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The Bat Atlas (Appendix 5; pp.133–155)

This atlas builds on and is part of the National Bat Monitoring Programme funded by the Wildlife and Countryside Directorate of the former Department of the Environment, Transport and the Regions (DETR), now a part of the Department for Environment, Food and Rural Affairs (DEFRA). © Crown Copyright 2001. Extracts of this Atlas may be made for non-commercial in-house use, subject to the source being acknowledged. Applications for reproduction should be made in writing to The Copyright Unit, Her Majesty's Stationery Office, St Clements House, 1-16 Colegate, Norwich NR3 1BQ.

Glossary of acronyms

BAP	- Biodiversity Action Plan	NBMP	- National Bat Monitoring Programme
BCT	- Bat Conservation Trust	NBN	- National Biodiversity Network
BTO	- British Trust for Ornithology	NBHS	- National Bats & Habitats Survey
CCW	- Countryside Council for Wales	PC	- Project Co-ordinator
CIS	- Countryside Information System	ODBC	- Open Database Connectivity
CROW	- Countryside and Rights of Way Act 2000	RHS	- River Habitat Survey
DETR	- Department of the Environment, Transport and Regions	RDB	- Red Data Book
DEFRA	- Department for Environment, Food and Rural Affairs	RDBMS	- Relational Database Management System
DOE (NI)	- Department of Environment, Northern Ireland	REML	- Residual Maximum Likelihood
EA	- Environment Agency	SAP	- Species Action Plan
EN	- English Nature	SEPA	- Scottish Environmental Protection Agency
GIS	- Geographical Information System	SFO	- Senior Field Officer
ITE	- Institute for Terrestrial Ecology	SNCO	- Statutory Nature Conservation Organisation
JNCC	- Joint Nature Conservation Committee	SNH	- Scottish Natural Heritage
NBCS	- National Bat Colony Survey	TAG	- Technical Advisory Group
		NSP	- Noctule, serotine, pipistrelle field survey

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Notes

NBMP executive summary

Introduction

1. Effective bat conservation relies on gathering information to identify changes in populations that are of conservation concern. In the UK, a paucity of quantitative historical data means that population trends of the 16 species of bats are, in general, poorly known.
2. In December 1995, the Department of the Environment, Transport and Regions commissioned a five-year programme of research (1996–2000), the National Bat Monitoring Programme, with the overall goal of developing an effective monitoring strategy for resident species of bat in the UK.
3. This programme is designed to address obligations to conserve bats under European directives and international agreements, in particular the Agreement on the Conservation of Bats in Europe (Bonn Convention) and the EU Habitats and Species Directive. It is expected to provide relevant information about bat numbers which can then be compared with targets outlined in national Biodiversity Action Plans and to provide data of value to broader conservation actions, and to policy development and implementation.
4. The programme relies on data gathered by volunteers across large numbers of sites. Identifying trends in such data with confidence is not a simple task, although well planned survey designs have reduced analytical difficulties. One of the most important features of any monitoring programme is to differentiate between natural fluctuations in population size and changes that are caused by anthropogenic factors. The NBMP has adopted sampling strategies to minimise bias and observation error, and maximise precision and hence the probability of detecting significant population changes as early in the monitoring process as possible. Power analyses have been employed to guide survey designs that will make reliable inferences about population trends.
5. Although there are obvious difficulties in monitoring bats, it is essential to improve techniques and establish a sustainable monitoring program that will contribute to conservation and policy interests.

Target species, methods and sampling

6. Three principal methods have been applied: observations at summer maternity roost sites, and at winter hibernation sites, together with summer field surveys using bat detectors. Target species in the programme are *Rhinolophus ferrumequinum*, *R. hipposideros*, *Eptesicus serotinus*, *Nyctalus noctula*, *Myotis daubentonii*, *M. nattereri*, *Pipistrellus pipistrellus* and *P. pygmaeus*.

7. Standardised monitoring protocols have been developed to collect UK-wide baseline data for each of the target species. To cross-validate, a double-sampling approach has been applied whereby each species is monitored by two of these methods.
8. Where appropriate, sites are sampled in an optimum random-stratified design to maximise the precision of national population estimates. The ITE land classification system is the base stratification system.

Progress and recommendations

9. The NBMP has demonstrated that trends in bat populations can be statistically identified from data collected through its monitoring schemes. The UK lesser horseshoe bat population has risen by approximately 4.8% per year (between 2.6% to 6.9%) over seven years (1993 to 1999). This upward trend is mainly due to an 11% per year rise (between 5.3% and 17.8%) over the previous three years (1997–1999). Differences exist between the English and Welsh populations, an overall decline of around –3.2% per year (between –8.1% and +2.0%) is evident in the English population, in contrast to a 6.2% per year rise (between 3.8% and 8.5%) in the Welsh population from 1993 to 1999. A longer run of data is needed to establish whether these trends will be sustained.
10. A range of pilot studies have been conducted, leading to the implementation of six key annual national monitoring schemes for eight target species of bat. Key schemes, the length of time they have been run and the number of sites included in the network are:

Maternity colony monitoring

- Lesser horseshoe 1993–2000 in Wales, 1995–2000 in England, 157 sites.
- Serotine 1997–2000, 54 sites
- Pipistrelle bats (both species) 1997–2000, 585 sites

Field survey monitoring

- Mixed species: noctule, serotine, both pipistrelle species 1998–2000, 367 sites.
- Daubenton's bats 1997–2000, 716 sites

Hibernation site monitoring

- All species present in hibernation sites in the UK, 1997–2000, 255 sites.

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11. Pilot studies highlighted problems in the use of a maternity colony monitoring scheme for Natterer's bats, and the need for an increased number of sites. Standardisation of greater horseshoe maternity colony counts has not been possible, but counts are currently being collated. Analyses of data from other schemes have not identified any major problems with current protocols, although some minor changes are recommended.
 12. Improved summer and winter distribution maps have been produced for all UK bat species, and published in a provisional UK Bat Atlas. Records for the maps were collated from a wide range of sources, and included resultant records from NBMP monitoring schemes.
 13. To date over 1,500 people have been recruited to the programme, and of these 851 volunteers have participated in monitoring schemes and contributed data. The volunteer recruitment rate has risen consistently from year-to-year and is still rising. Over 60 training workshops have been delivered. New and renewed recruitment and training initiatives are recommended.
 14. A dedicated relational database has been built (using Access 97) to store NBMP data. The database model and management systems have been reviewed and structural changes recommended to improve efficiency and ease of data transfer to Recorder 2000 and the Countryside Information System (CIS).
 15. Analyses to demonstrate the potential of integrating bat monitoring data with other strategic land use monitoring data is currently underway in collaboration with the Environment Agency.
 16. Key methodological recommendations are to maintain annual monitoring of target species by a volunteer network and to ensure a minimum of 30-40 sites per monitoring scheme are consistently surveyed each year. Monitoring schemes for two further species (brown long-eared and Leisler's bat) should be integrated into the programme over the next two years. Research studies to develop novel methods, in particular for woodland species, should be initiated over the next five years.
 17. There is no doubt that full and effective implementation of a monitoring programme for bats requires considerable improvements in our knowledge and understanding of bat populations. Accordingly, there is a need for a significant increase in research at the genetic, species and ecosystem levels. Surveillance schemes are in operation now. However, it is essential that schemes are supported by research and validation projects so that they can be assessed and improved.

Progress against key contract markers

Original progress marker	Progress against original set markers
"Efficient monitoring designed for each selected species"	○ Achieved. Three key monitoring methods have been developed and implemented by a volunteer network following standardised protocols. ○ Sampling designs of surveys have been formally assessed using power analysis. ○ All eight selected species are currently being monitored annually using one or more methods.
"Baseline data for each selected species"	○ Achieved. Baseline monitoring data has been collected for all eight selected species. ○ For some species, baseline data has been collected using two different methods to allow comparison in method accuracy.
"Improved distribution maps for each selected species"	○ Achieved. Provisional, up-to date 10km2 records have been collated from bat groups and other record sources in conjunction with the Chairman of BCT. ○ Distribution maps have been produced for all eight selected species, and in addition for all other UK species. ○ A Bat Atlas will be published and distributed to provide feedback to bat groups and other recorders.
"Identification of methods suitable monitoring other species of bat"	○ Achieved (given current technological restrictions). The potential application of current for methods and development of new monitoring methods for species currently not targeted has been summarised.
"Timetable in which selected species should be monitored over the long-term"	○ Achieved. Continuous annual survey regimens are recommended for all selected species to maintain volunteer continuity and the statistical power of the survey results. ○ Mechanisms for integrating non-target species into the programme over the short and long-term have been proposed. Monitoring objectives for target and non-target species have been proposed. ○ A 5-year (2001-2005) project timetable has been proposed.
"Costed options for monitoring each selected species. Costed options for a national monitoring strategy for all resident species"	○ Achieved. During the course of the programme it was evident that costing surveys on a species-by-species basis was inappropriate. Thus the fixed costs for core survey delivery, plus additional costings for inclusion of additional non-target species and associated research and development study costs have been estimated.
"Draft data model and data catalogue for database"	○ Achieved. A customised Access database (Bat Survey Database) has been developed and data model produced in conjunction with Blue-Bag Ltd. ○ The JNCC has issued a contract (2001) to test and improve data transfer capabilities from the Bat Survey Database.
"Draft data usage and exchange agreements for key suppliers and users"	○ Partly achieved. A data usage and exchange agreement was drafted in 1997. A formal review and updating of this agreement is needed.
"Preliminary analyses of environmental factors affecting bat distribution and abundance"	○ Achieved to a significant extent. Analysis of land class, weather and other factors affecting maternity colony counts of lesser horseshoe bats has been undertaken as a case example. Further analyses incorporating additional environmental factors are underway.
Additional BCT progress markers	Progress made beyond original set objectives
A countrywide network of skilled volunteers and training techniques to support recorders	○ Achieved. Recruitment of over 800 active volunteers has been reached. ○ A rigorous skills training programme of over 60 talks and bat identification workshops has been conducted making use of new training techniques and resources.
Initial trend results from monitoring schemes	○ Achieved. A statistically significant trend in lesser horseshoe bat populations has been identified, demonstrating the efficiency of the NBMP.
Greater awareness of UK bats and their conservation needs	○ Achieved to a significant extent. Implementation of the NBMP has involved collaboration with a wide range of other organisations. There has been widespread publicity about the project and results have been disseminated via conferences, meetings and articles in newsletters.

Summary of recommendations

- Recommendation 1:** Start a maternity colony monitoring and field survey scheme for Leisler's (*Nyctalus leisleri*) bat in Northern Ireland.
- Recommendation 2:** Start a UK maternity colony monitoring scheme for the brown long-eared bat (*Plecotus auritus*).
- Recommendation 3:** Review progress of autecological studies on swarming within the next two years to assess its potential as a national survey and monitoring or surveillance technique.
- Recommendation 4:** Review the advances made in automatic recording devices in the past few years to assess whether reductions in cost and improvements in technology have made the use of such equipment a feasible option.
- Recommendation 5:** Promote the development of bat detector technology towards improving standardisation of data, wider multi-species capabilities and assisting confident field identification either through active or remote field operation or later analysis.
- Recommendation 6:** Start developing a broad band multi-species field survey protocol.
- Recommendation 7:** Development of better techniques of locating bat colonies in trees and other non-building habitats.
- Recommendation 8:** Development of survey techniques for woodland bat species.
- Recommendation 9:** More effort and investment should be placed on marketing, publicity and recruitment in order to maintain and expand the NBMP volunteer network to ensure adequate geographical coverage. Areas of low volunteer density should be targeted.
- Recommendation 10:** A periodic review is recommended (once every five years) to maintain the balance of survey schemes operated within the overall programme. They should provide enough activity to maintain interest and involvement without overloading volunteers.
- Recommendation 11:** Continue to improve the quality of NBMP observers, by training in identification skills and fieldcraft, and through encouraging contact with other observers.
- Recommendation 12:** Develop a skills accreditation system and record changes in observer skill levels.
- Recommendation 13:** Define a minimum skills level that volunteers are required to have reached before participating in bat detector field surveys.
- Recommendation 14:** Improve availability of training resources to local groups/co-ordinator. A standard training resource package might include the NBMP training CD and overheads for talks.
- Recommendation 15:** Place greater emphasis on encouraging existing volunteers to recruit "buddies" or new member replacements when they can no longer cover a site. Consistent coverage of sites is paramount.
- Recommendation 16:** Invest in development of computerised systems to improve communication processes between volunteers and the office and the site allocation/re-allocation process.
- Recommendation 17:** Begin discussions with bat group representatives about recruiting an NBMP representative in each bat group responsible for site liaison and recruiting/maintaining an NBMP workforce on a local level. Discussion could also cover the potential for regional co-ordinators.
- Recommendation 18:** Pay experienced volunteers *in situ* to gap fill in under-represented areas.

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- Recommendation 19:** Explore the storage of scanned maps (with transect routes marked on them) on computer to reduce effort spent on map photocopying. Ordnance Survey will need to be consulted. Increased use of email will reduce postage costs.
- Recommendation 20:** More effort should be placed on prompt and more frequent delivery of results of surveys to volunteers. Standard database reports need to be built to extract information quickly in a simple format.
- Recommendation 21:** Promote greater outreach to NBMP stakeholders by holding annual regional gatherings to discuss data, methods and the future.
- Recommendation 22:** No major changes to the protocol are recommended. If feasible, guidelines should be issued on the training of inexperienced observers, which should include some counts made in the presence of an experienced observer.
- Recommendation 23:** Experiments of simultaneous but independent counts carried out by a second observer to assess accuracy and precision. A project using an infra-red imager, or any other aid to help get a more accurate 'true' count at a sample of sites would be of value.
- Recommendation 24:** An assessment of the relationship between the sample of colonies counted to that occurring in nature and of the movement of colonies and the formation of new colonies.
- Recommendation 25:** Run parallel transect surveys for all roost-monitored species for a minimum of 10 years or until trends between the two monitoring schemes can be compared.
- Recommendation 26:** Develop and test a stratified dawn transect survey to locate bats swarming on their return to maternity roosts at dawn. This will provide: 1) incorporation of new roost discovery into roost sampling monitoring schemes already in place; 2) location of roosts of less obvious species; and, 3) location of better samples of tree-roosting bats.
- Recommendation 27:** Encourage the monitoring of small sites and their rate of loss within the sampling strategy.
- Recommendation 28:** Some measurement of the relationship between numbers of bats visible and numbers of bats actually present is needed, but is very difficult to achieve. The potential of using endoscopes to search for hidden bats should be explored further.
- Recommendation 29:** Measurement of dispersal of bats between sites via long-term ringing studies and potentially short-term radio-tracking field research.
- Recommendation 30:** Detailed autecological study of factors affecting numbers of bats in hibernation sites.
- Recommendation 31:** Experiments with independent, simultaneous counts by different observers to assess observer differences in estimating numbers of bat passes and species identification success and assess observer accuracy in identifying species.
- Recommendation 32:** Experiments to measure detectability of bats in different habitats should be attempted or site habitat included as a covariable on trend models.
- Recommendation 33:** The degree to which the idealised route (NSP) was compromised can be recorded from maps submitted of survey routes, and an assessment made of whether apparent trends are a function of this degree.
- Recommendation 34:** Data from the NSP survey needs further review and possible changes made to the protocol. (see Chapter 6).
- Recommendation 35:** The use of heterodyne detectors should be retained for a minimum of seven years to permit a data series wherein trend estimation is possible without too many confounding factors. Also, no changes should be made to field survey protocols during this time.
- Recommendation 36:** The phasing in of new bat detector technology should be gradual and any changes in the monitoring protocol design made at the same time. In this way, all sites may be analysed together with covariates to adjust for the change in design.
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- Recommendation 37:** Calibration of all different detector types being used in the NBMP should be carried out regularly, and weighting factors incorporated into trend estimation models to account for sensitivity differences. Sensitivity tests of the detectors can be carried out in the field and in the laboratory (see Waters & Walsh 1994).
- Recommendation 38:** Review and test systems for web-based and email-based automated data entry to allow large amounts of data processing with low level staff input.
- Recommendation 39:** Improve validation of data at the entry stage to reduce data errors. Develop specialised computing routines to check data automatically.
- Recommendation 40:** Review database model and improve the structural design such that the volunteers component and data component are more closely linked.
- Recommendation 41:** Review the legal aspects of data collection and ownership by volunteers. Simple, standard guidelines on how to collect data from volunteers need to be drawn up for all societies collecting data on a large scale.
- Recommendation 42:** Review SNCO licensing and re-structure return forms to increase record return and compatibility for NBMP collation.
- Recommendation 43:** Finalise data exchange agreement between CCW and NBMP to improve NBMP's UK-wide lesser horseshoe bat dataset. Consider developing one recording form for both surveys and enter data onto a common database to reduce costs.
- Recommendation 44:** Investigate all sources of data collected for the greater horseshoe bat, and propose a way forward for national collation of data.
- Recommendation 45:** A meeting and production of a formal access and data exchange agreements is urgently needed between involved parties: DETR, BCT, JNCC, SNCOs.
- Recommendation 46:** A study to assess the problems of making NBMP compliant with emerging NBN standards. The suitability of Recorder 2000 as the primary data management tool will form a large part of this work.
- Recommendation 47:** Create a CIS transfer routine as an add-in to the NBMP Survey Database.
- Recommendation 48:** Review how BCT could best act as a data-provider and improve information dissemination to stakeholders. Determine the funding needed.
- Recommendation 49:** At this stage, no reduction in count number or reduction in survey frequency between years is recommended, and all schemes should remain annual with two counts.
- Recommendation 50:** Re-assessment through further power analyses when more data are available is recommended.
- Recommendation 51:** Production of table detailing desired and achieved sample sites for all surveys divided into UK, country and Environmental Zone. This will identify areas where more survey effort is required and allow the development of statistically defensible surveillance targets for each country of the UK.
- Recommendation 52:** Ensure a core sample of 30-40 sites for each scheme are consistently covered from year-to-year to enable UK estimates of trend. This may require employment of paid work.
- Recommendation 53:** It is important to state that at this stage, all power analysis results are preliminary. Further power analyses should be carried out when more data are available from different years to re-assess required sample sizes and survey designs.
- Recommendation 54:** Publish the maps in Bat Atlas form and disseminate to bat groups to stimulate searches for roost and hibernation sites in all areas.
- Recommendation 55:** Aim to produce a new set of maps in 10 years' time.
- Recommendation 56:** Encourage bat groups to maintain records in a standard form that allows easy transfer to

regional/national recording centres. The use of a standard recording package – Recorder 2000 – should be encouraged. Such a system should conform to NBN recommendations.

