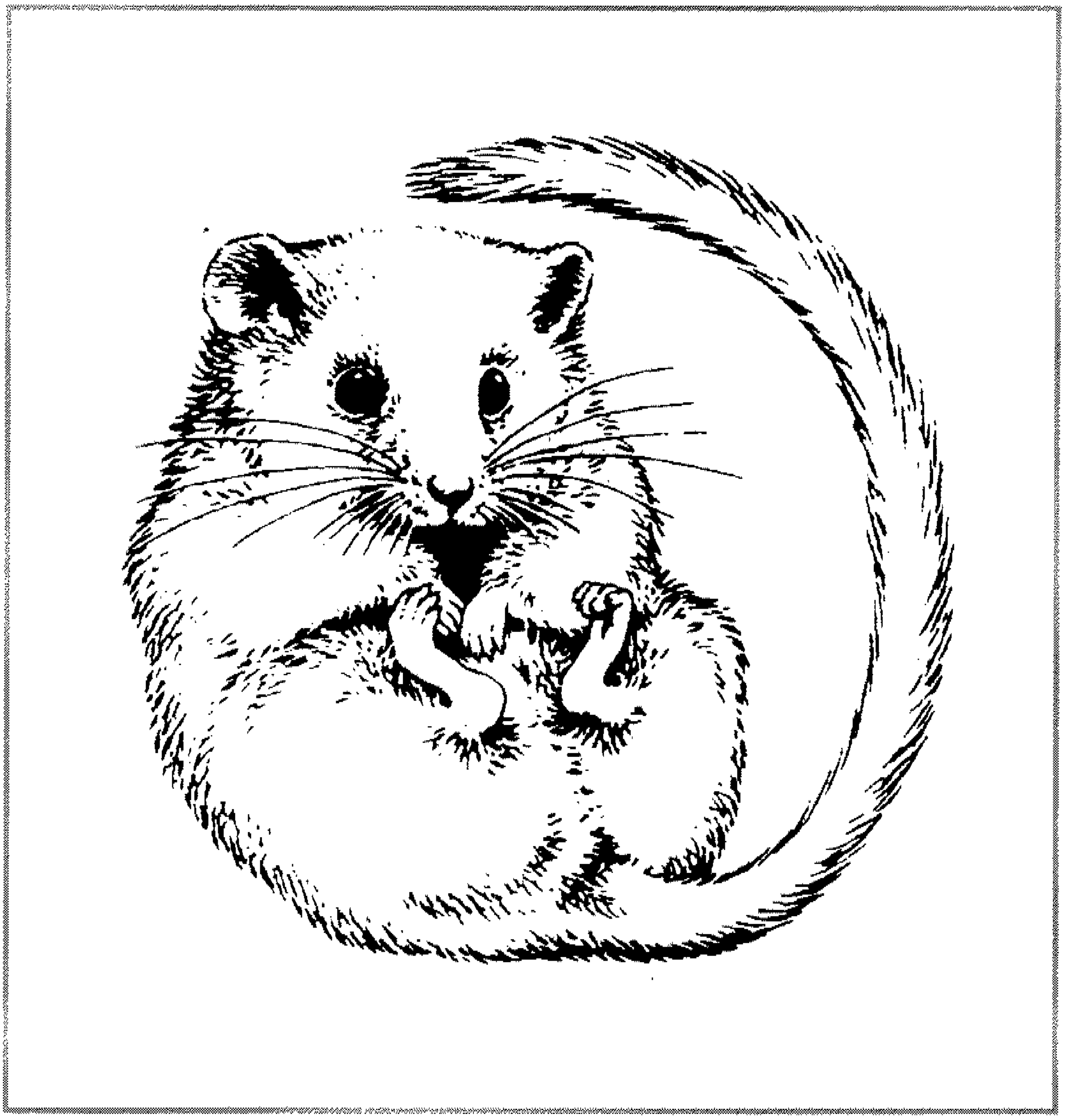
ENGLISH
NATURE

Status and woodland requirements of the dormouse in England

No. 166 - English Nature Research Reports



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Status and woodland requirements of the dormouse in England

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This study was jointly funded by:

The People's Trust for Endangered Species
&
English Nature

ISSN 0967-876X

Executive Summary

1. The dormouse *Muscardinus avellanarius* is a scarce, protected woodland species whose distribution has declined by more than half this century. The UK Biodiversity Action Plan commits the Government to restoring its range, by appropriate countryside management and reintroductions.

