AN ANALYSIS OF THE USAGE OF BATBOXES IN ENGLAND, WALES AND IRELAND

FOR

THE VINCENT WILDLIFE TRUST

BY

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Summary of Major Results

- Σ For sites in England and Wales there was a highly significant difference in batbox occupancy rate from west to east, ranging from 15% in Devon and west Wales to only 4% in the midlands and eastern England.
- Σ Occupancy rates showed a clear winter trough, with less than 2% in February rising to 10% in August/September.
- Σ In 1999, mean occupancy rate in winter was around 1.6%, whereas in 2002, 2004 and 2005 it was 5.7%. In the six summer months occupancy rate more than doubled over this period from around 6% to over 13.5%.
- Σ There was a highly significant difference in occupancy rates between batbox types. In general, concrete types were prefered to wooden ones.
- Σ Occupancy rates, bat counts and species counts all increased significantly with the length of time the boxes had been established.
- Σ For all six individual species/groups, occupancy rates differed significantly between batbox type, although the most frequently used type differed between species. Less marked differences occurred for bat counts.
- Σ Batbox height seemed to have a significant effect on occupancy and time to first use by Natterer's bats, which showed a strong preference for lower boxes.

Contents

Part I

The Use of Batboxes to Indicate the Presence of Barbastelle and Bechstein's bats

Introduction

The first part of this analysis investigates the possibility that batboxes can be used to record the presence of bats in areas where they were previously unknown. The primary hypothesis is that if boxes are placed in suitable sites within the known range of a species, they will be recorded. In other words, there will be no false negatives. The converse of this hypothesis is that if boxes are placed in sites outside the known range, they will not record bats. Of course, this doesn't equate to a false positive, because if the boxes do record the presence of bats, this simply increases our knowledge of their distribution.

So, already we have a logical inconsistency for testing these hypotheses. Consequently, this analysis is little more than an exploration of the locations of the VWT sites and sites that were previously known to be occupied by these species. Each species has been investigated independently, by plotting the two types of site plus the minimum convex polygons (MCP) for the known sites.

To test these distributions two statistical approaches have been used:

- Σ Firstly, for each species, a 2 x 2 contingency table of VWT sites with bats Present and Absent versus Inside and Outside the MCP has been created. The null hypothesis is that there was no difference between the present/absent ratios inside the MCP and outside. This assumes that our previously known MCP actually does represent the real distribution of the species. So, we should expect zero or a small number of positive records outside the MCP whereas we should find all or most sites with bats present within the MCP.
- Σ Secondly, the distance from each site to the nearest known site for the species has been calculated. The response variable was the number of bats recorded at each site. The null hypothesis was that there is no relationship between this count and the distance to the nearest known site. This analysis was repeated using the mean distance to the two nearest sites, the five nearest and all known sites, to give four different predictor variables.

Barbastella barbastellus

There are two main previously-known areas of Barbastelle locations (Fig. 1); a band across the midlands from west Wales to East Anglia and a zone along the south coast from Devon to Sussex. Whether these actually form two discrete areas or, indeed, whether they form only two areas, is open to interpretation. Eight VWT sites were established, six within or north of the midlands zone and two within the southern zone. Only the latter recorded Barbastelles, with two bats being recorded during two visits at Bryanston in Dorset and 18 bats during 17 visits to High Marks Barn in Devon.

The results of the 2x2 contingency analysis are given in Table 1. With such a small sample size it is not surprising that there is no evidence that the ratios between VWT sites with and without bats were different inside compared to outside the MCPs.

The correlations between the numbers of bats recorded in a VWT site and the distance to the nearest known site were strongly influenced by the six out of eight sites with zero counts. Consequently, none of these were significant (Table 2).

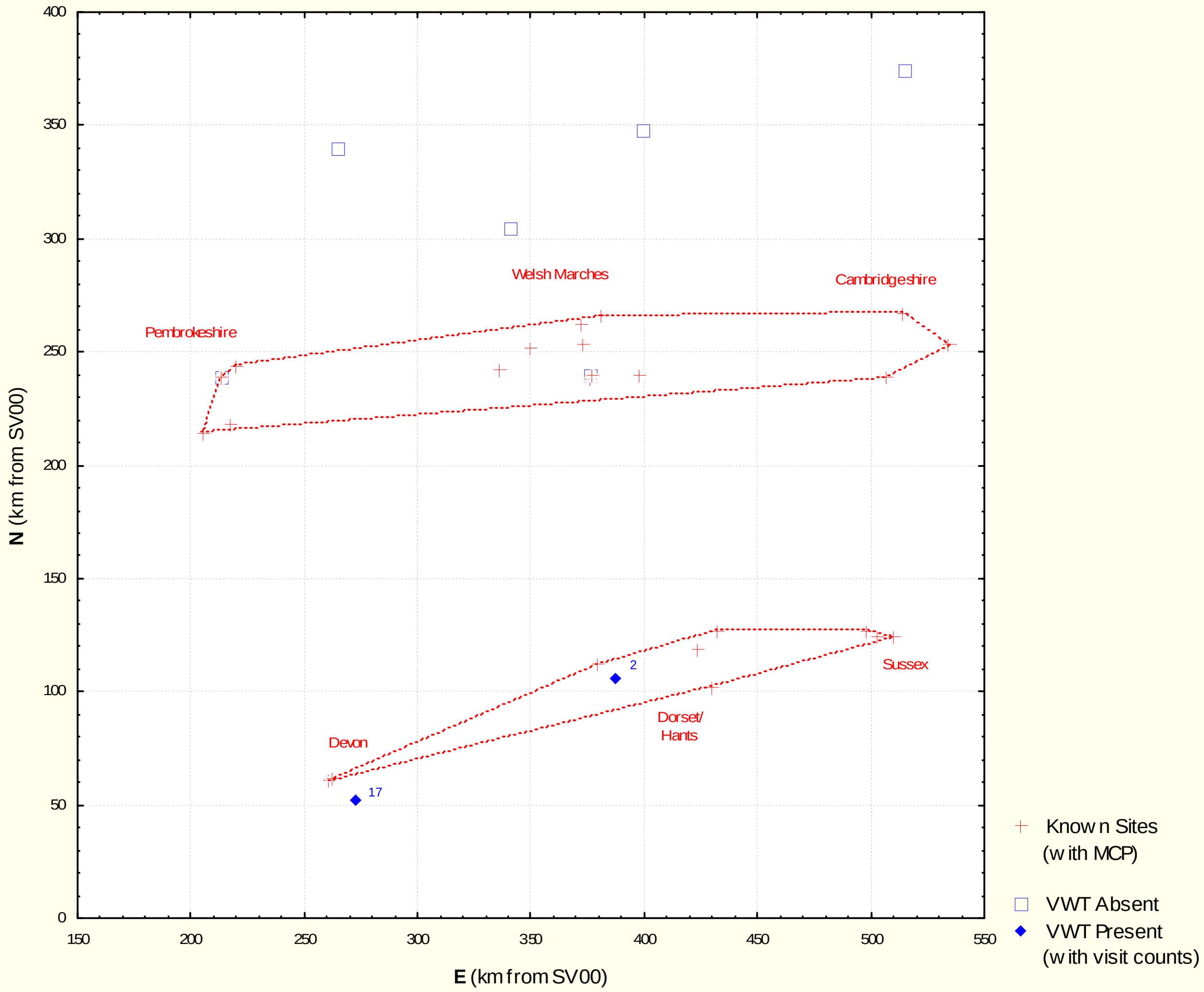

Fig. 1. The location of the previously known sites for Barbastelle bats and the VWT sites established specifically to record this species. Visit counts represent the number of visits in which the species was recorded

Table 1. 2 x 2 contingency table of number of sites with Barbastelles present or absent versus Inside and Outside the MCP

	Present	*Absent*	*Row totals*
Frequencies, Inside MCP	1	2	3
Frequencies, Outside MCP	1	4	5
Column totals	2	6	8
Chi-square (df=1)	0.18	*P* = 0.673	
Yates corrected Chi-square	0.18	*P* = 0.673	
Fisher exact p, one-tailed		*P* = 0.643	

Table 2. Spearman rank-order correlations between the number of Barbastelles counted at each VWT site and the distance to nearest previously-known sites.

	N	*Spearman R*	*p*
Nearest site	8	-0.234	0.577
Mean of nearest two sites	8	-0.265	0.526
Mean of nearest five sites	8	-0.094	0.826
Mean of all sites	8	-0.062	0.883

Myotis bechsteinii

The balance between VWT sites and previously known sites was opposite to the Barbastelle situation. The known distribution for Bechstein's is relatively small, ranging from Dorset to West Sussex and from the Isle of Wight to Wiltshire in the north, comprising ten sites. In contrast, the 33 VWT sites extended westward to Devon and northward to Powys and Shropshire (Fig. 2).

Of the eleven VWT sites within the MCP, six (55%) had at least one visit with records of Bechstein's bats. In contrast, only two of the 22 sites (9%) outside the MCP had positive records, and in each case only one visit. Clearly, this has extended the known range for the species, but the important point is that the proportion of false positives was significantly lower within the MCP compared to outside it (Table 1). Indeed, if the MCP is drawn excluding the single known site on the Isle of Wight, the four "absent" VWT sites around Lymington and Christchurch are removed from the MCP. This has the effect of altering the proportion of positive sites within the MCP to 86% and the proportion outside the MCP to 8%. The resultant Fisher's Exact $p = 0.0002$ which is very highly significant.

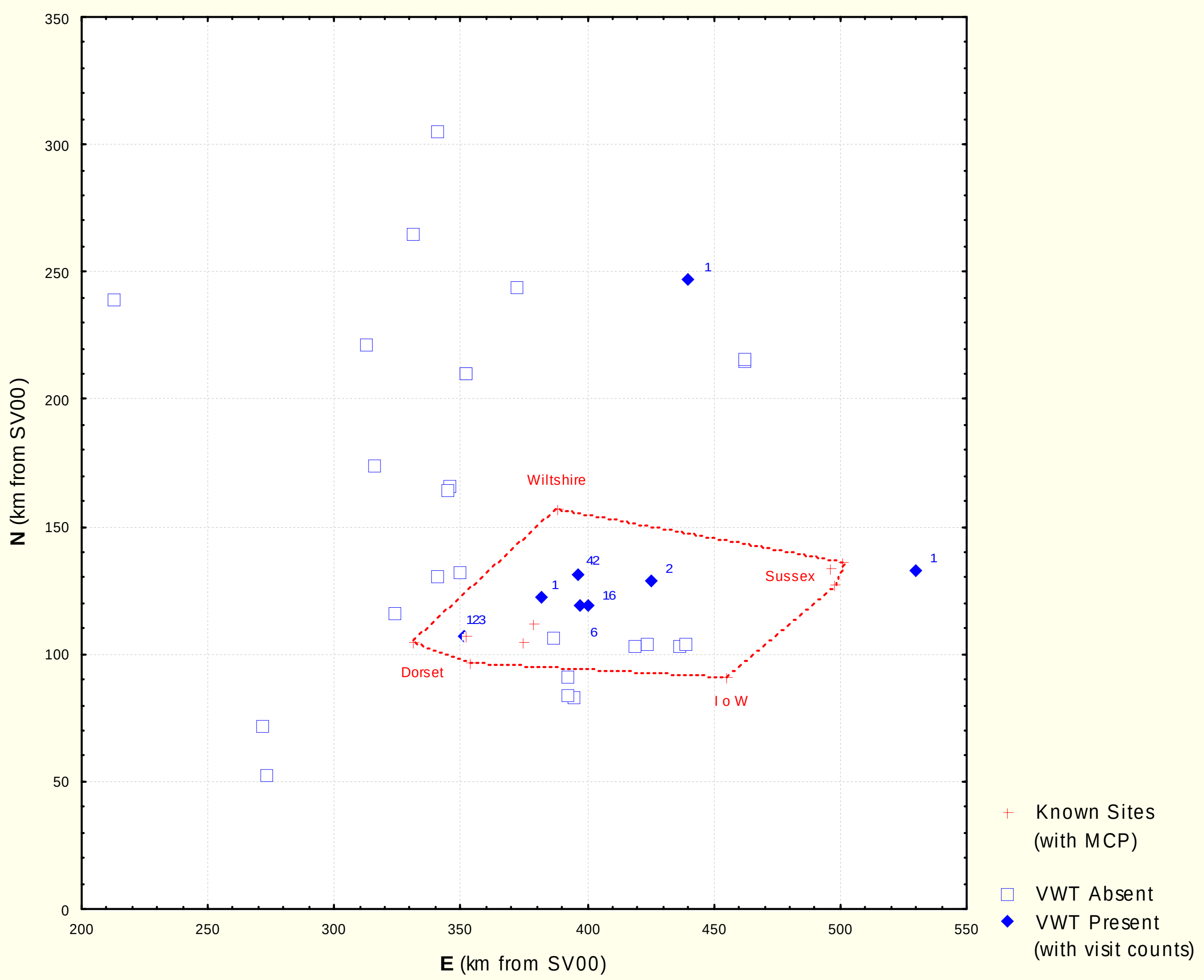

Fig. 2. The location of the previously known sites for Bechstein's bats and the VWT sites established specifically to record this species. Visit counts represent the number of visits in which the species was recorded

Table 3. 2 x 2 contingency table of number of sites with Bechstein's present or absent versus Inside and Outside the MCP

	Present	*Absent*	*Row totals*
Frequencies, Inside MCP	6	5	11
Frequencies, Outside MCP	2	20	22
Column totals	8	25	33
Chi-square (df=1)	6.81	*P* = 0.004	
Yates corrected Chi-square	4.79	*P* = 0.015	
Fisher exact p, one-tailed		*P* = 0.008	

Table 4. Spearman rank-order correlations between the number of Bechstein's counted at each VWT site and the distance to nearest previously-known sites.

	N	*Spearman R*	*p*
Nearest site	33	-0.337	0.055
Mean of nearest two sites	33	-0.405	0.019
Mean of nearest five sites	33	-0.363	0.038
Mean of all sites	33	-0.424	0.014

This result is confirmed by the analysis of distances to nearest known sites (Table 4). There was a significant negative relationship between the numbers of Bechstein's counted and the mean distance to all known sites. In other words, in sites where the average distance to all known sites was small, the counts of Bechstein's was greater (Fig. 3). Furthermore, it is clear that of the eight sites which had counts greater than zero, six of them had a mean distance to all known sites of between 60 and 70 kms. Within this range there are only four out of the 19 sites with zero counts.

In summary, it appears safe to say that there is no evidence that the absence of Barbastelle bats in bat-boxes precludes their presence at a site. However, for Bechstein's, it would be possible to infer that if you do not record bats in batboxes, the site is likely to be outside the known range of this species.

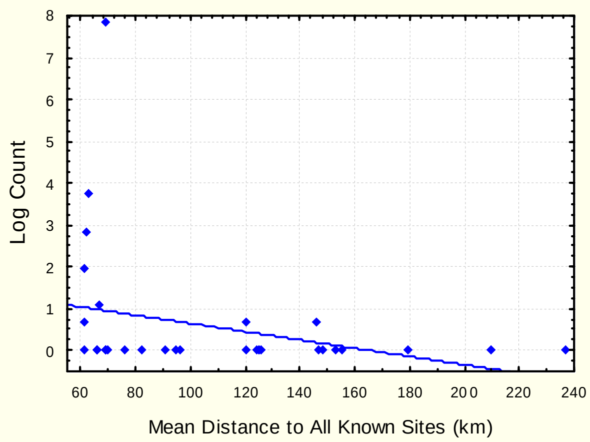

Fig. 3. The relationship between the log number of Bechstein's bats counted in VWT sites and the mean distance to all previously-known sites for this species.

PART II

ANALYSIS OF BATBOX USAGE

Introduction

The datasets used in this analysis have been derived from the VWT Batbox Database. This holds data from 52 sites collected over 20 years from England Wales and Ireland. With over 68,000 batbox inspections this represents a uniquely valuable record of the use of batboxes by bats.

However, the surveys from which the data were gathered were not designed as experiments to test specific hypotheses concerning batboxes usage. Rather, the work evolved over a number of years, with various and changing objectives. Consequently, the structure of the overall dataset is highly complex and has imposed severe limitations on the analyses. Furthermore, in the absence of *a priori* hypotheses, it has been necessary to derive a series of questions based on the variables recorded in the database.

It must be conceded, therefore, that much of the analysis simply constitutes "data mining". This term refers to the exploration of large datasets, with the aim of uncovering relationships between predictor and response variables. In the absence of controls, it can be difficult to be certain that any such relationships are causative. However, any strong relationships that are revealed can provide useful insight into factors affecting batbox usage.

Characteristics of the VWT Dataset that Influence the Analyses

There are three main characteristics of the dataset that have influenced how the analyses have been carried out. These are explained in some detail in this section, and will be alluded to in the Recommendations presented in the Summary.

Unbalanced Dataset

The main issue alluded to above is that the evolution of the surveys has resulted in a severely unbalanced dataset. A full explanation of the nature of balanced and unbalanced datasets is beyond the scope of this report, but it is worth introducing the concept to help explain the analytical procedures used here.

Firstly, it is necessary to define the unit of data recording. In database terms this is usually known as the record – in statistical terms it is known as the case. The basic unit in this dataset is the **batbox inspection**. This unit can be identified uniquely as a combination of the batbox ID and the Inspection number. At each batbox inspection the species and number of bats present was recorded – although usually this was "no species" and, therefore, "zero count". Now, this is the first source of unbalancing in the dataset, because batboxes had different numbers of inspections.

Secondly, batboxes were attached to trees, which introduced a level of clustering. This means that boxes cannot be treated as entirely independent units because, for example, the four boxes attached to an oak tree in one corner of a woodland are clearly a different group from the four attached to an ash tree 1km away – they don't constitute eight independent units. This introduces a second level of unbalancing in the dataset, because different numbers of batboxes were attached to different trees.

Finally, trees clearly belong to sites, and different numbers of trees were used within sites. In an analogous way to boxes on trees, trees within sites result in a further level of non-independence of batboxes.

These three effects constitute a spatial dimension, but there is also a temporal dimension to the dataset. Inspections took place at approximately one month intervals. However, not all sites, trees or boxes had inspections in every month. Furthermore, the first site was visited in 1985 and the last visit was made in 2005. But, again, not every site was visited in every year.

These factors allow us to construct what should be the complete, balanced dataset. Firstly, the number of boxes per tree was usually two, although 120 trees had only one box and 23 trees appeared to have at least five boxes over the lifetime of the survey. 98.3% of trees had up to four boxes. The number of trees per site ranged from 5 to 86, with a mean of 27. If we take the maximum values from these three factors, 52 sites x 86 trees x 4 boxes = 17,888 units. These are then crossed with 252 inspections (21 years x 12 months) which gives a total of 4,507,776 batbox inspections. So, the actual number of inspections represented about 1.5% of those in the fully balanced dataset. In other words 98.5% of the potential cells in this balanced model were empty.

In fact, the situation is not nearly as serious as this, because the three spatial factors are nested rather than crossed. In other words, boxes are nested within trees which, in turn, are nested within sites. This means that it is not essential to have the same number of boxes on each tree or the same number of trees within each site. However, serious unbalancing (*e.g.* 5 trees in one site and 86 in another) has inevitably caused problems in calculating within-tree variances.

The main problem with empty cells is that it is impossible to calculate interactions between factors when they are present. Not only are interactions important in their own right in interpreting the results of an analysis, they may also be required as the denominator in certain F-ratio tests of main factors. If the interaction cannot be calculated, then the main factor cannot be tested. The consequence of this is that the dataset has to be reduced to a subset where every level of the desired factors can be crossed with all other factors.

Confounded Factors

Two further considerations are important in designing the statistical models for analysis. Firstly, the characteristics of interest, such as the type of batbox, have not been assigned in a systematic way. Some sites had a range of batbox types, others had a different selection, whilst others had only a single box type. This means that batbox type is "confounded" with site, so that it is not possible to be certain which effects are due to batbox type and which are simply due to unknown site characteristics. Again, the only way to overcome this problem entirely is to extract subsets of the data, where two or more box types have all been used in a number of sites.

Degrees-of-Freedom

Secondly, factors which are recorded at the site or tree level should not be analysed at the batbox inspection level. This is to prevent the use of spuriously large sample sizes. For example, imagine a single site with ten trees, each of which has four boxes. Five of the trees are oak and five ash. The question of interest is "Does the number of bats per box differ between tree species?". Now, with 40 boxes, it would be tempting to carry out a simple one-way ANOVA with tree species as the factor of interest, with two levels, ignoring the actual trees themselves. The F-test would then have 1 and 38 degrees-of-freedom.

However, this would be incorrect because the true cases in this structure are the ten trees, with the four boxes representing repeated measures on each of the trees, The true degrees-of-freedom for the F-test should be 1 and 8 (with 30 degrees-of-freedom assigned to the error term). All other things being equal, the smaller d.f. will result in a lower significance level.

With a small and well-balanced dataset with a limited number of factors, it is possible to construct a statistical model which allows for reduced degrees-of-freedom. However, the large unbalanced dataset described here precludes this.

The Datasets Used for Analysis

The raw dataset comprised 68,715 records, each representing an inspection of a batbox in a site. In 5,986 of these, one or more bats were recorded, representing an occupation rate of 8.7%. In 24 cases, the box was occupied by two species of bat. The consequence of the characteristics of this dataset described in the previous section is that the analyses had to be carried out at three spatial levels:

- Site-based data (52 cases)
- Tree-based data (1,410 cases)
- Batbox-based data (3,024 cases).

Sites

The "top" level of analysis was carried out using Sites as the basic record, resulting in 52 cases. Predictor variables were recorded uniquely for each case. The response variables were aggregated over all boxes within each site, and for the non-temporal analyses, over all inspections as well.

Predictor Variables

A total of eight variables were recorded at the site level (Table 5). Five were recorded as part of the ongoing survey methodology, although three were not collected on all sites. The other three variables were recorded specifically for the Barbastelle/Bechstein's analysis described in Part II of this report. They were only recorded on 32 sites (Appendix I).

