Biodiversity and Conservation (2006) 15:2595–2610
DOI 10.1007/s10531-005-4879-x

Hedges and green lanes: vegetation composition and structure

M.P. WALKER[1,*], J.W. DOVER[1], T.H. SPARKS[2] and S.A. HINSLEY[2]
[1]*Applied Sciences, Faculty of Health and Science, Staffordshire University, Mellor Building, College Road, Stoke-On-Trent ST4 2DE, UK;* [2]*CEH Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire PE28 2LS, UK; *Author for correspondence (e-mail: m.p.walker@staffs.ac.uk; phone: +44-7855-881061)*

Received 14 July 2004; accepted in revised form 20 March 2005

Key words: Farmland, Field margins, Flora, Green lane, Hedgerow, Hedge, Vegetation, Verges

Abstract. In this paper the vegetation of 20 green lanes, defined as tracks bounded by hedgerows, is examined in terms of composition and structure and compared with that of 20 matched single hedgerows. For analysis the vegetation of the lanes was separated into three areas; central track, verges inside of hedgerows and verges outside of hedgerows. The vegetation of these areas was found to differ in species richness, community structure, plant strategies and environmental traits. When compared with verges of the matched single hedgerows, the inside verges and central track were greatly different whereas the outside verge appeared broadly similar. Green lanes contained significantly more plant species than matched single hedgerows, differences being most pronounced when compared as landscape units, rather than as a mean of the constituent parts. The potential effect of surrounding land use on green lane floral diversity is discussed as well as the importance of maintaining the structural diversity of green lanes for farmland biodiversity.

Introduction

Hedges are known to be valuable habitats for wildlife, especially so within landscapes subject to intensive farming practices (Dover and Sparks 2000; Hinsley and Bellamy 2000; Maudsley 2000; McCollin et al. 2000). During the latter half of the 20 th century the UK's stock of hedges declined substantially in response to the need for larger fields to optimise the efficiency of farm machinery and also due to neglect (Barr et al. 1993). Data collected in the Countryside Survey 1990 (Barr et al. 1993) showed a 17% decline in UK hedgerow length between 1984 and 1990, however the most recent survey of UK hedgerow stocks (Haines-Young et al. 2000) indicated a stable stock with a balance between hedgerow loss and creation. However, as newly created hedges will take time to develop their ecological potential, a simple equivalence in length between survey dates actually represents a degradation of the UKs hedgerow stocks.

Intensive farming practices continue to be detrimental to many species of non-pest flora and fauna in many countries throughout the World (Stoate 1996; Boutin and Jobin, 1998; Benton et al. 2002; Aude et al. 2003), despite the mitigating effects of agri-environment schemes (Carey et al. 2002), and hedgerows are seen as one of the last strongholds for many species in intensive farmland (Parish et al. 1994; Sparks et al. 1996; Boutin and Jobin, 1998). A third of Britain's plant species have been found in hedgerows (Barr et al. 1995) and although these are not restricted to hedgerows, many of their other habitats have been so reduced that hedges have become a valuable refuge. Diversity in hedgerow ground flora has declined in recent years (Barr et al. 1993) not only affecting the plant species themselves, but also the wildlife that relies upon them.

The structure of green lanes varies (Dover et al. 2000), but here are defined as two parallel hedges separated by an unmetalled (non-sealed) track. Recent work has shown them to be valuable habitat for butterflies (Dover, Sparks and Greatorex-Davies 1997; Dover et al. 2000; Dover and Sparks 2001), bumblebees and plants (Dover and Sparks 2001; Croxton et al. 2002; Croxton et al. 2005). Dover et al. (2000) showed that both the 'inside' of green lanes, the area enclosed by the two hedges, and the 'outside' of green lanes, the field sides of the boundary hedges to be superior to single hedges in butterfly species richness and abundance. Explanations proposed for differences between green lanes and hedges include modified microclimate, including enhanced shelter, lower agricultural inputs and less intensive management regimes, and higher structural diversity (Dover and Sparks 2001). Croxton et al. (2002) showed the inside of green lanes to be superior to the outside of green lanes in bumblebee abundance and richness and in plant species richness. Croxton et al. (2002) also showed that the inside, outside and 'central track' of green lanes had different plant communities. Croxton et al. (2005) extended this to show the tracks of green lanes had different communities to tracks and verges running alongside single hedgerows. Croxton et al. (2002) argued that the outside of green lanes could be used to represent the environment experienced by field boundary hedges, although this has been shown to not be the case for butterflies (Dover et al. 2000). In this paper, we revisit the vegetation of green lanes and compare it with nearby matched single hedges. The study area was located in a northern mixed farming area of England.

