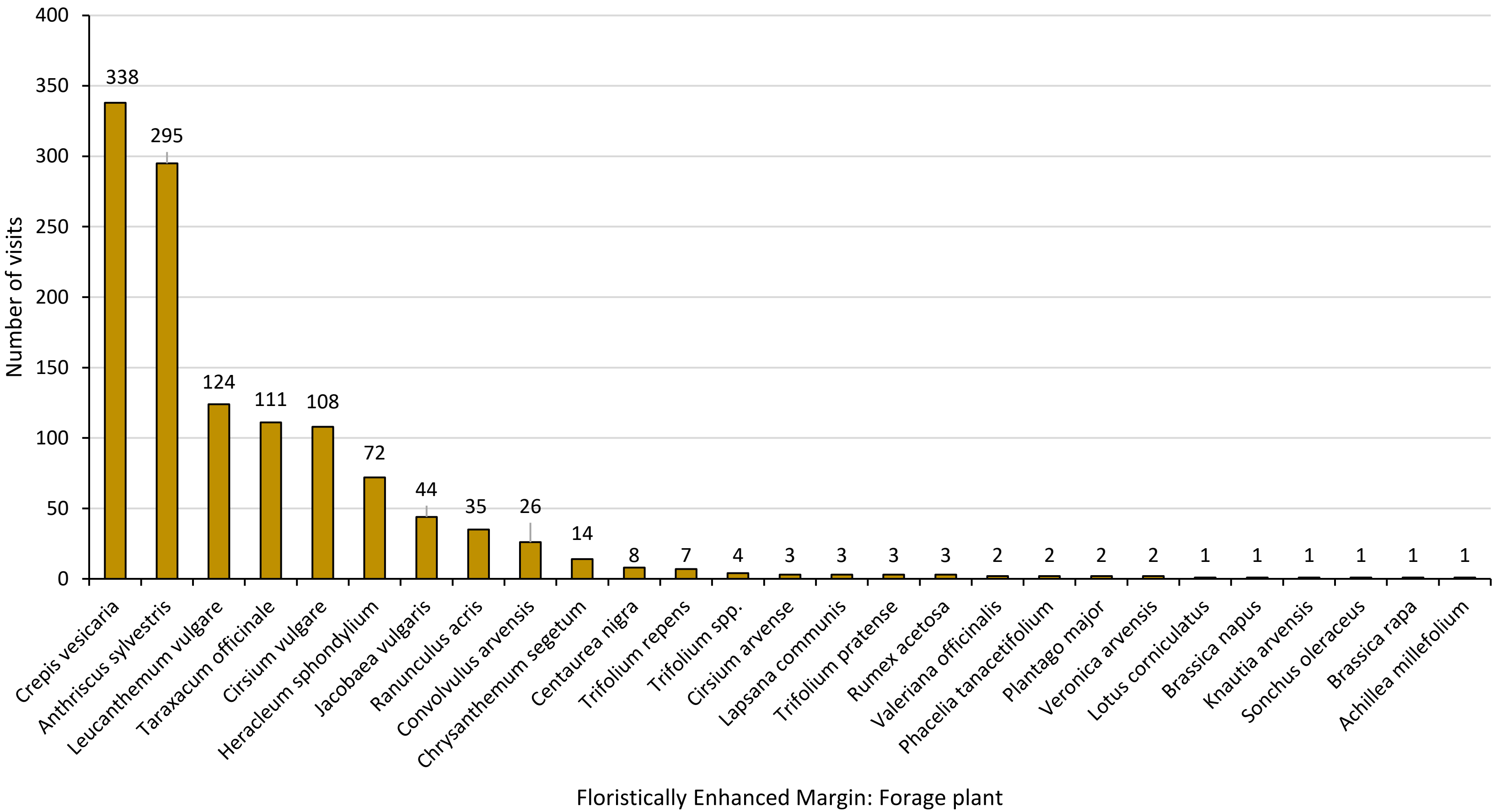

Figure 28. Total number of observed visits by hoverflies to each plant species in floristically enhanced margins in 2018 and 2019.

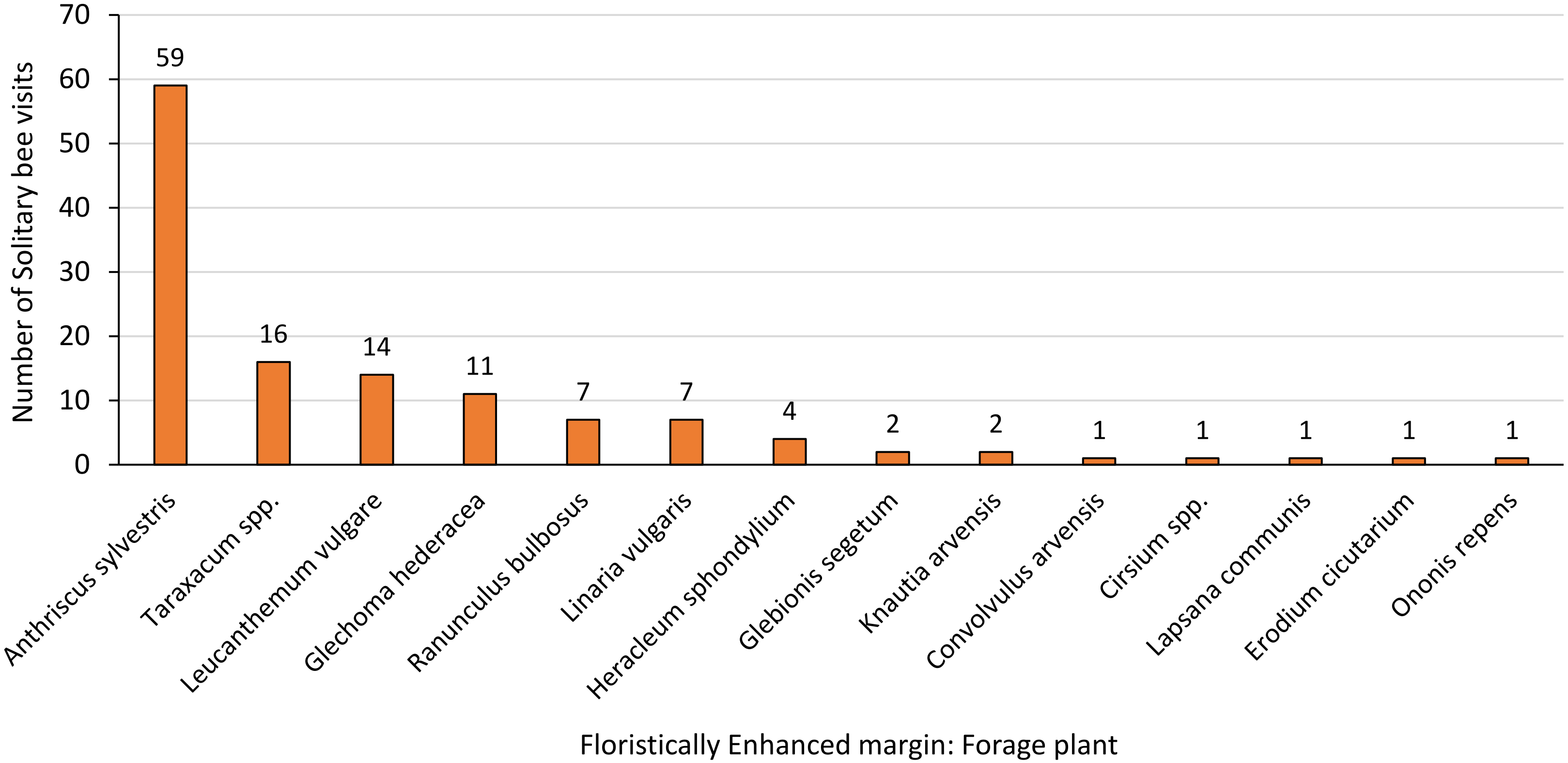

Figure 29. Total number of observed visits by solitary bees to each plant species n floristically enhanced margins in 2018 and 2019.

3.2.4. Vegetation characteristics

Floristically enhanced margin vegetation characteristics were found to be influenced by a range of management measures. The number of flower heads and proportion of bare ground was significantly negatively correlated with margin age, grass cover increased on margins over the same period of time (Table 14). Margin width negatively correlated with grass cover, vegetation height and vegetation density (Table 14). Compared to margins established by natural regeneration, sown margins had more flower heads, broad leaved cover and bare ground (Table 14).

Opposing effects of adjacent cropping and field boundary habitats were detected. The number of flower heads, broad-leaved species cover and bare ground was higher adjacent to cereal crops, but vegetation height and density was lower adjacent to cereal crops (Table 14).

Cutting regime had a significant impact on vegetation density, which was lower on margins that were cut during the spring/summer, compared to those that had not been cut that year (Table 14). On plots where cuttings were removed, we recorded increased vegetation height and density (Table 14).

Annual variance was evident in a number of the vegetation characteristics measured. The number of flower heads, broad-leaved species cover and bare ground cover were higher in 2019 than in 2018, conversely grass cover, vegetation height and density were lower in 2019 compared to 2018.

All of the vegetative characteristics showed significant non-linear relationships with location (Eastings, Northings) (Table 14).

Table 13. GAMM model estimates for the effect of floristically enhanced margin management measures on the number of flower heads (quasipoisson), grass cover (quasipoisson), broad leaved species cover (quasipoisson), bare ground cover (quasipoisson), height cover (gaussian) and density (gaussian) surveyed along pollinator transects. Survey was included as a random effect. Height and density were log+1 transformed. S is used to represent covariates with smooth. K is the maximum possible degrees of freedom allowed for a smooth term (S) in the model.. Equivalent degree of freedom have been abbreviated to EDF. Asterisks denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001. GAMM – survey as random effect.

	Flower heads		**Grass cover**		**Broad leaved species**		**Bare ground**		**Height**		**Density**	
	Est ± SE	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**	**Est ± SE**	**P**
Intercept	0.89 ± 1.25	N.S	**4.74 ± 0.67**	*******	**2.09 ± 0.46**	*******	1.65 ± 1.89	N.S	**4.87 ± 0.79**	*******	**4.12 ± 0.67**	*******
Age	**-0.37 ± 0.19**	*****	**0.25 ± 0.11**	*****	0.00 ± 0.07	N.S	**-1.02 ± 0.30**	*******	0.20 ± 0.12	N.S	0.07 ± 0.11	N.S
Width	0.19 ± 0.38	N.S	**-0.43 ± 0.17**	*****	0.14 ± 0.15	N.S	0.09 ± 0.49	N.S	**-0.51 ± 0.20**	*****	**-0.50 ± 0.17**	******
Soil fertility	-0.12 ± 0.13	N.S	0.07 ± 0.07	N.S	0.01 ± 0.05	N.S	-0.22 ± 0.19	N.S	-0.01 ± 0.08	N.S	0.02 ± 0.07	N.S
Adjacent cereal (Y)	**0.60 ± 0.27**	*****	-0.11 ± 0.11	N.S	**0.23 ± 0.10**	*****	**0.86 ± 0.32**	******	**-0.31 ± 0.13**	*****	**-0.33 ± 0.11**	******
Boundary type (other)	0.00 ± 0.30	N.S	**-0.35 ± 0.11**	******	-0.14 ± 0.11	N.S	**0.94 ± 0.33**	******	-0.17 ± 0.14	N.S	-0.14 ± 0.11	N.S
Establishment (sown)	**1.16 ± 0.41**	******	-0.20 ± 0.12	N.S	**0.71 ± 0.13**	*******	**0.78 ± 0.39**	*****	-0.17 ± 0.15	N.S	-0.15 ± 0.12	N.S
Cut (A/W)	-0.65 ± 0.43	N.S	-0.05 ± 0.14	N.S	0.14 ± 0.16	N.S	-0.32 ± 0.46	N.S	-0.10 ± 0.19	N.S	-0.18 ± 0.15	N.S
Cut (Sp/Su)	-0.76 ± 0.49	N.S	0.07 ± 0.19	N.S	0.00 ± 0.18	N.S	-0.26 ± 0.59	N.S	-0.34 ± 0.24	N.S	**-0.41 ± 0.20**	*****
Cuttings removed (Y)	0.37 ± 0.37	N.S	0.27 ± 0.18	N.S	-0.16 ± 0.14	N.S	-0.67 ± 0.53	N.S	**0.71 ± 0.22**	******	**0.67 ± 0.18**	*******
Year (2019)	**1.24 ± 0.32**	*******	**-0.31 ± 0.14**	*****	**0.60 ± 0.11**	*******	**1.86 ± 0.42**	*******	**-0.37 ± 0.17**	*****	**-0.46 ± 0.14**	******
	EDF	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**	**EDF**	**P**
s(Northings,Eastings)	**2**	******	**12.62**	*******	**2**	*******	**10.14**	*******	**10.72**	*******	**11.5**	*******

3.2.5. Species composition

Cutting floristic margins was found to significantly influence ground flora composition (figure 8; p<0.05). In this ordination cut floristically enhanced margins were associated with positive values of CCA1 and negative values were associated with uncut floristically enhanced margins. Species at the centre of the plot were universal (figure 30).