Table 5. Predictor variables analysed at the site level

Variable	*Data Type (levels)*	*No. of Records*
Easting	Continuous	52
Northing	Continuous	52
Woodland Type	Categorical (6)	47
Woodland Structure	Categorical (5)	45
Altitude	Continuous	37
Mean Diameter Breast Height	Continuous	32
Understorey	Categorical (3)	32
Age Structure	Categorical (2)	32

Easting and Northing were continuous variables used to describe the geographical location of the sites. The main problem with these data are that they are strongly influenced by the location of the five sites in Galway, Ireland (Fig. 4). These are clearly westerly outliers and also influence the distribution of the northing variable. The distribution of sites in England and Wales is fairly normal and symmetrical in both dimensions, indicating that the raw data can be used as continuous predictor variables.

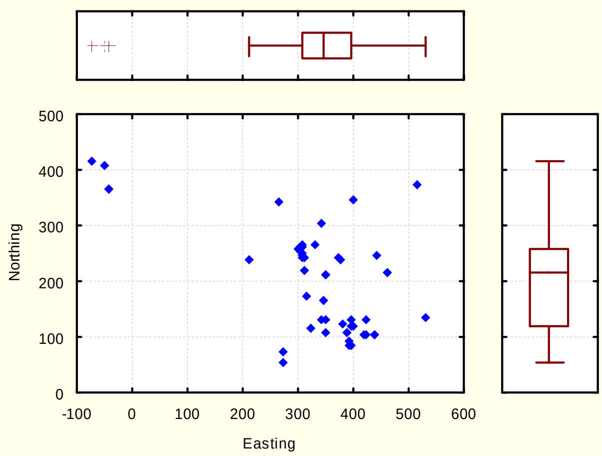

Fig. 4. The location of sites expressed in terms of km east and north of SV00. Box-and-whisker plots show the median and quartiles, with outliers.

Six Woodland Types were identified:

- Ancient semi-natural (16)
- Ancient replanted (13)
- Broad-leaved replanted (5)
- Mixed woodland (5)
- Riparian (5)
- Conifer plantation (3).

Woodland structure categories were somewhat confounded with the previous variable:

- Σ High forest (19)
- Σ Coppice with standards (22)
- Σ Rotational coppice (2)
- Σ Heath (2).

In 37 sites, the approximate altitude of each tree holding batboxes was recorded. This enabled the mean altitude for the site to be calculated, weighted by the location of the trees with boxes (Fig. 5). The data were strongly right-skewed with, in particular, an outlier at 270m (Mount Fancy).

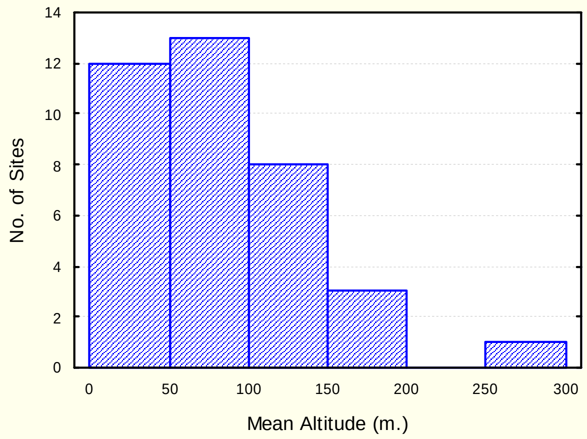

Fig. 5. Frequency histogram of mean Site Altitude.

32 sites had data for Understorey and Age Structure which were fairly evenly distributed:

Understorey;

- Σ Sparse (14)
- Σ Moderate (14)
- Σ Dense (4)

Age Structure:

- Σ Even-aged (14)
- Σ Diverse (18).

Finally, Mean Diameter Breast Height (DBH) showed a concentration around 100cm, with 60% of sites having a mean DBH of between 80 and 120cm (Fig. 6).

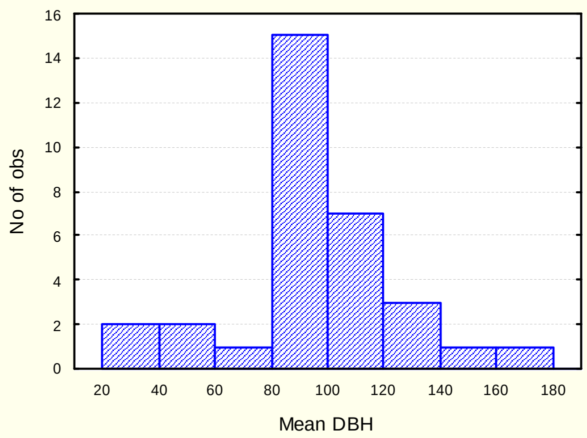

Fig. 6. Frequency histogram of mean Diameter Breast Height.

The Response Variables

Three response variables have been used in this analysis:

- Σ Occupancy Rate (Log PA-Ratio)
- Σ Bat Count (Log Bats Per Batbox Inspection)
- Σ Species Count (Log Species Per Inspection).

The first of these requires some explanation. The PA-Ratio (presence/absence ratio) is the number of inspections in which one or more bats were present divided by the number in which no bats were recorded. So, for example, if ten inspections were carried out on a box, and bats were recorded in two of them the PA-Ratio would be 0.25 (2 present/8 absent).

Two slight modifications have been made to this basic statistic. When the number of inspections with bats present equals zero, the PA-Ratio would simply reduce to zero, and no distinction would be made between boxes where no bats were recorded in one inspection and no bats were recorded from one hundred inspections. Clearly, the latter gives a much stronger indication of the absence of bats than the former. To reflect this, if the presence is zero, the PA-Ratio is calculated as

$$\frac{1}{(2 \times Inspections)}$$

For example, if no bats were recorded in 10 inspections, the PA-Ratio would be 0.05. However, if bats had been recorded in one of these , then the PA-Ratio would have been 1/9 or 0.11. In contrast if these recordings had been made from 12 inspections the PA-Ratios would have been 0.042 and 0.091 respectively.

The second modification is used when every inspection resulted in the presence of a bat – *i.e.* the number of absences was zero. In this case the PA-Ratio would be infinity due to division by zero. To maintain the symmetry of this statistic, the PA Ratio was calculated as (2 x *Inspections*).

The aggregations across batboxes and inspections were carried out in the same way for all three variables. Firstly, for each site, the total number of box inspections was tallied. This tally excluded the first inspection (coded 0, which was the visit to erect the box) and any visits where the status of the box on arrival was not classed as "OK". Then, the number of these which were occupied by any number of any bat species was used to calculate the PA-Ratio. The total count of all bats divided by the number of box inspections was used to calculate the Bats Per Box and the total tally of bat species divided by the number of inspections gave the Species Per Box variables. But, for these two variables, zero counts were omitted, meaning that they represented bat counts and species counts of occupied boxes only. The logs of all the variables normalised the data (Fig. 7),

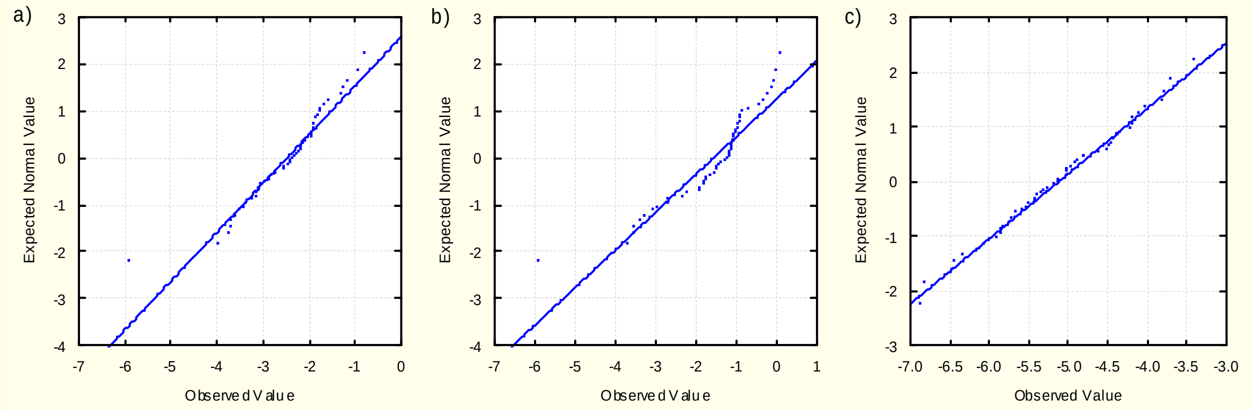

Fig. 7. Normal probability plots for a) Log PA-ratio, b) Log Bats per Box and c) Log Spp. per Box calculated for site-based data.

although the PA-Ratios and Bats per Box variables were severely influenced by a single outlier.

Temporal Variables

Two main temporal factors have been analysed at the site level; Year and Month. However, due to the extremely unbalanced nature of the data, it has not been possible to combine them into a single analysis. Indeed, Table 6 shows that it would be impossible to calculate an interaction term between these two factors as nearly half of the cells were empty – in other words, no visits were made to any sites in certain months. The table also shows that there was a much greater number of visits made during the summer months which was a deliberate methodological decision.

Consequently, month was analysed by aggregating data across all years (which still only gave data in five sites in December, for example). A separate dataset was created comprising 395 records, uniquely identified by Site and Month. The response variables were aggregated by tallying the number of inspections across all boxes in all years that the site was visited.

Similarly, year was analysed by aggregating across months. However, Table 6 shows the huge difference in site tallies before and after 1999. Furthermore before 1999, there were very few visits during the winter months, whereas there was a fairly consistent, albeit sparse, pattern of visits during the summer. Moreover, it was also considered sensible to divide the analysis of annual batbox usage by season due to behavioural and ecological factors.

So, two separate datasets were used to analyse the Year factor. Firstly, the six summer months (April – September) were aggregated over all years, giving a dataset with 253 records. Secondly, the six winter months (October – March) were aggregated from 1999 to 2005 to give a dataset with 181 records.

Table 6. Counts of sites visited in each month of each year during the survey

	Month												
Year	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	***Total***
1985				1	3	3	3	3	3	3			**3**
1986				2	2		2	2		3	2		**3**
1987					2		2	2	3				**3**
1988					1	3		3	3	3			**3**
1989					2		2		2				**2**
1990				3		1			2				**3**
1991					2	1		3		3			**3**
1992									3	3			**3**
1993				3	3				4				**3**
1994					4	4		5	3				**5**
1995				4	3	3	4	1	4				**5**
1996				1	4	4	2	1	2				**4**
1997			1	2	5	3	4	2	2	1			**6**
1998		1	4	5	10	6	11	6	7	1	2		**11**
1999		12	5	20	22	22	21	17	22	4			**24**
2000		8	5	34	32	32	27	32	33	17	1	2	**36**
2001	1	3	1	14	21	23	20	20	24	14	1	2	**25**
2002	3	2	4	34	35	38	35	23	31	10	3	1	**40**
2003	6	3	5	6	21	14	18	15	22	6	3	2	**30**
2004	2	2	7	11	19	11	20	8	23	6	2	2	**27**
2005	2	2	3	8	17	5	13	6	18	3		1	**23**
Total	**10**	**8**	**11**	**43**	**51**	**47**	**47**	**47**	**50**	**31**	**9**	**5**	

Trees

The dataset derived for the analysis of tree factors contained 1,410 records, representing each tree used within every site. The number of trees used per site varied from 5 in Coole to 86 in King's Wood (Appendix II). The median number of trees per site was 24.5, although eight sites had only six trees each.

Predictor Variables

Only three predictor variables were recorded for each tree. Two of these (East and North) represented the location of the tree within the wood. In 36 sites tree location data were recorded in the form of a grid of squares overlaid on the site, forming a pattern analogous to grid references for sites. These allowed the location of trees to be recorded in metres east and north of the SW corner of the grid. For the analysis, these were expressed as the percentage of the maximum easting and northing within the site. This had the effect of removing inter-site differences in the size and shape of the wood, which in turn reflected the location of the trees in terms of the north, south, east and west woodland boundaries. The 36 sites yielded 1,167

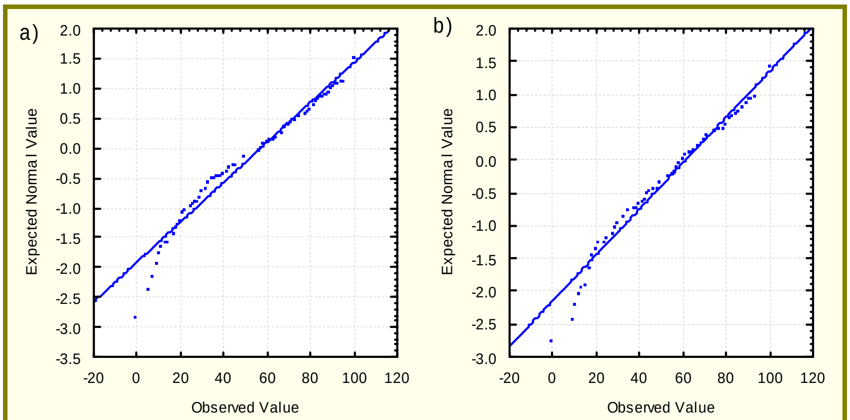

Fig. 8. Normal probability plots for a) Percentage Easting, b) Percentage Northing of trees within sites.

valid cases for each variable, both of which had significant departures from normality (Fig. 8).

The third variable recorded at this level was the tree species. A total of 25 species/genera of tree were recorded throughout the survey (Appendix IIb). However, many of these were used only rarely. For example, boxes were placed on only one holly and one horse chestnut. Furthermore, in the majority of cases, the tree was only identified to genus, mostly *Quercus*. Consequently, tree identification was aggregated to five named genera plus an "Other" category. This still resulted in a highly unbalanced dataset, with over 50% of the identified trees belonging to the genus *Quercus* (Fig. 9). In addition, the distribution of these tree categories was extremely unbalanced across sites with, for example, no sites having both *Abies* and *Pinus*.

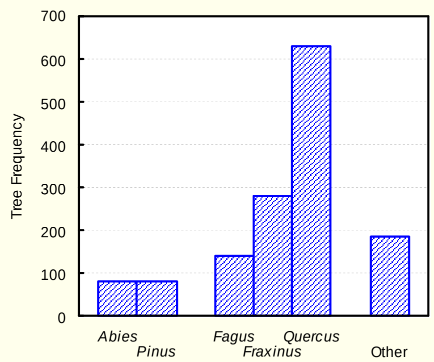

Fig. 9. Number of trees recorded in each of six genus/categories.

Response variables

The same response variables were used at this level of analysis as described for the Site-based dataset. The response variables were aggregated across all inspections of all the boxes located on each tree. The distributions of the response variables at this level appeared to be especially symmetrical, although the log Spp. per Box was somewhat platykurtic.

Batboxes

This dataset comprised 3,024 records, representing all the batboxes used in the 52 sites (Appendix III). The largest number of boxes used was 208 in King's Wood, with only 10 used in Coole. Ten sites had at least 100 boxes and the median number used was 50.

Predictor Variables

Four predictor variables were investigated at this level:

- Σ Box category (Concrete or Wooden)
- Σ Box type (six concrete types and four wooden types)
- Σ Box Location – Aspect (eight points of the compass)
- Σ Box Location – Height (in metres).

The first two variables were nested, with box type belonging to either the concrete or wooden category. Unfortunately, these two factors introduced one of the largest sources of unbalancing in the overall dataset. Firstly, only 240 boxes (7.9%) were wooden and these were only used in six sites. The breakdown by box type (Fig. 10) showed that over two-thirds of all batboxes were of a single type (2fn), with another 19% comprising the 1ff type. Furthermore, whereas the 2fn type was used in all but five of the sites, the 1fs, Martin, CJM, Mess

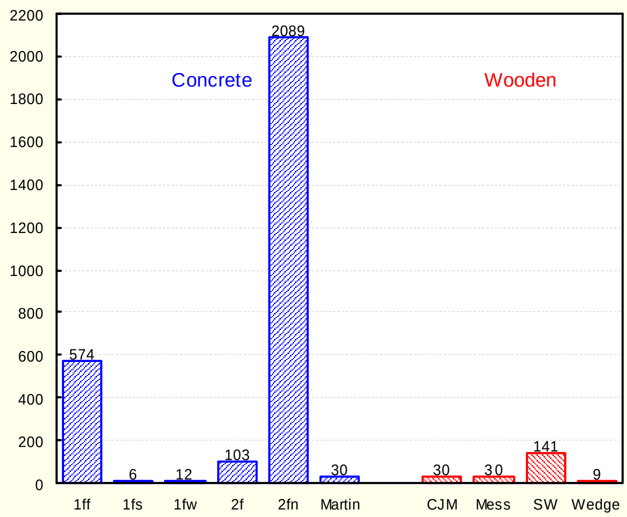

Fig. 10. Total numbers of each batbox type and category.

and Wedge types were all used in only one site (Appendix III). This severe imbalance has made it difficult to test the effects of different box types on the response variables.

The aspect that boxes were attached to their trees was recorded in a non-systematic way. About half were recorded on a four-point compass scale, whilst the other half were recorded on an eight-point scale giving the pattern shown in Fig. 11. To remove this artificial coding, the aspect variable has been recoded arbitrarily into the four points of the compass by recoding NW as north, SE as east, etc. this gives counts of 818, 695, 804 & 685 from north to west respectively.

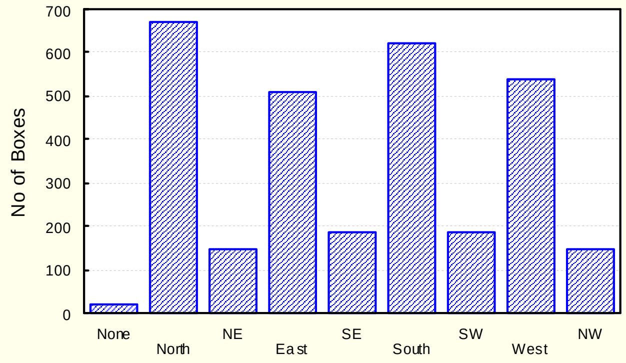

Fig. 11. Total numbers of batboxes set at different aspects.

Finally, the height at which batboxes were attached to their trees also varied in a non-random way (Fig. 12). 62% of boxes were set at 4m or less, with another 26% set at approximately 5m. To reduce the effect of the small number of extreme values, heights were recoded in to <= 4m, 5m, 6m and >= 7m categories.

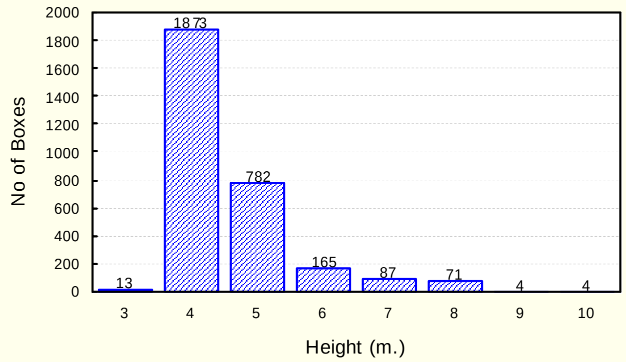

Fig. 12. Total numbers of batboxes set at different heights.

Response variables

Four response variables were analysed at the bat-box level. The three general variables of occupancy rate, bat count and species count all showed very symmetrical distributions (Fig. 13), although all three had slight departures from normality. Occupancy rate had valid cases for all 3,024 records, whereas Bat and species counts had 1,775 and 1,773 valid cases respectively

These variables were augmented by a time-based variable; the number of days before the box was first used. The log of this variable has slight left-skew, but was otherwise fairly well distributed (Fig. 14), although it suffered from the seasonal effect of multi-year samples. In other words, as most boxes were set up in the early summer, if a box remained unoccupied during the calendar year, the lack of inspections during the winter

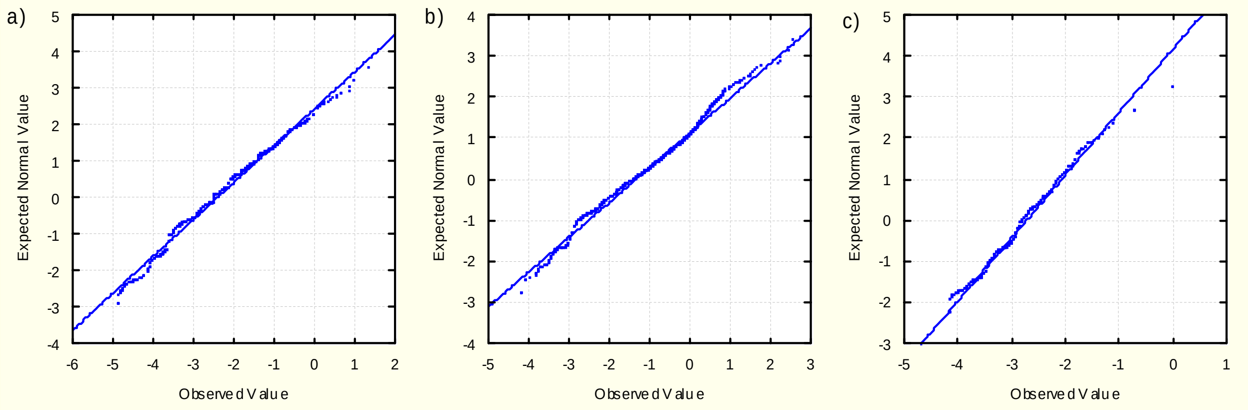

Fig. 13. Normal probability plots for a) Log PA-ratio, b) Log Bats per Box and c) Log Spp. per Box calculated for Batbox-based data.

months means that first-use showed a dip around 300 days, with another around 650, etc.

Temporal Variables

A second dataset was constructed at the batbox level of analysis. This had 1,916 cases and represented the total number of inspections at each site. Rather than the inspection number being used, in combination with Site, to identify the record, the inspection was expressed in terms of the number of days since the box was set. Although the log of this variable was significantly different from normal, it was at least reasonably symmetrical in its distribution (Fig. 15).