Methods

Selection of sites

Twenty sections of green lanes were identified from farmland within a 10 km radius of Chester 53 ° 11′ N 02° 53′ W (Figure 1). Green lanes, in this study, were defined as tracks bordered on each side by a hedgerow running through farmland and used by farm vehicles, livestock or horses. Lanes were only chosen where the width between hedges was more than 2 m and, with one exception, the track unmetalled. The one metalled lane used had become almost entirely covered in grass and moss. Each green lane was matched with a single hedgerow, paired for similar orientation, surrounding land use and

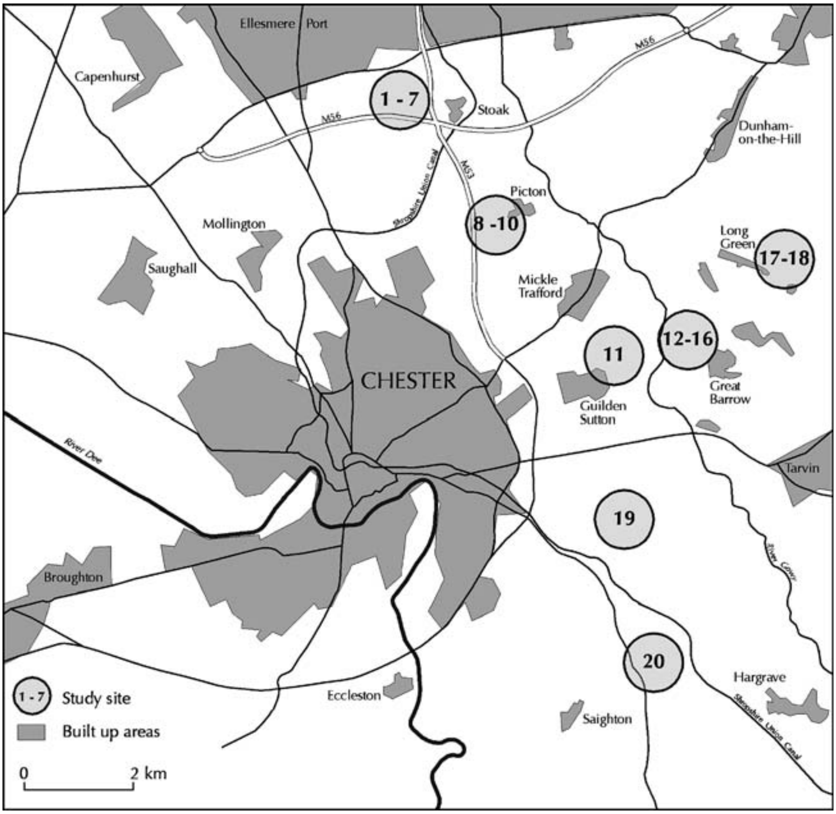

Figure 1. Map showing the positions of the 20 green lane and matched single hedgerow study sites used in this research.

height. All pairs of lane/matched single hedge were of the same length, and within the same 1 km^2grid square. In most cases one lane was matched with one hedge; however, due to difficulty in finding lanes it was necessary to split very long lanes into subsections which were then compared with different hedges. Subsections were only used if noticeably different in character, and each section was separated by a minimum of 100 m – the mean being 250 m.

Data collection

Green lanes

Five locations were selected at random on each lane. At each location the percentage cover of each plant species was recorded using a 50×100 cm quadrat from both outside verges, both inside verges and the central track, a verge being defined as the strip of vegetation either between the central track and the hedge (inside verge), or between the hedge and the crop of the

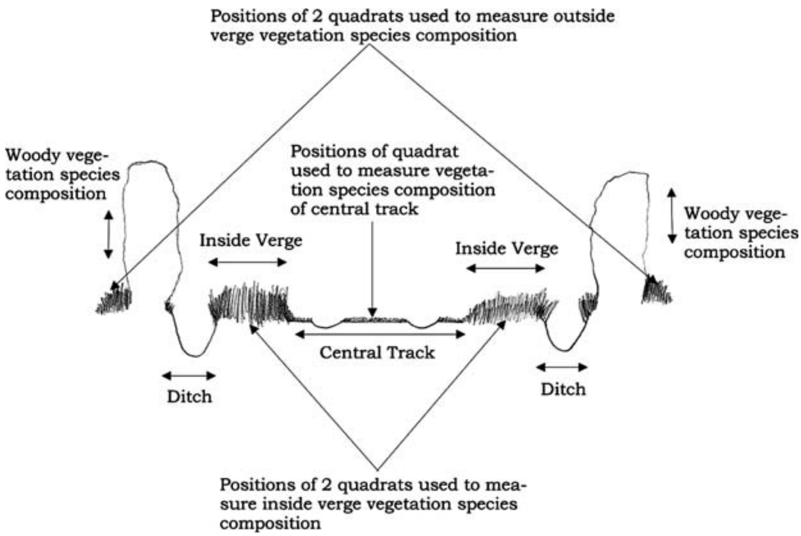

Figure 2. Diagram representing cross-section of green lane indicating positions of quadrats on inside verges, outside verges, and the central track.

bordering field (outside verge). The number and percentage composition of woody plant species forming the hedgerows was counted in a 5 m section at each location. A diagram of the positions of samples taken on green lanes is shown in Figure 2.

Hedgerows
Measurements on the matched single hedges were recorded as for the green lane, except for those features not present on a single hedge.

Analysis of data

A green lane may be compared with a matched single hedgerow by using two, quite different approaches. One approach compares the two on a like-for-like basis e.g. the two verges of a matched single hedgerow compared with two outside verges on a green lane. To take into account the green lane's more complex structure, a second approach is also used where green lane and matched single hedgerow are compared as different field boundary types or 'landscape elements'. This approach looks at a green lane as a unit consisting of a central track bordered by two inner verges, two hedgerows, and two outer verges, and compares its vegetation with that of the matched single hedgerow and the two verges either side.

Species richness

Ground vegetation: The number of species in the different parts of green lanes (outside verges, inside verges and central track), were compared with each other, and matched single hedgerows using two-way ANOVA.