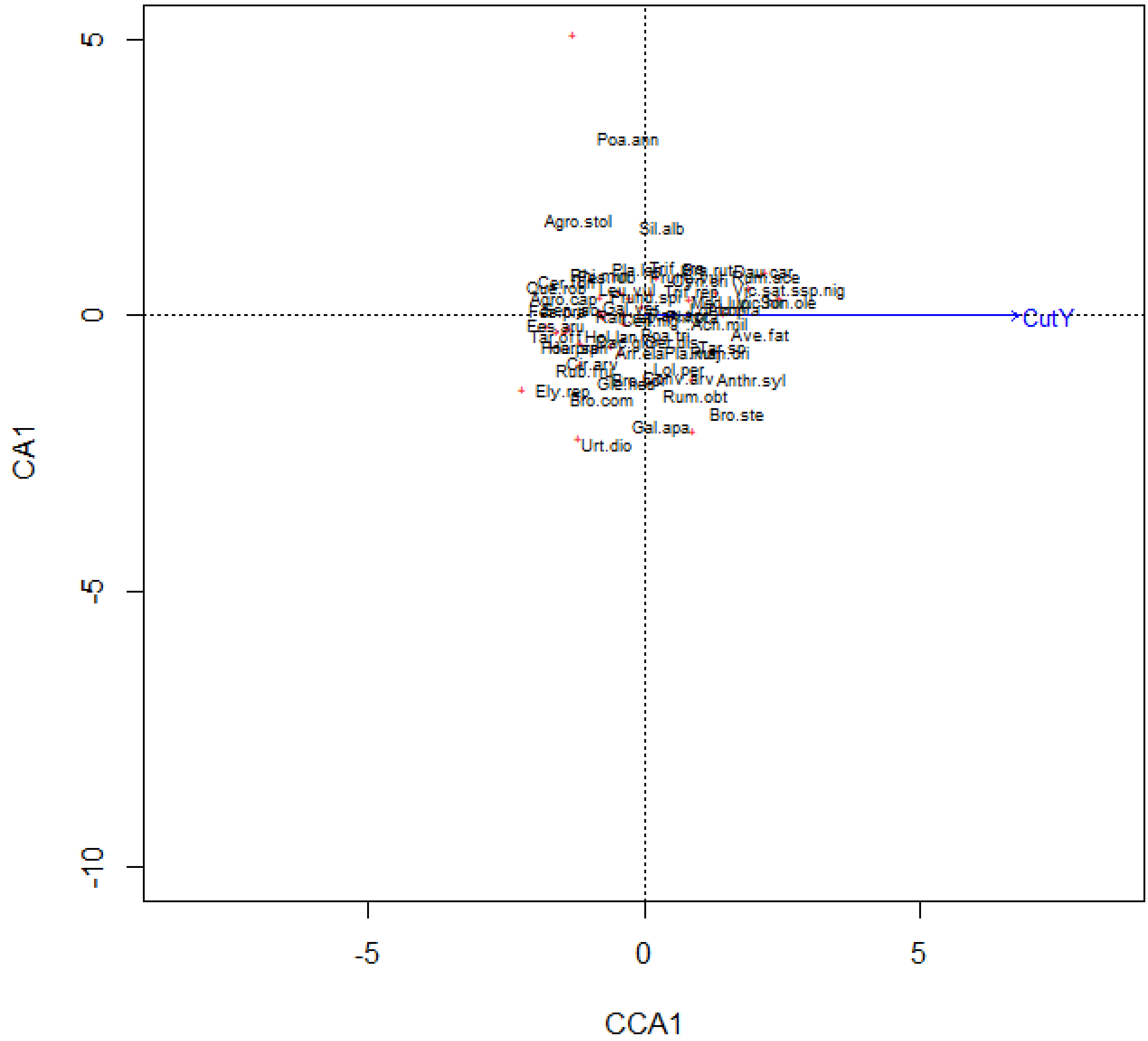

Figure 30. CAA ordinations for cultivated margins; site = red crosses; codes refer to scientific names of species; year (a/b), region (north, south, east, midlands), establishment, broad soil type (chalk, heavy, medium, sandy), broad adjacent habitat (hedge/other), adjacent cereal crop (Y/N), cutting time (not, spring/summer or autumn/winter), cuttings removed (Y/N), cut 2018/2019 are superimposed as vectors.

A total of 168 species of vascular plant were recorded in the 30 floristically-enhanced margins surveyed. The most frequent, found in more than 50% of the margins, were the grasses *Festuca rubra, Arrhenatherum elatius, Poa trivialis, Holcus lanatus* and *Dactylis glomerata,* and the dicotyledonous species *Centaurea nigra, Plantago lanceolata, Heracleum sphondylium, Cirsium arvense, Leucanthemum vulgare, Lotus corniculatus, Trifolium repens, Prunella vulgaris, Taraxacum spp., Geranium dissectum, Achillea millefolium* and *Ranunculus repens* (Table 15). The full list is included as Appendix XIII and XIV.Of these species, *Festuca rubra, Poa trivialis, Centaurea nigra, Leucanthemum vulgare, Lotus corniculatus, Trifolium repens, Prunella vulgaris* and *Achillea millefolium* are common constituents of commercially available seed mixtures marketed for use in stewardship schemes and are likely to have been sown.

Table 14. Species recorded in more than 50% of surveyed floristically-enhanced margins.

Species	**Number of quadrats**	**Number of margins**
Festuca rubra	408	27
Arrhenatherum elatius	284	27
Poa trivialis	355	26
Holcus lanatus	308	26
Dactylis glomerata	332	24
Centaurea nigra	240	23
Plantago lanceolata	148	22
Heracleum sphondylium	193	21
Cirsium arvense	98	21
Leucanthemum vulgare	236	19
Lotus corniculatus	168	18
Trifolium repens	128	18
Prunella vulgaris	78	18
Taraxacum spp.	68	17
Geranium dissectum	107	16
Achillea millefolium	76	16
Ranunculus repens	74	16

Of the 30 margins surveyed, four had been established solely by natural succession with no added seed, one had been sown with grass seed and later supplemented with broad-leaved species, with the method for establishment of another unknown. A total of 26 margins were therefore floristically enhanced and a further four were established by natural succession.

5.2.6. Relationships between vegetation and environmental factors

The only significant environmental variable in the Canonical Correspondence Analysis was age since establishment (P<0.002). All variables included in the analysis accounted for 43.6% of the variation in the data, and of this, age since establishment accounted for 25.0%. There was no significant association with soil type, time of cutting or whether a seed mixture had been used.

The ordination scatterplot of sites on axes 1 and 2 of the ordination showed a clear separation between the three margins that were two or fewer years since establishment and all other margins, and a smaller tendency towards separation between margins of 3-8 years old and those that were older, and the margins which had "failed" (<1% cover of sown species) (Figure 31). This can also be seen in Figure 32 where annual species typical of arable fields are associated with low values on the "age" vector and species typical of MG1 and OV24 hedge-bottom vegetation are associated with the higher values.

Results from analyses of variance for individual species (Table 16) show that annual and short-lived perennial species more typical of arable fields were significantly (P<0.05) less frequent in longer-established strips. These included *Poa annua, Rumex crispus, Sonchus oleraceus, Tripleurospermum inodorum, Avena fatua, Daucus carota, Medicago lupulina, Silene alba, Sonchus arvensis* and *Veronica arvensis*. The only species significantly more frequent in longer-established strips was the tussock-forming perennial grass *Dactylis glomerata* (P<0.01).

Typical constituents of seed mixtures sown in these situations showed a tendency to group in the centre of the scatterplot (Figure 32). This appeared to be independent of the age of establishment. Species typical of semi-natural stands of hedge-bottom vegetation (MG1b, OV24/25) tended to be grouped in the lower right of Figure 32.

Four species, *Arrhenatherum elatius, Bromus commutatus, Elymus repens* and *Galium aparine* were all significantly more frequent in margins that had not been sown with seed mixtures (Table 17).

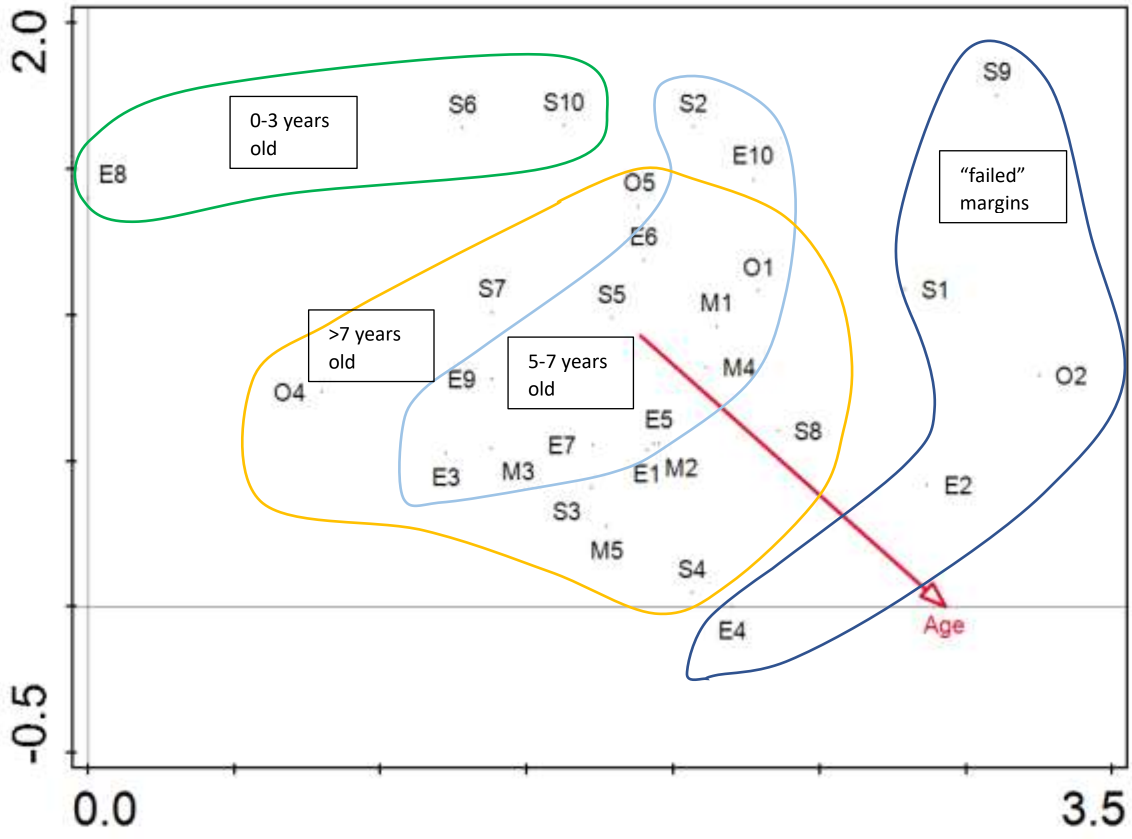

Figure 31. Unconstrained ordination of floristically enhanced field margin vegetation with superimposed “age” vector (P=0.002).

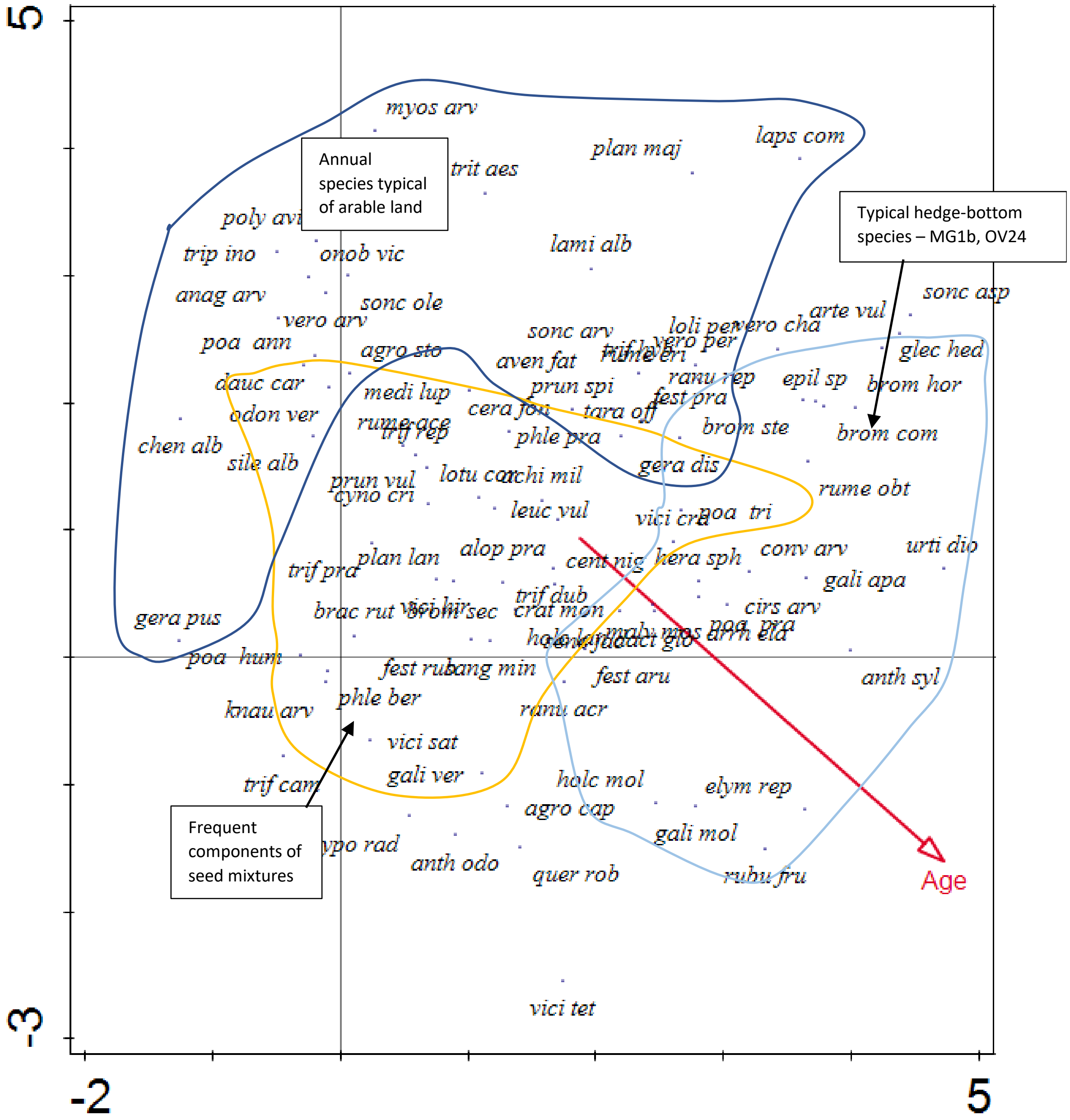

Figure 32. Unconstrained ordination of floristically enhanced field margin vegetation with superimposed “age” vector (P=0.002).

Table 15. Frequency and percentage cover of species in floristically enhanced margins of different ages since establishment. *** P<0.001, ** P<0.01, * P<0.05. Means with the same superscript letter are not significantly different

Mean Frequency				
Species	0-3 years	5-7 years	≥8 years	P
Dactylis glomerata	0.67^{a}	16.4^{b}	9.76^{ab}	**
Poa annua	8.67^{a}	1.0^{b}	0.59^{b}	**
Rumex crispus	7.0	2.70	0.53	*
Sonchus oleraceus	6.0^{a}	0.30^{b}	0.06^{b}	**
Tripleurospermum inodorum	8.33^{a}	0.50^{b}	0^{b}	***
Mean % cover				
Avena fatua	0.567^{a}	0.070^{b}	0.006^{b}	*
Conyza canadensis	0.33^{a}	0^{b}	0^{b}	**
Dactylis glomerata	0.667^{a}	16.64^{b}	6.11^{a}	**
Daucus carota	1.970^{a}	0.010^{b}	0.175^{b}	*
Medicago lupulina	14.33^{a}	0.430^{b}	2.525^{ab}	*
Poa annua	3.40^{a}	0.280^{b}	0.031^{b}	**
Rumex crispus	4.233^{a}	0.389^{b}	0.035^{b}	*
Silene alba	0.067^{a}	0.022^{ab}	0.012^{b}	*
Sonchus arvensis	0.20^{a}	0^{b}	0.025^{b}	*
Sonchus oleraceus	0.467^{a}	0.02^{b}	0.006^{b}	**
Veronica arvensis	0.067^{a}	0.011^{b}	0.006^{b}	*

Table 16 Percentage cover of species in field margins with added seed and without added seed

Species	No seed addition	With added seed	P
Arrhenatherum elatius	29.675	6.452	***
Bromus commutatus	1.467	0.072	***
Elymus repens	7.425	0.996	*
Galium aparine	3.975	0.132	*

4 Discussion

This study provides the first comprehensive assessment of how habitat management impacts the use of cultivated margins by a range of invertebrate species and plant species diversity and abundance. Our study also furthers our understanding of how the management of floristically enhanced margins impacts invertebrates and plants. The management of both margin types impacted the abundance and occurrence of a range of invertebrate species and species groups, it is likely that this was driven by differences in vegetative structure caused by habitat management.

