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Little and late: how reduced hedgerow cutting can benefit Lepidoptera.

Little and late: how reduced hedgerow cutting can benefit Lepidoptera

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Highlights

- Hedgerows provide breeding habitat, shelter and nectar for Lepidoptera
- Three management treatments were tested using a large-scale field experiment
- Management effects over three years varied with Lepidoptera life history traits
- Cutting hedges less often, less intensively and in winter benefits most Lepidoptera
- Hedgerow agri-environment schemes benefit Lepidoptera but could be improved further

Abstract

Hedgerows are a key semi-natural habitat for biodiversity in intensive agricultural landscapes across northern Europe and support a large invertebrate fauna. Management can have large effects on the value of hedgerows as a wildlife habitat, thus sensitive management is incentivised through agri-environment schemes (AES). We tested how current and potential future AES hedge management regimes affected the diversity and abundance of Lepidoptera species that utilise the hedge as a breeding resource, using a long term, multi-site, manipulative field experiment. Hedgerow management in some current AES options (reduced trimming frequency and cutting in winter) increased Lepidoptera abundance and the diversity of components of the Lepidoptera community linked with specific lifecycle traits. However, the most frequently applied hedgerow AES option currently applied in the UK (cutting once every 2 years in autumn) did not benefit Lepidoptera compared to standard hedgerow management outside AES (annual trimming in autumn). Decreasing the intensity of hedgerow trimming improves the diversity of the whole Lepidoptera assemblage, and should be considered as part of biodiversity conservation in farmed landscapes.

Keywords: Butterflies; Brown hairstreak; Entry Level Stewardship; Moths; *Thecla betulae*;

1 Introduction

Hedgerows are recognised as a priority habitat for conservation in Europe (JNCC, 2012) and protected by legislation in several countries (Baudry et al., 2000). They are a key semi-natural habitat in intensively farmed landscapes and provide food resources, breeding habitat and shelter for a wide range of plant and animal species (Wilson, 1979; Fuller et al., 1995; Dover and Sparks, 2000; Merckx and Berwaerts, 2010; Staley et al., 2013), as well as supporting ecosystem services such as pollination (Morandin and Kremen, 2013; Olsson et al., 2015) and pest control (Morandin et al., 2014). Hedgerows can also form part of dispersal networks for some animal species (Cranmer et al., 2012; Slade et al., 2013), which may become an increasingly important role in future adaptation to climate change (Lawton et al., 2010).

Hedgerow management in the UK most frequently consists of annual cutting with mechanised flails in early autumn, immediately after harvest, with hedgerows cut back to the same height and width each year (Sparks and Croxton, 2007). This removes almost all the previous season's growth, leaving limited food resources for over-wintering wildlife, few young stems on which buds form for the following year's flowers and berries (Sparks and Croxton, 2007; Staley et al., 2012), and little shelter or habitat for invertebrates (Maudsley et al., 2000) with repercussions for insectivorous birds and mammals. Agri-environment schemes (AES) incentivise more sympathetic management in the UK and elsewhere in Europe (Fuentes-Montemayor et al., 2011; Merckx et al., 2012), and in England 41% of hedgerow length is managed under the Entry Level Stewardship (ELS) AES (Natural England, 2009). Payments are available under ELS for cutting hedges less frequently than every year and in late winter rather than autumn (Natural England, 2013a), and comparable schemes operate in other countries (Fuentes-Montemayor et al., 2011). Hedges managed under ELS should be no less than 1.5m high after cutting (Natural England, 2013a), and in 2007 just over 50% of English hedges were over 2m tall, with around 45% between 1 and 2m, and a small minority under 1m (Carey et al. 2008). The most popular hedge management option currently applied in ELS, cutting once every two years in autumn, has been shown not to increase floral and berry resources for wildlife relative to hedges managed outside AES (Staley et al., 2012). A new Countryside Stewardship AES to be introduced in England in 2016 specifies that hedgerows trimmed every two years should be cut in January or February

(Natural England, 2015). There is an urgent need to test the effects of the full range of AES hedgerow management options on the conservation of biodiversity, in addition to developing new, improved management that could form part of future AES prescriptions.

