Bats as Indicators of Environmental Quality

R&D Technical Report E1-129/TR

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Statement of Use
This report describes the work undertaken to demonstrate that bats are cost-effective indicators of environmental quality. This study has demonstrated that the Daubenton's Bat Waterway survey delivers a waterbody environmental quality index cost effectively through the efficient management of volunteers.

Keywords
Bats, water quality, indicators, monitoring, biodiversity

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EXECUTIVE SUMMARY

The Bat Conservation Trust is delighted that the Environment Agency has enabled the Daubenton's Waterway Survey to take place in this season and presented the opportunity for the Trust to carry out this innovative research and development programme for bats as indicators of environmental quality.

The principal objective of this report is to demonstrate that bats are cost-effective indicators of environmental quality. The specific objectives were:

To demonstrate how bat monitoring and environmental quality datasets can be linked
To show how new technology can incorporate more bat species and also non-bat species on present surveys cost effectively.
To strengthen volunteer involvement through development of a tailored, volunteer management database.

A 'core' model of environmental factors significantly related to Daubenton's bat activity has been developed and insect biodiversity, waterway width & flow rate and the presence of trees have been identified as key factors. This confirms the hypothesis that bats directly indicate environmental waterway quality.

Further research is recommended to identify drivers behind population change and to evaluate the impact of climate change.

An evaluation study successfully introduced new technology into the Daubenton's Waterway Survey to enable several bat species to be surveyed simultaneously and increase the potential for monitoring waterway bat biodiversity. Further research is required to identify ways of reducing long-term costs of this new technology.

The Bat Conservation Trust is now in a position to provide excellent support to volunteers through the development of the Bat Information and Retrieval System.

The database system enhances the ability of BCT to effectively engage in collaborative projects, to manage volunteers in mammal monitoring schemes and to transfer data easily to the NBN.

This study demonstrates that the Daubenton's Bat Waterway survey delivers a waterbody environmental quality index cost effectively through the efficient management of volunteers. Monitoring must be long term to be meaningful and this requires committed long-term funding.

The overall recommendation is for the Environment Agency to continue funding the Daubenton's Waterway Survey and to use the population Index as a robust measure of waterway biodiversity.

1. INTRODUCTION

1.1 Objectives

The objective of this report is to demonstrate cost effective ways to implement a strategy to exploit the potential of bats as indicators of environmental quality.

1.2 Overall Strategy

The main body of the report is presented in three parts corresponding to three distinct, but closely related, project proposals:

1. River Habitat Survey /Daubenton's Bat Waterway Survey Analysis
   Results of the RHS survey analysis combined with the Daubenton's Waterway Survey are presented and show bats have value as indicators of environmental quality.

2. Extending the Scope of the Daubenton's Waterway Survey through the Evaluation of New Technology
   Results of a study to evaluate the feasibility of introducing new technology into the monitoring scheme and an analysis of the costs and benefits.

3. Development of an Integrated Database
   The development of the integrated database has facilitated effective management of volunteers to build on the present capacity and deliver a strategy to maximise the potential of bats as indicators of environmental quality.

1.3 Background on Daubenton's Bats

Bats are important contributors to mammalian biodiversity in the UK. The 16 recorded breeding species form roughly one third of the UK's land mammal fauna and are widely distributed through the range of habitats that form the wider countryside. Exceptionally rapid declines have been recorded in some species culminating in the extinction of the greater mouse-eared bat from the UK in 1993 (Stebbings, 1992). Even the commonest species, the pipistrelle bat, has shown evidence of substantial declines since 1981 (Stebbings 1988). Conservation concerns have resulted in comprehensive legal protection for bats (both national & international) and their transboundary movements resulted in the Agreement on Conservation of Bats (EUROBATS) coming into force in 1993.

The UK National Bat Habitat Survey (Walsh and Harris 1996) identified waterbodies and riparian habitats as important for bats. This close association with water makes them potentially valuable indicator of the health of water quality, insect biodiversity and associated waterside vegetation.

Daubenton's bat is distributed throughout the UK. It roosts close to waterbodies, normally in trees, although occasionally larger colonies congregate in riverside buildings, and feeds on insects just above or directly from the surface of rivers, canals, ponds and lakes.

1.4 Monitoring Daubenton's Bats on UK Waterways

The National Bat Monitoring Programme's Daubenton's bat waterway survey is the UK's current strategy for monitoring bats at waterways on a national level. The survey was established to monitor Daubenton's bat population at waterways throughout the UK in 1997 with funding from the Department of Environment, Food & Rural Affairs (DEFRA), formerly known as DETR. It is organised by the Bat Conservation Trust (BCT) who manage a UK-wide network of volunteer surveyors. In 2001, DEFRA funding ceased and the Joint Nature Conservation Committee (JNCC) have committed funds from 2001 to 2006. See Walsh *et al*, 2001 for overview.

The survey has involved collaboration with the EA's River Habitat Survey (RHS) since 1998. The RHS has collected habitat data at a random selection of waterbodies throughout the UK. The EA made the location of RHS sites available to the BCT and, where possible, survey sites are centred on the RHS sites to ensure optimal allocation of survey sites to participating volunteers. This approach allows an integrated analysis of the datasets to identify linkages between Daubenton's bats and environmental quality (see section 2).

1.5 Daubenton's Waterway Survey Protocol

The site allocation protocol is designed to be representative (where practical) of flowing waterbodies in the UK. Surveyors are allocated a 1km stretch of waterway - the exact location is centred on an RHS site (chosen at random) that is within 20km of the home address of the surveyor. Waterways less than 1m wide are excluded, as they are too small for Daubenton's bat to use. Surveyors are asked to make a day visit to the site to ensure it is safe to survey.

The method is designed to be simple, robust and repeatable to meet the basic principles of monitoring theory. Surveyors are asked to make two night visits to the site in August and to use an ultrasonic, heterodyne detector with a torch to identify Daubenton's bats and measure their activity. The 1km stretch is divided into ten survey points spaced approximately 100m apart (see Figure 1.1).

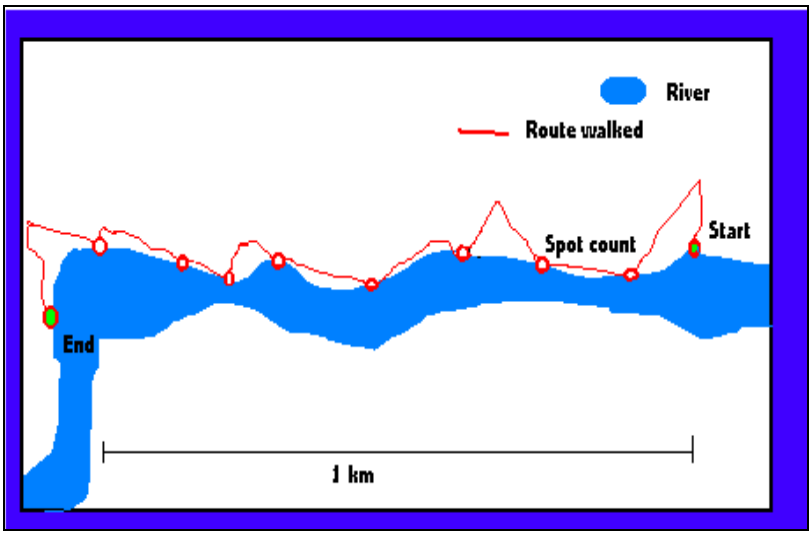


Figure 1.1: Example of Daubenton's waterway survey transect

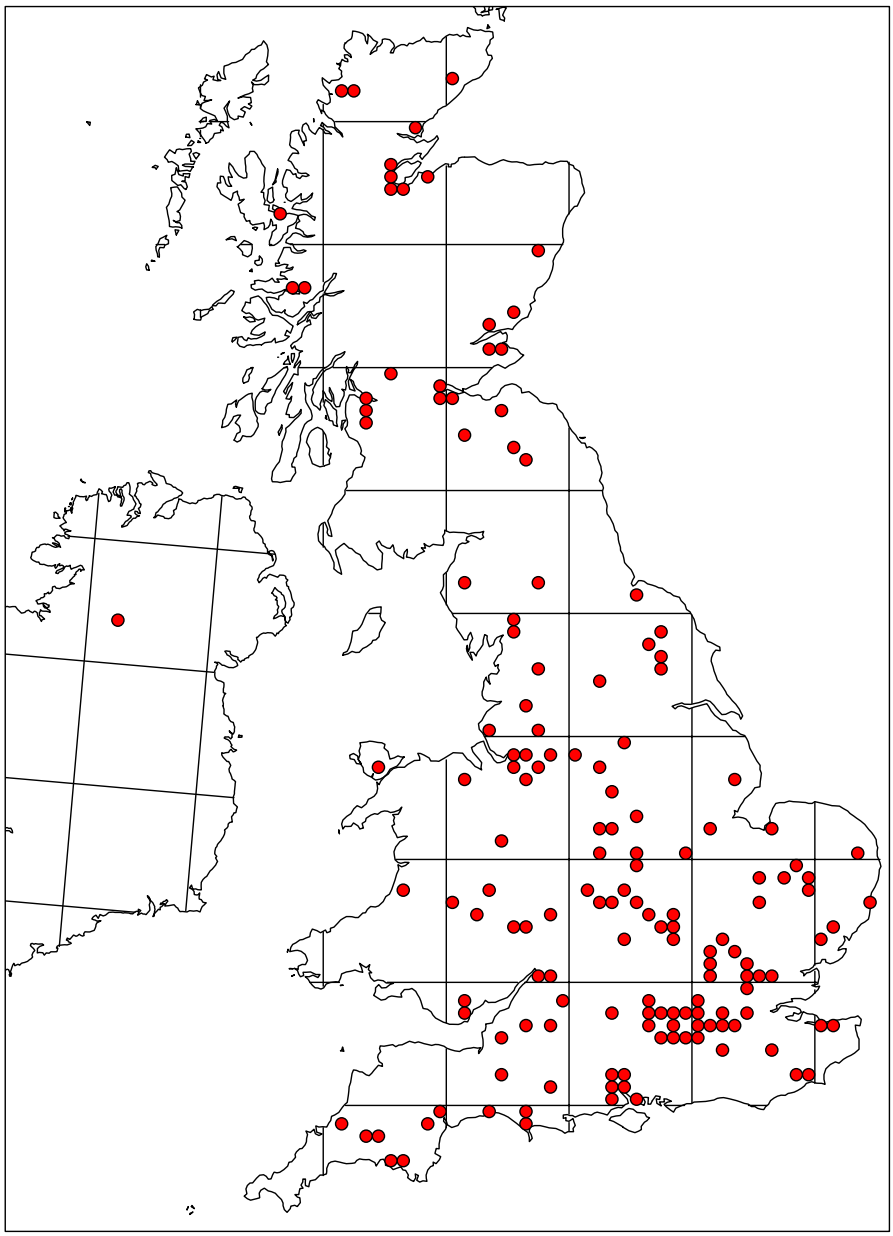
The survey starts at 40 minutes past sunset to coincide with the mean emergence time of Daubenton's bat. Surveyors stand at each spot for four minutes counting the number of Daubenton's 'passes' heard through the detector (see Fenton 1970 for definition). To confirm identification the torch is used to identify the bat skimming across the water surface as this behaviour is unique to Daubenton's bat. Daubenton's bat passes are identified only if heard and seen skimming the water surface. The number of bat passes, that are heard and sound like Daubenton's but may be another species are also recorded as 'Daubenton's unsure'. Sounds from other bats may be noted but are not officially recorded as bat passes. On each survey evening, observers record the total Daubenton's bat count and also weather conditions at the start of the survey: ambient temperature (degrees Celsius), cloud cover, wind speed and rain status. Observers are requested not to conduct counts in poor weather conditions (strong winds, heavy rain, cold temperatures). See APPENDIX A for full Protocol and recording sheets.

1.6 Daubenton's Bat Waterway Survey Dataset 2002

A full survey carried out in 2002 added to the existing monitoring dataset. A minimum of 168 people took part (additional people help the 'official' surveyor but they are not recorded) and sites were surveyed across all four countries (See Table 1.1 and Map 1.1 below).

Table 1.1: Number of sites surveyed and volunteers taking part in the Daubenton's Waterway Survey for each country for 2002

Country	Sites	Volunteers
England	144	171
Scotland	31	32
Wales	9	11
N. Ireland	1	1
Total	**185**	**215**



Map 1.1: Distribution of Daubenton's Waterway Survey sites undertaken in the UK in 2002 (n = 185)

The number of repeat sites completed in 2002 is shown in Figure 1.2. Repetition of sites is vital to maximise the power of the dataset. 835 sites were surveyed between 1997 and 2001 and are composed of sites surveyed in only one year (583) and sites surveyed in multiple years (252).

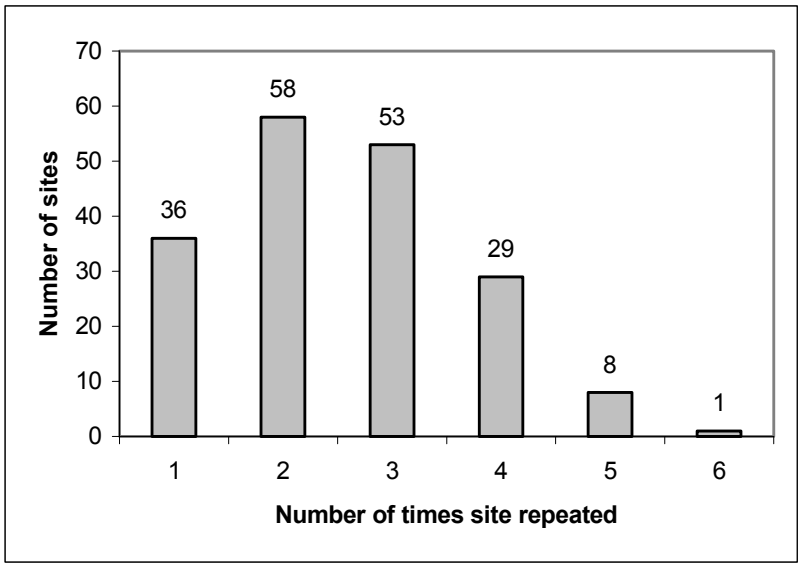


Figure 1.2: Number of repeat sites completed in 2002

The total number of counts at each spot in each site was averaged by the number of visits to the site to produce the mean count per spot. Residual Maximum Likelihood (REML) analysis was carried out on the log-transformed (x+1) mean count per spot (Table 1.2). All surveys where there were at least six valid spot counts are included and all sites are incorporated into the analysis, even if Daubenton's bats have never been recorded.

Table 1.2: REML analysis on Daubenton's waterway Survey Data 2002.

	Passes per point			Index 1998 = 100		
		95% conf limits			95% conf limits	
Year	Mean	lower	upper	mean	lower	upper
1997	0.91	0.59	1.30	107.2	69.0	153.3
1998	0.85	0.70	1.01	100.0	82.8	118.7
1999	1.05	0.89	1.23	123.8	104.5	144.8
2000	0.99	0.84	1.15	116.5	99.1	135.4
2001	1.07	0.82	1.35	125.4	96.0	158.8
2002	1.11	0.93	1.30	129.9	109.3	152.3

The results of the population trend analysis to date are shown in Figure 1.3. The 1997 index was initially very high due to selection bias amongst the sites in the pilot study and therefore sites only surveyed in 1997 have been excluded from the 2002 analysis. This results in a much more plausible value for the 1997 index, although its confidence limits are wide due to the small number of sites remaining in the analysis for that year.

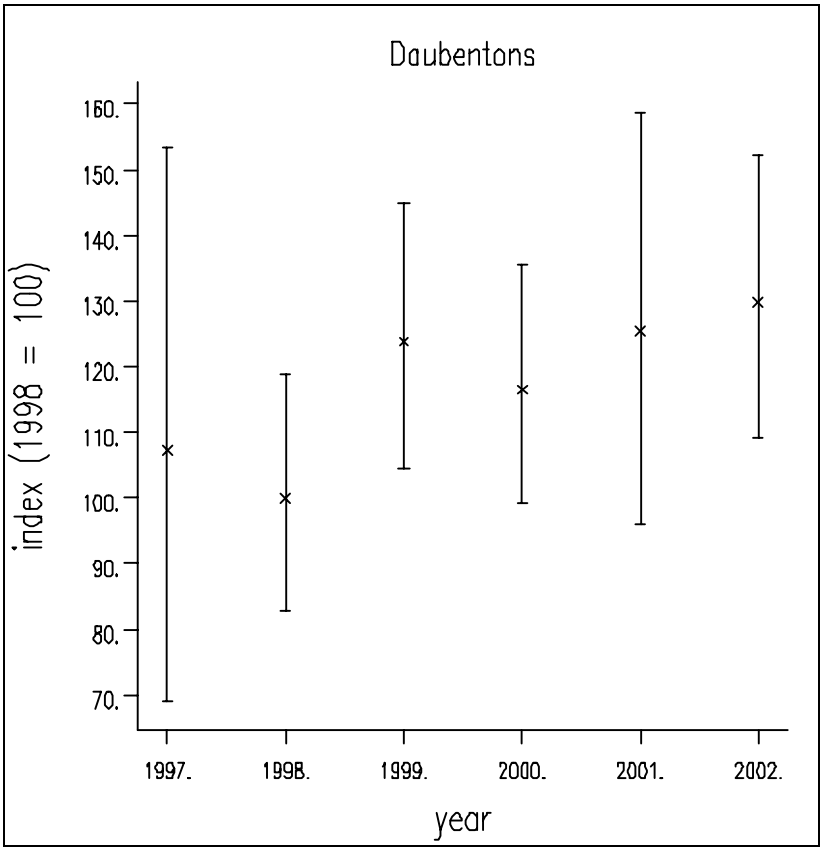


Figure 1.3: Daubenton's Waterway Survey Index 1997 to 2002. NB: The year-to-year differences are not statistically significant (χ^2 = 8.65 with 5 d.f., P=0.124).