- Recommendation 57:** Make a basic assessment of sampling intensity in different regions. Use this information to define recording targets for areas and thereby improve the evenness of recording.
- Recommendation 58:** Encourage groups to record sampling intensity measures and in the collation of data for any new maps, collect information relating to sampling intensity.
- Recommendation 59:** Continue efforts to determine the strengths and weaknesses of alternative methods of trend analysis. Organise a technical meeting to discuss appropriate methods.
- Recommendation 60:** Assess GIS needs and spatial referencing of NBMP survey routes/sites. Assess GIS habitat data and scale of data available, the costs-benefits of data capture and the potential of a central GIS for use by all mammal monitoring programmes.
- Recommendation 61:** Ensure adequate staff support is available to carry out routine seasonal NBMP procedures, such as map copying, mailouts etc.

1: Introduction

1.1 WHAT IS THE NATIONAL BAT MONITORING PROGRAMME?

In December 1995, the Department of the Environment, Transport and the Regions (DETR) commissioned a five-year programme of research, the "National Bat Monitoring Programme", with the overall goal of developing an effective monitoring strategy for resident species of bats in the UK (DETR Contract Reference CR018).

The National Bat Monitoring Programme (NBMP) aims to develop a strategy that will provide government and non-governmental organisations with accurate monitoring data on which to base advice relevant to the conservation needs of the UK's 16 species of bats. An essential long-term objective is to identify any rapid declines that require conservation action, and in combination with other monitoring programmes and strategic land use monitoring data, to investigate the possible causes of population changes. In a wider context, the NBMP aims to promote bat conservation through its strong partnership of skilled volunteers and professional BCT staff.

1.2 WHY IS MONITORING BATS IN THE UK IMPORTANT?

1.2.1 Conservation status of bat populations in the UK

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. Bats are a species-rich group widely distributed through the range of agricultural and non-agricultural landscapes, and habitats that form the wider countryside. Their reliance on insect prey and specialised feeding behaviour and habitat requirements suggest that they are likely to be valuable indicators of environmental change in the wider countryside.

The present distribution of bat species resident in the UK appears to be strongly influenced by climatic and habitat gradients. Many bat species occur in the UK at the northern limit of their European distribution, and so are absent from a significant part of the country (Corbet & Harris 1991). Such a distribution suggests that while the balance and status of UK bat populations are undoubtedly influenced by factors which are specific to the UK, they are probably also linked to factors such as climate change affecting European bat populations as a whole. Observations of bats disappearing from censused hibernation sites have demonstrated considerable changes in European bat populations from the 1950s to early 1980s (summarized in Daan, Glas & Voute 1980, Stebbings & Griffith 1986, Stebbings 1988). Exceptionally rapid decline rates and even local extinctions have been observed in the lesser horseshoe bat (*Rhinolophus hipposideros*), greater horseshoe bat (*Rhinolophus ferrumequinum*) and greater mouse-eared bat (*Myotis myotis*), while

significant increases have been observed in Daubenton's bats (*Myotis daubentonii*) (Kokurewicz 1995, Racey *et al.* 1998). In the UK, the two horseshoe bats have become very rare or extinct over significant areas of their former range within the UK (Stebbing 1988), and the greater mouse-eared bat became extinct in the UK in 1990 (Stebbing 1992).

A comprehensive review of the current status of UK bat populations has been compiled by Harris *et al.* (1995). The review provides the best estimates of population sizes and trends available to date, but highlights the lack of published quantitative data available either historically or currently, on which to base estimates of population size and trend. For the species currently breeding in Britain, current estimated national trends are that eight species are in decline, and populations of the other eight species appear either to be stable or are of unknown status.

Comprehensive wildlife legislation exists to protect all species of bat recognised in the UK, and their roosts, from disturbance (Wildlife and Countryside Act 1981, Wildlife Order 1985 – Northern Ireland, Habitats Regulations, 1994). The CROW Act was being finalised by Parliament at the time of compiling this report. It is a criminal offence to kill, injure or capture bats or to disturb them at their roosts, and roost sites themselves are protected. Public interest and concern about the conservation of bats reached noteworthy levels as a result of this legislation and led to the formation of a countrywide network of local "bat groups" working to promote bat conservation action.

The Bat Conservation Trust, a non-governmental organisation dedicated to bat conservation, was founded in the UK in 1990 and now acts as an umbrella organisation for the group network. Recognition of this structure as a suitable national survey framework resulted in the first national survey of bats and their habitats, funded by the Joint Nature Conservation Committee 1990–1992 (Walsh, Hutson & Harris 1993; Walsh, Harris & Hutson 1995, Walsh & Harris 1996 a,b). The survey provided data on habitat preferences and abundance of bats in the UK and was an important trial study. It demonstrated the practicality of assigning volunteers to carry out bat surveys within randomly selected 1km squares throughout the UK.

1.2.2 Bat population monitoring in the UK: history of the present

Historically, efforts to quantify bat population changes in the UK have been geographically fragmented and concentrated on just a few species. Assessments of regional population size have used non-random data collection methods that make it difficult to extrapolate results to a wider area (Walsh, Stebbings & Thompson 1987, Robinson 1992). For four species, *R. ferrumequinum*, *R. hipposideros* and *Pipistrellus* sp., some quantitative data have been collected, but for other UK species there is little quantitative informa-

tion upon which to base estimates of trends.

○ ***Rhinolophus ferrumequinum*** This is the best studied chiropteran in the UK, probably because the species is endangered, has a highly restricted range and is conspicuous and faithful to specific sites in winter and summer. Detailed counts have been made of banded animals in capture/mark/recapture studies at hibernacula since the 1940s, and counts made at summer roosts since the 1960s (Hooper 1983; Stebbings & Arnold 1987; Ransome 1989). However, no single standard counting protocol has been followed over time, and historical data is held independently by individuals who have studied specific populations in different parts of the species range. While declines in bat numbers were identified across its range between 1950 and 1980, counts over the past twenty years show small declines or stable populations in some areas and increasing populations in others (Harris *et al.* 1995). Compilation of these data to examine historical trends in the entire population across its UK range has not been published to date.

○ ***R. hipposideros*** This species has also been counted in both winter and summer sites without the application of a standardised protocol. The resultant picture is similar to that for *R. ferrumequinum*, with varying trends in localised areas, though whether this reflects real differences or methodological differences is unclear (see Harris *et al.* 1995). In order to determine precisely how populations are changing in this species, the Countryside Council for Wales (CCW) established a project to monitor maternity colonies in Wales in 1993 (Smith 1993), which was revised and extended to England in 1995 (Smith 1995). In an evaluation of the data in 1998, the Welsh lesser horseshoe population appeared to have remained stable over the 1993–1997 period, assuming that the roost counts were representative of changes in the whole population (Witter 1998). The same method is currently being used by NBMP in maternity colony monitoring for this and other species. Collaboration with CCW has resulted in the application of consistent methods in Wales and England, and data from the Welsh project are made available to the NBMP.

○ ***Pipistrellus* sp.** The longest running bat population surveillance programme at a national level in the UK is the National Bat Colony Survey (NBCS), initially funded by the Institute of Terrestrial Ecology and now privately run by the Robert Stebbings Consultancy Ltd. (see Mitchell-Jones & McLeish 1999). The NBCS began collecting data in 1978 and relies on standardised counts of bats emerging from summer maternity colonies (mainly of house-dwelling *Pipistrellus* sp). In an examination of this data, Stebbings estimated a 62% decline in *Pipistrellus* sp populations between 1978 and 1987 (Stebbing 1988). However, interpretation of the data has recently been questioned, and a re-analysis (including more recent data) identified a 43.5% decline in the UK *Pipistrellus* sp population from 1980 to 1992 (Harris *et al.* 1995). The NBCS currently runs in parallel to the NBMP, and while collaboration between the two projects has been dis-

cussed, an agreement as to how this process could be achieved has not yet been reached.

Despite the best efforts of many committed naturalists and biologists providing data on localised populations of bats, there has been no structured framework for monitoring bat populations at a national level. The National Bat Monitoring Programme was intended to fill this gap and provide the information on populations so urgently needed for conservation and management.

1.2.3. Contribution to practical and policy themes and issues

Population monitoring data are needed to enable conservation priorities to be set and also to measure the effects of nature conservation efforts as well as those of agricultural and other human activities which may affect bats. Interpretation of monitoring information will allow the UK to report against targets and objectives within the framework of national legislation, and international conventions, directives and agreements. Such policies have been a major stimulus to develop and adopt a national monitoring strategy for bat populations (Racey 2000).

Central to the aims and objectives of the National Bat Monitoring Programme (NBMP) is the collection of relevant and accurate information to tackle the research objectives set at the outset. Coupled with this is the need for the data collected to be of a wider value within a framework of practical and policy themes and issues (Box 1.1).

Box 1.1: Practical and policy themes and issues

- Contributing to current international initiatives such as those concerning biodiversity conservation, habitats and sustainable development
- Development of and assessing the influence of UK Government policies relating to agriculture, water and land use
- Development of processes for identification of species, sites and habitats of conservation concern
- Identification of factors affecting populations through integration with other monitoring data
- Informing decision-makers and the wider public about species of conservation concern
- Wider conservation and research issues

1.2.3.a Contributing to current international initiatives

Monitoring information needs for nature conservation in the UK are firmly anchored in a number of agreements at a global level:

- **Bonn Convention 1979/Eurobats 1991** The Agreement on the Conservation of Bats in Europe (Eurobats) was established within the Bonn Convention (Convention on

the Conservation of Migratory Species of Wild Animals, 1979). The Agreement recognises that endangered migratory species can be properly protected only if conservation activities are carried out over the entire migratory range of the species. Obligations under the Agreement have been developed into a Conservation and Management Plan, and place considerable emphasis on monitoring. The Agreement's Advisory Committee is, *inter alia*, currently working to identify species monitoring protocols that can be applied on a Europe-wide basis. The development of novel monitoring techniques and verification of existing techniques through the NBMP will help fulfil these fundamental obligations.

○ **The Convention on Biological Diversity 1992 (CBD)**

Perhaps the most comprehensive global agreement with relevance to bats, requiring signatory parties to "identify components of biodiversity.....and monitor, through sampling and other techniques, the components of biological diversity identified" (Article 7). The NBMP will provide valuable data on species abundance and richness in key habitats, regions and sites in the UK and thereby provide the data upon which action to conserve bat biodiversity may be based.

○ **Species Action Plans (SAPs)** Monitoring of populations and distribution is identified as an essential element in the national Biodiversity Action Plan (BAP). This importance is reflected in the local and regional SAPs being developed. Many of the latter have included specifications either for particular bat species or for bats in general with some emphasis on local concern. The NBMP will contribute to the implementation of BAPs at all levels.

○ **Habitats and Species Directive** The UK is also bound by the provisions of the European Union Habitats and Species Directive (European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora 1992). The Directive includes all bats as protected species (Annex IV), with commitments to maintain and restore their populations to a "favourable conservation status", and to carry out particular conservation measures (including the designation of Special Areas for Conservation and surveillance of the conservation status of species) for five bat species in the UK (Annex II). The interpretation of "favourable conservation status" has not been explored fully. However, the assumption is to be made that specific parameters will be adopted to judge this definition. NBMP data on relative population levels will provide potential parameters for guidance within the Directive.

○ **Sustainable development** In 1994, the Government published its Strategy for Sustainable Development, following the commitment made at the Earth Summit of 1992. One of the commitments in this document was to develop a set of indicators, which link environmental impacts with socio-economic activity, to help highlight the main issues and help both policy-makers and the public to understand them better. Local Authorities, as part of the Local Agenda 21 initiative, are currently in the process of

developing a set of indicators for use at local level. Mammal populations, including bats, might potentially serve as indicators of a variety of changes in the countryside. Their usefulness as indicators largely depends on the availability of population data at both national and local levels, and hence in the implementation of a monitoring programme.

○ **Pan-European Biological and Landscape Diversity Strategy**

As a contribution to the European Action Programme for Threatened Species (Action Theme 11 of the Pan-European Biological and Landscape Diversity Strategy), a new Red Data Book (RDB) of European vertebrates is in preparation. Monitoring mechanisms to provide current data on bat populations will be required to implement this theme and will assist in measuring the impact of other Action Themes, such as those concerned with the conservation of Cultural Landscapes. A Europe-wide Species Action Plan for the greater horseshoe bat has been published (Ransome & Hutson, 2000). In the long-term, the NBMP will provide data to contribute to future RDBs.

○ **Input to pan-European policy and action through development of monitoring techniques**

The development of novel techniques and verification of existing techniques to monitor a range of bat species will permit skills transfer at a pan-European level. Information from NBMP will assist government and voluntary conservationists to consider the best methodologies to adopt in order to formulate a co-ordinated approach to survey and monitoring on a Europe-wide basis. Such information and protocols are already being provided for pan-European projects being developed under the European Bats Agreement (6.1.3). It is hoped that this information will also help governments who are not signatories to the Agreement to develop appropriate policies and activity.

1.2.3.b Development of, and assessing the influence of, UK Government policies relating to agriculture, water and land use

○ **Agriculture** All agriculture policy affects biodiversity and the environment and, as such, protecting and enhancing biodiversity should become a central goal of agriculture policy and the mechanisms that deliver it. Trade policies such as the Common Agricultural Policy (CAP) and the General Agreement in Tariffs and Trade (GATT) currently take little or no account of the environment. Proposals to improve CAP and other agri-environment schemes will have to take particular note of species, such as bats, that rely on wider habitat quality and structure. Predictive models using data generated through the monitoring programme will inform decisions on the direction of land use change by identifying those changes that may improve the agricultural landscape for bats, as potential indicators of the health of the ecosystem. They will also pinpoint landscape areas where positive agricultural changes may be of most benefit to bat populations.

○ **Land use and landscape structure management** Bats are widely distributed through the range of landscapes and

habitats found in the UK and as such, their populations have the potential to be indicators of change in the wider countryside. Trends in their numbers in key broad habitats could usefully complement the strategic monitoring of land cover carried out by the DETR within the Countryside Survey research programme.

- **Development and local planning** Results from the NBMP will help local authorities and government agencies to identify important bat sites worthy of protection and careful management by placing local information in a national context. Information could be used to provide support for the local planning process, such as information on bat priority sites to be identified in local plans and to provide information to assist with decisions relating to planning applications. This would enable decision-making and policy formulation to be based on sound information, in line with "Planning Policy Guidance: Nature Conservation" (PPG9, 1994), and its revision in hand, and National Planning Policy Guideline 14 (NPPG14) in Scotland.

- **Local Agenda 21 strategies** In addition to the UN Convention on Biological Diversity, the Earth Summit held in Rio de Janeiro also launched the initiative of "Agenda 21". Local Agenda 21 provides a 'bottom-up' mechanism for meeting national plans for sustainable development through harmonising environmental, economic and social concerns. NBMP data could usefully be fed into the local strategy plans being formulated by local councils and authorities.

- **Water management** In fulfilling its functions, the Environment Agency (in Scotland, SEPA) has a duty generally to promote the conservation of flora and fauna dependent on the aquatic environment, and to take into account any effects that proposals relating to any of its functions may have on the environment (Water Resources Act 1991). Bats are closely associated with water bodies and riparian habitats in the UK. This is one of the key habitats identified in the UK National Bat Habitat Survey. One species targeted by the NBMP, *Myotis daubentonii*, roosts in close proximity to water and feeds on insects just above or directly from the water surface of rivers, canals, pond and lakes. Because of the high dependency of this species on water, its quality and associated vegetation, populations are predicted to be a valuable indicator of the general state of the aquatic environment. It follows that monitoring *M. daubentonii* populations along waterways could be used by the EA as part of a general appraisal of habitat and water quality and to assess changes as a result of management intervention. The collection of such data would also serve in distinguishing local, regional and national causative factors of the observed trends and used to produce EA management strategies (including national, large catchments and LEAPS (England & Wales only)) that will enhance the aquatic environment for bats in the UK.

