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Hedgerow management, dormice and biodiversity

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Hedgerow management, dormice and biodiversity

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PROTECTING OUR NATIVE ANIMALS AND THEIR HABITATS
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Contents

Summary

1. Hedgerows are of key importance for conservation in agricultural landscapes, but changes in their management in the last few decades are likely to have had a profound negative impact on biodiversity. Dormice used to occur frequently in hedgerows and are indicators of diversity. Understanding their needs in hedgerows is a priority action in the UK dormouse Species Action Plan.
2. We re-surveyed 59 hedgerow sites where dormice were present in the late 1970s and found that they are no longer present at 64% of sites. This equates to a 70% decrease over 25 years – a red alert decline. Extinction was strongly inversely correlated with hedgerow width; intensively managed sites no longer supported dormice.
3. We measured dormouse population density at 50 randomly selected 2km hedgerow sites stratified by region (Kent, Sussex, Somerset, Devon, Carmarthenshire) and management type (cut, uncut). Densities were within the norm for woodlands, so hedgerows can provide high quality habitat for dormice. Population density was strongly related to hedgerow height and shrub diversity; intensively managed, low diversity hedgerows lacked dormice. The presence of dormice was indicative of ancient hedgerows. Densities of juvenile dormice were inversely related to the proximity of ancient woodland (putative source populations), implying that hedgerows do act as dispersal corridors.
4. Radio tracking showed that dormice fed on bramble, dog-rose and hazel, but probably many other hedgerow shrub flowers and fruits too. Dormouse ranges in hedgerows were longer than those in woodlands, but covered an order of magnitude smaller area. This implies that dormice are constrained to feed within small areas and that hedgerows will therefore need to be diverse and productive to supply them with sufficient food.
5. Hedgerows with arable, as opposed to pastoral, as the adjacent land use and those with high hawthorn cover, were cut most frequently. The abundance of soft mast fruits (berries) increased from one to two years after hedgerow cutting and then slowly declined. The presence of small gaps in hedgerows (mean maximum gaps per site: 6.1%) was related to higher soft mast production, probably because of increased light and decreased competition amongst shrubs. Flailing had an additional negative impact on soft mast production. Hard mast fruit (seed) production was low until at least six years post cutting and then increased greatly.
6. We asked people who were personally involved, how hedgerows were managed in the 1920s and 1930s, before most mechanisation of hedgerow cutting. At the time of writing 56 questionnaire replies had been received. They show that on 68% of farms less than half the hedgerows were cut each year and that the average hedgerow cutting interval was six years. Observation suggests that hedgerow management is now much more uniform and intensive (nearly all hedgerows on a farm cut every year). Most hedgerows were managed by hand trimming and laying, whereas most today are flailed or mechanically trimmed.

Our results show that the long historic decline of the dormouse is still rapidly continuing in hedgerows. We recommend that most hedgerows are cut at three yearly intervals, with some left to grow for at least seven to ten years. It is important than only a minority of hedgerows on a farm are cut in any one year. Coppicing, or (better) laying, should be used to restore hedgerows that become gappy. These, and further recommendations given in our report, will form the basis of an advisory document about de-intensification of hedgerow management, which would benefit a host of biodiversity including the dormouse.

1. Introduction

It has long been recognised that hedgerows are of key importance for the conservation of biodiversity in agricultural landscapes. They provide: a habitat for many woodland edge and scrub-living species; food sources for a diverse array of taxa that are not inhabitants of hedgerows *per se*; and, almost certainly, habitat corridors vital for the successful dispersal of woodland species in particular. It is likely that hedgerows play at least two of these support functions for a significant proportion of species associated with them e.g. feeding sites and habitat corridors for greater horseshoe bats (*Rhinolophus ferrumequinum*). So the loss or change in management of hedgerows may have a disproportionate impact on associated species, placing them in double or triple jeopardy.

The enormous loss of hedgerows in Britain, especially during the 1960s, 1970s and early 1980s, is well known and documented. Changes in hedgerow management however, have received much less attention. There appear to have been three main changes, beginning mostly after the Second World War: an increase in the frequency of hedgerow cutting, such that most actively managed hedgerows now appear to be cut every year; the widespread adoption of mechanical flails to cut hedgerows; and, conversely, the complete neglect of active management of some hedgerows. There is little information on the impact of these management changes on the biodiversity supported by hedgerows. Intensification of management is likely to adversely affect flower and fruit production of woody hedgerow shrubs, with perhaps major impacts on the many species which depend on them for food. However total cessation of management leads hedgerows to become gappy, meaning that they are not stock proof and of lower value as habitat corridors (Bright 1998). There thus needs to be a management trade-off between these extremes. The key question is how intensively or frequently should hedgerows be managed to maximise their support for biodiversity?

In the past the dormouse *Muscardinus avellanarius*, a European protected species and a priority in the UK Biodiversity Action Plan, was frequently found in hedgerows (Rope 1886; Hurrell & MacIntosh 1984). Hedgerows may be permanently inhabited or used as habitat corridors during dispersal between woodlands (Bright & Morris 1996). Experimental translocations have shown that gaps in hedgerows restrict movement (Bright 1998), otherwise the habitat requirements of dormice occurring in hedgerows are unknown. Dormice are associated with woodlands of high woody species diversity and woodlands where structural heterogeneity is maintained by traditional management (Bright & Morris 1990). This implies that species rich hedgerows may be more likely to support dormice and that their presence is likely to be indicative of hedgerow biodiversity. It also suggests that dormouse abundance will be highly dependent on hedgerow management. The dormouse should thus be a sensitive indicator of appropriate hedgerow management and greater biodiversity.

1.1. Project Objectives

Understanding the requirements of dormice occurring in hedgerows is a high priority action in UK dormouse Species Action Plan (Anon 1995), which this report is primarily designed to address. However because the dormouse is a useful indicator and due to the necessarily large scale of our fieldwork, we are also able to provide much information of general importance for the conservation of hedgerow biodiversity. In particular, our work will contribute to the implementation of the Hedgerow Habitat Action Plan. Following from these broad aims, the specific objectives of our research were (*a précis of our approach to each objective is given in italics*):-

1. To determine whether there have been changes in the prevalence of dormouse populations in hedgerows in the recent past and, if so, why these have occurred. *We re-surveyed hedgerows where dormice occurred between 1975-1979.*
2. To determine the habitat requirements of dormice occurring in hedgerows, especially how these relate to hedgerow management. *We undertook a stratified random survey of dormice at 50 2km hedgerow sites.*
3. To assess how current management influences hedgerow structure and production of fruits. *We measured fruit production and hedgerow characteristics at the 50 sites (2 above).*
4. To quantify how hedgerow management has changed since the introduction of tractor-driven mechanical cutters and flails. *We conducted a questionnaire survey of people who were personally involved with hedgerow management in the 1920s and 1930s.*

2. Methods

2.1. Study sites

1975-1979 dormouse hedgerow sites
Hedgerow sites where dormice were present between 1975 and 1979 inclusive during the Mammal Society dormouse survey (Hurrell & MacIntosh 1984) were re-surveyed. Only those sites where dormice had been recorded as associated with a single habitat type, hedgerows, were included. At each site a 300m segment of hedgerow was sampled, sufficient to ensure that the exact site of a previous dormouse record was encompassed (Hurrell & MacIntosh (1984) recorded locations as Ordnance Survey national grid references to an accuracy of ± 100m).

Survey of five regions
A random sample of 50 sites stratified by region (10 sites in each of five regions) and within region by management type was surveyed. Management types were: cut hedgerows (three in each region) and uncut hedgerows (seven in each region). The former were hedgerows that had been cut (by any method) on both sides and the top the winter immediately before surveys began. The latter were hedgerows that had not been cut on both sides and/or the top for at least one year *i.e.* had at least one summers' growth. We determined how recently cutting has occurred from the presence of re-growth and by questioning landowners. Each site comprised a contiguous network of hedgerow totalling 2km in length, within a 2km^2 area. Regions were selected to encompass both the land class groups in which dormice occur and regions where at least a moderate number of woodland sites are known to be occupied.

2.2. Sampling dormouse populations

Nest tubes (Morris & Temple 1998) measuring 225×58×56 mm were used to sample dormice, which nest in them. Nest tubes were tied to hedgerow branches 20m apart, so that there were either 15 (re-survey of 1975-1979 sites) or 100 (survey of five regions) at each site. These allowed us to determine presence-absence of dormice at the 1975-1979 sites and dormouse abundance in the five regions. Nest tubes were put up in March-April, then checked the following September-October to measure post-breeding (autumn) abundance of adult (>16g) and juvenile dormice (≤ 16g, juvenile pelage; Bright & Morris 1989). Checks the following June were used to estimate pre-breeding (spring) abundance, though Carmarthenshire and Somerset regions could not be checked at this time because of restrictions due to the epidemic of foot and mouth disease. Surveys of the regions were conducted in 1999 and 2000, those of the 1975-1979 sites in 2000. The total number of distinctive nests present in September-October was used as a measure of whole-summer use of hedgerows by dormice.