Hedges and green lanes are clearly structurally different. We have used three approaches in analysing species richness. Firstly, equivalent sub-components of green lanes were compared to look at species richness differences within a lane (Figure 3a–c). Secondly the vegetation of a hedge (Figure 3d) was compared with the insides (e) and outsides (f) of a green lane. We were also interested in comparing hedges and green lanes as complete landscape elements and so thirdly, we have compared the vegetation of hedges with a sampling strategy which represents the entire range of subcomponents of green lanes (Figure 3d and g).

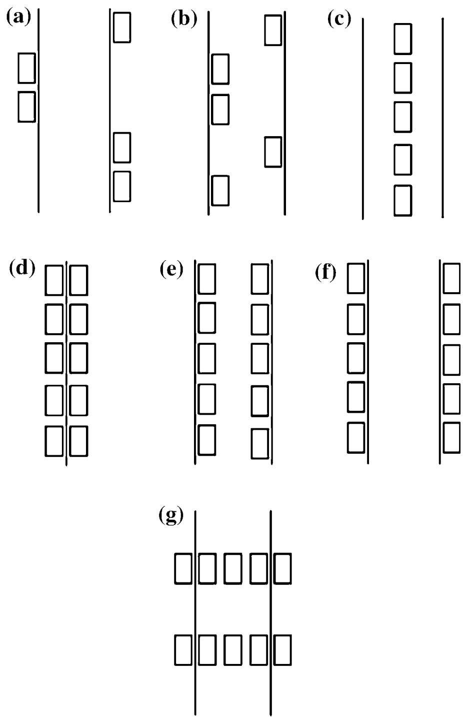

Figure 3. Diagrams representing various positions of quadrat samples used to calculate species richness. Diagrams a, b and c represent sampling strategies used to compare structural components of a lane with each other. These are (a) the outside verges, (b) the inside verges, and (c) the central track. Diagrams d, e and f represent sampling strategies used to compare various sub-components of green lanes with the equivalent on a single hedgerow, where (d) single matched hedgerow, (e) inside verges, (f) outside verges. Diagram g represents the sampling strategy used to represent a green lane as a landscape unit. (▯) Quadrat position, (|) hedge.

For the first method of analysis comparing green lane sub-components, species richness was calculated as the total combined species number in five quadrats per lane. For the inside and outside verges (Figure 3a and b) the five quadrats were randomly selected from the 10 sampled.

For both the second and third method of analysis, species richness was calculated as the sum of 10 quadrats per lane or hedgerow. For the sampling strategy representing the entire range of subcomponents of green lanes (Figure 3g) the positions of the two cross-sections were randomly selected for each lane.

Woody vegetation: The mean species richness of woody hedgerow plants per 5 m section was calculated. For green lanes the mean of the two hedgerows was used.

Individual species

The mean percentage cover for each plant species recorded was calculated for the inside verge, outside verge and central track of a lane, and the verge of a matched single hedgerow. Due to the data not meeting assumptions of normality, the nonparametric Friedman's two-way ANOVA was used for significance testing between these areas for all species with a mean value of 1% or more in any of the four areas. All significance testing in this study was performed using the Minitab 13 statistical package.

Ellenberg indicator and CSR values

Weighted mean indicator values for the ground flora (Hill et al. 1999) were calculated for each area of lane and hedge using mean percentage cover as weighting factors. Indices used were for L (light), M (moisture), R (reaction – an indicator of soil acidity, related to pH) and N (nitrogen). Weighted CSR values (Competitor, Stress-tolerator, Ruderal) were also calculated (Grime et al. 1988) using the same approach. The Kruskal–Wallis one-way ANOVA was used to test significance between areas for both Ellenberg and CSR values, followed, where appropriate, by multiple comparison testing (Siegel and Castellan 1988). A correlation matrix was constructed between Ellenberg and CSR values to check for inter-correlation between variables.

Plant communities

Plant community differences between the central track, both inside and outside verges of the lanes and the verges of the matched single hedgerows were assessed using Correspondence Analysis (CA) on mean percentage species cover on all 20 lanes and 20 hedgerows using down-weighting of rare species. This analysis was performed on all species using the Canoco package. The 'site effect' (variation caused by differences between the 20 sites) was eliminated using a series of 19 binary variables as covariables in the analysis. One-way ANOVA tests to examine for differences between the areas of green lanes and single hedgerows were performed on the first CA axis. To ascertain which species were most responsible for the positioning of sites along axis1, Pearson correlations were performed between the first axis and each plant species.

Results

Species richness

The inside verges appear to be the most species rich areas of a green lane, more so than either the central track or the outside verges (Table 1a). However it is when a green lane is treated as a whole landscape unit that the greatest difference in species richness compared with a matched single hedgerow is seen, the species richness of the lane being significantly greater ($p < 0.001$) (Table 1b). When the various sub-components of green lanes were compared with hedgerows (Table 1c) only the inside verge sub-component (Figure 3e) had significantly greater species richness ($p < 0.001$).

Woody vegetation

The species richness of woody hedgerow vegetation (Table 1d) for both green lanes and matched hedgerows was not significantly different ($p > 0.05$).