4.1. Cultivated margins

4.1.1. Invertebrates

The cultivated margins supported a diverse community of beneficial invertebrates including groups of key natural enemies active on the ground and potentially on the crop, such as a diverse community of Carabidae, but also Staphylinidae and Araneae. High numbers of flying natural enemies were also found, especially Parasitica (parasitic wasps), but also Syrphidae, Dolichopodidae, and Coccinellidae. The value of these taxa for pest control has been demonstrated, with the exception of the Dolichopodidae, despite their abundance and occurrence in a range of semi-natural habitats on farmland (Pfister et al., 2017). As such the value of cultivated margins is similar to that found for other types of field margin habitats and other agri-environment options (Holland et al., 2016). Previous studies of cultivated margins have focussed on evaluating their value for plants (Dicks et al., 2020) and this is the first comprehensive study showing their potential to support invertebrates.

The floral resources provided by the margins attracted a wide range of pollinating insects, especially bumblebees, solitary bees and Syrphidae. These made use of some of the arable plants such as corn marigold and poppies, but also some of the weed species, especially spear thistles which has also previously been reported (Wood et al., 2015a). Some bumblebee species and solitary bee taxa were most frequently observed visiting *Crepis vesicaria* (beaked hawk's-beard), *Taraxacum* spp. (dandelions) and *Sonchus* spp (sowthistles) (as found by Wood et al., 2015a and Nichols et al., 2019), species that would not typically be included in corn field annual seed mixes. Syrphidae were most commonly recorded foraging on the Asteraceae species including *Taraxacum* spp., *Leucanthemum vulgare* (ox-eye daisy) and *Glebionis segetum* (corn marigold). This is in agreement with previous studies which identified positive relationships between Syrphidae and Asteraceae species (Babaei et al., 2018). Overall, the findings here show the value of creating annual habitats through natural regeneration rather than sowing, and that weeds that are highly attractive to pollinators should be tolerated. Weeds also support a broader range of invertebrates, including those supporting functional biodiversity and acting as food for higher organisms (Smith et al., 2020).

The trends in invertebrate abundance seen here are largely driven by relationships between cultivated margin management and vegetative characteristics. We provide the first evidence of a relationship between soil cultivation and plant and invertebrate biodiversity value. There was evidence that soil cultivated by ploughing resulted in a higher proportion of bare ground, a result that is consistent with other studies (e.g. Moyse and Shellswell, 2016). Furthermore, compared to minimum tillage, ploughing reduced grass coverage on cultivated margins, in addition to lowering average vegetation height and density. For invertebrates, consistent negative impacts of ploughing were evident, lower total bee abundance and solitary bee occurrence were evident from pollinator surveys. This may be explained by the plant communities associated with ploughing, as although five broad-leaved species were more prevalent on ploughed plots, these were not valuable foraging plants for pollinators. D-vac suction sampling showed also that ploughing negatively impacted general invertebrate abundance, natural enemies and pollinator abundance. At a field scale ploughing is known to disturb ground nesting bees (Kim et al., 2006; Williams et al., 2010) due to changes in nest site conditions or, if sites are cultivated at an inappropriate time of year, due to nest destruction during larval development. Many other invertebrates (e.g. some Coleoptera species) overwinter in the soil, including all life stages (egg, larva, pupae, adult), and ploughing in the autumn/winter will increase the mortality rates of such invertebrates (Holland & Reynolds, 2003; Holland, 2004). In contrast, shallow non-inversion/minimum tillage favours ruderal species with short-lived seed but good spatial dispersal, commonly leading to a build-up of grass weeds, such as *Agrostis stolonifera* which have less value to beneficial invertebrates. However, dandelions which were used by a range of pollinators, were also more abundant on plots cultivated by minimum tillage. In locations where grass weeds can become dominant then ploughing could be used as a management tool. However, as the previous year's seeds are then buried, the plant community will reflect what is present in the seed bank and favour species with longer-lived seeds.

Some margins were cultivated in the autumn and five broad-leaved species were more prevalent in these plots compared to those cultivated in the spring, these included three species valued by pollinators: *C. capillaris*, *Medicago lupulina* and *Trifolium dubium*. On the other hand, two pernicious grasses were also prevalent in autumn cultivated margins.

Cultivated margins were divided between those that were rotated across farms annually and non-rotational margins that were not moved for two or more seasons. Previous studies have demonstrated that, compared to non-rotational set aside, rotational set-aside offers marked environmental benefits for wintering and breeding birds (e.g. Henderson et al., 1998; Poulsen et al., 1998).The effect of habitat rotation on other taxa or in relation to other agri-environment scheme habitats has, however, received very little attention in the literature (but see Ouda et al., 2018). Our results show that rotational cultivated margins were associated with fewer flower heads, broad-leaved species cover and lower vegetation heights which in turn negatively impacted bee abundance. This is an important finding which suggests that rotational margins have depleted seed banks possibly because their implementation on farmland isn't targeted towards farm areas with a history of diverse or abundant arable plant communities. However, of the cultivated margins investigated only six were rotational, therefore, we recommend that further research be carried out.

Previous studies have demonstrated that in general invertebrate abundance increases relative to arable field margin age, this is largely expected because older margins have a greater chance of invertebrate colonisation (Corbet 1995). Studies, however, have focused on a limited range of invertebrate groups e.g. Gastropoda, Carabidae (Noordijk et al., 2010). We report mixed results relative to cultivated margins with age negatively impacting the total number of wild bees recorded, but positively impacting *Bombus* spp. Older cultivated margins were associated with denser vegetation and less bare ground, we therefore hypothesise that for *Bombus* spp. the positive relationship with age was related to the nesting preferences of these species; the carder bees (Thoracobombus) such as the *Bombus ruderaricus* (common carder bee), for example, preferentially nest at the base of dense tussocks of grass and other common *Bombus* spp. prefer to nest under cover e.g. *B. terrestris* and *B. lucorum* (Edwards and Jenner, 2005). Our hypothesis linking margin age to margin density would, however, require further exploration in future studies.

Boundary type was only found to impact the abundance of *B. lapidarius* (red-tailed bumblebees) which were more commonly found on cultivated margins adjacent to hedgerows and woody habitats. For *B. lapidarius* it is possible that the presence of hedgerows adjacent to margins increased and extended flower availability therefore allowing this area to support greater numbers of foraging bumblebees than those adjacent cropped areas (Goulson, 2010). Alternatively, however, field boundary habitats may provide increased shelter for *B. lapidarius* thereby allowing them to forage for extended periods compared to open areas.

Larger cultivated margin habitats were associated with reduced broad-leaved species coverage, most likely because arable annual plants are typically concentrated in the first 4m of the field where inputs are usually lower. This resulted in fewer Staphylinidae and increased Syrphidae (hoverflies) abundance on these margins. For Syrphidae this result was unexpected, but may reflect the fact that broad-leaved species coverage did not directly relate to forage availability for this group.

For the other invertebrates, such as those collected by D-vac sampling, arable plants are known to be important and often the common weeds are those that are supporting the invertebrate community (Smith et al., 2020), including many phytophagous species that are host for parasitic wasps if crop pests are not suitable or abundant (Storkey et al., 2013). Many of these are now at low levels in crops (Lutman et al., 2007) owing to the development and use of highly effective herbicides, with impoverished seedbanks being common in many arable fields (Holland et al., 2008). The cultivated margins therefore help not just rare species, but also ensure that other species do not also become threatened. Weed seeds are also an important food resource for farmland wildlife, including some invertebrates, small mammals (Westerman et al., 2003) and especially farmland birds (Holland et al., 2006).

4.1.2. Rare species in cultivated plots

Species included in the list used by Plantlife to define and evaluate “Important Arable Plant Areas” (IAPS) in the UK (https://www.plantlife.org.uk/uk/discover-wild-plants-nature/habitats/arable-farmland/important-arable-plant-areas) were found at 26 of the 30 sites surveyed. This list includes a range of species in the IUCN-defined categories Near Threatened to from the locally notable to Critically Endangered (Cheffings & Farrell, 2005). Using the Plantlife defined criteria, two Oxfordshire sites are of national importance, while a further 10 sites are of county importance. One of the Oxfordshire sites is also of national importance because of the presence of a population of the Critically Endangered *Galeopsis angustifolia* in its only known Oxfordshire site.

High IAPA scores showed little association with environmental variables. High scoring sites were principally located on both sandy and chalky soils and the nationally important Oxfordshire site was on clay soil over limestone. Uncommon species which showed a preference for chalky soils included *Legousia hybrida, Anthemis cotula, Euphorbia exigua* and *Sherardia arvensis*, while *Glebionis segetum, Spergula arvensis, Anchusa arvensis, Silene noctiflora, Erodium cicutarium* and *Raphanus raphanistrum* were more frequent on sandy soils.

There were very few records for any IAPA species in the non-cultivated, floristically-enhanced margins. Cultivation is essential for the germination and survival to seed-production of these poorly-competitive annual plants (Grime et al, 1988). Open soil is required for germination and absence of a dense, shading canopy is necessary for subsequent growth. Field margins should always be evaluated when proposing agri-environment options for a farm. If perennial strips are established in margins where important populations or assemblages of arable plants occur it can result in the unwitting elimination of the farm’s most ecologically valuable feature. Some rare species including

Glebionis segetum and *Anthemis cotula*, both members of the Asteraceae, are also likely to be important for flower-feeding insects (Nichols et al, 2019).

4.1.3. Associations between vegetation of cultivated margins and environmental variables

Canonical Correspondence Analysis arranges species on axes depending on their occurrence within samples and ordinates samples on the basis of the species present. Sites and species can therefore be displayed in scatterplots using the same axes and with the same environmental variable vectors. The environmental variables found to be significant in the analysis were chalky and sandy soil, region and number of years since establishment. These only accounted for 49% of the variation in the data, and consequently the delineation of polygons enclosing groups of species and sites show considerable overlap. This is further compounded by the wide ecological amplitude of many of these species and also by the broad definition of the ecological variables used in the analyses. It is also clear that other environmental variables are important in determining the composition of the vegetation recorded here.

There was significant separation between species known to be characteristic of sandy soils and those characteristic of chalky soils. The vegetation of sandy soils can largely be referred to the NVC communities OV1 (*Viola arvensis-Aphanes microcarpa* community), OV4 (*Spergula arvensis-Chrysanthemum segetum* community), with OV15 (*Anagallis arvensis-Veronica persica* community) on heavier, more base-rich soils. The more species-rich stands on chalk can probably be referred to OV15b (*Legousia hybrida-Chaenorhinum minus* sub-community)(Rodwell, 2000). Only four individual species showed significant relationships with soil type, *Agrostis stolonifera* with sand, *Helminthotheca echioides* with clay/loam and *Sherardia arvensis* and *Sinapis arvensis* with chalk.

Sites were also closely associated with the two soil vectors. The majority of plots on chalk soils being associated with high values on the “chalk” vector, and the majority of plots on sandy soils being associated with high values on the “sand” vector. Anomalous sites included E9 where the site was adjacent to salt-marsh and several maritime species were present, S5 where the margin had not been cultivated in the previous year and S1 where the cultivated plot had been treated with herbicide. O2, although on a sandy soil, had vegetation including several species more typical of calcareous soils, and may have had some influence from the adjacent Jurassic limestone. The few sites on heavier clay and loam soils occupy a position on the scatterplot between the sites on sandy soils and those on chalk.

Phenology and Life Strategy (Grime et al, 1988) and information on germination periodicity (Wilson & King, 2002) can also be used to define groups of annual species as predominantly spring-germinating or predominantly autumn-germinating. These can also be enclosed by polygons in the ordination scatterplot. Several species including the typically autumn-germinating *Alopecurus myosuriodes* (Wallgren & Avholm, 1978) and *Veronica arvensis* (Baskin & Baskin, 1983) were significantly more frequent after autumn cultivation.

A polygon enclosing perennials and annuals typical of grassland suggests that a measure of cultivation efficiency could be included in the analysis and may explain further variation in the data. It is possible that this variation may be related to cultivation type. Significant differences between individual species were found between ploughed sites and minimum cultivated sites. The perennials *Agrostis stolonifera* and *Taraxacum spp.* were more frequent under minimum cultivation, while the annuals *Atriplex patula, Fumaria officinalis,* *Lamium hybridum, Persicaria maculosa* and *Silene noctiflora* were all more frequent after ploughing.

Less well-defined groups of species included those of dry, low fertility soils characterised by summed Ellenberg Indicator Values (Hill et al., 1999) for fertility and moisture of less than 10 and moist, high fertility soils with summed EIVs for fertility and moisture of more than 12.

4.1.4. Cultivation time

Guidelines for the establishment of cultivated plots or margins under Higher Level Stewardship (Anon, 2013) and Countryside Stewardship (Anon, 2017) specify cultivation to give a “firm, fine tilth, either in autumn or spring”. Difficult weather conditions in the spring of 2018 are likely to have been the reasons for the late cultivation of six margins in that year. A further two margins had not been cultivated at all. In five out of six of these late-cultivated margins, seedlings only were present and little was available as a nectar resource at the time of survey. It is possible that these seedlings would have developed to produce flowers later in the summer. It is likely that the much drier winter and spring of 2019 enabled appropriate cultivation in that year, although the lack of any plants at one site was attributed to a dearth of rain following the late spring cultivation.

One site in Southern England appeared to have been treated with broad-spectrum herbicide, resulting in a near-complete absence of plants.

4.1.5. Problem species

The great majority of rare and declining arable plants are poorly competitive. Highly nitrogen and phosphate-responsive species can pose a major problem to the survival of less competitive species in arable systems (Grime et al., 2008). There are however no established thresholds for the frequency and abundance of these highly competitive species and there is little knowledge of how the survivorship of rare species are affected through the growing season by changes in competitive weed cover.

Many of these species are perennials, able to survive cultivations by producing underground perennating organs (eg *Cirsium arvense, Sonchus arvensis, Artemisia vulgaris, Elymus repens*). Other competitive species include annual grasses (*Bromus spp, Alopecurus myosuroides*), other annuals (eg *Sonchus asper/oleraceus*) and rapidly-growing clonal perennials (eg *Agrostis stolonifera, Trifolium repens*). Cover of these species was high in the majority of cultivated margins, including O4 and O2 where there was also a high frequency of rare species.

While it is highly likely that a high cover of competitive species will suppress less competitive species it is not possible to quantify the extent of this in a survey of this type. The effects of competitive crop plants on rare annuals are well known (Wilson, 1990; Grundy, 1993) and this can be extrapolated to systems where competitive “weeds” interact with rarer species.