2. The primary objective of this study was to determine dormouse status and the types of woodlands they require for survival. Guidelines were needed to help formulate countryside management polices for English Nature Natural Areas, so work was done at a landscape, not individual site, scale. A stratified survey of 470 woodlands was undertaken in three contrasting Natural Areas. Results from an earlier survey in Herefordshire are included in the report for comparison.

3. As it is not possible to conduct a census, dormouse distribution had to be predicted from the attributes of a sample of woodlands which were surveyed. These were measures of woodland area, isolation and the number of boundaries around a site (equivalent to hedgerows). The predictions had a high degree of accuracy (72-88% correct) when tested against previous independent surveys, including the Great Nut Hunt, even though they did not account for habitat quality within sites. The survey provides a sound basis for future monitoring.

4. Where woodlands and hedgerows were fragmented (Greater Cotswolds, Herefordshire) dormice occurred almost exclusively in ancient woodlands. In the most fragmented landscape (Greater Cotswolds) they occurred only in very large woodlands (>50 ha). Where hedgerows and woodlands were little fragmented (High Weald, Blackdowns), dormice occurred frequently in small (5 ha) and recent woodlands. This confirms that habitat fragmentation is the major factor controlling distribution in southern Britain.

5. The study showed that management strategies should depend on the extent of woodland and hedgerow fragmentation. In less fragmented Natural Areas the strategy should be to conserve the existing arboreal integrity of the landscape, rather than site-based management. In fragmented Natural Areas the long term objective should be to reverse habitat fragmentation, especially where reintroductions are being attempted. Meanwhile, site-specific management should be targeted on large (>20 ha or preferably > 50 ha) ancient woodlands.

6. The second objective of this study was assess the influence of climate and habitat quality on large-scale (England wide) distribution. The rationale was that climate may have precipitated the extinction of dormice in northern England; its affects need to be known to help formulate conservation management. A sample of 144 woodlands was surveyed, stratified to control for the affects of habitat fragmentation.

7. Dormouse abundance was strongly correlated with climate along a south-north (Dorset to Shropshire), but not a west-east (Devon to Kent) transect. This provides the first quantified evidence that south-north distribution is controlled by climate. Populations north of Shropshire may be highly vulnerable and climate-limited.

8. The dormouse's large-scale habitat requirements are shared with an ancient landscape community of species of high conservation priority. Their conservation should be integrated and guidelines provided for each Natural Area. To this end a programme of future work is outlined, including determination of dormouse requirements in hedgerows, extending the work on predictive distribution to other Natural Areas and comparing and integrating the requirements of ancient landscape species with those of the dormouse. Trials to examine the effects of reversing habitat fragmentation are proposed.

Contents

Project Objectives

The project had three objectives, all of which have been fully addressed:-

Objective 1: To determine dormouse status and the types of woodlands needed for survival in England.

Objective 2: To predict dormouse distribution using survey data and validate these predictions using data from previous surveys.

Objective 3: To assess the influence of climate and habitat differences on status.

The first two objectives are addressed in Part 1, which deals with the status and woodland requirements of the dormouse on a regional scale. Objective 3 is addressed in Part 2, which examines the trends in dormouse status on a national scale.

Part 1: Status and Woodland Requirements of the Dormouse in Contrasting Landscapes

Introduction

The importance of understanding the processes that control large scale distribution is increasingly recognised, especially in relation to wildlife conservation. Most current knowledge of these processes relates to small spatial scales (100s of metres), while policies of countryside management are usually formulated on regional or national scales (10s to 100s of kilometres; May, 1994). Studies at large spatial scales are limited by the availability of complete census data for species that can be used as representative models of a community. In this context, ideal model species should be widely distributed, but be confined to a particular habitat and poorly mobile. The habitat of such a species can be easily identified and comprehensively censused and the species' lack of mobility makes it an indicator of the most threatened, relict, habitats. In these respects the dormouse *Muscardinus avellanarius* provides an excellent model.