2.3. Radio tracking

Dormice at several sites were fitted with miniature radio transmitter collars between July and October, mostly in 2000. We experienced considerable difficulties in finding sufficient dormice during mid-summer (when there was time in the fieldwork schedule to undertake radio tracking), since nest tube occupation rates, like those of nest-boxes (Morris, Bright & Woods 1990), are low at this time. Dormice were tracked from the beginning to the end of their nocturnal activity period for 3-8 nights. About once per hour their position along a hedgerow was recorded, together with the dominant shrub species/suite of species at that position. From these data we calculated: the total length of hedgerow range used over the tracking period; the total distance travelled per night; and the proportion of position records in different species/suites of species of shrubs.

2.4. Measuring habitat quality and fruit production

Hedgerow structure and composition was quantified in 10m segments of hedgerow centred on alternate (odd numbered) nest tubes. We recorded: average maximum height (measured from the base of shrubs); average maximum width; the percentage cover of each woody shrub and vine species; whether a hedgerow was cut (within the last year) on the top, on one side or on both sides; whether there was evidence of flailing (assessed by distinctive stripping of large sections of shrub bark and splitting of woody stems); whether a hedgerow was on a bank; whether the shrub branches at its base were dense (basal density); whether there was evidence of hedgerow laying; the land use on each side (arable, pastoral, road). From percentage cover data of shrubs and vines, we calculated Simpson’s index of diversity. In addition we recorded the number of years since a segment of hedgerow had been cut on the top and/or both sides, based on re-growth and questioning of landowners. We estimated the percentage of hedgerow that lacked woody vegetation (had gaps) between adjacent nest tubes i.e. along a 20m section of hedgerow. Gaps were breaks in hedgerow woody vegetation of at least 0.3m sufficient to allow domestic stock to pass through. We counted the number of woody shrubs that can be used to index a hedgerow’s age (Pollard, Hooper & Moore 1974) in a 30m length of hedgerow.

During mid-September to mid-October 2000 we counted fruits of each shrub and vine species in 1m wide segments of hedgerow centred on alternate nest tubes (i.e. 50 samples per site, counts on one side and the top of hedgerows). From these data we calculated the mean abundance of soft mast fruits (berries of: hawthorn, bramble, dog rose, blackthorn, bryony) and hard mast fruits (seeds of: ash, field maple, beech, sycamore, hornbeam, hazel, oak).

2.5. Questionnaires about past hedgerow management

We produced a questionnaire asking only people who were personally involved with hedgerow management between World Wars I and II (i.e. c. the 1920s and 1930s) for information about how hedgerows used to be managed (see the Appendix). This sought answers to the following questions: the name of the place and the county where a person was involved with hedgerow management; how frequently hedgerows were cut (including: trimming, coppicing, laying); what percentage of hedgerows on a farm were cut in any one year; in what months of the year were hedgerows cut; the type of management used (including: trimming with a cross-cutter, trimming by hand, laying, coppicing, other); if hedgerows were trimmed whether this was: on both sides and the top, one side only, the top only; whether hedgerow management changed depending on whether adjacent land was under arable or pasture, and, if so, how it changed; whether hedgerows were managed to produce any useful products and, if so, what these were; whether hedgerow management before World War I differed from that which was conducted between the wars.

The questionnaire was very kindly distributed to the targeted people by: Council for the Protection of Rural England regional groups; County Wildlife Trusts; the National Hedge Laying Society; English Nature local teams; Farming and Wildlife Advisory Group officers; and other groups and individuals with an interest in hedgerow management.

2.6. Statistical analysis

Much of the data obtained was not normally distributed, but instead represented proportions (binomial errors), counts (Poisson errors) or had a constant coefficient of variation (gamma errors). We thus relied heavily on generalised linear models (in GENSTAT) to construct statistical models of response variables (dormouse abundance, fruit abundance etc).

3. Result and discussion

3.1. Persistence of dormouse populations in hedgerows

In total 59 sites where dormice had been present between 1975 and 1979 were re-surveyed. Other past sites were visited but could not be surveyed because hedgerows had apparently been removed (3 sites), become incorporated in recently planted woodland (2 sites) or the grid reference of the site was erroneous (1 site).

The sampling protocol was clearly sufficient to detect the presence of dormice (distinctive nests); 80% of positive sites were found after inspecting only eight of 15 nest tubes at each site (Fig. 1).

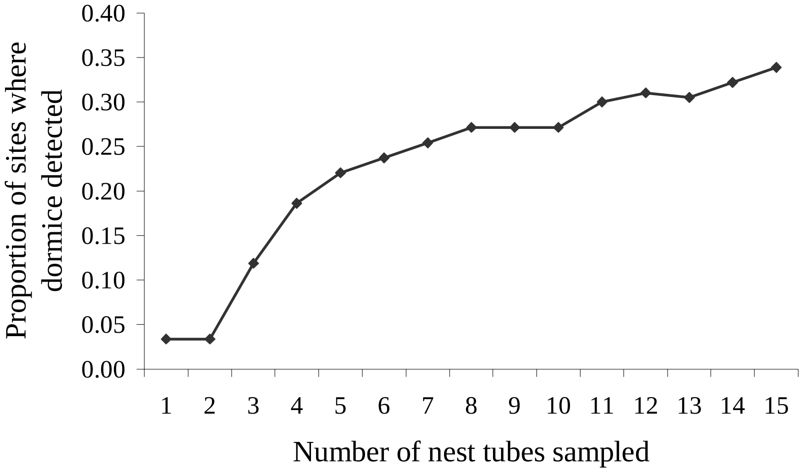

Figure 1 The relation between the number of nest tubes at a site sampled and the proportion of sites where the presence of dormice (distinctive nests) was detected.

Evidence of dormice was found at 21 (35.5%) of the 59 sites (Fig. 2). This suggests that dormice have become extinct in 64.5% of hedgerow sites in, on average, 23 years, a rate of loss of 2.8% y^{-1}. This equates to a 70% decrease over 25 years and thus constitutes a red alert decline.

A generalised linear model showed that hedgerow width was by far the most important variable explaining the survival of dormouse populations (Table 1; Fig. 3). Hedgerow height could not replace hedgerow width in the model. An increase in width from 2m to 3m is predicted by the model to increase the persistence of dormice at sites by 53%, an increase from 2m to 4m to increase persistence by 66%. The number of years since a hedgerow was cut was strongly correlated with hedgerow width (F_{57}=7.69, p=0.007). Thus hedgerow size/cutting frequency is a major determinant of dormouse population persistence in hedgerows. Neither easting or northing could be included as explanatory variables in the model. Thus there is no evidence that loss of dormouse populations in hedgerows has been disproportionately high in some regions.

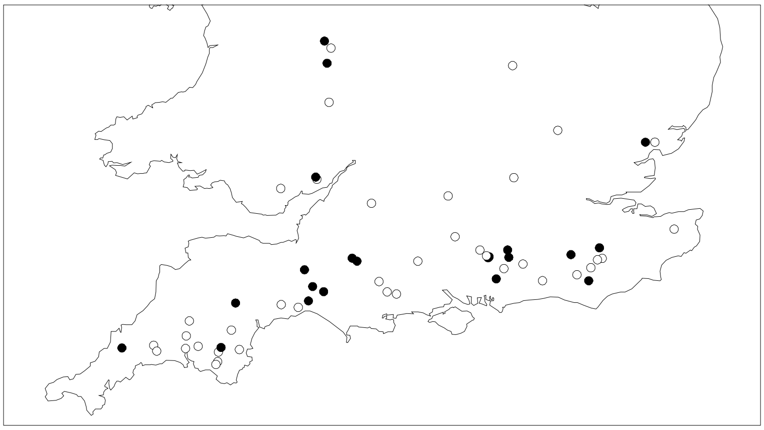

Figure 2 Distribution of sites (n=59) where dormice were present between 1975-1979 and where they were absent (open circles) or still present (black circles) in 2000.