It is not possible therefore to use the results of this work to specify acceptable thresholds for the total cover of competitive weeds or for the cover of individual species. Indeed, some species such as *Cirsium arvense* and *Sonchus arvensis* are likely to be beneficial for nectar and pollen-feeding insects (Nichols et al., 2019) and will contribute to the importance of cultivated margins for invertebrates (Holland et al., 2014, 2015; Wood et al., 2015). The presence of competitive species in a cultivated margin is also a factor influencing the acceptability of this management option to farmers, and the presence of species such as

Cirsium arvense, Sonchus arvensis and *Bromus spp* will be a serious deterrent to the adoption of cultivated margins (Swan, 2020 in press). It is clear therefore that the establishment of acceptable cover and frequency thresholds for competitive species, and development of management strategies for their control will be important when formulating recommendations for future agri-environment schemes.

4.2. Floristically enhanced margins

4.2.1. Invertebrates

A diverse community of beneficial invertebrates was found in these margins, including high numbers of pest natural enemies and pollinating insects. The pitfall trapping showed that there was a diverse and more even community of carabid beetles compared to the cultivated margins, many of which are known predators of crop pests. Likewise, the D-vac suction samples contained a high proportion (95%) of natural enemies of which a high proportion were parasitic wasps, a key group of natural enemies for most crop pests. Current UK agri-environment schemes only offer one option that has been specifically designed to benefit biological control (beetle banks), although a wide range of other options also support natural enemies to some degree (Holland et al., 2014, 2020). The extent to which such habitats increase levels of pest control is poorly understood as the majority of studies only measure natural enemies in the habitat itself. Of 138 publications that investigated the contribution of semi-natural habitats to pest control, most measured abundance of predators (70%) or parasitism (22%) within the habitats and only 22% reported pest levels and of these only 9% measured predators and 6% parasitism (Holland et al., 2017). The contribution of grassy field margins has been investigated in detail and shown to have an impact on pest control in the adjacent crop (Holland et al., 2012) and there are examples which show that flower strips can also benefit biological control (e.g. Sutter et al., 2018) and can have an even greater benefit if sown with seed mixes containing the plant species known to support natural enemies (Carrie et al., 2012; van Rijn et al., 2013; Tschumi et al., 2016).

These margins were mostly frequented by bumblebees rather than solitary bees. This is because the seed mixes currently available are targeted towards bumblebees containing common species of Fabaceae (vetches, clovers, trefoils) and knapweed. These are attractive to a relatively small suite of bumblebees and solitary blees; only 32% of solitary bees found on farmland visited sown wildflower species (Wood et al., 2015a). If a wider range of species is to be supported then they will need diversifying (Wood et al., 2015, 2017). More recently further species have been identified that are as attractive or of greater attraction than previously known to wild bees and these could be incorporated in seed mixes (Nichols et al., 2019). These were identified following assessments of single stands of wildflowers used for seed production and as the different species are were next to each other provides a strong selection test. The foraging assessments conducted in this project also supported these findings. For bumblebees, key species identified by Nichols et al. (2019) were kidney vetch (Anthyllis vulneraria), meadow crane's-bill (Geranium pratense), greater knapweed (Centaurea scabiosa), smooth hawk’s beard (Crepis capillaris) and wild marjoram (Origanum vulgare). In this study another Crepis species, C. vesicaria (beaked hawk’s-beard) and dandelions were important along with some weed species, especially spear thistle. For solitary bees, perennials such as rough chervil (Chaerophyllum temulum), pignut (Conopodium majus) and primrose (Primula vulgaris) were key forage plants identified by Nichols, but as in this study a range of weeds were also well- visited e.g. sowthistle (Sonchus oleraceus) and dandelions (Taraxacum spp.). Some of these and other well-visited species such as meadow crane's-bill, dandelions, hawk’s-beard species and wild marjoram are found in some mixes but could be more widely incorporated, species such as meadow crane's-bill, dandelions, hawk’s-beard species and wild marjoram. A range of weeds should also be tolerated such as sowthistles and spear thistles. Extending the flowering period would also help with species such as primrose (Primula vulgaris), red dead nettle (Lamium purpureum) and ground ivy (Glechoma hederacea). Knapweed species were, as previously known, attractive for both bumblebees and solitary bees. Many of the annual and perennial species most commonly used by the wild bees were also visited by hoverflies, although cow parsley (Anthriscus sylvestris) was the most visited perennial plant.

Sowing specific mixtures of perennial grass and wildflower legume species to create floristically enhanced margin habitats has clear advantages in terms of enhancing the quality of arable field margins. Such margins were associated with increased total bee and hoverfly abundance, and we propose two explanations for the increased activity evident on sown over naturally regenerated margins. Across the survey period sown margins were associated with increased flowerhead abundance and higher coverage of broad-leaved species, it is therefore evident that sown margins are better at providing sustained forage throughout the season compared to those established by natural regeneration. They also had fewer pernicious grasses that can become dominant. Sown mixes typically include only non-dominant grasses and a mixture of wildflowers and legume plants (Carvell et al., 2007). We therefore recommend replacing naturally regenerated margins with sown margins if the grass component of the habitat becomes dominant, unless the margins are adjacent to a species-rich field boundary where natural colonisation by species-rich vegetation might reasonably be expected. Secondly, bare ground cover was significantly higher on sown margins which for hoverflies may represent basking areas e.g. *Pipizella spp.* (Ball and Morris 2013). For solitary bees, specifically mining bees that nest underground, bare ground provides additional nesting habitat that is often scarce on farmland (Nichols et al., 2020).

In contrast, carabids, were more abundant on margins established by natural regeneration. Carabids are polyphagous predators which means that unlike pollinators they do not depend on floral resources when feeding. The high vegetation coverage offered by naturally regenerated margins may therefore provide more feeding opportunities for these beetles and shelter carabids from their predators. The strong negative relationship insectivorous birds have with percentage bare ground cover suggests that food accessibility may be more influential in determining habitat use than food abundance (Butler & Gillings 2004; Devereux et al., 2006; Atkinson et al., 2005). For example, high bare ground cover has been linked to increased foraging by yellowhammer and corn bunting on farmland, in part because their invertebrate food items, which include Carabids, become more accessible (Moorcroft *et al.,* 2002).

The vegetative characteristics of floristically enhanced margins were found to change over time, with older margins becoming dominated by grass and containing fewer flowerheads to support foraging pollinators. Contrary to our expectation’s hoverfly abundance increased with margin age, this may however be linked to older margins having a greater chance of invertebrate colonisation because their location is known (Corbet 1995).

Cropping adjacent to floristically enhanced margins was only found to influence one pollinator species, the red-tailed bumblebee, the abundance of which increased when margins were located adjacent to cereal crops. This species is known to have a large foraging range which includes fields of mass flowering crops (Goulson, 2010). We suggest that in the absence of such crops red-tailed bumblebees may become more reliant on field edge habitats, including floristically enhanced margins, when feeding.

Contrary to Smith & Everette (2010), we found that grass cover declined with margin width, probably because invasion from adjacent field boundaries was less important giving the herbaceous plants more chance of survival. Furthermore, cutting regime significantly influenced margin structure with spring/summer cutting reducing margin height and Staphylinidae abundance. It is common practice for floristic margin cuttings to be left *in situ,* although Smith & Everett (2010) highlighted that this can negatively impact floral diversity as herbaceous species are smothered whilst also increasing soil fertility. Other techniques to maintain the cover of herbaceous cover have been tested with varying success, such as applying a graminicide when grasses build up and scarifying the sward to allow spread of herbaceous species (Westbury et al., 2008).

Overall, our pollinator foraging data from 2019 showed that spear thistles and bird's-foot trefoil attracted the highest number of foraging bumblebees. Previous research by Carvell et al. (2007) concluded that bumblebee richness and abundance was highest in sown Fabaceae patches. In the UK seed mixes targeting bumblebees have historically contained Fabaceae species, including bird's-foot trefoil, and they have been shown to attract large numbers of the seven most common bumblebee species, as found in the study. This can increase the nest densities of some bumblebee species by 2-3 fold (Wood et al., 2015b). They do not however increase plant diversity on farms and if the rarer species are to be encouraged and also solitary bees which have different foraging preferences to bumblebees (Wood et al., 2015a, 2016), then a much broader range of plant species need to be established (Wood et al., 2017). This study also showed that a range of other plant species were visited, many of which are not typically included in seed mixes. Annual weeds were also important for some bumblebees and solitary bees and the cultivated margins helped contribute to the overall plant diversity. There was also some overlap with the foraging preferences of wild bees and hoverflies as the latter were most commonly found foraging on *Crepis* spp. (Hawk's beards) and *Anthriscus sylvestris* (cow parsley). This relationship can be explained by the nectar availability provided by these plants (van Rijn and Wackers, 2015). *Crepis* spp. are not usually a species included in sown flower mixtures. Solitary bees also showed a strong preference for cow parsley followed by dandelions when foraging. Nichols et al. (2019) ranked dandelions 6th in their solitary bee foraging study and the Asteraceae species in general were shown to be important for a range of solitary bee species, representing 20% of solitary bee visitations. In conclusion, there is some scope for the improvement of wildflower margins by adding in a greater range of plant species, although some will also naturally colonise over time. Tolerance of some weed species would also benefit the pollinators, especially spear thistle which is less invasive than creeping thistle. The cultivated margins were also shown to provide floral foraging resources, especially for solitary bees and hoverflies. Solitary bees were most frequently observed on *Sonchus oleraceus* (common sowthistle), which is an annual weed, and was also attractive to hoverflies This species can spread rapidly in the cultivated margins and may need controlling if it spreads to the detriment of the other arable plants. These margins are also more likely to contain bare ground that is often in short supply on arable farms, yet when made available is readily colonised by some solitary bee species (Nichols et al., 2020).

4.2.2. Vegetation composition

The most important factor affecting the composition of perennial vegetation in field margins was age since establishment. Vegetation in the most recently-established margins was characterised by a high frequency of annual species typical of regularly cultivated arable land and early successional stages. These species included the annuals *Myosotis arvensis, Tripleurospermum inodorum, Bromus sterilis, Sonchus oleraceus* and *Geranium dissectum,* and the biennials and short-lived perennials *Silene latifolia, Agrostis stolonifera, Rumex crispus, Senecio jacobaea* and *Daucus carota*.

The most recently established margin (E8) was established in the year it was surveyed and was similar in appearance to the surveyed cultivated margin, with a Plantlife IAPA score (Byfield & Wilson, 2007) of 31, greater than the cultivated margin on the same farm. Species on the IAPA list were recorded only at E8 and at S6 (*Anthemis cotula* only). The S6 margin was only two years old at the time of survey. The dense and closed swards in well-established margins offer little opportunity for poorly-competitive annual plants to germinate. That annual species of conservation value were present in these recently established perennial margins suggests that care should be taken to avoid siting this option in positions where it can be detrimental to the existing ecological interest.

Species that showed a positive association with the "age" vector in the CCA analysis included both those typically included in seed mixes for floristic enhancement (eg *Galium verum, Centaurea nigra, Leucanthemum vulgare, Agrostis capillaris* and *Anthoxanthum odoratum*) and opportunistic species frequent in the MG1 (*Arrhenatherum elatius* grassland)-related vegetation characteristic of hedge-bottoms (Rodwell, 1992; Wilson, 2019). The latter include *Arrhenatherum elatius, Elymus repens, Urtica dioica* and *Anthriscus sylvestris*.

The overall trajectory of the vegetation through time appears to be from the initial segetal and ruderal vegetation of the cultivated arable field margin to vegetation related to MG1 grassland, modified by the addition of the seed mixture. Many sown species appear to germinate readily and are present in the developing grasslands from the first year onwards, while the short-lived species typical of open conditions decline and are very uncommon after two years.

Of the 30 margins surveyed, originally thought to have been established by drilling a seed mixture, four were subsequently found to have been established solely by natural succession with no added seed, one had been sown with grass seed and later supplemented with broad-leaved species, with the method for establishment of another (O3) unknown. A total of 25 margins were therefore floristically enhanced, a further four were established by natural succession and one was dropped from the analysis.

Of the 25 floristically enhanced margins, five had less than 3% cover of probably sown broad-leaved species. While this is to be expected at sites in the earliest stages of establishment (e.g. E8), the other sites with very low cover had been under management for between six and nine years and it can be assumed that the establishment of floristically-enhanced margins at these sites had failed, with limited likelihood of further development in the largely dense, closed swards.

Species considered significant agricultural weeds or potentially detrimental to the establishment of floristically enhanced margins were present in most of the margins, but generally at very low frequency and cover. *Elymus repens*, *Bromus sterilis* and *Galium aparine* were the only species with more than 10% cover and only at four sites, all of which were failed floristically-enhanced margins or unsown margins. *Trifolium repens* is a nitrogen-fixing species regarded as detrimental to species-rich grassland restoration (Warren, 2001; Anon, 2013), and may indicate high phosphate content in the soil. It had greater than 10% cover at four sites, all of these sites however also had high cover of sown broad-leaved species. *Trifolium repens* is included in many seed mixes designed for use in stewardship option field margins along with other nitrogen-fixing species of the *Fabaceae*, and this may be a limiting factor in their long-term success. At least one company which specialises in seed mixtures for conservation projects uses no *Fabaceae* in many of its mixtures.

No significant difference was found by CCA analysis between margins established by natural succession and floristically enhanced margins. The plot of margins on axes 1 and 2 of the ordination however shows that the 12 margins which had more than 10% cover of sown broad-leaved species were grouped in the lower central part of the diagram, and this corresponded with the grouping of sown broad-leaved species A. The four long-established sites with the lowest cover of broad-leaved species were grouped in the top right part of the diagram, and were associated with perennial species typical of nutrient-rich sites (Grime et al, 1988; Hill et al, 1999). The four non-sown sites showed no obvious grouping. This lack of significant effect may be due to the failure of the seed mixture to establish in some margins, but may also be due to the great variability in vegetation composition between sites. The groupings of sites in the CCA plot suggests that there may be an effect, but additional data would be needed to determine whether this exists.

Some species, *Arrhenatherum elatius, Bromus commutatus, Elymus repens* and *Galium aparine,* produced significantly greater cover in non-sown margins. This may relate to methods used for seed-bed preparation before sowing or may be a result of competitive pressure from the sown species.

While an analysis of sward development in relation to time since establishment and method of establishment was not the object of this survey, it has nevertheless provided some indications of how well and how rapidly these margins can establish. This may have some relevance to results-based payments for agri-environment options, but further targeted data from margins in the earliest stages of development and from naturally-regenerated margins are required if more meaningful conclusions are to be drawn about the rates of development and expected outcomes under different conditions.

5 Recommendations

5.1 Cultivated margins

Establishment

Cultivated margins established using minimum tillage benefitted a broad range of beneficial invertebrates. The reduced level of soil disturbance helps the survival of invertebrates whose life-stages live within the soil while also encouraging perennial plants, such as *Taraxacum* species that were used by many pollinator groups. Ploughing reduced grass weeds and encouraged some annual plant species and in some situations may be more appropriate. For example, if there are rare arable plant species that persist better under a ploughing regime. However, ploughing could be used as a management tool if grass weeds build up and threaten the broad-leaf arable plants. Alternatively, the use of graminicides to reduce the grass weed burden may be more appropriate and would reduce the damage to soil dwelling invertebrates.