Lepidoptera comprises one of the largest insect orders in the UK with over 2900 species (Bradley, 2000), and has the largest number of species listed as high conservation priority in the UK (165 Lepidoptera species of 379 terrestrial invertebrate species listed in section 41 of the Natural Environment and Rural Communities Act 2006; Webb et al., 2010). The widespread declines in the abundance and ranges of many butterfly and moth species (Warren and Bourn, 2011) are largely attributed to habitat loss and fragmentation as a result of agricultural intensification, together with other drivers such as climate change (Fox, 2013; Fox et al., 2014). Lepidoptera form a key part of many terrestrial food webs, and are a major food source for insectivorous animals (Fox et al., 2014). Many species are associated with hedgerows, which provide larval food plants, nectar for adults, shelter and overwintering habitats (Dover et al., 1997; Merckx and Berwaerts, 2010). Previous work from one experimental site has demonstrated that hedgerow management can affect the abundance of immobile Lepidoptera larval feeding guilds and their trophic interactions with parasitoids (Facey et al. 2014). In contrast, Fuentes-Montemayor et al. (2011) found that hedgerow management under AES had no effect on populations of macro or micro-moths, but they focussed only on adult moths flying in the vicinity of hedgerows. There is also increasing evidence that hedges may facilitate the use of other semi-natural habitats by Lepidoptera in agricultural landscapes. Slade et al. (2013) found that macro-moths moving between fragmented woodlands were more abundant at isolated trees that were located along a hedgerow rather than out in a field, and Merckx et al. (2009) showed that moth diversity and abundance were increased by hedgerow trees when these were present in a landscape with high uptake of AES options.

Here, we present the first multi-site, long term field experiment assessing the effects of both current and potential future AES options for hedgerow management on Lepidoptera communities that have a direct trophic link with the hedgerow, by sampling and rearing larvae and pupae from within the hedge. Importantly, our focus on the juvenile stages means that we are able to evaluate the management impacts on use of hedgerows as a breeding habitat by Lepidoptera. This approach avoids attracting adult moths that may be utilising resources in other nearby habitats and across the wider countryside (Fuentes-Montemayor et al. 2011; Merckx and Slade, 2014). We experimentally tested the effects of hedgerow management regimes, including options currently in the English ELS AES (reduced cutting frequency and cutting in winter), standard practice outside AES (annual cutting in autumn) and a reduced cutting intensity treatment that could form part of future hedgerow management prescriptions, on the abundance and diversity of Lepidoptera caterpillars and pupae across five geographically separated sites over three years. We tested the following hypotheses: H1) Lepidoptera diversity and abundance will be greater on hedgerows that are cut less frequently than annually and those that are cut in winter; H2) cutting hedgerows at a reduced intensity to retain recent growth will increase Lepidoptera abundance and diversity, compared to hedges cut back to a standard height and width.

2 Methods

2.1 *Field sites and experimental design*

Experimental hedgerows on five field sites were located across southern UK, all on working farms. Two of these sites contained mature hedgerows dominated by hawthorn (*Crataegus monogyna*): Marsh Gibbon, Oxfordshire (planted in 1840: 51°53'N, 1°03'W); and Woburn, Buckinghamshire (planted between 1793 and 1799: 51°58'N, 0°37'W). The other three sites consisted of one blackthorn (*Prunus spinosa*) dominated site at Waddesdon Estate, Oxfordshire (Waddesdon blackthorn: 51°50'N, 0°53'W); a mixed species hedgerow site planted under the Countryside Stewardship AES in the mid-1990s at Waddesdon Estate, Oxfordshire (Waddesdon mixed: 51°50'N, 0°56'W) and a traditional mixed species hedge growing on a bank in Yarcombe, Devon (planted 200 – 300 years ago: 50°51'N, 3°03'W).

Three experimental treatments were applied in full factorial combination: 1) frequency of cutting (once every 1 vs. 2 vs. 3 years); 2) timing of cutting (early autumn, September vs. late winter, January / February); and 3) intensity of cutting (standard cutting to the same height and width each time vs. incrementally raising the cutter bar by approximately 10 cm each time the hedge is cut, resulting in a slightly wider and taller hedge). Treatments were applied to 20 m long contiguous hedgerow plots, replicated in three randomised blocks at each of the five sites. In addition, each block contained a control plot that was not cut during the experiment (Figure 1). All experimental plots within a site contained the same woody tree and shrub species. .

Hedge cutting treatments were applied using tractor mounted flails, operated by local contractors who regularly cut the hedges on each farm, to ensure that the cutting was representative of hedgerow cutting in the wider countryside. All experimental plots including the controls were cut prior to the start of the experiment in late winter (January / February 2010). Hedgerow cutting treatments were applied for 3 years from September 2010. The winter cutting treatments were not applied at the Waddesdon blackthorn field site, due to a shortage of suitable hedgerow. Total replication of each factorial combination of the three cutting treatments was thus 15 (for autumn cutting treatments) or 12 (for winter cutting treatments as these were not applied at the Waddesdon blackthorn site) across the five field sites.