The three standard response variables were calculated for this dataset (clearly, "Days to First Use" was derived from this variable and so could not be used with it). The logs of these variables all showed only a minor departure from normality. The bat and species count variables each had 1,285 valid cases, indicating that 631 records had zero occupancy rates.

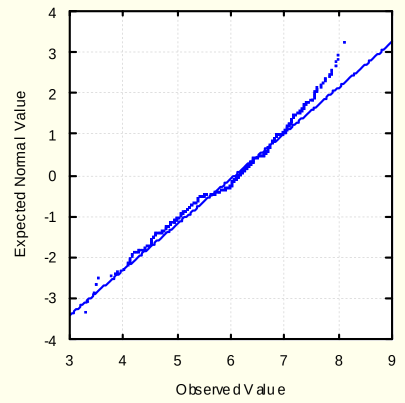

Fig. 14. Normal probability plot of the log of "Days to First Use" of a batbox.

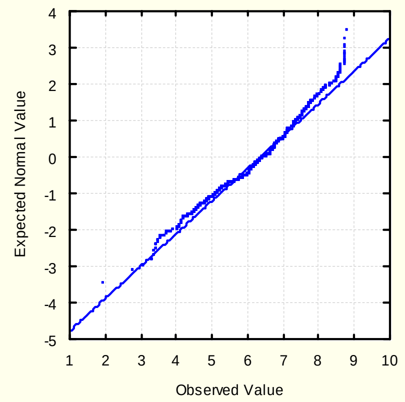

Fig. 15. Normal probability plot of the log of "The Number of Days Set" for a batbox.

The Statistical Models

Model Building Procedures

All statistical analyses were carried out using Statistica version 6.1.[#] The General Linear Model (GLM) module was used throughout to construct Analysis-of-Variance (ANOVA) and Analysis-of-Covariance (ANCOVA) models.

Due to the severely unbalanced nature of the data it was not possible to fit all main factors and interactions in single models. Furthermore, this also precluded the use of stepwise processes for fitting the effects. Instead, models were built with main effects first and then, where possible, interactions were included between significant main effects. All factors were treated as fixed except site, which was treated as a random effect when it was included. In most models very few interactions could actually be fitted.

In the previous section (The Datasets Used for Analysis) it was shown that most of the response variables had symmetrical and reasonably normal distributions, especially when their logarithm was used. As a further test of robustness, the residuals from all models were inspected for normality and homogeneity of variance. In general, these statistics were very acceptable, although the individual species analysis did show some significant deviations. This reflects the small sample sizes in these analyses and suggests that their results should be interpreted with caution

Alpha levels

The highly fragmented nature of this analysis means that many separate models have had to be constructed to

[#] StatSoft, Inc. (2004). STATISTICA (data analysis software system), version 6. www.statsoft.com.

analyse the effects of different predictor variables. Added to this is the fact that four different response variables have been used. The consequence of this is that many hundreds of significance tests have been carried out, which introduces the problem of multiple-testing.

For example, if you undertake 20 significance tests, with an alpha-level set to 0.05, then one of these tests is likely to reach this level of significance by chance. There are a number of ways of accounting for this phenomenon, but in a large-ranging analysis such as this, a subjective decision to use conservative alpha-levels is probably the best. Throughout this analysis the following interpretations of observed alpha levels have been used:

- $\alpha > 0.01$ = Not significant
- $0.01 > \alpha > 0.001$ = Marginally significant (of interest but should be accepted with caution)
- $0.001 > \alpha > 0.0001$ = Significant (can be confidently accepted as a real effect)
- $\alpha < 0.0001$ = Highly significant (undoubtedly a real and strong effect).

Analysis of Site Factors

Due to the differing numbers of records in this dataset that had valid predictor values, the site factors have been analysed using four separate models:

- Σ Analysis of geographical location (52 cases)
- Σ Analysis of woodland type and structure (43 cases)
- Σ Analysis of woodland altitude (37 cases)
- Σ Analysis of understorey, age and tree size (31 cases).

Geographical Location

The location of the 52 sites is shown in Fig. 16. Clearly, their distribution reflects the location of VWT staff, with concentrations in Galway, east Wales and the English marches, and Somerset, Dorset and Hampshire.

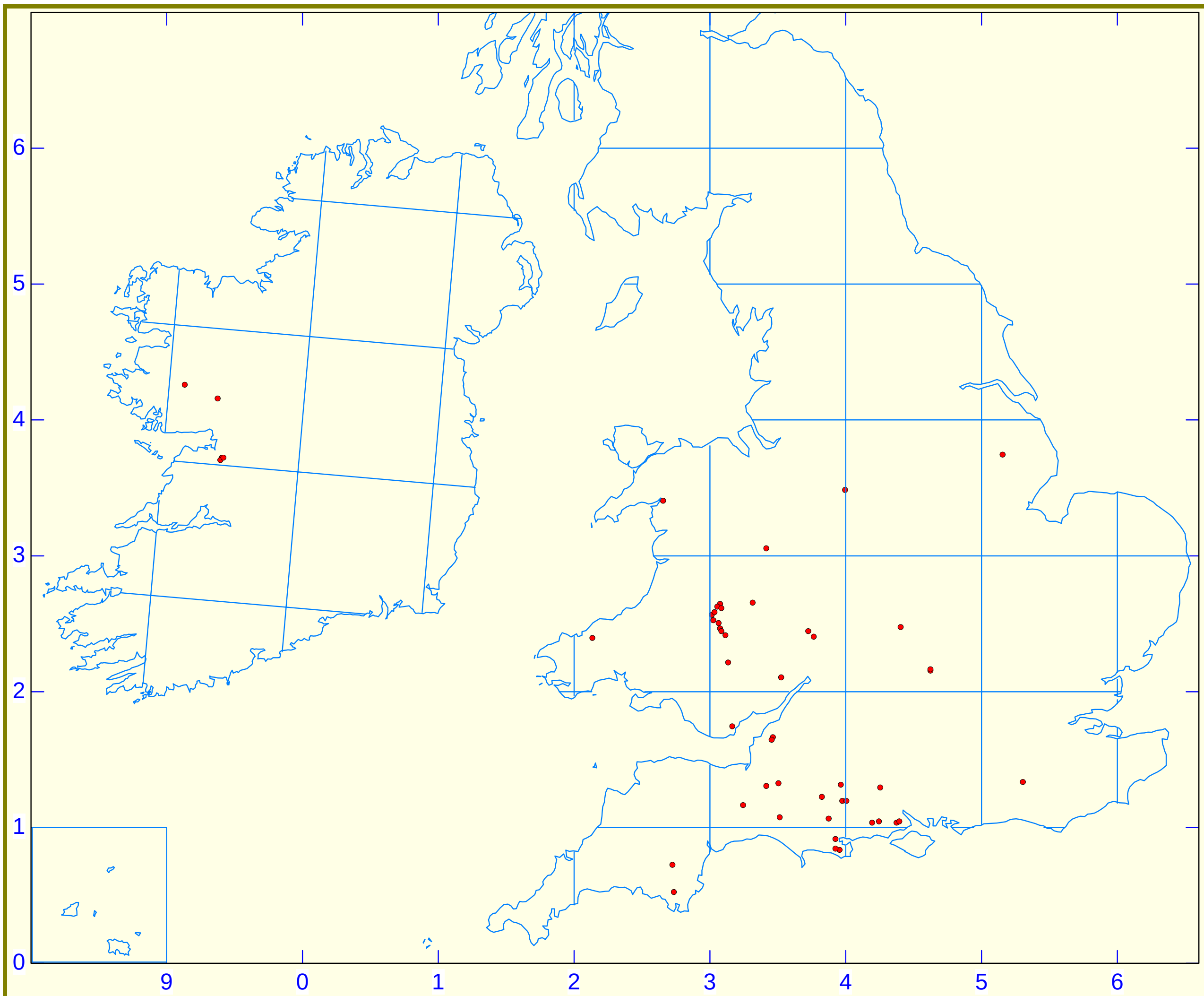

Fig. 16. Location of sites within England, Wales and Ireland.

Sites in Great Britain have grid references based on the Ordnance Survey of Great Britain and Northern Ireland. These have been converted to eastings and northings representing the number of kilometres east and north of OS point SV00 (approximately 100km west of the Isles of Scilly). For example, the town of Pembroke has an approximate grid reference of SN00 which is 200km east and 200km north of SV00, so the eastings and northings are both 200.

The five sites in the Republic of Ireland are based on the Irish Grid Reference. Not only does this have a different reference point, but the grid is not parallel to the British grid. However, for the purposes of this analysis, the grid references for the Irish sites have been converted to **approximate** eastings and northings on the British grid (with an error of less than 10km). This results in negative eastings as all the Irish sites are west of SV00.

Multiple-regression models of the three response variables predicted by easting and northing were constructed using Type III sums-of-squares. In the initial models using all the data (Table 7a), the only effect that was marginally significant was the site northing on Spp. per Box. This was a positive relationship with greater numbers of bats recorded per box for more northern sites.

Table 7. Effects of geographical location on the use of sites by bats.

Variable	*P*		
	Occupancy	*Bats per box*	*Spp. per Box*
a) All Data			
Easting	0.3987	0.6683	0.1488
Northing	0.2341	0.8839	0.0020
b) Excluding Outliers			
Easting	<0.0001	0.0037	0.4814
Northing	0.0849	0.9515	0.0015

However, reference to Fig. 16 shows most of the northern-most sites were also the sites in Galway in Ireland. Furthermore, Fig. 17 shows that the relationship between site eastings and occupancy rate is very strongly influenced by the five Irish sites. This graph also shows that a single outlying site in England (Mount Fancy) also has a strong influence on this relationship. Further explanation of the problem with this site is given below under Woodland Characteristics.

Rerunning these analyses, but excluding the five Irish sites and the single outlier gives the results presented in Table 7b. Now the effect of easting on occupancy has become highly significant. From this model, sites in Devon and west Wales were predicted to have an occupancy rate of over 15%, whereas the figure for sites in the midlands and south-east England was less than 4%. There was no equivalent effect of northings on this response variable.

Table 7b shows that there was a marginally significant effect of easting on the number of bats per box. The model predicts approximately three times as many bats in western sites as eastern. The effect of site northing on the number of species per box was slightly more significant for these English sites, although using the conservative alpha values, still only marginally so. Nevertheless, the mean number of spp. per 100 boxes increased from around 0.4 per 100 inspections on south coast sites to approximately 1.2 per 100 in the north midlands.

Woodland Characteristics

Six predictor variables were analysed using three different models against each of the three response variables. Firstly, site altitude appeared to have no effect on any of the three response variables. However, the outlying site (Mount Fancy) becomes apparent through this predictor variable (Fig. 18). Whereas the mean occupancy rate across the sites with altitude data was approximately 6%, the occupancy rate in Mount Fancy was only 0.3%. By excluding this site from the analysis, no significant effect was detected for any of the three response variables.

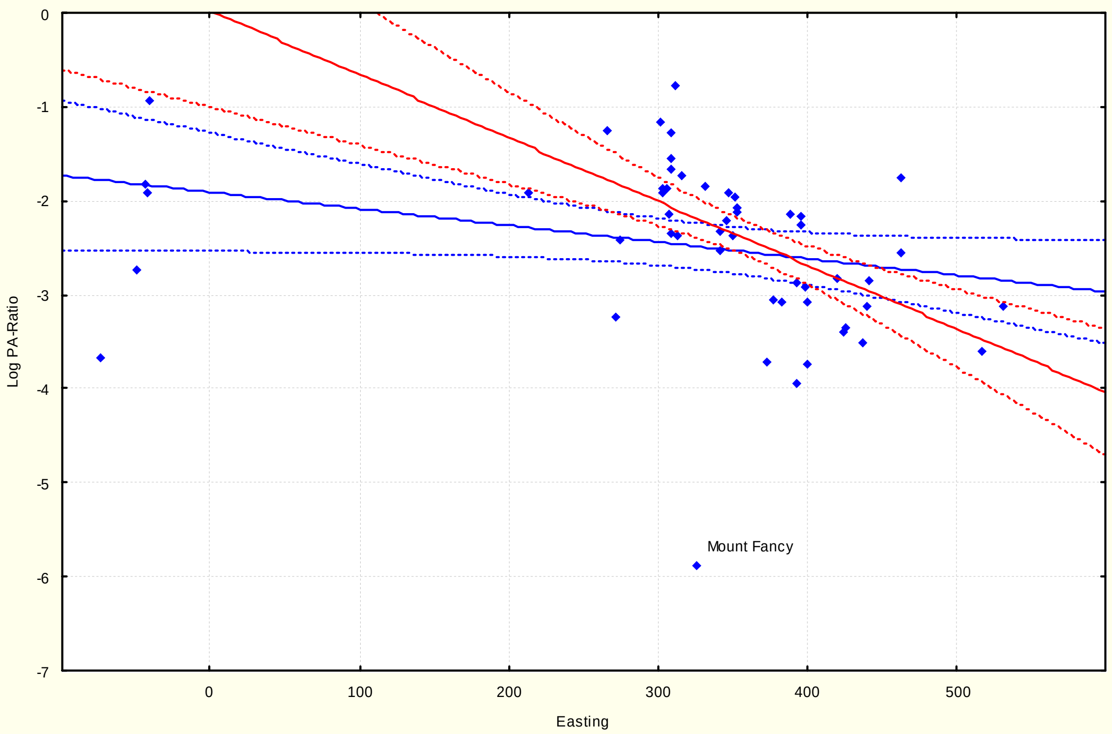

Fig. 17. Mean occupancy rate per site plotted against eastings (km west of SV00). The best-fit regression line with 95% confidence bands is shown in blue. Note the effect of the extreme western sites in Ireland and the single English outlier which has extremely low occupancy. Excluding these six points results in the red best-fit regression line with 95% confidence bands.

None of the other five factors were found to be significant for any of the three response variables. They were analysed using two separate models to account for the different numbers of valid cases.

Summary of Site Analyses

The three response variables all exhibit large ranges in their values. Even ignoring the outlying site, occupancy ranged from over 30% of box inspections to under 2%. The range of bat counts was even greater with a maximum count of 110 bats per 100 box inspections, and a minimum of 2.5 per 100 inspections. The outlier was not apparent in spp. per box, and the range of values was smaller, from 0.1 to 3 spp. per 100 box inspections.

Despite these large ranges the only site based variable which appears to have

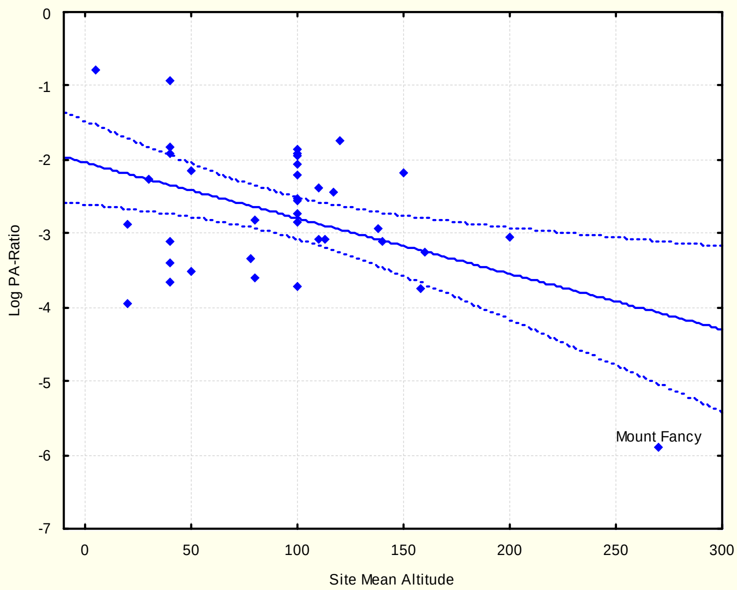

Fig. 18. The relationship between mean occupancy rate per site and altitude. The best-fit regression line with 95% confidence bands is shown. Note the effect of the single English outlier which has extremely low occupancy and is 2½ times higher than the median site altitude.

had a significant effect was Site Easting. The implication from this is that either there were insufficient data points (*i.e.* sites), or there are other, unrecorded variables which were causing the different occupancy rates and counts.

Temporal Factors

The statistical models used for these analyses were univariate Repeated-Measures ANOVA, with Month or Year as the repeating factor as appropriate. Type II sums-of-squares were used and no other site-based terms were included in the models.

Month Effects

Month proved to be a very highly significant factor for all three response variables (Table 8a). In particular, occupancy rate showed a clear distinction between winter and summer months (Fig. 19a). There appears to be a clear trend from the low of February/March (when occupancy was around 1.8% of batbox inspections), with a steady rise in spring and summer to a high in August/September, when the rate was approximately 10% of inspections. The slight kink in early summer probably is only marginally significant. Furthermore, the site counts in November, December and January were much lower, hence the large confidence intervals, suggesting that there were no significant differences between these months.

The trends for Bats per Box and Spp. per Box were similar but not so pronounced. In particular, the

Table 8. Results of temporal analyses at the site level, using three different response variables. Results are presented separately for the effect of a) Month and Year, based on b) the six winter and c) the six summer months.

	D. F.	*F*	*p*
a) Month			
Occupancy	11, 332	18.802	0
Bats per Box	11, 253	4.918	<0.0001
Spp. per Box	11, 253	6.403	<0.0001
b) Year (winter months)			
Occupancy	6, 100	9.608	<0.0001
Bats per Box	6, 50	4.398	0.0012
Spp. per Box	6, 50	3.651	0.0044
c) Year (summer months)			
Occupancy	20, 167	5.649	<0.0001
Bats per Box	20, 167	4.0944	<0.0001
Spp. per Box	20, 167	2.992	<0.0001

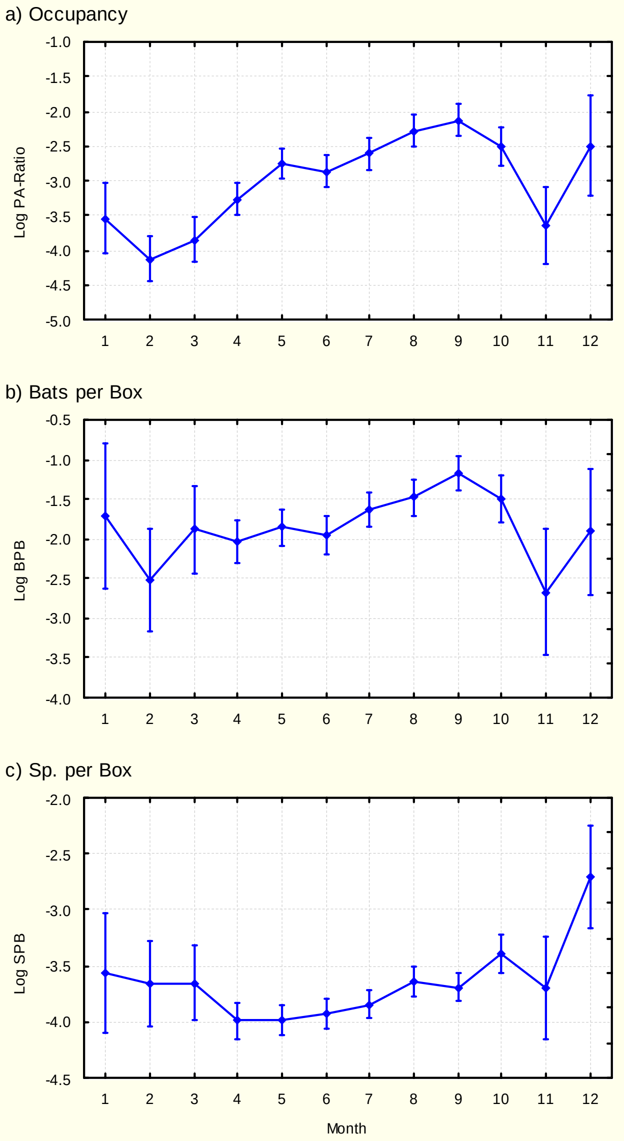

Fig. 19. The effect of Month on a) Occupancy, b) Bats per Box and c) Spp. per Box. Plots display the Least-Squares Means with 95% Confidence intervals.

mid-winter low is either not so different, as in the count of Bats per Box (Fig. 19b), or not significant at all in Spp. per Box (Fig. 19c). Indeed, *post-hoc* tests showed that the difference between bat counts in May/June and September were only marginally significant.

Species counts appeared to peak in October (at around 3.3 sp. per 100 box inspections) which was significantly greater than the May count at around 1.8 spp.. per 100 inspections. Although the December mean (6.7 spp.. per 100 inspections) appears to be significantly greater than all the summer months, *post-hoc* testing confirms that this was not a truly significant effect. (Note that the graphs in Fig. 19 show the least-squares means predicted from the ANOVA models, which are strongly influenced by small sample sizes.)

Year Effects

Partly due to much smaller sample size, the analysis of year effects, especially based on winter months (Table 8b), was less significant. Nevertheless, winter occupancy rates did show a highly significant difference between years (Fig. 20). However, the apparent upward trend over this seven-year period was illusory, with *post-hoc* testing indicating that the only truly significant differences were between 1999, when mean occupancy rate was around 1.6%, and 2002, 2004 and 2005. Mean occupancy in these three years was about 5.7%, and was not significantly different between them. There were only marginal year effects for Bats per Box and Spp. per Box.

The analysis of year effects in the summer months was based on 21 years data. All three response variables were highly significant (Table 8c). However, it is clear from the means plots for all three variables (Fig. 21) that the data from the early years prior to 1999 were influenced strongly by small sample sizes.