The dormouse is afforded full legal protection and the UK Biodiversity Action Plan commits the Government to restoring its distribution range which has been eroded by more than half this century (Hurrell & MacIntosh, 1984; Bright, Morris & Mitchell-Jones, *in press*). It is a completely arboreal woodland species (Bright & Morris, 1990; 1991; 1992a). A survey of Herefordshire (Bright, Mitchell & Morris, 1994) showed that dormice were largely distributed in ancient woodlands (origin pre AD 1600) and were rare in recent woodlands, especially those that were isolated. It was estimated that *isolated* woodlands needed to be at least 20 ha in extent to support viable populations. The density of habitat corridors (hedgerows) was found to be related to woodland occupancy by dormice, implying that these could be important for dispersal between sites. A recent field experiment has confirmed that continuous arboreal, hedgerow links between sites are probably vital for dispersal (Bright, *in preparation*).

This part of the report deals with an extension of the Herefordshire survey to three other contrasting regions (data from the Herefordshire survey have been included in some sections, where comparisons with it were useful). These were English Nature Natural Areas, biogeographic units which are being introduced as the basis for regional conservation management. Thus this part of the report deals with dormouse distribution on a regional scale. It examines correlates of dormouse presence or absence and uses these to predict distribution. Strong contrasts in distributional patterns emerge, which are closely correlated with woodland cover and fragmentation. The results show that management should be on a regional, not only site-specific scale, what large-scale management is required and how this should differ between regions. They imply that the dormouse is a sensitive indicator of an *ancient landscape community* of animals and plants, which is currently highly threatened.

Methods

Selection of survey sites

Methods closely followed those tested in Herefordshire by Bright *et al.* (1994). Surveys were conducted within three distinctive biogeographic regions ("Natural Areas"), as defined by English Nature: Greater Cotswolds, Blackdowns and High

Weald (Fig. 1). Within each, a sample of woodlands stratified by age, area and isolation was surveyed. Within each stratum survey woodland were selected randomly. Three woodland age classes were identified from the Nature Conservancy Council's (NCC) ancient woodland inventory (Spencer & Kirby, 1992) and Ordnance Survey 1:25,000 maps:

1. **Ancient semi-natural woodland (ASNW)**, which has a natural or semi-natural growth form. It occurs on sites thought to have supported woodland continuously or at least since AD 1600.
2. **Ancient replanted woodland (ARW)**, which is planted with native or non-native trees, growing on an ancient woodland site.
3. **Recent woodland (RW)**, which is not listed in the NCC inventory and is less than 200 years old.

This classification was verified in the field using plants and physical features indicative of ancient woodlands (Peterken, 1974). Only woodlands of 2 ha or more were considered, as the NCC inventory does cover smaller woodlands. Some sites had areas of both ancient semi-natural and ancient replanted woodland. Accordingly, ASNW sites were defined as <50% replanted and ARW sites as >= 50% replanted. In practise this definition yielded highly distinct categories, despite apparent overlap between ASNW and ARW.

Within age classes, samples were stratified by both the area of a woodland and its isolation, measured from Ordnance Survey 1:25000 maps using a bitpad. For ancient woodlands, total area included any connected patches of recent woodland. There were five area strata: 2-5 ha; 6-10 ha; 11-20 ha; 21-50 ha; 51 ha+. Isolation was measured as the distance to the nearest ASNW or ARW. There were five isolation strata: <500 m; 501-800 m; 801-1100 m; 1101-1400 m 1400 m +. Twelve woodlands from each size class were surveyed, except for larger or more isolated strata, where there were sometimes insufficient woodlands within a region.