Table 1 Generalised linear model of extinction/survival of dormice at sites in the year 2000 where they were present between 1975-79 (response variable in GENSTAT; binomial errors, logit link, n=59). Explanatory variables shown resulted in a significant increase in deviance when deleted from minimum adequate models (approximate p values are shown, df=1). Parameter estimates and standard errors [s.e.] are in logits. There were no significant first order interactions between the explanatory variables.

explanatory variable	parameter estimate	s.e.	deviance	P	% deviance explained
Constant	-3.67	-1.26			
Bramble berries	0.00298	0.00160	4.68	0.045	6.0
Dense at base	-0.0227	-0.00984	5.90	0.015	7.6
Cut one side	-0.0206	-0.0100	4.96	0.026	6.4
Hedgerow width	1.35	0.417	15.61	<0.001	20.3
				Total deviance explained	*40.3%*

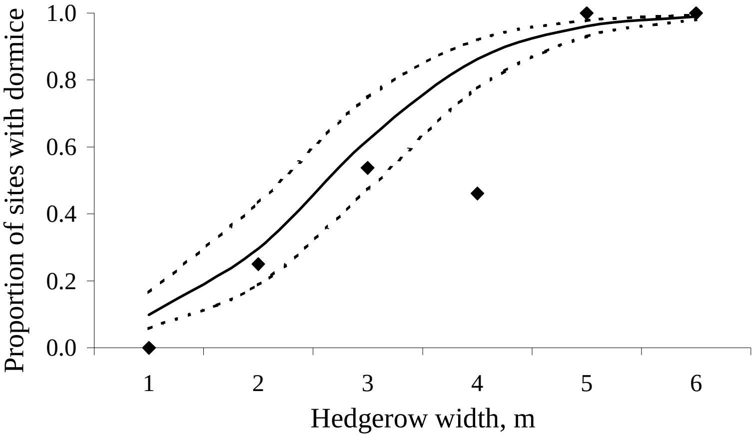

Figure 3 The relation between hedgerow width and the proportion of sites where dormice survived between 1975-1979 and 2000. Data are shown condensed into 1m width categories

(diamonds), together with the fitted line (solid line) and standard errors (dotted lines) from a generalised linear model (Table 1).

3.2. Population density and correlates of abundance of dormice in hedgerows

Figure 4 shows the 50 sample sites in the five regions. Dormouse population densities were calculated based on the length and width of hedgerow sampled, including only sites where dormice were present. Densities in autumn were (mean ± s.e. per ha) 3.69±0.74 (n=25 sites), densities in spring were 1.31±0.67 (n=14; note that the number of sites with dormice present in spring is lower because Somerset and Carmarthenshire regions could not be visited in 2001). Data from the National Dormouse Monitoring Programme show that mean autumn densities are c. 3-5 per ha in woodlands (F. Sanderson & P. Bright unpublished). Thus dormouse population densities in hedgerows appear similar to those in other habitats. Densities were much higher in uncut than cut hedgerow sites, being 7.2 times higher in autumn and 3.3 times higher in spring (autumn: t_{23}=4.03, p=0.001; spring: t_{12}=5.94, p<0.001; Fig. 5).
7.

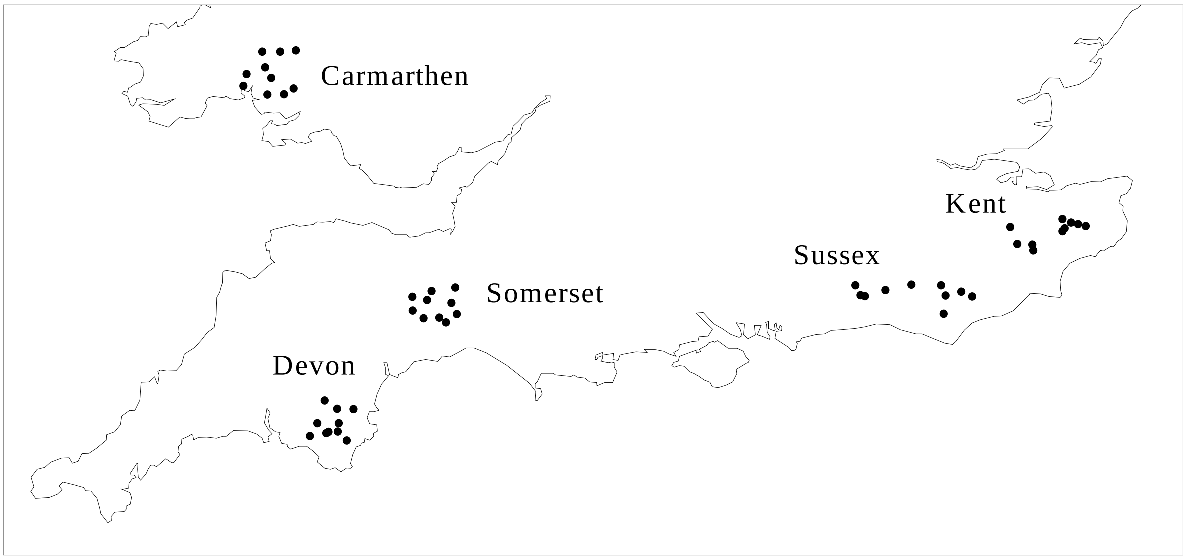

Figure 4 The 50 study sites in five regions of southern England and Wales.

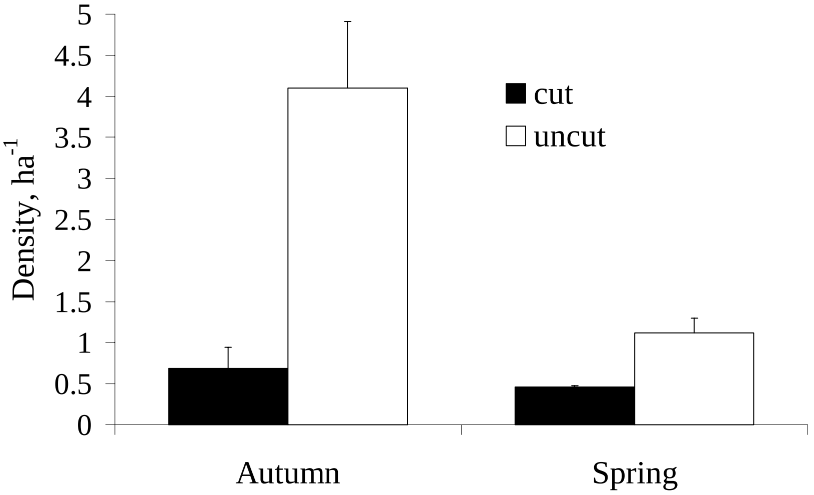

Figure 5. Mean (± s.e.) population density of dormice in cut and uncut hedgerows, post-breeding (autumn, n=25 sites) and pre-breeding (spring, n=14 sites).

Generalised linear models showed a highly consistent pattern of variables influencing dormouse abundance (Table 2). In general abundance in spring and autumn varied rather little between regions, though dormice were very scarce in Carmarthenshire and tended to be more abundant in Sussex and Somerset. The abundance of summer nests confirms this pattern.

Spring abundance was strongly directly related to hedgerow shrub species diversity and to a lesser extent hedgerow height (Table 2). Autumn abundance of adults was also strongly related to both species diversity and hedgerow height. Autumn abundance of juveniles was most strongly related to hedgerow height, which explained 31% of the deviance in the model. It was correlated with species diversity and inversely with distance to the nearest ancient woodland via hedgerows (Table 2). The abundance of summer nests, which should give the most reliable index of pan-seasonal use of hedgerows by dormice, was strongly related to hedgerow height which explained 35% of the model deviance. Abundance of nests was also strongly related to oak cover, species diversity and basal hedgerow density, but these variables explained up to only 7% of the deviance each (Table 2). Hedgerow width could not replace hedgerow height in any of these models and there was no significant interaction between these explanatory variables.

Together these highly consistent models, which explain much of the variation in dormouse/nest abundance, show that hedgerow size (height) is the primary influence on dormouse abundance. Hedgerow shrub diversity is of strong, but secondary importance. For juvenile dormice, close proximately to ancient woodland increases abundance, almost certainly because it is a source of dispersing juveniles. Proximity to woodland, of any type, did not influence the abundance of adult dormice. This, plus the fact that all sites occupied in the autumn were also occupied in the following spring, shows that hedgerows were permanently inhabited and not used solely by dispersing individuals. To support autumn densities of adults and independent juveniles of $3ha^{-1}$ (close to the national mean density in woodlands) the models predict that hedgerows need to at least 4m high. Hedgerows 3m in height are predicted to support densities of only $1.1ha^{-1}$.