2. RIVER HABITAT SURVEY/DAUBENTON'S BAT WATERWAY SURVEY ANALYSIS

2.1 Introduction

2.1.1 The River Habitat Survey (RHS) dataset

RHS is a system for assessing the character and quality of rivers based on their physical structure. Over 5000 randomly selected 500m stretches of waterbodies have been surveyed using the RHS methodology resulting in a comprehensive dataset representative of UK waterbodies. The sites were surveyed by trained surveyors in spring and summer 1994, 1995 and 1996. The survey method is divided into two parts; a detailed check at 10 survey points within the 500m section and a general sweep-up checklist. For a full description of the survey refer to The River Habitat Survey, Report 2, May 1998. The 'spot' data includes large numbers of missing values and so all the models (including the univariate analyses) exclude sites where these were missing. There are occasional missing values in the remaining data, but not enough to cause major problems with the modelling strategy.

2.1.2 The Daubenton's bat waterway survey (DBWS) dataset

Since 1998 the Daubenton's bat waterway survey has, where possible, surveyed RHS sites and this approach facilitated the potential for combining the datasets. The Daubenton's bat data used (395 sites) consists of the means on the log(x+1) scale of the counts at individual spots, averaged over all surveys at each site. This measure is quite highly correlated with a simple mean of counts per survey, but should be rather less vulnerable to the distorting effects of very high numbers of passes at one or more spots. Only sites with at least two bat surveys are included.

2.1.3 General Quality Assessment scheme (GQA)

The GQA scheme is designed to provide an accurate and consistent assessment of the state of water quality and how it changes over time. The Chemistry GQA describes quality in terms of three chemical measurements that detect the most common types of organic pollution from sewage treatment works, agriculture and industry. The Biology GQA describes quality in terms of 83 groups of macroinvertebrates, the presence of pollution sensitive species suggests better water quality. The GQA data, taken from 1995 and 2000 grades, includes a large numbers of missing values and so all the models exclude sites where these were missing. There are occasional missing values in the remaining data, but not enough to cause major problems with the modelling strategy.

2.1.4 June agricultural census data

This dataset is collated by DEFRA and provides a general picture of agriculture in a specified area. Data from all farms within a 2km radius of Daubenton's survey sites

were taken only from the 2000 census dataset as most other years used just a sample of farms.

2.1.5 Overall objectives of analysis

To identify key waterway factors that influence Daubenton's bat activity.

2.1.6 Specific objectives of analyses

- To relate Daubenton's bat activity to waterway features identified from the RHS and GQA surveys
- To produce a 'core' model of environmental indicators affecting Daubenton's bat activity
- To investigate Daubenton's bat activity to land use outside the confines of the waterbodies
- To assess the present Daubenton's bat survey methods and identify improvements

2.2 Methods

2.2.1 General analysis approach

The large number of variables involved with the use of different datasets makes this an inherently complex analysis and the following stepped approach was taken:

- Univariate correlations between RHS, GQA data and Daubenton's bat passes were identified
- A 'core' model was then produced that included only terms which were undoubtedly significant or which were needed to meet assumptions of the analysis.
- Other variables were investigated by adding them one at a time to the 'core' model
- More detailed investigation of interesting variables
- General agricultural factors in the wider landscape were investigated for their effect on bat activity
- Investigation of the survey method for assessing Daubenton's bat activity

2.3 Results and Observations

2.3.1 Univariate analysis

Significant univariate relationships between individual RHS variables and log mean bat passes are shown in Tables 2.1 and 2.2 and APPENDIX B, Figure B1. For a full list of variables analysed refer to APPENDIX B, Table B1.

Table 2.1: Univariate regressions for main RHS data. Stars indicate conventional levels - * P<0.05, ** P<0.01, *** P<0.001 and 10% indicates P<0.1 (almost significant).

	Linear regression		Quad-ratic	
Term	Slope	Sig.	Sig.	Description
East	-0.0006	**	*	Easting in km
PCA2	0.1516	***	***	Described as 'energy' in RHS documentation
Tree	0.0205	**	*	Adding together left & right scores
Trshade	0.0194	NS	*	tree shading adding together left & right bank scores[1]
Trover	0.0284	NS	*	trees overhanging from section J; adding L & R scores[1]
Embank	-0.2882	*	NS	Mean embankment height
Water_de	0.0931	10%	NS	Water depth
Water_wi	0.4469	***	***	Water width
Choked	-0.1925	**	**	>33% of channel choked n=0, y=1
Slope	-0.0920	*	*	M/km
Flow_cat	0.0706	***	***	0-10 score
Scrub	-0.0581	*	*	Adding L & R scores[1]
imp_gr	0.0320	*	*	Improved grassland, adding L & R scores[1]
Urban	-0.0211	NS	*	Adding L & R scores[1]
sp_braid	0.1322	10%	10%	Braided channels using standard scores[1]
sp_watme	0.3292	*	*	water meadow using standard scores[1]

([1]Scores are none=0, present=1, extensive=2)

Table 2.2: Univariate regressions for RHS 'spot' survey data and GQA data. Stars indicate conventional levels - * P<0.05, ** P<0.01, *** P<0.001 and 10% indicates P<0.1 (almost significant).

	Linear Regression		Quad-ratic	
Term	Slope	Sig	Sig	Description
IG	0.2023	**	**	Improved/Semi-improved grassland
SC	-0.3975	*	*	Scrub
SU	-0.1842	10%	10%	Suburban/Urban development
WL	0.1658	NS	10%	Wetland
algae	-0.1984	**	*	filamentous algae
ASPT_00	0.1059	***	***	GQA data: average score per taxa 2000
NTaxa_00	0.0113	***	**	GQA data: number of taxa 2000
class00	*	**	***	GQA data: classification.

Significant environmental factors correlated with Daubenton's bat activity were investigated further to assess their importance to foraging Daubenton's bats through the development of a 'core' model.

2.3.2 Development of 'core' model

Normally the model that fits the data best, usually arrived at via a stepwise approach, is presented. However, in this case, there are many potential explanatory variables, with a substantial number of these showing signs of a significant relationship and, as a result, there are many alternative models. The best stepwise model (using a non-automatic approach and fitting interactions and non-linearities) gives an adjusted R^2 of 47.4%, but a limited search for alternative models using a best subsets approach revealed many alternative models with similar R^2 values.

2.3.3 Assumptions of regression analysis

Regression analysis assumes that the individual data points are approximately independent and this assumption may be unrealistic if spatial correlations are present. Variograms were therefore used to test for such relationships and in the initial models there was a problem, with sites near each other tending to have similar residuals. However, fitting OS northings and eastings as spline functions (generalised additive models, GAMs) in order to model large scale differences in abundance removed this problem, and so these terms have been forced into all the models described (except the univariate ones).

2.3.4 Producing the 'Core' model

After an initial stepwise procedure and after checking for non-linearities and interactions the following 'core' model was selected. All the terms in it were either essential to meet the assumptions (northing and eastings) or were highly significant, irrespective of what other terms were included in the model (except of course if a closely related variable is forced in). The significance of terms is shown in Table 2.3 below and the estimated fitted lines, after adjusting for the effects of other terms in the model, is shown in APPENDIX B, Figure B2. Adjusted R^2 for this model is 39.1%.

Table 2.3: Significance of terms in the core model. Test statistics are for adding each term to the model after fitting other terms.

Term	F	d.f.	P	Comments
NTaxa_00	13.43	1,197	<0.001	Linear fit
Flow_cat	4.62	4,197	0.001	Spline with 4 d.f.
Width	3.86	4,197	0.005	Spline with 4 d.f.
Northing x Easting	2.50	9,197	0.010	Splines of northings and eastings, plus interaction between linear terms.
Tree	6.26	1,197	0.013	Linear fit

The least significant term in this model is 'tree', but has been included in the 'core' model as opposed to the next section as there were strong *a priori* reasons for believing it to be important. Warren *et al* (2000) in a study on an upland river in northern England found Daubenton's bat activity was highest along river sections that had trees on both sides. The borderline significance in the present study may have been due to the fact

that RHS data and Daubenton's activity data were collected on different surveys and sites may not have matched exactly. Where matches were not exact the RHS sample site would be in the same 1km square.

The 'core' model developed fits in with previous studies of this species that demonstrate its preference for foraging over calm water (Boonman *et al,* 1998*).* Rippled water interferes with their echolocation system and reduces their ability to identify insect prey. Large, slow moving rivers are associated with calm water surfaces.

The model is in contrast with some other studies that imply Daubenton's bat benefits from poor water quality. For example, *Myotis daubentonii* is widely reported to be increasing in numbers throughout mainland Europe (Daan, 1980; Voûte et al., 1980; Von Helversen et al., 1987; Cerveny & Bürger, 1990; Weinrich & Oude Vosharr, 1992; Kokurewicz, 1995) and it has been suggested that this is due to increased food supplies associated with the eutrophication of fresh waters (Kokurewicz, 1995; Vaughan *et al*., 1996). Racey *et al.* (1998) has shown that small eutrophic rivers in Scotland can support as many bats and as high insect densities as large oligotrophic ones. However this conclusion was based on a small sample size in a restricted geographic area of the UK and other factors may have been influential. The scope of the present analysis is much wider

2.3.5 Demonstration of other relationships for the 'core' model

Table 2.4 shows those variables which are significant or nearly significant when added to the core model. The three most significant principal components consist of very high loadings for the variables coniferous plantation (within 5m), improved grassland and coniferous woodland (within 50m) respectively, which are the three most significant variables shown in Table 2.4.

Table 2.4: test statistics for adding variables to the core model.

Term	Slope	F	d.f.	P	Comments
Conif Plantation (< 5m)	2.58	8.88	1, 196	0.003	Only 5 non-zero points
Improved Grassland	0.16	7.92	1, 196	0.005	Interaction with river size
Conif (within 50m)	0.22	7.82	1, 196	0.006	Only 8 non-zero points
Tall Herb	-0.27	7.80	1, 196	0.006	Possibly non-linear
Scrub	-0.037	3.62	1, 196	0.058	Not sig if IG added first

Whilst the relationships with coniferous plantations (within 5m) and conif (coniferous plantations within 50m) initially look interesting, they are based on only a few sites where coniferous plantations were present and cannot be considered reliable. The negative relationship of tall herbs and Daubenton's activity requires further investigation (see section 2.3.8) as it may be due to the presence of tall herbs obscuring the view of Daubenton's bat and not a direct effect of the herbs themselves. By contrast improved grassland (within 5m) shows a much more even distribution of scores. As well as the significant linear fit shown in Table 2.4 there are significant interactions with the Flow_category (F=8.03 with 1 and 195 d.f., P=0.005) and width (F=6.36 with 1 and 195 d.f., P=0.012). Both these interactions indicate a change in the effect of

improved grassland with increasing river size, and so if one is fitted the other ceases to be significant.

Two possible explanations why improved grassland could 'appear' to influence bat activity are 1) other habitat features are correlated with improved grassland or 2) improved grassland is the dominant land use category and other categories may have a negative relationship with activity. These hypotheses were tested in the following analysis.

2.3.6 Investigation into Daubenton's bat activity and general agricultural land use using the June agricultural census dataset.

Analysis
Univariate relationships between individual June census variables and log mean bat passes are shown in Table 2.5.

Table 2.5: Univariate regressions for main June census data. Stars indicate conventional levels - * P< 0.05, ** P<0.01, *** P<0.001 and 10% indicates P<0.1 (almost significant). Areas (hectares) and animal numbers are log-transformed for regression.

	Linear regression		Quad-ratic	
term	slope	Sig	Sig	Description
h10	0.12355	***	***	Area farmed in 2km radius
a32	-0.08905	NS	NS	Bare fallow (not set-aside)
a99	0.01867	NS	NS	Total arable crops
b99	-0.03705	NS	**	Total veg and salad grown in open
c99	0,04533	NS	NS	Total orchards and fruit
d99	-0.04530	NS	NS	Nursery stock, flowers, Xmas trees
f99	0.25034	NS	10%	Glasshouse
g1	0.09402	**	**	Grass sown in last four years
g2	0.15722	***	***	Other grass (not rough grazing)
g5	0.06891	*	10%	Rough grazing (not common land)
g11	0.00800	NS	NS	set-aside
g14	0.09912	**	**	woodland (only on agricultural holdings)
g17	0.06145	NS	NS	Other land
g99	0.15145	***	***	Total grassland, set-aside, woodland *etc*
k98	0.11135	***	***	Total cattle
l98	-0.00846	NS	NS	Total pigs
m98	0.05151	**	*	Total sheep
s7	0.16012	***	N/A	No of farms with fishing diversification

Table 2.6 shows the significance of the terms when added to the 'core' model produced earlier.

Table 2.6: test statistics for adding variables to the 'core' model

Term	slope	F	d.f.	P	Comments
k98	0.069	9.33	1,173	0.003	Total cattle
g5	0.077	7.00	1,173	0.009	Rough grazing (not common land)
g2	0.081	5.31	1,173	0.022	Other grass (not rough grazing)
g99	0.079	4.87	1,173	0.029	Total grassland, set-aside, woodland *etc*
m98	0.031	4.01	1,173	0.047	Total sheep
a32	-0.103	3.94	1,173	0.049	Bare fallow (not set-aside)
g14	0.066	3.28	1,173	0.072	woodland (only on agricultural holdings)
g1	0.049	3.22	1,173	0.075	Grass sown in last four years
h10	0.057	3.12	1,173	0.079	Area farmed in 2km radius
s7	0.067	2.73	1,173	0.100	No of farms with fishing diversification
c99	-0.056	1.16	1,173	0.284	Total orchards and fruit
l98	-0.012	0.67	1,173	0.413	Total pigs
f99	0.116	0.48	1,173	0.491	Glasshouse
d99	-0.049	0.43	1,173	0.512	Nursery stock, flowers, Xmas trees
g17	0.022	0.30	1,173	0.585	Other land
a99	0.005	0.15	1,173	0.704	Total arable crops
g11	0.008	0.13	1,173	0.715	set-aside
b99	-0.011	0.06	1,173	0.810	Total veg and salad grown in open

Other grass (g2), Rough grazing (g5) and Total cattle (k98) all remain significant although with slightly larger P values than when fitted on their own (Table 2.6). The Fishing Diversification variable, which is no longer quite significant, is correlated with river width and flow rate and therefore becomes much less important when these are allowed for. Area farmed in 2km radius (h10) is also much less significant than in the univariate analysis, largely due to a correlation with NTaxa_00 *i.e.* areas with little or no farmland have low NTaxa_00 and low bat counts.

Grassland habitats aside there are no significant relationships with agricultural variables suggesting Daubenton's activity is influenced mainly by environmental factors immediate to the waterbody.

2.3.7 Examination of grassland and Daubenton's bat activity

If grassland is significantly related to bat activity we would predict that when grassland categories from the Agricultural Census dataset were added to the original 'core' model (that included the grassland/waterway width interaction term from the RHS dataset) the significance of the grassland/waterway width interaction term would be reduced. Analysis revealed that the grassland and grassland/waterway width interaction terms remained significant (F = 6.7 and 5.51 with 1 and 170 d.f. respectively, P = 0.01 for the grassland term and P = 0.02 for the grassland/waterway width interaction term. This

suggests that local habitats correlated with grassland are having an effect and that removal of grassland from the 'core' model is justified.

2.3.8 Investigation into the relationship between 'unsure passes' and the presence of tall herbs

The percentage of 'unsure passes' was analysed using an angular transformation, disregarding sites with only one survey or less than twenty passes in total. TH (tall herbs within 5m) had a significant positive relationship with the percentage of 'unsure passes' (t=2.24, with 149 d.f., P=0.026). Other variables associated with 'unsure passes' include embankments, floating vegetation and braided channels. This shows that 'detectability' of Daubenton's bat is influenced by the surveyor's view of the water surface.

2.4 Conclusions

1. The analysis demonstrates that the Daubenton's Bat Waterway survey dataset can be merged successfully with Environment Agency environmental datasets e.g. the RHS and GQA datasets
2. Significant environmental factors identified in the 'core' model of Daubenton's activity fit well with small-scale university-based research thus demonstrating the robustness of data collected on UK-wide volunteer based surveys
3. Daubenton's bat activity is highest at wide, tree-lined and slow flowing waterbodies associated with a high biodiversity of insects
4. Daubenton's bat activity is significantly related to insect biodiversity (NTaxa_00) demonstrating its use as a cost-effective indicator species of a pollution-sensitive biodiversity group. High insect biodiversity is associated with good chemical water quality
5. The lack of non-significant relationships with wider agriculture factors suggests scarce conservation investment to enhance foraging areas for Daubenton's bat would be most effective if confined to the waterbody
6. Both the survey location and vegetation adjacent to the surveyor influence the number of positive Daubenton's bat sightings

2.5 Recommendations

1. Results from the Daubenton's Bat Waterway Survey should contribute to an annual indicator of the overall environmental 'health' of waterbodies in the UK
2. Data from the Daubenton's Bat Waterway Survey could be incorporated into the RHS dataset
3. Based on the results of the current analysis a predictive model of Daubenton's bat distribution throughout the UK should be developed and tested
4. Insect activity and weather has been investigated extensively and the potential for the Daubenton's Bat Waterway Survey in monitoring climate change should be assessed
5. Collection of simultaneous, additional monitoring data on non-bat species should be considered to extend the present biodiversity measurement. This would require

additional investment in the present volunteer workforce but would allow additional species to be monitored more cost-effectively than establishing new surveys.