From 1999 onwards, there appeared to be strong upward trends for all three response variables. Occupancy rate more than doubled from around 6% to over 13.5% and bats per box increased from about 12 per 100 batbox inspections to over 33. Finally, sp. counts increased from a mean of 1.2 per 100 inspections to over 2.7 per 100 inspections

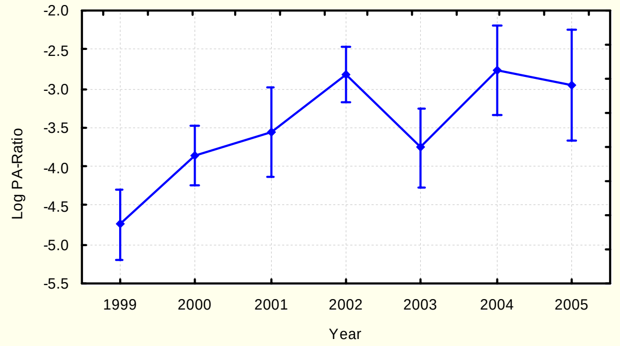

Fig. 20. Mean occupancy rates by Year for winter months. Least-Squares Means are plotted with 95% Confidence intervals.

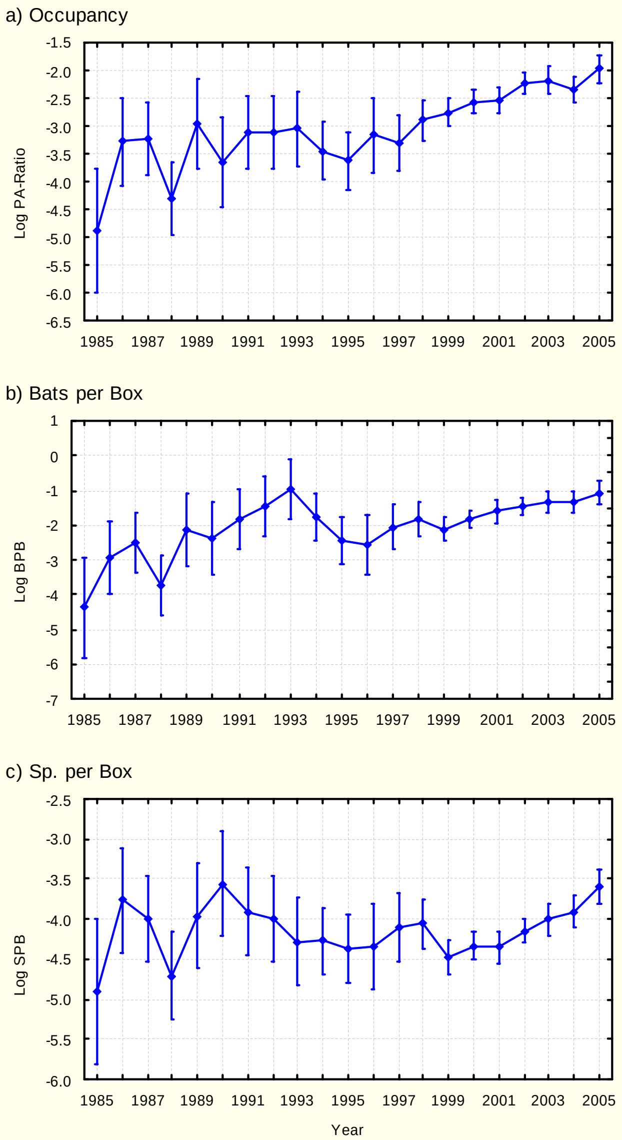

Fig. 21. Mean occupancy rates by Year for summer months. Least-Squares Means are plotted with 95% Confidence intervals.

in 2005. This was confirmed by using separate-slopes ANCOVA with sigma-restricted parameterisation. For all three response variables, there was a very highly significant increase with year, despite allowing for discrete site effects.

Analysis of Tree Factors

For the analysis of factors at the individual tree level, a dataset was constructed with 1,410 records. The response variables were amalgamated across box inspections by tree. Essentially only two predictor variables were recorded at this level; the spatial location of the tree within the site and the tree species. However, the highly significant effect of site on the response variables had to be accounted for by including site as a random factor. This had the effect of analysing the effects of the predictor variables within site, whilst ignoring their between-site variation.

Spatial Location of Trees

An ANCOVA model was constructed with Site as a random categorical factor, and the Percent Easting and Northing fitted as continuous predictors. All three response variables were tested separately in this model (Table 9).

The dataset for occupancy had 1,167 cases and was the only model with a significant geographic effect. However, even the apparently significant effect of easting only resulted in a range of occupancy of 7.7% of box inspections for trees on the western boundary of the site, falling to 5.2% on the eastern boundary. Indeed, Only 1.3% of the observed variation in occupancy was accounted for by within site location on the east-west axis. Furthermore, no effects on any of the response variables were detected for Northings, so these two factors probably had little genuine effect on occupancy rates or counts of bats.

Table 9. Results of ANCOVA models for the location of trees within sites. (Site effects were fitted to account for between-site variation, but were of no intrinsic interest.)

	D. F.	*F*	*p*
Occupancy			
Site	35	18.0811	0.0000
Easting	1	12.9493	0.0003
Northing	1	3.0309	0.0820
Error	1129		
Bats per Box			
Site	35	10.65090	0.0000
Easting	1	7.09841	0.0079
Northing	1	1.23887	0.2660
Error	744		
Spp. per Box			
Site	35	29.4233	0.0000
Easting	1	0.0118	0.9137
Northing	1	0.1098	0.7404
Error	743		

Tree Species

Because of the severely unbalanced distribution of tree genera within sites, simple ANOVA models were constructed firstly, including Site and Genus as the predictive factors, but with no interaction between them. In these models, neither occupancy nor bat counts showed even marginally significant differences between tree genera. In contrast though, there did appear to be a significant difference ($p = 0.0039$) in the number of species per box inspection on different tree genera. Inspection of the least-squares means from this model suggested that there was a higher species count on *Fraxinus* than on *Quercus*, but due to the severely unbalanced nature of the models, it was difficult to confirm this. In particular, these results could have been influenced by the intrinsic difference in the distribution of these two species in England. For example, in western-most sites (less than 300km east), *Fraxinus* usually comprised more than 45% of the trees, whereas in the eastern sites they comprised less than 10% of the trees used. In contrast, *Quercus* comprised less than 25% of the trees in the western sites, but more than 50% in the east.

In an attempt to remove the biases caused by the unbalanced datasets, a series of subsidiary analyses were run on subsets of the data. In particular, the differences between *Abies* and *Pinus* were investigated in the eleven sites that contained one or other genus, and the 15 sites which contained both *Fraxinus* and *Quercus*.

In the former case, nested ANOVA models were constructed with Site nested within the two levels of Genus.

In all cases, genus was not significant However, the "Site nested in Genus" effect was also highly significant, indicating that there was also a difference between sites with the same genus of tree .

The models containing *Fraxinus* and *Quercus* included the interaction between Site and Genus. Most importantly, this model accounted for the intrinsic difference in the distribution of these two tree genera between sites, because only sites with both spp. were included.

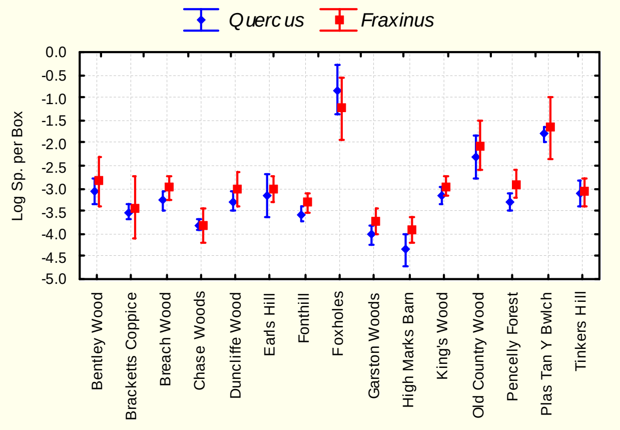

Fig. 22. The interaction between Site and species counts for the fifteen sites containing both *Fraxinus* and *Quercus* .

In this case, the effect on occupancy was not significant, but there was a marginal effect on bat counts. (p = 0.0044) and species counts (p = 0.0041). The former model predicted 34 bats per 100 batbox inspections on *Fraxinus*, but only 23 per 100 inspections on *Quercus*. The latter model predicted 5.3 species per 100 inspections and 4.5 species per inspection respectively. Furthermore, in both cases, the Genus x Site interactions were not significant (Fig. 22), indicating that the effects were constant across sites.

Analysis of Batbox Factors

A dataset of 3,024 records was constructed representing the tallies across inspections of all batboxes in 52 sites. In addition to the three standard response variables, a fourth variable was included at this level; the number of days for an occupied box to be found, as described in The Datasets Used for Analysis.

All Predictive Factors

An initial exploratory model was constructed using each of the predictor variables separately. However, due to the unbalanced nature of the dataset, no interactions were included. Nevertheless, the use of Type III sums-of-squares enabled the effect of each factor in turn to be investigated, allowing for the effects of all other factors. Site was included as a random factor.

Firstly, neither aspect (recoded on a four-point scale) nor box heights (recoded as <=4m, 5m, 6, >=7m) were significant predictors of any of the four response variables (Table 10). On the other hand, all four responses were highly significantly influenced by box type. In addition, occupancy was also different between the broad categories of box type (concrete and wooden) although this result was only marginally significant.

Table 10. Results of 5-way nested ANOVAs for four response variables. Site was also fitted as random factor. (Note that the slight difference in valid N for the last two response variables was due to missing values for bat species and dates, respectively.)

		Occupancy		*Bat Count*		*Sp. Count*		*First Used*	
		(N = 3024)		*(N = 1775)*		*(N = 1773)*		*(N= 1770)*	
Effect	*D. F.*	F	p	F	p	F	p	F	p
Box Category	1	7.86	0.0051	4.45	0.0350	0.32	0.5713	1.97	0.1610
Box Type (Box Category)	8	29.75	0.0000	6.63	0.0000	13.35	0.0000	8.11	0.0000
Aspect	3	1.21	0.3031	2.61	0.0498	3.43	0.0164	2.49	0.0589
Box Height	3	2.09	0.0996	2.85	0.0363	3.36	0.0181	2.09	0.0990

However, interpretation of these results is complicated by the severely unbalanced nature of the data. For example, the strongest effect of batbox type was apparent on occupancy rates. When the least squares means are plotted for each of the ten box types (Fig. 23a), there appear to be some very clear distinctions. Most obviously, within the wooden category, the SW type has a lower mean occupancy rate than the CJM or Messenger types. Probably of even greater significance is the lower occupancy rate in the 2fn type compared to the 1ff, 1fw or 2f concrete boxes. However, the least squares means are those predicted from the ANOVA model and are severely affected by absence of interactions resulting from the large number of missing cells. In contrast, the weighted means and confidence intervals (Fig. 23b) are calculated directly from the data (weighted by the number of observations in the respective cells). These show a completely different pattern of relationships – for example, very little difference between the wooden box types, and a highly reduced mean occupancy rate for the Martin type. The reasons for this are twofold; firstly, the uneven distribution of the different box types between sites and, secondly, the different numbers of the different boxes used overall. The only way to remove this discrepancy is to construct models that are, if not fully balanced, at least full-rank (*i.e.* they have no empty cells).

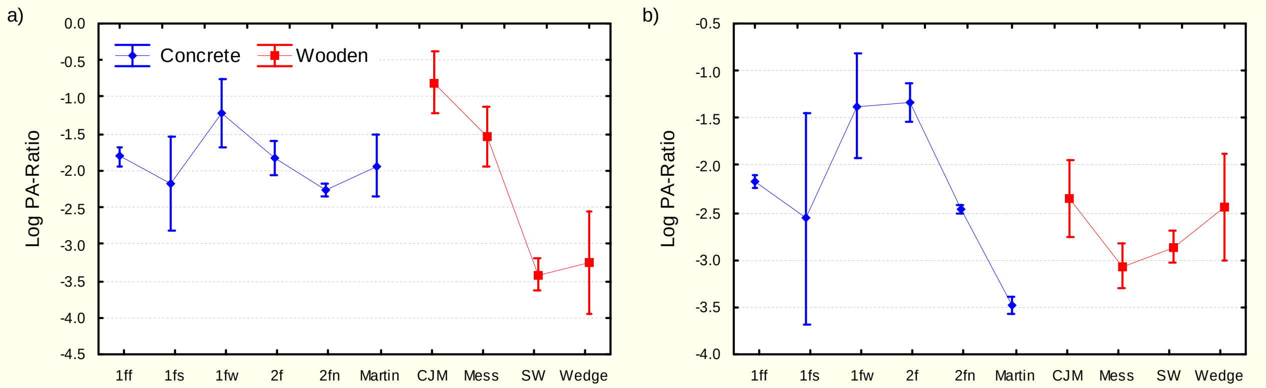

Fig. 23. Occupancy rate by batbox type and category. Means and 95% confidence intervals calculated by a) least squares and b) weighted means methods.

Batbox Category and Type

To overcome the unbalanced nature of the previous models, seven specific comparisons have been investigated using different subsets of the data. All except two of the comparisons used the 2fn box type as the reference.

Each of the subsets held only those sites where at least one of each of the box types of interest were used. In this way, a Site x Box type interaction term could be calculated. This in turn meant that the predicted least squares means from the model would be the same as the unweighted means, and the confidence intervals for each cell could be calculated more precisely. It should be pointed out that three of the comparisons could only be made on a single site, so no site term or interaction was required in those cases. Furthermore, as the sites have now been deliberately selected to have certain characteristics (presence of specific batbox types), Site should no longer be treated as a random factor. Rather it should be treated as a fixed factor, but now the conclusions cannot be generalised across all sites – they apply only to the specifically chosen sites.

Type 1ff versus 2fn

This comparison was made on eight sites. Occupancy was very highly significant between the two types, with considerably higher rates in the 1ff type (Table 11). The model predicted a mean occupancy rate of 12.9% in these types of box, compared to only 8.5% in the 2fn type. However, the interaction between site and box type was also highly significant (Fig. 24). Although this difference was clear in four sites, there were no significant differences in the other four, which indicates that the distinction may be influenced by other factors.

Bat count and sp. count showed no differences between these two batbox types, but time to first use was highly significant. The average time to first use for 1ff boxes was approximately 300 days, whereas the mean for the 2fn boxes was 450 days. Furthermore, the interaction between site and box type was not significant, indicating that the differences were consistent across all eight sites.

Table 11. Summary of 2-way ANOVAs of Site x Box Type (1ff v 2fn).

		Occupancy (N = 709)		*Bat Count (N = 570)*		*Sp. Count (N = 570)*		*First Use (N = 570)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Box Type	1	23.11	0.0000	0.19	0.6620	6.20	0.0131	16.55	<0.0001
Site x Box Type	7	5.42	0.0000	4.64	0.0000	1.41	0.1995	1.75	0.0951

Type 1fw versus 2fn

These two box types were used on five sites. Unfortunately, the maximum number of 1fw boxes used was 4 (in Bracketts Coppice) – usually it was only one or two. This meant that the least squares confidence limits calculated from the models for the 1fw types were very wide, which reduced the power of the model to detect effects.

Nevertheless, both occupancy rates and bat counts showed highly significant differences between the two box types (Table 12). Whereas occupancy rates were only about 7.6% in the 2fn types, the mean occupancy was 23% in the 1fw type (although the 95% confidence intervals were 15% to 33%. Bat counts were approximately 32 per 100 box inspections in the 2fn types, but were over five times that in the 1fw types (mean = 165 bats per 100 inspections with 95% C. I. = 80 to 360). In both these cases, the interactions with site were not significant.

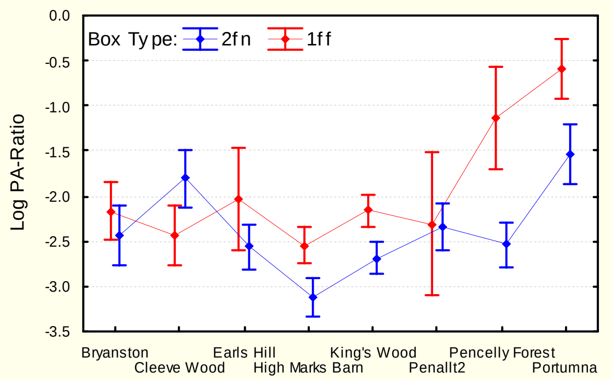

Fig. 24. Comparison of occupancy rate between 2fn and 1ff batbox types in the eight sites where both types were used. Plots show least squares means and 95% confidence intervals.

Table 12. Summary of 2-way ANOVAs of Site x Box Type (1fw v 2fn).

		Occupancy (N = 378)		*Bat Count (N = 324)*		*Sp. Count (N = 324)*		*First Use (N = 324)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Box Type	1	23.01	0.0000	19.05	0.0000	4.13	0.0431	2.41	0.1216
Site x Box Type	4	1.73	0.1421	2.65	0.0335	2.16	0.0730	1.39	0.2369

Type 2f versus 2fn

The 2f box type was used in ten sites, usually with 12 boxes per site. Unfortunately, in one site (Disserth) there were no 2fn types used, so the comparison could only be made in the other nine. Occupancy rates and time to first use were not significantly different in the two types of box (Table 13). However, there was a marginally significant difference in the bat counts, with approximately 45 bats per 100 inspections in the 2f type, but only 24 per 100 inspections in the 2fn. The difference in the species counts was even more significant, with 10.8 species per 100 inspections in the 2f, but only 7.5 in the 2fn. In both cases the interactions were not significant.

Table 13. Summary of 2-way ANOVAs of Site x Box Type (2f v 2fn).

		Occupancy (N = 133)		*Bat Count (N = 119)*		*Sp. Count (N = 119)*		*First Use (N = 114)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Box Type	1	2.54	0.1140	8.30	0.0048	15.66	0.0001	3.29	0.0728
Site x Box Type	8	2.17	0.0349	2.10	0.0422	0.66	0.7295	1.92	0.0656

Type 1fs versus 2fn

Only six of the 1fs box type were used and only in a single site (Breach Wood). A simple one-way comparison with the 90 2fn boxes showed no significant effect on any of the response variables.

Type SW versus 2fn

The SW box type was the main wooden type of box used in the survey. A total of 141 boxes was used in four sites, with at least 25 boxes in each site. However the numbers of matching 2fn types was usually much lower, again reducing the power of the tests.

Nevertheless, occupancy and first use were both highly significantly influenced by box type (Table 14). In contrast to all the previous analyses, the 2fn type had a much higher occupancy rate than the SW, (22.3% compared to 5.7% respectively). The site interaction was not significant, with three of the four sites individually showing large differences.

Table 14. Summary of 2-way ANOVAs of Site x Box Type (SW v 2fn).

		Occupancy (N = 203)		Bat Count (N = 163)		Sp. Count (N = 163)		First Use (N = 163)	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Box Type	1	35.49	0.0000	6.20	0.0138	9.96	0.0019	20.40	0.0000
Site x Box Type	3	1.84	0.1404	2.58	0.0554	1.18	0.3180	5.45	0.0014

The reason for the lower occupancy rate in the SW boxes might be partially explained by the time taken to be first used, which was very significantly greater than for the 2fn types. The ANOVA model predicted a mean time to first use of about 850 days, compared to only 270 days for the 2fn. However, the site interaction was also significant (Fig. 25), revealing that only one site (Erwood Station) showed this significant difference. Furthermore, it can be seen that the very high figure for SW was strongly influenced by the Aberedw boxes, many of which were left up for over ten years before being first used.

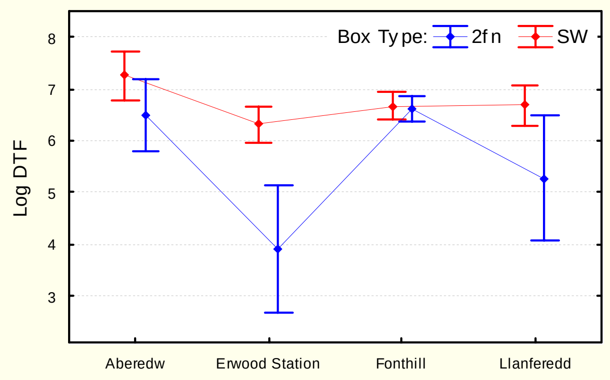

Fig. 25. Comparison of time taken to first use between 2fn and SW batbox types in the four sites where both types were used. Plots show least squares means and 95% confidence intervals.

Finally, there was a significant difference in mean species count between the two types of box. The SW boxes had a mean count of only 4.1 species per 100 inspections, whereas the 2fn boxes had 6.3 species. Of course, this may also have been influenced by the long periods of time that the boxes in these sites were set.

Type Wedge versus 2f

Nine Wedge boxes were used in Shaky Bridge, alongside one type 2fn and twelve type 2f. Rather than make a spurious comparison with the single 2fn box, and given that differences between 2f and 2fn boxes have already been explored, a comparison was made in this site between the Wedge and type 2f.

Occupancy rate was very significantly lower in the Wedge boxes than the 2f types (Table 15). In the Wedge boxes the mean rate was only about 11%, whereas occupancy was approximately 30% in the 2f boxes. Again this may be explained in part by the significantly greater time taken to use Wedge boxes (over 700 days) compared to only 150 for the 2f boxes.

Table 15. Summary of 1-way ANOVA of Box Type (2f v Wedge) in Shaky Bridge.

		Occupancy (N = 203)		Bat Count (N = 163)		Sp. Count (N = 163)		First Use (N = 163)	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*P*	*F*	*p*
Box Type	1	37.51	0.0000	0.01	0.9363	4.40	0.0523	13.52	0.0020

Types 1ff v Martin v CJM v Messenger

Three types of batbox; the concrete Martin and the wooden CJM and Messenger types were only used in one site (Tinker's Hill). Thirty of each type were used alongside thirty 1ff boxes. No 2fn boxes were used in this site. Consequently, this site was used for a four-way comparison of all four response variables (Table 16). Occupancy rate was significantly different in the four box types, with mean occupancy being much greater in the CJM types compared to the other three (Fig. 26a). Mean occupancy rate in the CJM boxes was about 8.7% whereas the pooled mean for the other three was approximately 3.6%. A similar pattern was found for species counts (Fig. 26c) although the significance levels of the individual comparisons were only marginal. Finally, there was a significant difference between the number of bats recorded in the CJM boxes (19.6 bats per 100 box inspections) compared to the Messenger boxes (8.1 per 100 inspections; Fig. 26b).

Table 16. Summary of 1-way ANOVA of Box Type (1ff v Martin v CJM v Messenger).