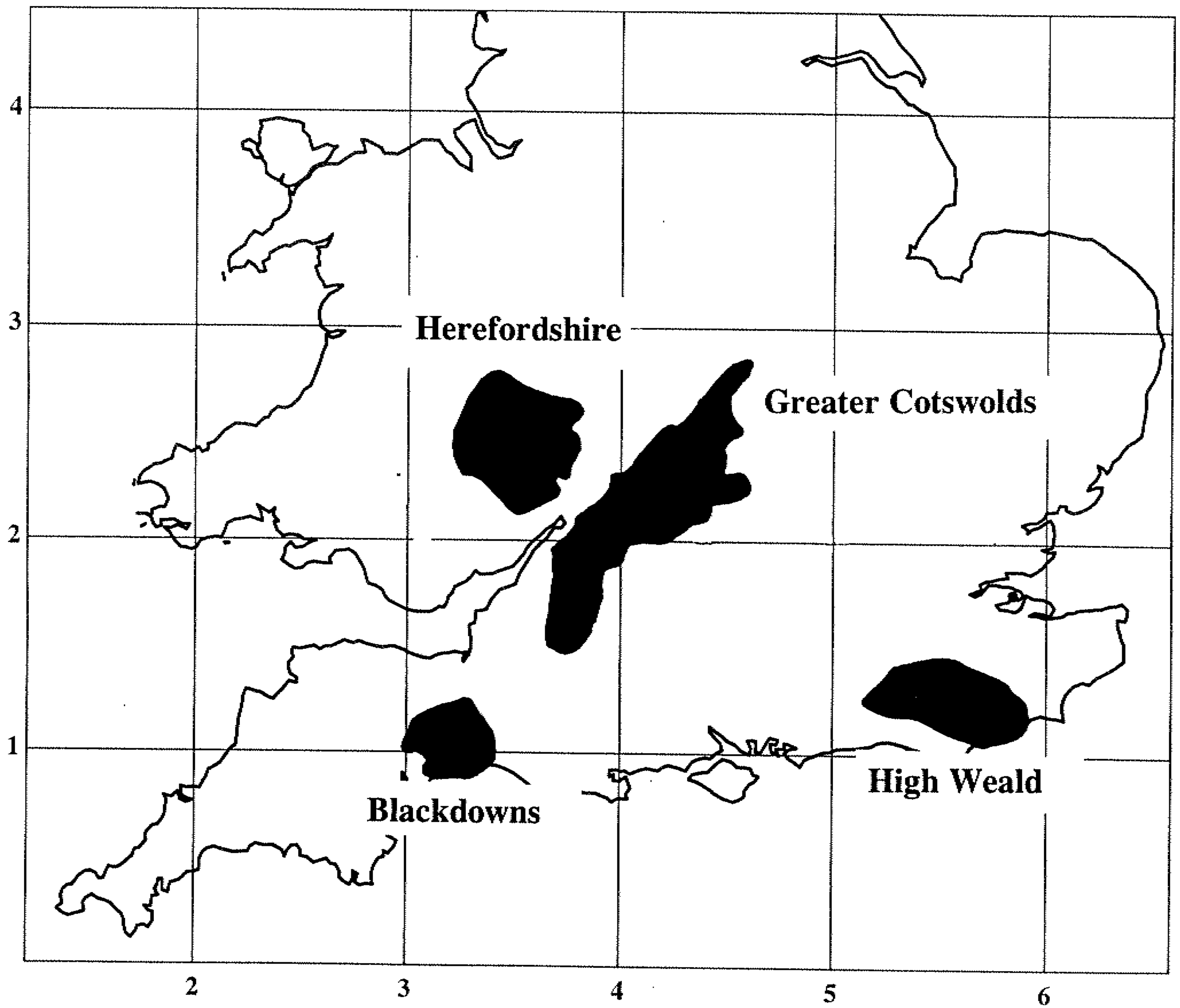
Field survey methods

Presence or absence of dormice was assessed by searching for hazel *Corylus avellana* nut shells on the woodland floor, which bore the highly distinctive signs of being opened by dormice (Hurrell, 1980; Hurrell & MacIntosh, 1984; Bright *et al.* 1994). Dormice are likely always to utilise hazel nuts where available, and so leave signs of their presence, since these are a very important pre-hibernal food source (Richards *et al.*, 1984; Bright & Morris, 1992b). Surveys were conducted between October 1994 and February 1995, by four surveyors who were trained to the same standard by PWB. They were monitored at regular intervals in the field.

The field survey was in two stages, designed to maximise the probability of detecting dormice. Firstly, the whole of each wood was searched to find areas for subsequent quadrat surveys. These were patches of potentially suitable dormouse habitat (Bright & Morris, 1990) where hazel shrubs were heavily fruiting. This method should have removed any bias due to heterogeneous distribution of dormice within woods. Search time was directly proportional to the area of a woodland, so the method was not biased against larger sites. Where hazel was absent or fruiting poorly, woodlands were not surveyed and were replaced by sites that fell into the same survey stratum.