6. An analysis of the Agricultural Census Data and bat activity collected on the general bat field survey should be initiated to assess the potential of bats as 'health' indicators of the wider countryside
7. The 'visibility' of the surveyor to the waterbody surface should be recorded on future surveys

3. EXTENDING THE SCOPE OF THE DAUBENTON'S BAT WATERWAY SURVEY THROUGH EVALUATION OF NEW TECHNOLOGY

3.1 Introduction

3.1.1 Introduction to the evaluation study

Bats are monitored on UK waterways through the NBMP Daubenton's Waterway Survey. This field project has been successfully carried out for six years by volunteers using heterodyne bat detectors. The introduction of new technology in the form of the broadband, frequency division-type detector can potentially extend the scope of the current survey by enabling surveyors to monitor several additional species with minimal additional cost. To test the feasibility of expanding the scope of the survey in this way, experienced volunteers tested a protocol using the Duet, a new detector that combines both heterodyne and frequency division systems, during a pilot survey in August 2002. This section outlines the initial concept and presents the methods, results, conclusions and recommendations arising from the study.

3.1.2 Overview of ultrasonic detectors

Bats produce ultrasonic calls as part of the echolocation process and ultrasonic detectors convert ultrasound to audible sound enabling surveyors to listen and survey for echolocating bats. The species, immediate environment and behaviour of bats all influence the type of calls produced making identification from bat calls a complex process.

There are three systems for converting ultrasound to audible sound: heterodyne, frequency division and time expansion:

Heterodyne systems have a restricted frequency range (around the dialled frequency) and although appropriate for single species/genus surveying are poor on multi-species surveys where species use different peak frequencies. The restricted frequency range allows only very limited sonogram analysis of recordings and species identification relies on the skill of the user. These detectors are the standard tools for the majority of surveyors and present BCT field protocols are written for heterodyne detectors (including the Daubenton's field survey). Ultrasound is converted to audible sound in real time with this process.

Frequency division systems have an unrestricted ultrasonic frequency range and are appropriate for both single and multi-species surveys. Recordings from this system can be used to produce sonograms of bat calls (via appropriate computer software) and species identification is made from post-survey analysis of sonograms. Although historically this system has been little used in the UK its use is becoming more prevalent. Ultrasound is converted to audible sound in real time with this process.

Time expansion systems have an unrestricted ultrasonic frequency range and are appropriate for both single and multi-species surveys. Recordings from this system can be used to produce sonograms of bat calls (via appropriate computer software) and species identification is made from post-survey analysis of sonograms. At present its use is more widespread than frequency division and the quality of resultant sonograms is much better than frequency division. Ultrasound is converted to audible sound through slowing the original sound and the process does not work in real time.

For a more detailed explanation of the systems involved refer to Russ 1999.

3.1.3 Introducing new detector systems into monitoring schemes

Robust monitoring datasets rely on replicating survey protocols at defined temporal intervals and introduction of new technology requires careful management if it is not to confound long-term population trend analyses. There are variations between bat detector models; sensitivity at a particular frequency is one factor that could affect monitoring conclusions. Changing between heterodyne and frequency division systems could also confound monitoring conclusions.

3.1.4 The Duet detector

Features of the Duet detector make it suitable for introducing change to the present survey with minimal risk to the consistency of the existing population trend dataset. The detector employs both heterodyne and frequency division systems and the design allows the surveyor to listen with the heterodyne system as in previous surveys but make simultaneous recordings in frequency division. This approach allows the heterodyne dataset to continue as before whilst introducing an additional frequency division set in parallel. The Duet employs a different microphone type from some standard detectors and this could potentially affect sensitivity and encounter rate, however indications from NBMP analysis to date suggests that this is not significant.

3.2 Methods

3.2.1 Evaluation of study equipment

The equipment was distributed to each volunteer to enable participation in the evaluation study. The equipment needed includes:
1x Duet bat detector (Stag Electronics)
1x Portable mini disc player/recorder
Headphones
2x blank minidiscs per site
Additional equipment provided by volunteers:
Torch

3.2.2 Identifying surveyors most likely to use the Duet

The Duet detector was distributed to volunteers who were most likely to use it on field surveys. The database was checked for people who had contributed to field surveys most consistently and these were identified as the most suitable volunteers. The list was refined through personal knowledge and contact with individuals. A total of 25 Duet detectors were distributed to volunteers to participate in the survey. An additional objective of distributing the detector to key volunteers was to demonstrate that their efforts for bat conservation had been recognised and appreciated. The response from some recipients demonstrated that this objective had been met.

3.2.3 Training

To enable surveyors to use the Duet effectively training was provided to the relevant surveyors. Although the Duet is relatively simple to use, operating the mini disc recorder was more problematical and required training, as most surveyors had never used one before. To facilitate training, a short demonstration video was made and distributed to relevant surveyors. Training workshops were carried out through the UK and included training on using the Duet/mini disc recorder. In addition, a comprehensive protocol was written detailing best practice (section 3.2.4).

Table 3.1: Training Workshops Completed 2002.

Date	Audience	Attendees	Focus on Duet
11 April	Surrey Bat Group	40	+
21 April	Essex BG,	25	
27 April, 4 May,	Kent BG	20	+
25 May	Welsh bat workers conference	100	+
30 May,	Surrey BG part 2, practical.	12	+
1-2 June	East Midlands regional BGs	19	+
8 June	North Bucks BG	10	+
13 June	Cardiff BG	30	
22-23 June	West Yorkshire BG	6	+
13-14 July	Lincolnshire BG	14	+
20 July	Suffolk BG	16	+
27-28 July	Arborists, Surrey and Berkshire BGs	70	
10 Aug	Somerset BG	15	
6-8 Sept	BCT National Conference, Reading	60	+
20-21 Aug	Cumberland BG Westmoreland & Furness BG, English Nature,	24	

3.2.4 Survey protocol

Surveyors were asked to follow the same field survey protocol as in previous years (see section 1.5) and to use the heterodyne part of the Duet to record bat activity. Whilst

listening through headphones. Volunteers also made recordings in frequency division via the TAPE output of the Duet into the mini disc recorder. This approach ensures continuation of the existing heterodyne dataset whilst simultaneously collecting the frequency division data. At the end of the survey, surveyors were asked to send the mini disc to the BCT office for analysis. For detailed protocol see APPENDIX C.

3.2.5 Sampling approach for analysis of recordings

Sonogram analysis requires skilled personnel and is time consuming. The method devised was realistic (based on the number of suitable people able to analyse the recordings within the time period) and was designed to meet the specific objectives of this report. Thus rather than carrying out an analysis of every recording a sampling approach was taken:

(i) Each surveyor made recordings at all of the ten spots even if they heard no bats present. Thus each survey night generated 10, four-minute recordings with a total of 40 minutes recording time.
(ii) One minute of each four-minute recording (the first minute) was fed into the computer resulting in 10 minutes worth of data per survey night.
(iii) Initial analysis was carried out on recordings from alternate spots i.e. spot 2, 4, 6, 8 and 10. Each one-minute section of recording was scanned for the presence/absence of bat calls.
(iv) Sections were divided into 12 sections of 5-seconds duration for in-depth analysis.
(v) Alternate (to minimise pseudoreplication) 5-second sections i.e. 0-5 s, 10-15s, 20-25s, 30-35s, 40-45s and 50-55s were examined in detail and all bat calls within these sections were identified where possible.

3.2.6 Identification of bat calls

When bat calls were recognised, they were identified, where possible, to genus/species. The minimum number of species present in each sample was estimated by analysing the pattern of calls. For full technical details on call identification, refer APPENDIX D

When pipistrelle bats (Genus *Pipistrellus*) were identified, the peak frequency (PF) of a series of calls (at least 5 wherever possible) was measured to use as a tool for separating to species level. The peak frequency is taken from the power spectrum and represents the frequency of maximum energy or amplitude. Pipistrelle bats were classified by species on the basis of the known maximum and minimum peak frequencies taken from measurements of the three resident UK species after Vaughan *et al* (1997). Table 3.2 shows the peak frequency ranges.

Table 3.2: Peak Frequency range for pipistrelle identification

Species name	Species	Mean PF	Range
Common pipistrelle	P.pipistrellus	45kHz	44-48kHz
Soprano pipistrelle	P.pygmaeus	55kHz	52[1] kHz
Nathusius pipistrelle	P. nathusii	39kHz	38-40khz
Pipistrellus spp.	N/a	N/a	40-44kHz+ 48-52kHz+

[1]Calls that are apparently pipistrelle but with peak frequencies not within the range of the three known UK species identified as Pipistrellus spp.
Bat calls that were too faint to be identified properly or to have peak frequency measurements taken were recorded as 'unidentified' bats.

3.2.7 Estimating bat activity

In addition to identifying bat species, an estimate was made of the number of bats recorded in each five second segment. Each species has a characteristic pulse length and pulse repetition rate when flying in its typical habitat. Bats generally combine the wing beat and echolocation call in a one to one ratio to minimise the cost of echolocation (see Jones 1994). This means that there must be a period between each call when the bat is unable to echolocate as calls cannot overlap, and this period is characteristic for each species. This period is known as the average interpulse interval (IPI) and is related to the size of the bat and the habitat. When a long, slow call is made there must be a pause before the next call, and as the bat is likely to be large, the wing beat frequency will be low. If another call immediately follows it is likely to be from another individual. By looking closely at the sequence of calls it is possible to estimate whether one, two or three bats are present at the same time. Estimating abundance of bats that make short calls with a short IPI is more difficult than those that use long calls. If more than one species call is recorded in the same sequence this obviously means there is more than one bat present.

3.3 Results and Observations

3.3.1 Summary of recordings returned

34 surveyors took part in this project and returned data, and these volunteers completed 56 survey nights (not all of them with the Duet), returning 45 recordings to the BCT office. In general the quality of the recordings was good. One volunteer had difficulties operating the minidisc recorder and this resulted in a high number of tracks with no data on and one survey being spread across two discs, however the recording quality was acceptable. Difficulties like this add to the post survey analysis time. However, additional training resources to help volunteers learn how to operate the equipment efficiently could solve most of these difficulties.

Analysis time:
The analysis procedure consists of six steps
Step 1 – check the minidisc recordings to verify correct number of spots have been completed. Also check the recording sheets for any problems noted and to corroborate track listing with spot numbers.

Step 2 – Modify the computer settings and set up the sound card and sound analysis software (all analysis carried out on BatSound Pro version 2.1 software, © Petersson Elektronic)
Step 3 - Feed 1 minute recordings into the computer via the line-in portal connected to the minidisc recorder via the line-out. Record presence / absence of bats at each spot at the same time.
Step 4 – Divide each minute into 5 second sections for further analysis
Step 5 Identify and record bat species wherever possible and estimate the number of bats present. Make a note of any other ultrasonic signals, interesting features (e.g. social calls) and copy into reference files. Note any difficulties.
Step 6 – Re-assess difficult calls with additional help.

On average for each site the 5 minutes of actual recordings took about 30 minutes including checking the discs, setting the volume levels to minimise clipping etc. For the 10 x 5 minute recordings done in this study the total time taken to transfer to the computer was 5 hours.

The analysis was much more variable in time. The total time taken for analysis in this study was 13 hours. Recordings with many bats take much longer to analyse than those with few bats. Dividing the minute long sections into 5 second sections is time consuming using BatSound as the measuring scale is not particularly user-friendly. The speed at which recordings are analysed increases as experience and confidence is gained in identification. The initial two recordings took three times as long to analyse as the last two.

3.3.2 Presence / absence results

Of the ten sites analysed, only one had no bats at any of the spots. From a total of fifty spots across the ten sites, 35 spots (70%) had bats present (Table 3.3).

Table 3.3: Presence / absence for the ten sites and 50 spots

Site Code	110503	110623	210416	210585	110809 new	110465	110601	110770	310560	110470
Observer	HR	IJC	AY	JH	JM	ST	KH	NW	JM2	JP
Date	18 Aug	30 Aug	13 Aug	21 Aug	29 Aug	19 Aug	28 Aug	29 Aug	29 Aug	21 Aug
Spot 2	0	1	1	1	1	1	0	0	1	1
Spot 4	0	1	0	1	1	1	0	0	1	1
Spot 6	1	1	1	1	1	0	0	1	1	1
Spot 8	1	1	1	1	1	0	0	0	1	1
Spot 10	1	1	1	1	1	1	0	0	1	0
Total	3	5	4	5	5	3	0	1	5	4

0= bats absent, 1 = bats present

3.3.3 Species encountered

The following species list was derived from the analysis of bats encountered (Table 3.4) (see APPENDIX E for full results).

Daubenton's (Myotis daubentonii)
Common pipistrelle (Pipistrellus pipistrellus)
Soprano pipistrelle (*Pipistrellus pygmaeus*)
Unidentified pipistrelle species (P+ see section 3.2.6)
Noctule (Nyctalus noctula)
Possible other Myotis species
Unidentified bat species

Table 3.4: Presence of bat species at spots.

	No of spots where species present	**% of total spots (n=50)**
Daubenton's bat	22	44
Soprano pipistrelle P55	15	30
Common pipistrelle P45	9	18
Pipistrelle species	4	8
Noctule	1	2
Other Myotis species	2	4
Unidentified bat	11	22

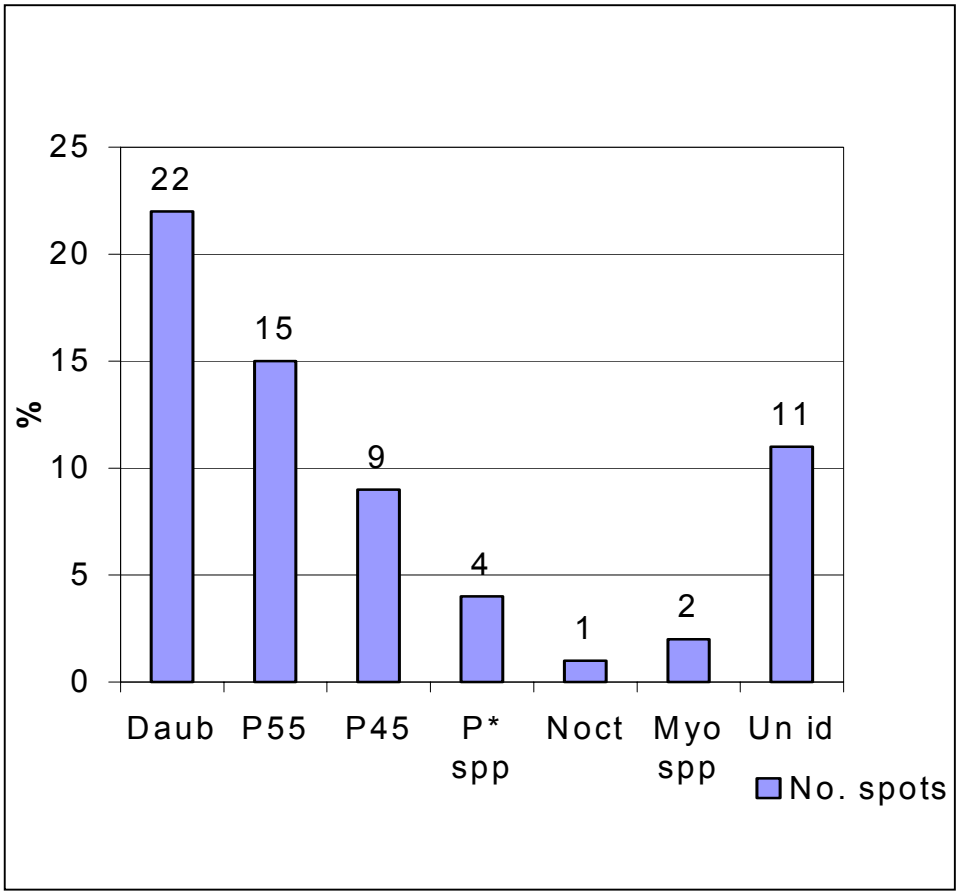


Figure 3.1: Number of spots at which different species were recorded.

Daubenton's bats were the species most commonly encountered as would be expected in this survey. Soprano pipistrelles were encountered at 18% more spots than common pipistrelles. Two of the sites were in Scotland where the soprano pipistrelle is generally more numerous than the common (unlike in most parts of England where the reverse is true). In addition, soprano pipistrelles are known to be more commonly associated with water bodies than the common pipistrelle. Other Myotis species were thought most likely to be whiskered bats, although differentiation between the Myotis species is problematic. Myotis spp. was assigned only in cases where the calls were different enough from the usual Daubenton's type call i.e. generally slower repetition rate, higher average IPI and shorter bandwidth to suggest a different species was likely to be present. This does not guarantee that these are not calls from Daubenton's. Obviously more than one species could be present at any one spot.

3.3.4 Species diversity

Table 3.5: Species diversity at individual spots

Site code/Obs	Spot 2	Spot 4	Spot 6	Spot 8	Spot 10
210416/AY	1	0	1	1	1
110503/HR	0	0	2	3	1
110623/IJC	1	1	2	0[1]	2
210585/JH	1	1	1	1	1
110809/JM	1	1	2	1	1
110470/JP	2	1	1	1	0
310560/JM2	5	6	4	2	2
110601/KH	0	0	0	0	0
110770/NW	0	0	1	0	0
110465/ST	1	1	0	0	1

[1]no species recorded although bat was present because it was unidentified.

The number of species at different spots was calculated, excluding unidentified bats. At one spot the only observation was an unidentified bat and this was excluded from the diversity analysis along with the other unidentified records. None of the bat calls analysed were classified as 'unidentified' because the species was unfamiliar or unknown; all of them were 'unidentified' because the bat call was too far away or too poor to be analysed with the same accuracy as the rest. The assumption is therefore that the unidentified bats encountered were likely to be of one of the species already listed (although this would not necessarily be the case if more calls were sampled, as the likelihood of encountering a rare bat would increase).