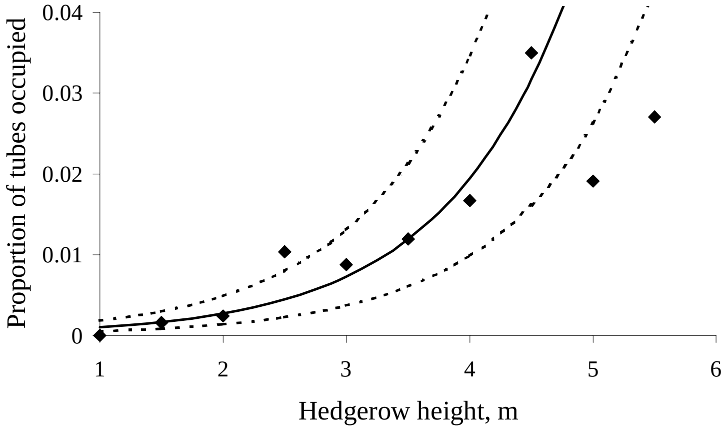

Figure 6 The relation between hedgerow height and the proportion of nest tubes occupied by adult dormice in autumn. Data are shown condensed in 0.5m height categories (diamonds), together with the fitted line (solid line) and standard errors (dotted lines) from a generalised linear model (Table 2).

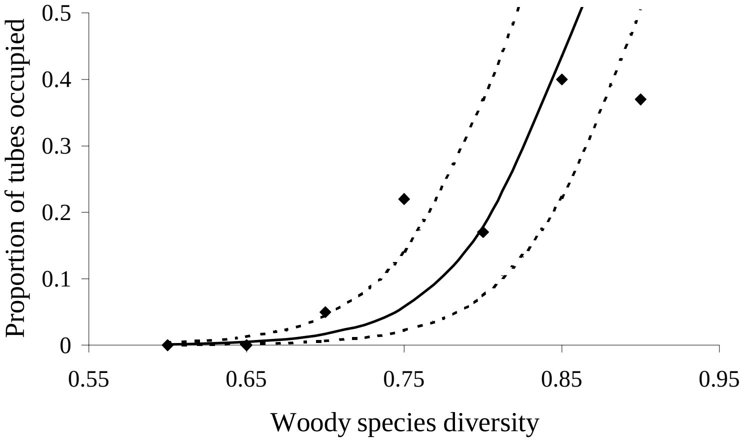

Figure 7 The relation between hedgerow shrub diversity (Simpson’s index) and the proportion of nest tubes occupied by adult dormice in autumn. Data are shown condensed in 0.05 diversity index categories (diamonds), together with the fitted line (solid line) and standard errors (dotted lines) from a generalised linear model (Table 2).

Unsurprisingly there was a clear relationship between elapsed time since a hedgerow was cut and hedgerow height (Fig. 8). In combination with the models, this suggests that hedgerows should be cut at most once every three years and preferably every five to six years in order to maintain dormouse populations at close to the national average density.

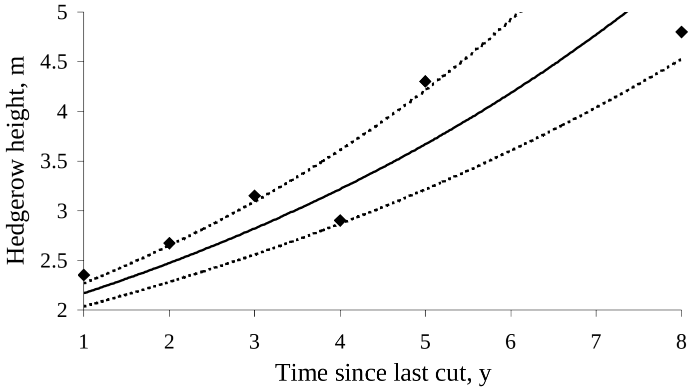

Figure 8 The relation between elapsed time since hedgerow cutting and hedgerow height, showing observed mean height for each year class (diamonds) and the fitted line (± s.e) from a non-linear regression: height=$1.901\times e^{(0.1313\times \text{years since cut})}$, $F_{1,48}$=12.46, p<0.001. No hedgerows with six or seven years growth were sampled.

Table 2 Generalised linear models of the proportion of nest tubes occupied by dormice in spring in three regions; the proportion occupied by adults and, separately, by juveniles in autumn; and the proportion of tubes with dormouse nests during a whole summer (response variables in GENSTAT; binomial errors, logit link). Explanatory variables shown resulted in a significant increase in deviance when deleted from minimum adequate models (approximate p values are shown, df=1, except where stated). Parameter estimates and standard errors [s.e.] are in logits. There were no significant first order interactions between the explanatory variables.

explanatory variable	parameter estimate	s.e.	deviance	p	% deviance explained
Spring abundance; n=30; Region d.f.=2					
$\text{Region}_{\text{Sussex}}$	-17.3	4.54	4.96	0.047	10.7
$\text{Region}_{\text{Kent}}$	-18.6	5.15			
$\text{Region}_{\text{Devon}}$	-18.1	5.06			
Hedgerow height	0.446	0.195	5.87	0.015	12.7
Species diversity	16.1	5.58	10.4	0.001	22.6
					Total deviance explained: 46%
Autumn abundance: adults; n=50; Region d.f.=4					
$\text{Region}_{\text{Sussex}}$	-27.2	6 .01	10.4	0.034	12.8
$\text{Region}_{\text{Kent}}$	-29.2	6.74			
$\text{Region}_{\text{Devon}}$	-28.5	6.64			
$\text{Region}_{\text{Carmarthen}}$	-35.5	40.5			

Region$_{\text{Somerset}}$	-28.3	6.64			
Species diversity	25.3	7.06	18.6	<0.001	22.9
Hedgerow height	0.988	0.265	21.3	<0.001	26.2
					Total deviance explained: 61.9%
Autumn abundance: juveniles; n=50; Region d.f.=4					
Region$_{\text{Sussex}}$	-14.8	2.85	8.52	<0.001	4.6
Region$_{\text{Kent}}$	-16.2	3.25			
Region$_{\text{Devon}}$	-16.1	3.23			
Region$_{\text{Carmarthenre}}$	-24.5	25.0			
Region$_{\text{Somerset}}$	-15.2	3.26			
Hedgerow height	0.931	0.139	59.1	<0.001	31.9
Species diversity	11.05	3.47	11.7	<0.001	6.3
Distance ancient woodland via hedgerows	-0.000429	0.000125	11.6	<0.001	6.2
					Total deviance explained: 49%
					Total summer nests: n=50; Region d.f.=4
Region$_{\text{Sussex}}$	-17.02	1.99	125	<0.001	23.4
Region$_{\text{Kent}}$	-18.6	2.23			
Region$_{\text{Devon}}$	-18.8	2.25			
Region$_{\text{Carmarthenre}}$	-19.3	2.70			
Region$_{\text{Somerset}}$	-16.7	2.21			
Oak cover	0.1207	0.0255	22.2	<0.001	4.1
Dense at base	2.184	0.502	19.7	<0.001	3.7
Species diversity	13.44	2.25	40.8	<0.001	7.6
Hedgerow height	1.0925	0.0936	188	<0.001	35.3
					Total deviance explained: 74.1%

It was not possible to include variables describing the pattern of hedgerow cutting (e.g. whether cutting was on one or both sides) in the models of dormouse abundance (Table 2) because these covaryed with hedgerow height. Consequently a multivariate analysis of variance was run using the presence-absence of dormice at sites as a factor and the proportions of hedgerow sites cut on one side, cut on both sides, cut on the top and cut on both sides and the top as explanatory variables. This showed that the pattern of cutting did influence the presence-absence of dormice (Wilk's $\lambda=0.797$, $F_{4,45}=2.82$, $p=0.036$). Cutting, other than on one side only, negatively influenced the presence of dormice ($F_1 \geq 6.26$, $p \leq 0.016$; Fig. 9). Thus cutting a hedgerow on the top only, negatively influenced the presence of dormice as much as cutting on both sides.

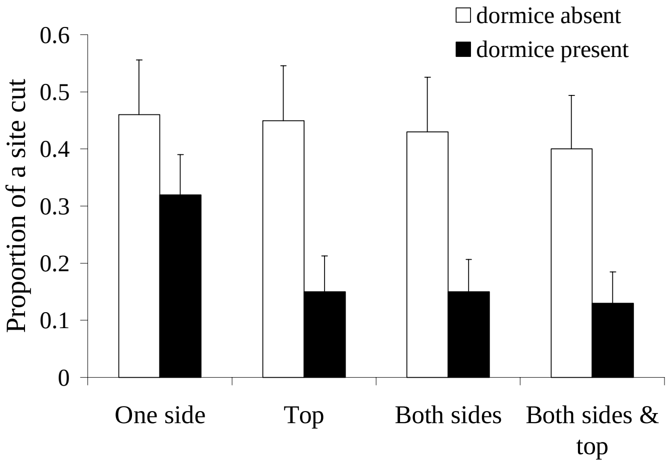

Figure 9 The mean (± s.e.) proportion of a hedgerow site cut on one side, the top, both sides and both sides and top, for sites where dormice were present and where they were absent.