2.2 *Lepidoptera collection and identification*

Lepidoptera larvae and pupae were collected in May from experimental plots for each of 3 years (2011 – 2013), using a modified beating method (Maudsley et al., 2002; Amy et al., 2015). A 2 m long × 11.2 cm wide section of guttering was inserted through the width of each hedgerow plot approximately 80 cm above the ground. The hedgerow was beaten five times with a 2 m long × 27 mm diameter steel range pole, approximately 1 m above the inserted length of guttering. Invertebrates which were knocked into the guttering were swept gently using a soft paint brush into a plastic bag, which was sealed, stored in a cool box and then at 4 °C in a refrigerator for up to 48 h. Each hedgerow plot was sampled in three places on each occasion, spaced at 5 m, 10 m and 15 m along its length. The invertebrate samples from these three positions on each plot were then combined.

Lepidoptera larvae and pupae were separated from other invertebrates in the laboratory. Where possible, Lepidoptera larvae were identified to species (later instars of many macro-moth species, e.g. The Magpie *Abraxas glossulariata*, Yellow-tail *Euproctis similis*) using Porter (2010), Sterling and Parsons (2012) and online resources (ukmoths.org.uk). Pupae and larvae that could not be identified were reared individually on hawthorn foliage in glass tubes with small air holes in plastic lids. Fresh hawthorn foliage was provided every 2-3 days and frass removed from the tubes. Larvae were reared in an open-sided insectary, to ensure external temperature and day-length cues for pupation and adult emergence. Emerging adults were identified to species.

The height of the woody vegetation in each hedgerow plot was measured to the nearest 10 cm using graduated poles. Heights were measured each year at five evenly spaced positions along each plot.

2.3 *Statistical analysis*

The beating method sampled Lepidoptera from a fixed height above the guttering as it was not possible to beat the full height of each plot consistently, because plot height varied depending on whether each plot had been cut recently. Abundance of Lepidoptera larvae and pupae were scaled for plot height each year, by multiplying abundance by average height for each plot. The converted Lepidoptera data were combined to give cumulative data across the three years of sampling.

Shannon-Wiener diversity indices and species richness were calculated for each plot. In addition, we divided species into two groups based on their susceptibility to cutting regimes using life cycle information in Emmet and Heather (1991). We defined species as likely to be 'vulnerable' to autumn cutting if they occurred as eggs, larvae or pupae on woody hedgerow plants in September, and as 'robust' if they occurred as adults, or as larvae or pupae within the soil or detritus in September.

The effects of cutting frequency, cutting timing, cutting intensity and the interactions between them on Lepidoptera abundance and Shannon-Wiener diversity indices were tested using linear mixed effect models (LMEs), and the effects on species richness were tested using generalised linear mixed effects models (GLMMs) with a Poisson distribution. Site was included as a random variable in all mixed effect models (Faraway, 2005). Lepidoptera abundance could not be analysed as count data using GLMMs, as following scaling by plot height (above) these data no longer consisted of integers, a requirement for a Poisson distribution. Lepidoptera abundance and Shannon-Wiener diversity were log transformed prior to analysis, and model diagnostics showed this was an appropriate transformation.

Interactions and factors that did not contribute significantly to LME or GLMM models were removed one at a time, and changes in the explanatory power of the model were tested using likelihood ratio tests (LRT, Faraway, 2005). All analyses were carried out in R version 3.0.3 (R Core Develoment Team, 2014) using packages lme4 (Bates et al., 2015) and vegan (Oksanen et al., 2013).

3 Results

Over 3 years 1100 Lepidoptera pupae and larvae were collected, 789 of which were identified to 61 species. A number of specimens could not be identified because they died during the rearing process, or parasitoids hatched out instead of adult Lepidoptera. Emergence rate was 74% on average, and differed slightly between sites (average maximum 83% at the Waddesdon mixed species site, minimum average emergence rate 71% at Yarcombe, emergence rate differed significantly only between Waddesdon mixed species and Yarcombe, $t_{152} = 2.15$, $P < 0.05$). All but one species were moths; the only butterfly species collected was brown hairstreak (*Thecla betulae*).

3.1 *Lepidoptera abundance*

There were significantly more (16%) larvae and pupae on hedges cut in winter compared with those cut in autumn ($t_{152} = 2.02$, $P < 0.05$; Figure 2). Hedgerow plots cut every 3 years also had a significantly higher abundance (4%) than those cut annually ($t_{152} = 2.7$, $P < 0.01$) while plots cut once every 2 years did not differ from those cut annually. There was a nearly significant interaction between the timing and frequency of hedgerow trimming (LRT $\chi^2_2 = 5.9$, $P = 0.052$), which indicated that the increased abundance due to winter trimming may be limited to hedgerow plots cut once every 1 or 2 years. There was no significant effect of trimming intensity, or any interaction involving trimming intensity and the other cutting treatments, on abundance.