- **Forest management** One of the Forestry Commission objectives set out in "Sustainable Forestry – The UK

Programme" is "to conserve and improve the biodiversity, landscape, and cultural heritage of our forests and woodlands". This relates to a Statement of Principle agreed at the Rio Earth Summit. Forest was identified as a key habitat for bats in the UK National Bat Habitat Survey and the significance and threats to bats of forest loss or unsympathetic management through loss of roosting and foraging opportunity have been highlighted by almost all contributors to a global action plan on Microchiroptera to be published by IUCN (Hutson, Mickleburgh and Racey 2001). The effect of forest management practices, and identification of best practice, on a Europe-wide scale is the subject of a transboundary project proposal being developed under the European Bats Agreement. Monitoring data collected through the NBMP will provide information on bat populations and species richness in key habitats such as forest. Analyses of species-specific bat population data and strategic land cover data will aid in identifying the effect of forest policy and identifying best management practices to conserve bat biodiversity in forests.

1.2.3.c Development of processes for identification of species, sites and habitats of conservation concern

Data collected in the monitoring programme will facilitate effective targeting of conservation action (including the selection of species of conservation concern, key sites and priority habitats) by a wide range of organisations and individuals. Bats are potentially valuable indicators of the general health of the environment.

- **Special Areas of Conservation (SACs)** The implementation of the EU Habitats and Species Directive has been a high priority for the UK statutory conservation agencies. The Directive contains a range of measures, one of which requires the UK to submit to the European Commission a list of high quality conservation sites (SACs) proposed for inclusion in the EU Natura 2000 site network. SACs only apply to Annex II species at present (*R. ferrumequinum*, *R. hipposideros*, *Barbastella barbastellus* and *Myotis bechsteinii*). Improved national data on the distribution of bat species abundance and richness within regions and key habitats in the UK can be usefully incorporated into the selection criteria philosophy for SACs. SACs for bats are currently largely restricted to roost sites and in the future need to incorporate essential, core habitat. Long term monitoring data is vital to judge the effectiveness of SACs in contributing to the overall performance of the Natura 2000 network and in order to gain early warning for necessary remedial conservation measures to be implemented. It will also contribute to the assessment of the effectiveness of the wider protected area network in the UK, both statutory and non-statutory.

- **Habitat Action Plans (HAPs)** Action plans for the protection and long term management of habitats of conservation value are in preparation. NBMP data could be incorporated into the development of and monitoring of management targets. The top two wildlife habitats listed as having the most species of conservation concern within

the Biodiversity Steering Group Report (Vol 1, Chapter 2, p25) are broad-leaved woodland and standing open water. These correspond directly with the two most important habitats for bats identified by regression analyses in the National Bat Habitats Survey 1990–1992. Similar analyses will be conducted with data from the NBMP, and models will be of more value being at a species-specific level.

1.2.3.d Identification of factors affecting populations through integration with other monitoring data

While long-term population monitoring data are available for some wildlife taxa, e.g. birds, the essential development of monitoring for other groups is currently in the development phase. It is important that consideration be given at an early stage to ensuring that all such monitoring is carried out in a way that allows integration with other fauna and flora monitoring and with such strategic monitoring as that for land cover and vegetation being carried out through the DETR-sponsored Countryside Survey. It should also allow input to the widest assessment of policy impact and the development of the most effective cross-cutting research and policy needs.

The modeling of scenarios of environmental change and prediction of their likely consequences on bat populations is an essential basis for the development and monitoring of appropriate environmental and agricultural policies sensitive to bats. The collection of quantitative national data on bat populations, and the relation of these data to land use and other environmental data sets, will identify possible causes of change in populations, and also predict the quantitative impact on bats of pre-defined change scenarios.

1.2.3.e Informing decision-makers and the public about species of conservation concern

Decision-makers at all levels require access to relevant and accurate information on wildlife populations if effective management prescriptions are to be designed and put into action. Raising public awareness of, and involvement in environmental issues is a central issue raised in the Government's White Paper "This Common Inheritance" in 1990 and under the 1992 Convention on Biological Diversity.

1.2.3.f Wider conservation and research issues

Bat diversity decreases with increasing latitude and this is readily apparent in the distribution of species in the UK. There is some evidence of current changes in distribution of some species in Europe. Improved distribution maps resulting from the NBMP will provide records charting the movement of species ranges. Several aspects of the ecology of bats resident in the UK indicate sensitivity to climatic conditions: bats are hibernators; they are reliant on insect populations; they use torpor in summer in response to perturbations in food supply/inclement weather; birth timing is highly influenced by spring temperature conditions; and their roosting requirements appear to be highly sensitive to ambient temperatures. It therefore seems likely that bat populations will be influenced by long-term climate change. What this influence might be is difficult to predict at this stage, but if it

involves increased climatic perturbation at temperate latitudes, the effect on bat populations may be negative.

1.3 SPECIFIC GOALS AND OBJECTIVES OF THE NATIONAL BAT MONITORING PROGRAMME

The NBMP was established to address the monitoring of all UK bat populations at a national level. The specific objectives are set out in Box 1.2.

Box 1.2: NBMP aim and objectives (as listed in contract sections 1 and 4)

AIM

The aim of the project is to develop effective monitoring strategies for resident species of bats in the UK. The project will produce baseline monitoring data on numbers and distribution of selected species in a framework that will enable analysis of possible causes of population change and the consequences of changing environmental conditions to be carried out.

OBJECTIVES

- To set out a long-term strategy for monitoring the 16 species of bats resident in the UK and outline monitoring methodology options for each species
- To develop and implement effective monitoring programmes for selected species which have populations of a sufficient size to provide reasonable data from a countrywide survey involving volunteer participation
- To obtain baseline monitoring data for each selected species which can be used to analyse the ecological determinants of the distribution and abundance of bat species

1.4 OVERVIEW OF PROGRAMME APPROACH

1.4.1 Geographical scope, target species, and principal methods

The geographical range of the monitoring programme is the whole of the UK: England, Wales, Scotland and Northern Ireland. Information has also been received from the Isle of Man and the Channel Islands.

Seven target species were originally selected for inclusion within the programme. This was expanded to eight species in 1997 (Box 1.3), when scientific evidence was released supporting the reclassification of "pipistrelle" bats into two distinct species *Pipistrellus pipistrellus* (common) and *Pipistrellus pygmaeus* (soprano) Jones & Barratt 1999). Rapid training in distinguishing the two species with bat detectors has led to the field surveys providing data for these species individually. The process of separating roosts has only just begun, and information based on maternity roost counts contained within this report are presented for the two species combined as "pipistrelle".

Species were chosen according to conservation concern

Box 1.3: Eight target species of bat

- *Rhinolophus ferrumequinum* greater horseshoe bat
- *Rhinolophus hipposideros* lesser horseshoe bat
- *Myotis daubentonii* Daubenton's bat
- *Myotis nattereri* Natterer's bat
- *Pipistrellus pipistrellus* common pipistrelle
- *Pipistrellus pygmaeus* soprano pipistrelle
- *Eptesicus serotinus* serotine bat
- *Nyctalus noctulus* noctule bat

and because they constitute a representative range of different roosting, feeding and habitat selection strategists with populations of a sufficient size to provide sufficient data for countrywide surveys. *M. nattereri* was additionally included as a recognised difficult species which might give indications to the monitoring of other difficult species. At the end of a five-year development phase, the project will review target species included in the programme and consider novel methods for non-target species.

For long-term success the programme requires reliable methods to estimate trends in relative abundance that balance disturbance to animals, survey effort and cost, and geographical coverage. Reviewing current methodology three "best available" methods were identified that could feasibly be applied at a large-scale (Box 1.4).

Box 1.4: Three principal methods

- counts of bats at hibernation sites
- counts of bats at maternity colony roosts
- field surveys of bats using bat detectors

All three methods have their drawbacks, either through the nature of the bats themselves, through exogenous factors that influence bat behaviour or through current skill levels of those undertaking monitoring. To evaluate methods and strengthen conclusions, each target species is therefore being monitored using at least two of these methods for comparison.

1.4.2 Volunteer network and management

Several country-wide monitoring and recording programmes, most notably those for birds (Greenwood 2000) and butterflies (Van Swaay 2000) are currently operating mainly due to the work of volunteers. Within these programmes, volunteers play a significant role in carrying out the bulk of the field work. However, any volunteer force requires co-ordination by well-organised professional staff. In the NBMP, two professional staff are responsible for the design of monitoring concepts, all organisation and co-ordination, assessment and analysis of the monitoring data and interpretation and presentation of the results. Office and field assistance is contracted on a seasonal basis. All co-ordination is carried out centrally.

A network of skilled and dedicated volunteers carries out

the majority of NBMP fieldwork across the country. The NBMP volunteer force consists mainly of recruits from an existing network of bat groups in the UK. Volunteers from these groups already have considerable bat expertise and provide long-term continuity and commitment to monitoring throughout the regions and countries of the UK.

Other key members of the NBMP volunteer-force are householders with bats roosting in their homes, members of other nature groups and the wider-public. Recruitment is targeted on areas of low coverage, and includes leaflet distribution, talks and popular articles.

A major thrust of the programme is to raise skill levels amongst volunteers through training. Each year a programme of bat identification workshops for beginners has been organised, together with a series of workshops introducing time expansion techniques for more advanced volunteers. An "electronic bat" has been developed which enables indoor training of volunteers during the winter season, and a species identification training manual has been published together with an accompanying CD.

Volunteers represent a valuable resource to the monitoring programme. In return there is great community value in people actively participating in conservation projects on a voluntary basis. To maintain this spirit, the NBMP ensures adequate feedback is provided to volunteers. Feedback is achieved through personal correspondence, regular progress talks delivered regionally and nationally, and through a dedicated annual newsletter, *Bat Monitoring Post*. In addition, the BCT's quarterly newsletter, *Bat News*, reports survey progress to BCT members. NBMP information, including a downloadable newsletter, is available on the BCT web site (www.bats.org.uk).

1.5 REPORT TOPICS

The primary task in establishing the NBMP has been to develop the technical capacity to carry out standardised surveys of bats on a wide geographical scale. This first five-year phase (1996–2000) has concentrated on the development of techniques and their practical application using a volunteer workforce. While a strong emphasis has been placed on the statistical design of monitoring schemes, the NBMP has sought to meet real field-based needs.

Chapter 2 provides a detailed examination of the ecology of bats in the UK and the options available to monitor them. Chapters 3 and 4 deal with the development of a volunteer force and three key monitoring protocols. Data handling is examined in Chapter 5. Chapter 6 presents the baseline monitoring data-sets collected by the NBMP from 1996 to 1999. A detailed power analysis of the data is presented separately in Chapter 7. Chapter 8 discusses the baseline distribution maps collated by BCT as a part of the NBMP. Chapter 9 then explores examples of trend and distribution-related conservation analyses that can be applied to NBMP data. Finally, Chapter 10 evaluates the programme's first five-year phase, sets out simple recommendations and the future direction of the programme.

2: Species biology and monitoring options

2.1 BACKGROUND BIOLOGY

2.1.1 Bats in summer roosts

2.1.1.a Maternity colonies

For most bat species, the majority of known maternity colonies roost in buildings or tree hollows. These roosts are composed almost entirely of females – the majority of which are pregnant at the time of establishment of the colony each year, though some non-breeding females and males may be present. Maternity colonies are usually established in mid- to late spring. Birth of the young generally occurs in June to mid-July. In any one colony, births tend to be closely synchronised. The colony disperses in late summer at the end of the lactation period (August onwards). The location of adult males in summer is largely unknown since they tend to roost individually or in small groups.

2.1.1.b Birth dates

Birth dates differ between species and often between colonies but few quantitative data are available. There may be a latitudinal difference in birth dates as well as differences between years. Pregnancy continues at a rate determined by the mothers' foraging success and roost ambient temperatures, so that climate has a considerable influence on its duration. Poor weather conditions and hence variable food supplies in spring tend to retard birth dates. Quantified data are available for *Rhinolophus* sp. (Ransome & McOwat, 1994). Ransome has produced regression equations of mean birth date on climatic variables which could be used to assess the range over which birth date will vary under differing climatic scenarios and a similar pattern could be assumed to hold true for the birth dates of other species.

2.1.1.c Colony size dynamics

Colony size differs between species and may vary with latitude and/or with habitat quality/availability. There is some evidence suggesting that *Pipistrellus pygmaeus* forms larger colonies than *Pipistrellus pipistrellus* (Barlow & Jones 1999), but the relative distribution of the two species across the UK has not yet been identified systematically. Numbers of bats present at individual colonies follows a predictable pattern during summer. Numbers of bats increase gradually at the colony as females arrive and a peak in adult female bats is presumably reached just prior to birth of the young. Close to this time colony numbers are assumed to be more stable than at other times. After birth, mothers may often remain inside the roost with their young or make many foraging flights during a single night – causing emergence counts to become more variable. The young begin to fly after three weeks of age, generally late July or early August, and become independent at about six weeks, after which mothers disperse while the young remain for a short time before

dispersing (at least in *Pipistrellus* sp.).

Numbers of bats emerging from the roost vary on a night-to-night basis. Poor weather conditions may cause some bats to remain in the roost, although under normal conditions the majority of bats will leave the roost. Variation in three counts made at *R. hipposideros* roosts in Wales was found to be small. Little or no data is available on the fluidity of roost composition for most species, however evidence from ringing and genetic studies has demonstrated that breeding adult females are highly philopatric; remaining with the same colony from year to year (e.g. Thompson *et al* 1992, Burland *et al.* 1999, Entwistle *et al.* 2000).

2.1.1.d Roost site fidelity

Roosting sites of maternity colonies may be occupied for many successive summers or for a single year or sporadically with bats present some years and absent in others. Bats may remain at a single roost site throughout the summer period or shift between roosting site one or more times. In more mobile species such as *M. daubentonii* and *Pipistrellus* sp., evidence suggests that while whole colonies may use a selection of main roosting sites through the summer – these are situated in close proximity to each other (e.g. Thompson *et al* 1992). The occurrence and frequency of roost switching in different species has not been studied in detail and remains unquantified. Similarly, the reasons for roost switching have not been determined. Hypotheses include parasite build-up, changes in habitat requirements which might occur if bats successively exploit different parts of their home range, and thermoregulatory reasons (Lewis 1995). Three species – the *Rhinolophus* sp. and *Eptesicus serotinus* exhibit a high degree of site fidelity both over successive summers and during the summer season. *M. nattereri* bats appear to shift roost sites relatively frequently, but regularly use certain roost sites at certain times during the summer (Smith 2000, Swift 1997). *N. noctula* and *M. daubentonii* both frequently roost in tree hollows in the summer and frequently switch roost sites. *M. daubentonii* that roost in buildings however appear to be less mobile. Despite roosting in houses, *P. pipistrellus* are also nomadic. In addition to whole colonies switching roost sites, colonies sometimes occupy several roost sites in close proximity and movement of bats may occur between these roosts. Recent data suggests that *Pipistrellus pygmaeus* form larger, more roost-faithful colonies, while *P. pipistrellus* form smaller, more nomadic colonies (Barlow & Jones 1999).

2.1.1.e Bat dispersal: colony formation and extinction

The degree of emigration/immigration of individual bats from/to other or completely new roosts throughout the summer is largely unknown. Ransome (1989) has examined

movement of marked *R. ferrumequinum* and reached the conclusion that emigration of individuals balances immigration approximately, and that both occur only at a low rate. Movements between colonies are rarely detected (Thompson *et al.* 1992, Entwistle *et al.* 2000) and recent genetic evidence for several bat species has indicated that maternity colonies are distinct with females demonstrating strong philopatry and males dispersing locally (*M. bechsteinii*, *Plecotus auritus*, *N. noctula* – VIIth European Bat Research Symposium programme of abstracts 1996, Burland *et al.* 1999). No information is available on what constitutes the maximum or minimum viable size of a colony in a given area or at a given roost site. The size when a colony is likely to go extinct, or what happens in the extinction process, is not known. If a colony reaches a size below a minimum viable level, remaining bats may join other larger colonies or all perish, or if the colony reaches a size above the maximum sustainable level, bats may disperse to form new colonies, however there is no evidence to support this. Studies into this process would be valuable as it may be important to determine the rate of formation/extinction to measure population expansion/decline with higher accuracy.

2.1.1.f Emergence behaviour

The time at which bats emerge is related to sunset time, but often differs due to the prevailing climatic conditions or surrounding roost conditions (e.g. cloudier nights are darker and thus emergence tends to be earlier, roosts with little woodland cover nearby will tend to have bats emerging later from them). Emergence times differ between species and are relatively well documented. Some species (both *Rhinolophus* sp., *M. daubentonii* and *M. nattereri*) emerge when it is truly dark, rather than dusk, which may introduce counting errors. *M. nattereri* and both *Rhinolophus* sp. tend to exhibit light sampling behaviour and confusion over the number of bats emerging and going back into the roost also introduces counting errors. Bats cannot sense infra-red light, but infra red counting equipment is expensive. Bats can sense red light, but it has been shown in a study conducted for the NBMP that it does not affect the emergence behaviour of pipistrelle bats to the extent that it prevents bats emerging (Guest 1999). Not all bats leave the roost site every night, but it is probable that the great majority do so on fine nights. Poor prevailing climatic conditions such as low temperatures or rainfall may cause bats to become torpid and remain inside the roost. Bats may even shift roost sites to cooler roosts in order to facilitate torpor.