Ellenberg indicators and CSR

The Ellenberg indicator values for light (L), moisture (M), reaction (R) and nitrogen (N) for each area of green lanes and matched single hedgerows are given in Table 2. The significantly greater L-value indicates that more light is

Table 1. Mean herbaceous vegetation species richness values ± standard error (a) comparing structural components of green lanes, (b) using a landscape element approach to compare lanes and matched hedgerows, (c) comparing structural sub-components of green lanes with matched hedgerows, and (d) comparing mean woody species richness per hedgerow of green lane and per matched hedgerow.

	Mean ± SE
(a) Structural components of green lanes	
Inside verges	$15.45^{b} \pm 0.65$
Outside verges	$12.15^{a} \pm 0.79$
Central track	$12.65^{a} \pm 1.18$
(b) Landscape element approach	
Green lane	$23.50^{a} \pm 1.20$
Matched hedgerow	$15.75^{b} \pm 0.92$
(c) Hedgerow vs. structural components of green lanes	
Matched hedgerow	$15.75^{a} \pm 0.92$
Inside lane verges	$20.95^{b} \pm 0.92$
Outside lane verges	$17.55^{a} \pm 0.83$
(d) Hedge species	
Green lanes	$1.88^{a} \pm 0.11$
Matched hedgerows	$1.68^{a} \pm 0.11$

Values that share the same superscript letter are not significantly different ($p > 0.05$). No adjustment was made for multiple comparison testing.

Table 2. Ellenberg and CSR values ± standard error for the inside verges, outside verges and central track of green lanes, and the verges of matched single hedgerows.

	Light	Moisture	Reaction	Nitrogen
Inside verge	$6.28^{c} \pm 0.06$	$5.80^{a} \pm 0.08$	$6.56^{a} \pm 0.05$	$6.59^{b} \pm 0.10$
Outside verge	$6.70^{ab} \pm 0.05$	$5.53^{a} \pm 0.05$	$6.38^{a} \pm 0.09$	$6.27^{ab} \pm 0.11$
Central track	$6.91^{a} \pm 0.06$	$5.72^{a} \pm 0.09$	$6.35^{a} \pm 0.07$	$6.10^{a} \pm 0.07$
Single hedgerow	$6.53^{bc} \pm 0.05$	$5.72^{a} \pm 0.08$	$6.45^{a} \pm 0.07$	$6.37^{ab} \pm 0.11$
	C	S	R	
Inside verge	$0.66^{b} \pm 0.02$	$0.18^{b} \pm 0.02$	$0.16^{a} \pm 0.01$	
Outside verge	$0.60^{b} \pm 0.01$	$0.16^{b} \pm 0.01$	$0.25^{b} \pm 0.02$	
Central track	$0.44^{a} \pm 0.03$	$0.10^{a} \pm 0.01$	$0.45^{c} \pm 0.03$	
Single hedgerow	$0.63^{b} \pm 0.02$	$0.15^{ab} \pm 0.01$	$0.25^{b} \pm 0.02$	

Values that share the same superscript letter are not significantly different ($p > 0.05$). See text for levels of significant differences between pairs.

received in the central track than the inside verges of green lanes ($p < 0.001$). The N values indicate that the highest fertility of soil is found on the inside verges and the lowest on the central track. For L, R and N the values for the outside of the green lane hedge and the matched single hedgerow verge are similar, with no significant difference between them ($p > 0.05$).

CSR values (Table 2) indicate that plant species occurring on the central track of green lanes have the lowest value for Competitors and Stress-tolerators, and the highest value for Ruderals, indicating a higher amount of disturbance than the other parts of the lanes. For both Competitor and Ruderal values the differences between the central track and the other areas of the lane is highly significantly different ($p < 0.001$).

The inside verges of green lanes exhibit a higher Competitor, and Stress-tolerator value than all other areas of lanes and matched single hedgerows, whereas they have the lowest Ruderal value – significantly lower than all other lane areas ($p < 0.05$) indicating that the 'inside' species are subject to lower disturbance than elsewhere.

The verges 'outside' the hedges of the green lanes and the matched single hedgerow verges have intermediate levels of stress and disturbance. As was shown for the Ellenberg values, the CSR values for these two areas are very similar, and are not significantly different ($p > 0.05$).

The correlation matrix between Ellenberg and CSR values (Table 3) reveals that many of the indicator values are significantly inter-correlated. Caution is therefore required in using these values to interpret the results.

Individual floral species

Of the 30 species which had $> 1\%$ cover in green lanes and hedgerows (Table 4), 10 species were most abundant in the inside verges of green lanes, with six of these significantly so; in particular *Urtica dioica, Rubus fruticosus*

Table 3. Correlation matrix between Ellenberg (L, M, R, N) and CSR (C, S, Rud) values for inside verges (IS), outside verges (OS) and central track (Mid) of green lanes, and the verges of matched single hedgerows (Hedge).

	L	M	R	N	C	S
M	−0.253*					
R	−0.115	−0.063				
N	−0.358**	−0.005	0.703***			
C	−0.596***	0.124	0.414***	0.544***		
S	−0.264*	−0.15	−0.333**	−0.397***	0.115	
Rud	0.629***	−0.035	−0.214	−0.282*	−0.828***	−0.467

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

and *Hedera helix* were most abundant. In contrast four species were recorded as most abundant on the outside of the lane, these being grasses characteristic of farmland such as *Dactylis glomerata*, *Deschampsia flexuosa*, *Arrhenatherum elatius*, and *Lolium perenne*; only the latter two species showed significant differences between the four areas.