3.2 *Species richness and Shannon-Wiener diversity of Lepidoptera*

Lepidoptera species richness was greater (18%) on plots cut for incremental growth compared with standard cutting, though the difference between incremental growth and standard plots was not quite statistically significant (LRT χ^2_1 = 3.7, P = 0.054; Figure 3). Shannon-Wiener diversity of the whole community was significantly greater (15%) on hedgerow plots cut for incremental growth compared with those cut to a standard height and width each time (LRT χ^2_1 = 3.9, P < 0.05; Figure 4). There was also a non-significant trend towards an interaction between the frequency, timing and intensity of cutting (LRT χ^2_2 = 4.7, P = 0.096), as plots cut incrementally every two years in winter had reduced Shannon-Wiener diversity.

Species richness of the 'vulnerable' species group was significantly affected by an interaction between the frequency and timing of cutting (LRT χ^2_2 = 6.9, P < 0.05), as plots cut in autumn had a greater species richness (54%) if they were cut once in 3 years compared with every year (z_{151} = 2.6, P < 0.05). Species richness of the 'robust' species group was not affected by the frequency, timing or intensity of hedgerow cutting.

Shannon-Wiener diversity of the 'robust' species group was significantly greater (15%) on hedgerow plots cut for incremental growth compared with standard plots (t_{117} = 2.3, P < 0.05; Figure 5) as was found for the whole Lepidoptera community. In addition, there was a nearly significant interaction between the intensity and timing of cutting, indicating that for this 'robust' species group, the effect of cutting intensity was stronger for plots cut in autumn (LRT χ^2_1 = 3.83, P =0.0504). Shannon-Wiener diversity of the 'vulnerable' species group was not significantly affected by any of the cutting treatments.

4 Discussion

This is the first long-term, multi-site field experiment assessing the effects on Lepidoptera of both current and potential future AES options for hedgerow management. Lepidoptera abundance was most strongly affected by the timing of trimming, and was increased by 16% on hedgerow plots cut in late winter, as well as being 4% greater on hedges cut once every 3 years. The majority of hedges not in AES (approximately 237 000 km; Natural England, 2009) are cut every year in early autumn after crops are harvested (Sparks and Croxton, 2007), so the current most common hedgerow management practice outside AES results in a lower abundance of Lepidoptera larvae and pupae than could be achieved under some AES management options. While our experimental work was conducted in southern England, other European countries have AES that specify reduced cutting frequencies and cutting at a particular time of year (e.g. Fuentes-Montemayor et al., 2011), so the findings of our study have broad geographical relevance.

The Shannon-Wiener diversity of hedgerow Lepidoptera assemblages was more strongly affected by the intensity of cutting than by frequency or timing, with a large increase (15%) in diversity on plots that were cut less intensely, relative to those cut back to a standard height and width. Lepidoptera species richness was also greater on plots cut for incremental growth. Cutting intensity does not form part of current hedgerow English AES prescriptions (Natural England, 2013a, b, 2015), so this shows a strong potential benefit of introducing a reduced cutting intensity option in the future. Current AES that promote cutting of hedges once every 3 years and cutting in winter thus benefit Lepidoptera by increasing their abundance, as well as the diversity of part of the Lepidoptera assemblage. However, our results show no benefit to Lepidoptera of cutting in autumn once every 2 years, currently the most popular hedgerow option in England within the ELS AES (Table 1). There has been a shift away from this option of cutting once every 2 years in autumn due to a reduction in the incentives (number of points awarded) offered under ELS for this option in 2013 (Table 1), and this option does not form part of new Countryside Stewardship AES which has just started in 2016 (Natural England, 2015).

Uptake of AES hedgerow options that specify trimming in January or February may be limited by poor access for hedgerow management in wet conditions in late winter, and dependant on the timing of agricultural activities. Many landowners choose to cut hedges immediately after harvest when no crops are present to restrict access, prior to sowing winter crops. Incremental trimming could be a useful addition to AES hedgerow options where late winter cutting is not an option. In addition to increasing Lepidoptera diversity as shown here, incremental trimming may result in some hedgerow berries being retained for overwintering wildlife compared with cutting back to the same height and width each year which removes all recent growth. Over the long term, incremental trimming would result in hedges that are taller and wider (on a two year incremental trimming cycle, hedge height would increase approximately one metre over 20 years). If landowners do not want larger hedgerows they have two options following a period of incremental trimming; cutting hedgerows back to their original height and width periodically, or rejuvenating hedgerows to encourage regrowth from the base using a technique such as coppicing or hedge-laying. The pros and cons of different rejuvenation methods, including the use of a circular saw to cut several years of thick, woody growth from a large hedgerow, has been the subject of another large-scale manipulative field experiment and are discussed elsewhere (Amy et al., 2015, Staley et al., 2015).