The second stage of the survey was conducted within the previously selected areas. Quadrats on the woodland floor measuring 10m by 10m were searched continuously for 20 minutes for dormouse gnawed hazel nut shells. Search effort was terminated as soon as one or more (mode=2) distinctively gnawed hazel shells were found, or after five quadrats had been sampled. Dormice were assumed to

Fig. 1. The English Nature Natural Areas surveyed for dormice during this study. The area of Herefordshire surveyed during a previous study (Bright *et al.* 1994) is also shown.



be absent if no distinctive hazel nut shells were discovered after five quadrats had been searched (Bright *et al.* 1994).

Map-derived attributes and analytical approach

Five woodland attributes were derived from the NCC inventory or from maps. These were: (a) total site area; (b) distance from a survey woodland to the nearest ancient woodland (i.e. ASNW or ARW); (c) distance from a survey woodland to the nearest ancient woodland greater than 20 ha; (d) area, in ha, of ancient woodland in the nine 1km grid squares centred on the survey woodland. This was calculated ignoring the area occupied by the survey woodland as: area of woodland in 9 1km squares - area of survey site / (900 - area of survey site) * 900; (e) an index of the number of boundaries marked on the map radiating out from the survey woodland (number of boundaries/area of woodland). The number of boundaries was very closely correlated with the number of hedgerows, based on a field survey of 30 woodland sites in each region ($p<0.001$ for all regions).

Correlates of the presence or absence of dormice were examined using multiple logistic regression (SPSS package: Norusis, 1990). Inevitably, some of the independent variables were intercorrelated (though correlation coefficients were not large) and might thus have been exchangeable in the regression models (Norusis, 1990). However, analyses run excluding one variable at a time showed a consistent pattern of relationships between dormouse occurrence and the independent variables. Thus the final models are not adversely influenced by intercorrelation of independent variables. The affects of potentially outlying data points, identified by having high leverage and large standardised residuals (Hosmer & Lemeshow, 1989; Norusis, 1990) were examined. These points amounted to no more than 5% of the sample in any one region. If removed they had no impact on the models and so were retained.

Prediction of distribution

The attributes of all non-surveyed woodlands ($>=2$ ha) in each region were measured, as for survey woodlands. These attributes were used in logistic regressions to obtain probabilities of dormouse occurrence for each woodland; probabilities of >0.50 were taken as predicting dormouse presence. Predicted distribution was tested against that known from two previous independent surveys (Hurrell & MacIntosh, 1984; Bright, Morris & Mitchell-Jones, 1996). These lack fully quantified measures of dormouse absence, so only sites where dormice were known to be present were considered.

Results

In total 470 woodlands were surveyed, 170 in the Greater Cotswolds, 109 in the Blackdowns and 142 in the High Weald. Some woods ($n=49$) were surveyed in the Exmoor and Quantocks Natural Area, the original intention being to combine data for these woodlands with those for the nearby Blackdowns. However, the two data sets proved be to very heterogeneous and combining them was not justified. There were too few data for Exmoor and the Quantocks for a separate analysis for this region. These data have thus not been used in the present analyses, but are available for inclusion in future work.

Correlates of dormouse incidence within woodland age classes

Ancient semi-natural woodland
Dormouse incidence in the Greater Cotswolds was strongly correlated with an interaction between site area and the number of boundaries (Table 1). Examining the correlations separately, showed that site area was the strongest correlate of dormouse incidence. Dormouse incidence was low in ASNW (and other age classes) in woodland of less than 51 ha, but increased sharply in larger woodlands (Fig. 2).

The majority of variance in incidence in the High Weald was explained by site area and a complex of attributes that measure woodland isolation (Table 1). Examining the correlations separately, showed that site area was not independently correlated with incidence. In the Blackdowns, attributes that measure woodland isolation, but not site area, were also correlated with incidence (Table 1).

Ancient replanted woodland
Site area alone was correlated with dormouse incidence in the Greater Cotswolds (Table 2). This contrasts with both other regions, where attributes measuring woodland isolation were weakly correlated with incidence (Table 2).