Broad-leaf plant cover was lower in larger margins and thus they may be more appropriate in locations where there is the possibility of aggressive plants invading from the field boundary. It would also be easier to selectively treat such invasive plants with a herbicide in a wider margin, provided such applications were permitted under the scheme rules.

Annual management

Rotational cultivated margins were associated with lower flower abundance and in turn lower wild bee abundance, although bumblebees favoured older margins. Given the higher use of cultivated margins by solitary bees, annually rotated margins should be discouraged and only permitted when invasive and less beneficial weeds are dominating the flora to the detriment of other more desirable species. Instead cultivated margins that are implemented in the same location over longer periods should receive higher financial reward and encouragement.

The most appropriate management may not always favour both rare arable plants and invertebrates and decisions should be made depending on the perceived priority. If rare arable plants are present then management for those should be the priority. However, in their absence it may be more appropriate to adopt management that also protects the invertebrates, such as minimum tillage and greater tolerance of the problem weed species that are also utilised by invertebrates, such as *Sonchus* species.

Future research
Cultivated margins contained a rich diversity of arable plants and the vegetation and seeds are a valuable food source for a range of wildlife including grazing mammals, rodents and invertebrates. These animals form important dietary components for a wider range of species including birds and invertebrates. Arable plants are critical to many invertebrates consumed by farmland birds and this includes common species such as *Poa annua, Stellaria media, Fumaria officinalis, Sinapis arvensis, Senecio vulgaris, Persicaria lapathifolia, Sonchus spp., Matricaria discoidea, Persicaria maculosa, Agrostis spp., Lamium purpureum, Lamium album, Veronica spp., Atriplex spp., Myosotis* spp. and *Anagallis arvensis*. (Smith et al., 2020). Levels of invertebrates have declined in arable crops and are considered below the levels needed to sustain populations of key farmland birds. Further investigations of their wider value are needed, especially for sustaining insects important in the diet of farmland birds, and also their use by birds, bats and small mammals.

Future research could consider the effectiveness of a mixed approach to non-rotational cultivated margins management e.g. to determine if 2-3 years of minimum tillage followed by a plough is effective (Andrew Cooke, *pers. comm.*)

5.2 Floristically enhanced margins

Establishment
There is some scope for the improvement of floristically enhanced margins established by sowing. For example, commercially available seed mixtures could incorporate a wider range of plant species to encourage utilisation by a greater diversity of pollinator species. In this and other studies only the seven most common bumblebee species were typically found and more effort is needed to support the rarer species. Previous agri-environment scheme options have focussed predominantly on encouraging Fabaceae, although these are primarily of use to long-tongued bumblebees. In surveys on arable farms in southern England 148 bee and wasp species were found (Wood et al., 2015a), representing almost half of the UK solitary bee species, demonstrating the potential to encourage these through provision of a greater range of plant species. A number of publications (e.g. Nichols et al., 2019) have provided recent recommendations and the suggested additions supported by this study are: *Crepis capillaris*, *C. vesicaria*, *Geranium pratense*, *Geranium pyrenaicum*, *Centaurea scabiosa*, *Daucus carota*, *Origanum vulgare*, *Ononis repens*, *Primula vulgaris*, *Chaerophyllum temulum*, *Anthyllis vulneraria* and *Anthriscus sylvestris*. Some of these are already included in some wildflower seed mixes.

Floristically enhanced margins had fewer aggressive weed species and therefore should be sown with recommended and diverse seed mixes. Whenever possible seed mixes from locally sourced seed should be used to preserve the local provenance and species typical for the area used.

Annual management

Some agricultural weeds also received a high number of visits by pollinators, relative to pollinator visitation to other plants within floristically enhanced margins, and should be tolerated in floristic margins provided they do not become dominant to the detriment of other species. These weed species include *Cirsium vulgare*, *Taraxacum* species, *Convolvulus arvensis*, *Sonchus* species, *Sinapis arvensis* and *Papaver rhoeas*. *Papaver rhoeas* is sometimes included in perennial seed mixes to provide colour in the first year. *Cirsium arvense* was also of value although would require close management to prevent excessive spread.

General recommendations

We recommend that the surveys be repeated in the future as our results were based on only two years of data, both of which were characterised by extreme weather conditions, the first year was affect by a cold wave in late winter, the "beast from the east", and the second year from some extremely high summer temperatures.

Cultivated margins support a different plant and invertebrate community to that of the floristically enhanced margin, whilst also providing an alternative more open vegetation structure. Given their use by wildlife and by pollinators and pest natural enemies thereby boosting the natural capita of agricultural land, we therefore recommend that measures are put in place (appropriate financial support for farmers and training of agri-environment scheme advisors) to encourage greater uptake, even where rare arable plants are not present.

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Appendix I. Site selection

A list of farms eligible for surveys was supplied to us by Natural England. From this list farms were selected at random in each region. Some farms were excluded if they were too far from the core area (9 farms).

To ensure selected margins met the project requirements some preliminary information was collected from landowners or farm managers prior to surveys. This included:

- For both margin types: number at site, adjacent boundary type (s), shape (plot or strip), measurements (length and width, m), age
- If the cultivated margin was rotational or non-rotational (and if non-rotational, how often moved)
- If floristically enhanced margin were sown or natural regeneration
- If the floristically enhanced margin was cut annually, when they were cut and if the cuttings were removed

In 2018, 34 farms were contacted, including 3 farms not on the original list. Eleven farms did not want to participate in the project, were not contactable or said they would consider participating in 2019 surveys. Eight farms were rejected due to their margins being directly adjacent to another HLS option (e.g. a cultivated margin next to a wild bird seed mixture plot) or were managed atypically (e.g. if disturbance from the public was highly likely or if the cultivated margin was only partly cultivated or sown). This aimed to prevent surveying margins whose results would be affected by uncommon practices. Unfortunately, nine participating farms did not answer all the preliminary questions or admit to atypical management. This resulted in farms with atypical margin management being included in the study despite trying to avoid this.

In 2019, 24 farms were contacted. Five farms did not want to participate or were not contactable. Two farms were rejected because the margins were directly adjacent to another HLS option. One farm was rejected because the margin was rotational, and another farm was rejected for not being within one of the regions.

Appendix II. Procedure for pitfall trap sampling

Appendix II. Pitfall trapping dates

Pitfall collection dates 2018			
Farm code	Survey 1	Survey 2	Survey 3
E1	08-May	04-Jul	05-Sep
E2	08-May	03-Jul	05-Sep
E3	08-May	03-Jul	05-Sep
E4	09-May	03-Jul	04-Sep
E5	09-May	03-Jul	04-Sep
M1	16-May	03-Jul	05-Sep
M2	15-May	04-Jul	04-Sep
M3	14-May	06-Jul	06-Sep
M4	14-May	06-Jul	06-Sep
M5	23-May	05-Jul	04-Sep
S1	08-May	02-Jul	05-Sep
S2	08-May	02-Jul	05-Sep
S3	10-May	05-Jul	04-Sep
S4	10-May	05-Jul	04-Sep
S5	18-May	02-Jul	05-Sep
Pitfall collection dates 2019			
Farm code	Survey 1	Survey 2	Survey 3
E6	7-May	2-Jul	5-Sep
E7	7-May	2-Jul	5-Sep
E8	8-May	2-Jul	5-Sep
E9	8-May	1-Jul	5-Sep
E10	7-May	1-Jul	5-Sep
O1	7-May	3-Jul	29-Aug
O2	7-May	3-Jul	29-Aug
O3	7-May	4-Jul	30-Aug
O4	7-May	4-Jul	29-Aug
O5	8-May	4-Jul	30-Aug
S6	3-May	27-Jun	27-Aug
S7	2-May	28-Jun	27-Aug
S8	2-May	28-Jun	27-Aug
S9	2-May	28-Jun	27-Aug

S10	3-May	27-Jun	27-Aug

Appendix III. Table of Dvac suction sampling dates

2018 suction sampling dates	
Farm code	**Suction sampling date**
E1	30-May
E2	30-May
E3	29-May
E4	29-May
E5	29-May
M1	06-Jun
M2	05-Jun
M3	06-Jun
M4	06-Jun
M5	05-Jun
S1	20-Jun
S2	20-Jun
S3	19-Jun
S4	19-Jun
S5	20-Jun
2019 suction sampling dates	
Farm code	**Suction sampling date**
E6	19-Jun
E7	19-Jun
E8	19-Jun
E9	18-Jun
E10	18-Jun
O1	17-Jun
O2	17-Jun
O3	17-un
O4	17-Jun
O5	18-Jun
S6	4-Jun
S7	3-Jun
S8	3-Jun
S9	3-Jun
S10	4-Jun

Appendix IV. Table of pollinator transect walk dates and vegetation assessments dates which accompanied pollinator transects

Appendix IV a. Table of pollinator transect walk dates.

Transect walk dates 2018						
Farm code	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**	**Survey 5**	**Survey 6**
E1	01-May	30-May	27-Jun	23-Jul	29-Aug	26-Sep
E2	01-May	30-May	26-Jun	23-Jul	29-Aug	26-Sep
E3	01-May	30-May	26-Jun	23-Jul	29-Aug	26-Sep
E4	02-May	29-May	25-Jun	24-Jul	28-Aug	27-Sep
E5	03-May	29-May	25-Jun	24-Jul	28-Aug	27-Sep
M1	10-May	15-Jun	26-Jun	27-Jul	29-Aug	28-Sep
M2	08-May	06-Jun	27-Jun	24-Jul	30-Aug	27-Sep
M3	11-May	07-Jun	29-Jun	25-Jul	31-Aug	26-Sep
M4	07-May	07-Jun	30-Jun	25-Jul	31-Aug	26-Sep
M5	23-May	06-Jun	28-Jun	24-Jul	28-Aug	27-Sep
S1	01-May	01-Jun	25-Jun	25-Jul	29-Aug	27-Sep
S2	01-May	01-Jun	25-Jun	25-Jul	29-Aug	27-Sep
S3	02-May	06-Jun	28-Jun	26-Jul	28-Aug	24-Sep
S4	02-May	06-Jun	28-Jun	26-Jul	28-Aug	24-Sep
S5	11-May	01-Jun	25-Jun	25-Jul	05-Sep	27-Sep
Transect walk dates 2019						
Farm code	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**	**Survey 5**	**Survey 6**
E6	30-Apr	29-May	25-Jun	1-Aug	30-Aug	23-Sep
E7	30-Apr	30-May	25-Jun	30-Jul	29-Aug	24-Sep
E8	29-Apr	30-May	24-Jun	30-Jul	29-Aug	23-Sep
E9	1-May	29-May	24-Jun	1-Aug	29-Aug	23-Sep
E10	30-Apr	30-May	25-Jun	1-Aug	30-Aug	24-Sep
O1	30-Apr	30-May	26-Jun	2-Aug	22-Aug	26-Sep
O2	30-Apr	5-Jun	26-Jun	1-Aug	22-Aug	25-Sep
O3	30-Apr	5-Jun	26-Jun	1-Aug	22-Aug	25-Sep
O4	30-Apr	30-May	27-Jun	1-Aug	22-Aug	25-Sep
O5	1-May	30-May	27-Jun	2-Aug	23-Aug	25-Sep
S6	23-Apr	23-May	20-Jun	24-Jul	20-Aug	19-Sep
S7	23-Apr	22-May	21-Jun	25-Jul	20-Aug	18-Sep
S8	23-Apr	22-May	21-Jun	25-Jul	20-Aug	18-Sep
S9	7-May	22-May	21-Jun	26-Jul	20-Aug	18-Sep
S10	23-Apr	23-May	20-Jun	24-Jul	20-Aug	19-Sep

Appendix IV b. Vegetation assessment dates which accompanied pollinator transects

Pollinator and vegetation assessment dates 2018						
Farm code	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**	**Survey 5**	**Survey 6**
E1	01-May	30-May	27-Jun	23-Jul	29-Aug	26-Sep
E2	01-May	30-May	26-Jun	23-Jul	29-Aug	26-Sep
E3	01-May	30-May	26-Jun	23-Jul	29-Aug	26-Sep
E4	02-May	29-May	25-Jun	24-Jul	28-Aug	27-Sep
E5	03-May	29-May	25-Jun	24-Jul	28-Aug	27-Sep
M1	10-May	15-Jun	26-Jun	27-Jul	29-Aug	28-Sep
M2	08-May	06-Jun	27-Jun	24-Jul	30-Aug	27-Sep
M3	11-May	07-Jun	29-Jun	25-Jul	31-Aug	26-Sep
M4	07-May	07-Jun	30-Jun	25-Jul	31-Aug	26-Sep
M5	23-May	06-Jun	28-Jun	24-Jul	28-Aug	27-Sep
S1	01-May	01-Jun	25-Jun	25-Jul	29-Aug	27-Sep
S2	01-May	01-Jun	25-Jun	25-Jul	29-Aug	27-Sep
S3	02-May	06-Jun	28-Jun	26-Jul	28-Aug	24-Sep
S4	02-May	30-May	28-Jun	26-Jul	28-Aug	24-Sep
S5	11-May	01-Jun	25-Jun	25-Jul	05-Sep	27-Sep
Pollinator and vegetation assessment dates 2019						
Farm code	**Survey 1**	**Survey 2**	**Survey 3**	**Survey 4**	**Survey 5**	**Survey 6**
E6	30-Apr	29-May	25-Jun	1-Aug	30-Aug	23-Sep
E7	30-Apr	30-May	25-Jun	30-Jul	29-Aug	24-Sep
E8	29-Apr	30-May	24-Jun	30-Jul	29-Aug	23-Sep
E9	1-May	29-May	24-Jun	1-Aug	29-Aug	23-Sep
E10	30-Apr	30-May	25-Jun	1-Aug	30-Aug	24-Sep
O1	30-Apr	30-May	26-Jun	2-Aug	22-Aug	26-Sep
O2	30-Apr	5-Jun	26-Jun	1-Aug	22-Aug	25-Sep
O3	30-Apr	5-Jun	26-Jun	1-Aug	22-Aug	25-Sep
O4	30-Apr	30-May	27-Jun	1-Aug	22-Aug	25-Sep
O5	1-May	30-May	27-Jun	2-Aug	23-Aug	25-Sep
S6	23-Apr	23-May	20-Jun	24-Jul	20-Aug	19-Sep
S7	23-Apr	22-May	21-Jun	25-Jul	20-Aug	18-Sep
S8	23-Apr	22-May	21-Jun	25-Jul	20-Aug	18-Sep
S9	7-May	22-May	21-Jun	26-Jul	20-Aug	18-Sep
S10	23-Apr	23-May	20-Jun	24-Jul	20-Aug	19-Sep

Appendix V. Selection of margin photos.

Floristically enhanced margins

E1

Figure 33. E1 early May 2018

Figure 34. E1 late May 2018

Figure 35. E1 – June 2018

Figure 36. E1 - July 2018

Figure 37. E1 – August 2018

Figure 38. E1- September 2018

S1

Figure 39. S1 – April 2018

Figure 40. S1 - May 2018

Figure 41. S1 June 2018

Figure 42. S1 - July 2018

Figure 43. S1 - August 2018

Figure 44. S1 - September 2018.