2.1.2 Bats in winter hibernation

2.1.2.a Hibernation and hibernation sites

All UK bat species have the ability to enter a state of torpor for energy budgeting. In torpor, the bat becomes inactive and allows its body temperature to fall below its usual regulated level, thus saving energy. Hibernation is an extended form of torpor, lasting for days, weeks or months, which occurs on a seasonal basis, in response to a prolonged fall in temperature or reduction in food supply. All bats in the UK hibernate during the winter season, and this can involve short or longer movements between summer roost and winter hibernation sites (hibernacula). It is likely that some bats,

e.g. especially *P. nathusii*, migrate into the UK in winter (Russ *et al.* 2000) and it is possible that some of the population of some species migrate from the UK in winter. The majority of known hibernacula are underground sites that are accessible to humans. Such sites include a range of natural caves, mines and a variety of artificial tunnels and other underground or semi-underground structures.

2.1.2.b Bat species that use underground sites

While some species are considered highly reliant on underground habitats for hibernation, other species are not so reliant and, indeed, some species are very rarely recorded in such sites (Hutson, 1993). Both species of *Rhinolophus* are regarded as highly reliant on underground habitats. In contrast, some of the species that are widespread and more commonly encountered in summer (notably *Pipistrellus* sp., *N. noctula* and *E. serotinus*) are rarely encountered in underground sites in winter. *Plecotus auritus* occur regularly and are widespread in such sites but in very small numbers in relation to their widespread and common occurrence in summer roosts. The several species of *Myotis* make up the bulk of observations in most winter sites.

2.1.2.c Timing of occurrence and maximum counts

Bats may begin to occupy hibernation sites in early autumn and some may still be present in late spring, but in relatively small numbers in most sites. As a general rule maximum counts are achieved in the depths of winter: in January and February. However, some sites are favoured by *Rhinolophus* sp. in late autumn or early spring, and monitoring of such sites is carried out accordingly. Apart from extrinsic factors that affect counts (such as weather) and are discussed below, it is frequently noted that the peak numbers of other individual species do not always occur at the same time (Hutson pers obs). Thus peak numbers of *P. auritus* are frequently recorded in December, peak numbers of *M. daubentonii* bats in January and of *M. nattereri* bats in February. Thus the combination of maximum counts for each species may present a figure far in excess of any one maximum count at the site, but nevertheless represents a minimum number of bats using the site. Despite these anomalies, most observations are made in January and February since these have given the best spectrum of data, and this is the period recommended for NBMP.

2.1.2.d Behaviour of bats in hibernation

Different species have different microclimatic requirements for successful hibernation, and in some species these requirements vary in response to changing weather conditions. Preferred sites tend to be those that offer a range of microclimatic conditions via a varied physical structure. Some bats need purchase, even if only small irregularities, to hang in open spaces, while others prefer crevices or other hollows out of the main chamber or passageway. Both species of *Rhinolophus* hang in the open, like plums, and it is unlikely that these species will be missed in hibernation site surveys. Many *Myotis* species also select relatively open sites, e.g. *Myotis myotis*, *M. mystacinus*. However, others e.g. *M. nattereri*, crawl into cracks and crevices to hibernate and so are difficult to see and to count.

Bats do not usually remain in continuous hibernation throughout the winter. They will arouse and become active at intervals of days or weeks to drink, move to a different hibernation site or even mate (Ransome 1971, Park *et al.* 2000). In mild weather, bats will arouse to feed at any time during the winter period (Avery 1985). Movement of bats between sites is not well documented.

2.1.3 Bats in flight

2.1.3.a Behaviour of flying bats

Flight allows bats to exploit insects up to 10km or more, but generally within 2km, from their day roost. Insects tend to concentrate in patches at highly productive habitats such as woodlands and water bodies and this is where groups of bats also congregate to feed. On emergence bats travel to suitable foraging areas with smaller species of bat preferentially flying along linear landscape features such as hedgerows or treelines; many commuting bats are thus encountered just after emergence. Bats may forage for a short time in one place and then move on to other foraging areas within their home range area. These foraging sites are regularly re-visited by individuals. The foraging activity of most bat species tends to be highly concentrated just after dusk and activity begins to tail off towards midnight. A second but lower peak in activity occurs just before dawn. Some species, e.g. some *Myotis* and *Plecotus* species may be active at the same level throughout the night and behaviour of all species can change according to reproductive status.

2.1.3.b Bat Passes and feeding buzzes

Bats rely on vocalizations (echolocation) for communication and orientation when commuting or foraging. It is possible to detect the presence of bats, assess the level of activity in an area and potentially identify the species emitting the call using a bat detector. When sampling bats with a bat detector, the unit generally measured is the number of "bat passes" heard over a bat detector. A bat pass is defined as a sequence of echolocation calls registered indicating a bat in transit (Fenton 1970). A train of echolocation calls are heard that get louder and quieter as the bat flies by the observer. When the echolocation calls increase in repetition rate to a point where the receiver can no longer separate the calls and a noise like blowing a raspberry is heard, the bat pass can be designated a "feeding buzz". A feeding buzz represents a bat attack on an insect. Thus 'fly-by' bat passes and feeding buzzes can be recorded separately. Generally feeding buzzes and bat passes are auto-correlated, with feeding buzzes being encountered at a lower rate (Walsh, Harris & Hutson 1993, O'Donnell 2000). It is difficult to differentiate species on the basis of feeding buzzes because all species produce similar sounds at this stage. Because bat detectors do not differentiate between several passes by the same bat and single passes by several bats the counts represent an index of relative activity or relative abundance in different habitats rather than actual numbers of bats and hence counts cannot be extrapolated to an absolute population density figure. However, in measuring trends, bat passes provide a population index.

If many bats are foraging at the same site, bat passes

may be difficult to distinguish. Bats often fly in beats along lines of vegetation, paths cut through vegetation or circle round and round in openings or over water often foraging in groups. This leads to the problem that bat passes recorded are not statistically independent and to the question of how many bat passes to record when activity is constant. A time limit of five seconds of activity might be an appropriate cut off point to count discrete bat passes when activity is constant. Another possible solution is not to record bat passes at all but to record the length of time bats were active within set time periods e.g. two minutes out of a 10 minute sampling period. However this is difficult to estimate and is open to error stemming from observer differences.

2.1.3.c Echolocation call properties and foraging style

Echolocation call properties are intimately linked with foraging and flight style. Species which forage by open space hawking above vegetation use lower frequencies (20–30 kHz) and their calls are loud and can be detected 30–100m away. These include *N. noctula* and *E. serotinus*, although *E. serotinus* usually forages at lower altitudes and more often in edge situations than noctules. Species which practice open space hawking between vegetation use slightly higher frequencies (40–60 kHz), their calls are reasonably loud and can be detected up to five – 10m away. These include *Pipistrellus* which forage in edge/gap habitats. Species which glean insect prey from vegetation and forage within woodland habitats use a range of call frequencies usually peaking at circa 50 kHz, but calls are generally faint and can only be detected at short distances (<3m). These include *M. nattereri* which forages within woodland. *M. daubentonii* forages by aerial hawking but more frequently by trawling prey off the surface of water. Although flight behaviour of this species is characteristic, it can feed around trees where its calls become similar to other *Myotis* species such as *M. nattereri*.

The detection range of each species by bat detectors has not been measured accurately because of the difficulties in doing so, but detection rates do differ between species due to echolocation call properties. Because of this, comparisons of abundance cannot be reliably made between species and can only be made if weighting factors for the differential detectabilities are applied to the data collected. However, since detection rate remains constant within a species, changes in abundance can be examined within species.

Detection rates within species will differ between habitats. In cluttered habitats such as woodland, detection distances of bats will decrease because of their sonar adaptations to flying in clutter and the obstruction of the clutter itself. It is therefore recommended that trends are compared within the three main types of habitat clutter – open, edge and cluttered habitats. Habitat selection by each bat species will lead to some species only being recorded in one of these types, while others may be recorded in two or all three types.

2.1.3.d Species identification

With some experience, most British species (except some *Myotis* species) can be identified and discriminated between

using a combination of visual observation and bat detector output when they are within their preferred habitats. Occasionally bats are recorded within clutter when they generally forage in open spaces and vice-versa. In these situations, their echolocation calls can change and species identification may become problematic – especially for *Myotis* species. Observers will differ in their ability to discriminate between species and this is difficult to standardise for. Training workshops are being organised to increase the skill level of volunteers taking part in the project. For the most part the species selected for this programme and the nature of the proposed survey technique allow a high expectation of accurate identification.

2.1.3.e Bat detector properties

Several different models of heterodyne-based mini-detector are now in use by bat workers. These include detectors made by Skye Electronics, Stag Electronics and UltraSound Advice. Models of detector differ in their tuning, bandwidth and sensitivity and therefore the use of different models of detector introduces bias which affects the numbers of bats which can be detected during a survey. This bias is small and randomised in surveys, but may become significant if advances in bat detector technology significantly increases sensitivity.

The factor most likely to affect the numbers of bats detected is sensitivity. Sensitivity differs between bat detectors produced by different manufacturers and affects the number of bats detected. The probability of detecting a bat depends on the volume of space bounded by the maximum range of detection which is proportional to the cube of the detector's sensitivity. Thus a detector that is twice as sensitive as another can potentially sample eight times the volume of the environment. In a field experiment, Waters & Walsh (1994) demonstrated that bat detectors with high sensitivities detected significantly higher numbers of bat passes. This clearly has implications for time series data – since improvements in bat detector technology are likely to lead to an increase in sensitivity of bat detectors in general use. Standardisation on a single bat detector brand is logistically not achievable for large scale studies. However, in the National Bats and Habitats Survey 70% of volunteers used only one model of detector (USA Mini II) and in forms recently returned to the monitoring project, 72% of volunteers own one model of detector (BatBoxIII). Thus detector model can be standardised probably to an 80% level. As seen in Waters & Walsh (1994) it is possible to determine accurately the sensitivity of all models on the market and thus we

will be able to weight the data collected accordingly and factor out any potential bias. One untested variable is the extent to which battery voltage affects detector performance. The BatBox III detector, which has a short battery lifespan, reduces the number of bat passes recorded by half after 20 hrs of use (O'Donnell 2000). It is therefore important to maintain a rigid standardised survey protocol.

2.2 TARGET AND NON-TARGET SPECIES

In designing the NBMP, it was clear that not all species could be monitored at this stage, and that a representative group of species had to be selected. Target species (shown shaded, Table 2.1) were selected based on conservation concerns and the practicality of carrying out large scale monitoring methods. They also represent a range of roost requirements, foraging habitats, feeding strategies and distributions.

The target species group at this stage clearly omits two BAP species that have a high conservation concern (*M. bechsteinii* and *B. barbastellus*) and other rare species (e.g. *P. austriacus*). This is either because the behaviour of the species makes data collection logistically difficult on a large scale or the species is too rare or too few sites are known about to expect a reasonable sized set of data.

Table 2.1 Resident UK bat species and key monitoring options. Target NBMP species are shown shaded

Resident species	Hibernacula	Maternity roosts	Bat detector field survey
<i>R. ferrumequinum</i> *	X	X	(ID)
<i>M. daubentonii</i>	X	(?B)	X
<i>M. nattereri</i>	X	(?B)	(ID)
<i>P. pipistrellus</i> *		X	X
<i>P. pygmaeus</i> *		X	X
<i>E. serotinus</i>		X	X
<i>N. noctula</i>		(?)	X
<i>P. nathusii</i>		(?)	(?, ID)
<i>M. brandtii</i>		(?,ID)	(ID)
<i>M. mystacinus</i>		(?,ID)	(ID)
<i>M. bechsteinii</i> *			(?, ID)
<i>B. barbastellus</i> *	?		(?, ID)
<i>N. leisleri</i>		(?)	(?, ID)
<i>P. auritus</i>	ID	(B)	
<i>P. austriacus</i>		(?ID)	

X on its own means this strategy is being applied.

B indicates behaviour makes data collection difficult.

ID indicates identification of species makes data collection difficult.

? indicates species is too rare or too few sites are known to expect a reasonable set of data.

B, ID or ? with () means this strategy may have the potential to be applied in the future if improvements are made in identification technology, understanding behaviour or an increased number of known sites.

Blank spaces are where the strategy is not applicable.

* denotes BAP species.

2.2.1 Monitoring options for target species

Information about target species (Box 2.1) is presented in this section, with a short discussion on the use of each of the three chosen key monitoring options.

Box 2.1: Species of bat currently targeted by the NBMP

○ <i>Rhinolophus ferrumequinum</i>	greater horseshoe bat
○ <i>Rhinolophus hipposideros</i>	lesser horseshoe bat
○ <i>Myotis daubentonii</i>	Daubenton's bat
○ <i>Myotis nattereri</i>	Natterer's bat
○ <i>Eptesicus serotinus</i>	serotine bat
○ <i>Nyctalus noctula</i>	noctule bat
○ <i>Pipistrellus pipistrellus</i>	common pipistrelle
○ <i>Pipistrellus pygmaeus</i>	soprano pipistrelle

2.2.1.a *R. ferrumequinum*

Roost counts – monitoring potential HIGH

Intensive surveys for potential roosts of this species have been carried out and it is likely that the 14 known breeding roosts represent the majority of breeding roosts in the UK. The rarity of this species confers a high requirement for monitoring and the intensive autecological study carried out by Ransome over the last 40 years means there is much published information on its behaviour and ecology, including unique data on roost dynamics. Roost philopatry and stability are high and external counts are feasible making this one of the species particularly suited to summer roost counts. To monitor new roost formation as a result of an expanding population, new roost survey methods need developing. The restricted roost preference of this species (large, old houses and barns) may make this a feasible option.

Hibernation counts – monitoring potential HIGH

This species makes regular use of and is highly reliant on underground habitats for hibernation. A large and obvious species in hibernation sites since it hangs freely from the roof or a wall promontory. Since counts can be considered highly reliable and the species is very reliant on underground sites for hibernation, the regular checking of hibernation sites is considered a reliable means of population monitoring. A large number of potential sites within and beyond the current range of the species are regularly surveyed and should provide evidence of range and population expansion.

Field surveys – monitoring potential INAPPROPRIATE at present

The unique echolocation call of this species makes it instantly recognisable but the directionality and low amplitude of the calls means that the use of ultrasonic detectors would provide limited information at present. However improvements in ultrasonic detector technology are being made and this may become a viable option in the future.

2.2.1.b *R. hipposideros*

Roost counts – monitoring potential HIGH

This species appears to exhibit similar behaviour patterns and roost behaviour to *R. ferrumequinum* with both species preferring older buildings with large lofts or disused barns that offer a range of roost sites. The restricted range of this species and the intensive surveys for potential roosts means that the known breeding roosts represent the majority of major breeding roosts in the UK. A great deal of data on roost counts of this species already exists mainly due to the efforts of CCW in Wales, within a 20% band which provides a baseline for detecting significant increases/decreases. Preliminary analysis from summer roost counts in England suggests colony size in June fluctuates in colony size. Summer roost counts are a feasible option for monitoring this species, although to monitor new roost formation as a result of an expanding population, appropriate roost survey methods need to be developed.

Hibernation counts – monitoring potential HIGH

Makes regular use of and is highly reliant on underground habitats for hibernation although many sites have small numbers of bats. A smaller and less obvious species than the greater horseshoe bat, but generally hanging free and in the open. Individuals often hibernate in lower and more concealed positions, where they may be overlooked, but in general the same applies to this species as for greater horseshoe. Some sites contain high numbers of these bats, many sites are used by very small numbers. Survey sites are graded on their ease of surveying, which allows a comparison of simple sites (if bats are present they will be encountered) against complex sites (bats present but not all are encountered because they can be hidden from surveyor's view). This approach allows us to evaluate count variance between site types of different complexity and make recommendations for the future. The regular survey of underground sites is considered a reliable means of population and distribution monitoring.

Field survey – monitoring potential INAPPROPRIATE at present

The unique echolocation call of this species makes it instantly recognisable but the directionality and low amplitude of the calls means that the use of ultrasonic detectors would provide limited information at present. However improvements in ultrasonic detector technology are being made and this may become a viable option in the future, and some preliminary work in Wales shows potential.

2.2.1.c *M. daubentonii*

Roost counts – monitoring potential MEDIUM

This is one of the more challenging species in terms of the appropriateness of summer roost counts. Although found throughout the UK, relatively few roosts are known as this is considered to be a mainly tree roosting species. However, bat detector workshops carried out over the last three years have resulted in more roosts of this species being discovered. Many of the known roosts appear to be highly mobile which requires repeated visits in order to make counts feasible. There is some suggestion that large colonies in buildings may form more stable roosts although to date there have

been no systematic summer roost counts of this species throughout the UK so present knowledge on the potential robustness of roost counting is limited. Lack of knowledge should not inhibit trials to evaluate the effectiveness of this monitoring technique.

Hibernation counts – monitoring potential HIGH

Regular and widespread use of and high reliance on underground habitats for hibernation. More or less obvious species. This species is the most widespread and abundant hibernator in underground habitats. It is known that in some sites a significant proportion of the bats present may not be visible during the course of routine surveys, being either deep in wall or ceiling crevices or in floor scree. It is also likely that a significant proportion of the total population does not hibernate in surveyable sites. Nevertheless, the proportion that is visible is assumed to be representative of the population as a whole and hibernation site survey has a high capability to indicate population and distribution change.