Recent woodland
In the Greater Cotswolds, too few recent woodlands were occupied by dormice to allow an analysis. In the High Weald and the Blackdowns a complex of attributes measuring woodland isolation were strongly correlated with dormouse incidence. Site area did not feature in these correlations, except for a single interaction term in the regression for the Blackdowns (Table 3).

Correlates of dormouse incidence within regions

Table 4 shows logistic regressions of dormouse incidence for all surveyed woodlands within each region. Site area was the dominant correlate of incidence in the Greater Cotswolds. By contrast, measures of isolation correlated with incidence in the Blackdowns and the High Weald; site area only featured as a minor interaction term in the regression for the High Weald. The number of boundaries was the strongest correlate of incidence in the Blackdowns, but not the High Weald, where distance to the nearest ancient woodland or nearest 20 ha ancient woodland was a stronger correlate (Table 4).

Comparison of woodland distribution between regions

Attributes of all woodlands (surveyed and not surveyed) for each region are summarised in Table 5. A multivariate analysis of variance (MANOVA) was used to compare the five woodland attributes between regions. It showed that there were highly significant differences in attributes between regions and between woodland age classes, but that these were confounded by significant interactions between region and age (Table 6). In other words, differences in attributes between regions and between age classes were not entirely consistent across regions or age classes.

The significant differences (as determined by Tukey tests with Bonferroni adjustments) can be summarised as follows. ARWs were larger than all other age classes. RWs were smaller, except in the Blackdowns where there were large RWs and small ASNWs. RWs were more isolated than ancient woodlands (ASNWs or ARWs), except in the Blackdowns. There were more boundaries around ancient woodlands than RWs, again except in the Blackdowns were ASNWs had fewest boundaries.

Table 1. Logistic regression analysis of factors related to dormouce incidence in **ancient semi-natural woodland** in contrasting regions of England.

a) Greater Cotswolds Natural Area. The regression correctly classified 88.2% of 68 survey sites. χ^2 goodness-of-fit, p=0.46.

Variable	Coefficient	Wald χ^2	R*	p
Site area × number of boundaries interaction	0.015	10.78	0.36	0.001
Constant	-2.510	26.14	-	0.000

b) Blackdowns Natural Area. The regression correctly classified 78.9% of 38 survey sites. χ^2 goodness-of-fit, p=0.38.

Variable	Coefficient	Wald χ^2	R*	p
Distance to the nearest ancient woodland × distance to the nearest 20ha ancient woodland interaction	-0.0003	3.78	0.19	0.050
Distance to the nearest ancient woodland × area of ancient woodland in nine 1-km squares interaction	-0.0001	3.00	0.14	0.083
Constant	2.692	9.74	-	0.001

c) High Weald Natural Area. The regression correctly classified 69.7% of 66 survey sites. χ^2 goodness-of-fit, p=0.25.

Variable	Coefficient	Wald χ^2	R*	p
Site area	0.158	5.82	0.20	0.015
Area of ancient woodland in nine 1-km squares	-0.023	3.30	0.12	0.069
Number of boundaries	-0.307	4.68	0.17	0.030
Site area × distance to the nearest 20ha ancient woodland interaction	-0.0004	5.90	0.21	0.015
Site area × area of ancient woodland in nine 1-km squares interaction	-0.0009	3.16	0.11	0.075
Area of ancient woodland in nine 1-km squares × number of boundaries interaction	0.0028	4.26	0.16	0.039
Constant	1.717	1.90	-	0.168

* The R statistics can be interpreted as the partial contribution of a variables to the regression model.

Table 2. Logistic regression analysis of factors related to dormouce incidence in **ancient replanted woodland** in contrasting regions of England.

a) Greater Cotswolds Natural Area. The regression correctly classified 87.1% of 39 survey sites. χ^2 goodness-of-fit, p=0.46.

Variable	Coefficient	Wald χ^2	R*	p
Site area	0.0470	6.58	0.34	0.010
Constant	-3.568	11.98	-	0.000

b) Blackdowns Natural Area. The regression correctly classified 84.2% of 19 survey sites. χ^2 goodness-of-fit, p=0.58.