Cultivated margins

Figure 45. E3 – April 2018.

Figure 46. E3 - May 2018.

Figure 47. E3 – June 2018.

Figure 48. E3 July 2018.

Figure 49. E3 August 2018.

Figure 50. E3 September 2018.

S3

Figure 51. S3 April 2018

Figure 52. S3 - May 2018.

Figure 53. S3 - June 2018.

Figure 54. S3 July 2018.

Figure 55. S3 August 2018.

Figure 56. S3 - September 2018.

Appendix VI. Vegetation assessments dates which accompanied DVac suction sampling

Farm code	***Detailed botanical assessment dates***
East farm 1	08-Jun
East farm 2	06-Jun
East farm 3	06-Jun
East farm 4	07-Jun
East farm 5	07-Jun
Midlands farm1	12-Jun
Midlands farm 2	11-Jun
Midlands farm3	13-Jun
Midlands farm 4	13-Jun
Midlands farm 5	14-Jun
South farm 1	28-Jun
South farm 2	28-Jun
South farm 3	25-Jun
South farm 4	25-Jun
South farm 5	01-Jul

Appendix VII. Summary of Cultivated margin and Floristically enhanced margins site characteristics.

Appendix VII a. Summary of cultivated margins site characteristics.

Farm code	Survey year	Region	Rotational	Margin age	Cultivation type (PL = plough; MT = Min-till; PH = Power Harrow)	Soil fertility	Width (m)	Adjacent boundary	Adjacent cereal crop (Y=Yes; N=No)
E1	2018	East	NR	8	PL	2	6	Hedge	N
E10	2019	East	NR	6	PL	3	5.5	Other	N
E2	2018	East	NR	6	PL	2	6	Hedge	Y
E3	2018	East	NR	5	PL	2	6	Hedge	Y
E4	2018	East	NR	8	PL	2	4	Hedge	N
E5	2018	East	NR	17	MT	3	6	Hedge	N
E6	2019	East	R	4	MT	2	4.5	Other	N
E7	2019	East	NR	3	MT	2	6	Hedge	N
E8	2019	East	NR	3	PL	3	25	Other	N
E9	2019	East	NR	7	MT	5	68	Hedge	Y
M1	2018	Midlands	NR	5	MT	3	23	Hedge	N
M2	2018	Midlands	NR	8	MT	4	50	Hedge	N
M3	2018	Midlands	NR	8	MT	1	100	Other	N
M4	2018	Midlands	NR	15	MT	1	6	Hedge	Y
M5	2018	Midlands	R	1	MT	4	40	Other	Y
O1	2019	Oxford	NR	6	MT	2	50	Hedge	Y
O2	2019	Oxford	NR	15	MT	3	5	Hedge	N
O3	2019	Oxford	NR	10	PL	4	7	Hedge	Y
O4	2019	Oxford	NR	20	PL	3	6	Hedge	N
O5	2019	Oxford	NR	9	MT	3	6	Other	N
S1	2018	South	NR	9	MT	2	40	Other	N
S10	2019	South	R	1	MT	5	7	Hedge	Y
S2	2018	South	NR	6	MT	3	19	Hedge	Y
S3	2018	South	NR	8	MT	3	75	Other	N
S4	2018	South	R	0	MT	3	12	Other	Y
S5	2018	South	NR	17	MT	2	6	Hedge	N
S6	2019	South	NR	2	MT	3	4	Hedge	N
S7	2019	South	R	1	MT	3	8.5	Hedge	N
S8	2019	South	R	14	PL	3	28	Hedge	N
S9	2019	South	NR	9	MT	5	6	Hedge	Y

Appendix VII b. Summary of Floristically enhanced margin site characteristics. Cutting times are been abbreviated (Sp.Su = Spring Summer; Au.Wi = Autumn Winter and Not=not cut).

Farm code	Survey year	Region	Margin age	Establishment (S = seed; N= Natural regeneration)	Soil fertility	Width (m)	Adjacent cereal crop (Y=Yes; N=No)	Cutting time	Adjacent boundary
E1	2018	East	8	S	2	6	Y	Sp.Su	Hedge
E10	2019	East	6	S	3	5	Y	Au.Wi	Other
E2	2018	East	6	S	2	6	Y	Au.Wi	Hedge
E3	2018	East	5	S	2	12	Y	Au.Wi	Hedge
E4	2018	East	6	N	2	6	N	Au.Wi	Hedge
E5	2018	East	5	S	3	6	N	Not	Hedge
E6	2019	East	15	S	2	6	N	Au.Wi	Hedge
E7	2019	East	6	S	2	6	N	Au.Wi	Hedge
E8	2019	East	0	S	3	12	N	Au.Wi	Hedge
E9	2019	East	7	S	5	6	Y	Au.Wi	Hedge
M1	2018	Midlands	15	N	3	6	Y	Sp.Su	Hedge
M2	2018	Midlands	8	S	4	6	Y	Sp.Su	Hedge
M3	2018	Midlands	9	S	1	6	Y	Sp.Su	Hedge
M4	2018	Midlands	15	S	1	4	N	Sp.Su	Other
M5	2018	Midlands	6	S	4	6	Y	Sp.Su	Hedge
O1	2019	Oxford	6	S	2	4	N	Au.Wi	Hedge
O2	2019	Oxford	15	N	3	6	N	Not	Hedge
O3	2019	Oxford	8	N	4	7	Y	Au.Wi	Hedge
O4	2019	Oxford	9	S	3	18	Y	Au.Wi	Hedge
O5	2019	Oxford	9	S	3	6	N	Au.Wi	Hedge
S1	2018	South	8	S	2	5	Y	Au.Wi	Other
S10	2019	South	1	S	5	6	Y	Sp.Su	Hedge
S2	2018	South	6	S	3	4	Y	Sp.Su	Hedge
S3	2018	South	8	S	3	7	N	Au.Wi	Other
S4	2018	South	15	N	3	5.5	Y	Not	Other
S5	2018	South	7	S	2	5	Y	Au.Wi	Hedge
S6	2019	South	2	S	3	4.5	Y	Au.Wi	Hedge
S7	2019	South	9	S	3	6	Y	Sp.Su	Hedge
S8	2019	South	12	S	3	5	N	Au.Wi	Hedge
S9	2019	South	9	S	5	4	Y	Sp.Su	Hedge

Appendix VIII. List of Carabidae species recorded in 2018 across the East, Midlands and the South on cultivated (CM) and floristically enhanced margins (FEM). Nationally scarce species are highlighted in red and biodiversity action plan species in purple.

	East		Midlands		South	
Carabid species	**CM**	**FEM**	**CM**	**FEM**	**CM**	**FEM**
Abax parallelepipidus					X	X
Agonum muelleri	X		X	X		
Amara aenea	X				X	X
Amara apricaria	X	X	X	X		
Amara bifrons	X				X	X
Amara communis	X	X	X	X		
Amara consularis	X				X	X
Amara eurynota	X	X	X	X		
Amara familiaris		X				
Amara fulva			X	X		
Amara Lunicollis	X	X			X	X
Amara plebeja		X		X	X	
Amara similata	X	X				
Anchomenus dorsalis	X	X	X	X		
Asphidion flavipes	X	X			X	X
Badister bullatus		X		X		
Badister sodalis	X					
Batenus livens	X					
Bembidion biguttatum				X	X	X
Bembidion lampros	X	X	X	X		
Bembidion quadrimaculatum	X	X	X	X	X	X
Bembidion tetracolum	X	X	X	X		
Bradycellus verbasci	X		X	X	X	X
Calathus erratus	X				X	
Calathus fuscipes	X	X	X	X	X	X
Calathus melanocephalus	X	X	X	X	X	X
Calathus rotundicollis	X					
Carabus granulatus			X	X		
Carabus monilis			X	X	X	X
Carabus nemoralis			X			
Carabus problematicus	X		X	X	X	X
Carabus violaceus	X	X	X	X		
Cicindela campestris	X				X	X
Clivina fossor			X	X		
Curtonotus aulicus	X	X	X			
Cychrus caraboides	X	X	X	X		
Demetrias atricapillus	X	X		X		
Dromius quadrimaculatus		X			X	X

Harpalus affinis	X	X	X	X	X	
Harpalus rufipes	X	X	X	X	X	X
Leistus ferrugineus	X	X	X	X	X	X
Leistus fulvibarbis	X				X	X
Leistus spinibarbis						X
Loricera pilicornis	X	X	X	X		X
Microlestes minutulus	X					
Nebria brevicollis	X	X	X	X		
Nebria Salina	X					
Notiophilus biguttatus	X	X				
Ocys harpaloides	X		X		X	X
Ophonus ardosiacus			X			
Oxypselaphus obscurus	X	X		X		
Panagaeus bipustulatus		X				
Platyderus depressus	X					
Platynus assimilis	X				X	X
Poecilus cupreus	X	X	X	X		
Poecilus versicolor	X	X	X	X		
Pterostichus macer				X		
Pterostichus madidus	X	X	X	X		
Pterostichus melanarius	X	X	X	X		
Pterostichus niger	X	X	X	X		
Pterostichus strenuus		X		X	X	X
Pterostichus vernalis	X	X	X	X		
Stomis pumicatus			X	X		
Syntomus foveatus	X					
Synuchus vivalis	X	X			X	X
Trechus quadristriatus	X	X	X	X	X	X
Zabrus tenebrioides				X	X	X

Appendix IX. D-Vac data summary for Cultivated margin samples.

Appendix IX. DVac data summary for Cultivated margin samples. Sum and average abundance of each taxa recorded in D-Vac suction samples over the study.

Taxa	Total recorded	Average per margin	Taxa	Total recorded	Average per margin
Linyphiidae	38	0.316667	Nabidae	1	0.008333
Thomisidae	12	0.1	Nabidae nymph	1	0.008333
Lycosidae	2	0.016667	Reduviidae	0	0
Other Araneae	166	1.383333	Saldidae	0	0
Araneae Juveniles	3	0.025	Parasitica	1739	14.49167
Opiliones	11	0.091667	Formicidae	37	0.308333
Cantharidae	4	0.033333	Andrenidae	0	0
Carabidae Adult	8	0.066667	Anthophoridae	0	0
Carabidae Larvae	1	0.008333	Apidae	1	0.008333
Coccinellidae adult	0	0	Colletidae	0	0
Coccinellidae larvae	29	0.241667	Halictidae	0	0
Elateridae	2	0.016667	Megachilidae	0	0
Mordellidae	0	0	Sphecidae	0	0
Melyridae	0	0	Vespidae	0	0
Oedemeridae	5	0.041667	Vespidae larvae	0	0
Scydmaenidae	0	0	Neuroptera adult	2	0.016667
Staphylinidae adult	63	0.525	Neuroptera larvae	3	0.025
Staphylinidae larvae	26	0.216667			
Forficulidae	0	0			
Bombyliidae	0	0			
Calliphoridae	0	0			
Conopidae	0	0			
Dolichopodidae	129	1.075			
Empididae	8	0.066667			
Fanniidae	0	0			
Hybotidae	53	0.441667			
Lonchopteridae	93	0.775			
Muscidae	104	0.866667			
Syrphidae adults	8	0.066667			
Syrphidae larvae	0	0			
Sarcophagidae	1	0.008333			
Scathophagidae	8	0.066667			
Stratiomyidae	1	0.008333			
Tachinidae	1	0.008333			
Anthocoridae	2	0.016667			

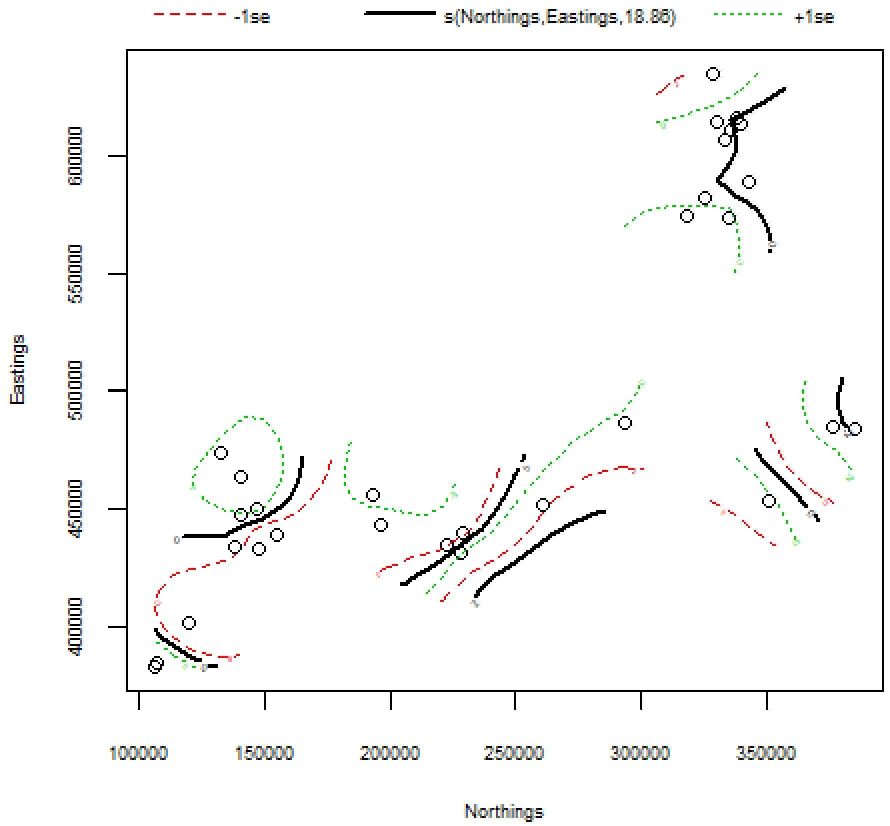
Appendix X. Results of pollinator and natural pest enemy correlation test on cultivated margins.

Appendix X. GAMM model estimates for the relationship between pest natural enemies and pollinators sampled with a D-Vac suction sampler on cultivated margins (quasipoisson). Location was included as a spatial smooth, but the results are not presented here. denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.