Field surveys – monitoring potential HIGH

The unique foraging style of this species makes it relatively easy to identify in the field and thus eminently suitable for large scale surveys with volunteers. There is much published field research on this species which show that they use stable (night-to-night) foraging sites in the middle of the summer.

2.2.1.d *M. nattereri*

Roost counts – monitoring potential LOW

This is probably the most difficult species to monitor by summer roost counts. Although fairly common throughout the UK, relatively little is known about this species. An intensive autecological study is being carried out on this species which should reveal more about its roost behaviour and colony dynamics. The main problems are lack of known roosts, highly mobile colonies and difficulties in counting bats emerging from roosts.

Hibernation counts – monitoring potential HIGH

Regular and widespread use of underground habitats for hibernation. Probably of medium reliance on such sites. More or less obvious species. *M. nattereri* is recorded as widely as *M. daubentonii* and from a wider range of types of underground sites, but is less reliant on key sites. This may be related to evidence that many of these animals move into underground sites only during periods of particularly severe weather. Assuming that the bats recorded in underground sites are representative of the population and that the weather factor is evened out over time, it is considered that hibernation site survey has a high capability to indicate population change – although changes may take longer to identify with confidence.

Field survey – monitoring potential INAPPROPRIATE at present

This is the most difficult of the species selected to monitor in the field because it has a quiet echolocation call and the call type overlaps with other species. It emerges late and favours cluttered environments. However the problems presented by this species are representative of many of the

remaining species which are not being monitored and any experience gained may help to extend the monitoring programme.

2.2.1.e *E. serotinus*

Roost counts – monitoring potential HIGH

This is one of the easiest species to count from summer roosts because it emerges early in good light, and all known roosts are in buildings. Although some colonies are mobile the majority appear to be sedentary. However mobile colonies use the same roosts every year and this means that count timing is important. Feedback from the pilot project run in 1996 was good and householders will be able to participate in counts.

Hibernation counts – monitoring potential NOT APPROPRIATE

Very rare in underground habitats in winter and with no reliance on such sites. There are so few records of this species in underground habitats that hibernation site surveys cannot contribute to the monitoring of populations or distribution.

Field survey – monitoring potential MEDIUM

This is a large bat with a loud echolocation call and its distribution is restricted to the south of Britain. There is potential overlap in its call structure with *Nyctalus* sp. but visual observations can reduce misidentifications. With experience and training, volunteers will be able to positively identify this species. As this species is apparently scarce throughout its range, extensive coverage will be required to collect sufficient records.

2.2.1.f *N. noctula*

Roost counts – monitoring potential MEDIUM

One of the easiest species to count emerging from maternity roosts because it emerges early in the evening in good light. However, maternity roosts are seldom found in houses and almost always from tree holes. This means that relatively few roosts are known for this species in comparison with its known distribution although more roosts have been found in recent years as the result of training workshops. Colonies appear to be highly mobile throughout the summer but the same roosts are used every year and thus count timing is important. The reliance on tree roosts by this species makes it a good indicator for tree roosting bats.

Hibernation counts – monitoring potential NOT APPROPRIATE

There are very few records of this species in underground habitats in the UK and hibernation site surveys cannot contribute to the monitoring of populations or distribution.

Field survey – monitoring potential HIGH

This is a large species with a very loud echolocation call. It generally has a distinctive echolocation call although there is potential for confusion with Leisler's bat, and occasionally serotine. Leisler's bat is considered to be rare and the restricted distribution of the serotine means that in most parts of the country identification should be easy. Visual observations can positively identify this species and with

training and experience there should be few misidentifications. We rate the potential success of this monitoring strategy as high.

2.2.1.g *P. pipistrellus* / *P. pygmaeus*

Roost counts – monitoring potential *P. pipistrellus* – MEDIUM; *P. pygmaeus* – HIGH

Both are common species, widespread throughout the UK. There are at least 15,000 *Pipistrellus* sp. roost records currently held in the English Nature 'BATSITES' database and the overwhelming majority of these are from houses. Colonies emerge in good light and are easily counted by inexperienced volunteers. Some colonies are mobile and use many roosts throughout a summer season. However, anecdotal evidence suggests that each roost is used at a similar time of year albeit for a short period. Recent research suggests colony mobility may vary with pipistrelle species – *P. pygmaeus* forming large stable roost and *P. pipistrellus* forming small, mobile roosts. *P. pygmaeus* appears to be more common in Scotland. We rate the potential success of this monitoring strategy as high for *P. pygmaeus* and medium for *P. pipistrellus*.

Hibernation counts – monitoring potential INAPPROPRIATE

Rare in underground habitats in winter and with no reliance on such sites. There are few records of this species in underground habitats and hibernation site survey cannot contribute to the monitoring of populations or distribution. Where the species does occur in underground habitats, there has been no published account of whether they are *P. pipistrellus* or *P. pygmaeus*.

Field survey – monitoring potential *P. pipistrellus* – HIGH, *P. pygmaeus* – HIGH

Both these species have a medium-loud call with a unique call structure. The potential for overlap with other species is small and training and experience has already demonstrated the ability of observers to successfully distinguish between *P. pipistrellus* and *P. pygmaeus*.

A summary page of information about each target species is presented in Appendix 1.

2.2.2 Monitoring options for non-target species

The following account covers all European species recorded in the UK but not currently targeted by the National Bat Monitoring Programme; it includes vagrants, in line with the considerations for wider mammal monitoring currently being investigated by JNCC.

For each species a brief statement on its status and relevant ecology is followed by proposed targets of future monitoring and discussion on potential methodologies to achieve those targets. These targets are for a ten-year period, although other developments may enable improved monitoring methodologies to

be implemented (for some species). A summary of these monitoring targets and mechanisms to achieve these targets is included in Chapter 10.

Discussion is also presented on more general requirements which would assist in meeting these targets (e.g. stratified woodland survey, improved field detector identification, distribution/population databases).

2.2.2.a *Myotis bechsteinii*

A rare species in south and central England, with one confirmed record in Brecknock and a possible record in Clwyd (see Harrington, Hutson & Catto, 1995). The species is a UK BAP species, included in the EU Habitats and Species Directive Annex II and a target species under the European Bats Agreement 2nd Meeting of Parties, 1998, Resolution 2, Consistent Monitoring Methodologies.

There are two current autecological studies in UK, one in Dorset based on a maternity colony using bat boxes and one in Sussex based on a population using natural tree holes in an ancient woodland. There is no publication of the results of these studies yet. A second Sussex breeding site is known, but is not the subject of a research study. Since the above BCT report there has been a considerable increase in the number of records as a result of increased interest in trapping at underground sites during the night in the autumn.

The recommendation of the European Bats Agreement for the consistent monitoring of this species is through the use of bat boxes. At present there is insufficient use of bat boxes by this species in the UK to establish a reliable monitoring protocol. Increased installation of suitable bat boxes may provide further sites for monitoring and there is the possibility of identifying roost sites by radio-tracking bats trapped at autumn 'swarming' sites. The autecological studies may provide information enabling the location of further roost sites from targeted searches. Meanwhile, surveillance through winter hibernation site monitoring and autumn

Box 2.2: Species of bat currently not targeted by the NBMP

○ <i>Myotis bechsteinii</i>	Bechstein's bat
○ <i>Myotis brandtii</i>	Brandt's bat
○ <i>Myotis myotis</i>	greater mouse-eared bat (extinct in Britain)
○ <i>Myotis mystacinus</i>	whiskered bat
○ <i>Pipistrellus kuhlii</i>	Kuhl's pipistrelle bat (vagrant)
○ <i>Pipistrellus nathusii</i>	Nathusius' pipistrelle bat
○ <i>Pipistrellus savii</i>	Savi's pipistrelle bat (vagrant)
○ <i>Eptesicus nilssonii</i>	northern serotine bat (vagrant)
○ <i>Vespertilio murinus</i>	parti-coloured bat (vagrant)
○ <i>Nyctalus leisleri</i>	Leisler's bat
○ <i>Barbastella barbastellus</i>	Barbastelle bat
○ <i>Plecotus auritus</i>	brown long-eared bat
○ <i>Plecotus austriacus</i>	grey long-eared bat

trapping (where appropriate) can be maintained. This will allow some monitoring of distribution, but very limited data on population change.

2.2.2b *M. brandtii*

This species is widespread and frequent in Great Britain, possibly as far north as southern Scotland but absent from Northern Ireland. It is similar in appearance to the whiskered bat (*M. mystacinus*) from which it can only be separated with confidence by close examination in the hand. Both are woodland and hedgerow species, although *M. brandtii* may more regularly use the inside of woodland and *M. mystacinus* the edge. Both species are found in small numbers in suitable underground hibernation sites and frequently occur together. Summer maternity colonies are most frequently reported in western Britain and northern England.

The monitoring of summer maternity colonies is feasible, but the species needs to be confirmed and care should be taken since the same site may also be used by pipistrelle bats. At present confident identification with a bat detector is not possible (even as a species-pair and certainly not as individual species), but they can be included in bat detector surveys as *Myotis* sp. Most observers do not separate the two species in hibernation sites, since that would require unnecessary levels of disturbance, so records from such sites are usually lumped as whiskered/Brandt's; however, there have been attempts in most sites, at some time in their history, to establish which of the two species are present. Both species frequently occur during autumn nights at underground 'swarming' sites and studies at such sites may help with understanding distribution and status. It is likely that the species will also occur in above ground autumn 'swarming' sites such as churches.

2.2.2c *Myotis myotis*

Currently believed to be extinct in the UK since 1990. It is a UK BAP species and of high priority in a range of European treaties. Its possible continued presence in UK has been suggested from one or two purported identifications by bat detector, but has not been confirmed. The species is currently showing signs of recovery in north-west Europe and so its re-establishment in the UK is possible. Almost all UK records were from hibernation sites. Sites where the species was previously recorded are still monitored along with other potential sites in the same areas. Suitable hibernation sites within its former distribution should continue to be monitored. Where possible bat detector records are identified, recordings suitable for sound analysis should be made and, if appropriate, further efforts made to confirm the presence of the species.

2.2.2d *Myotis mystacinus*

See above under *Myotis brandtii*.

2.2.2e *Myotis kuhlii*

Recorded seven times in UK. At least three of these records are clear imports, but at least three of the records have no indication that they are other than of natural occurrence. It is widespread in southern Europe and occurs into most of Africa and western Asia. There are indications that the

species is currently spreading northwards in Europe with increased records reported as far apart as France and the Ukraine. In France it is recorded to the northern coasts of Brittany and Normandy, and there is one record from Jersey.

The species is distinctive in the hand and is identifiable with a bat detector. Bat workers should be kept aware of the potential of this species occurring naturally in the UK.

2.2.2.f *Pipistrellus nathusii*

A widespread principally north European species that is a marked migrant. It has been recorded from examined individuals about 100 times in the UK, mostly in the last ten years. It is recorded throughout Great Britain. Two maternity colonies are known in Northern Ireland and a very small colony in Lincolnshire. It has also been identified by bat detector, especially from social calls located in the summer and early autumn. Russ (2000) reviews its distribution and status in the UK.

The species was regarded as a vagrant and then a regular migrant until about ten years ago. It must now be regarded as resident but the UK population is supplemented by migrants from continental Europe in the autumn.

As currently understood, this is still a rare species in the UK. The three known summer colonies will continue to be monitored, but greater effort could be applied to determine more about the status and distribution through the use of bat detectors, possibly concentrating on the identification of social/territorial calls. It may then be possible to incorporate the species into field monitoring programmes.

2.2.2.g *Pipistrellus savii*

A southern European species which is unlikely to occur naturally in the UK. Nevertheless there are a number of records (Fisher 1998) of which at least one south coast record cannot be related to any likely importation. Apart from the records given by Fisher (1998) there are one or two other records that may relate to this species.

The species is distinctive in the hand, although may be confused as a diminutive *E. nilssonii*.

2.2.2.h *Eptesicus nilssonii*

There is one record from Surrey in 1987 (and possibly 1986) (Greenaway and Hill 1988) and one from a North Sea oil installation (PA Racey, pers obs). The species is widespread in Fennoscandia, Baltic States and parts of central and northern Europe, but largely absent from countries of the western seaboard southwards from Denmark. It is not particularly migratory. At present any occurrence in the UK is likely to be purely by chance.

The species is distinctive in the hand, and could only be confused with *P. savii*, although there is no overlap in size.

2.2.2.i *Vespertilio murinus*

A migratory species for which there are about ten records from UK, including several from the Shetland Islands and North Sea oil installations and only two mainland records

since 1990 (Essex and the Isle of Wight). Two of the early records may be of ship-assisted passage. A visitor from Norway was confident (from bat detector observation) that the species was present in Southampton, but this has not been confirmed.

The species is widespread in southern Scandinavia and north and central Europe, though absent from all but the east of Belgium and France, and from Iberia and much of the Mediterranean. A colony of uncertain status is recorded from the Netherlands.

This is a very distinctive species in the hand, identifiable with a bat detector and with a very distinctive social call in late autumn.

2.2.2.j *Nyctalus leisleri*

This is regarded as a relatively scarce species of patchy distribution north to parts of Scotland. It is relatively common in Northern Ireland. Known maternity colonies are recorded from bat boxes and buildings. It does not occur in monitored hibernation sites. It is possible to identify the species with a bat detector, although separation from noctule bat is difficult. There has been a recent autecological study in Eire and there are two current studies in Northern Ireland, where the noctule bat does not occur.

The species was the subject of a Europe-wide symposium in Germany in July 2000; the contributions to this meeting will not be published for some years. It is not known if studies significant to surveillance and monitoring were presented.

At present there are not enough known summer maternity roosts to provide an adequate sample for monitoring. An understanding of the nature of the patchy distribution in Great Britain may assist in identifying further summer colonies.

Recommendation 1: Start a maternity colony monitoring and field survey scheme for (*Nyctalus leisleri*) in Northern Ireland.

2.2.2.k *Barbastella barbastellus*

A rarely recorded species in the UK, but widely distributed in England and with some records in Wales. Status and distribution in UK were reviewed by BCT in Harrington, Hutson & Catto (1995). It is not recorded in Northern Ireland but has recently been proposed for addition to the Eire list. The species is a UK BAP species and regarded as a priority in a wide range of European treaties and other initiatives. It was the subject of a special Europe-wide symposium in Germany in 1987 and the reports of the meeting are expected to be published with the report of the *N. leisleri* bat meeting (see 2.2.2j).

At the time of the BCT report no existing maternity colonies were known in UK, but subsequently colonies have been found in Norfolk, Sussex, Somerset, Hampshire and possibly Ceredigion. The first is in a barn, the others in trees.

It is rarely but widely recorded in hibernation sites. It is a very distinct species in the hand and has the potential for survey by bat detector. Autecological studies are in progress in Norfolk, Sussex and Devon.

2.2.2.l *Plecotus auritus*

A widespread and common species throughout most of the UK. It is frequent in roof spaces, but not always particularly obvious. There have been recent autecological studies in Scotland, Surrey and Sussex, and there is currently a radio-tracking project to study foraging behaviour in Yorkshire.

Small numbers occur in hibernation sites and would allow distribution monitoring. The species uses very quiet echolocation calls and so studies by bat detector are hardly possible.

Although it emerges from summer roosts late in the evening and may use multiple exit points, it is now considered feasible to make reliable summer maternity colony counts. The species is widespread and relatively common in much of Europe, although in many areas it does not occur in houses.

As a relatively common and widespread house-dwelling species that particularly relies on woodland for foraging, it is regarded as an important species to incorporate into monitoring/surveillance.

Recommendation 2: Start a UK maternity colony monitoring scheme for the brown long-eared bat (*P. auritus*).

2.2.2.m *Plecotus austriacus*

A rarely recorded species of southern England occurring from mid-Sussex in the east to Devon and possibly Cornwall in the west. It is mainly recorded from a fairly narrow coastal strip, but up to 25km inland in Sussex and to North Devon and Somerset in the west. There are a few stray records as far north as Leicestershire. The species is widespread in central and southern Europe.

It can be difficult to separate from *P. auritus*. Within its known area of distribution, a large number of roost sites identified as being occupied by 'long-eared bats' from drop-pings may include a number of grey long-eared bat colonies. Mixed colonies are recorded. The species is rarely recorded in hibernation sites and is not possible to separate the two species by bat detector.

2.3 POSSIBLE FUTURE MONITORING TECHNIQUES AND RESEARCH RECOMMENDATIONS.

2.3.1 Autumn 'swarming'

Bats of many species collect at certain sites during the night in the autumn, principally August to October. They arrive well after dark and depart before dawn. They appear to spend much of the period in flight. There is a high turnover of individuals, most are male and a large proportion

of those are immature. There is some seasonality in the occurrence of species and in the age and sex classes of some species. The function of this behaviour is not well-understood. Caves and other underground habitats are important for a wide range of species, but above surface structures, such as churches, are also used. The trapping of bats at such sites has been a widespread survey method in continental Europe for many years, but such study has only recently begun to be developed in the UK. Most of the current work is at underground habitats and there has been almost no such work at above ground sites (e.g. Battersby, 2000). The numbers and species arriving at such sites can vary greatly from night to night, probably depending on weather and other factors. A PhD study based at Bristol University is currently investigating the behaviour at underground sites. The variability of trap rates and the intrusive nature of the study (and the antisocial hours involved) may make this a difficult method to apply to population monitoring. This may provide a valuable mechanism for acquiring more (admittedly fairly low-level) data on difficult species groups such as *Myotis*, *Plecotus* and *Barbastella*. The combined use of radio-telemetry could be used to establish the day roosts used by these species.