		Occupancy (N = 203)		*Bat Count (N = 163)*		*Sp. Count (N = 163)*		*First Use (N = 163)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*P*	*F*	*p*
Box Type	1	17.10	0.0000	5.59	0.0026	9.68	<0.0001	1.48	0.2508

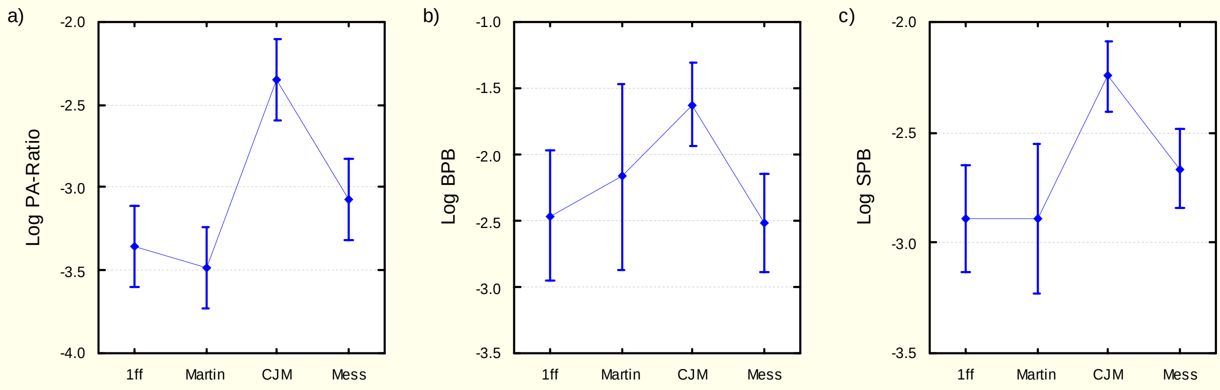

Fig. 26. Comparison of the four box types used in Tinker's Hill. Least squares means and 95% confidence intervals are plotted for a) occupancy rate, b) bat counts and c) species counts.

Temporal Factors

An additional dataset was created at the batbox level which included the variable "Number of Days Set" (*c.f.* The Datasets Used for Analysis). Three ANCOVA models were created, with Site as a random categorical predictor and Days Set as a continuous predictor. Their interaction term was also included in the model, using type III sums-of-squares. All three response variables were very significantly predicted by the number of days that the boxes had been set (Table 17). But, their interactions with Site were also highly significant, indicating that this overall response was not uniform across sites.

The overall pattern, however, was very clear. The models used log(Days Set) as a continuous predictor variable. But to illustrate the predictive power of this variable, the raw data were converted to years since the box was set and used to categorise the three response variables (Fig. 27). These show a very clear linear trend.

Firstly, the mean occupancy rate (back transformed from the logs of the raw data) increased from 7.6% for boxes set less than a year to approximately 18% for boxes set more than four years (Fig. 27a). Despite the somewhat high mean for boxes set between one and two years, the pattern is clear, with a significant distinction between boxes set for less than a year, between one and three years and those set for more than three years.

Table 17. Summary of 1-way ANCOVA models of Site x Number of Days Set.

		Occupancy (N = 1916)		*Bat Count* (N = 1284)		*Sp. Count* (N = 1284)	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*P*
Days Set	1	46.71	0.0000	13.24	0.0003	15.18	0.0001
Site x Days Set	51	2.49	0.0000	2.07	0.0000	2.45	0.0000

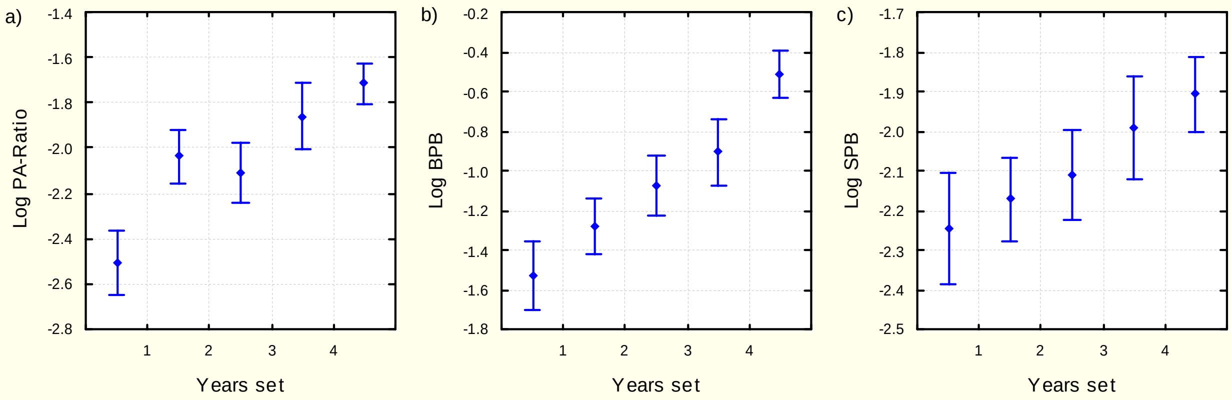

Fig. 27. The effect of the number of years for which the batboxes were set on a) occupancy rate, b) bat counts and c) species counts. Raw means and 95% confidence intervals of log-transformed data are plotted.

Secondly, the trend for bat counts is highly linear in the log of the counts (Fig. 27b). Mean counts in boxes set for less than a year were approximately 22 per 100 inspections, rising to approximately 60 per 100 inspections for boxes set for more than four years. Indeed, the highly significant contrast between this mean and the mean for boxes set for three to four years suggests that the trend continues for longer periods.

Finally, species counts also increased in a log-linear fashion with time (Fig. 27c). The mean species count in boxes set for less than a year was about 8 species per 100 inspections, rising to 15 per 100 inspections in boxes set for more than four years. (Clearly, this number is "off the scale" for British bat species – the index simply shows that boxes that have been set for a long time, have a more diverse collection of species using them.)

Summary of Batbox Factors

The factors of height and aspect appeared to have no influence on any of the response variables used in these analyses. When these factors were incorporated into ANOVA models with batbox type they were always non-significant (*c.f.* Table 10).

Subsidiary analyses, analogous to those reported for batbox type, were carried out on selected sites where all heights and aspects were used. This enabled the intrinsic site differences to be accommodated and site interactions calculated. The only factor which was significant was when aspect was recoded into either the northern or southern quadrants (*i.e.* ignoring E and W and recoding NE, SE, SW and NW accordingly). This model incorporated data from all 52 sites, which showed significantly greater box occupancy (p = 0.0031) in south facing boxes (mean rate = 10.7%) compared to north facing boxes (9%). The interaction with site was not significant and the model was very robust with well distributed residuals.

In contrast, box category and type were highly significant factors. Firstly, there was a significant difference in occupancy rates between concrete and wooden boxes (p = 0.0051) with mean occupancy in concrete boxes of 13.25 compared to 9.65 in wooden. However, none of the other three response variables showed a significant effect.

Batbox type clearly had a very strong influence on all the response variables used at this level of analysis. However, as described above, the severely unbalanced nature of the data, with most batboxes being of only one type (2fn) and the others unevenly distributed between sites, makes interpretation difficult. The seven separate comparisons were an attempt to overcome this, and to summarise these, the occupancy rates have been displayed as a matrix of miniature plots (Fig. 28). From this, it is clear that the 1ff, 1fw and SW types all had significantly higher occupancy rates than 2fn, although there was no differences between the 2fn and the 1fs and 2f types. However, note that for the three significant contrasts, the mean occupancy rate for the 2fn boxes were also different. The 2f versus Wedge contrast was unique, so it is impossible to say how these two compare with the other types without referring to the full model (Fig. 23 on page 27).

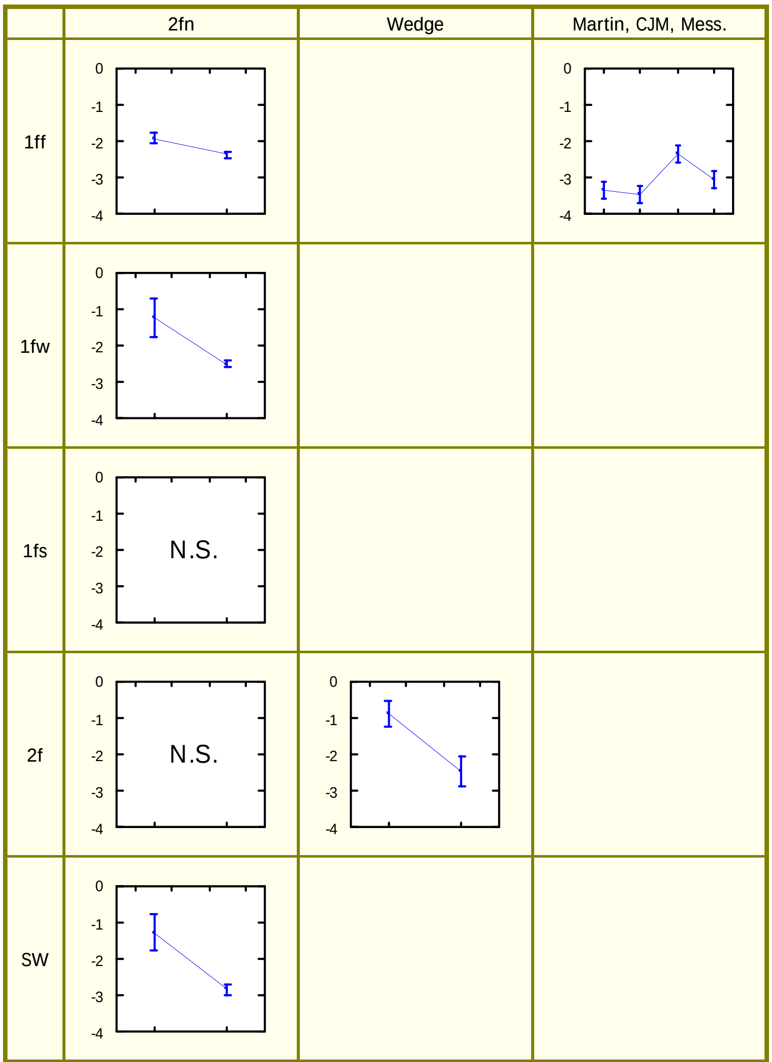

Fig. 28. Matrix of individual box type comparisons of occupancy rate (log PA-Ratio). Within each chart, the box type identified in the row heading is plotted as the left-hand mean & C.I., whilst the column heading is the right-hand plot(s).

Two separate contrasts were made with the 1ff type, firstly against the 2fn and secondly, in one site against the Martin, CJM and Messenger types. Given that the 2fn had a significantly lower occupancy rate than the 1ff, this implies that had it been used on the site with the four boxes, it would have been significantly lower than all of them, except possibly the Martin.

So, in summary, of the concrete boxes, the 1fw and 1ff types appear to have the highest occupancy rate and significantly higher than the 2fn. By implication they are also better than the 1fs and 2f types, which were indistinguishable from the 2fn. Of the four wooden types, the SW had significantly higher occupancy rates than the 2fn, but the wedge had significantly lower occupancy than the 2f. Given that the 2fn and 2f were not significantly different from each other, this indicates strongly that the SW would have been preferred over the Wedge had they been placed together. Finally, the CJM type appears to have higher occupancy rates than the Messenger type, and a suggestion that it would have been preferred to the Wedge type as well.

Similar matrices of comparisons could be made for the other response variables, but with fewer significant results there is little to be gained. Suffice it to say that for three of the significant occupancy contrasts, there was also a significant time to first use effect, which probably explains part of the differences in occupancy. Overall, the length of time that a box had been erected was a highly significant predictor of all three response variables. Only two comparisons each were significant for bat counts and species, which suggests that they are influenced inconsistently.

Species Accounts

Introduction

Where possible, all bat records were identified to species. Only 25 of the 23,671 bat counts (0.1%) were not identified (Appendix IV). Of the remainder, 632 (2.7%) were only identified to genus, almost all being *Pipistrellus*. A further 2,608 bats were recorded as *P. pipistrellus/pygmaeus*, mostly before the two species had been distinguished. So, including the latter category, 97.2% of counted bats were recorded to species.

The number of inspections where species were recorded is presented in Fig. 29a. Half the inspections where bats were present yielded *Pipistrellus*, with a further 24% recording *Nyctalus*. The species breakdown of these

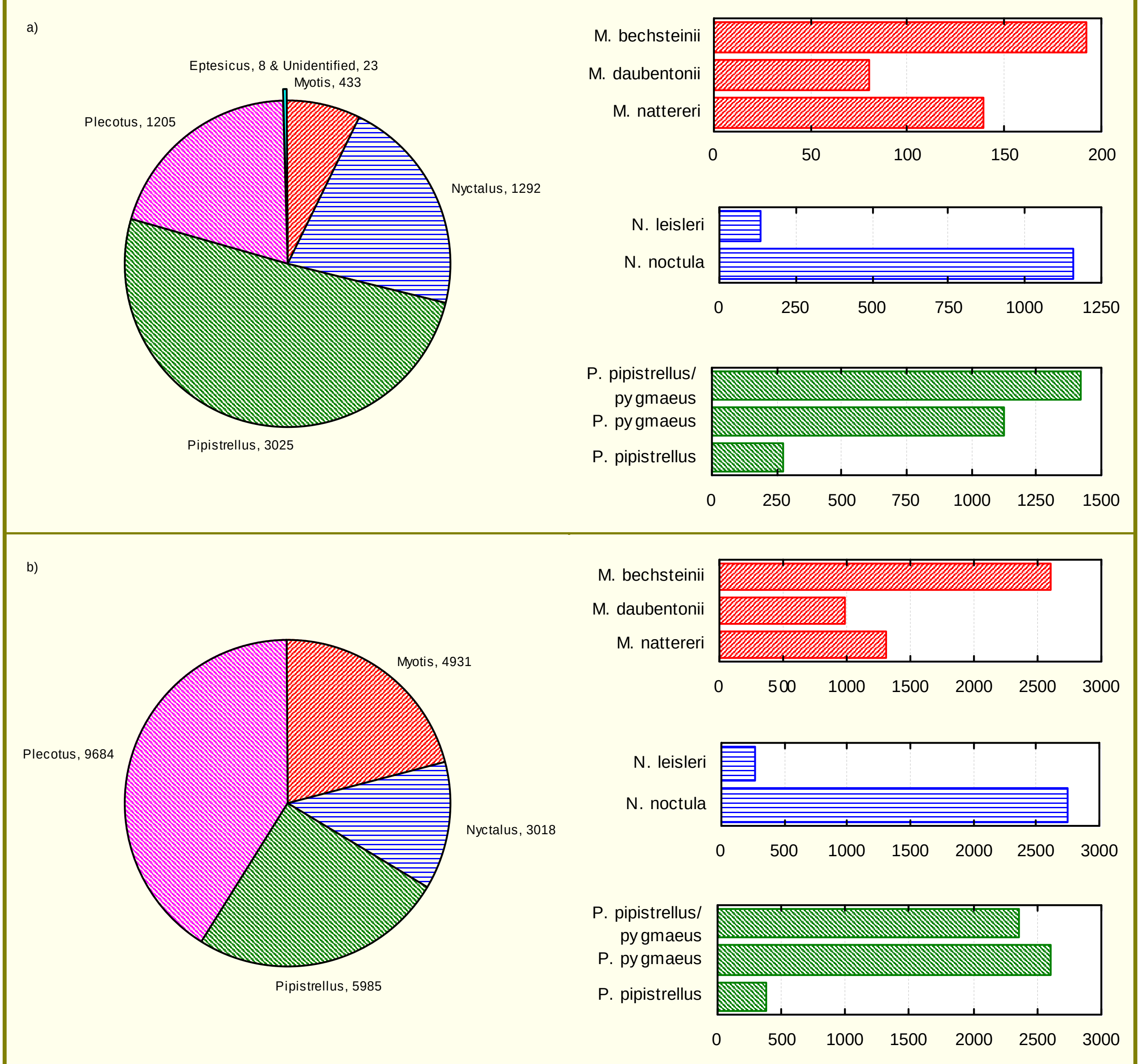

Fig. 29. Species breakdown of a) batbox inspections and b) bat counts by major genera and species.

two genera were fairly unequal, especially the latter, although there is already a clear distinction between the two new *Pipistrellus* species. Finally, three of the five *Myotis* species were recorded in between 80 and 190 inspections.

An equivalent breakdown of individual bat counts is given in Fig. 29b. The pattern here is different, with the largest overall count being of *Plecotus auritus*, suggesting that they were found in larger clusters within boxes than the other species. In addition, the three *Myotis* species, especially *M. bechsteinii* were also counted in larger numbers than their inspection tallies suggested. For example, in Bracketts Coppice boxes were used for breeding, whereas at other sites they were used by individuals. However, it is important to point out that all these data are strongly influenced by the differential effort that went into certain sites.

Multi-species Analysis

Six species/genera were recorded in sufficient numbers to make individual analysis of their data worthwhile. Although the occupancy rates and bat counts of the three *Myotis* species shown in Fig. 29 were quite low, two of them in particular are of interest to the VWT, so they were treated as separate species. *Plecotus auritus* and *Nyctalus noctula* were recorded frequently and with large counts, so they were also included. However, all *Pipistrellus* records were aggregated to the genus, partly because of the large number of unidentified records and partly the *pipistrellus/pygmaeus* amalgam, which between them accounted for half of the 5,985 records.

Three response variables were calculated for each of these six independently:

- Occupancy Rate (Log PA-Ratio)
- Bat Count (Log Bats per Box Inspection)
- First Use (Log Days to first Use).

Before analysing the responses of individual species to the predictor variables, it was considered valuable to analyse the species together, to identify differences between species. To do this, a multivariate dataset for the six species/genera was calculated for occupancy. Instead of a single measure of occupancy, in this dataset each batbox had six measures, one for each species. A repeated-measures ANOVA model was then calculated including Site, Box Type, Aspect and Height as four categorical predictor variables and Species as the repeated measure. Note that box category (concrete versus wooden) was not included in this model. No primary interactions could be included due to the unbalanced data, but the interaction of Species with the other four factors was included. This model is useful because it allows the overall ability of the predictor variables to be assessed, but also how they differ between species.

This model was only possible for occupancy, however, because the other two response variables were only calculated for the occupied boxes. So when the multiple species data were compiled, a huge number of empty cells was created, preventing the Species interactions from being calculated.

The results of the 5-way ANOVA are shown in Table 18 (note the different error terms used for the four site-based factors and the repeated-measure factor; Species). Firstly, this factor was very highly significant, indicating that occupancy rates varied greatly between species (Fig. 30). *Post hoc* tests showed no significant difference between the three *Myotis* species, with a pooled occupancy rate of around 3.7%. The other three were significantly greater than this with rates of 4.7% for *Nyctalus*,

Table 18. Full results of 5-way repeated-measures ANOVA of Occupancy by Species.

	D. F.	*F*	*p*
Site	51	521.92	0.0000
Box Type	9	31.12	0.0000
Aspect	3	2.49	0.0582
Height	3	1.86	0.1343
Error	2970		
Species	5	25.77	0.0000
Species x Site	255	18.11	0.0000
Species x Box Type	45	15.37	0.0000
Species x Aspect	15	1.44	0.1171
Species x Height	15	3.06	<0.0001
Error	14850		

4.2% for *Plecotus* and 6.0% occupancy for *Pipistrellus*.

Of the four main factors, Site is of no intrinsic interest, but Box Type was a highly significant predictor of occupancy rates overall across species (Fig. 31). This result is not dissimilar to the overall analysis carried out under Analysis of Batbox Factors (Fig. 23a on page 27) – in particular the pattern amongst the concrete boxes. However, the relative occupancy rates between the CJM and Messenger compared to the Wedge box type have reversed.

To explain this, it is necessary to investigate the highly significant interaction between species and box type (Fig. 32). The first important effect is that increased mean occupancy for the wedge box is due to five species, whilst *Pipistrellus* has significantly lower occupancy. In contrast, and as expected from Fig. 30, this genus had significantly higher occupancy rates in six of the other nine box types. The other species of interest was *Nyctalus* which was found at higher occupancy rates in type 1fw than all other species. Note also the difference between *M. bechsteineii* and *M. daubentonii* in the 1fw, SW and Wedge box types.

The two other main factors in this model – Aspect and Height – were not significant. Furthermore, the interaction between Aspect and Species was also not significant, indicating fairly clearly that Aspect had no influence on occupancy rates. However, the

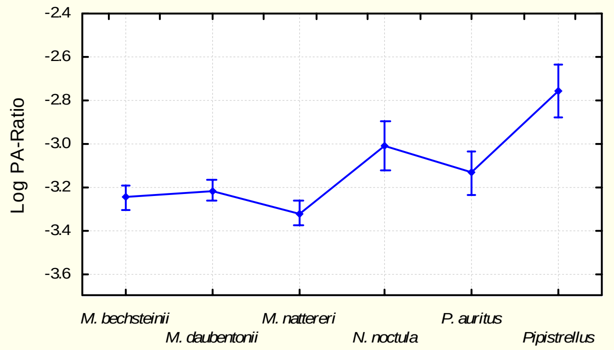

Fig. 30. Mean occupancy rates for ten batbox types calculated from species-based repeated-measures ANOVA. Plots show least squares means and 95% confidence intervals.

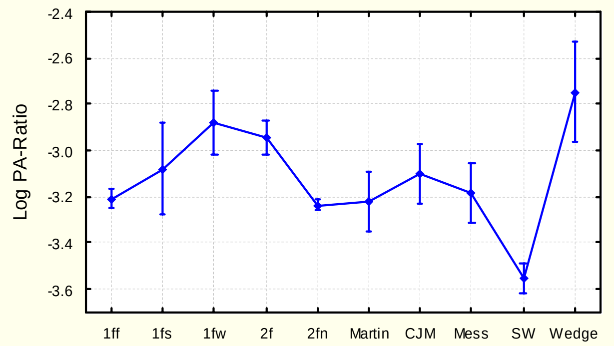

Fig. 31. Mean occupancy rates for ten batbox types calculated from species-based repeated-measures ANOVA. Plots show least squares means and 95% confidence intervals.