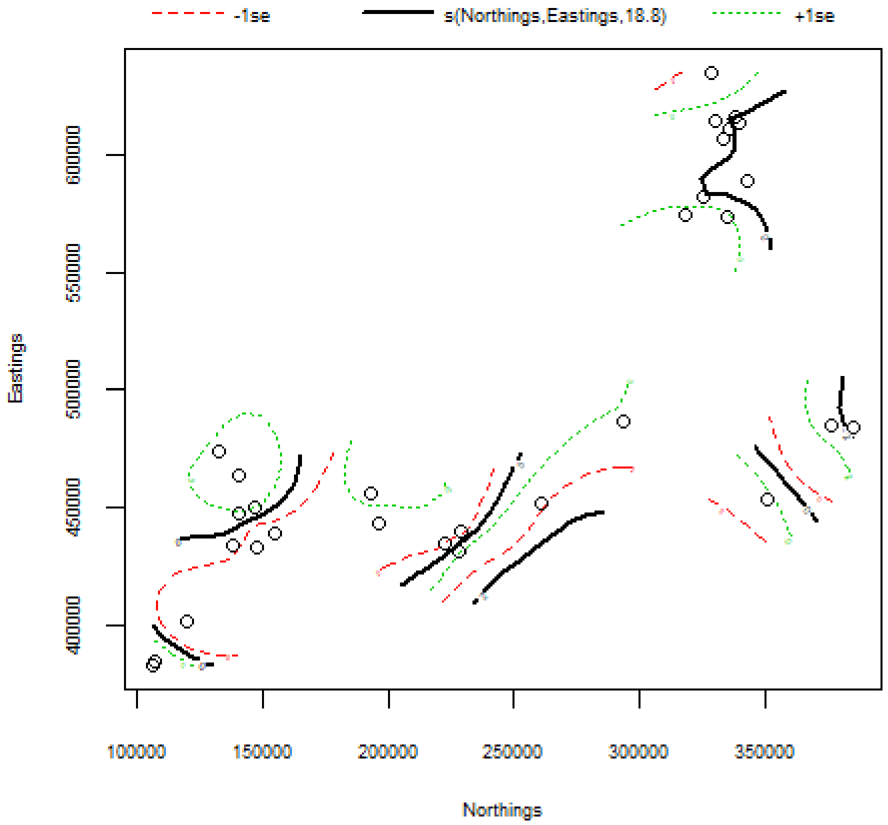
Coefficient	Estimate	Std Error	t-value	P
Intercept	2.34	0.37	6.28	***
Total pollinators	0.06	0.02	2.73	**
Year (2019)	0.67	0.74	0.91	0.36

Appendix XI. Response curves displaying spatial patterns in Cultivated margin data

Appendix XIa. Response curves displaying spatial signal from GAM model of summed invertebrates from DVac suction samples on Cultivated margins.



Appendix XIb. Response curves displaying spatial signal from GAM model of natural pest enemy invertebrates from DVac suction samples on Cultivated margins.



Appendix XII. Pollinator transect walk data summary for Cultivated margin samples.

Appendix XII. Pollinator transect walk data summary for Cultivated margin samples. Sum and mean abundance of each taxa recorded in D-Vac suction samples over the study.

Taxa	Total recorded	Average per margin
Hoverfly	1480	8.222222
Anthophora	1	0.005556
Bombus vestalis	0	0
Hylaeus	316	1.755556
Megachile	0	0
Garden bumblebee	2	0.011111
White-tailed bumblebee	44	0.244444
Solitary bee (unidentified to genus)	4	0.022222
Early bumblebee	3	0.016667
Nomada	0	0
Andre	166	0.922222
Buff-tailed bumblebee	59	0.327778
Common carder	51	0.283333
Red-tailed bumblebee	159	0.883333
Osmia	2	0.011111
Honey.Bee	109	0.605556
Tree bumblebee	2	0.011111
Lasioglossum	19	0.105556
Sphecodes	30	0.166667
Panurgus	2	0.011111
Halictus	26	0.144444
Colletes	73	0.405556

Appendix XIII. List of grass species recorded across Norfolk (N), Midland (M) and South (S) on cultivated and floristically enhanced margins.

Grasses		FM 2018			CM 2018			FM 2019			CM 2019		
COMMON NAME	***SCIENTIFIC NAME***	***N***	***M***	***S***	***N***	***M***	***S***	***E***	***S***	***O***	***E***	***S***	***O***
Annual fescue	*Vulpia myuros*								X				
Annual meadow grass	*Poa annua*	X	X	X	X	X	X	X	X			X	
Awned canary-grass	*Phalaris paradoxa*						X						
Barley	*Hordeum vulgare*							X	X	X			
Black bent	*Agrostis gigantea*		X	X	X	X	X						
Black-grass	*Alopecurus myosuroides*			X	X	X	X		X	X			
Brome fescue	*Vulpia bromoides*					X	X		X			X	
Cock's-foot	*Dactylis glomerata*	X	X	X	X	X	X	X			X	X	X
Common bent	*Agrostis capillaris*	X	X	X		X		X			X	X	X
Common meadow-grass	*Poa pratensis*	X	X	X									
Common wheat	*Triticum aestivum*									X	X	X	X
Common wild oat	*Avena fatua*			X			X	X		X	X		
Common windgrass	*Apera spica-venti*									X	X		
Couch grass	*Elymus repens*	X	X	X	X	X		X	X		X	X	X
Creeping bent	*Agrostis stolonifera*	X		X	X	X	X	X		X	X	X	X
Creeping soft grass	*Holcus mollis*	X							X	X			
Crested dog's-tail	*Cynosurus cristatus*	X	X	X			X	X		X	X	X	X
Erect brome	*Bromus erectus*										X	X	
False oat grass	*Arrhenatherum elatius*	X	X	X	X		X	X	X	X	X	X	
Great brome	*Bromus diandrus*			X		X	X	X		X	X		
Green bristlegrass	*Setaria sp*												X
Meadow brome	*Bromus commutatus*		X				X	X	X	X	X	X	X
Meadow fescue	*Festuca pratensis*		X	X							X		X
Meadow foxtail	*Alopecurus pratensis*		X	X							X	X	X
Narrow-leaved meadow-grass	*Poa angustifolia*		X	X									
Perennial ryegrass	*Lolium perenne*	X	X	X	X	X	X	X	X	X			X
Red fescue	*Festuca rubra*	X	X				X	X		X		X	X
Rough-stalked meadow-grass	*Poa trivialis*	X	X	X	X	X	X		X			X	
Rye brome	*Bromus secalinus*		X					X	X	X	X	X	X
Sheep's fescue	*Festuca ovina*											X	
Soft brome	*Bromus hordeaceus*			X		X	X		X	X	X	X	X
Spreading meadow-grass	*Poa humilis*	X									X		
Sterile brome	*Bromus sterilis*		X	X	X	X	X	X			X	X	X
Sweet vernal grass	*Anthoxanthum odoratum*	X		X				X			X	X	X
Tall fescue	*Festuca arundinacea*	X	X								X		
Timothy-grass	*Phleum pratense*	X	X	X			X	X				X	

Tufted hair-grass	*Deschampsia cespitosa*			X								X	
Wood false-brome	*Brachypodium sylvaticum*			X			X						
Yellow oatgrass	*Trisetum flavescens*										X	X	
Yorkshire fog	*Holcus lanatus*	X	X	X	X	X		X			X	X	X

Appendix XIV List of dicotyledonous species recorded across Norfolk (N), Midland (M) and South (S) on cultivated and floristically enhanced margins.

		FM 2018			CM 2018			FM 2019			CM 2019		
SCIENTIFIC NAME	**COMMON NAME**	**N**	**M**	**S**	**N**	**M**	**S**	**E**	**S**	**O**	**E**	**S**	**O**
Acer spp.	Maple	X											
Achillea millefolium	Yarrow	X	X	X				X			X	X	
Acrocarpous mosses	Upright moss							X					
Aethusa cynapium	Fool's parsley					X		X		X	X	X	X
Agrimonia eupatoria	Agrimony			X						X			
Agrostemma githago	Corncockle									X			
Agrostis stolonifera	Creeping bent				X								
Amaranthus spp.	Spiny amarath								X				
Amsinckia micrantha	Common fiddleneck							X					
Anacamptis pyramidalis	Pyramidal orchid										X		
Anagallis arvensis	Scarlet pimpernel				X	X	X	X	X	X	X		
Anchusa arvensis	Small bugloss				X	X		X			X	X	X
Anthemis austriaca	Austrian chamomile									X	X	X	X
Anthemis cotula	Stinking chamomile						X		X				
Anthriscus caucalis	Bur chevil									X			
Anthriscus sylvestris	Cow parsley		X	X	X			X	X	X	X	X	X
Aphanes arvensis	Parsley piert				X		X	X		X			
Arabidopsis thaliana	Thale cress					X		X					
Arctium minus	Lesser burdock				X	X	X		X		X		
Arenaria serpyllifolia	Thyme-leaved sandwort					X	X	X	X	X	X	X	X
Artemisia vulgaris	Mugwort			X	X	X	X	X		X	X	X	X
Atriplex patula	Common orache				X	X	X	X	X	X			
Atriplex prostrata	Spear-leaved orache							X					
Barbarea spp.	Winter cress							X					
Bellis perennis	Common daisy			X				X	X				
Brachythecium rutabulum	Rough-stalked feather-moss	X	X	X					X	X	X		
Brassica napus	Rapeseed							X		X			
Brassica rapa	Wild turnip						X						

Bryophyte	Liverworts, hornworts and mosses			X		X	X						
Calystegia sepium	Hedge bindweed					X		X			X	X	X
Camelina sativa	Gold-of pleasure							X	X	X			
Capsella bursa-pastoris	Shepherd's purse			X	X	X	X			X			
Carduus nutans	Musk thistle			X			X						
Centaurea cyanus	Cornflower									X			
Centaurea nigra	Common knapweed	X	X	X				X			X	X	
Centaurea scabiosa	Greater knapweed			X	X						X	X	
Cerastium diffusum	Sea mouse-ear							X	X	X			
Cerastium fontanum	Common mouse-ear chickweed	X	X	X		X	X		X	X	X	X	X
Chaenorhinum minus	Small toadflax								X				
Chaerophyllum temulentum	Rough chervil						X	X	X	X	X	X	X
Chamaenerion angustifolium	Rosebay willowherb					X	X						
Chenopodium album	Fat-hen				X	X	X		X		X	X	X
Chenopodium rubrum	Red goosefoot							X	X	X			
Cichorium intybus	Common chicory			X									
Cirsium arvense	Creeping thistle	X	X	X	X	X	X	X	X	X	X	X	X
Cirsium vulgare	Spear thistle			X	X	X	X	X	X		X	X	X
Clematis vitalba	Old man's beard						X				X		
Convolvulus arvensis	Field bindweed	X	X	X					X		X	X	X
Conyza canadensis	Canadian fleabane					X		X	X		X	X	X
Cornus sanguinea	Common dogwood										X	X	X
Coronopus squamatus	Greater swinecress							X	X	X		X	X
Corylus avellana	Hazel										X		
Crataegus monogyna	Hawthorn	X	X	X				X		X	X	X	X
Crepis capillaris	Smooth hawksbeard						X	X			X	X	X
Crepis vesicaria	Beaked hawk's-beard			X				X	X	X	X	X	X
Cynosurus cristatus	Crested dog's-tail			X									
Daucus carota	Wild carrot										X	X	X
Epilobium adenocaulon	American willowherb							X					
Epilobium hirsutum	Hairy willowherb					X	X	X	X	X			
Epilobium montanum	Broad-leaved willowherb	X		X			X	X					
Epilobium parviforum	Hoary willowherb					X	X	X					
Epilobium spp.	Willowherb species					X	X						
Equisetum arvense	Field horsetail					X		X	X	X			
Erodium cicutarium	Common stork's-bill					X							X
Euphorbia exigua	Dwarf Spurge						X						
Euphorbia helioscopa	Sun spurge				X		X	X	X	X			
Euphorbia peplus	Petty spurge				X			X	X	X			
Eurhynchium swartzii	Swartz's feather moss										X	X	

Fallopia convolvulus	Black bindweed				X	X	X	X	X				
Filago vulgaris	Common cudweed							X	X		X		
Fraxinus excelsior	European ash		X				X	X					
Fumaria muralis	Common-ramping fumitory				X								
Fumaria officinalis	Common fumitory				X	X	X	X	X	X			
Galeopsis tetrahit	Common Hemp-nettle					X		X	X	X			
Galium album	Hedge bedstraw	X									X		
Galium aparine	Cleavers	X		X		X	X	X		X		X	
Galium verum	Lady's bedstraw	X	X	X							X	X	X
Geranium dissectum	Cut-leaved crane's-bill	X	X	X	X	X	X	X				X	X
Geranium molle	Dove's-foot Crane's bill					X		X					
Geranium pratense	Meadow Cranesbill			X									
Geranium pusillum	Small-flowered crane's-bill		X		X	X		X			X		
Geum urbanum	Wood avens						X	X		X			
Glebionis segetum	Corn marigold				X	X		X	X				
Glechoma hederacea	Ground-ivy	X		X			X		X	X			X
Gnaphalium uliginosum	Marsh cudweed				X	X							
Hedera helix	European ivy			X								X	X
Helianthus annuus	sunflower							X					
Helminthotheca echioides	Bristly oxtongue					X		X	X				
Heracleum sphondylium	Hogweed	X	X	X	X	X	X		X			X	
Holcus mollis	Creeping soft grass											X	
Hypericum perforatum	Perforate St John's-wort								X	X			
Hypochaeris radicata	Common cat’s-ear	X	X					X				X	
Jacobaea vulgaris	Ragwort					X		X	X	X	X		
Juncus bufonius	Toad rush				X	X							
Juncus effusus	Soft rush		X										
Kickxia spuria	Roundleaf fluellen						X	X					
Knautia arvensis	Field scabious	X									X	X	X
Lactuca serriola	Prickly lettuce					X			X				
Lamium album	White dead-nettle	X		X	X			X	X	X	X		
Lamium amplexicaule	Henbit dead-nettle					X		X			X		
Lamium hybridum	Cut-leaved dead-nettle				X	X		X	X				X
Lamium purpureum	Red dead-nettle					X	X			X			
Lapsana communis	Nipplewort				X		X	X		X		X	
Lathyrus pratensis	Meadow vetchling			X							X		X
Legousia hybrida	Venus' looking glass								X				
Leontodon autumnalis	Autumn hawkbit							X	X	X			
Leontodon autumnalis	Autumn hawkbit										X		
Lepidium coronopus	Swine cress				X								
Leucanthemum vulgare	Ox-eye daisy	X	X	X		X	X	X			X	X	X

Linaria vulgaris	Common toadflax									X	X	X	X
Lipandra polysperma	Many-seeded goosefoot					X				X			
Lotus corniculatus	Bird's-foot trefoil	X	X	X		X						X	
Lotus pedunculatus	Greater bird's-foot-trefoil			X									
Lychnis flos-cuculi	Ragged robin			X									
Malva moschata	Musk mallow			X							X		
Malva sylvestris	Common mallow							X		X			
Matricaria discoidea	Pineapple weed							X		X			X
Matricaria recutita	Scented mayweed							X					
Medicago lupulina	Black medick		X	X		X	X	X					X
Mercurialis annua	Annual mercury							X	X				
Myosotis arvensis	Field forget-me-not			X		X	X	X	X	X	X	X	X
Odontites vernus	Red bartsia						X				X		
Onobrychis viciifolia	Sainfoin											X	X
Ononis spinosa	Spiny restharrow										X		
Ophrys apifera	Bee orchid		X										
Origanum vulgare	Wild marjoram										X	X	X
Orobanche minor	Lesser broomrape							X	X	X			
Papaver dubium ssp lecoquii	Babington’s poppy							X	X	X			
Papaver hybridum	Rough poppy							X	X	X			
Papaver rhoeas	Common poppy	X			X	X	X			X	X		
Persicaria lapathifolium	Pale persicaria				X	X	X	X					
Persicaria maculosa	Redshank				X	X	X	X	X	X	X		
Phacelia tanacetifolium	Blue or purple tansy							X		X			
Phleum bertolonii	Smaller cat's-tail												X
Plantago lanceolata	Ribwort plantain	X	X	X	X		X	X			X		
Plantago major	Greater plantain			X	X	X	X	X	X		X		
Poa pratensis	Common meadow-grass												X
Poa trivialis	Rough-stalked meadow-grass						X						
Polygonum aviculare	Common knotgrass			X	X	X	X			X	X	X	X
Polygonum rurivagum	Cornfield knotgrass							X	X				
Potentilla reptans	Creeping cinquefoil			X				X	X			X	
Prunella vulgaris	Self-heal	X	X	X			X						X
Prunus domestica	Common plum	X											
Prunus spinosa	Blackthorn	X		X								X	X
Pteridium aquilinum	Bracken										X		
Pulicaria dysenterica	Common fleabane										X		
Quercus robur	Common oak	X	X				X		X	X		X	
Ranunculus acris	Meadow buttercup	X	X	X							X		X
Ranunculus bulbosus	Bulbous buttercup						X						X