Recommendation 3: Review progress of autecological studies on swarming within the next two years to assess its potential as a national survey and monitoring or surveillance technique.

2.3.2 Mating roosts

The territorial calls of males of some species are distinctive and associated with mating roosts. In particular this applies to *Pipistrellus* sp. and *Nyctalus* sp. Initial work in the Netherlands (H. Limpens & K. Kapteyn, pers comm) suggests that plotting mating territories of these species may provide a feasible method of monitoring. However there are problems in 1) variability in the ability to identify individual territories between species, and 2) an unquantified turnover of males occupying such territories.

2.3.3 Bat detectors – automatic (remote) recording devices

There have been many recent advances in the development of automatic recording devices that can be stationed in the field for varying periods of time. These are effective in recording relative levels of summer bat activity and possibly numbers of bats exiting roosts. The triggering mechanism of equipment designed to log activity may be influenced by bat behaviour, cricket calls, rustling vegetation and rain. Equipment designed to record calls on tape create large quantities of material to extract data from. At present they have limited application for species identification (but that may change) and limited use on a large scale due to cost and risk of damage by rain or vandals.

Recommendation 4: Review the advances made in automatic recording devices in the past few years to assess whether reductions in cost and improvements in technology have made the use of such equipment a feasible option.

2.3.4 Bat detectors – time expansion and frequency division detectors

All NBMP surveys currently use heterodyne bat detectors, which convert ultrasound to audible sound in real time but have to be tuned to the frequency of the bat echolocation call. Surveyors therefore have to tune to a specific frequency, limiting the number of species they can detect adequately. Heterodyne detectors provide limited frequency information and bat identification rests with the ability of the surveyor. Two alternative broad-band systems exist which can sample all frequencies simultaneously, enabling the surveyor to pick up all species without the need for tuning: these are time expansion and frequency division. At the present time there are drawbacks to both of these systems regarding their suitability to wide-scale use. However, developments are currently being made by manufacturers, in consultation with NBMP staff and bat workers, which may make these systems more widely available and valuable survey tools in the near future. (see Chapter 4 for a full discussion in relation to NBMP survey schemes).

Recommendation 5: Promote the development of bat detector technology toward improving standardisation of data, wider multi-species capabilities and assisting confident field identification either through active or remote field operation or later analysis.

Recommendation 6: Start developing a broadband multi-species field survey protocol.

2.3.5 Survey techniques for tree-roosting and other non-building roosting species

The design and evaluation of novel methods for surveys of non-building roosting species, in particular for woodland species, need to be developed.

Recommendation 7: Development of better techniques of locating bat colonies in trees and other non-building habitats.

Recommendation 8: Development of survey techniques for woodland bat species.

3: Volunteer network

3.1 INTRODUCTION

To implement the NBMP it has been necessary to:

1. Develop and maintain a network of volunteers covering all regions of the UK

This has involved developing recruitment schemes and materials, outreach in the form of talks to local bat groups and the development of cross-links with staff of other conservation groups and organisations.

2. Improve volunteer identification skills through training

This has involved the development of training materials, including an electronic bat and CD ROM, plus the development of introductory and advanced bat detector workshops.

3. Organise field work participation

This has involved the development and distribution of support material and recording forms, encouragement of consistent site coverage, provision of professional coverage in areas of low volunteer support.

4. Provide project feedback to the volunteer network

This has involved the production of an annual NBMP newsletter, *Bat Monitoring Post*, published by the NBMP team, and a quarterly NBMP column published by the BCT in its newsletter, *Bat News*.

3.1.1 Why use volunteers to implement the NBMP?

The decision to use volunteers was based primarily on the practical need to achieve wide-scale surveillance of animals that are, at best, difficult to count. Nocturnality, colony formation and a temporally restricted activity cycle, all limit the practicability of employing professional surveyors to count bats. The time frame available for roost and field surveys is restricted to around five months from mid-April to mid-September, limiting the time window available to complete surveys. Because bats are only active at night, the number of sites that can be surveyed in a single day is restricted to one, limiting the maximum number of sites that could potentially be covered within this time window. In response to inclement weather (strong winds and rain), bats become less active, often remaining within the roost, and surveys are curtailed. Given the nature of weather in the UK, this acts to further limit the number of available survey days in an unpredictable manner. Taking these practical points into consideration, the most logical conclusion is that surveyors should be *in situ* and available in order to achieve maximum coverage at a reasonable cost. This contrasts with

the situation for many other mammals, where multiple site coverage over a longer time span is a feasible option (e.g. water vole survey, badger survey, see Macdonald, Mace & Rushton 1998).

By 1990, a country-wide network of over 90 bat groups was firmly in place, providing a potential framework on which to base volunteer surveys. A national survey of bat habitat use (Walsh & Harris 1996 a,b) capitalised on this framework in 1992, and demonstrated that volunteers could be relied upon to carry out randomised site surveys. The aim of the NBMP was to establish a more structured volunteer network to pilot the use of volunteers to conduct regular, rather than one-off, national surveys. Ultimately, the choice between using volunteers, or employing professionals or paid surveyors to carry out fieldwork is not a simple one. In the NBMP, while professional staff manage the monitoring projects, no single member of staff was employed solely to conduct field work. Instead, experienced surveyors living in areas where coverage was low were paid to survey a range of "gap" sites, while volunteers carried out the bulk of the fieldwork across well-populated areas. This was a cost-effective way of gathering data of sufficient quantity and quality to meet monitoring objectives.

3.1.2 Involvement of volunteers in NBMP projects

Volunteers were involved in all the survey schemes operated by the NBMP. The methods used for these projects are discussed in detail in the next chapter. However, because projects are referred to in this chapter, a summary of each project is given below (Box 3.1).

Box 3.1 NBMP monitoring schemes implemented 1996-2000

1. Maternity roost counts (pipistrelle, serotine, lesser horseshoe, greater horseshoe, Natterer's). Volunteers count bats as they emerge from roost sites at dusk, two counts are made, a week apart, from late May to mid June.
2. Hibernacula counts (all species present). Volunteers count hibernating bats in underground sites, two counts are made; one in January and one in February.
3. A single species "Daubenton's Waterway Survey". Volunteers survey a 1km stretch of river for Daubenton's bats, using bat detectors. Two counts are made during August.
4. A multi species "Noctule, Serotine and Pipistrelle Survey" (NSP). Volunteers survey a 3km route within a 1km square for these species using bat detectors. Two counts are made during July.

3.2 DEVELOPMENT AND MAINTENANCE OF VOLUNTEER NETWORK

3.2.1 Volunteer recruitment

Volunteer recruitment has been a major focus of the NBMP. A total of 1,580 people currently make up the NBMP volunteer force network (October 2000), of which 851 have taken part in surveys and contributed data. Annually, the recruitment rate has increased and shows no sign of slowing (Figure 3.1) and the number of people contributing from the pool of volunteers signing up to the NBMP has remained consistent at around 50% (Figure 3.2).

Figure 3.1 Volunteer recruitment rate 1996-1999



3.2.1.a Recruitment sources and cross links with other conservation organisations

NBMP staff have attended meetings and given talks to a variety of groups in order to foster cross-links with bat groups and staff of other conservation organisations with country or nation-wide coverage. These include the BTO, BTCV, The Mammal Society, Wildlife Trusts, The National Trust, the Environment Agency, English Nature, Scottish Natural Heritage, Countryside Council for Wales. Volunteers have been recruited from a diverse range of sources (Box 3.2)

Talks and workshops require a large investment in terms of organisation and staff input. However, they provide an opportunity for outreach. The opportunity for volunteers to talk to NBMP staff and vice-versa has been invaluable in recruitment, in encouraging data return, and in designing, testing and refining methodologies. They are particularly valuable in recruiting volunteers for field surveys (Figure 3.2). Other important recruitment methods include the production of leaflets (Figure 3.2), which requires a small initial investment, but has a cascade effect, drawing recruits from a broad area. There is much scope for increasing publicity and recruitment.

There can be a time-lag before volunteers join the programme and contribute to any surveys. Some require training before they can participate and this can take time to

implement whilst others join up and never participate. It takes several years to identify each group and amend the database accordingly. The number of active and non-active members is shown in Fig 3.3.

3.2.1.b Volunteer distribution

The distribution of NBMP volunteers can be seen in Map 3.1. As expected, the volunteer network is most extensive in southern England. In the British Trust for Ornithology's Breeding Bird Survey (BBS), the distribution of sample plots is stratified by the availability of observers. In the NBMP, we opted to stratify by ITE land classes (Bunce *et al.* 1996) – simplified to six main Environmental Zones (Howard *et al.* 1999). It should be noted that observer distribution was not known *a priori*, but approximates the proportional abundance of Environmental Zones in the UK. Stratifying by Environmental Zones therefore has a similar end result, allowing maximum use of available volunteers, while avoiding results that are biased towards those parts of the UK which have most volunteer observers. Stratification by observer density *post hoc* may be applied in the future or at the analytical stage if necessary.

Box 3.2: Recruitment methods

Talks: Talks explaining what the NBMP was trying to achieve and how volunteers could get involved. Targeted in areas of low volunteer density.

Workshops: Primarily used to increase volunteer skills, but also aimed at recruitment. Targeted in areas of low volunteer density. Early training workshops were intensive, with fieldwork carried out on Friday and Saturday night. Later workshops were carried out during the day.

Word of mouth: Existing NBMP members are sent blank survey forms which they pass across to friends/relatives.

Roost owner leaflets: Leaflets aimed at roost owners are sent to bat groups/roost visitor licence holders who give them to householders with bats. Householders return a FREEPOST reply slip and are sent colony count forms.

Bat detector leaflets: Leaflets aimed at purchasers are sent to bat detector manufacturers/suppliers and included with every new bat detector sold. People returning the FREEPOST reply slips are sent details of local workshops and asked in which surveys they would like to participate.

Internet: Information pages about the NBMP are posted on the BCT web site, including a downloadable version of the NBMP newsletter *Bat Monitoring Post* and a downloadable registration form. Volunteers can post the registration form or can now email it back to the office.
www.bats.org.uk

Magazine articles: General articles are written by NBMP staff and published in various magazines (examples include *BBC Wildlife* magazine, *Gardener's World*, *Nature Watch*)

Figure 3.2 Volunteer origin for each project expressed as a % of recruitment sources

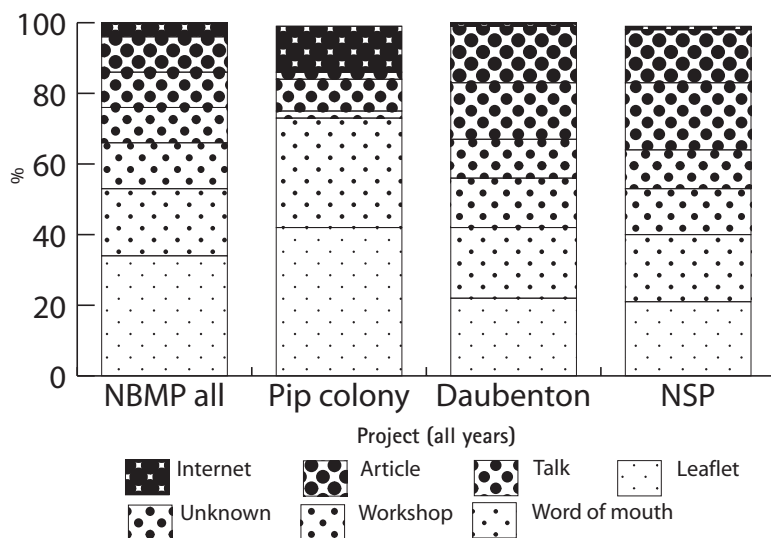
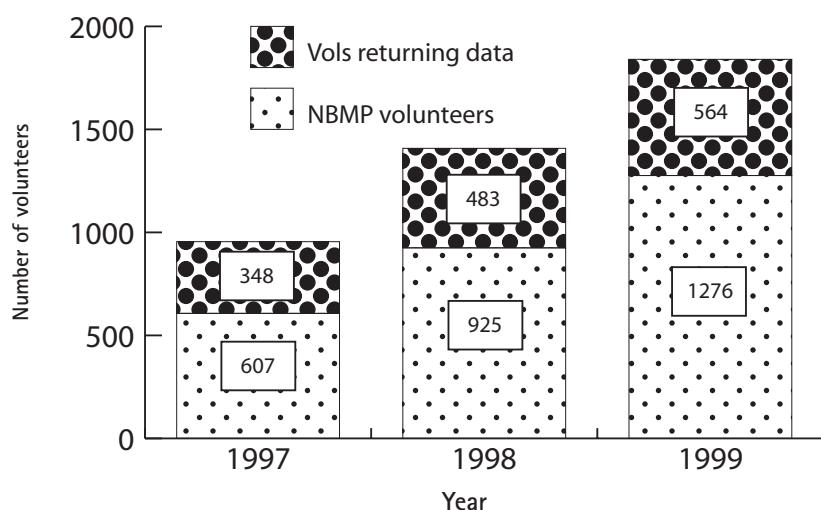


Figure 3.3 Cumulative number of volunteers recruited and contributing to the NBMP since the start of the programme in 1996



3.2.1.c Maintaining interest

Most volunteers taking part in surveys do so in order to see bats. In colony and hibernacula monitoring schemes this is almost guaranteed. However, the randomisation of site selection in field surveys means that the encounter rate with bats can be low in many sites. While this is infrequent in the Daubenton's waterway surveys, it is much more frequent in the noctule, serotine and pipistrelle (NSP) field survey (in 1999, 24.6% of sites were negative for bats). This can be a disheartening experience for volunteers especially if they have to resurvey the same site every year. Proportional stratification results in fewer "poor" sites being included in the schemes – since such areas make up a smaller proportion of the UK. When the variance in bat abundance in these areas is taken into account, the sample size needed to improve precision is increased, but if the cost and difficulty in sur-

veying these sites is considered, sample sizes may be reduced in such areas. Having a mixture of surveys helps to maintain interest in the programme, but more consideration must be given to making participation in surveys an interesting opportunity rather than a chore.

Recommendation 9: More effort and investment should be placed on marketing, publicity and recruitment in order to maintain and expand the NBMP volunteer network to ensure adequate geographical coverage. Areas of low volunteer density should be targeted.

Recommendation 10: A periodic review is recommended (once every five years) to maintain the balance of survey schemes operated within the overall programme. They should provide enough activity to maintain interest and involvement without overloading volunteers.

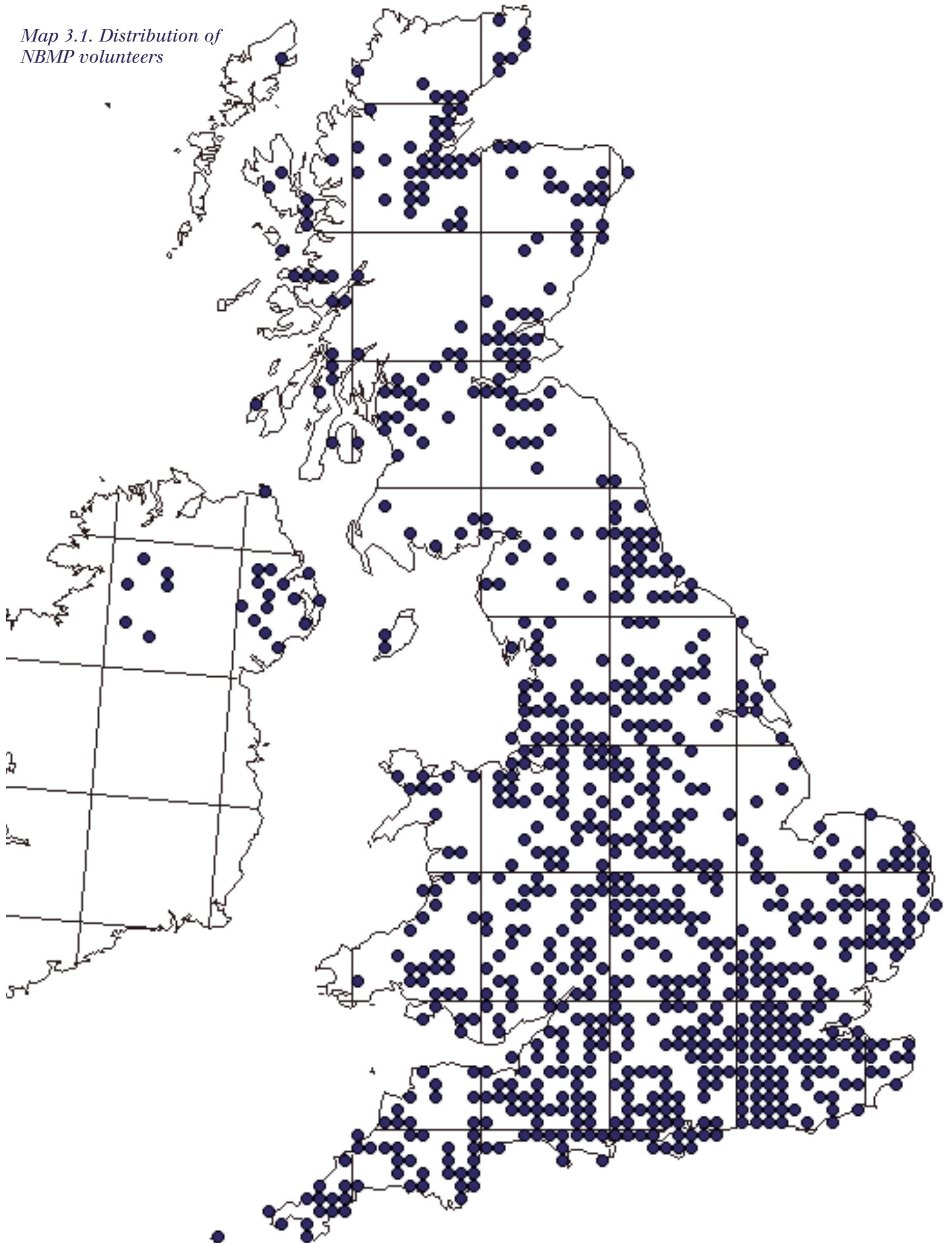
3.3 VOLUNTEER SKILLS TRAINING

NBMP volunteers range from having no previous survey skills to having considerable expertise in bat identification and field survey techniques. NBMP projects also range in their participatory requirements. Participation in some schemes requires little or no previous experience, while participation in others requires substantial skills in bat field survey techniques. This allows the matching of volunteers to particular projects. Volunteers may progress from simple to more complex projects as their skill levels increase, thereby providing interest and incentive to carry on contributing to the NBMP over the longer-term. All monitoring schemes were designed to be carried out with minimum skills, so that participation may be maximised. However, field surveys, in particular, involve the identification of bats in the field, and thus participants need adequate training in this area.