A generalised linear model showed that dormice were more likely to be present in cut hedgerows and, to a much lesser extent, in uncut hedgerows if these were ancient (Table 3; Fig 10). This confirms that, because of their need for species-rich habitats, dormice are indicators of ancient hedgerows. However management clearly has a stronger impact on presence than hedgerow age.

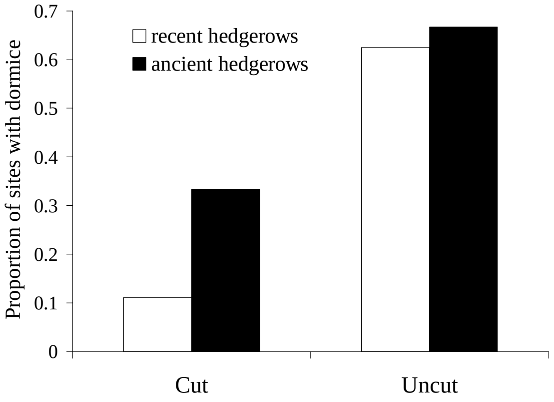

Figure 10 The proportion of sites with dormice present in relation to hedgerow management and age.

Table 3 Generalised linear model of the presence-absence of dormice in relation to hedgerow age and management (GENSTAT; binomial errors, logit link, n=50). Explanatory variables shown resulted in a significant increase in deviance when deleted from minimum adequate models (approximate p values are shown, df=1). Parameter estimates and standard errors [s.e.] are in logits. There were no significant first order interactions between the explanatory variables.

explanatory variable	parameter estimate	s.e.	deviance	p	% deviance explained
$\text{Region}_{\text{Sussex}}$	-0.96	1.03	22.40	<0.001	32.3
$\text{Region}_{\text{Kent}}$	-1.67	2.65			
$\text{Region}_{\text{Devon}}$	-3.49	2.38			
$\text{Region}_{\text{Carmarthenshire}}$	-6.36	2.82			
$\text{Region}_{\text{Somerset}}$	-1.43	2.51			
$\text{Hedgerow age}_{\text{ancient}}$	-0.96	1.03	4.15	0.042	6.1
$\text{Hedgerow age}_{\text{recent}}$	1.15	0.90			
$\text{Management}_{\text{cut}}$	-0.96	1.03	7.18	0.007	10.5
$\text{Management}_{\text{uncut}}$	1.47	0.99			
				Total deviance explained	*48.9%*

3.3. Ranging and feeding behaviour of dormice in hedgerows

Usable data were obtained for 20 dormice, 13 males and seven females. The number of nights dormice were tracked varied from 3-8, so analyses were weighted by the number of nights of data for each animal. The total length of hedgerow used over the tracking periods did not differ between males, females, adults and juveniles (ANOVA of hedgerow length log transformed: $F_{1,17.\ \text{sex}}=2.03$, p=0.17; $F_{1,17.\ \text{age}}=1.52$, p=0.23; Fig. 11). However the power of this test was probably rather low owing to the very unequal numbers of males and females tracked. The mean (± s.e.) total length of hedgerow used was 185±47m. Distances travelled per night also did not differ between sexes or ages (ANOVA: $F_{1,17.\ \text{sex}}=2.06$, p=0.12; $F_{1,17.\ \text{age}}=0.18$, p=0.67; Fig. 12). The mean (± s.e.) distance travelled per night was 295±23m.

The total distance travelled per night by dormice in hedgerows was longer than that travelled by dormice in woodlands (156m per night; Bright & Morris 1991; 1992). Similarly the length of hedgerow ranges was greater than the diameter of ranges in woodland (110m; Bright & Morris 1991; 1992). Assuming hedgerows were 3m wide the mean area of hedgerow used would have been only 0.055ha, an order of magnitude smaller than range areas in woodland which average 0.32-0.45ha (Bright & Morris 1991; 1992). This suggests, firstly, that hedgerows must provide a higher density of food than woodlands, otherwise dormice would be unable to subsist in such small areas. Lack of shading of hedgerow shrubs compared with the woodland understorey almost certainly means this is the case. Secondly, though distances travelled in hedgerows were greater than in woodland they were still short for an animal of the dormouse's body size and in no way compensated for the necessarily very narrow width of hedgerow ranges. The strong implication is that the dormouse is behaviourally or energetically constrained to use small ranges whatever the habitat type. This means that hedgerows will need to be highly productive in order to support dormice within small ranges. Alternatively, dormice might completely shift their ranges, using different segments of hedgerow seasonally. The presence of individually marked dormice the same segments of hedgerow in both spring and autumn, however, strongly suggested this was not the case.

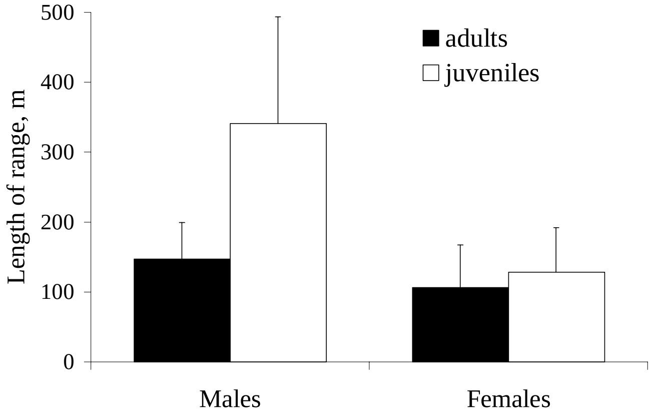

Figure 11 Lengths (mean± s.e) of dormouse home ranges in hedgerows.

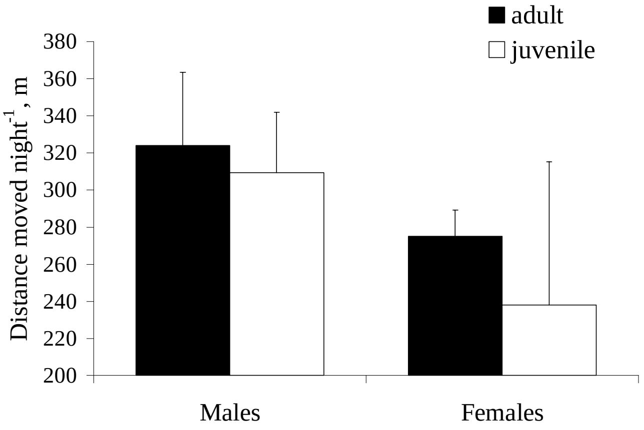

Figure 12 Distances travelled per night by dormice living in hedgerows (mean± s.e).

The frequency of radio position fixes in different hedgerow shrub species is shown in Figure 13, together with the percentage cover of those shrubs in hedgerows. Radio tracking records are certain to underestimate the use of some plants, such as honeysuckle, because these were tangled with other shrubs and dormice could usually not be directly observed. However, it is clear that bramble, hazel and dog rose were used disproportionately compared to their availability in hedgerows. Hawthorn was avoided. This pattern of shrub utilisation fits well with what we know about dormouse foraging behaviour in other habitats, except that dog rose has not previously been recorded as significantly utilised.

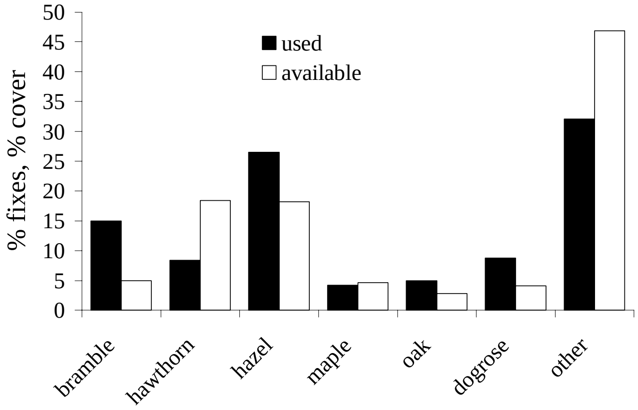

Figure 13 The percentage of radio locations (fixes/use) in different hedgerow shrubs compared to the percentage cover of those shrubs in hedgerows (availability).