Facey et al. (2014) found that Lepidoptera with concealed larvae (e.g. leaf miners, case bearers) were more abundant on hedges cut once every 2 or 3 years compared with those cut annually, and had greater species richness on hedges cut in winter rather than autumn. Their findings for concealed Lepidoptera are broadly similar to those of the current study, but in contrast Facey et al. (2014) found no effect of timing or frequency of cutting on free-living larvae, which form the majority of the Lepidoptera assemblage in the current study. Facey et al. (2014) focussed on Lepidoptera at a single field site in one year, so the data were less comprehensive and more affected by annual variation in insect populations than those analysed above, which were collected from five field sites over three years. Fuentes-Montemayor et al. (2011) surveyed adult moths using heath light traps next to hedges that were in AES (cut once every three years) vs. those that were not in AES (for which the most common management is annual trimming), but in contrast to our study found no effects of hedge management. Heath light traps attract moths over fairly short distances (averages of 10-27m in woodlands depending on moth family, Merckx and Slade, 2014), but as hedges are narrow, linear habitats they are likely to attract and sample adult moths from neighbouring habitats such as field margins and crops, in addition to those using the hedgerow. This may reduce the likelihood of detecting hedgerow management treatment effects. Neither Fuentes-Montemayor et al., (2011) nor Facey et al. (2014) tested trimming intensity, shown here to be the strongest driver of Lepidoptera diversity.

The response of Lepidoptera species richness and diversity to the frequency and timing of hedgerow cutting varied with life cycle traits in the current study. More Lepidoptera species are likely to be in larval diapause or pupating in soil or detritus in late winter than in early autumn, when leaves are still present on hedgerow plants (Emmet and Heather, 1991). We split Lepidoptera species using temporally sensitive classes into ‘vulnerable’ species using foliage in early autumn vs. ‘robust’ species. Frequency and timing of cutting was important for ‘vulnerable’ species, since species richness for this group was maximised by cutting hedges in winter or once in three years, while in contrast diversity of the ‘robust’ group of Lepidoptera species was most strongly increased by reducing cutting intensity. Over half of the Lepidoptera species sampled in this study were in the ‘vulnerable’ group (39 out of 61 species) so late winter cutting would be generally beneficial for hedgerow Lepidoptera, though individual species may be disadvantaged by this (e.g. Brown hairstreak butterfly discussed below). The effects of cutting timing may also be modified under other environmental drivers such as future climate change, which many moth and butterfly species are highly sensitive to (Fox et al., 2014). A mixed regime of cutting timing might be most beneficial for maximising Lepidoptera diversity. The complexity of enforcing this prescription is likely to make it untenable at a national level within AES, but it could be achieved in schemes where AES management is more specifically tailored to individual farms (e.g. in the higher tier of the new Countryside Stewardship scheme in England; Natural England, 2015) or on a regional basis.

Brown hairstreak (*T. betulae*) was the only Lepidoptera species found in this study that is classified of high conservation priority in the UK (listed in section 41 of the Natural Environment and Rural Communities Act 2006; Webb et al., 2010). It flies from late June to September and larvae feed on *Prunus* species, mainly blackthorn (*P. spinosa*). Female brown hairstreak butterflies lay eggs on young blackthorn stems close to a bud or base of a spine which remain over winter (Merckx and Berwaerts, 2010), and are thus vulnerable to mechanised hedge trimming. If hedges are cut in early September, female brown hairstreaks may lay eggs later in September after trimming, but eggs laid on hedges prior to winter hedge management are likely to be cut off or destroyed during flailing. Too few brown hairstreak caterpillars were found in the current study to detect effects of hedgerow management on this one species, so ongoing brown hairstreak winter egg surveys are being conducted. In areas where brown hairstreak are known to be present, early autumn trimming of hedges containing blackthorn may be better for this species than cutting in late winter. In the majority of the UK, where brown hairstreak is absent, the majority of Lepidoptera species are likely to benefit from winter trimming. As discussed above, it may be possible to tailor hedgerow management to benefit brown hairstreak in specific areas, using a scheme such as the higher tier of the new Countryside Stewardship scheme, where management can be targeted using regional and local objectives (Natural England, 2015).