Pipistrelle calls that fell between the accepted peak frequency ranges to classify to species were recorded as pipistrelle species (Pip?). The majority of these calls fall between 49 and 51.5 kHz. The likelihood is that these are emitted by common pipistrelles in a cluttered environment resulting in a shortened inter-pulse interval and increased peak frequency. An alternative explanation is that these are calls of a soprano pipistrelle emitted in an open environment (although the waterway survey is restricted to rivers, canals and streams and does not incorporate lakes and ponds and so this is unlikely. It has been postulated that there could be a fourth pipistrelle species in the UK that typically emits calls around the 50-51kHz mark. Given the plasticity of the pipistrelle type of call (Russo and Jones 2002) and the lack of any specimens that appear to be anatomically distinct from known species, this is questionable.

Call sequences that appeared to be pipistrelle-like (due to duration, IPI, rhythm, structure etc.) but that were not sufficiently long or defined for a reliable assessment of the peak frequency to be made, were also categorised as unidentified bat calls.

Table 3.6: Species diversity at spots

No of species	0	1	2	3	4	5
No. of spots	16	23	7	1	2	1

As expected the majority of spots that had bats present were found to have 1 or 2 species flying simultaneously. However there were 'hot spots' of species diversity with

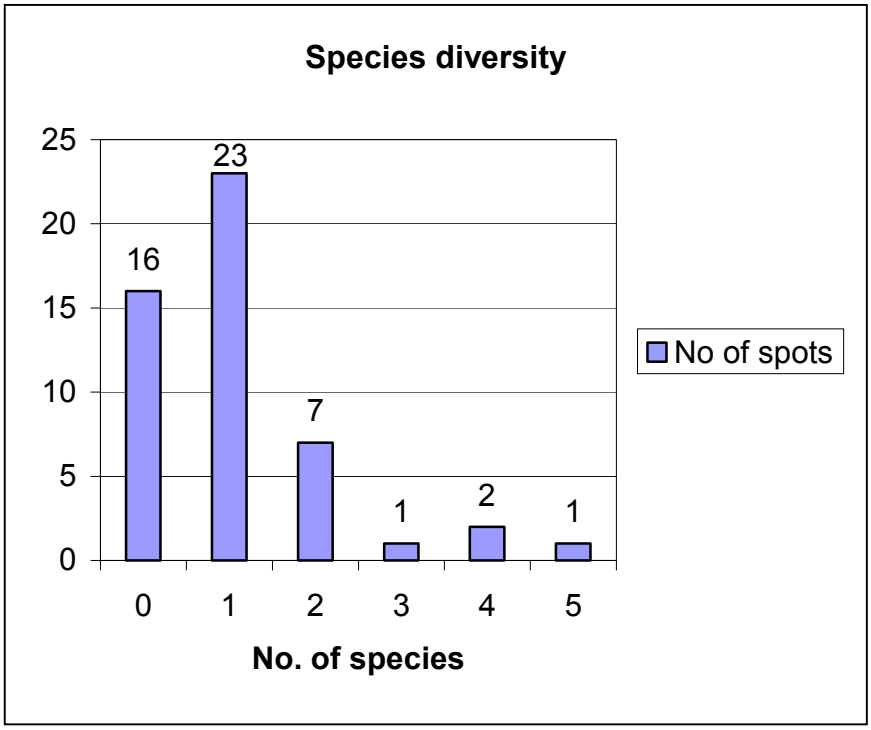


Figure 3.2: Species diversity and 'hot spots'

4, or 5 species present at the same spot during the first minute of survey time (see Figure 3.2).

Of the spots with one species present, the most common species found alone was the Daubenton's bat (see Table 3.7).

Table 3.7: Single species occurrence at spots

Species	Daubenton's	Common pip	Soprano pip	Pipistrelle spp.
No of spots	13	3	4	1

When two species were flying together the combination most frequently encountered was the Daubenton's bat and the soprano pipistrelle (3 spots), both species traditionally associated with waterways. Common and soprano pipistrelles were recorded together at

2 spots as were soprano pipistrelles and indeterminate pipistrelle species. Daubenton's and common pipistrelles were found together at one spot (see Table 3.8).

Table 3.8: associated species where 2 species present

Species combination	Daub & soprano pip	Common & soprano pip	Soprano & Pip ? spp	Daub & common pip
No. spots	3	2	1	1

The spot with three species flying together was found to have Daubenton's, soprano and common pipistrelles (Table 3.9). Two spots were host to combinations of four species (Table 3.10). One of these was an interesting combination of Daubenton's bat, soprano pipistrelle, noctule bat and another Myotis species, most likely to be the whiskered bat (*Myotis mystacinus*). The spots where four and five species were present (Table 3.11) at the same spot were at the same site. This site had high bat diversity at every spot (more than 1 species at each one).

Table 3.9: associated species where 3 species present

Species combination	Daubenton's, common & soprano pip
No. of spots	1

Table 3.10: associated species where 4 species present

Species combination	Daubenton's, common pip & soprano pip and pip ? spp	Daubenton's, soprano pip, noctule & ?Myotis
No. of spots	1	1

Table 3.11: associated species where 5 species present

Species combination	Daubenton's, common pip & soprano pip, pip ? spp & ? Myotis.
No. of spots	1

3.3.5 Estimating bat abundance

When only one species was present, the maximum number of bats it was possible to separate into individuals was 3. The maximum number of bats estimated in a single five second section is 4 individuals (Table 3.12, where more than one species was present) (see Figure 3.3).

Table 3.12: No of 5 second sections with multiple bats

	No of sections N=300	% of total
0 bats	184	61.3
1 bat	69	23
2 bats	43	14.3
3 bats	3	1
4 bats	1	0.3

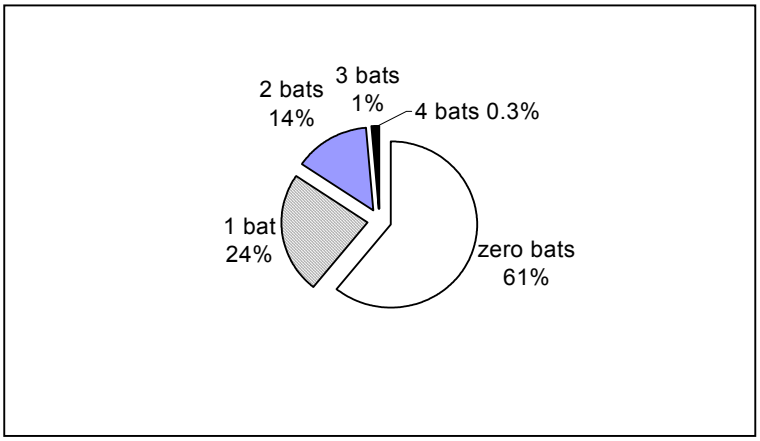


Figure 3.3: Bat activity – number of 5 second sections with multiple individual bats (n=300 the total number of 5 second sections subjected to analysis)

Table 3.13: Analysis of bat activity at spots

Max no of bats at a spot	No of spots N=50	% of total
1bat	23	46
2	9	18
3	1	2
4	2	4
5	1	2

3.3.6 Non-chiropteran biodiversity

At least three different kinds of Orthopteran calls characterised by regular low frequency sounds, sometimes with distinct stridulations, were identified.

3.4 Discussion and Summary

3.4.1 Broadening the scope of the survey

The results of this evaluation study demonstrate that the scope of the Daubenton's survey can be effectively widened by the introduction of the Duet detector. The combination of a broadband survey tool and post analysis can provide additional information in areas such as:
Additional species coverage
Additional bat information
Improved measure of bat activity
Importance of waterway for bat feeding habitats
Including non-bat biodiversity

3.4.2 Wider species coverage

Using the broadband Duet detector delivers a monitoring method for more species without significantly increasing the amount of survey effort. Volunteers need some training to empower them to use the equipment effectively in the initial stages. Further training in bat identification is minimised as volunteers are able to utilise the skills they already have by continuing to listen in heterodyne at the same time as frequency division.

This study has demonstrated that several new species can easily be incorporated into the waterway survey. In addition it would be expected that greater and lesser horseshoe bats, serotines, barbastelle, Leisler's and Nathusius' pipistrelles could also be detected where present.

Increasing the species coverage will help to strengthen monitoring by providing overlap for some species across several surveys to provide a method of cross checking any apparent population trend. European species that may be occasional visitors but may also be at the edge of their range and potentially expanding distribution into the UK may also be picked up through the more widespread use of broadband systems. Records of parti-coloured bat (*Vespertilio murinus*), Kuhl's pipistrelle (*Pipistrellus kuhli*) and Savi's pipistrelle (*Pipistrellus savii*) are still rare in this country but possibly because surveyors are not listening at the best frequencies for these species, which use different ranges than the UK bats. In addition surveyors are unfamiliar with these calls and are not able to identify them with heterodyne detectors.

3.4.3 Additional bat information

The Duet coupled with post survey analysis facilitates the collection of additional bat information that strengthens knowledge about the UK bat fauna. Social calls are made by many species when feeding over waterways. As more social calls are catalogued and analysed they will become more useful in identification of the species and also to understand what the bat is doing. Social calls are more likely to be species specific than echolocation calls and distinctive structures have been identified in the calls made by the three resident pipistrelle species (Barlow and Jones 1997, Russ et al 1998, and

Russo and Jones 2002). In this study, social calls were captured by the Duet and processed to produce a sonogram. Figure 3.4 shows a sonogram of a soprano pipistrelle recorded at one of the sites.

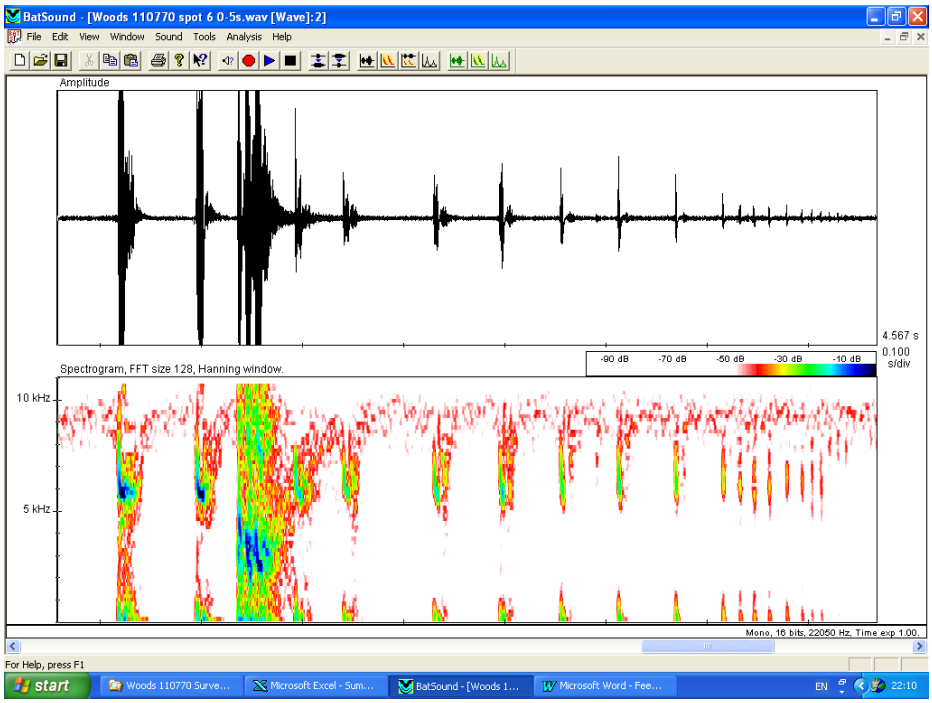


Figure 3.4: Soprano pipistrelle social call (social call on the left with dark areas of high intensity).

Social calls carry further in air than echolocation calls because the low frequency component is greater to 'advertise' over a greater range. This means that social calls can be detected even when no echolocation call is recorded, extending the range of the survey. For difficult to record species such as the brown long-eared bats, which make very quiet echolocation calls, recording social calls may offer the only method of gathering information using bat detectors.

3.4.4 Estimating bat activity

The Duet is a useful tool for estimating bat activity as it records in real time allowing continuous recording with no 'blind' time or sampling. It is possible to get a more accurate estimation of the number of species and perhaps the number of bats present. Those bat passes recorded as "unsure" using a heterodyne detector may be another species, for example a soprano pipistrelle, that can easily be confused with a Daubenton's when flying in a confined space. Post analysis allows an improved assessment of the number of species present.

3.4.5 Feeding habitat quality

Further analysis of the data into how bats are using the waterway would be possible using this method. Feeding buzzes are distinctive patterns of bat calls that can be readily identified from the Duet recordings. During a feeding buzz the pulse repetition rate increases to up to 200 pulses/second and the bat switches to steep sweeping calls as it closes in on, and captures its prey. Feeding buzz sequences are similar for all UK bats except the horseshoes (Figure 3.5)

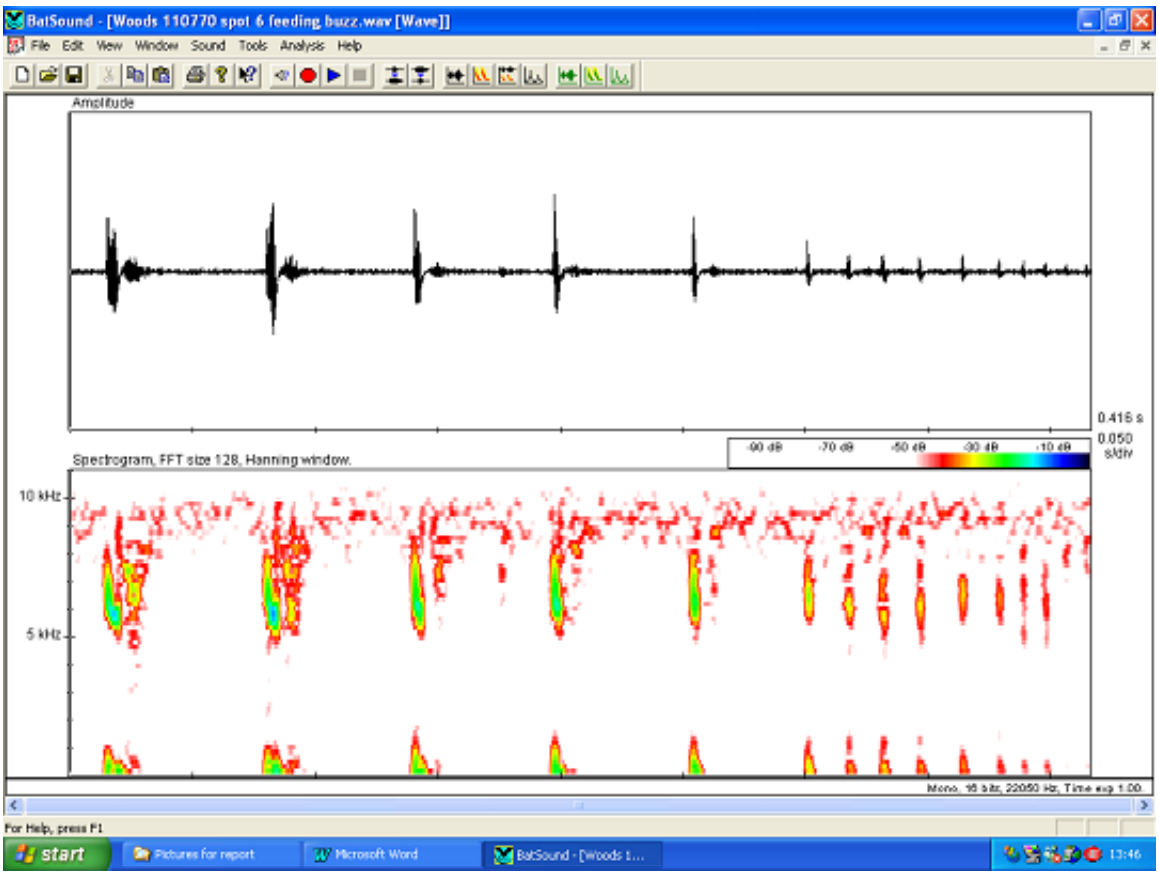


Figure 3.5: Feeding buzz from soprano pipistrelle

Recording the number of feeding buzzes at a spot would provide an indication of the quality of feeding habitat. Good bat feeding habitat is likely to be strongly correlated with high insect density and diversity as illustrated by the GQA/RHS/Daubenton's bat waterway survey analysis in chapter 2.

3.5 Recommendations

1. Further analysis of recordings from this study (more species, statistical tests) e.g.
- analysis of species associations from a larger sample to determine community relationships e.g. cluster analysis and dendrograms
- examine relationship between encounter rate of different species and spots/time
- analyse relationships between species diversity and spot numbers/time

2. Encourage use of Duet on field surveys

3. Use of the Duet adds post survey costs but this could be offset if some volunteers were trained to analyse recordings

4. Use of WAV recorders rather than minidiscs to eliminate time taken to feed in results

5. Development of automatic program to sample, select and file recordings of a given size (reduce time chopping recordings into sections)

6. Research to develop automated identification via programme replicating steps in analysis process

7. Build library of Duet reference calls, echolocation and social calls

8. Develop distance learning resources to enhance training and enable volunteers to analyse their own recordings – CD ROM, with sounds, video clips and a broad band detector manual.

4. DEVELOPMENT OF INTEGRATED DATABASE

4.1 Introduction

The overall aim was to enable BCT to deliver an excellent service to volunteers and to ensure BCT is in the position to easily engage in wider mammal monitoring/surveillance developments

4.1.1 Objectives

To clarify all BCT needs from a relational database – including ensuring the database will ease transference of information to the NBN.
To research the following possibilities for acquisition of a database:
To develop a BCT relational database
To purchase the database as a ready-made package
To work in partnership with other stakeholders – i.e. use existing databases
To develop a BCT relational database
To ensure BCT has the right training and expertise to maintain the database

4.2 Progress

4.2.1 Database specification

The BCT developed a specification for the database outlining all the essential requirements; this involved all the BCT staff and key volunteers.