3.4. Hedgerow management, structure and fruit production

A generalised linear model showed that hedgerow cutting interval was related to surrounding land use (Table 4). The model parameter estimates suggest that hedgerows with pasture as the adjacent land use were cut at a mean interval of 2.8 years, whilst those with arable as the adjacent land use were cut a mean interval of 1.2 years. Cutting interval was also inversely related to hawthorn cover and directly to the proportion of a 2km hedgerow length on a bank (Table 4). Hedgerows on banks are mostly ancient, those dominated by hawthorn (at least outside eastern and central England) are of recent origin. It thus appears that recent hedgerows were cut more frequently than ancient ones.

The proportion of a hedgerow with gaps (for definition see 2.4) was related inversely only to the proportion of a hedgerow that was flailed (Table 4). However, the model explained only 15% of the deviance and the parameter estimate was very small; the impact of flailing on hedgerow gappyness was thus marginal. The mean percentage of gaps (1.78%) was anyway very small.

In a generalised linear model gaps in a hedgerow explained the largest proportion of the deviance (18%) in soft mast abundance (Table 4); increasing gaps by 10% would increase soft mast production by the same percentage. This suggests that decreased competition between hedgerow shrubs and increased light levels resulting from greater edge, strongly enhanced production of soft mast fruits. Note however that the mean proportion of gaps in hedgerows we sampled was low (2%). Hedgerow cutting interval explained 12% of the deviance. Soft mast abundance peaked two years after cutting and declined thereafter (Fig. 14). The increase in soft mast production between one and two years post-cut is probably due to at least two processes: some shrub species not fruiting heavily or at all on new wood; and annually cut (especially flailed) shrubs having insufficient energy reserves to fruit. The decline in soft mast production three and more years after cutting is likely to be due partly to increased shading, but mostly to the lack of moderately frequent cutting which stimulates fruiting. The model suggested that flailing an entire hedgerow would reduce soft mast production by 47%, but this effect explained little of the deviance in soft mast abundance (4%; Table 4). Nevertheless, flailing clearly has an additional negative impact on soft mast production.

A generalised linear model showed that the abundance of hard mast fruits was most strongly related to cutting interval (39% of the deviance), parameter estimates suggesting that a change from annual to eight yearly cutting would increase hard mast production by 90% (Fig. 15). This is clearly related to the life history of the shrub species concerned, whence fruiting only begins once size or age thresholds have been reached. There is thus clearly a trade-off between the production of hard and soft mast, which each have a different relationship to cutting interval. The proportion of a hedgerow on a bank was also related to hard mast abundance (10% of the deviance explained), a 10% increase was predicted to increase hard mast abundance by 28%. This is probably because the tops of hedgerows on banks are too high for mechanical cutting, especially considering the positive relation between banks and cutting interval (Table 4).

Table 4 Generalised linear models in GENSTAT of: (a) the interval between hedgerow cutting; (b) the proportion of a hedgerow with gaps; (c) the abundance of soft mast fruits; (d) the abundance of hard mast fruits. Explanatory variables shown resulted in a significant increase in deviance when deleted from minimum adequate models (approximate p values are shown). Parameter estimates and standard errors [s.e.] are in logs (Poisson errors) or logits (binomial errors) of the raw data, as indicated in the table.

Explanatory variable	parameter estimate	s.e.	Deviance	p	% deviance explained
(a) Cutting interval, Poisson errors, log link					
Proportion on bank	0.651	0.313	4.31	0.038	9.8
Land use$_{pastoral}$	1.03	0.208	6.57	0.010	15.0
Land use$_{arable}$	0.183	0.573			
Hawthorn cover	-0.0228	0.0110	4.63	0.031	10.5
			Total deviance explained: 35.3%		
(b) Proportion of hedgerow with gaps, binomial errors, logit link					
Constant	-3.04	0.139			
Proportion flailed	-0.631	0.242	7.80	0.008	15.4
			Total deviance explained: 15.4%		
(c) Abundance of soft-mast fruits, Poisson errors, log link					
Cutting interval$_1$	2.43	0.182	46.2	<0.001	12.0
Cutting interval$_2$	2.22	0.361			
Cutting interval$_3$	1.66	0.392			
Cutting interval$_4$	1.70	0.464			
Cutting interval$_5$	0.729	0.532			
Cutting interval$_8$	1.46	0.637			
Proportion flailed	-0.755	0.193	15.2	<0.001	4.0
Proportion gaps	0.00251	0.000277	72.8	<0.001	18.9
			Total deviance explained: 34.8%		
(d) Abundance of hard mast fruits, Poisson errors log link					
Cutting interval$_1$	-1.27	0.403	20.0	0.001	40.1
Cutting interval$_2$	-0.893	0.894			
Cutting interval$_3$	-0.805	0.934			

Cutting interval$_4$	-1.33	1.53			
Cutting interval$_5$	0.904	1.09			
Cutting interval$_8$	1.09	0.880			
Proportion on bank	1.05	0.467	5.02	0.025	10.0
				Total deviance explained:50.1%	

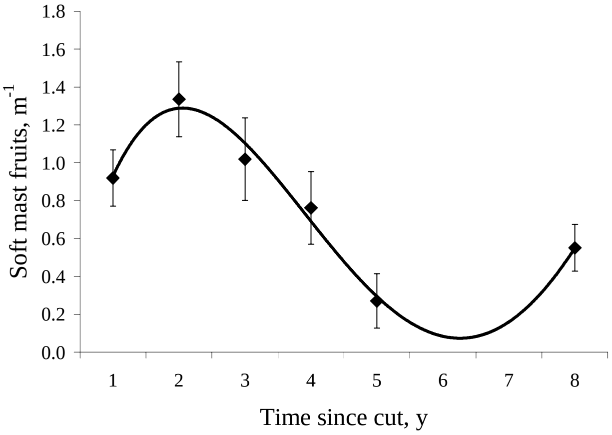

Figure 14 The relation between time since a hedgerow was cut and the density of soft mast fruits. Raw data (diamonds) and their associated standard errors are shown.

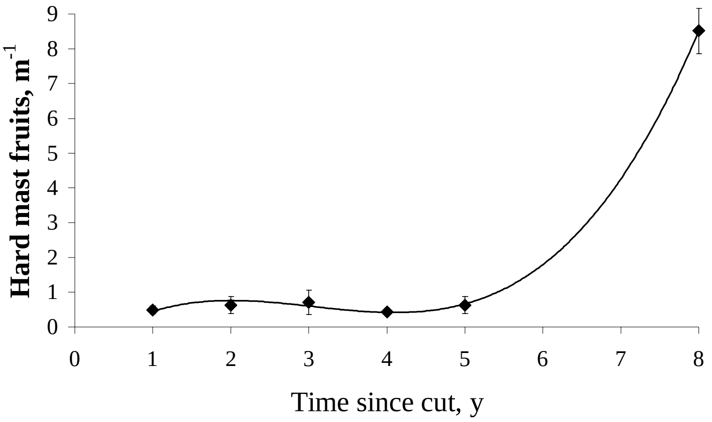

Figure 15 The relation between time since a hedgerow was cut and the density of hard mast fruits. Raw data (diamonds) and their associated standard errors are shown.

3.5. Hedgerow management during the inter-war years

At the time of writing we had received 56 replies pertaining to sites throughout much of southern England and Wales (Fig. 16). The frequency distribution of the proportion of hedgerows on a farm cut per year was bimodal (Fig. 17). On 68% of farms less than half of the hedgerows where cut each year (mean±s.d. percentage cut: 12.3±8.4%). On 32% of farms more than 50% of hedgerows where cut each year (mean ± s.d. percentage cut: 85.5±14.6%). There was a tendency for farms with arable as the dominant land use to cut a larger proportion of their hedgerows in any one year. No directly comparable contemporary data on hedgerow cutting are currently available, but observation suggests that, on average, close to 100% of hedgerows on individuals farms are now cut each year.