4.1 *Conclusions*

This study shows that current AES which promote a reduced hedgerow cutting frequency (once in 3 years) and cutting in winter may benefit Lepidoptera through increased abundance and greater diversity of part of the Lepidoptera assemblage. The most frequent AES hedgerow option currently applied under ELS in England, cutting in autumn once every 2 years, does not benefit Lepidoptera and has previously been shown not to increase hedgerow resources for other wildlife groups (Staley et al., 2012), compared to standard non-AES hedge management. Reducing the intensity of hedgerow trimming could increase diversity across the whole Lepidoptera assemblage, and should be considered as a potential addition both to future AES prescriptions and more broadly within landscape management.

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Table and figure legends

Table 1

Uptake (kms) of hedgerow options in the Entry Level Stewardship (ELS) agri-environment scheme (AES) before and after revision of options in 2012, and the ELS points associated with each option. EB8 and EB10 involve ditch management in addition to hedgerow management. The requirements for hedgerow management under EB8 and EB10 are the same as for EB1 and EB3 respectively. Data obtained from Natural England (2013a) and Emily Ledder (Natural England, personal communication). * points awarded for hedge only / hedge and ditch management.

Figure 1

Layout of experimental hedgerow blocks at Woburn field site and factorial combinations of treatments manipulating the frequency (once every 1, 2 or 3 years), timing (A = autumn, September, W = winter, January or February) and intensity (S = cut back to standard height and width, I = incremental growth, cut to allow 10 cm of recent growth to remain on sides and top) of hedgerow cutting, and a control treatment that was not cut for the duration of the experiment. Each treatment was replicated once at each of three blocks, and applied to 20 m long contiguous hedgerow plots. Control plots were not cut during the experiment.

Figure 2

Cumulative abundance (mean ± SE) of Lepidoptera larvae and pupae in hedgerow plots subject to cutting frequency, timing and intensity treatments over three years (2011 – 2013).

Figure 3

Species richness (mean ± SE) of the Lepidoptera larvae and pupae in hedgerow plots subject to cutting frequency, timing and intensity treatments over three years (2011 – 2013).

Figure 4

Diversity (Shannon-Wiener index, mean ± SE) of the Lepidoptera community in hedgerow plots subject to cutting frequency, timing and intensity treatments over three years (2011 – 2013).

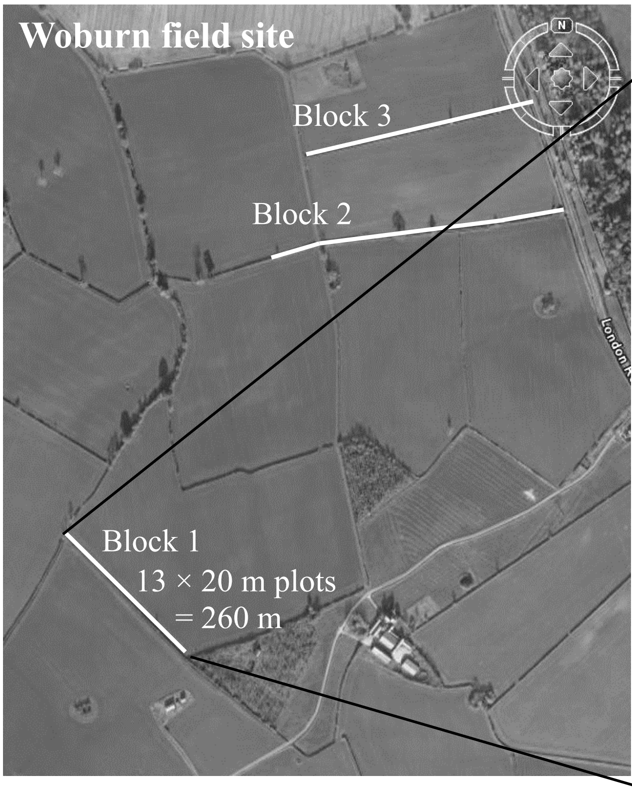
Figure 5

The response of Lepidoptera to the frequency, timing and intensity of hedgerow cutting of hedgerow, divided by life cycle stage and location in September: *left*) Lepidoptera species that are not likely to be present on the hedgerow as they are pupae or larvae within soil or detritus in September, or adults that can fly away in response to the disturbance of hedge trimming; and *right*) species that are likely to be on the hedgerow in September, as they are present in leaves as larvae or pupae, or are eggs on hedgerow plants.