4.2.2 Investigation of potential options

Options were investigated:
Purchasing a Package – Razors Edge, Alms and other packages proved expensive and difficult to develop according to BCT's specific needs in relation to the National Bat Monitoring Programme
Partnership Approach – organisations approached related conservation NGOs to develop the concept of shared resources but this option proved impractical at this time
Developing a Package – BCT invited proposals according to the specification from two IT specialists with a proven track record in this field

4.2.3 Approach selected

BCT commissioned Martin Newman to develop a relational database entitled:
BCT Information Retrieval System (BIRS)

4.2.4 The Bat Information Retrieval System (BIRS)

BIRS is an integrated, personal information management system providing the following facilities:
Management of name and address, email, phone and other biographical details including multiple organisational affiliations, phone numbers, email and physical addresses for individuals
Common name and address lists across all aspects of the Trust's work
Assignment of multiple attributes to all persons (e.g. Volunteer, staff, conference attendee)
Local control of "term lists" (e.g. title lists Mr/Mrs/Dr etc)
Management of Organisation details independent of named individuals
Management of anonymous data (e.g. anonymous callers)
Recording of telephone numbers and other contact details
Integration with the Royal Mail's Postcode Address File (PAF)
Integration with Outlook email client
Computer Telephony Integration (CTI) provides pop ups of details about phone callers using Caller Line Identification (CLI)
Helpline call recording
Donation management - Appeals may be prepared and responses to appeals and *ad hoc* donations recorded
Meetings management – meetings may be defined, bookings made and invoicing managed
Meetings and donation data may be viewed from the point of view of a person or from the viewpoint of a particular meeting or appeal
Data exchange with external Membership management (whilst allowing external agency to continue managing membership)
Simple query building
Provision for creating complex queries external to BIRS and subsequent import for use in the system
Commonly used reports and printouts provided
Export to Excel allows users to manipulate data and produce reports not included in the system
Security model allows for Administrators to manage "term lists" and other system functions
Design allows for Web interface to be built for remote users with low data bandwidth.

BIRS uses a Microsoft SQL 2000 backend database with a front end written using Access 2000, with some elements written in Visual Basic 6. The database server should be a P700MHz 320MB W2k server as a minimum, although for low use a lower specified machine with Microsoft Database Engine 2000 (MSDE 2000) rather than full SQL Server will be adequate. As SQL Server Integrated Security is used either a Domain or Active Directory is required unless being run on a single standalone machine. Client's machines should run Windows 95 minimum with at least 64MB RAM. Both user and technical documentation is provided as HTML compiled help files and are available separately on CD.

Postcode management software is provided by AFD Postcode Plotter and Computer Telephony Integration by Samsung's SmartPop technology.

4.3 Outcomes / outputs

BIRS is now in use at BCT
BCT is now in a position to effectively engage in collaborative projects to manage volunteers in mammal monitoring.
BCT is in a position to transfer data to the NBN, after due regard to the Data Protection Act
BCT is in a position to enable remote access of database by volunteers

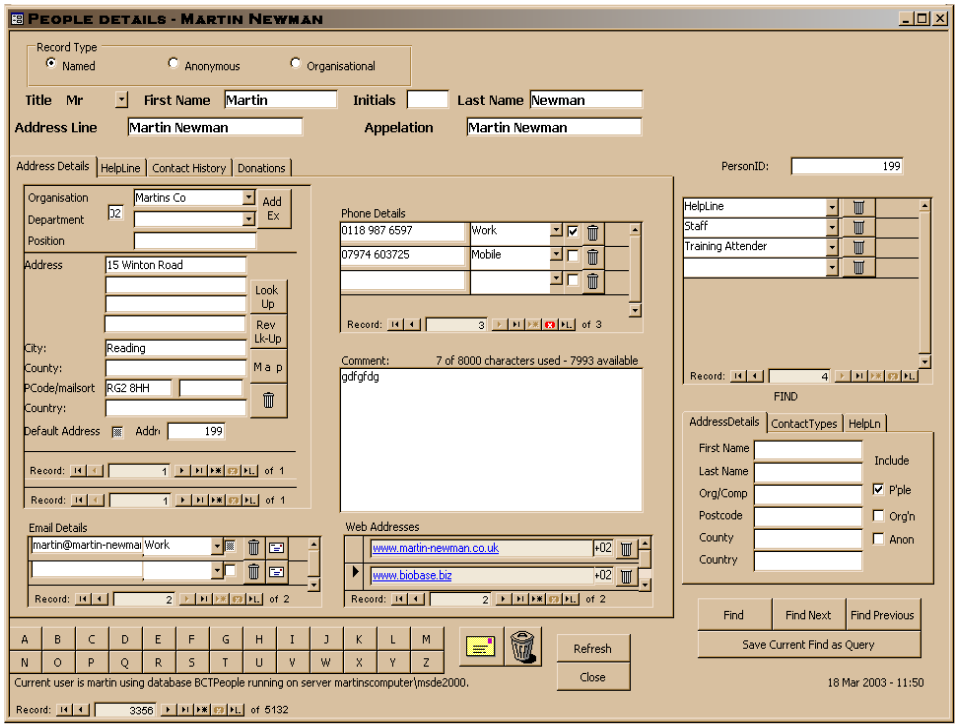
A copy of the completed, unpopulated, database will be sent to the Environment Agency, who will be the sole owner, though the database structure will be freely available for use by BCT, and by other monitoring organisations on request. This will be on CD due end of March 2003.

4.4 Expenditure

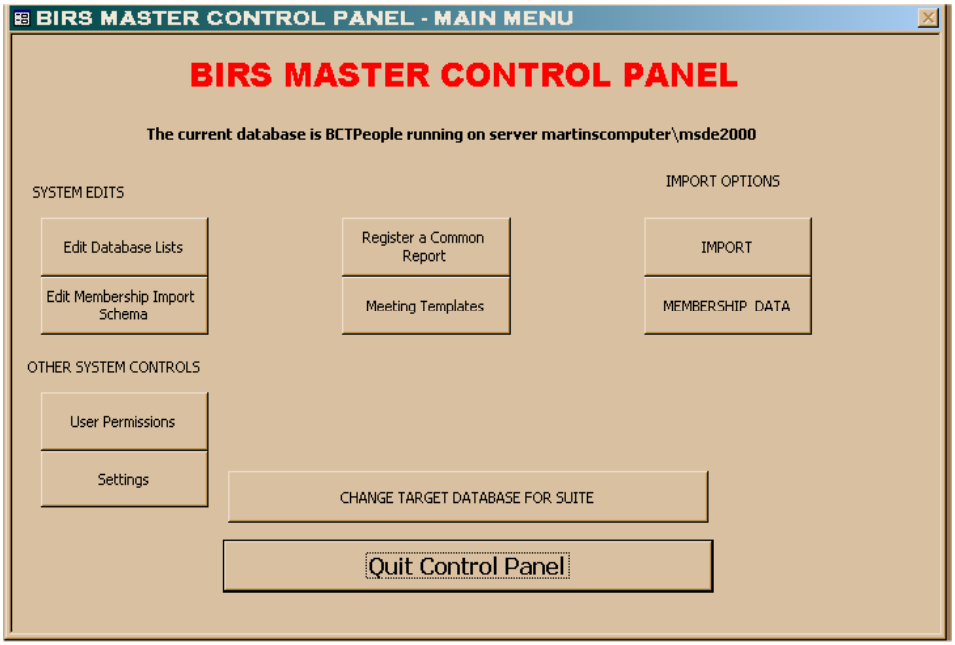
£7, 450 spent as outlined in the original application
£2,000 additional funds secured from the Mammals Trust UK for Helpline database development
Additional funding for postcode software and web interface secured from DEFRA in March 2003 to enable the Helpline to operate outside office hours
Support from the Environmental Action Fund 'Bats & People' project, in terms of staff time and expertise enabled the database development

4.5 Examples of Interface for BIRS

4.5.1 Data entry screen



4.5.2 Administrative Counsel



5. OVERALL SUMMARY AND CONCLUSIONS

The Bat Conservation Trust is delighted that the Environment Agency has enabled the Daubenton's Waterway Survey to take place in this season and presented the opportunity for the Trust to carry out this innovative research and development programme for bats as indicators of environmental quality.

The principal objective of this report was to demonstrate that bats are cost-effective indicators of Environmental quality. The specific objectives were:

1) To demonstrate how bat monitoring and environmental quality datasets can be linked
2) To show how new technology can incorporate more bat species and also non-bat species on present surveys cost effectively.
3) To strengthen volunteer involvement through development of a tailored volunteer management database.

5.1 RHS Analysis and Daubenton's Waterway Survey Conclusions

It is clear from analysis of the River Habitat Survey data in conjunction with the Daubenton's Bat Waterway Survey data, that Daubenton's activity can be related to habitat features and that bat activity can provide an index of environmental quality on UK waterways.

A 'core' model of environmental factors significantly related to Daubenton's bat activity identified insect biodiversity, waterway width & flow rate and the presence of trees as key factors. Analysis also revealed methods for strengthening data collection methods.

5.2 Using New Technology to Monitor Biodiversity

New bat detectors were incorporated onto the present Daubenton's bat survey successfully in 2002 and their use allowed the scope of the project to be expanded to include more bat species without an increase in volunteer survey effort. In addition the new technology has potential for Orthopteran species to be surveyed, helping to create a biodiversity index at waterways.

Utilising this new technology increases costs by adding to post survey analysis time and measures need to be taken to minimise this.

5.3 Database Development

The Bat Conservation Trust is now in a position to provide excellent support to volunteers participating in survey and monitoring work, and all other aspects of bat conservation through the development of the Bat Information Retrieval System.

This report demonstrates that the present Daubenton's Bat Waterway survey delivers a waterbody environmental quality index cost effectively through effective management of volunteers and the capacity for volunteer management and support has been enhanced by the development of the integrated database system.

6. SUMMARY OF RECOMMENDATIONS

1. Results from the Daubenton's Bat Waterway Survey should contribute to an annual indicator of the overall environmental 'health' of waterbodies in the UK

2. Data from the Daubenton's Bat Waterway Survey could be incorporated into the RHS dataset

3. Based on the results of the current analysis a predictive model of Daubenton's bat distribution throughout the UK should be developed and tested

4. Insect activity and weather has been investigated extensively and the potential for the Daubenton's Bat Waterway Survey in monitoring climate change should be assessed

5. Collection of simultaneous, additional monitoring data on non-bat species should be considered to extend the present biodiversity measurement. This would require additional investment in the present volunteer workforce but would allow additional species to be monitored more cost-effectively than establishing new surveys.

6. An analysis of the Agricultural Census Data and bat activity collected on the general bat field survey should be initiated to assess the potential of bats as 'health' indicators of the wider countryside

7. The 'visibility' of the surveyor to the waterbody surface should be recorded on future surveys

8. Further analysis of recordings from this study (more species, statistical tests) e.g.
   - analysis of species associations from a larger sample to determine community relationships e.g. cluster analysis and dendrograms
   - examine relationship between encounter rate of different species and spots/time
   - analyse relationships between species diversity and spot numbers/time

9. Encourage use of Duet on field surveys

10. Use of the Duet adds post survey costs but this could be offset if some volunteers were trained to analyse recordings

11. Use of WAV recorders rather than minidiscs to eliminate time taken to feed in results

12. Development of automatic program to sample, select and file recordings of a given size (reduce time chopping recordings into sections)

13. Research to develop automated identification via programme replicating steps in analysis process

14. Build library of Duet reference calls, echolocation and social calls

15. Develop distance learning resources to enhance training and enable volunteers to analyse their own recordings – CD ROM, with sounds, video clips and a broad band detector manual.

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APPENDIX A

Daubenton's Waterway Survey Protocol and Recording Forms

National Bat Monitoring Programme
Daubenton's Bat
Field Survey 2003 Instructions

A. INTRODUCTION

Thank you for volunteering to participate in the National Bat Monitoring Programme (NBMP); an initiative funded by the JNCC designed to track population trends in UK bats. The NBMP runs integrated monitoring schemes and we rely upon our team of volunteers to make this possible. We are pleased that the Environment Agency is now a major sponsor of this survey. We hope you find this an enjoyable bat-watching exercise and feel that you are making a positive contribution to bat conservation.

B. AIM

The aim of this survey is to walk a route along a randomly allocated 1 km stretch of river/canal. The activity of Daubenton's bats is recorded at 10 stopping points along the route on two evenings between the 1st and 30th of August.

C. METHODS

C1. When to survey

- Two separate evening counts should be made, one in each of the survey date periods given below and at least five days apart.
- Survey period 1: **1-15 August**
- Survey period 2: **16-30 August**

C2. Equipment

- tuneable bat detector
- stopwatch
- recording sheets/notebook
- pencil/pen
- rough map
- torch

C3. Selecting a route

- If you are surveying a **REPEAT SITE** go to SECTION C4.
  *Note: A repeat site is one that has been surveyed previously either by you or another NBMP volunteer. Repeat sites have a **site code** in the top right hand corner of the corresponding survey form e.g. 110001.*

- If you are surveying a **NEW SITE** go to SECTION C5.

C4. REPEAT SITE

Survey materials:

- **1 x blank map**
- **1x map with survey route**
- **survey form**
- **field card**
- **landowner letter**
- **spot description & landowner form**
- **sunset timetable**
- **health and safety guidelines**

- Use the map with the survey route marked on it, along with the spot descriptions, to guide you around the route.

- Carry out a daytime check of the survey route in case there are changes that may have rendered it unsafe or inaccessible.

- If any section is inaccessible and you need to change a spot, make it as close to the original spot as possible. Ensure that spots remain at least 80m apart and try not to miss out spots entirely.

- If you have to alter your route please draw the new route on the blank map and indicate in the box provided on the survey form that a change has been made.

- Write any revised spot descriptions on the spot description form.

- If your spot locations have changed you will need to return two maps – one with the new route and another with the original route.

- If you have repeated the survey in exactly the same way you do not have to return any maps.

- **Go to section C6**

C5. NEW SITE

Survey materials:

- **landowner letter**
- **survey form**
- **field card**
- **sunset timetable**
- **map copying protocol**
- **spot description & landowner form**
- **health and safety guidelines**

- In your letter you will see that you have been allocated two or more six-figure grid references. Each grid reference corresponds to a point along a stretch of river or canal. Please select the most accessible, convenient and safe one to survey *and write the grid reference of that site onto your Field Survey Form.* The grid references are from a random sample of sites that were previously surveyed by the Environment Agency (EA) for a project called the 'River Habitat Survey'. A large amount of data has already been collected for these sites, including variables such as water quality, river flow and bank vegetation which can be used to contribute to our analysis.

- Please copy three blank maps of the waterbody you have chosen, using the 'Map Copying Protocol' provided. Use one of these copies as your rough copy in the field. The other two should be returned to us – one blank and one with your route clearly marked. OS maps of your local area should be available in your library.

- On your map, identify a potential route of just over 1km in length along your river/canal. The route must include the six-figure grid reference point somewhere along it – ideally it should be the **mid-point** of your route.

- Carry out a daytime check of the survey route in case it might be unsafe or inaccessible. Your chosen waterbody should be >2m in width.

- Select a start point to your route that is convenient for both reaching the bank and standing to record bats. Clearly mark this as your first spot on the map.

- From this starting point walk along the river/canal, pacing out rough 100m intervals as you go. After each 100m, select the nearest point at which you can see the water-surface.

- Repeat this until you have selected a total of 10 such points or “spots”. Note: Do not choose spots because you think they will be "good" for bats as this will bias the results - just stick to points that allow you to access the bank and record bats.

- During your daytime walk of the route describe a feature/landmark for each spot/stopping point to help you to identify it. These spot descriptions must be of permanent/long-term features wherever possible. If the site is featureless, you may need to pace it out. Write the descriptions on the spot description form.

- You are likely to have to make detours away from the river. This may mean your route is slightly over 1km, but this does not matter.

- On your map mark and number each spot and where you started and finished.

- Record access gates and suitable parking areas, if relevant, on the spot description and landowner form.

- **Go to section C6**

C6. Landowner Permission

- A letter is enclosed to identify you to landowners. It is important that you gain permission in advance from any landowners or custodians if you are entering private property or sites with restricted access.

- Record landowner details and which section of the route that they apply to on the form provided. Please ask them to sign the landowner permission box if possible.

- Note any changes in landowner details from previous years.

C7. Field Methodology

Ensure you are in position to begin your survey about **40 minutes** after sunset – refer to the Sunset Times sheet enclosed. It might be useful to record your results in a notebook whilst you are completing the survey and then transfer these to the survey form later.

- Just prior to starting the survey record the:
  - **time**
  - **temperature**
  - **weather conditions**

- Note the weather conditions on the survey form (for cloud cover: Clear = no cloud – 1/3 cover, Patchy = 1/3 – 2/3 thick cloud or 100% thin cloud cover, Full = 100% thick cover).

- At each spot tune your detector to **35 kHz** and simultaneously use a torch to scan the water to check whether Daubenton's bats can be seen skimming across the water-surface.

- Daubenton's bat calls sound like a rapid click akin to machine-gun fire or marbles being dropped on a tile floor. They can be confused with Natterer's bats, which sound similar (although weaker and more like a rapid crackling). Typically, Natterer's bats fly erratically above the level of Daubenton's bats and tend to not trawl the water-surface.

- Stand still and count the number of Daubenton's bat passes for a total of **4 minutes.** Record the number of passes on the survey form.

- If you hear a bat that you think sounds like a Daubenton's bat, but you did not see it skimming over the water-surface, record it an "Unsure Daubenton's Bat". Ignore bat passes of other species.

- At the last point, record your finish time. If you are forced to abandon the survey early, note down the location, time and reason for stopping.

D. SURVEY TIPS

- Please ensure the battery in your detector is fresh.

- A **bat pass** is a continuous stream of echolocation calls indicating a bat flying past. If constant activity is heard estimate the number of times a bat flies past.