Variable	Coefficient	Wald χ^2	R*	p
Distance to the nearest ancient woodland	-0.0096	3.26	0.23	0.070
Distance to the nearest ancient woodland × number of boundaries interaction	0.0010	3.55	0.25	0.050
Constant	0.256	0.08	-	0.769

c) High Weald Natural Area. The regression correctly classified 78.1% of 33 survey sites. χ^2 goodness-of-fit, p=0.33.

Variable	Coefficient	Wald χ^2	R*	p
Distance to the nearest 20ha ancient woodland	0.0026	4.29	0.26	0.038
Area of ancient woodland in nine 1-km squares	0.0133	3.53	0.21	0.060
Constant	-3.676	6.52	-	0.010

* The R statistics can be interpreted as the partial contribution of a variables to the regression model.

Table 3. Logistic regression analysis of factors related to dormouce incidence in **recent woodland** in contrasting regions of England.

a) Greater Cotswolds Natural Area. Too few sites recent woodland sites were occupied by dormice in this region to permit analysis.

b) Blackdowns Natural Area. The regression correctly classified 73.0% of 52 survey sites. χ^2 goodness-of-fit, p=0.38.

Variable	Coefficient	Wald χ^2	R*	p
Distance to the nearest ancient woodland	0.0127	7.36	0.27	0.006
Distance to the nearest 20 ha ancient woodland	0.0042	7.64	0.27	0.005
Area of ancient woodland in nine 1-km squares	-0.114	5.15	0.20	0.023
Number of boundaries	0.969	6.27	0.24	0.012
Site area × distance to the nearest ancient woodland interaction	0.000078	2.99	0.11	0.083
Distance to the nearest ancient woodland × distance to the nearest 20ha ancient woodland interaction	-0.000002	7.81	0.28	0.005
Distance to the nearest ancient woodland × number of boundaries interaction	-0.0005	4.46	0.18	0.034
Distance to the nearest 20ha ancient woodland × area of ancient woodland in nine 1-km squares interaction	0.000002	4.72	0.19	0.029
Distance to the nearest 20 ha ancient woodland × number of boundaries interaction	-0.00002	6.77	0.25	0.09
Constant	-17.163	7.09	-	0.007

c) High Weald Natural Area. The regression correctly classified 88.3% of 43 survey sites. χ^2 goodness-of-fit, p=0.25.

Variable	Coefficient	Wald χ^2	R*	p
Distance to the nearest 20 ha ancient woodland	0.0051	5.29	0.27	0.021
Area of ancient woodland in nine 1-km squares	-0.0534	6.04	0.30	0.014
Distance to the nearest ancient woodland × distance to the nearest 20ha ancient woodland interaction	-0.000005	5.54	0.28	0.018
Area of ancient woodland in nine 1-km squares × number of boundaries interaction	0.0077	8.42	0.38	0.003
Constant	-0.0256	0.00	-	0.987

* The R statistics can be interpreted as the partial contribution of a variables to the regression model.

Table 4. Logistic regression analysis of factors related to dormouce inidence in contrasting regions of England.

a) Greater Cotswolds Natural Area. The regression correctly classified 89.4% of 170 survey sites. χ^2 goodness-of-fit, p=0.94.

Variable	Coefficient	Wald χ^2	R*	p
Site area	0.036	21.78	0.47	<0.001
Distance to the nearest 20ha ancient woodland	-0.0004	3.15	0.11	0.075
Constant	-2.709	25.84	-	0.000

b) Blackdowns Natural Area. The regression correctly classified 74.4% of 109 survey sites. χ^2 goodness-of-fit, p=0.45.

Variable	Coefficient	Wald χ^2	R*	p
Number of boundaries	0.083	6.19	0.17	0.012
Number of boundaries × ancient semi-natural woodland interaction	-	7.76	0.16	0.020
Number of boundaries × ancient replanted woodland interaction	0.046	2.31	0.04	0.128
Number of boundaries × recent woodland interaction	0.019	0.36	0.00	0.543
Constant	-0.353	0.79	-	0.372

c) High Weald Natural Area. The regression correctly classified 82.2% of 142 survey sites. χ^2 goodness-of-fit, p=0.42.