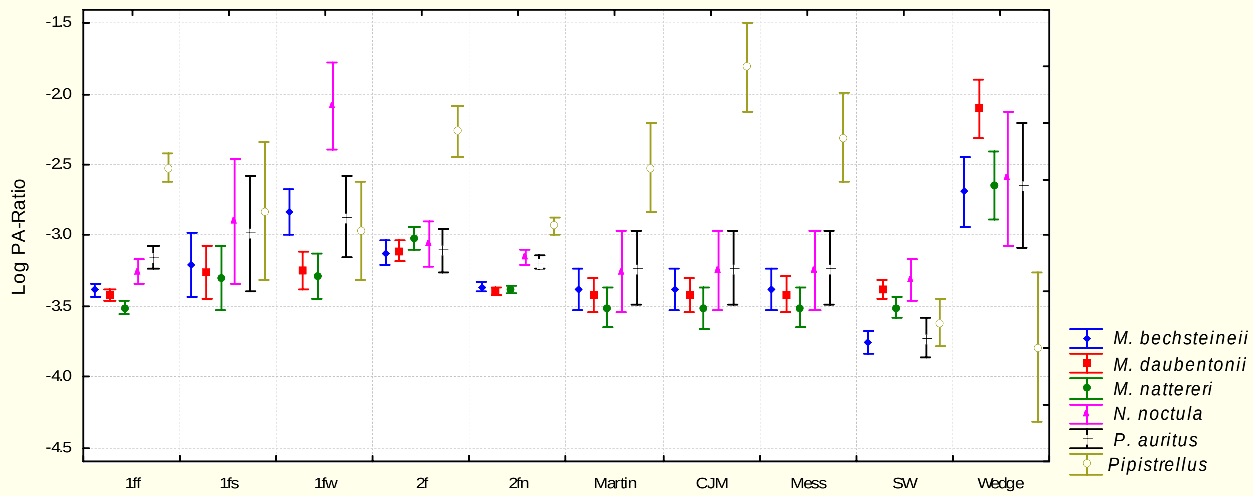

Fig. 32. The interaction between Species and Batbox Type on mean Occupancy rates calculated from the species-based repeated-measures ANOVA. Plots show least squares means and 95% confidence intervals.

interaction between Height and Species was highly significant. In this case, *Nyctalus* behaved differently from the other species with a clear increasing occupancy rate with height, whereas the others displayed no clear patterns.

The results of this analysis indicate that, firstly, it will be informative to analyse species individually and, secondly, that the ANOVA models should contain Box Type and Height as the factors of interest. Consequently, six subsets of the data were created, containing just the sites in which each species was found. For the occupancy response variable, this usually still resulted in sample sizes of many hundreds, but for bat counts and first use which were only calculated for occupied boxes, the sample sizes were often less than 100. This may have resulted in some factors being non-testable.

Myotis bechsteinii

Bechstein's bats were recorded in eight sites, and showed a highly significant difference in both occupancy rate and counts between them. However the patterns between sites for these two response variables were quite different. Occupancy rate was extremely high on Foxholes (Fig. 33a) with approximately 26%. Four other sites had similar occupancies with three (Chase Woods, Fonthill and Garston Woods) with a mean occupancy rate of less than 2%. On the other hand, although the mean bat count in Foxholes was higher than any other site, it was not significantly so. Indeed, the only significant contrasts between sites were the high count in Bracketts Coppice (200 bats per 100 box inspections) compared to Fonthill and Garston Woods (approximately 15 per 100 inspections).

Table 19. Summary of 3-way ANOVAs for *M. bechsteinii*.

		Occupancy (N = 766)		*Bat Count (N = 96)*		*First Use (N = 96)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*
Site	7	424.0	0.0000	10.01	0.0000	1.75	0.1089
Box type	2	19.42	0.0000	26.00	0.0000	0.70	0.4061
Height	3	0.61	0.6081	1.32	0.2733	0.24	0.8684

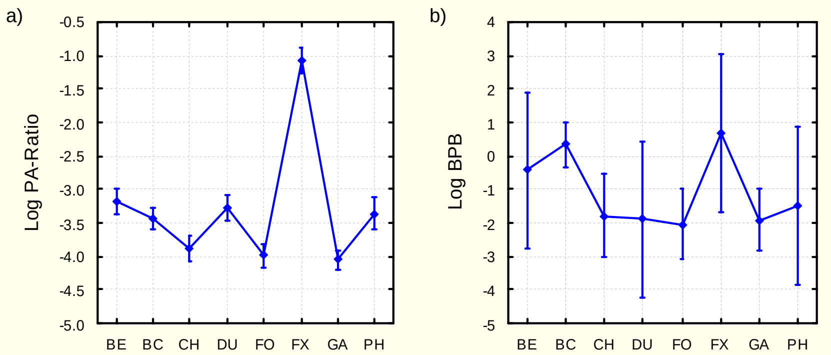

Fig. 33. a) Mean occupancy rates and b) mean bat counts for *M. bechsteinii* on eight sites calculated from 3-way ANOVA. Plots show least squares means and 95% confidence intervals.

Three different batboxes were used in the eight sites, with Bechstein's showing a strong preference. Occupancy was significantly higher in the six 1fw boxes (used in Bracketts Coppice and Garston Woods) with a mean rate of approx. 7.4%, than the 2fn (3.3%) or the SW, (although the untransformed least-squares mean was calculated from the model at 2.2%, in fact the true occupancy rate of the SW box type was zero). As a result, bat counts could only be contrasted between the 1fw and 2fn types with only three of the former. Nevertheless, a significant difference was found with a mean count of over 200 bats per 100 inspections in the 1fw, compared to around 7 per 100 inspections in the 2fn.

No significant differences in any of the three response variables was found for batbox height.

Myotis daubentonii

Daubenton's bats were recorded in nine sites and showed a highly significant difference in occupancy rates between them (Table 20). *Post hoc* tests showed four distinct groups, with the highest occupancy rate in Penault (10.9%). This was followed by a group of six sites with a mean occupancy of 3.2%, Garryland with 1.9% and finally High Marks Barn with only 1% (Fig. 34a). Despite this very clear distinction, bat counts and first use were not significantly different between sites.

Table 20. Summary of 3-way ANOVAs for *M. daubentonii.*

		Occupancy (N = 688)		Bat Count (N = 37)		First Use (N = 37)	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*
Site	7	128.1	0.0000	1.37	0.2603	1.97	0.1117
Box type	6	11.65	0.0000	0.92	0.4089	0.41	0.6699
Height	3	2.55	0.0549				

Box type was also a significant factor in determining occupancy rates. Seven different box types were used in these sites, but of those, the 1fs 1fw and Wedge types were only used in small quantities (6, 4 and 9 respectively) and in single sites. Nevertheless, *post hoc* testing showed that the only significant contrast was between the Wedge box type and the others, with the former having a 7.6% occupancy rate compared to between 2% and 3% in the others (Fig. 34b).

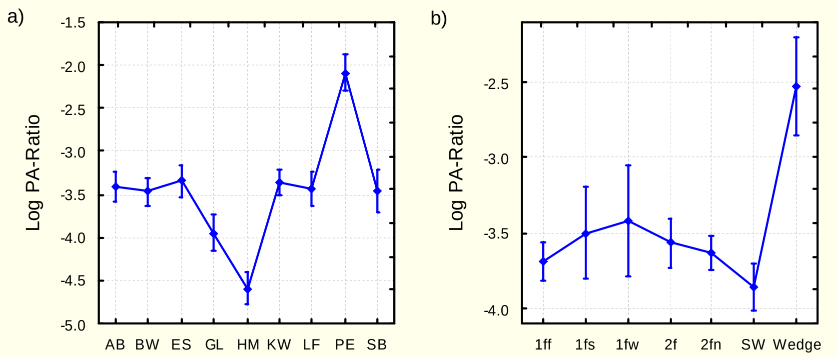

Fig. 34. Mean occupancy rates for *M. daubentonii* in a) nine sites and b) seven box types, calculated from 3-way ANOVA. Plots show least squares means and 95% confidence intervals.

Although this result should be treated with some caution, because Wedge boxes were only used in Shaky Bridge, a subsidiary analysis of this site alone comparing the twelve 2f types with the nine Wedge boxes, confirmed the difference. Despite a very small sample size the mean occupancy rate of 7.2% in the Wedge boxes was significantly higher than the 3.1% in the 2f types (p = 0.0039) so, it does appear that when they have a choice, Daubenton's bats prefer Wedge type boxes to other types.

Myotis nattereri

Natterer's bats were found in a total of 18 sites, although in 11 of these they were only found in one or two batboxes. However, in contrast to the other two *Myotis* species, all three response variables were highly significantly different across sites (Table 21). Most importantly, Foxholes and Grey Park Wood stood out with much higher occupancy rates than all other sites, with 27% and 13% respectively (Fig. 35a). No other exclusively homogeneous groups could be identified, but the three sites with the lowest occupancy rate (Bracketts Coppice, Fonthill and High Marks Barn) had between 1.3% and 1.5% occupancy.

Table 21. Summary of 3-way ANOVAs for *M. nattereri.*

		Occupancy (N = 1583)		Bat Count (N = 101)		First Use (N = 101)	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*
Site	17	594.0	0.0000	9.84	0.0000	9.95	0.0000
Box type	6	14.03	0.0000	0.07	0.9296	1.05	0.3539
Height	3	3.85	0.0093	0.03	0.9751	15.32	0.0000

Bat counts were also significantly different between sites although, due to the much smaller sample size, it was more difficult to distinguish contrasts. Breach Wood and Corf Bluff had the two highest mean counts with approximately 85 and 65 counts per 100 inspections respectively. These were significantly higher than Bracketts Coppice and Garston Woods, with about 3 bats per 100 inspections.

Finally, days to first use was also highly significant, unlike the other two *Myotis* species (Fig. 35b). Interestingly, the differences between sites did not appear to explain much of the variation in occupancy rate. For example, Foxholes had the quickest use with a mean of about 20 days, the other site with high occupancy (Grey Park Woods) had a mean of 55 days, which was not distinguishable from nine other sites. In contrast, Aberedw and Breach Wood had average occupancy rates, but very slow use (an average of around 10 years before use).

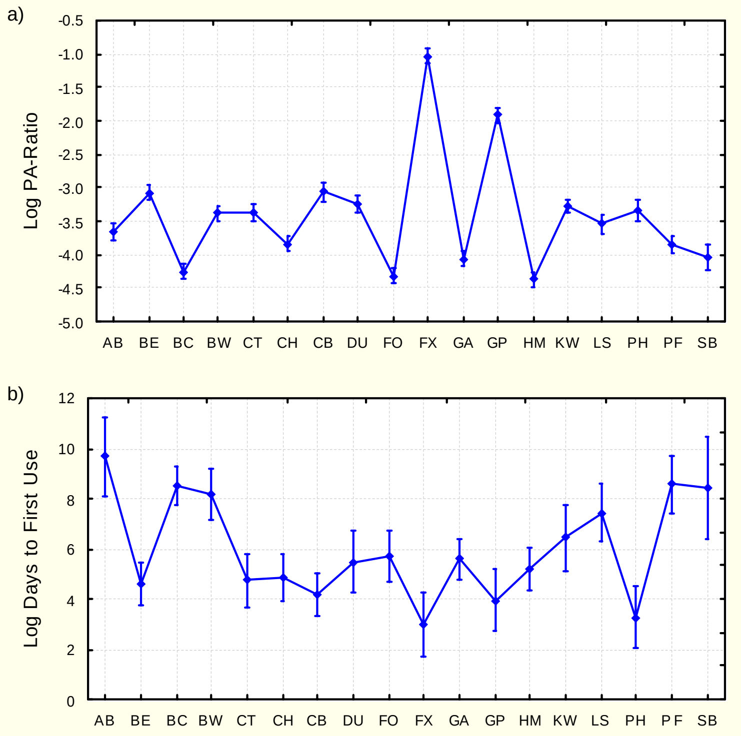

Fig. 35. a) Mean occupancy rates and b) days to first use for *M. nattereri* across 18 sites, calculated from 3-way ANOVAs. Plots show least squares means and 95% confidence intervals.

Of most interest though is Box Type, which was a significant predictor of occupancy rates, but not the other response variables (Fig. 36). Seven different types were used, but two of them, 1fs and Wedge types were only used in only one site each. Nevertheless, within the five concrete types, there was a significantly greater occupancy rate in the 2f (4.3%) compared to the 1ff and 2fn types (2.7% and 2.2% respectively). The latter boxes were used in hundreds across several sites in common, so their difference is probably truly significant. There also appeared to be a significant difference between the two wooden types, although they were used in different sites. In summary, it appears that Natterer's bats preferred 2f boxes when available (and possibly Wedges as well) but actively avoided 1ff types.

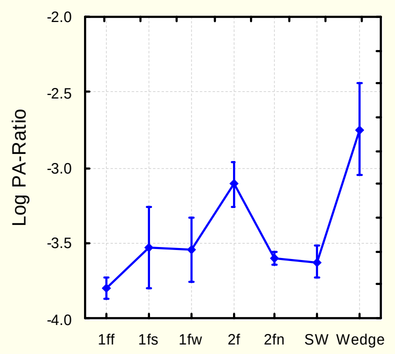

Fig. 36. Mean occupancy rates for *M. nattereri* in seven box types, calculated from 3-way ANOVA. Plots show least squares means and 95% confidence intervals.

Natterer's also differed from the other *Myotis* species by appearing to respond to the height of the boxes (Table 21). Occupancy rate was just significantly different (using our conservative α levels), although it was difficult to interpret this from the least-squares means. However, by utilising the weighted means, it appears that there was a clear and continuous decline in occupancy with height. At 4m or less, occupancy was approximately 3%, declining to only 1.6% at 7m or over.

However, first use was also highly significant, but did not explain occupancy. Boxes set at 4m or less had mean days to first use of over 3000, compared to only 180 for boxes set at 7m or over. This may have been due to the small sample size (104 boxes only), but the effect is still highly significant.

Nyctalus noctula

Noctules were found in 25 sites and showed highly significant differences in both occupancy rate and counts (Table 22). The complexity of these relationships is shown in Fig. 37. As with M. *nattereri* Foxholes had the highest occupancy rate (33%), significantly greater than Grey Park Wood, next with 17.5%. Two other sites, Leckwith Wood and Penault also had high occupancy rates (around 15%) which were significantly higher than all other sites except Plas Tan Y Bwlch. At the other end of the scale, Fonthill had an occupancy rate of only about 2%. The majority of sites (16) were not significantly different with occupancy rates between 3% and 5.5%.

Bat counts had a different pattern between sites (Fig. 37b). Leckwith Wood and Erwood station had the highest counts with a mean of approximately 65 bats per 100 box inspections. Foxholes, Grey Park Wood and Plas Tan Y Bwlch also had high bat counts, but single boxes in these sites meant that their calculated confidence limits were very wide. Bracketts Coppice had the lowest mean count with 4.5 bats per 100 inspections, with tight confidence limits. Similarly Breach Wood, King's Wood and Pencelly Forest had low counts (around 9 or 10 bats per 100 inspections), which were significantly less than the two highest sites.

Table 22. Summary of 3-way ANOVAs for *N. noctula*.

		Occupancy		*Bat Count*		*First Use*	
		(N = 1697)		*(N = 379)*		*(N = 380)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*
Site	24	424.0	0.0000	10.01	0.0000	2.23	0.0009
Box type	5	9.24	0.0000	8.17	0.0000	4.93	0.0002
Height	3	4.27	0.0052	1.21	0.3058	3.53	0.0151

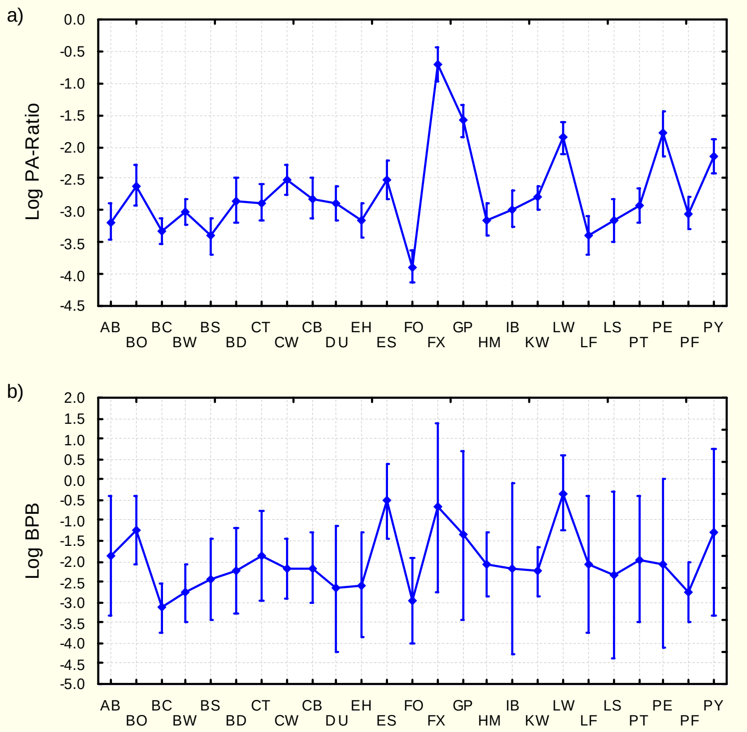

Fig. 37. a) Mean occupancy rates and b) bat count for *N. Noctula* across 25 sites, calculated from 3-way ANOVAs. Plots show least squares means and 95% confidence intervals.

Six different box types were used in these 25 sites and all three response variables showed a significant difference between types (Fig. 38). However, the patterns were very different. Firstly occupancy was significantly higher in the 1fw boxes (18.2%) than all others, which were not significantly different from each other at around 5%. Bat counts were also significantly greater in 1fw boxes (with a calculated mean of over 90 bats per 100 inspections) than all other types, ignoring the single 1fs box. However, the five 2f boxes also had significantly lower bat counts (only 1 per 100 inspections) than the 1ff or 2fn boxes, both of which had substantial sample sizes. Finally, the Time to First Use variable showed yet another pattern, with no significant difference between the concrete boxes with a mean time to first use of around 550 days. However, the 23 SW boxes had a mean of five years, which was significantly greater than the 1ff, 1fw and 2fn box types.

As detected in the Multi-species Analysis, there was a significant effect of box height on occupancy rates for noctules, although this model showed only a marginal effect. Nevertheless, the calculated least-squares means show a very clear trend of increasing occupancy with height (Fig. 39). At 4m or less, mean occupancy rate was 5.0%, rising to 7.2% at 7m or above.

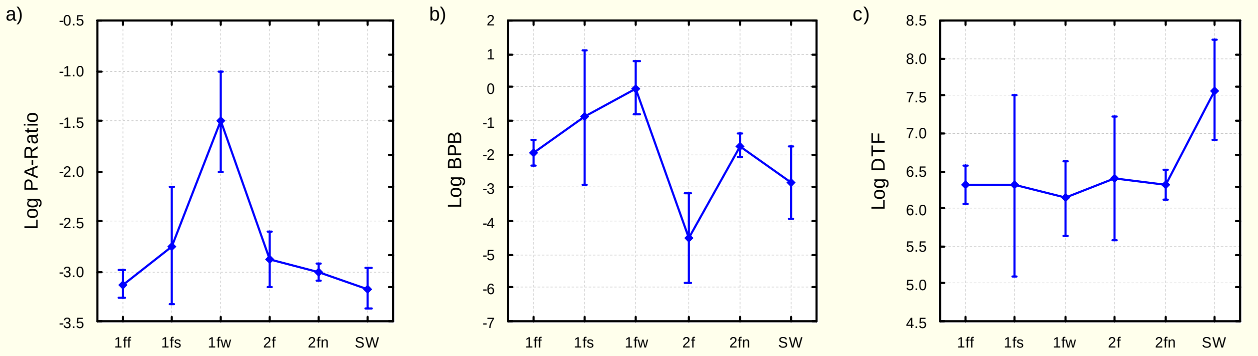

Fig. 38. Mean a) occupancy rates, b) bat counts and c) days to first use for *N. noctula* in six box types, calculated from 3-way ANOVAs. Plots show least squares means and 95% confidence intervals.

Plecotus auritus

Brown long-eared bats were found in 40 sites and were the most commonly recorded species in the survey. Although their overall mean occupancy rate was only around 4%, the mean count in 679 boxes was approximately 28 per 100 box inspections. Both these variables showed highly significant variation between sites (Table 23).

As with previous species, Foxholes had the highest occupancy rate (with about 23%), significantly greater than any other site. This was followed by a group of five sites (Chambers Farm, Consall NP, Grey Park Wood, Old Country Wood and Penault) that had a mean occupancy rate of around 10%, which was higher than all other sites. High Marks Barn stood out as having a significantly lower occupancy rate (1.4%) than all other sites.

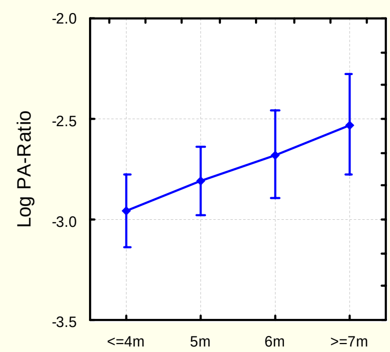

Fig. 39. Mean occupancy rates for *N. noctula* in boxes set at four different height categories, calculated from 3-way ANOVA. Plots show least squares means and 95% confidence intervals.

The pattern for bat counts was quite different, although Foxholes still had a significantly higher count than most other sites with over 700 bats per 100 box inspections. Few other contrasts were clear, due to the small sample sizes, although Bryanston, High Marks Barn and Knockma, with around 5 bats per 100 inspections, were significantly lower than many other sites.