Ranunculus repens	Creeping buttercup	X	X	X		X	X	X		X			X
Raphanus raphanistrum	Wild radish				X			X		X			
Reseda lutea	Wild mignonette	X	X				X						
Rhamnus cathartica	Common buckthorn						X						
Rhinanthus minor	Yellow rattle										X	X	X
Rosa canina	Dog rose						X	X	X	X	X		
Rubus fruticosus	Blackberry							X	X	X		X	
Rumex acetosella	Sheep's sorrel			X		X		X	X	X	X		X
Rumex crispus	Curly dock	X	X	X	X	X	X	X	X				X
Rumex obtusifolius	Broad-leaved dock	X	X	X	X	X	X	X	X	X	X		
Salix cinerea	Sallow		X										
Sambucus nigra	Elder							X		X			
Sanguisorba minor	Salad burnet			X							X	X	X
Scandix pecten-veneris	Shepherd's-needle						X						
Senecio erucifolius	Hoary ragwort		X					X				X	X
Senecio vulgaris	groundsel	X	X	X	X	X	X	X	X	X	X		X
Sherardia arvensis	Field madder			X			X	X			X	X	
Silene latifolia	White campion	X			X	X				X	X		
Silene noctiflora	Night-flowering catchfly				X			X				X	
Sinapis arvensis	Charlock					X		X			X	X	
Sisymbrium officinale	Hedge mustard				X	X		X			X		
Solanum nigrum	Black nightshade				X	X	X						
Solanum tuberosum	Potato					X							
Sonchus arvensis	Field sowthistle	X			X	X	X	X		X		X	
Sonchus asper	Prickly sow-thistle	X			X	X	X	X				X	
Sonchus oleraceus	Common sowthistle									X	X		
Spergula arvensis	Corn spurrey				X	X		X	X	X		X	
Stachys arvensis	Field woundwort							X	X	X			X
Stellaria holostea	Greater stitchwort								X				
Stellaria media	Chickweed	X			X	X		X	X				
Tanacetum vulgare	Tansy		X										
Taraxacum spp	Dandelion	X	X	X	X	X	X	X	X	X			X
Thlaspi arvense	Field pennycress				X	X		X					
Torilis japonica	Erect hedge-parsley										X		
Torilis nodosa	Knotted hedge-parsley							X	X	X			
Tragopogon pratensis	Meadow salsify							X		X			
Trifolium aureum	Large hop clover							X		X			
Trifolium campestre	Hop trefoil		X							X	X	X	
Trifolium dubium	Lesser trefoil		X					X	X	X	X	X	X
Trifolium hybridum	Alsike clover						X				X	X	X
Trifolium incarnatum	Crimson clover							X		X			
Trifolium pratense	Red Clover	X	X	X			X	X					X

Trifolium repens	White clover	X	X	X		X	X			X	X	X	
Tripleurospermum inodorum	Scentless mayweed			X	X	X	X			X	X		
Ulmus minor	Field elm	X											
Urtica dioica	Stinging nettle	X		X	X	X	X			X	X	X	
Urtica urens	Small nettle				X	X							
Valerianella dentata	Narrow-fruited cornsalad									X			
Veronica arvensis	Field speedwell	X		X		X	X		X			X	
Veronica chamaedrys	Germander-leaved speedwell	X		X					X			X	
Veronica persica	Common field-speedwell	X			X	X	X		X			X	
Veronica polita	Grey field-speedwell								X				
Vicia cracca	Tufted vetch		X									X	
Vicia hirsuta	Hairy tare		X			X			X			X	
Vicia sativa	Common vetch	X	X	X					X			X	
Vicia tetrasperma	Smooth tare	X	X	X					X				
Viola arvensis	Field pansy				X	X	X		X			X	

Appendix XV. DVac summary results FEM

Appendix XV. DVac data summary for Floristically enhanced margin samples. Sum and average abundance of each taxa recorded in D-Vac suction samples over the study.

Taxa	Total recorded	Average per margin	Taxa	Total recorded	Average per margin
Linyphiidae	81	0.675	Anthocoridae	0	0
Thomisidae	13	0.108333	Nabidae	19	0.158333
Lycosidae	19	0.158333	Nabidae nymph	35	0.291667
Other Araneae	618	5.15	Reduviidae	0	0
Araneae juveniles	1	0.008333	Saldidae	0	0
Opiliones	34	0.283333	Parasitica	6211	51.75833
Cantharidae	2	0.016667	Formicidae	54	0.45
Carabidae adult	1	0.008333	Andrenidae	0	0
Carabidae larvae	1	0.008333	Anthophoridae	0	0
Coccinellidae adult	2	0.016667	Apidae	0	0
Coccinellidae larvae	13	0.108333	Colletidae	0	0
Elateridae	1	0.008333	Halictidae	1	0.008333
Mordellidae	1	0.008333	Megachilidae	0	0
Melyridae	2	0.016667	Sphecidae	0	0
Oedemeridae	10	0.083333	Vespidae	0	0
Scydmaenidae	0	0	Vespidae larvae	0	0
Staphylinidae adult	44	0.366667	Neuroptera adult	0	0
Staphylinidae larvae	35	0.291667	Neuroptera larvae	6	0.05
Forficulidae	0	0			
Bombyliidae	0	0			
Calliphoridae	0	0			
Conopidae	0	0			
Dolichopodidae	154	1.283333			
Empididae	16	0.133333			
Fanniidae	1	0.008333			
Hybotidae	109	0.908333			
Lonchopteridae	182	1.516667			
Muscidae	264	2.2			
Syrphidae adults	15	0.125			
Syrphidae larvae	0	0			
Sarcophagidae	1	0.008333			
Scathophagidae	52	0.433333			

Stratiomyidae	7	0.058333
Tachinidae	3	0.025
Anthocoridae	0	0

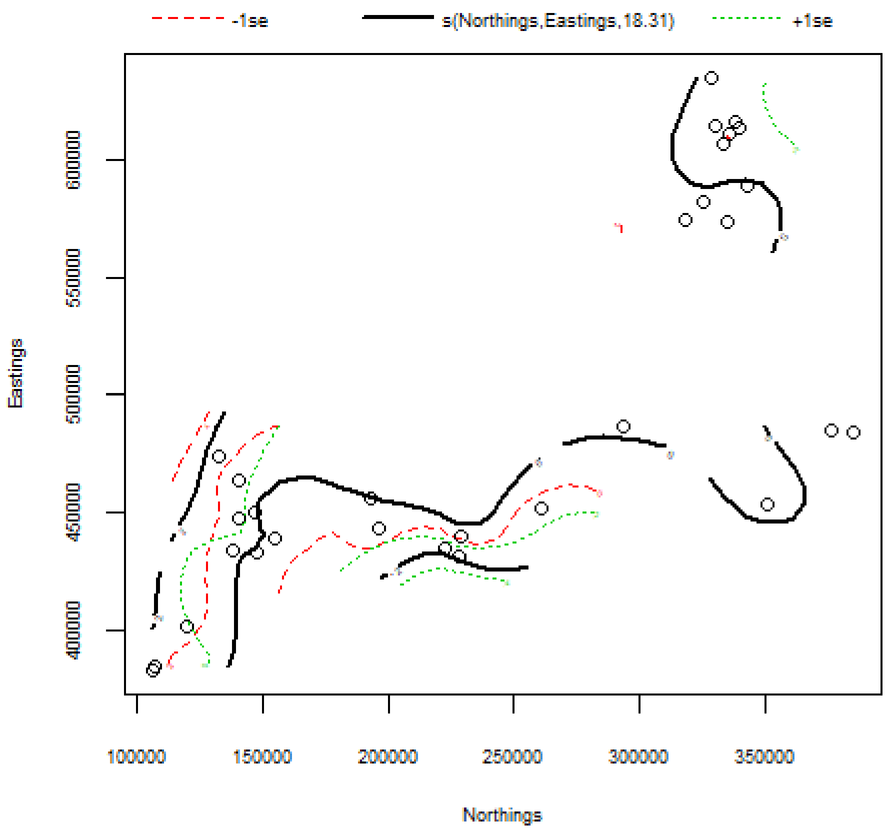
Appendix XVI. Results of pollinator and natural pest enemy correlation test on Floristically enhanced margins.

Appendix XVI. GAMM model estimates for the relationship between pest natural enemies and pollinators sampled with a D-Vac suction sampler on floristically enhanced margins (quasipoisson). Location was included as a spatial smooth, but the results are not presented here. denote significant relationships: *=p < 0.05, **=p < 0.01, ***=p < 0.001.

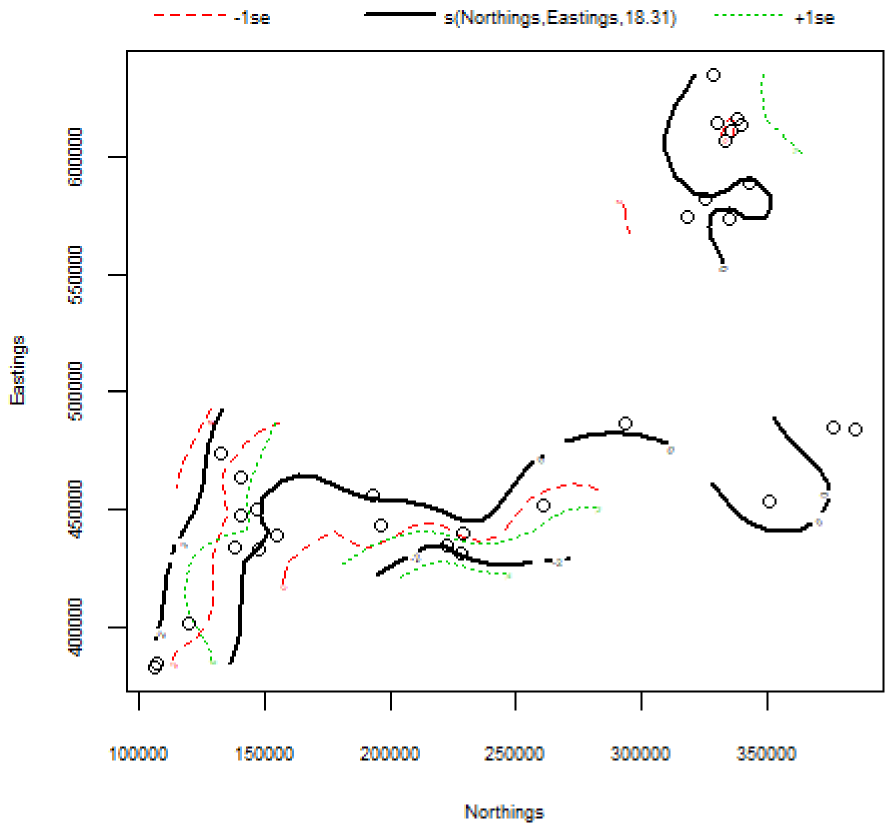
Coefficient	Estimate	Standard Error	t-value	P
Intercept	3.99	0.18	22.09	<0.001
Pollinator abundance	0.01	0.01	0.84	0.40
Year (2018)	-0.49	0.35	-1.40	0.17

Appendix XVII. Response curves displaying spatial patterns in Floristically enhanced margin data.

Appendix XVIIa. Response curves displaying spatial signal from GAM model of summed invertebrates from DVac suction samples on Floristically enhanced margins.



Appendix XVIIb. Response curves displaying spatial signal from GAM model of natural enemies from D-Vac suction samples on Floristically enhanced margins.



Appendix XVIII. Pollinator transect walk data summary for Floristically enhanced margins samples.

Appendix XVIII. Pollinator transect walk data summary for Cultivated margin samples. Sum and average abundance of each taxa recorded in D-Vac suction samples over the study.

Taxa	Total recorded	Average per margin
Hoverfly	1503	8.35
Anthophora	0	0
Bombus vestalis	4	0.022222
Hylaeus	11	0.061111
Megachile	1	0.005556
Gardenbumblebee	2	0.011111
White-tailed bumblebee	77	0.427778
Solitary bee (unidentified.to.genus)	5	0.027778
Early bumblebee	14	0.077778
Nomada	19	0.105556
Andre	51	0.283333
Buff tail	75	0.416667
Common carder	75	0.416667
Red tail	274	1.522222
Honey bee	188	1.044444
Tree bumblebee	2	0.011111
Lasioglossum	38	0.211111
Sphecodes	16	0.088889
Halictus	22	0.122222

Appendix XIX. Plant species included in the IAPA scoring system (Byfield & Wilson, 2005).

SCIENTIFIC NAME	**COMMON NAME**	IAPA score
Agrostemma githago	Corncockle	9
Anchusa arvensis	Small bugloss	1
Anthemis cotula	Stinking chamomile	7
Anthriscus caucalis	Bur chevil	3
Apera spica-venti	Loose-flowered silky-bent	6
Bromus secalinus	Rye brome	7
Centaurea cyanus	Cornflower	8
Chaenorhinum minus	Small toadflax	1
Erodium cicutarium	Common stork's-bill	1
Euphorbia exigua	Dwarf Spurge	6
Filago vulgaris	Common cudweed	6
Geranium pusillum	Small-flowered crane's-bill	2
Glebionis segetum	Corn marigold	7
Kickxia elatine	Sharp-leaved fluellen	2
Kickxia spuria	Roundleaf fluellen	3
Lamium amplexicaule	Henbit dead-nettle	1
Legousia hybrida	Venus' looking glass	3
Lipandra polysperma	Many-seeded goosefoot	2
Mercurialis annua	Annual mercury	1
Papaver dubium ssp lecoquii	Babington's poppy	2
Papaver hybridum	Rough poppy	3
Raphanus raphanistrum	Wild radish	1
Scandix pecten-veneris	Shepherd's-needle	9
Sherardia arvensis	Field madder	1
Silene noctiflora	Night-flowering catchfly	7
Spergula arvensis	Corn spurrey	7
Stachys arvensis	Field woundwort	6
Torilis nodosa	Knotted hedge-parsley	3
Valerianella dentata	Narrow-fruited cornsalad	8
Veronica polita	Grey field-speedwell	2
Vicia tetrasperma	Smooth tare	2