- Detectors are directional. **For Daubenton's bats always hold a detector at 90^0, pointing it across the surface of the water.**

E. SAFETY AT NIGHT

- <u>Please read the Health and Safety note enclosed.</u>

Fieldworkers should not put themselves in a position that could place them, or others, in danger. The Trust does not take any responsibility or liability for any actions and subsequent consequences from the activities of fieldworkers. The BCT has a Health and Safety field policy for its employees that has been distributed to bat groups and is available to all field workers.

F. WHAT TO RETURN

REPEAT SITES:

- Survey form
- If your spots or route have changed please return both maps with your new route/spots and original route/spots.
- If you have repeated the survey in exactly the same way you do not have to return any maps
- Landowner & spot description form

NEW SITES:

- Survey form
- One map with your route marked on it and one blank map
- Landowner & spot description form

PLEASE RETURN YOUR COMPLETED FORMS AS SOON AS POSSIBLE TO:

NBMP
FREEPOST *LON10138*
London
If you use a stamp it saves us money *SW8 4BR*

Many thanks for helping with this important project. We would also like to thank the following organisations for their valuable contribution to the National Bat Monitoring Programme.

National Bat Monitoring Programme
Daubenton's Bat
Field Survey Form 2003

JOINT NATURE CONSERVATION COMMITTEE

Site Code
Office Use

Grid Reference of site:	**County/Admin area site is in:**	LC: Office use
Waterway Name:		**EA Code:** **Office use**
Site Name (office use) **:**		
Your Name:		
Your Address:	**Postcode:**	
	Day Tel:	
	Email:	
	Bat Detector make used:	
Is the site (or any part of it) on National Trust land?	Yes / No	
Is the site a SAC or a SSSI?	SAC / SSSI / Neither / Don't know	
My bat species identification skills are:	Poor / OK / Good / Very good	
My length of field experience with a bat detector is:	Less than 1 yr / 2-3 yrs / Over 3 years	

Survey 1 (1 - 15 August)				**Survey 2** (16 - 30 August)			
DATE ____/____/ 03				**DATE ____/____/ 03**			
Start Time:		**Finish Time:**		**Start Time:**		**Finish Time:**	
Temp	^{0}C	**Wind** *(circle one)*	Calm Light Breezy	**Temp**	^{0}C	**Wind** *(circle one)*	Calm Light Breezy
Cloud *(circle one)*	Clear (0 - ⅓) Patchy (⅓ - ⅔) Full ($^3/_3$)	**Rain** *(circle one)*	Dry Drizzle Light rain	**Cloud** *(circle one)*	Clear (0 - ⅓) Patchy (⅓ - ⅔) Full ($^3/_3$)	**Rain** *(circle one)*	Dry Drizzle Light rain

	Bat Passes			**Bat Passes**	
Spot	Daubenton's Bat	Unsure Daubenton's Bat	**Spot**	Daubenton's Bat	Unsure Daubenton's Bat
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		

Have you altered the location of any spot(s) along your route ? Yes / No

Waterway Characteristics

Shelter: What percentage of the waterway is sheltered by trees or overhanging vegetation on either of the banks?

None ☐ up to 50% ☐ greater than 50% ☐

Water channel: How much of the waterway surface that is smooth/calm?

None ☐ up to 50% ☐ greater than 50% ☐

Channel width: Approximate width for majority of length _____m

Access to water's edge: The ability to detect Daubenton's bats seems to be influenced by the surveyor's view of the water. Please record the number of spots where, if Daubenton's bats were present, you would have a good chance of seeing them. Exclude spots where your view was obscured e.g. by vegetation or by you standing on a high embankment.

Number of spots with a clear view of the water_____

Additional Notes - Please give any relevant details below:

Please return completed forms to :

NBMP
FREEPOST LON10138
London
SW8 4BR

If you use a stamp it saves us money

Consent to release of records

By returning this data sheet to the NBMP you consent to your data being accessible by the BCT, the JNCC and others subject to the approval of the JNCC and the BCT. Your intellectual copyright of the data will be recognised at all times. We will be entering your personal information onto a computerised database. Please let us know if you object to this.

Please tick here if you DO NOT wish this information to be held by a local bat group for monitoring purposes ☐

Thank you for your valuable contribution to the Monitoring Programme!

APPENDIX B

RHS ANALYSIS

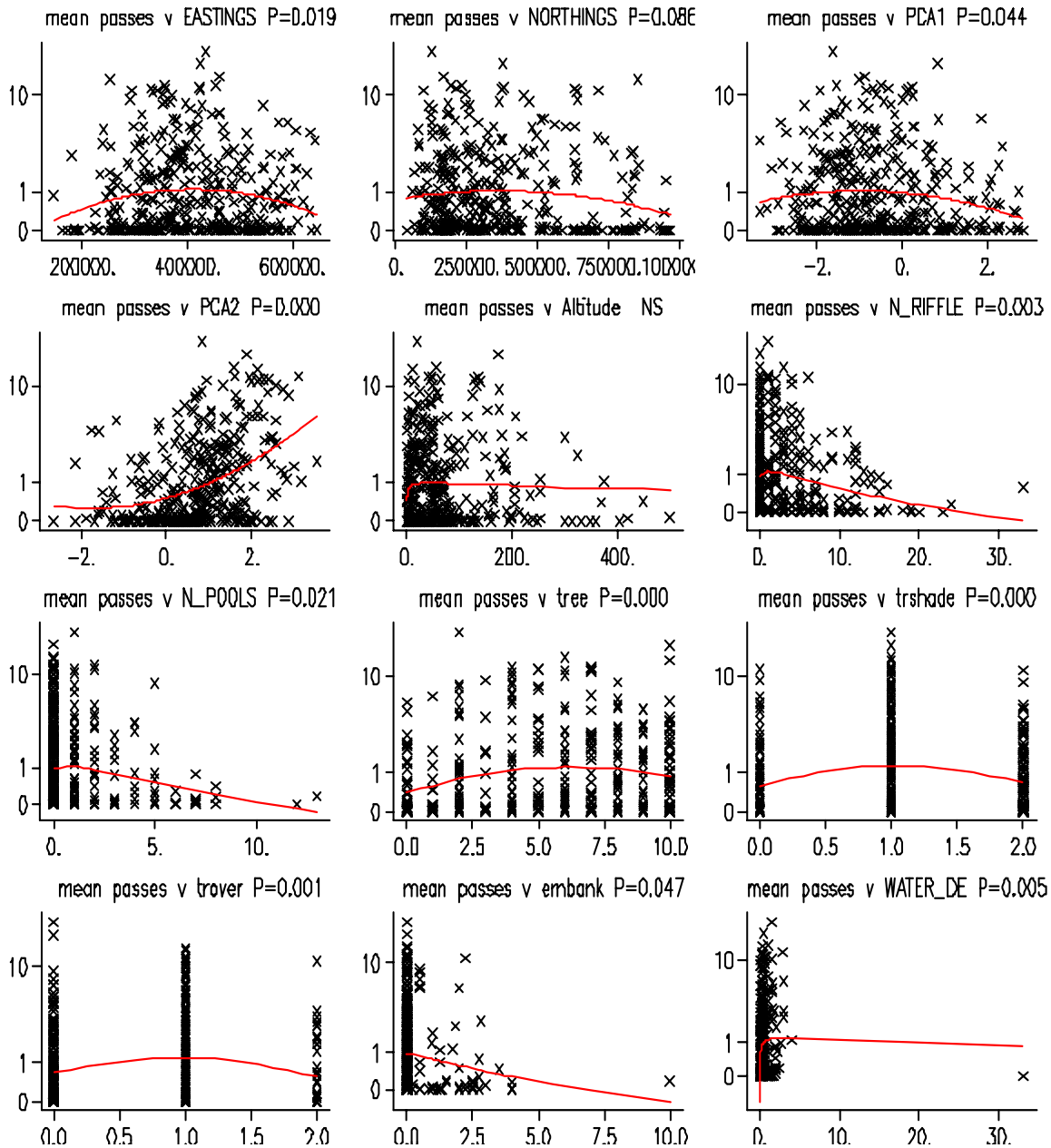
Table B1: **Univariate regressions for main RHS data. Stars indicate conventional levels - * P<0.05, ** P<0.01, *** P<0.001 and 10% indicates P<0.1 (almost significant).**

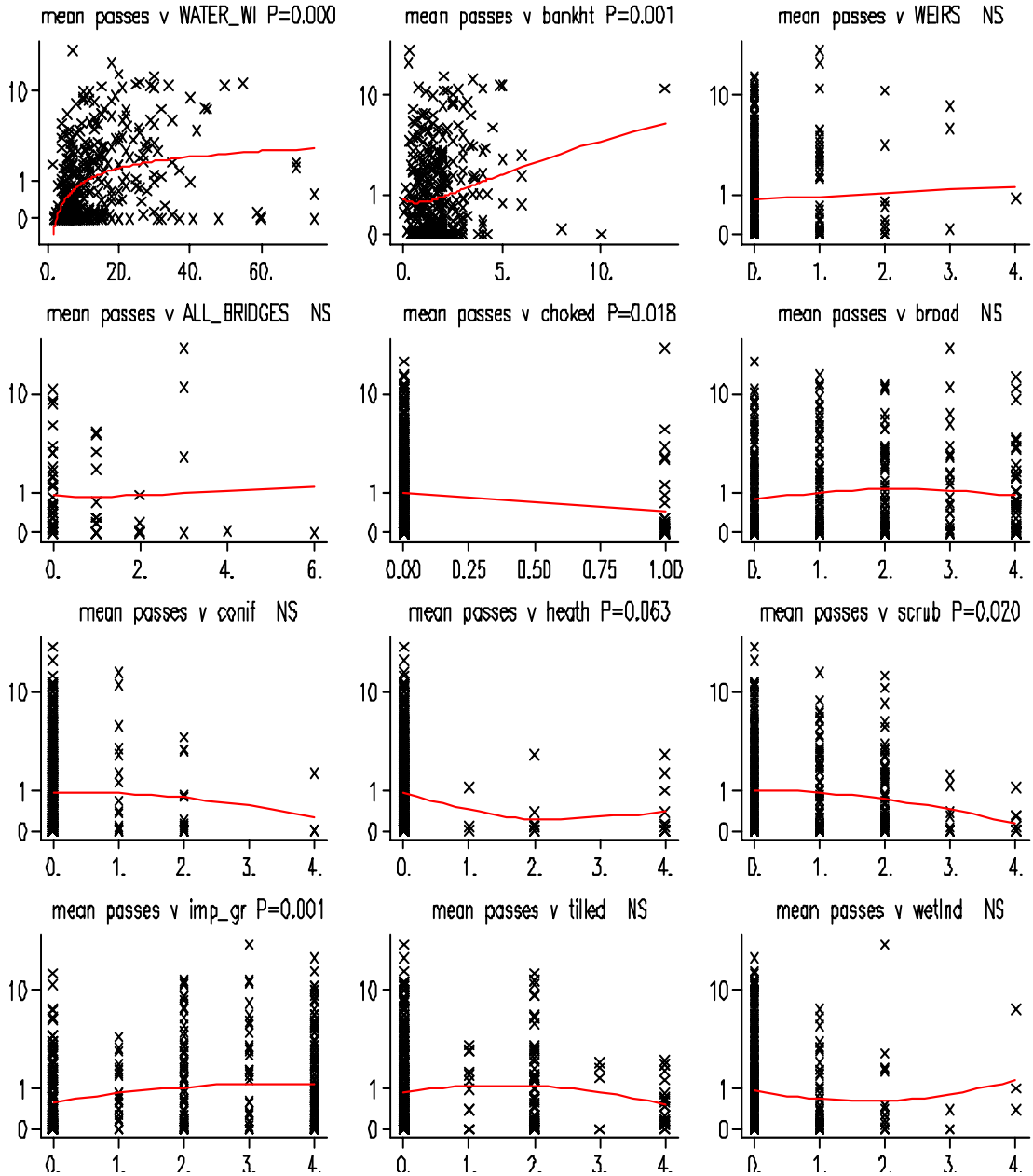
	Linear regression		Quadratic	
Term	slope	Sig	Sig	
North	0.0002	NS	NS	OS northing in km
East	-0.0006	**	*	easting in km
PCA1	0.0052	NS	NS	PCA score taken from database
PCA2	0.1516	***	***	As above – described as 'energy' in documentation
Altitude	0.0552	NS	NS	
N_RIFFLE	-0.0577	NS	NS	from section D
N_POOLS	-0.1474	10%	NS	from section D
Tree	0.0205	**	*	from section J; adding together L & R scores
Trshade	0.0194	NS	*	tree shading from section J; adding together L & R scores*
Trover	0.0284	NS	*	trees overhanging from section J; adding together L & R scores*
Embank	-0.2882	*	NS	Section L: mean height
WATER_DE	0.0931	10%	NS	Section L: depth
WATER_WI	0.4469	***	***	Section L: width
Bankht	0.1643	NS	NS	Section L: mean bank height
WEIRS	-0.0190	NS	NS	Section M
Choked	-0.1925	**	**	Section PQ: n=0, y=1
Slope	-0.0920	*	*	Section A
Flow_cat	0.0706	***	***	Section D: as 0-10 score
Broad	0.0072	NS	NS	Section H: adding L&R scores*
Conif	0.1570	NS	NS	Section H: adding L&R scores*
Heath	-0.0238	NS	NS	Section H: adding L&R scores*
Scrub	-0.0581	*	*	Section H: adding L&R scores*
imp_gr	0.0320	*	*	Section H: adding L&R scores*
Tilled	-0.0123	NS	NS	Section H: adding L&R scores*
Wetlnd	-0.0178	NS	NS	Section H: adding L&R scores*
Urban	-0.0211	NS	*	Section H: adding L&R scores*
Waterfal	-0.1211	NS	NS	Section K: using standard scores*
Cascades	0.0103	NS	NS	Section K: using standard scores*
Rapids	0.0301	NS	NS	Section K: using standard scores*
Riffles	-0.0360	NS	NS	Section K: using standard scores*
Runs	0.0415	NS	NS	Section K: using standard scores*
Boils	-0.0053	NS	NS	Section K: using standard scores*
Glides	-0.0194	NS	NS	Section K: using standard scores*
Pools	-0.0567	NS	NS	Section K: using standard scores*
Margdead	-0.0294	NS	NS	Section K: using standard scores*
Expobedk	-0.0357	NS	NS	Section K: using standard scores*
Expoboul	-0.0139	NS	NS	Section K: using standard scores*
sp_braid	0.1322	10%	10%	Section O: braided channels using standard scores*
sp_art_o	-0.1065	NS	NS	Section O: artificial open water using standard scores*
sp_nat_o	-0.0829	NS	NS	Section O: natural open water using standard scores*
sp_watme	0.3292	*	*	Section O: water meadow using standard scores*
sp_fen	-0.2317	NS	NS	Section O: using standard scores*
sp_bog	-0.2128	NS	NS	Section O: using standard scores*
sp_carr	-0.0218	NS	NS	Section O: using standard scores*
sp_marsh	0.0017	NS	NS	Section O: using standard scores*
sp_flush	0.0496	NS	NS	Section O: using standard scores*

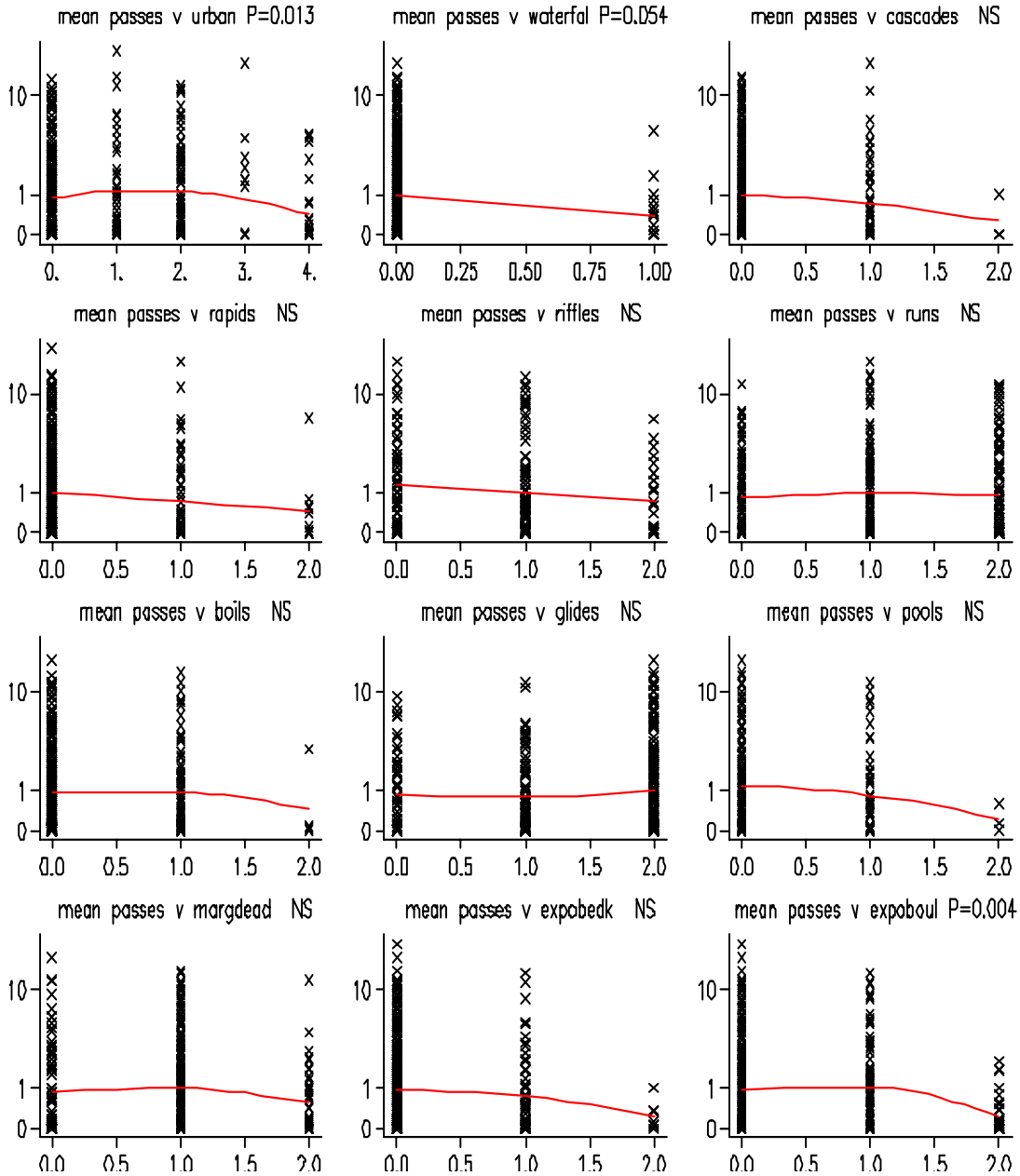
(* scores are none=0, present=1, extensive=2)