Table 1

ELS options	ELS agreements starting 2009 – 2012			ELS agreements starting 2013 – 2014		
	Option hedgerow cutting regime	Points per 100m*	Length of hedgerow (km)	Option hedgerow cutting regime	Points per 100m*	Length of hedgerow (km)
EB1 / EB8	Cut both sides of each hedgerow not more often than once in 2 years	22 / 38	60,811.33	Hedgerow management for landscape: Cut both sides of each hedgerow not more often than once in 2 years	16 / 38	6,505.09
EB3 / EB10	Cut both sides of each hedgerow not more often than once in 3 years	42 / 56	28,409.58	Hedgerow management for landscape and wildlife: Cut both sides of each hedgerow not more often than once every 3 years or cut each hedgerow no more than once every 2 years between 1 January and 28 February.	42 / 56	5,083.14

Figure 1



Plot number	Treatment number	Hedgerow cutting treatment frequency, timing, intensity
1	13	Control
2	2	2, A, S
3	8	2, W, S
4	9	3, W, S
5	6	3, A, I
6	10	1, W, I
7	4	1, A, I
8	5	2, A, I
9	1	1, A, S
10	3	3, A, S
11	7	1, W, S
12	12	3, W, I
13	11	2, W, I

Figure 2

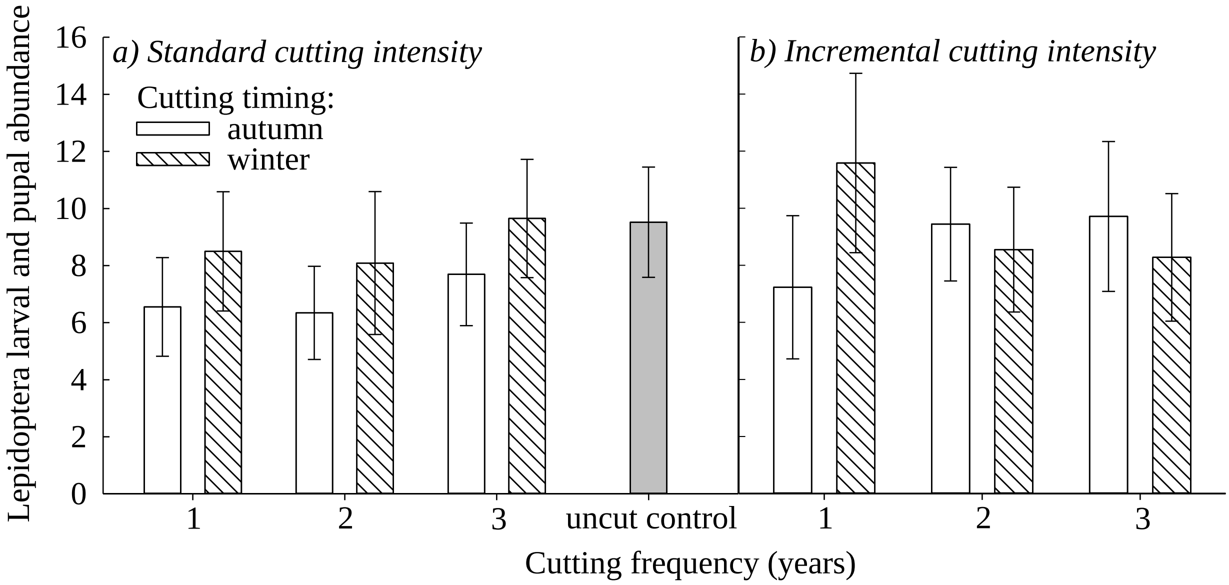


Figure 3

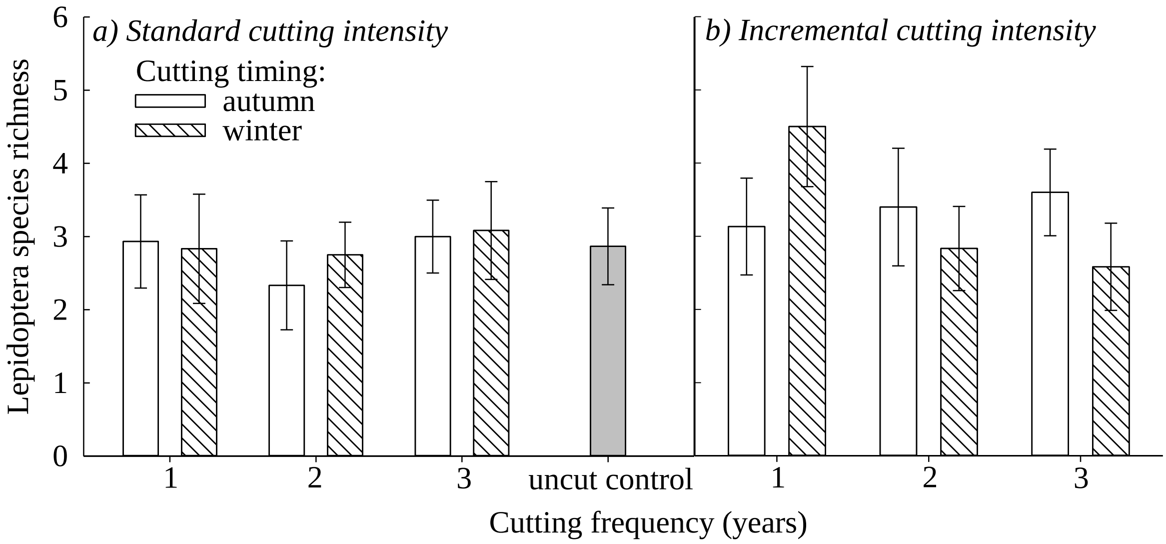


Figure 4

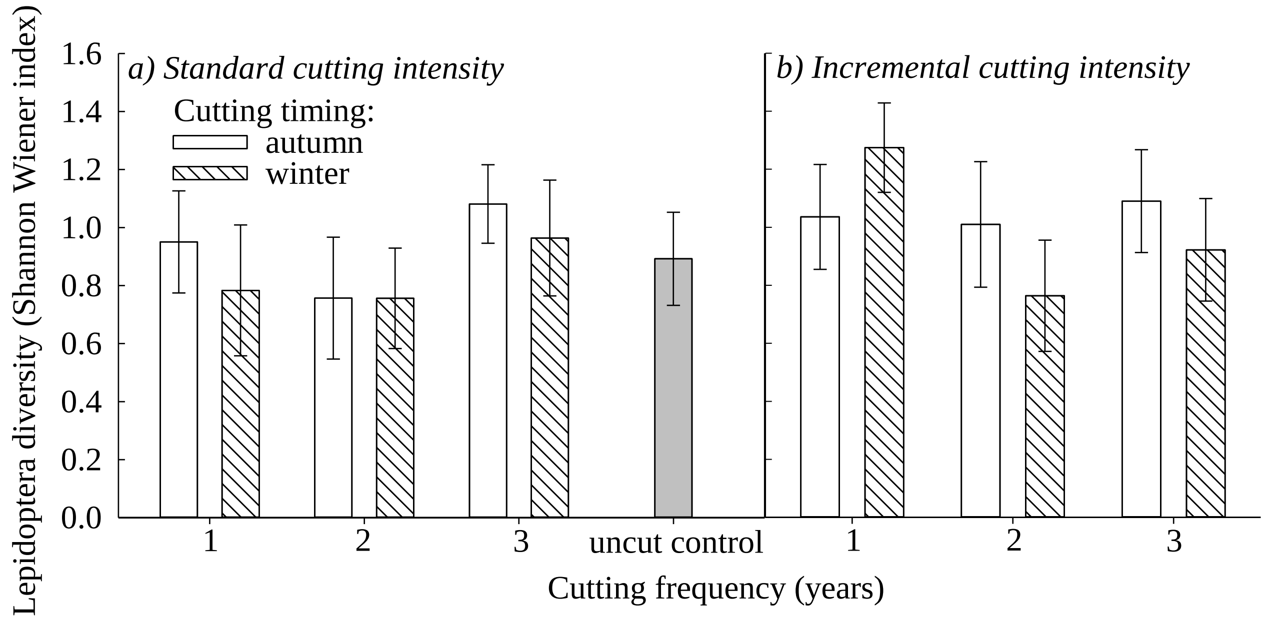

Lepidoptera diversity (Shannon Wiener index)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
a) Standard cutting intensity
Cutting timing:
autumn
winter
b) Incremental cutting intensity
1
2
3
uncut control
1
2
3
Cutting frequency (years)

Figure 5

Species divided by their stage and location in September

Larva or pupa in soil / detritus or adults

E.g. *The Chestnut* (*Conistra vacinii*), adults in September

• Diversity (Shannon-Weiner) 15% greater on incremental growth hedgerow plots compared with standard cutting intensity

Larva or pupa on hedgerow foliage, or eggs on hedge plants

E.g. *Hedya nubiferana*, larvae present in foliage that is silked together (spinnings) in September

• For hedges cut in autumn, species richness was 54% greater if cut once every 3 years compared with every year.