Variable	Coefficient	Wald χ^2	R*	p
Distance to the nearest 20ha ancient woodland	0.002	4.38	0.11	0.036
Site area × distance to the nearest ancient woodland interaction	-0.0002	3.49	0.09	0.061
Site area × number of boundaries interaction	0.001	3.87	0.10	0.049
Distance to the nearest ancient woodland × distance to the nearest 20ha ancient woodland interaction	0.0002	4.52	0.11	0.033
Distance to the nearest ancient woodland × number of boundaries interaction	0.004	4.37	0.11	0.036
Distance to the nearest 20ha ancient woodland × number of boundaries interaction	-0.001	2.77	0.06	0.095
Constant	-1.107	7.95	-	0.004

* The R statistics can be interpreted as the partial contribution of a variable to the regression model.

Table 5. Summary statistics for woodland sites of 2 ha or more in four contrasting landscapes in England. Data for Herefordshire from Bright, Mitchell & Morris (1994).

Age class	n	Site density, /km^2	Mean site area, ha (SD)	Mean distance to the nearest 20ha ancient woodland, m (SD)	Mean number of boundaries around a site (SD)
Greater Cotswolds Natural Area, 3176 km^2					
ASNW	286	0.090	30.84 (81.57)	1804 (1955)	9.33 (8.04)
ARW	103	0.032	34.62 (48.34)	2318 (2363)	9.15 (8.86)
RW	892	0.280	9.13 (16.62)	2724 (2192)	6.07 (3.86)
Total/ Mean	1281	0.403	16.02 (44.38)	2486 (2188)	7.05 (5.53)
Blackdowns Natural Area, 785 km^2					
ASNW	95	0.121	9.76 (22.96)	3503 (2757)	9.46 (5.28)
ARW	35	0.044	25.34 (41.49)	2864 (1933)	11.57 (9.21)
RW	261	0.332	17.58 (37.28)	2874 (2124)	11.89 (10.31)
Total/ Mean	391	0.498	16.37 (34.96)	3026 (2289)	11.27 (9.27)
High Weald Natural Area, 1492 km^2					
ASNW	726	0.486	24.57 (72.34)	599 (573)	11.83 (11.06)
ARW	102	0.068	84.98 (229.94)	465 (523)	19.75 (21.54)
RW	337	0.225	20.60 (107.35)	671 (607)	8.62 (9.03)
Total/ Mean	1165	0.780	28.71 (107.15)	608 (581)	11.60 (12.18)
Herefordshire, 2113 km^2					
ASNW	379	0.179	17.99 (26.32)	1254 (1359)	8.88 (5.97)
ARW	127	0.060	43.35 (61.12)	1134 (1441)	13.01 (9.93)
RW	203	0.096	10.75 (15.27)	1980 (1811)	7.26 (3.73)
Total/ Mean	709	0.335	20.46 (35.01)	1441 (1552)	9.16 (6.65)

Table 6. Comparison of woodland site attributes for four regions, using a multivariate analysis of variance (MANOVA). Where significant differences were detected between regions or age classes, multiple range tests with Bonferroni adjustments were preformed to examine differences between pairs of regions or age classes. Results of the latter are reported in the text.

Factor/ variable	step-down F	df	p
Region × woodland age class interaction			
Site area	5.99	6,3516	<0.001
Distance to the nearest ancient woodland	14.12	6,3516	<0.001
Distance to the nearest 20ha ancient woodland	4.57	6,3516	<0.001
Area of ancient woodland in nine1-km squares	2.64	6,3516	0.140
Number of boundaries	9.40	6,3516	<0.001
Region			
Site area	14.39	3,3516	<0.001
Distance to the nearest ancient woodland	71.71	3,3516	<0.001
Distance to the nearest 20ha ancient woodland	110.06	3,3516	<0.001
Area of ancient woodland in nine1-km squares	1.33	3,3516	0.262
Number of boundaries	32.17	3,3516	<0.001
Woodland age class			
Site area	27.61	2,3516	<0.001
Distance to the nearest ancient woodland	56.08	2,3516	<0.001
Distance to the nearest 20ha ancient woodland	0.02	2,3516	0.975
Area of ancient woodland in nine1-km squares	0.39	2,3516	0.677
Number of boundaries	11.74	2,3516	<0.001