Of the eight species recorded as most abundant in single hedgerow verges, most abundant were farmland grasses such as *Elymus repens* and *Holcus mollis*, and the woody hedge species *Prunus spinosa*. The forb *Cirsium arvense* was equally as abundant in both the green lane outside verges and single hedgerow verges. All except *Elymus repens* showed significant differences in occurrence between the four areas.

Eight species were recorded as most abundant on the central track, six of these species showing significant differences in occurrence between the four areas. Of these the perennial grass species *Agrostis stolonifera* had the highest central track abundance, followed by the forbs *Ranunculus repens* and *Trifolium repens*.

Plant communities

The Correspondence Analysis reveals differences between the communities of ground vegetation occurring in these areas of the green lanes and the hedgerows (Figure 4). The plot reveals broad separation between vegetation communities from the three sampled areas of green lanes, the most prominent separation being with the central track. Outside verge communities appear similar to the communities of the matched single hedgerow verge, indicated by the broad overlap of points, whereas both inside verge and central track are mostly separated from the matched single hedgerow indicating a difference in communities between these areas. One-way ANOVA revealed all areas to be significantly different on the first axis of variation ($p < 0.001$) (Table 5) apart from the outside verge of the green lane and the matched single hedgerow verges, which were not significantly different from one another ($p > 0.05$). All the plant species significantly correlated ($p < 0.05$) with the first axis of

Table 4. Percentage cover values ± standard error for vegetation species found to occur on the inside verges, outside verges and central track of green lanes, and the verges of matched single hedgerows at a level > 1% for one or more of these areas.

Species	Inside verges	Outside verges	Central track	Single hedgerow	*p*
Grasses and rushes					
Agrostis stolonifera	3.9 ± 0.8	9.5 ± 3.0	20.0 ± 3.1	9.1 ± 2.4	**
Arrhenatherum elatius	8.5 ± 2.9	11.0 ± 1.7	1.0 ± 0.7	10.2 ± 2.5	***
Dactylis glomerata	3.8 ± 0.7	8.5 ± 1.7	7.6 ± 2.3	7.1 ± 1.7	ns
Deschampsia flexuosa	0.5 ± 0.5	2.5 ± 1.1	1.2 ± 0.6	1.6 ± 0.6	ns
Elymus repens	3.0 ± 1.0	3.6 ± 0.9	0.9 ± 0.3	4.3 ± 1.3	ns
Festuca gigantea	0.3 ± 0.2	0.3 ± 0.3	0.0	1.7 ± 1.2	ns
Festuca rubra	0.0	0.0	1.1 ± 1.1	0.0	ns
Holcus lanatus	1.8 ± 0.6	1.4 ± 0.6	4.8 ± 1.6	0.7 ± 0.4	ns
Holcus mollis	1.3 ± 0.5	4.1 ± 1.2	1.3 ± 1.0	5.5 ± 1.6	**
Juncus bufonius	0.0	0.0	1.3 ± 0.8	0.0	**
Lolium perenne	0.4 ± 0.2	11.5 ± 2.2	6.4 ± 2.8	9.8 ± 2.5	***
Poa annua	0.0 ± 0.0	0.5 ± 0.3	4.1 ± 1.9	0.1 ± 0.1	*
Broadleaved species					
Ballota nigra	0.1 ± 0.1	0.1 ± 0.1	0.0	1.0 ± 1.0	ns
Cirsium arvense	1.7 ± 0.4	2.3 ± 0.7	0.2 ± 0.1	2.3 ± 0.6	**
Conopodium majus	0.9 ± 0.3	0.5 ± 0.2	0.4 ± 0.3	1.1 ± 0.6	ns
Epilobium hirsutum	1.3 ± 0.7	0.4 ± 0.4	0.1 ± 0.1	0.2 ± 0.1	ns
Filipendula ulmaria	2.5 ± 1.5	0.0 ± 0.0	0.7 ± 0.6	0.8 ± 0.5	ns
Galium aparine	1.2 ± 0.3	0.5 ± 0.4	0.0 ± 0.0	0.5 ± 0.2	***
Heracleum sphondylium	2.0 ± 0.5	1.0 ± 0.3	1.0 ± 0.5	1.4 ± 0.8	ns
Plantago major	0.0 ± 0.0	0.5 ± 0.4	4.0 ± 1.4	0.0 ± 0.0	***
Ranunculus repens	3.8 ± 0.9	1.9 ± 0.7	9.6 ± 2.4	3.3 ± 1.5	*
Rumex obtusifolium	1.3 ± 0.3	0.7 ± 0.4	1.2 ± 0.4	0.7 ± 0.2	ns
Stachys sylvatica	2.4 ± 0.6	0.3 ± 0.2	0.2 ± 0.2	0.1 ± 0.0	***
Trifolium repens	0.1 ± 0.1	0.0 ± 0.0	6.4 ± 1.7	0.0 ± 0.0	***
Urtica dioica	21.7 ± 3.7	12.7 ± 2.7	1.5 ± 0.4	17.2 ± 4.2	***
Woody species					
Hedera helix	4.5 ± 1.4	2.9 ± 1.1	0.0 ± 0.0	0.6 ± 0.2	***
Prunus spinosa	1.5 ± 0.5	1.3 ± 0.4	0.0	2.4 ± 0.8	**
Rosa canina	1.5 ± 0.5	0.7 ± 0.2	0.2 ± 0.2	0.7 ± 0.3	**
Rubus fruticosus	13.7 ± 2.3	5.3 ± 0.9	1.0 ± 0.6	3.8 ± 0.7	***
Ulex europaeus	0.1 ± 0.1	0.3 ± 0.2	0.0	1.0 ± 1.0	ns

ns = $p > 0.05$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

variation are shown in Table 6. This revealed that the grass species *Arrhenatherum elatius*, *Lolium perenne* and *Poa annua*, as well as the forbs *Plantago major* and *Trifolium repens* were most correlated with this axis and so strongly contributed to the positioning of the different sites along it.