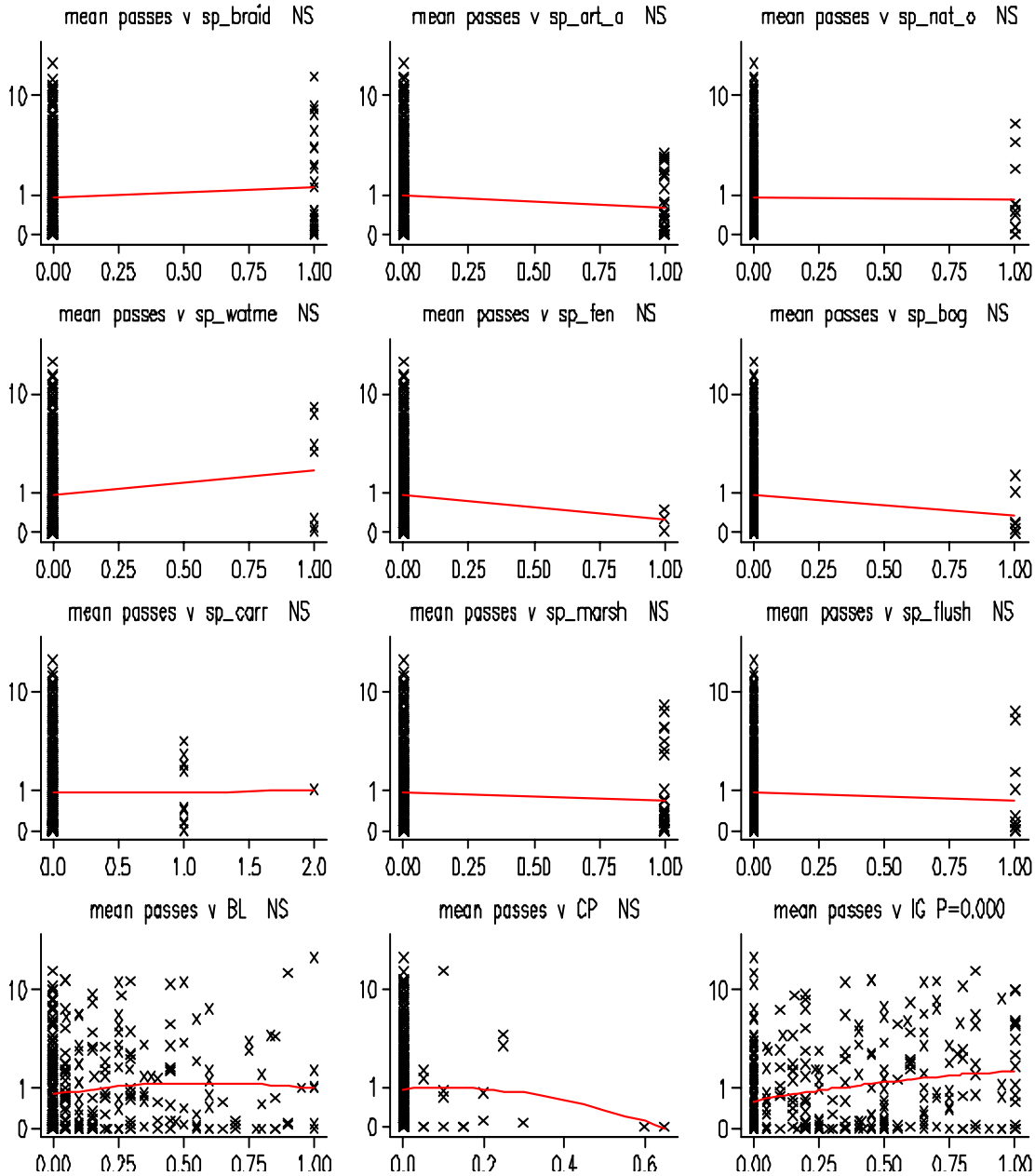
GRAPHS OF DAUBENTON'S PASSES AGAINST RHS DATA

Figure B1: **Crosses are data points expressed as geometric means of counts per spot (TotalLog/10 from table WWSurvey). Line is a quadratic fit of the habitat variable, modelling the site (geometric) mean passes per spot. P-values relate to this model.**




mean passes v WATER_WI P=0.000
mean passes v bankht P=0.001
mean passes v WEIRS NS
mean passes v ALL_BRIDGES NS
mean passes v choked P=0.018
mean passes v broad NS
mean passes v conif NS
mean passes v heath P=0.063
mean passes v scrub P=0.020
mean passes v imp_gr P=0.001
mean passes v tilled NS
mean passes v wetlnd NS


mean passes v urban P=0.013
mean passes v waterfal P=0.054
mean passes v cascades NS
mean passes v rapids NS
mean passes v riffles NS
mean passes v runs NS
mean passes v boils NS
mean passes v glides NS
mean passes v pools NS
mean passes v margdead NS
mean passes v expobedk NS
mean passes v expoboul P=0.004


mean passes v sp_braid NS
mean passes v sp_art_a NS
mean passes v sp_nat_o NS
mean passes v sp_watme NS
mean passes v sp_fen NS
mean passes v sp_bog NS
mean passes v sp_carr NS
mean passes v sp_marsh NS
mean passes v sp_flush NS
mean passes v BL NS
mean passes v CP NS
mean passes v IG P=0.000

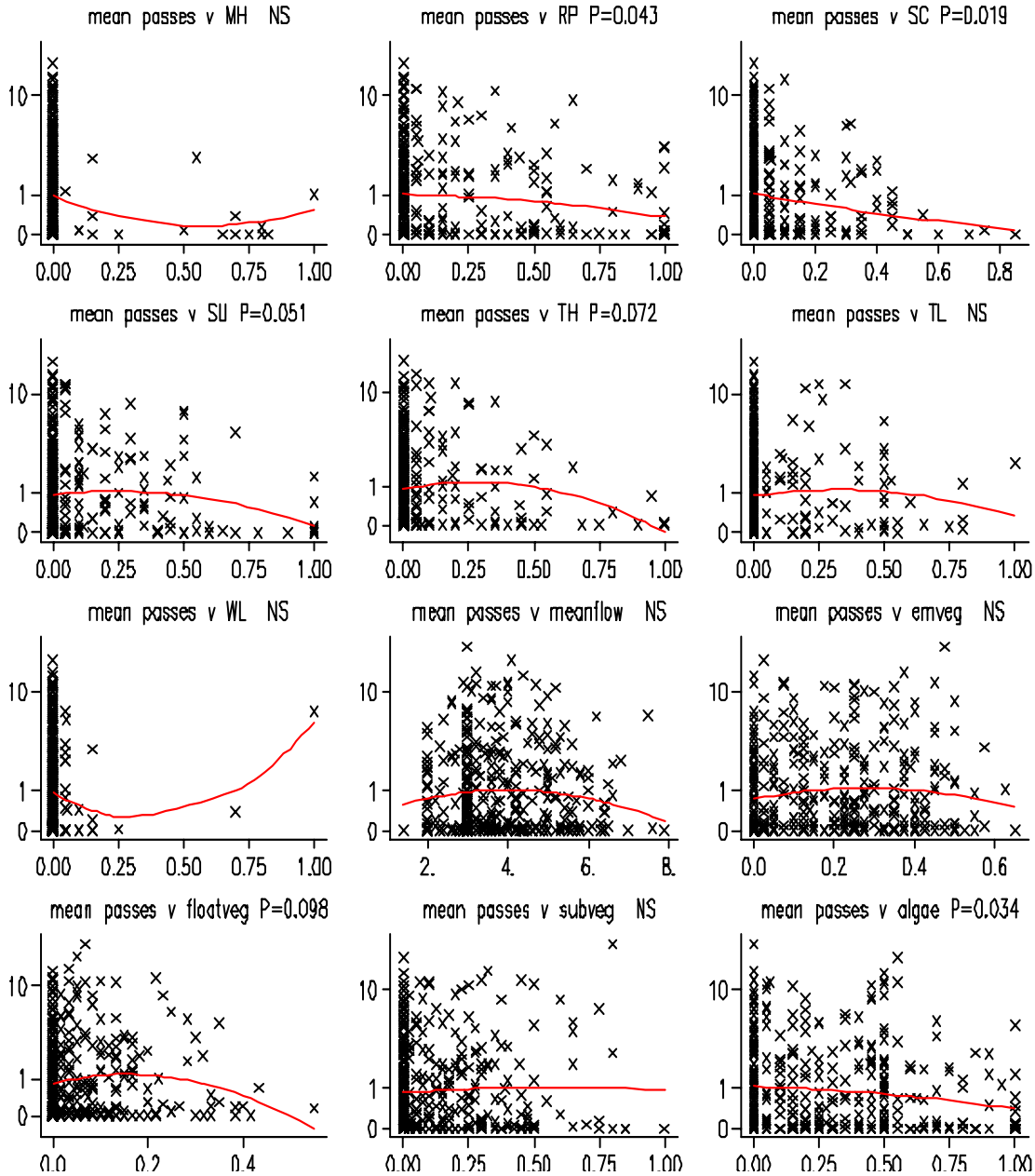
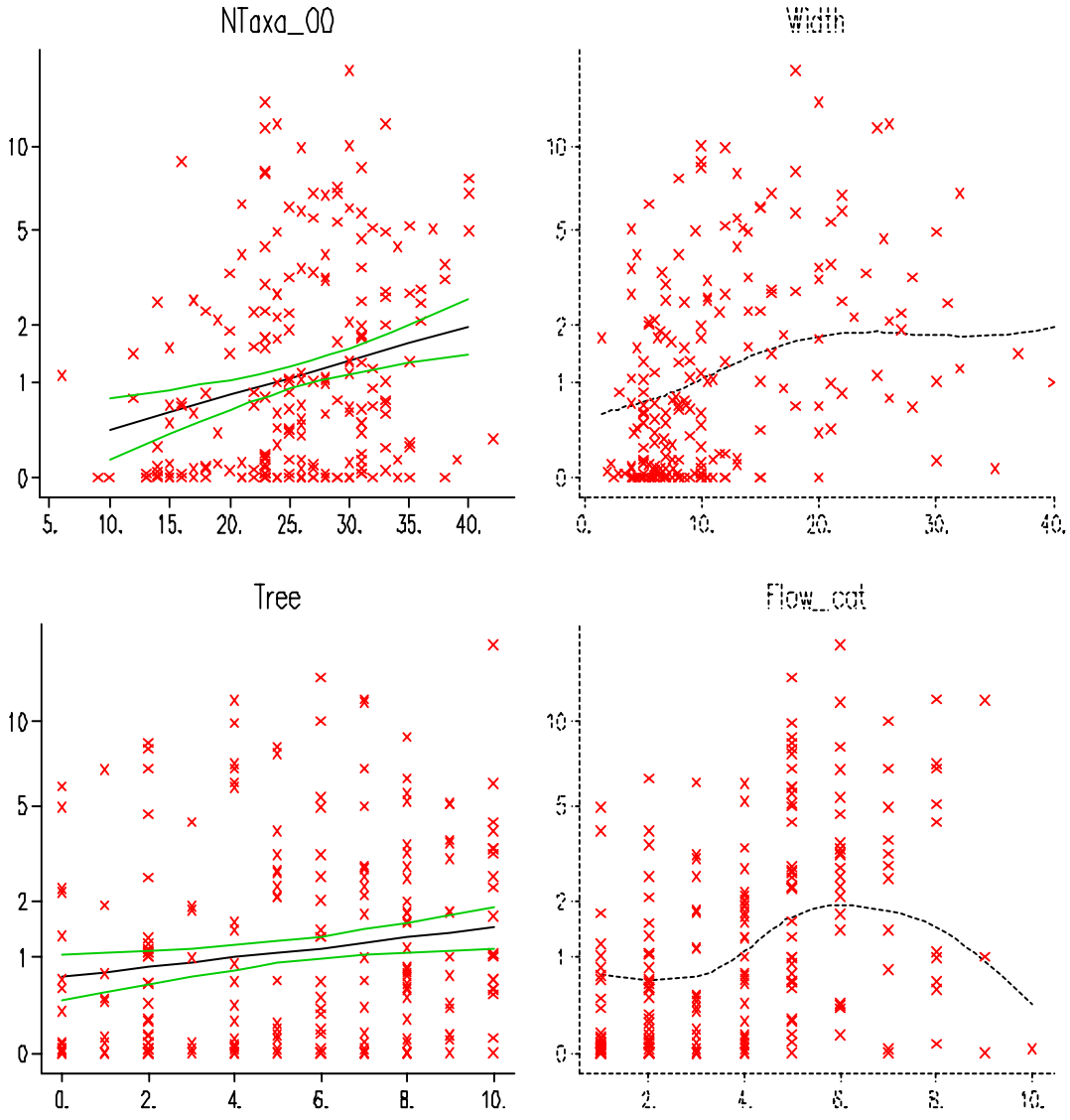

mean passes v MH NS
mean passes v RP P=0.043
mean passes v SC P=0.019
mean passes v SU P=0.051
mean passes v TH P=0.072
mean passes v TL NS
mean passes v WL NS
mean passes v meanflow NS
mean passes v emveg NS
mean passes v floatveg P=0.098
mean passes v subveg NS
mean passes v algae P=0.034

Figure B2: **Fitted lines for the terms in the core model. Each fitted line is calculated holding all other terms in the model constant at their mean value, so, for example, the width fitted values are calculated for a site in the middle of England and Wales, with average abundance of trees, average water quality and average flow category. Green lines are 95% confidence limits on the fitted line. Y-axis is the mean log count per spot with the axis labelled on the natural scale.**



APPENDIX C

PROTOCOL FOR USING THE DUET DETECTOR ON THE DAUBENTON'S BAT FIELD SURVEY

Protocol for using the Duet detector on the Daubenton's bat field survey

The use of the Duet detector will extend the present data collection capabilities of NBMP field surveys and this 'pilot' year gives us an opportunity to make a full evaluation of the Duet. If you wish to help us assess the Duet, follow the protocol outlined below when undertaking the Daubenton's bat survey.

General protocol for using the Duet & mini disc recorder on NSP surveys

Use the heterodyne system of the Duet at each spot, recording the number of 'passes' encountered of each relevant species and write this data on the standard NSP recording form.

In addition we would like you to record in frequency division onto your recorder at each spot

It is vital that we know which tracks on the mini disc refer to which spots so please follow the recording procedure underneath.

Recording procedure with the mini-disc recorder at NSP 'spots'

This protocol is written for the SONY MZ-R900 mini disc recorder but the principle will be the same for other mini disc recorders.

Use a new mini disc for each survey and ensure that you have set the DATE/CLOCK on the mini disc recorder correctly.

At the start of each 4-min recording session 'spot' slide the REC button of the mini disc to the right. The red light under the REC slider will turn on whilst it is recording.

At the end of each 4-min recording session 'spot' press the REF button of the Duet for 2 secs then press the STOP (sometimes called the CHARGE) button on the mini disc recorder and wait for it to write the data to the disk.

The REF button puts out a specific tone and this tells us when the recording session has finished when we play the recording into the computer. After the data has been written to the disc write down which track number(s) refer to that spot.

Whilst recording, listen in heterodyne mode and write down the number of 'passes' on the recording form as normal. This is important, as we need to continue the heterodyne dataset from previous years.

A practice run before the actual survey will help you get everything running smoothly.

Sending the recorded mini-disc to the NBMP

Please label the mini disc clearly with the grid reference of the site, the date of the survey and the surveyor and send it to the office as soon as possible. Include the sheet that describes which mini disc tracks refer to which spots as well. Do not merge/name tracks, as it is easier for us to deal with the original mini disk. It will take us quite a bit

of time to analyse all the recordings so please don't wait until both legs have been completed but send the disc, after each survey night has finished, to the office. If you are able to play the recording into the computer please do so for your own interest/records but still send us the original recorded mini disc. We will return the mini disc to you if you wish.

We hope that you have a successful survey, with favourable weather and do get in touch with us at the office if you have any queries about the Duet/mini disc recorder or the Daubenton's survey.

APPENDIX D

IDENTIFICATION PROCESS FOR DUET RECORDINGS

Identification process for Duet recordings

1. Look at and play sequence
Listen to the calls. If there is clearly more than one different sound then there must be more than one type of bat.
If there may be more than one bat of the same species, select the sequence and listen to it again. Then look at the combined oscillogram view. Where there is more than one bat of the same type, the peaks in the oscillogram for each pulse occur more frequently and closer together than would usually be possible if there was only one bat present (due to the 1:1 relationship between each wing flap and each call). This relationship is true for most UK species and in most situations (except during a feeding buzz). Use the spectrogram view to estimate how many bats and record.

2. Look at the shape of pulses
Use the shape of the spectrogram and the shape of the oscillogram as an initial clue. Looking only at the shape without going any of the further analysis procedures leads to mistakes in identification.

Myotis bat calls are generally a steep frequency modulated (FM). Pipistrelles use a FM sweep with a Constant Frequency tail. However, Pipistrelle calls can sometimes be confused with a Myotis sweep especially when there is much background noise, recording quality is poor and when flying in a closed habitat extending the sweep and shortening the levelled tail.