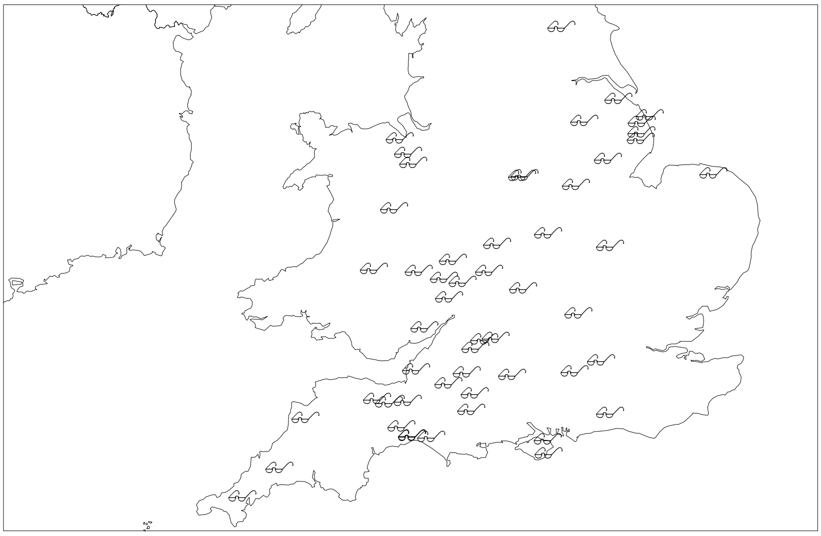

Figure 16 Distribution of sites (single farms and districts) where people who responded to the questionnaire were involved with hedgerow management between World Wars I and II.

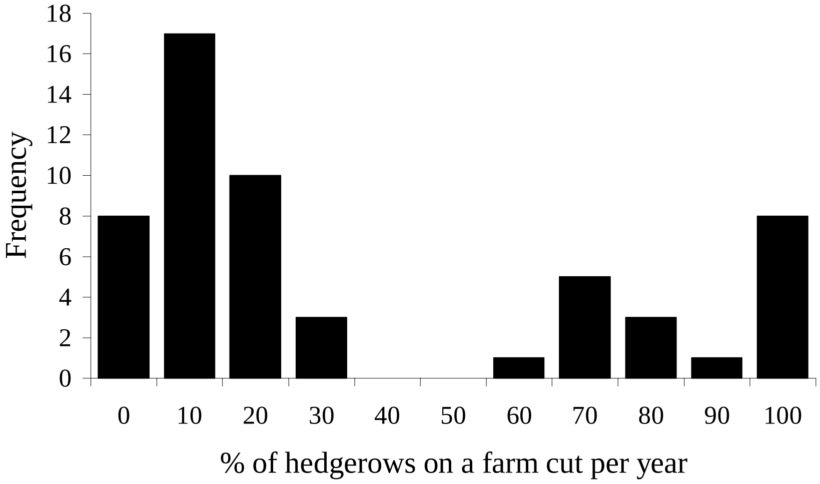

Figure 17 The frequency distribution of the percentage of hedgerows on a farm that were cut each year during the inter-war years.

The frequency distribution of cutting intervals was skewed to the right (Fig. 18), with a mean (± s.d.) of 6.2±5.9 years. Thirty percent of hedgerows were cut each year. We cannot estimate current cutting frequency from our regional data because we do not know the proportions of our sampling strata (cut and uncut hedgerows) in the landscape. However, observation strongly suggests that over 90% of hedgerows are currently cut each year. There has thus been a major increase in hedgerow cutting frequency since the 1920s and 1930s.

Cutting took place mostly between October and March inclusive (Fig. 19). Observation suggest that hedgerows are currently mostly cut in the same months. Hedgerows were in the past generally cut on both sides and the top, rarely on one side and/or the top only (Fig. 20). Our regional data, though *not* directly comparable, imply that there may have been a major change in cutting patterns: on average 38% of a regional site was cut on one side only; only 26% of a site was cut on both sides and the top. The implication is that there has been a shift away from cutting both sides and the top of a hedgerow at once to cutting only one side of a hedgerow at a time.

Management methods have clearly changed: on 53% of farms hedgerows were trimmed by hand, on 49% they were layed and on 15% they were coppiced (Fig. 21). Our regional data suggest that laying and coppicing are now very infrequent: there was no recent evidence of either management method at the 50 sites, although 48% of sites showed evidence of past laying. By contrast 68% of sites were managed by mechanical flailing – a method not in use in the 1920s and 1930s. This change in management methods is highly likely to have had two ecological consequences: a decrease in the production of soft mast, since this is negatively influenced by flailing (Table 4); and an decrease in hedgerow branch density, which laying and coppicing management were used to maintain.

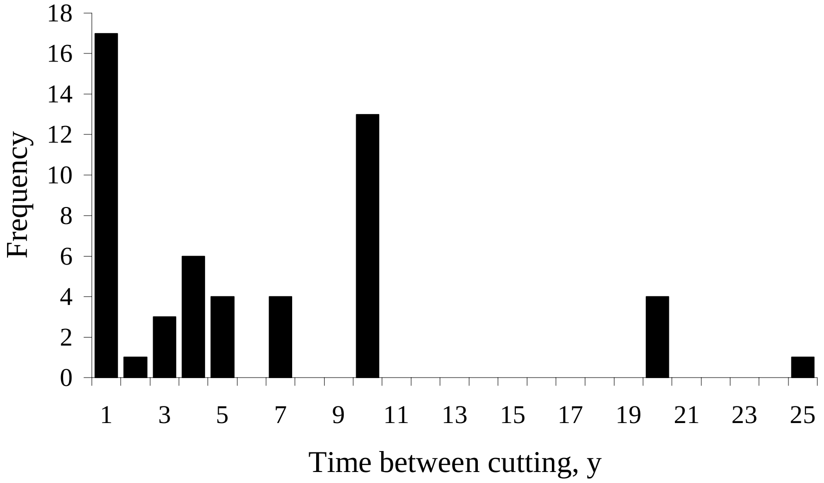

Figure 18 The frequency of hedgerow cutting in the inter-war years.

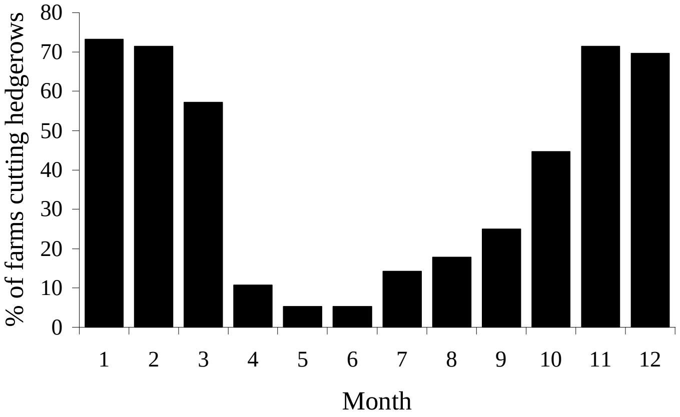

Figure 19 The percentage of farms where hedgerows were cut in different months during the inter-war years.

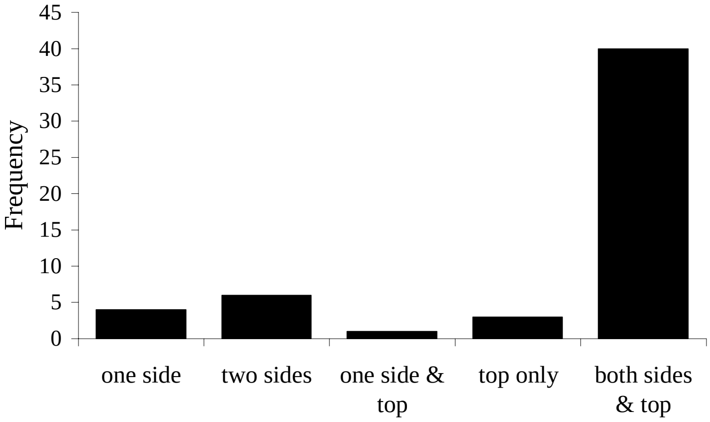

Figure 20 The frequency of different patterns of hedgerow cutting during the inter-war years.

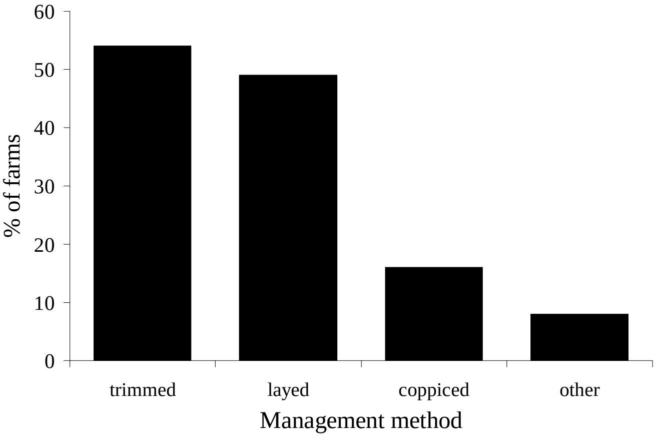

Figure 21 The frequency of different hedgerow management methods used during the inter-war years

4. Conclusions for conservation

There has been a 64% decline of dormouse occurrence in hedgerows since the late 1970s, equating to a red alert decline of 70% over 25 years. The long, historic, decline of the dormouse is thus continuing at a rapid rate.