Discussion

The green lanes surveyed in this study clearly contained a greater diversity of plant species than their matched single hedgerow counterparts. The difference

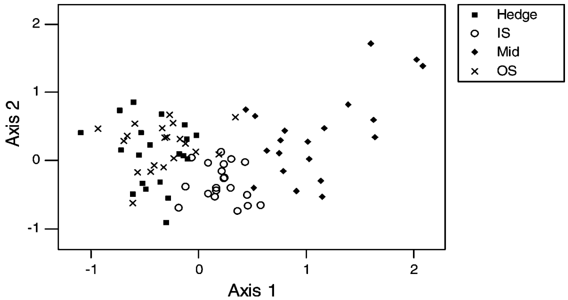

Figure 4. CA analysis plots for herbaceous vegetation taken from 3 positions on each of 20 green lanes (IS = inside verge, OS = outside verge, Mid = central track) and on 20 matched single hedgerow verges. Log-transformations have been performed on both x and y axes.

Table 5. Significance results for 2-way ANOVA tests between inside verges (IS), outside verges (OS) and central track (Mid) of green lanes, and the verges of matched single hedgerows (Hedge) for the first axis of variation obtained from CA analysis.

Axis 1	OS	Mid	Hedge
IS	***	***	***
OS		***	ns
Mid			***

ns = $p > 0.05$; *** $p < 0.001$.

Table 6. Plant species found to be significantly correlated ($p < 0.05$) with the first axis of variation obtained from CA analysis.

Species	r	p
Grasses		
Agrostis stolonifera	−0.34	**
Arrhenatherum elatius	−0.40	***
Elymus repens	−0.35	**
Lolium perenne	−0.41	***
Poa annua	0.39	***
Broadleaved species		
Cirsium arvense	−0.34	**
Cirsium vulgare	−0.24	*
Persicaria maculosa	0.27	*
Plantago major	0.40	***
Polygonum aviculare	−0.24	*
Trifolium repens	0.44	***
Urtica dioica	−0.34	**
Woody species		
Prunus spinosa	−0.33	**

Pearson correlation coefficients (r) and associated p values are shown.
ns = $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

is most pronounced when the effect of the structure of the green lane is taken into account by comparing the green lane on a landscape element basis with the matched single hedgerow, i.e. a green lane consists of two parallel hedges with two inside verges, two outside verges and a track running down its centre, whereas a single hedgerow consists simply of a hedge with a verge on either side. An increased vegetation diversity of green lanes when treated as a landscape unit is partly a result of the differing environmental factors provided by the various parts of green lane structure as implied by the work of Dover et al. (2000) for butterflies, and Croxton et al. (2002) for both bumblebees and vegetation.

The results here show, that in terms of vegetation species, the inside verge of the lane is significantly more diverse than the outside verge. Pesticide drift is known to reduce plant species richness in hedgerow verges (Kleijn and Snoeijing, 1997). The verge species richness difference across a green lane hedge shown here may be a result of the buffering effect of hedges to pesticide drift as suggested by Tsiouris and Marshall (1998). The CA also indicates that the vegetation communities occurring in these two areas are substantially different from each other in the majority of green lanes studied. The Ellenberg values indicate which environmental conditions are reflected by these plant communities; plants found in the inside verge are more shade tolerant than those in the outside and also prefer greater levels of moisture. The abundance of the species *Stachys sylvatica* on the inside verges emphasises this relationship. These results are supported by those obtained by Croxton et al. (2002). The greater shade on the inside verges of the lanes could result from the parallel nature of the hedgerows, especially on the narrowest lanes, where both hedgerows may shade each verge for part of the day. The faces of hedgerows bordering the inside edges of the green lanes used in this study only received irregular cutting, perhaps once every 3 or 4 years whereas the outside faces of the hedges tended to receive annual cuts (Personal comm. landowners). This lower level of management results in bushier, overhanging hedges on the inside of lanes that may provide more shade.

The Ellenberg N-Value, indicates higher fertility 'inside' the lanes than outside. Croxton et al. (2002) suggested this might result from the leaching of fertilisers from adjacent field applications into green lane ditches, a build up of humus from fallen leaves and other vegetative material, and defecation from birds and other animals in overhanging hedges and trees as possible contributors to this. For the majority of lanes surveyed in this study, all of these suggestions still apply. However, for a quarter of grasslands bordering the lanes, no fertilizer application or muck-spreading was recorded in the study year. In these cases grass was grazed by cattle and so their defecation would be a likely source of nutrient leaching in a similar way to inorganic fertilisers. Caution must be taken in interpreting Ellenberg values due to a strong correlation between Ellenberg N-values and CSR Competitor values. As Competitor values and Ruderal values are strongly negatively correlated, it may be that disturbance rather than nutrient levels are the factors most heavily influencing the plant species found in these areas.