Nine box types were used in the sites where long-eared bats were recorded. Of these the vast majority were of the 2fn (70%) and the 1ff (19%), although SW boxes comprised 5% of the total. Occupancy rates were significantly different between box types (Fig. 41a), although it is difficult to interpret from the least-squares means where the contrasts lie. This is largely due to the fact that actual occupancy rate for the Martin, CJM and Messenger boxes was zero. So, two conclusions can probably be drawn. Firstly, that there was no significant difference in occupancy rates between the concrete boxes and, secondly, the occupancy rate in the SW boxes (2.4%) was significantly lower than any of the concrete boxes.

Table 23. Summary of 3-way ANOVAs for *P. auritus*.

		Occupancy (N = 2730)		Bat Count (N = 679)		First Use (N = 680)	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*
Site	39	99.22	0.0000	4.24	0.0000	3.68	0.0000
Box type	8	9.74	0.0000	8.74	0.0000	2.55	0.0269
Height	3	2.51	0.0569	0.26	0.8545	1.82	0.1419

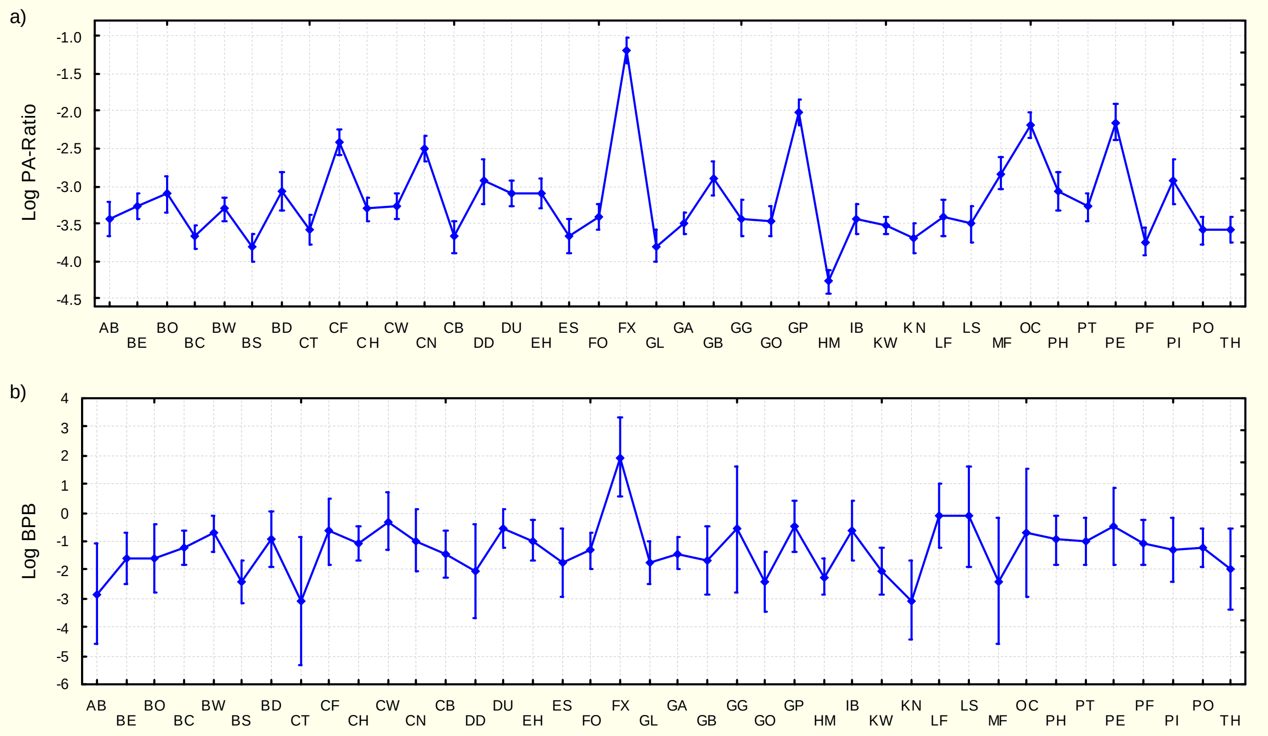

Fig. 40. a) Mean occupancy rates and b) mean bat counts for *P. auritus* across 40 sites, calculated from 3-way ANOVAs. Plots show least squares means and 95% confidence intervals.

The absence of any bats in the Martin, CJM and Messenger box types meant that the comparison of bat counts was restricted to six types (Fig. 41b). The pattern here confirmed that for occupancy, with the only significant contrast being between the 1fw and 2fn concrete types and the SW wooden type. Mean counts were 90, 30 and 8 bats per 100 inspections respectively. The only significant difference between concrete boxes was a significantly lower count (18 bats per 100 inspections) in the 1ff type compared to the 1fw boxes.

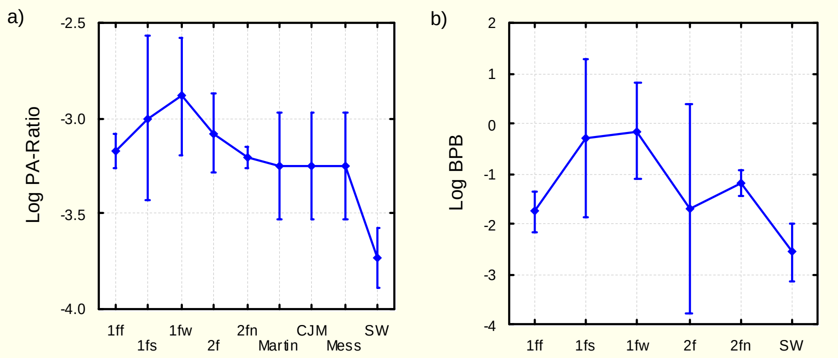

Fig. 41. a) Mean occupancy rates in nine box types and b) bat counts in six types for *P. auritus*, calculated from 3-way ANOVA. Plots show least squares means and 95% confidence intervals.

Pipistrellus

Records of *Pipistrellus* were the most ubiquitous, being found in 50 sites and comprising approximately half of the occupancy records (Fig. 29a). Indeed the highest occupancy rate for any species was found in Foxholes with 27% of box inspections recording pipistrelles (Fig. 42a). Other sites with very high occupancy were Ballykyne (18%) and Grey Park Wood, LlanStephan, Old Country Wood, Penault and Plas Tan Y Bwylch which all had over 12% occupancy.

In contrast, High Marks Barn had a mean occupancy rate of only just over 1%. This was a real effect, not one generated by the least squares ANOVA calculation because, despite a total of over 9,500 box inspections in this site, only 102 yielded pipistrelle records. Other notably low occupancy sites were Bracketts Coppice, Chase Woods, Corfe Bluff, Garston Woods and Tinkers Hill, all with less than 3% occupancy.

Table 24. Summary of 3-way ANOVAs for *Pipistrellus*.

		Occupancy		*Bat Count*		*First Use*	
		(N = 2972)		*(N = 1114)*		*(N = 1110)*	
Effect	*D. F.*	*F*	*p*	*F*	*p*	*F*	*p*
Site	49	85.52	0.0000	10.61	0.0000	5.59	0.0000
Box type	9	35.94	0.0000	15.93	0.0000	7.93	0.0000
Height	3	1.65	0.1750	1.14	0.3331	3.15	0.0243

Bat counts were also very significantly different between sites. The highest mean count was in Foxholes with over 90 bats per 100 inspections, followed by Leckwith Wood and Penault each of which had mean counts of over 60 bats per 100 inspections. Ballykyne, which had the second highest occupancy rate had approximately 45 bats per 100 box inspections. Not surprisingly, High Marks Barn had the lowest mean count with less than

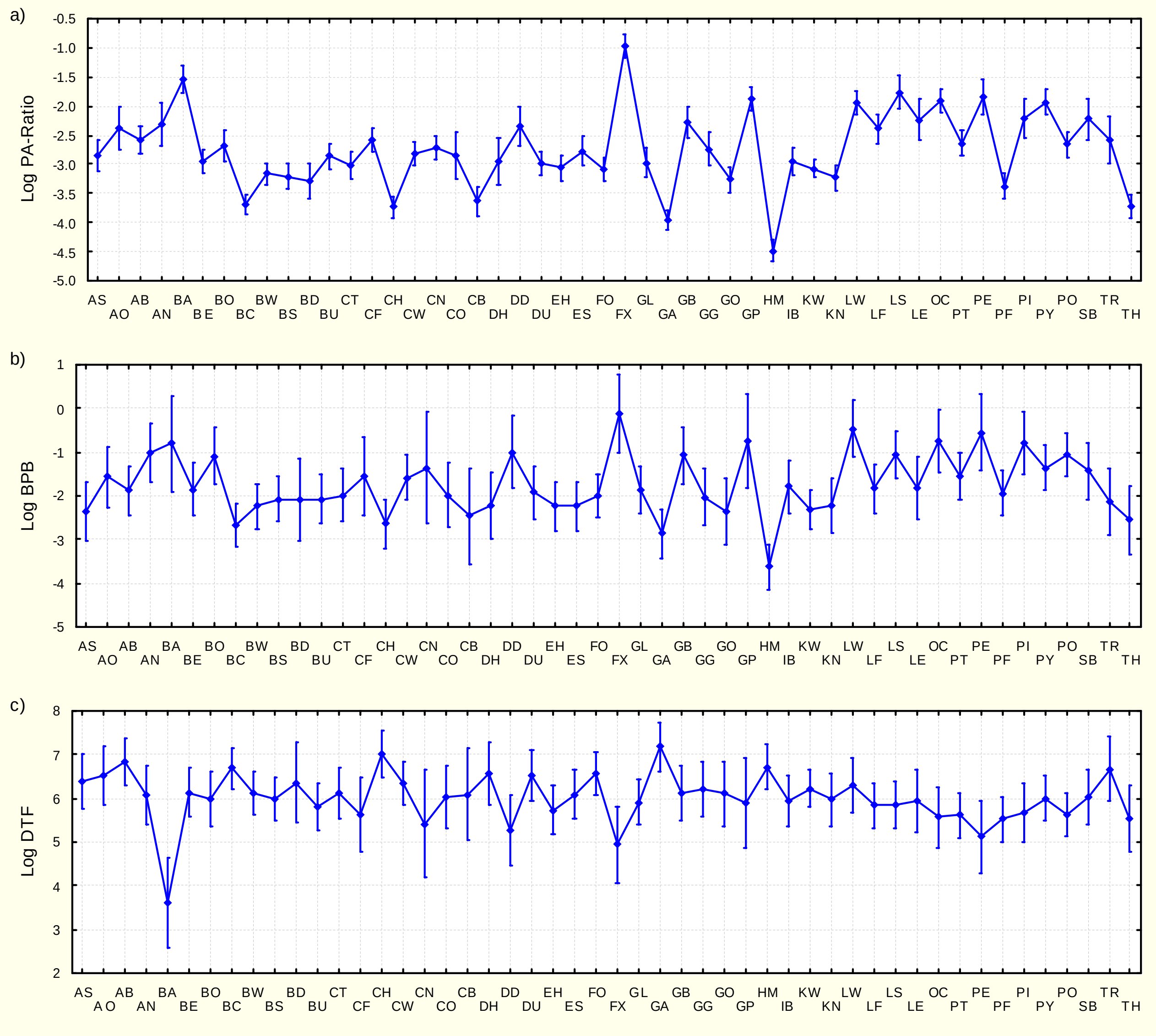

Fig. 42. a) Mean occupancy rates, b) bat counts and c) days to first use for *Pipistrellus* across 50 sites, calculated from 3-way ANOVAs. Plots show least squares means and 95% confidence intervals.

3 bats per 100 inspections, followed by Garston Woods with around 5.5 per 100 inspections.

Finally, the time to first use explained some of the high occupancy rates. For example, Ballykyne had the second highest occupancy rate and pipistrelles were significantly quicker in using boxes in this site (around 40 days) than all but four other sites. Foxholes, with the highest occupancy and counts, was the next quickest with a mean first use of around 140 days, followed by Penault at 170 days. The two sites with the slowest usage rates were Garston woods and Chase Woods, both of which had a mean first use of over three years. Interestingly, High Marks Barn, which stood out as having very low occupancy and bat counts was not unusually slow in being used with a mean of 800 days.

All three response variables were highly significantly different in the ten different box types used in these sites. Overall, the highest occupancy was found in the CJM boxes, although it should be emphasised that these were only used in one site; Tinkers Hill (Fig. 43a). Extracting this site as a subset (with 30 each of four boxes), gave a mean occupancy in the CJM boxes of 5.9% which was significantly higher than the other three types (1ff, Martin and Messenger). The Wedge type was only used in one site, but the SW boxes were used in four sites in reasonable numbers, so the extremely low occupancy (2.7%) was probably a genuine effect. Within the concrete box types, the only significant contrasts were between the 2fn (5.2%) compared to the 1ff (7.8%) and the 2f (10.5%).

Differences in bat counts were also highly significant, but were more difficult to interpret due to smaller sample sizes (Fig. 43b). Again the largest effect was seen between the 2fn boxes with a mean count of only 12 bats per 100 box inspections and the 1ff and 2f boxes with approximately 21 and 35 per 100 inspections respectively. The SW type had significantly lower counts than these three concrete boxes with a mean count of 6.6 per 100 inspections.

Finally, the time to first use also showed a significant difference between box types (Fig. 43c). Small sample sizes obscured any effects for six of the box types. For the remaining four, the only significant contrast was between the 2f boxes which were only taking an average of 150 days to be used, compared to the 1ff (310 days), the 2fn (385 days) and the SW boxes (510 days).

In summary, the only wooden box used on more than one site, the SW, was clearly avoided by pipistrelles, taking longer to be used, and then having lower occupancy rates and bat counts than concrete boxes. Of the three concrete boxes used widely, there was a very strong avoidance of the 2fn types with much lower occupancy and bat counts. In contrast, pipistrelles appeared to favour 2f boxes, by using them much more quickly and then having higher occupancy and counts.

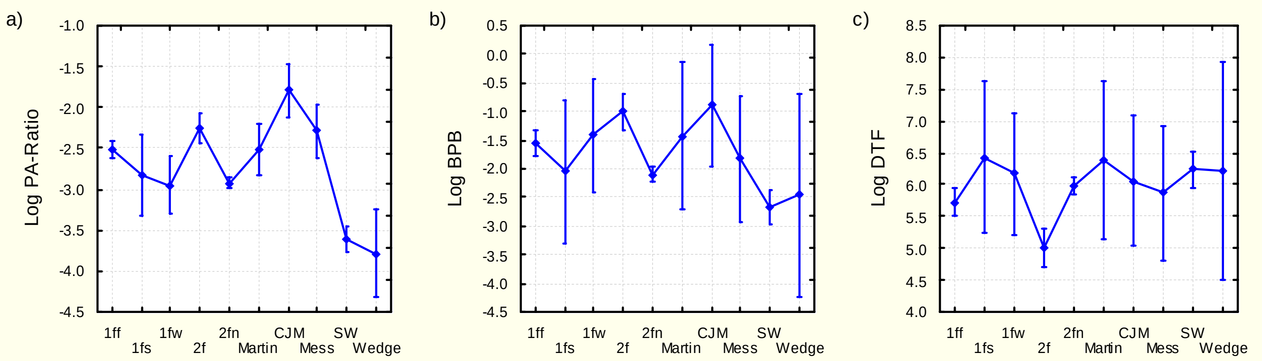

Fig. 43. Mean a) occupancy rates, b) bat counts and c) days to first use for *Pipistrellus* in ten box types, calculated from 3-way ANOVAs. Plots show least squares means and 95% confidence intervals.

Discussion

Summary of Factors Affecting Batbox Usage

Site Factors

The first set of the analyses was carried out at the site level. These analyses were undertaken on all species aggregated together, to give a general picture of batbox usage across all species. This resulted in relatively small datasets with between 31 and 52 cases only, depending on the predictor variables that were recorded in each site. Nevertheless, some significant results were found.

Firstly, for sites in England and Wales only (*i.e.* excluding the five Irish sites) there was a highly significant decline in occupancy rate from west to east, ranging from 15% in Devon and west Wales to only 4% in the midlands and eastern England. There was also a decline, though less significant, in the number of bats per box from west to east. And finally, the number of species per box inspection increased from the south coast to the north midlands. So, clearly, batboxes do reveal significant geographical variation in the population statistics of bats throughout England and Wales.

No other factors recorded at the site level had a significant effect on any of the response variables.

The temporal analysis carried out at the site level showed a number of very significant effects. Firstly, there were very highly significant differences in all three response variables in different months, although the patterns were different for each response variable. Occupancy showed a clear winter trough, with less than 2% in February rising to 10% in August/September. Small sample sizes in the winter months made this trend less clear for bats per box and species per box.

The analysis of year effects was split into annual counts based on winter months and counts based on summer months. From 1999 to 2005 there was a significant difference in occupancy rates during the winter months. In 1999, mean occupancy was around 1.6%, whereas in 2002, 2004 and 2005 this rose to 5.7%. For the six summer months all three response variables showed a highly significant increase from 1999 to 2005. Occupancy rate more than doubled from around 6% to over 13.5% and bats per box increased from about 12 per 100 batbox inspections to over 33.

Tree Factors

This set of analyses was based on a dataset with 1,410 records, representing all the trees used during the survey. Two predictor variables were analysed at this level; location of the tree within the site and the tree species. There were some marginally significant effects of tree location, but they accounted for such a small proportion of the overall variation that they are probably unimportant predictors.

Similarly, tree species did not seem generally to be a significant factor in influencing batbox usage. However, there was a marginal difference in the bat counts in the fifteen sites with boxes on both *Fraxinus* and *Quercus*. Boxes attached to *Fraxinus* had 34 bats per 100 inspections, whereas in boxes attached to *Quercus* there were only 23 per 100 inspections.

Batbox Factors

The bulk of the analyses carried out for this project were undertaken at the batbox level. This yielded a dataset of 3,024 records and the maximum amount of information that could be analysed.

Box type appeared to be the most significant factor influencing all four response variables used for these analyses. However, this general result was strongly influenced by the different numbers of the ten different boxes used. The two most frequently used boxes were the 1ff and 2fn types, comprising over 90% of all records. There was a highly significant difference in occupancy rate between these two types, with approximately 12.9% in 1ff boxes compared to only 8.5% in the 2fn type. This may have been partially explained by the time to first use. In 1ff boxes this averaged 300 days, whereas in 2fn boxes it was 450 days.

The 2fn type was also used as a reference for the less frequently used boxes, by selecting those sites where both types were placed. The 1fw type was used in five sites alongside the 2fn and had significantly higher occupancy rates (23% compared to 7.6%) Bat counts were also over five times higher in 1fw boxes, with over 165 bats per 100 inspections compared to 32 for 2fn boxes.

The SW wooden box type was used in four sites alongside the 2fn. In this case though, the wooden boxes had significantly lower occupancy rates (5.7%) compared to the 2fn (22.3%). This may have been partially explained by much greater time to first use in the SW boxes. The ANOVA model predicted 850 days for the wooden box compared to only 270 for the 2fn type.

Temporal effects were analysed at the batbox level by using a predictor variable which was the number of days set before inspection. For all three response variables there was a very highly significant increase with the length of time that the box had been set. For example, in boxes set for less than a year bat counts were approximately 22 per 100 box inspections, but in boxes which had been set for over four years the count was around 60 per 100 inspections.

Summary of Individual Species Analyses

Six species/genera were analysed individually, using occupancy rate, bat counts and time to first use as the response variables. Table 25 shows the effects on these response variables of site, box type and height as predictors of each species. The first column gives the overall mean of the response variable for each species. So, for example, mean occupancy rate for Bechstein's bats across all sites in all years and all box types was 3.0% Similarly, the mean bat count for this species across all sites, *etc.*, was 13.8 bats per 100 inspections.

Site effects are shown in the next three columns. Firstly, the significance of the effect is shown, colour-coded as explained in the section "Alpha levels" in the Introduction. If the effect is significant, the maximum and minimum mean values are shown from a one-way breakdown. So, for example, Bechstein's bats had their highest mean occupancy rate in Foxholes (23.4%) and their lowest rate in Garston Woods (1.3%). The next three columns show the equivalent results for the effect of box type and the last column shows the effect of box height. As the latter was a continuous variable, when significant, it is simply marked as a positive or negative relationship.

This table shows that all six species groups had significantly different occupancy rates across sites. Two sites stood out, with five of the six species having their highest occupancy in Foxholes, and four having their lowest in High Marks Barn. Occupancy was also highly significantly different for all species across box types. The height at which boxes were set appeared to be less important, although Natterer's bats showed a significantly higher occupancy rate in lower boxes and noctules showed a marginally significant preference for higher boxes.

Differences in bat counts were also largely significant across sites and box types, with the notable exception of Daubenton's bats. Also, Natterer's bats did not appear to have a preference for any particular box types. Finally, the time to first use was a much more variable statistic, with no apparent effects in Bechstein's and Daubenton's. Natterer's showed a highly significant difference between sites and appeared to take significantly longer to use high boxes than lower ones.

Table 25. Summary of species analyses for a) Occupancy Rates, b) Bat Counts and c) Time to First Use.