3. Select call series to analyse
If possible select a series of five calls to examine more closely. Five is an easy number but this can also be done with 2 or more calls.

Measure the distance from the start of the first call to the end of the last call in the sequence using the oscillogram to show where the sound commences. This is a subjective judgement to a certain extent therefore it is important to choose a consistent point to start from throughout the analysis and to avoid using the spectrogram as a guide

4. Calculate the Average Inter Pulse Interval (IPI)
Measure the entire duration of five (or n) pulses. Divide the time taken for (n) calls by the number of intervals (n-1) so for 5 calls there are 4 intervals.
This gives the average inter-pulse interval (IPI). Note this down and check against known average IPIs (See table at end or refer to references e.g. Vaughan et al 1997, Russ 1999, and Russo and Jones 2002).

c.50 - 80ms Myotis
c.75 - 100ms Pipistrellus
c.225+ms Nyctalus

5. Calculate roughly the number of calls per second
Divide 1000ms (1 second) by the average IPI to get a rough estimate of the average number of calls per second or repetition rate.

6. Look at the power spectrum.
Using the same set of calls, highlight them again and look at the power spectrum graph. If there is a clear peak, take a measurement of the highest point. If there is no clear peak this is likely to be a Myotis bat (although Myotis bats show a small peak it is not of the same magnitude as the other vespertilionid bats because they use short, FM sweeps)

Check the peak frequency value against the references. Use the rules for pipistrelles to assign species. This will be the average peak frequency of all calls and if there is an unexpected outcome there may be more than one species.

7. Measuring duration of calls

This measurement can be useful but it is unreliable with frequency division recording, as some information is lost. However, it can be used as a pointer, for example Myotis bats usually make calls that are only 1-3ms long and longer pulses are unlikely to be a Myotis bat. BatSound also has a pulse length analysis tool.

8. Rhythm

The type of rhythm and its regularity is assessed in a qualitative way by listening and looking at the regularity of space between pulses. Objective assessment is made using the pulse interval analysis tool on BatSound to produce a histogram. If the rhythm is regular the calls will be evenly spaced and hence have a similar pulse interval.

9. Separating Myotis bats

In this case Myotis species were classified only as Daubenton's or Myotis spp. Only when the calls were obviously different in pulse shape, repetition rate and rhythm from the usual Daubenton's type of call were they classified as Myotis spp.

Daubenton's

Daubenton's bat calls are identified primarily by sound – Daubenton's bats tend to have a 'tik-ke tik-ke' two part call when flying over the water and the rhythm is regular as it trawls the surface at a regular height without making many twists and turns. A typical Daubenton's call shape has a curvature or kink in the last third although this could be an artefact of the proximity of the bat to water.

Whiskered and Brandt's

Each pulse from a whiskered bat tends to be a little more distinct and the rate tends to be slightly slower with a larger inter-pulse interval and a less regular rhythm than Daubenton's. Whiskered calls are slightly longer in duration than either Natterer's or Daubenton's. Brandt's bats calls are indistinguishable from whiskered.

Natterer's

Natterer's bat calls over water tend to have a wider bandwidth than the other Myotis species and particularly end at frequencies below 30kHz. The calls tend to be straighter and shorter than the other species, with an erratic rhythm.

Bechstein's

Recordings of Bechstein's bats are extremely rare and little data is available about the calls in given situations. It would be virtually impossible to identify Bechstein's call from a Duet recording made in the field.

Species	Peak energy kHz	IPI average inter-pulse interval Ms	Duration (ave) ms	Notes on echolocation calls	Social calls
Common pipistrelle	41.7 - 51.8	93 (102.5±33)	6.3 (5.9)		4 sweeps. Last one at similar freqs
Soprano pipistrelle	48.8 - 61.6	81 (89.1±35)	5.7 (5.5)		3 sweeps and last is higher freq
Nathusius' pipistrelle	36 - 44.1	103	7.7	Varies call often in open. Drops sweep and freq lowers to 36.	3 parts with a trill at end -short calls of inc freqs
Noctule	16.8 - 26.0	140 (372.5±144 for QCF portion)	19.6 (22.1 QCF)	2 part call. If peak of 2nd part below 20kHz = prob. a noctule	Many different kinds
Leisler	21.1 - 36.6	226 * (187.5±80)	10.9* (5.3)	2 part call. Less of 2nd parts than noctule & peak not below 20.	2 types - from tree holes, long & shallow sweep very low. In open many kinds.
Serotine	25.6 - 42.4	116 (125.8±15)	6.2 (7.3)	Single call.	
Barbastelle	36.8*	64* (108.4±67 for stronger call)	4.4* (3.4)	2 part but one much stronger with peak at 32.	
Greater HS	80 - 84	83 (90.2±34)	49 (50.5)	Long note & sweep each end	
Lesser HS	106-113	80 (70.4±24.5)	40.3 (43.6)	Long note & sweep each end	
Brown / grey long-eared	(33)	104 (76.8±38.7)	1.7 (2.3)	Mainly quiet, short sweeps. In open uses a call of very low, reg pulses.	
Daubenton's	(47)	70 (75.5±29)	6.2 (3.2)	Often has bend at bottom and missing frequencies	Upside down J shape sometimes appears
Natterer's	(47)	67 (80.1±40)	4.5 (4.7)	Long calls almost straight down. Often harmonics	
Whiskered / Brandt's	(47.5)	86 (113±56)	4.7 (4.2)	Shorter bandwidth than Natt, less regular than Daub.	
Bechstein's		96	2.5	Very quiet and short	

*Lack of calls to analyse means values are suspect. Start and End frequencies not included here because frequency division is not reliable for those measurements. Averages can be a guide but in closed environments and early on in the evening calls may be shortened, IPI's decrease and frequencies rise.
Non-bracketed values based on Jon Russ's book (1999) and Vaughan, Jones and Harris (1997).
Values in brackets are based on Russo and Jones 2002.

APPENDIX E

DAUBENTON'S WATERWAY SURVEY ANALYSIS

RESULTS FOR DUET RECORDINGS

Observer	Site code	Date
AY	210416	13-Aug

	No.spots
Daub	1
Pip 45	1
Pip 55	1
Pip?	1
Un-id	1
Myo?	0
Noctule	0

Spot	Sec	No.bat	Daub	P45	P55	P?	Un id	Other	Pip Peak	Notes	Check
2	0-5	1				1			48.8		
2	10-15										
2	20-25										
2	30-35										
2	40-45										
2	50-55										
4	0-5										
4	10-15										
4	20-25										
4	30-35										
4	40-45										
4	50-55										
6	0-5										
6	10-15										
6	20-25	1		1					46.2		
6	30-35	1					1			poor s:n	
6	40-45	1		1					46.5		
6	50-55										
8	0-5										
8	10-15										
8	20-25	1	1								
8	30-35										
8	40-45	1	1								
8	50-55										
10	0-5										
10	10-15	1			1				57.3		
10	20-25										
10	30-35										
10	40-45										
10	50-55										
		7.00	2	2	1	1	1				

Observe	Site code	Date
HR	110503	18-Aug
	No.spots	
Daub	3	
Pip 45	2	
Pip 55	1	
Pip?	0	
Un-id	1	
Myo?	0	
Noctule	0	

Spot	Secs	No.bat	Daub?	P45	P55	P?	Un id	Other sp	Pip peak	Notes	Check
2	0-5										
2	10-15										
2	20-25										
2	30-35										
2	40-45										
2	50-55										
4	0-5										
4	10-15										
4	20-25										
4	30-35										
4	40-45										
4	50-55										
6	0-5	1	1								
6	10-15										
6	20-25										
6	30-35										
6	40-45	1	1								
6	50-55	1		1					48.4		
8	0-5	2		1			1		45	poor recording	
8	10-15	2		1	1				45.9, 55.2		
8	20-25	2		1	1				45.6, 58.9		
8	30-35	2		1			1		45.1		
8	40-45	2	1	1					45.3		
8	50-55	2		1			1		46.3	poor quality	
10	0-5										
10	10-15										
10	20-25	1	1								
10	30-35	1	1								
10	40-45	1	1								
10	50-55										
Total		18.00	6	7	2		3				

Obs	Site cod	Date	Spot	Sec	No ba	Daub	P45	P55	P?	Un id	Other	Pip Peak	Notes	Check
IJC	110623	30-Aug	2	0-5	1			1				52.6		
			2	10-15										
		No of sp	2	20-25										
	Daub	2	2	30-35										
	Pip 45	0	2	40-45	1			1				54.1	feeding buzz	
	Pip 55	3	2	50-55	1					1			Poor s:n ratio	
	Pip?	1	4	0-5	1	1								
	Un-id	4	4	10-15										
	Myo?	0	4	20-25	1					1				
	Noctule	0	4	30-35										
			4	40-45										
			4	50-55										
			6	0-5										
			6	10-15										
			6	20-25										
			6	30-35										
			6	40-45	1			1				55		
			6	50-55	2			1	1			54.0, 49.7		
			8	0-5										
			8	10-15										
			8	20-25										
			8	30-35										
			8	40-45										
			8	50-55	1					1				
			10	0-5	2	1		1				56.4		
			10	10-15	2	1		1				56.4		
			10	20-25	1			1				58		
			10	30-35	2	1				1				
			10	40-45	2	1		1				57.8		
			10	50-55	1	1								
			Total		19.00	6	0	8	1	4				

Obs	Site code	Date
JH	210585	21-Aug
	No of spots	
Daub	5	
Pip 45	0	
Pip 55	0	
Pip?	0	
Un-id	0	
Myo?	0	
Noctul	0	

Spot	Sec	No bats	Daub	P45	P55	P? (f	Un id	Other sp	Pip Peak	Notes
2	0-5	2	2							
2	10-15	2	2							
2	20-25	2	2							
2	30-35	1	1							
2	40-45	2	2							
2	50-55	2	2							
4	0-5	1	1							
4	10-15	1	1							
4	20-25	1	1							
4	30-35	1	1							
4	40-45	1	1							
4	50-55	1	1							
6	0-5	1	1							
6	10-15	1	1							
6	20-25	1	1							
6	30-35	1	1							
6	40-45									
6	50-55									
8	0-5	2	2							
8	10-15	1	1							
8	20-25	1	1							
8	30-35	1	1							
8	40-45	1	1							
8	50-55	2	2							
10	0-5	1	1							
10	10-15	2	2							
10	20-25									
10	30-35	1	1							
10	40-45	1	1							
10	50-55	1	1							
		35.00	35							

Observe	Site code	Date
JM	110809	29-Aug
	No of spots	
Daub	4	
Pip 45	1	
Pip 55	1	
Pip?	0	
Un-id	1	
Myo?	0	
Noctule	0	

Spot	Sec	No bats	Daub	P45	P55	P?	Un id	Other sp	Pip Peak	Notes	Chck
2	0-5										
2	10-15	1	1								
2	20-25										
2	30-35										
2	40-45										
2	50-55	1					1			Prob Daub	
4	0-5									Poor quality at thi	
4	10-15										
4	20-25	1	1								
4	30-35										
4	40-45										
4	50-55										
6	0-5	1			1				56.5		
6	10-15	1		1					47.7		
6	20-25										
6	30-35										
6	40-45										
6	50-55										
8	0-5									Social calls but no	
8	10-15										
8	20-25										
8	30-35	1	1								
8	40-45	1	1								
8	50-55										
10	0-5	1	1								
10	10-15										
10	20-25										
10	30-35	1	1								
10	40-45	1	1							feeding buzz	
10	50-55										
Total		10.00	7	1	1		1				

Obs	Site code	Date
JP	110470	21-Aug

Daub	2
Pip 45	2
Pip 55	1
Pip?	0
Un-id	0
Myo?	0
Noctule	0

Spot	Sec	No bats	Daub	P45	P55	P?	Un id	Other sp	Pip Peak	Notes	Check
2	0-5	1			1				55.1		
2	10-15										
2	20-25										
2	30-35										
2	40-45										
2	50-55	1	1								
4	0-5	1	1								
4	10-15										
4	20-25										
4	30-35										
4	40-45										
4	50-55										
6	0-5										
6	10-15	1		1					44.6		
6	20-25										
6	30-35										
6	40-45	1		1					45.4		
6	50-55										
8	0-5										
8	10-15										
8	20-25										
8	30-35	1		1					47.6		
8	40-45										
8	50-55										
10	0-5										
10	10-15										
10	20-25										
10	30-35										
10	40-45										
10	50-55										
Total		6.00	2	3	1						

Observer	Site code	Date	Spot	Secs	No bats	Daub	P45	P55	P?	Un id	Other sp	Pip Peak	Notes	Check
JM2	310560	29-Aug	2	0-5	2	2								
			2	10-15	2	1		1				56.4		x
Species	No of spots		2	20-25	2			1			? Myo		Slow Myotis bat e	
Daub	4		2	30-35	2	1			1			51.2		
Pip 45	3		2	40-45	2		1				? Myo		Myotis type again	
Pip 55	5		2	50-55	2		1		1			47.1, 51.2		
Pip?	2		4	0-5	2			1			noctule	54.8		
Un-id	3		4	10-15	2						? Myo		Strong peak 40.7	
Myo?	2		4	20-25	2	1		1				53		
Noctule	1		4	30-35	1			1				53.8		
			4	40-45	1			1				53.4		
			4	50-55	2	1		1				53.8		
			6	0-5	3	1	1		1			46.3, 49.6		
			6	10-15	2	1				1				
			6	20-25	2	1		1				54.7		
			6	30-35	2	1	1					46.3		
			6	40-45	2	1				1			v faint unid bat	
			6	50-55	3	1			1	1		51.2	1 faint again	
			8	0-5	3		1	1		1		44.6, 55.5		
			8	10-15	2		1	1				45.4, 56.4		
			8	20-25	2		1	1				44.6, 59.1		
			8	30-35	4		1	2		1		44.4, 56.	Social calls, unid	
			8	40-45	2		1	1				45.3, 57.3		
			8	50-55	2		1	1				45.3, 53.9		
			10	0-5	2	1		1				53.9		
			10	10-15	2	1				1				
			10	20-25	2	1		1				53.8		
			10	30-35	2	1		1				56.4		
			10	40-45	2	1				1				
			10	50-55	2	1		1				55.5		
			Total		63	18	10	19	4	7	4			

Obs	Site code	Date
KH	110601	28-Aug
Daub	0	
Pip 45	0	
Pip 55	0	
Pip?	0	
Un-id	0	
Myo?	0	
Noctule	0	

Spot	Sec	No bats	Daub	P45	P55	P?	Un id	Other sp	Pip Peak	Notes
2	0-5									
2	10-15									
2	20-25									
2	30-35									
2	40-45									
2	50-55									
4	0-5									
4	10-15									
4	20-25									
4	30-35									
4	40-45									
4	50-55									
6	0-5									
6	10-15									
6	20-25									
6	30-35									
6	40-45									
6	50-55									
8	0-5									
8	10-15									
8	20-25									
8	30-35									
8	40-45									
8	50-55									
10	0-5									Non-bat nc
10	10-15									
10	20-25									
10	30-35									
10	40-45									
10	50-55									
Total										

Observ	Site code	Date
NW	110770	29-Aug
	No of spots	
Daub	0	
Pip 45	0	
Pip 55	1	
Pip?	0	
Un-id	0	
Myo?	0	
Noctule	0	

Spot	Sec	No. bats	Daub	P45	P55	P? (	Un id	Other sp	Pip Peak	Notes	Check
2	0-5										
2	10-15									social/insect 33kHz	
2	20-25										
2	30-35										
2	40-45										
2	50-55										
4	0-5									Insect stridulations	
4	10-15										
4	20-25										
4	30-35										
4	40-45										
4	50-55										
6	0-5	1			1				57	Feed buzz + socials	
6	10-15	1			1				56.9		
6	20-25	1			1				56.4		
6	30-35	1			1				56.9		
6	40-45										
6	50-55										
8	0-5										
8	10-15										
8	20-25										
8	30-35										
8	40-45										
8	50-55										
10	0-5										
10	10-15										
10	20-25										
10	30-35										
10	40-45										
10	50-55										
Total		4.00			4						

Observer	Site code	Date
ST	110465	19-Aug
	No of spots	
Daub	1	
Pip 45	0	
Pip 55	2	
Pip?	0	
Un-id	1	
Myo?	0	
Noctule	0	

Spot	Sec	No bats	Daub	P45	P55	P? (	Un id b	Other sp	Pip Peak	Notes	Chck
2	0-5										
2	10-15	1			1				56.7		
2	20-25	1					1			faint pip?	
2	30-35										
2	40-45										
2	50-55	1					1			faint pip	
4	0-5										
4	10-15	1			1				57		
4	20-25										
4	30-35										
4	40-45										
4	50-55										
6	0-5										
6	10-15										
6	20-25										
6	30-35										
6	40-45										
6	50-55										
8	0-5										
8	10-15										
8	20-25										
8	30-35										
8	40-45										
8	50-55										
10	0-5	1	1							Loud insect noise a	
10	10-15										
10	20-25										
10	30-35	1	1								
10	40-45										
10	50-55	1	1								
		7.00	3		2		2				

Summary Table of number of spots with species present

	110623	310560	110503	210585	110770	NEW	210416	110470	110465	110601	TOTAL
	IJC	JM2	HR	JH	NW	JM	AY	JP	ST	KH	
Daub	2	4	3	5	0	4	1	2	1	0	22
Pip 45	0	3	2	0	0	1	1	2	0	0	9
Pip 55	3	5	1	0	1	1	1	1	2	0	15
P?	1	2	0	0	0	0	1	0	0	0	4
Un-id	4	3	1	0	0	1	1	0	1	0	11
Myo?	0	2	0	0	0	0	0	0	0	0	2
Noctule	0	1	0	0	0	0	0	0	0	0	1