The CSR values indicate how these plant communities differ in their life history traits and the inside verges of lanes appears to present a less disturbed environment than the outside, although only the Ruderal value is significantly different. A greater level of disturbance would be expected on the outside from grazing livestock and occasional ploughing on the outside edges of the verges bordering arable fields.

The central track of the green lanes harbours a plant community different to the other areas of the lanes. The lanes studied by Croxton et al. (2002) were in a fully arable landscape, where the central track was found to consist more of a grassland community than the other areas. This study shows that the same is true for green lanes in a mixed arable and grassland landscape with the perennial grass species *Agrostis stolonifera* and *Lolium perenne* and the forb *Ranunculus repens* most abundant in both cases. Ellenberg values reveal that the plant communities of the central track have a significantly higher light score than the inside verges, indicating that this area is less shaded. Our data confirms the findings of Croxton et al. (2002) in that the central track appears to be damper and have lower soil fertility than the outside of the hedge.

Lower nutrient levels are likely to be due to the distance from the ditch, and the buffering effect of the hedge (Tsiouris and Marshall 1998) from applications of artificial fertilisers and muck-spreading in bordering fields, but some nutrient inputs are likely from defecation of farm animals when moved from field to field along the lanes. The ruts in green lanes may also act as temporary linear water storage ponds creating damper conditions around the central track compared to the freer draining and ditched inner verges.

The high Ruderal, and low Stress-tolerator and Competitor values indicate that the central track is more disturbed than the other areas of the lane. This is probably as a result of trampling by livestock, horses and people, mowing and flattening by vehicles, resulting in an abundance of trampling-tolerant species such as *Plantago major*. Again, inter-correlations need to be taken into account, and the strong correlation found between CSR Ruderal and Ellenberg L-values suggests that it may be disturbance rather than light largely influencing these results. Disturbance may also contribute more to the results than nutrient levels, as discussed above.

Unlike Croxton et al. (2002) this study directly compared the vegetation of the outside verge of a green lane with that of a matched single hedgerow. The results of this study shows that the outsides of these two field boundaries are in fact broadly similar in both vegetation community structure and species diversity and in Ellenberg and values for light, pH and fertility as well as stress and disturbance represented by CSR values. Both communities are made up chiefly of *Urtica dioica* as well as agricultural weeds such as *Arrhenatherum elatius* and *Elymus repens* and grasses commonly sown for fodder such as *Lolium perenne* and *Dactylis glomerata*. The only difference in these field boundaries lies in the level of moisture indicated by the Ellenberg M-value. Although not significant, the trend suggests that the moisture content of the soil is higher alongside a matched single hedgerow than along the outside of a green lane. Higher levels of soil moisture in matched single hedgerows may, as with green lanes, also be heavily influenced by the presence of ditches, with 14 out of 20 matched single hedgerows having a ditch alongside them. Croxton et al. (2002) assumed that the outside of a green lane was analogous to matched hedgerows in both bee and vegetation component. We confirm their assumption for vegetation but urge caution in their assumption of this for bumblebees as Dover et al. (2000) found that the outside of green lane contained more species and a greater abundance of butterflies than single hedgerows.

This research confirms that green lanes are reservoirs of biodiversity in the impoverished modern agricultural landscape. It also underlines the importance of the structure of green lanes and the need to maintain its various components. The two outside verges of green lanes resemble matched single hedgerows in terms of their floral composition, however, when the areas inside the hedges of a green lane are also included the species diversity greatly increases and far exceeds that of a matched single hedgerow. A green lane should therefore be recognised as a single landscape unit, for if one hedgerow of a green lane is lost, many aspects of its vegetation diversity may rapidly decline. To maintain the diversity of vegetation inside green lanes requires continued usage of green lanes by farm vehicles, livestock, horses and people to prevent lanes from becoming overgrown and eventually strips of linear woodland, which, although valuable in their own right would be unlikely to maintain the structural and plant community diversity found in green lanes. The vegetation of the outside verges of green lanes are likely to benefit from management found to be beneficial to the flora of single hedgerow verges such as wildflower/grass strip planting (Moonen and Marshall 2001). The richness of the herbaceous flora of green lanes appears to be derived from the heterogeneous abiotic conditions resulting from the size, structure and use of green lanes. The surfacing of green lanes for improved accessibility usually with tarmac or concrete is clearly a real threat to biodiversity.

Dover et al. (2000) commented that green lanes were not recognised as a specific landscape element in the Countryside Survey 1990 (Barr et al. 1993) and indeed they are still not recognised as a linear landscape feature in the most recent Countryside Survey (Haines-Young et al. 2000). Loss/gain statistics for green lanes are therefore still unknown limiting the recognition of the need to protect them. A continued effort needs to be placed into researching the usage of green lanes by other groups of organisms, and also into beneficial methods of managing, maintaining, restoring and creating new green lanes.

Acknowledgements

The authors would like to thank all the Cheshire farmers and landowners of hedgerows and green lanes used in this study for granting permission to access their land, and for answering questions on management regimes. M. Walker gratefully acknowledges the financial support of Staffordshire University's Institute for Environmental and Sustainability Research (IESR) during this doctoral research. We are grateful to Rosie Duncan for providing Figure 1.