3.3.1 Training for hibernacula visits

Surveyors are required to train for and obtain a licence from the relevant statutory nature conservation body to survey winter sites, although unlicensed surveyors are permitted to accompany licensed surveyors on visits. At present there is a network of trainers throughout the UK who carry out training for licences. Thus there is little requirement for NBMP staff to assist with such training.

*Map 3.1. Distribution of
NBMP volunteers*



3.3.2 Training for colony counts

No formal training by NBMP staff is needed for surveyors to participate in colony counts. However a degree of previous experience is recommended for some species and participation requires prior knowledge of the behaviour of colonial bats.

Pipistrelle and **serotine** bats both emerge from their roosts early (just after sunset) so they can be seen in the dusk and counted without the aid of bat detectors. Therefore a reasonably competent person following the standard protocol can make satisfactory counts of these species without needing prior experience. However, bat householders and new recruits are encouraged to make the first count with the guidance of an experienced surveyor to ensure they are counting as accurately as possible.

Lesser horseshoe and **Natterer's** bats both emerge late after sunset when it is dark, and a bat detector is required to aid counts. Also the confusing emergence behaviour of these species – "light sampling" of bats flying into and out of the roost site repeatedly – means that surveyors require previous experience before making counts. Counts of these species are generally restricted to local bat group members.

Colony counts are a useful "introductory" project for NBMP surveyors because of the high chance of encountering bats of known species. If surveyors have access to a bat detector they can practice their identification skills and this acts as a good introduction to field surveys.

3.3.3 Training for bat detector field surveys

The NBMP has invested heavily in training in order to meet field survey monitoring target objectives regarding geographical coverage and data quality and has carried out 62 bat identification workshops and a further 57 talks throughout the UK (Map 3.2).

The NBMP runs two bat detector field survey projects that require bat identification skills:

- Noctule/serotine/pipistrelle (NSP) survey in July requiring ADVANCED training and identification skills and a significant previous field experience
- Daubenton's bat survey in August requiring BASIC training and identification skills and some previous field experience

3.3.3.a Development of training material

A programme of training workshops has been run annually to address needs, and this has included the development of specialised training materials. These are:

Bat Identification CD/Manual: Training procedures have developed over the past five years and in 1999 a standard CD/manual was produced to compliment workshops. The CD is given free to all surveyors who have participated in field

surveys acting as both an incentive and reward.

Electronic Bat: The quality of training has been improved considerably with the innovative development of an electronic bat. This device emits ultrasonic bat calls in real time and allows the trainees to practice their identification skills with their own bat detectors. This device, developed for the NBMP by David Bale, is unique to the NBMP and has proved an invaluable training aid that allows training to take place indoors during the day.

3.3.3.b Training workshop format

Workshops early in the NBMP's development were organised and run by the NBMP's Field Officer. However, as staff time is limited, more and more workshops have been organised by members of local bat groups and/or county Wildlife Trusts, with encouragement from the NBMP. Organisers are sent a list of NBMP volunteers within a 50 mile radius of the venue and asked to advertise the workshop. A list of workshops is also placed in the project's newsletter, *Bat Monitoring Post*, in spring, although more workshops are often organised later in the summer.

Workshops are intensive and cover all aspects of heterodyne detector use and identifying species for NBMP field projects. The typical format of a workshop is given in Box 3.3 below.

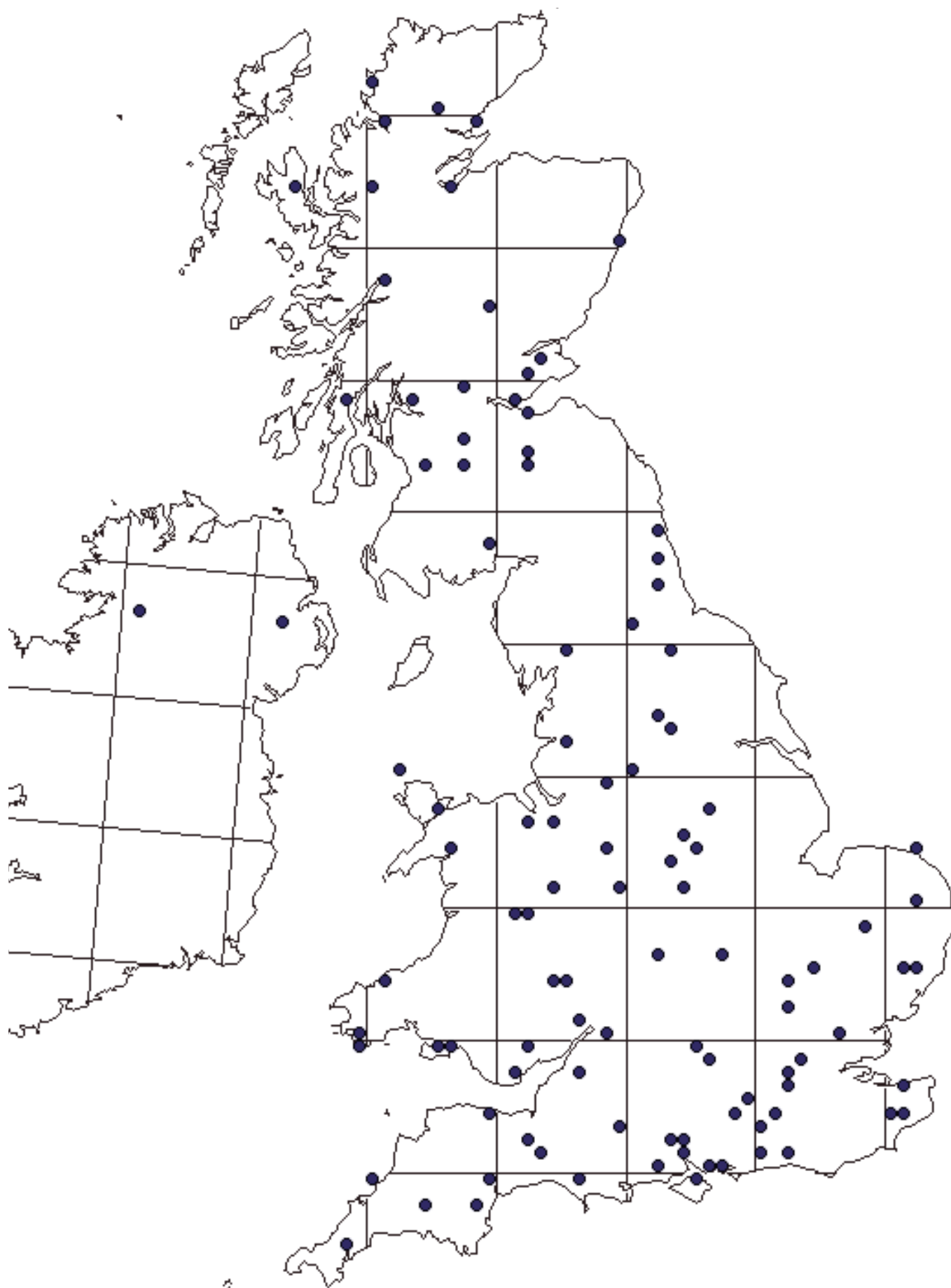
Box 3.3: Training workshop format

1. Talk on NBMP objectives
2. Echolocation calls of each species
3. How heterodyne detectors convert ultrasound to audible sound with a demonstration of how to calibrate detectors
4. A comparison of the original sounds bats produce with the resultant sounds coming from the heterodyne detector
5. How humans process sound and, through use of reference sounds, how to describe bat calls
6. Interactive session with Electronic Bat to summarise above information
7. Bat walk in evening to put theory into practice

Weekend workshops are based on the same format but more emphasis is put on fieldcraft with participants trying to locate roosts by following bats throughout the night until sunrise. Participants are encouraged to practice their skills before participating in field surveys. Workshops provide a valuable outreach function, giving NBMP staff an opportunity to meet surveyors and vice versa.

Adequate field skills are important to improve the quality of field survey counts. In all survey schemes, it is important to quantify the level of training/expertise volunteers have, and how this changes with time, as well as how long each volunteer has surveyed the same site, since this is likely to affect their counts. Increased skills are likely to result in

Map 3.2 Distribution of NBMP talks/workshops (119) 1996–1999



increased numbers of bats being identified correctly, and increased roost or hibernation site counts as volunteers get more used to their sites.

- Recommendation 11:** Continue to improve the quality of NBMP observers, by training in identification skills and fieldcraft, and through encouraging contact with other observers.
- Recommendation 12:** Develop a skills accreditation system and record changes in observer skill levels.
- Recommendation 13:** Define a minimum skills level that volunteers are required to have reached before participating in bat detector field surveys.
- Recommendation 14:** Improve availability of training resources to local groups/co-ordinators. A standard training resource package might include the NBMP training CD and overheads for talks.

3.4 ORGANISATION OF VOLUNTEER FIELD WORK PARTICIPATION

Monitoring bats is a nocturnal activity and sites in certain land classes can involve surveys in difficult terrain e.g. random sites in marginal uplands. Such sites can often be a considerable distance from roads. Unfortunately reception for mobile phones in these areas is often poor or non-existent. Volunteer surveyors on these sites must be physically fit and have good nocturnal navigational skills and we encourage surveyors to pair up with friends to survey these sites. There is a health and safety issue associated with such activities. At present, the NBMP sends a simple two-page risk assessment sheet (Appendix 2) to each field surveyor and this refers them to the BCT health and safety policy for further advice if required.

The operational management of surveys and flow of data from volunteers to office and vice-versa depends on efficient communication systems. Currently all management is carried out from a central office. Informal trials of appointing regional co-ordinators have met with little success. One forgot to distribute forms, resulting in no data being collected in a particu-

lar area, and one did not return the data for over a year. However, the possibility of setting up some form of regional co-ordination system should be explored further, as this is a system successfully operated by other organisations (e.g. BTO). The scale of bat groups in comparison with bird groups needs to be taken into consideration, however. Many bat groups consist of only one or two active members, who are currently over-worked with the high level of bat enquiries they deal with during the summer season. Even regionally, there are fewer people who are likely to want to take on a regional co-ordination responsibility in comparison with regional BTO members.

Annually, the operation of surveys involves:

- Identification of volunteer participants for each monitoring scheme
- Site selection in relation to targets and matching volunteers to sites
- Arranging coverage of gaps to achieve targets
- Production of survey materials: maps and protocol guidelines
- Mailing of material to volunteers
- Return and handling of data

3.4.1. Identification of volunteer participants for each monitoring scheme

NBMP volunteers have a wide range of experience – from roost owners prepared to count ‘their’ colony to experienced fieldworkers. All NBMP members are sent a letter/FREEPOST return card at the end of each year. The letter describes the skills/experience/equipment required to take part in each of the following year’s surveys and the card requests information on how many and which surveys the volunteer would like to participate in next year. Information from returned cards is used to produce targeted mailing lists for each survey. Surveyors not returning cards, but who have previously participated are included. Because surveys do not overlap in timing, each volunteer can participate in multiple surveys if they wish.

Each survey requires different skill/experience/equipment to participate in effectively (Table 3.1).

Table 3.1 Degree of experience required to participate in NBMP surveys

	No detector required	Detector required	Detector required	Licence required
Pip colony count	✓			
Serotine colony count	✓			
L. horseshoe count			✓	
Natterer’s count			✓	
NSP			✓	
Daub field survey		✓		
Hibernation survey				✓

Thus to participate in the pipistrelle and serotine counts a surveyor only requires knowledge of a suitable roost. Both these species emerge whilst it is still light and hence no detector is required. For the lesser horseshoe and Natterer’s colony counts a bat detector is required as both species are difficult to see at emergence time. For the Daubenton’s bat field survey, species identification is aided by

torchlight, as a bat seen skimming across the water surface is taken as a record of a Daubenton's bat. This simple rule means that a reasonably competent surveyor can participate in this survey with little previous experience. However a detector is required to gauge activity and count the number of bat 'passes'. For the NSP field survey a detector and significant previous field experience and/or training is required. At present we have restricted this survey to species where only simple identification rules are required in order to keep identification as robust as possible.

3.4.2 Site selection in relation to targets and matching volunteers to sites

Each project aims to meet a minimum target of 30–40 sites repeated each year for national trend estimates, and 120–160 for country level trend estimates (see Chapter 7 for details about how these targets were defined). Targets to meet proportional sampling within ITE Land Class strata were calculated at the start of each project, and are re-calculated each year.

A computer programme was developed which stores a randomised selection of 5,000 1km square sites across the UK, with associated land class information. It also stores volunteer home grid references, and grid references of sites which have been surveyed. Sites are weighted based on the target sampling proportions for each land class. When sites drop out and new sites need to be allocated, the programme re-weights each land class, and sites of particular value in terms of land class are flagged for selection. Annually, existing surveyors are automatically re-allocated their previous site, unless it was unsurveyable in the previous year. New surveyors are matched with either (a) a previously surveyed site where the previous surveyor has resigned (generally this means they have moved home) or (b) a new site. It is possible to search for potential new volunteers around an existing or new site, or to search for existing or new sites around a volunteer. Each search captures sites within 20km of a volunteer, or volunteers within 20km of a site. This is used to maintain consistency in coverage of previously surveyed sites and to maintain land class targets when allocating new sites.

Colony sites/hibernation sites: Colony or hibernation sites are selected by volunteers from a pool of known sites. Many colony counters – especially for pipistrelle and serotine species – are roost owners. Surveyors are sent details of local bat group contacts to identify a site if required. Local liaison with colony site/hibernation site owners is important.

NSP field survey: To participate in this survey volunteers must have access to a heterodyne bat detector and have some previous experience of using one. This restricts the number of volunteers who are able to participate in the survey. 1km² sites are drawn from the pool of 5,000 random sites throughout the UK. All potential sites – existing and new – are captured within a 20km radius of each volunteer (on average this is around ten sites). Sites are then selected by hand and visually inspected on OS 1:25 000 maps. Dangerous sites or sites with likely access problems are not

assigned. Assigned sites are then photocopied with a random route overlaid.

Daubenton's field survey: For the Daubenton's waterway survey, sites are selected from the pool of Environment Agency River Habitat Survey sites (which includes Scotland). In a similar manner, triangulation within a radius of 20km from the volunteers home captures a subset of sites (with associated land class information) that can be potentially allocated to each volunteer. All potential sites – existing and new – are captured within a 20km radius of each volunteer (on average this is around ten sites). Sites are then selected by hand and visually inspected on OS 1:25 000 maps. Dangerous sites or sites with likely access problems are not assigned. Assigned sites are then photocopied with a mark indicating the RHS site grid reference of the site.

For all survey maps, stickers are produced with site and surveyor details, and an OS copyright code. These are attached to the maps by hand

Recommendation 15: Place greater emphasis on encouraging existing volunteers to recruit "buddies" or new member replacements when they can no longer cover a site. Consistent coverage of sites is paramount.

Recommendation 16: Invest in development of computerised systems to improve communication processes between volunteers and the office and the site allocation/re-allocation process.

Recommendation 17: Begin discussions with bat group representatives about recruiting an NBMP representative in each bat group responsible for site liaison and recruiting/maintaining an NBMP workforce on a local level. Discussion could also cover the potential for regional co-ordinators.

3.4.3 Arranging coverage of gaps to achieve targets

A combination of approaches have been employed to cover sites in under-represented areas. Payments have been made to experienced surveyors living *in situ* in under-represented areas to survey a range of gap sites. One site is always surveyed for free by the surveyor, and then payments made to cover travel expenses per site for additional sites. This reduces travel costs. A second approach was for the Senior Field Officer to take a vehicle and three other experienced surveyors to an area, and for the team to cover gap sites.

Recommendation 18: Pay experienced volunteers *in situ* to gap fill in under-represented areas.