Loss of dormice from hedgerows is of high conservation concern because: (i) the dormouse is an indicator of biological diversity; if it has gone many other species will have been lost too; (ii) loss from hedgerows, which are almost certainly dispersal corridors, implies that dormouse populations have become more isolated and that metapopulation (in the most general sense) connectivity has broken down in many areas. This is likely to precipitate dormouse extinctions in woodlands; and (iii) Population densities in hedgerows are as high as the average for woodlands, so the removal of hedgerows and instigation of management inimical to dormouse needs will have significantly reduced dormouse populations nationally.

Extinction of dormice at late 1970s sites was strongly inversely related to hedgerow size (specifically hedgerow width, which in our 1970s sample of sites was more strongly correlated with dormouse extinction than hedgerow height). Reduction of hedgerow size through intensification of management was thus undoubtedly the main cause of extinctions. It would have led to much lower availability of food and cover for dormice in hedgerows. There was no evidence that extinction rates differed regionally.

Dormouse populations in a stratified random sample of hedgerows reached densities similar to those found nationally in woodlands. Thus hedgerows can offer valuable habitat for dormice.

Hedgerow height was the main correlate of dormouse abundance in our random sample of hedgerows. This does not conflict with the finding that hedgerow width, not height, was most strongly related to dormouse survival at the 1970s sites, because hedgerow width and height are inevitably correlated. However since our regional data provide a much larger, and thus more reliable, sample than the 1970s sites, we suggest that hedgerow height, rather than width, needs to be used as a measure of suitability for dormice. Uncut hedgerows were more likely to be occupied by dormice. Cutting a hedgerow on its top had as much impact on dormouse density as cutting on both sides. Thus intensive hedgerow management clearly had a strongly negative impact on dormouse density. The intensification of hedgerow management in the last few decades (see below) will therefore greatly have reduced the abundance of dormice.

Hedgerow shrub diversity was also an important correlate of dormouse density. Dormice were indicators of ancient hedgerows. Thus less diverse hedgerows, especially those more recently planted in the midlands and East Anglia, are unlikely to support dormice. Dormice are indicators of hedgerow biodiversity.

Dormice were less abundant in hedgerows in Carmarthenshire, most abundant in Sussex. These differences were not related to hedgerow management or composition, but probably to regional abundance of dormice.

The abundance of juvenile dormice in hedgerows was inversely related to the distance to ancient woodland, a probable source of dispersing animals. This implies that hedgerows are used by dormice as dispersal corridors.

Range lengths of dormice inhabiting hedgerows were greater than those of dormice in woodlands. However range areas were an order of magnitude smaller than those in woodland. We conclude that the dormouse is constrained to occupy only small ranges and that hedgerows will consequently need to be large and diverse to support them.

Hedgerows with arable as the adjacent land use were cut more frequently than those adjacent to pasture, as were those dominated by hawthorn; hedgerows on a bank were cut less often. These patterns of cutting are not new, but have probably been polarised by the conversion of land use from pastoral to arable in recent decades. The net effect is intensification of hedgerow management and concomitant reduction in hedgerow biodiversity.

Frequent, usually annual, cutting of hedgerows prevents the production of hard mast. Annual cutting leads to lower production of soft mast than cutting at two or three year intervals. Flailing has an additional negative impact on soft mast production. It is thus very clear that hedgerow cutting intervals need to be lengthened (see below).

Our questionnaire to people who were managing hedgerows between the wars strongly suggests that hedgerow management has changed enormously since that time. Having shown it is possible to collect such information, there is now a need to obtain comparative contemporary data for the same farms/districts; otherwise we cannot make a direct comparison of how management has changed. Meanwhile is appears that the average hedgerow cutting interval has decreased from six years to one year; that the proportion of hedgerows on a farm cut in any one year has greatly increased; and that the vast majority of hedgerows are no longer managed by methods (laying, coppicing) which promote high branch density. These changes mean that hedgerows now produce much less mast that formerly and that they are less dense, both of which strongly negatively impact on hedgerow biodiversity. We shall be able to model past mast production once data on contemporary management are available.

We recommend the following hedgerow management practise, which would benefit dormice and very probably the vast majority of hedgerow biodiversity too:

1. Except where road safety or access preclude it, hedgerows should be trimmed at three yearly intervals at most and maintained at a height of at least three and preferably four meters.
2. A proportion of hedgerows on a farm, say at least 30%, should be left to grow for at least seven to ten years.
3. It is important not to cut all hedgerows on a farm in any one year, so that some heavily fruiting hedgerows are always present. As a guide, we suggest 10-30% cutting in any one year.
4. Flails should, if at all possible, not be used to manage hedgerows.
5. Coppicing or, even better, laying should be used to manage hedgerows that become gappy or lack dense branches at their base.
6. If hedgerow size needs to be restricted, avoid cutting the top of a hedgerow and cut one side.
7. When planting new hedgerows, use at least five and preferably seven different shrub/tree species.
8. Grant aid to support these measures should be targeted to areas where dormice still occur in hedgerows and areas where recolonisation is likely. The forthcoming Mammals Trust UK survey of dormice in hedgerows will provide much information to help with this targeting.

5. Acknowledgements

We are hugely indebted to the many land owners and managers who very kindly allowed us to work on their property and the many people who contributed to the questionnaire on past hedgerow management. Dr Valerie Keeble (People's Trust for Endangered Species) and Dr Tony Mitchell-Jones (English Nature) were instrumental in getting this long overdue research off the ground; we are immensely grateful for their support. Center Parcs enlightened environmental policy led to support without which the project could not have been undertaken; we are much indebted to Erica Spurrier and Barry Collins in particular. We thank Dr Roger Mitchell (English Nature) and Earthwatch-UK for support, especially, in the early stages of the project. Mike Hogan undertook a significant proportion of the fieldwork. Volunteers from the People's Trust for Endangered Species and Earthwatch helped us greatly for which we are also much indebted. Council for the Protection of Rural England local groups, County Wildlife Trusts (and especially Andrew Craven) and the National Hedge Laying Society very kindly helped with the questionnaire on past hedgerow management.

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7. Appendix

7.1. Questionnaire about past hedgerow management

Pre-War Hedgerow Management Questionnaire

During the last 70 years there have been major changes to the way hedgerows are managed. These are likely to have greatly affected mammals, birds and other wildlife. We are collecting information on how hedgerows were managed in the past. This will be used to help draw up advice about hedgerow management. We are keen to hear from anyone who was personally involved with hedgerow management between the First and the Second World Wars, *i.e.* approximately during the 1920s and 1930s.

Please could you answer the questions below ONLY if you were personally involved with managing hedgerows BETWEEN WORLD WAR ONE AND WORLD WAR TWO. If you know someone who was involved in hedgerow management during this period, please could you pass this sheet onto them.

1. *Where were you involved in hedgerow management?*

   Name of place... .... County...................................

2. *In your experience how often were hedgerows cut (that is, trimmed, layed, coppiced etc), in the period between WW1 and WW2?*

   Every...year(s)

3. *Roughly what percentage of hedgerows on the farm were cut in any one year?*

   ....%

4. *In what months of the year were hedgerows cut?*

   ....to ....

5. *What type(s) of hedgerow management were used?*

   trimming with cross-cutter ☐ trimming by hand ☐

   laying ☐ coppicing ☐ other (please describe) ☐

6. *If hedgerows were trimmed, was this done on:-*

   both sides & the top ☐ one side only ☐ the top only ☐

Please continue to the next sheet ⇒

7. *Did hedgerow management change depending on whether the field was under arable or pasture?*

   Yes/No.....................................

   If YES, please briefly describe how the hedgerow management changed.

8. *Where hedgerows managed to produce any useful products (e.g. faggots, firewood or berries)?*

   Yes/No.....................................

   If YES, please briefly describe what was produced.

9. *Do you know whether hedgerow management on the farm before World War One was different than hedgerow management conducted between World War One and World War Two? Please briefly describe any differences.*

Please also fill in you name and address below, so we can send you the results of *Pre-War Hedgerow Management Questionnaire*.

Name..

Address ....

....

Thank you very much for you help.

Please return this survey sheet by 1st March 2002 to:

Dr P Bright
School of Biological Sciences,
Royal Holloway University of London,
Egham,
Surrey TW20 OEX.

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