References

Aude E., Tybirk K. and Bruus Pederson M. 2003. Vegetation diversity of conventional and organic hedgerows in Denmark. Agriculture, Ecosystems and Environment 99: 135–147.

Barr C.J., Britt C.P. and Sparks T.H. 1995. Hedgerow Management and Wildlife: A Review of Research on the Effects of Hedgerow Management and Adjacent Land on Biodiversity. ITE/ADAS.

Barr C.J., Bunce R.G.H., Clarke R.T., Fuller R.M., Furse M.T., Gillespie M.K., Groom G.B., Hallam C.J., Hornung M., Howard D.C. and Ness M.J. 1993. Countryside Survey 1990. Department of the Environment, Main Report.

Benton T.G., Bryant D.M., Cole L. and Crick H.Q.P. 2002. Linking agricultural practice to insect and bird populations: a historical study over three decades. Journal of Applied Ecology 39: 673–687.

Boutin C. and Jobin B. 1998. Intensity of agricultural practices and effects on adjacent habitats. Ecological Applications 8: 544–557.

Carey P.D., Barnett C.L., Greenslade P.D., Hulmes S., Garbutt R.A., Warman E.A., Myhill D., Scott R.J., Smart S.M., Manchester H.J., Robinson J., Walker K.J., Howard D.C. and Firbank L.G. 2002. A comparison of the ecological quality of land between an English agri-environment scheme and the countryside as a whole. Biological Conservation 108: 183–197.

Croxton P.J., Carvell C., Mountford J.O. and Sparks T.H. 2002. A comparison of green lanes and field margins as bumblebee habitat in an arable landscape. Biological Conservation 107: 365–374.

Croxton P.J., Hann J.P., Greatorex-Davies J.N. and Sparks T.H. 2005. Linear hotspots? The floral diversity of green lanes. Biological Conservation 121: 579–584.

Dover J.W., Sparks T.H. and Greatorex-Davies J.N. 1997. The importance of shelter for butterflies in open landscapes. Journal of Insect Conservation 1: 89–97.

Dover J.W., Sparks T., Clarke S., Gobbett K. and Glossop S. 2000. Linear features and butterflies: the importance of green lanes. Agriculture, Ecosystems and Environment 80: 227–242.

Dover J. and Sparks T. 2000. A review of the ecology of butterflies in British hedgerows. Journal of Environmental Management 60: 51–63.

Dover J.W. and Sparks T.H. 2001. Green lanes: biodiversity reservoirs in farmland?. In: Barr C.J. and Petit S. (eds), Hedgerows of the World: Their Ecological Functions in different landscapes. IALE (UK), Lymm, pp. 241–250.

Grime J.P., Hodgson J.G. and Hunt R. 1988. Comparative Plant Ecology: A Functional Approach to Common British Species. Unwin Hyman, London.

Haines-Young R.H., Barr C.J., Black H.I.J., Briggs D.J., Bunce R.G.H., Clarke R.T., Cooper A., Dawson F.H., Firbank L.G., Fuller R.M., Furse M.T., Gillespie M.K., Hill R., Hornung M., Howard D.C., McCann T., Morecroft M.D., Petit S., Sier A.R.J., Smart S.M., Smith G.M., Stott A.P., Stuart R.C. and Watkins J.W. 2000. Accounting for Nature: Assessing Habitats in the UK Countryside. DETR, London.

Hill M.O., Mountford J.O., Roy D.B. and Bunce R.G.H. 1999. Ellenberg's Indicator Values for British Plants. HMSO, Norwich.

Hinsley S.A. and Bellamy P.E. 2000. The influence of hedge structure, management and landscape context on the value of hedgerows to birds: a review. Journal of Environmental Management 60: 33–49.

Kleijn D. and Snoeijing G.I.J. 1997. Field boundary vegetation and the effects of agrochemical drift: Botanical change caused by low levels of herbicide and fertilizer. Journal of Applied Ecology 34: 1413–1425.

Maudsley M. 2000. A review of the ecology and conservation of hedgerow invertebrates in Britain. Journal of Environmental Management 60: 65–76.

McCollin D., Jackson J.I., Bunce R.G.H., Barr C.J. and Stuart R. 2000. Hedgerows as habitat for woodland plants. Journal of Environmental Management 60: 77–90.

Moonen A.C. and Marshall E.J.P. 2001. The influence of sown margin strips, management and boundary structure on herbaceous field margin vegetation in two neighbouring farms in southern England. Agriculture Ecosystems and Environment 86: 187–202.

Parish T., Lakhani K.H. and Sparks T.H. 1994. Modelling the relationship between bird population variables and hedgerow and other field margin attributes. I. Species richness of winter, summer and breeding birds. Journal of Applied Ecology 31: 764–775.

Siegel S. and Castellan N.J. 1988. Non-parametric Statistics for the Behavioural Sciences. McGraw-Hill, New York.

Sparks T.H., Parish T. and Hinsley S.A. 1996. Breeding birds in field boundaries in an agricultural landscape. Agriculture, Ecosystems and Environment 60: 1–8.

Stoate C. 1996. The changing face of lowland farming and wildlife Part 2 1945–1995. British Wildlife 7: 162–172.

Tsiouris S. and Marshall E.P.J. 1998. Observations on patterns of granular fertiliser deposition beside hedges and its likely effects on the botanical composition of field margins. Annals of Applied Biology 132: 115–127.