	Overall weighted mean	*Site Effect*			*Box Type Effect*			*Height Effect*
		Sig.	*Max*	*Min*	*Sig.*	*Max*	*Min*	
a) Occupancy								
M. bechsteinii	3.0%	***	Foxholes 23.4%	Garston Woods 1.3%	***	1fw 6.9%	SW 2.2%	NS
M. daubentonii	2.2%	***	Penault 10.9%	HMB 1.0%	***	Wedge 7.4%	SW 2.1%	NS
M. nattereri	2.7%	***	Foxholes 26.3%	HMB 1.2%	***	Wedge 6.0%	1ff 2.2%	** -ve
N. noctula	4.0%	***	Foxholes 33.2%	Fonthill 2.0%	***	1fw 18.1%	SW 4.0%	* +ve
P. auritus	3.9%	***	Foxholes 23.3%	HMB 1.4%	***	1fw 5.3%	SW 2.3%	NS
Pipistrellus	4.8%	***	Foxholes 27.7%	HMB 1.1%	***	2f 9.5%	2fn 5.2%	NS
b) Bat Counts	*Bats per 100 inspections*							
M. bechsteinii	13.8	***	Foxholes 196	Fonthill 12.9	***	1fw 190	2fn 6.3	NS
M. daubentonii	34.5	NS			NS			NS
M. nattereri	19.3	***	Breach Wood 74	Shaky Bridge 2.2	NS			NS
N. noctula	11.7	***	Leckwith Wood 72	Bracketts Cop. 4.4	***	1fw 98	2f 1.1	NS
P. auritus	27.7	***	Foxholes 703	Castle Top 4.6	***	1fw 85	SW 7.7	NS
Pipistrellus	12.9	***	Foxholes 88	HMB 2.7	***	2f 36	SW 6.9	NS
c) First Use	*Days*							
M. bechsteinii	840	NS			NS			NS
M. daubentonii	1188	NS			NS			NS
M. nattereri	944	***	Castle top >5000	Bracketts Cop. 20	NS			*** -ve
N. noctula	766	**	Duncliffe Wood 1737	Foxholes 140	**	SW 1949	1fw 469	NS
P. auritus	633	***	Aberedw 2000	Foxholes 82	NS			NS
Pipistrellus	452	***	Garston Woods 1310	Ballykyne 37	***	1fs 600	2f 150	NS

Outline Recommendations for Future Fieldwork

These analyses have highlighted many of the problems with extracting useful information from severely unbalanced datasets. These often arise for perfectly understandable reasons, such as the evolution of a project over time with changing priorities, individual site restrictions, time and effort constraints on staff and unexpected problems such as loss of boxes. However, if the main objective of a study is explicitly to test hypotheses about batbox usage, rather than a more general aim to gather data on bats in batboxes, then it is essential to structure the survey more rigorously. This also has the advantage that hypotheses can often be tested with greater power and with less effort in a well-designed experiment. The overall objective will be to test hypotheses of practical rather than theoretical interest, such as:

- The type of box. Restrict this to three or four basic types
- The height and orientation of boxes on trees
- The type of woodland. Try to restrict this to three or four basic types, such as conifer plantation, semi-natural ancient woodland, hazel coppice with oak or chestnut standards and riparian woodland with alder or willow
- The location and species of trees within woodlands.

In addition to testing these specific hypotheses, it will be necessary to gather data on geographical and temporal variation. This will ensure that the results have a generality and robustness to be of universal interest rather than just applicable to a few sites, or the result of aberrant years.

The following recommendations are based on the assumption that the survey will continue for a number of years and that there is no requirement for all the current sites to be retained. Furthermore, although the design is fairly constrained, the actual numbers recommended could be modified.

- Select 10 sites, with convenient locations, which can be retained confidently for a number of years. They should be located with a good geographical spread, for example, two in each of Galway, mid-Wales, the midlands, the south-west and the Dorset/Hampshire area. Avoid sites with extreme characteristics such as altitude or proximity to urban/industrial areas, unless these are questions of particular interest.
- In each site, select 20 trees, preferably only of specific genera. Clearly, this will be dependent on the sites, but try to include several genera in all sites. Also, select trees in all parts of the woodland, if possible using a grid-based system to ensure a random or regular location.
- Establish the number of boxes per tree. For example, if there are four different box types being tested it would be sensible to decide on one of each type per tree.
- Within the constraints of the size of the tree, randomly locate each box at a unique height and orientation. For example, the range of available heights might be 2.5m to 6m at 0.5m intervals giving eight unique heights. Similarly, the orientation might be based on eight points of the compass. To ensure an even spread of locations, both within trees and between them, for each tree place each box randomly at one of four heights, each 1m apart either on the metre or half metre scales, and each at one of four-points of the compass, either N-S or NE-SW orientation. This will ensure a full crossing of box type, height and orientation both within and between sites.
- If possible, arrange for sites to be visited entirely within one day on a bi-monthly basis. This halves the amount of effort compared to monthly, and probably still gives a sufficiently detailed pattern throughout the year.
- Continue the survey for at least two whole years and preferably four to five to account for aberrant seasonal or year effects.

This design would require a total of 800 boxes, 200 of each of four types. They would be located on 200 trees and over a five-year period visited 30 times. This would result in 24,000 batbox visits, which is about 40% of the current survey's effort. However, this would allow a much more powerful analysis of the effects of these factors and should allow firm recommendations to be made on the practicalities of locating and setting batboxes.

There may be additional questions that would be of interest to investigate. For example, if the aim of using batboxes is as a research tool, then it would be very interesting to know how variable the records are over a short period of time or at various times of day. Instead of a single visit six times a year, one visit in winter and one in summer could be expanded to, say, three visits on adjacent days. For the purpose of the main analysis, these could be aggregated or just the first visit used. This might also give some indication of the effect of the inspection on the bats. Similarly, the time of day that each box was visited could be controlled in a systematic way, or at least recorded, so that this effect could be evaluated.

If the main aim of setting the boxes is as a conservation tool to provide suitable habitat for bats and so increase their local populations, it would be necessary to have an independent measure of bat presence. This could be achieved by manually recording bats using bat detectors, or setting up automatic recording stations. In this way, it would be possible to compare spatial and temporal variation in batbox usage with estimates of actual bat presence in the woods.

It should be emphasised that these recommendations are simply broad outlines and will obviously be influenced by specific VWT requirements and constraints.

Appendices

Appendix I

Site-based Predictor Variables

Site Name	Region	E	N	Woodland Type	Woodland Structure	DBH	Understorey	Age Structure	Altitude (m.)
Abbotstanding	England	437	103	Ancient semi-natural	Coppice with Standards	108	Moderate	Diverse	50
Abercamlo	Wales	308	265	Riparian	High Forest				
Aberedw	Wales	308	247						
Aberithon	Wales	301	256	Riparian	High Forest				
Ballykyne	Ireland	-73	417	Conifer Plantation					40
Bentley Wood	England	425	130	Ancient replanted	Coppice with Standards	113	Sparse	Even-aged	78
Boultibrooke	Wales	331	266	Ancient semi-natural	High Forest	156	Sparse	Diverse	100
Bracketts Coppice	England	351	107	Ancient replanted	Coppice with Standards	99	Moderate	Diverse	100
Breach Wood	England	341	130	Broad-leaved replanted	Coppice with Standards	91	Moderate	Diverse	100
Bryanston	England	388	106	Mixed	High Forest	104	Sparse	Diverse	50
Buckland	Wales	313	221	Ancient semi-natural	High Forest				
Burley	England	424	104	Ancient semi-natural	High Forest	175	Sparse	Even-aged	40
Castle Top	England	420	103	Ancient semi-natural	High Forest	139	Sparse	Even-aged	80
Chambers Farm	England	516	374	Mixed		80	Sparse	Even-aged	80
Chase Woods	England	398	119	Ancient replanted	Rotational Coppice	96	Dense	Diverse	138
Cleeve Wood	England	347	166	Broad-leaved replanted	Coppice with Standards	133	Sparse	Diverse	100
Consall Nature Park	England	399	348	Broad-leaved replanted	High Forest	98	Moderate	Diverse	158
Coole	Ireland	-42	365	Ancient replanted	Coppice with Standards				40
Corfe Bluff	England	395	83	Mixed	Coppice with Standards	53	Sparse	Even-aged	30
Disserth	Wales	303	258	Riparian	High Forest				
Duck Decoy	England	462	215	Ancient semi-natural	Coppice with Standards	95	Moderate	Diverse	100
Duncliffe Wood	England	382	122	Mixed	Coppice with Standards	95	Moderate	Diverse	110
Earls Hill	England	341	305	Ancient semi-natural	High Forest	115	Moderate	Diverse	
Erwood Station	Wales	309	244						
Fonthill	England	396	131	Ancient replanted	Coppice with Standards	94	Moderate	Even-aged	150
Foxholes	England	441	247	Ancient replanted	High Forest	89	Sparse	Even-aged	100

Site-based Predictor Variables (cont.)

Site Name	*Region*	*E*	*N*	*Woodland Type*	*Woodland Structure*	*DBH*	*Understorey*	*Age Structure*	*Altitude (m.)*
Garryland	Ireland	-43	364	Ancient replanted	Coppice with Standards				40
Garston Woods	England	400	120	Ancient replanted	Rotational Coppice	92	Dense	Diverse	113
Great Breach Wood	England	350	132	Broad-leaved replanted	Coppice with Standards	111	Moderate	Diverse	110
Great Goswell	England	439	104	Ancient replanted	Coppice with Standards	99	Sparse	Even-aged	40
Great Ovens	England	392	91	Conifer Plantation	Heath	41	Sparse	Even-aged	20
Grey Park Wood	England	272	73	Ancient semi-natural	High Forest	126	Dense	Diverse	160
High Marks Barn	England	274	53	Mixed	High Forest	116	Dense	Diverse	117
Icen Barrow	England	392	84	Conifer Plantation	Heath	40	Sparse	Even-aged	20
King's Wood	England	346	165	Ancient replanted	Coppice with Standards	112	Moderate	Diverse	100
Knockma	Ireland	-49	408	Ancient replanted	Coppice with Standards				100
Leckwith Wood	Wales	316	174	Ancient semi-natural	High Forest				
Llanfaredd	Wales	307	251						
Llanstephan	Wales	311	242						5
Llanyre	Wales	305	262	Riparian	High Forest				
Mount Fancy	England	325	117	Ancient semi-natural	Coppice with Standards	97	Moderate	Diverse	270
Old Country Wood	England	372	244	Ancient semi-natural	High Forest	40	Moderate	Even-aged	100
Paddockhurst	England	531	134	Broad-leaved replanted	Coppice with Standards	91	Sparse	Even-aged	140
Penallt2	England	352	210	Ancient semi-natural	Coppice with Standards				
Penault	England	352	211	Ancient semi-natural	Coppice with Standards	85	Moderate	Even-aged	100
Pencelly Forest	Wales	213	239	Ancient semi-natural	Coppice with Standards				
Piddington	England	463	216	Ancient semi-natural	Coppice with Standards	93	Sparse	Even-aged	120
Plas Tan Y Bwlch	Wales	266	341	Ancient replanted	High Forest				
Portumna	Ireland	-41	365	Ancient replanted	Coppice with Standards				40
Shaky Bridge	England	308	261						
The Rocks	Wales	303	253	Riparian	High Forest				
Tinkers Hill	England	377	240	Ancient semi-natural	High Forest	88	Moderate	Diverse	200

Appendix II

a) Numbers of Trees per Site

The number of trees per site on which batboxes were erected. Sites marked with * had no spatial location data and the site marked # had no tree species data recorded.

Site	Tree Count	Site	Tree Count
Abbotstanding	11	Garryland	25
Abercamlo	6 *	Garston Woods	38
Aberedw	14 *	Great Breach Wood	15
Aberithon	6 *	Great Goswell	14
Ballykyne	20	Great Ovens	25
Bentley Wood	49	Grey Park Wood	47
Boultibrooke	11 #	High Marks Barn	62
Bracketts Coppice	31	Icen Barrow	24
Breach Wood	41	King's Wood	86
Bryanston	30	Knockma	21
Buckland	10 *	Leckwith Wood	25 *
Burley	23	Llanfaredd	9 *
Castle Top	26	Llanstephan	6 *
Chambers Farm	50	Llanyre	6 *
Chase Woods	68	Mount Fancy	17
Cleeve Wood	26	Old Country Wood	50
Consall Nature Park	50	Paddockhurst	12
Coole	5	Penallt2	27 *
Corfe Bluff	20	Penault	10
Disserth	6 *	Pencelly Forest	35 *
Duck Decoy	8	Piddington	7
Duncliffe Wood	45	Plas Tan Y Bwlch	50 *
Earls Hill	25 *	Portumna	32
Erwood Station	6 *	Shaky Bridge	6 *
Fonthill	58	The Rocks	6 *
Foxholes	50	Tinkers Hill (Berington)	60

b) Breakdown of Trees by Species/Genus/Group.

Type	*Genus*	*Species*	*Common Name*	*No. of Trees*
Broadleaf	Acer	Acer campestre	Field maple	7
Broadleaf	Acer	Acer pseudoplatanus	Sycamore	24
Broadleaf	Aesculus	Aesculus hippocastanum	Horse chestnut	1
Broadleaf	Alnus	Alnus glutinosa	Alder	30
Broadleaf	Betula	Betula pendula	Silver birch	23
Broadleaf	Betula	Betula sp.	Birches	13
Broadleaf	Castanea	Castanea sativa	Sweet chestnut	45
Broadleaf	Fagus	Fagus sylvatica	Beech	142
Broadleaf	Fraxinus	Fraxinus excelsior	Ash	286
Broadleaf	Ilex	Ilex aquifolium	Holly	1
Broadleaf	Platanus	Platanus acerifolia	London plane	5
Broadleaf	Populus	Populus canescens	Grey poplar	2
Broadleaf	Populus	Populus sp.	Poplars	9
Broadleaf	Prunus	Prunus sp.	Prunus	2
Broadleaf	Quercus	Quercus petraea	Pedunculate oak	10
Broadleaf	Quercus	Quercus robur	English oak	72
Broadleaf	Quercus	Quercus sp.	Oaks	548
Broadleaf	Salix	Salix sp.	Willows	1
Broadleaf	Tilia	Tilia cordata	Small-leaved lime	10
Broadleaf	Tilia	Tilia sp.	Limes	6
Conifer	Abies	Abies sp.	Firs	81
Conifer	Pinus	Pinus nigra	Corsican pine	9
Conifer	Pinus	Pinus sp.	Pines	2
Conifer	Pinus	Pinus sylvestris	Scottish pine	69
Conifer	Ptsuga	Pseudotsuga menziessi	Douglas fir	9
Unidentified				13

Appendix III

Number of batboxes used in each site, with breakdown by box category and type.

Site	Concrete						Wooden				Totals
	1ff	1fs	1fw	2f	2fn	Martin	CJM	Mess.	SW	Wedge	
Abbotstanding	0	0	0	0	25	0	0	0	0	0	**25**
Abercamlo	0	0	0	6	6	0	0	0	0	0	**12**
Aberedw	0	0	0	14	6	0	0	0	25	0	**45**
Aberithon	0	0	0	6	6	0	0	0	0	0	**12**
Ballykyne	0	0	0	0	40	0	0	0	0	0	**40**
Bentley Wood	0	0	0	0	100	0	0	0	0	0	**100**
Boultibrooke	0	0	0	0	25	0	0	0	0	0	**25**
Bracketts Coppice	0	0	4	0	80	0	0	0	0	0	**84**
Breach Wood	0	6	3	0	90	0	0	0	0	0	**99**
Bryanston	30	0	0	0	30	0	0	0	0	0	**60**
Buckland	0	0	0	0	20	0	0	0	0	0	**20**
Burley	0	0	0	0	50	0	0	0	0	0	**50**
Castle Top	0	0	0	0	50	0	0	0	0	0	**50**
Chambers Farm	100	0	0	0	0	0	0	0	0	0	**100**
Chase Woods	0	0	0	0	150	0	0	0	0	0	**150**
Cleeve Wood	30	0	0	0	30	0	0	0	0	0	**60**
Consall Nature Park	100	0	0	0	0	0	0	0	0	0	**100**
Coole	0	0	0	0	10	0	0	0	0	0	**10**
Corfe Bluff	0	0	0	0	40	0	0	0	0	0	**40**
Disserth	0	0	0	12	0	0	0	0	0	0	**12**
Duck Decoy	0	0	0	0	15	0	0	0	0	0	**15**
Duncliffe Wood	0	0	0	0	90	0	0	0	0	0	**90**
Earls Hill	10	0	0	0	50	0	0	0	0	0	**60**
Erwood Station	0	0	0	12	2	0	0	0	30	0	**44**
Fonthill	0	0	0	0	52	0	0	0	59	0	**111**
Foxholes	0	0	0	0	97	0	0	0	0	0	**97**
Garryland	0	0	0	0	50	0	0	0	0	0	**50**
Garston Woods	0	0	2	0	90	0	0	0	0	0	**92**
Great Breach Wood	0	0	0	0	30	0	0	0	0	0	**30**
Great Goswell	0	0	0	0	25	0	0	0	0	0	**25**
Great Ovens	0	0	0	0	50	0	0	0	0	0	**50**
Grey Park Wood	0	0	0	0	100	0	0	0	0	0	**100**
High Marks Barn	75	0	1	0	76	0	0	0	0	0	**152**
Icen Barrow	0	0	0	0	51	0	0	0	0	0	**51**
King's Wood	104	0	0	0	104	0	0	0	0	0	**208**
Knockma	0	0	0	0	50	0	0	0	0	0	**50**
Leckwith Wood	0	0	0	0	50	0	0	0	0	0	**50**
Llanfaredd	0	0	0	12	2	0	0	0	27	0	**41**
Llanstephan	0	0	0	12	12	0	0	0	0	0	**24**
Llanyre	0	0	0	6	6	0	0	0	0	0	**12**
Mount Fancy	0	0	0	0	40	0	0	0	0	0	**40**
Old Country Wood	0	0	0	0	100	0	0	0	0	0	**100**
Paddockhurst	0	0	0	0	25	0	0	0	0	0	**25**
Penallt2	5	0	0	0	45	0	0	0	0	0	**50**
Penault	0	0	0	0	22	0	0	0	0	0	**22**
Pencelly Forest	10	0	0	0	50	0	0	0	0	0	**60**
Piddington	0	0	0	0	15	0	0	0	0	0	**15**
Plas Tan Y Bwlch	50	0	0	0	0	0	0	0	0	0	**50**
Portumna	30	0	2	0	30	0	0	0	0	0	**62**
Shaky Bridge	0	0	0	12	1	0	0	0	0	9	**22**
The Rocks	0	0	0	11	1	0	0	0	0	0	**12**
Tinkers Hill (Berington)	30	0	0	0	0	30	30	30	0	0	**120**
Totals	**574**	**6**	**12**	**103**	**2089**	**30**	**30**	**30**	**141**	**9**	**3024**

Appendix IV

a) Breakdown of number of inspections and bat counts by species.

Latin Name	*Common Name*	*Inspections*	*Bat Count*
Chiroptera	Unidentified bat species	23	25
Myotis	Myotis sp.	1	1
Myotis mystacinus	Whiskered bat	15	16
Myotis brandtii	Brandt's bat	2	3
Myotis nattereri	Natterer's bat	139	1315
Myotis bechsteinii	Bechstein's bat	192	2604
Myotis daubentonii	Daubenton's bat	80	988
Myotis mystacinus/brandtii	Whiskered/Brandt's bat	4	4
Eptesicus serotinus	Serotine	8	8
Nyctalus	Noctule/Leisler's	1	1
Nyctalus noctula	Noctule	1158	2750
Nyctalus leisleri	Leisler's bat	133	267
Pipistrellus	Pipistrelle	199	629
Pipistrellus pipistrellus	Pipistrelle (Common)	275	384
Pipistrellus pygmaeus	Soprano pipistrelle	1128	2364
Pipistrellus pipistrellus/pygmaeus	Pipistrelle/Soprano pipistrelle	1423	2608
Barbastella barbastellus	Barbastelle	19	20
Plecotus	Long-eared bats	1	1
Plecotus auritus	Brown long-eared bat	1204	9683
Totals		**6005**	**23671**

b) Distribution of Species Records between Sites

The number of boxes per site in which each species was recorded

Site	*M. bechsteinii*	*M. daubentonii*	*M. nattereri*	*N. noctula*	*P. auritus*	*Pipistrellus*	*Other*
Abbotstanding	0	0	0	0	0	12	0
Abercamlo	0	0	0	0	0	10	0
Aberedw	0	2	1	3	2	29	0
Aberithon	0	0	0	0	0	10	0
Ballykyne	0	0	0	0	0	3	0
Bentley Wood	1	0	10	0	10	21	0
Boultibrooke	0	0	0	9	4	12	0
Bracketts Coppice	57	0	2	51	51	42	1
Breach Wood	0	1	6	22	34	33	1
Bryanston	0	0	0	9	21	49	2
Buckland	0	0	0	5	8	4	0
Burley	0	0	0	0	0	21	0
Castle Top	0	0	2	6	1	21	0
Chambers Farm	0	0	0	0	5	5	0
Chase Woods	5	0	7	0	92	26	1
Cleeve Wood	0	0	0	22	6	30	0
Consall Nature Park	0	0	0	0	6	2	5
Coole	0	0	0	0	0	9	4
Corfe Bluff	0	0	24	24	13	3	0
Disserth	0	0	0	0	0	9	1
Duck Decoy	0	0	0	0	2	6	1
Duncliffe Wood	1	0	1	2	30	20	0
Earls Hill	0	0	0	3	28	25	1
Erwood Station	0	14	0	24	5	26	0
Fonthill	19	0	6	6	70	79	2
Foxholes	1	0	1	1	3	5	0
Garryland	0	10	0	0	26	40	12
Garston Woods	11	0	5	0	69	18	1
Great Breach Wood	0	0	0	0	4	14	0
Great Goswell	0	0	0	0	1	12	0
Great Ovens	0	0	0	0	6	8	0
Grey Park Wood	0	0	1	1	9	3	0
High Marks Barn	0	1	29	78	69	43	13
Icen Barrow	0	0	0	1	6	21	0
King's Wood	0	1	2	63	10	106	11
Knockma	0	0	0	0	3	16	20
Leckwith Wood	0	0	0	8	0	12	0
Llanfaredd	0	7	0	2	6	31	0
Llanstephan	0	0	2	1	2	25	0
Llanyre	0	0	0	0	0	8	0
Mount Fancy	0	0	0	0	1	0	0
Old Country Wood	0	0	0	0	1	10	0
Paddockhurst	1	0	1	0	13	0	0
Penallt2	0	0	0	2	12	31	0
Penault	0	1	0	1	3	5	1
Pencelly Forest	0	0	2	26	17	34	0
Piddington	0	0	0	0	5	10	0
Plas Tan Y Bwlch	0	0	0	1	0	40	0
Portumna	0	0	0	0	30	58	25
Shaky Bridge	0	8	1	0	0	14	2
The Rocks	0	0	0	0	0	8	0
Tinkers Hill	0	0	0	0	3	38	9