3.4.4 Volunteer turnover – maintaining consistent coverage

The number of volunteers participating in projects each year can be seen in Table 3.2 below with a small proportion of volunteers (~15%) surveying multiple sites for each project.

Because each survey is separated temporally, volunteers are able to take part in more than one survey each year if they wish (Table 3.3).

Forty-three volunteers took part in all three surveys, which demonstrates a high degree of commitment to the NBMP.

To date the emphasis has been on building up a network of active volunteers and survey sites throughout the UK but the challenge for the long-term is to ensure a sufficient

Table 3.2 No of volunteers participating in each project per year (1997-99)

	No. of volunteers participating / year		
	1997	1998	1999
Pipistrelle colony count	181	295	363
Serotine colony count	24	22	29
L. horseshoe colony count	N/A	11	29
NSP field survey	N/A	149	153
Daubenton's field survey	200	196	204
Hibernation survey	42	39	43

Table 3.3 Multiple-survey volunteer participation in 1999

	No. of volunteers participating		
	Pip colony count	NSP	Daubenton's survey
Pip colony count	363	63	80
NSP	63	153	91
Daubenton's survey	80	91	204
All three surveys	43	-	-

Table 3.4 Volunteer statistics for pipistrelle colony count 1997-99

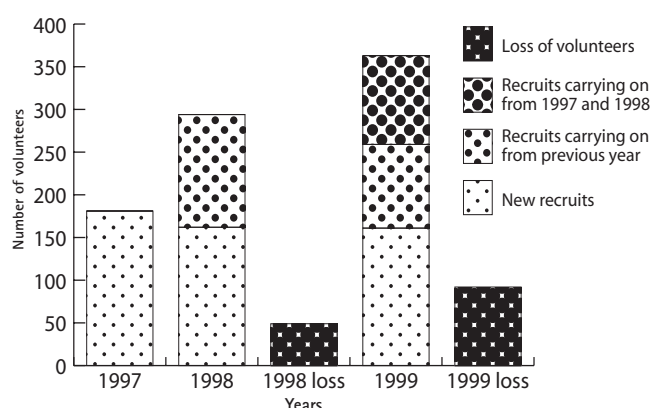
Volunteer statistics					
Year	Number	No retained from previous year	Loss (from previous year)	Gain (new recruits)	Net Gain / loss
1997	181	-	-	181	+ 181
1998	294	132	- 49 (27%)	162	+ 113
1999	363	202	- 92 (31%)	161	+ 69
		(104 took part in all three years)	(21% for those taking part in both 97 & 98)		

number of these sites are monitored annually for the next 20 years. Implementation of the monitoring programme requires repeat, yearly surveys of the same sites, preferably by the same surveyor to keep observer variance to a minimum. Loyalty rates i.e. volunteers participating in surveys annually, provide information on which to base estimates of the long-term stability of data collection.

The pipistrelle colony count and Daubenton's field survey have been carried out for three years (1997-1999) and provide preliminary data on likely future loyalty rates. The loyalty figures for the pipistrelle colony count can be seen in Figure 3.4 and Table 3.4 below.

There is a loyalty rate of 71% from year to year but this rate rises to 79% for those who have taken part in two consecutive years. Thus volunteers who have contributed for two years in a row are more likely to participate in future surveys. Many colony surveyors are roost owners and hence have a high fidelity to 'their' colony. The general satisfaction from colony counts is high because there is a good chance of encountering bats.

Figure 3.4 Volunteer recruitment gain and loss for pipistrelle colony monitoring 1997-1999



The loyalty figures for the Daubenton's field project can be seen in Table 3.5. It shows there is an average loyalty rate of 53% from year to year and this rises to 65% for those who have already taken part in two consecutive years. This survey is more difficult than the colony counts because it requires a bat detector, to walk a stretch of river at night and there is a lower encounter rate with bats.

Clearly volunteers who participate in consecutive years are a valuable resource for the future of the NBMP.

At the end of each year all NBMP members are mailed a FREEPOST survey card, together with a letter asking them which surveys they would like to contribute

Table 3.5 Volunteer statistics for Daubenton's field project 1997-99

Volunteer statistics					
Year	Number	No retained from previous year	Loss (from previous year)	Gain (new recruits)	Net Gain / loss
1997	200	-	-	200	+ 200
1998	196	99	- 101 (51%)	97	- 4
1999	204	114	- 82 (42%)	90	+ 8
		(64 took part in all three years)	(drops to 35% for those taking part in both 1997 & 1998)		

to in the following year. The results from these survey cards (shown in Table 3.6) are used to produce targeted mailing lists for each survey.

Thus for the Daubenton's survey, for every one volunteer signing up to participate in the survey, 0.54 sites are actually completed and returned. Thus to reach a target of 160 sites, a pool of roughly 296 people would need to be sent forms. To ensure 160 repeat sites are surveyed we need to involve more volunteers to cover natural loss from the programme.

Since the ratio of volunteers sent survey forms to sites completed is approximately 2:1, as a general rule, double the number of volunteers to sites are needed to reach a target number of sites.

Survey cards are cost-effective by targeting resources on volunteers who are most likely to participate in particular surveys. If survey forms for each survey were mailed to all NBMP members this would increase staff input (+ associated production costs) by at least 300%.

3.4.5 Production of survey materials: maps and protocol guidelines

Support material is vital to ensure that standard protocols are followed accurately by volunteers and the correct data are captured. The amount of support material produced and associated effort involved in production varies by survey scheme (Table 3.7).

Example copies of forms are given in Appendix 3.

Table 3.6 Number of volunteers signing up and actually participating in NBMP surveys during 1999. The potential pool of volunteers who have expressed an interest in participating in projects previously is given in the first column

	NBMP Vols	Signing up for survey	Survey Participation	No of sites surveyed	Sites surveyed per single volunteer signing up
Pip colony count	1276	541	363	418	0.77
NSP field survey	1330	305	153	208	0.68
Daubenton's field survey	1349	435	204	236	0.54

In all cases, surveyors and site details are pre-printed on forms for repeat sites and surveyor's details only are printed on forms for new sites. This avoids surveyors writing unnecessarily, thus minimising mistakes, permits the checking of details by surveyors, ensures returned forms are easy to read and demonstrates to the surveyor the link

between themselves and the site. A set of forms with no pre-printed information is also included in survey packs, since many volunteers decide at the last moment to do another site or pass the forms onto someone else they know who wishes to take part.

The production of OS maps for surveys has been a time-consuming and laborious task. In 1999 alone, a total of 1,061 maps were sent out for field surveys. As the programme continues and more sites are repeated then the task becomes easier as maps have already been photocopied and are stored in the office.

Ordnance Survey Copyright

Each year, a fee is paid to the OS for copyright. The fee is based on the number of maps produced and each map has to have a copyright number printed on to it.

Recommendation 19: Explore the storage of scanned maps (with transect routes marked on them) on computer to reduce effort spent on map photocopying. Ordnance Survey will need to be consulted. Increased use of email will reduce postage costs.

3.4.6 Feedback mechanisms

Volunteers receive feedback through:

○ Quarterly NBMP column in the BCT newsletter, *Bat News*

○ Personal correspondence thanking volunteers

○ An annual NBMP newsletter, *Bat Monitoring Post* (Figure 3.5)

○ Conference presentations and local group talks delivered across the country

Table 3.7 Support material designed and produced for NBMP survey schemes

	Colony counts	Hibernacula counts	NSP survey	Daubenton's survey
Instructions	+	+	+	+
Data sheet	+	+	+	+
Habitat sheet	+	+	+	+
Sunset Timetable			+	+
Land access letter			+	+
Risk assessment			+	+
OS Map of site			+	+

3.5.1 Estimated monetary value of data collected in 1999

Volunteer's time and expenses in carrying out surveys are supplied for free. Estimates of the value of the data collected are presented in Tables 3.8 and 3.9. These are based on paying professional bat consultants an hourly fee of £30.00/hour (BCT's standard rate).

The figure of £350,580, for one year's data collection, gives a guide to the minimum cost of employing professional data collectors per year although expenses

(mileage and accommodation) would need to be factored in as well, significantly increasing these costs.

Using the same formula above for all the data collected

Figure 3.5 Example front page of 16-page newsletter



Recommendation 20: More effort should be placed on prompt and more frequent delivery of results of surveys to volunteers. Standard database reports need to be built to extract information quickly in a simple format.

Recommendation 21: Promote greater outreach to NBMP stakeholders by holding annual regional gatherings to discuss data, methods and the future.

3.5 STRENGTHS, WEAKNESSES AND COSTS OF A VOLUNTEER FORCE

There are few examples of similar bat monitoring projects in Europe on which to base judgements on the long-term sustainability of volunteer-based monitoring schemes. Most countrywide biodiversity monitoring initiatives do not include bats because of the operational difficulties of bat monitoring (see for example Hinterman, Weber and Zangger 2000). The best example is the Dutch Mammal Monitoring Project (Zoogdiermonitoring) which is government funded. The Dutch Mammal Society organises the project which monitors selected mammal species including bats. A mix of volunteers and professionals (with the mix weighted towards professional input) carries out project fieldwork. Bat monitoring activities include: winter counts of hibernating bats, counts of maternity colonies, transect counts of advertising male bats and transect counts of passing bats (mixed species) (Limpens, 1993). However, no formal sampling strategies are in place. A set-back occurred two years ago, when the rising costs of maintaining coverage in bat detector based field surveys (due to a lack of volunteers) could no longer be met. Government funding was withdrawn from these surveys, alternative sponsors could not be found, and the surveys were discontinued. Roost and hibernation site monitoring continue with government support. This demonstrates the cost-benefit advantage of utilising a volunteer network over professional surveyors, and emphasises the need to nurture the network through sound programme management.

since the NBMP's inception to the end of 1999, we value our present dataset at a minimum of £900,127. This does not include travel/subsistence or staff time that would add significantly to the costs. The above formula gives a rough guide to the cost of collecting data where there are a target number of sites to survey. Clearly other factors, such as the technical competence required to carry out surveys or the spatial distribution of survey sites would influence costs.

Table 3.8 Time needed to complete annual surveys

Project	Travel time to/from site	1st visit (access/daylight route walk)	Evening survey time	Total hours/site
Colony	1 hr * 3 visits	0.5 hrs	2 hrs * 2 surveys	7.5
NSP	1 hr * 3 visits	4 hrs	2.5hrs * 2 survey	12
Daub	1 hr * 3 visits	4 hrs	2 hrs * 2 surveys	11
Hib	2 hrs * 2 visits	-	5 hrs * 2 surveys	14

Table 3.9 Estimated cost of contracting survey work

NBMP projects	Total surveys completed	Estimated hours	Estimated cost based on payment of £30.00/hr
Colony counts *	545	4,088	£122,640
NSP	208	2,496	£74,880
Daubenton's	236	2,596	£77,880
Hibernation	179	2,506	£75,180
Total	1,168	11,686	£350,580

*Includes pipistrelle (418), lesser horseshoe (86) and serotine (41) colonies

4: Programme methods

4.1 NBMP STUDY DESIGN

4.1.1 Principal methods and target species

In designing the NBMP, it was clear that not all species could be monitored at present, and that simple counting techniques would be required in order to recruit enough observers to cover a large number of sites. Techniques also needed to minimise disturbance to animals. Reviewing current methodology three "best available" methods for abundance monitoring were identified that can be applied at a large scale (Box 4.1). Distributional assessment has been carried out through the collation of records held by local bat groups and other organisations, and records from all NBMP schemes, and is considered in Chapter 8.

Box 4.1: Key methods

- counts of bats at hibernation sites
- counts of bats at maternity colony roost sites
- field surveys of bats using bat detectors

All three methods have their drawbacks, either through the nature of the bats themselves, through exogenous factors that influence bat behaviour or through current skill levels of those undertaking monitoring. To evaluate methods and strengthen conclusions, a double-sampling approach is being taken whereby each target species is being monitored using at least two of these methods where possible (Table 4.1).

Table 4.1 NBMP Target Species and key monitoring schemes being implemented in the first 5-year phase 1996-2000

	Hibernation counts	Roost counts	Field survey
<i>R. ferrumequinum</i>	X	X; collation	
<i>R. hipposideros</i>	X	X	
<i>M. daubentonii</i>	X		X
<i>M. nattereri</i>	X	()	
<i>E. serotinus</i>		X	X
<i>N. noctula</i>			X
<i>P. pipistrellus</i>		X	X
<i>P. pygmaeus</i>		X	X
X – being implemented () – being tested and/or counts are being collated from other sources			

4.1.2 Statistical considerations

Identifying trends in count data with confidence is not a simple task. However careful consideration of survey design and formal sampling strategies at the onset can help lessen

analytical difficulties. There have been two recent reports contracted by the DETR incorporating significant text on the statistical aspects of designing monitoring studies (Macdonald, Mace and Rushton 1998, Toms, Siriwardena and Greenwood 1999). We therefore refer readers to these reports for a broader look at some of the statistical foundations underpinning monitoring survey design. Here, key concepts are introduced: bias and precision, identifying statistically and biologically significant population changes and achieving a representative sample of the whole population.

4.1.2.a Bias and precision

Bats are difficult to count, and even using the best available sampling methods there will be uncertainties inherent in population estimates and estimates of trend. Knowledge of the behaviour and ecology of bats suggests that for all available counting methods, not all animals will be detected, introducing bias to population estimates. In trend estimation however, repeatable counts do not have to be accurate in a sense that the population estimate is close to the actual population figure. If the counts are consistently wrong for any reason, the changes from year to year can still be measured accurately using repeatable methods to achieve high precision. When dealing with small populations and inconsistencies in counts that vary, however, bias remains problematic. Thus the ability to count bats as accurately as methods permit and with the same detectability each year remain an essential attribute of a successful bat population monitoring scheme. However, the effects of small sources of bias are often over-emphasised in comparison with a lack of precision (see Toms, Siriwardena & Greenwood 1999). For this reason, it is important to measure or justifiably estimate the magnitude of bias and to take this into consideration when balancing bias and precision in monitoring schemes.

4.1.2.b Identifying statistically and biologically significant population changes

Ecological research has also demonstrated that bat population numbers are likely to fluctuate naturally, usually because of the effects of weather on reproduction and survival and potentially because of density-dependent feedback (Ransome 1989, Ransome & McOwat 1994). Thus the ability to identify and distinguish between natural and anthropogenic driven population changes is a second essential attribute of a successful bat monitoring scheme. To detect biologically important trends that are present, requires applying a statistical test to assess whether the population remains unchanged over time or not. In the design of monitoring schemes, it is of central importance to ensure that the probability of detecting a change (known as the statistical "power" of the test) is high. If a downward trend goes undetected due to low power, the continued existence of the species may be threatened. It is also important to agree what magnitude of change constitutes a biologically important change for a species, and thus at what target point action is triggered. This requires an understanding of natural

population fluctuation levels and any cycles of long-term fluctuations that may exist through concomitant measurement and research.

4.1.2.c Achieving a representative sample of the whole population.

A third essential consideration is that in sampling sites and areas, the estimates gained can be justifiably generalised to infer what the population as a whole is doing. To make inferences about UK populations, sampling must encompass the gradients of climate, landscape types and habitat coverage that exist across the UK and by implication must be geographically well spread. An efficient strategy to achieve this is to apply some form of stratified random-sampling, with a large number of smaller sample units (Cochran 1977). However, the statistical constraints of such a design must be balanced against practical considerations. When random-sampling is not practical, it is important to understand and define just what has been sampled and to what part of the population an answer may be applied.

4.1.2.d Statistical working group

In designing and implementing monitoring protocols for the NBMP a balance was sought between statistical elements and practicalities of land access. Early on in the development of the programme, a working group was set up to assess available methods and sampling strategies. Input was sought from population statisticians and researchers involved in monitoring other species (birds, mammals). A review of summer monitoring techniques, sampling strategies and survey design was produced by Prof. Buckland (unpublished, copies held by BCT). The points highlighted by the working group regarding statistical design (bias, precision, sampling) and potential validation procedures are discussed in relation to the three key monitoring methods below. The majority of Prof. Buckland's report is reproduced within the discussion sections below (with permission), so that the discussion could be divided by the key monitoring methods. In referring to the original report, readers will find the same text, but the discussion of field monitoring and roost monitoring are considered together. The statistical detection of important changes (power) and how this can help improve monitoring scheme designs are discussed in the next chapter.

4.1.3 Sample units, stratification and sample allocation

4.1.3.a Sample units

For maternity colony and hibernation site monitoring schemes, the roost site (e.g. house) or hibernation site (e.g. mine) are the sampling units. For field survey schemes, the 1km square was selected as a convenient sampling unit. It integrates with the National Grid and Ordnance Survey maps, and is widely used for planning at the strategic scale. Further, it is feasibly surveyed within a single evening.

4.1.3.b Stratification

In order to avoid bias in the selection of samples, site sampling should be based on objective sampling procedures. If samples are selected on a purely random basis, the risk is

that by chance, a number of samples may be drawn from the extreme ends of the population distribution, resulting in skewed population estimates atypical of the whole population being sampled. To minimise this risk, stratification systems are used to divide the population into a range of representative groups or "strata", so that all sections of the population are sampled. The value of stratification goes beyond the simple increase in efficiency and adds the capability of extrapolating data from samples to the whole of the country in a structured way.

Stratification to maximise precision of estimates can be an integral part of the sampling strategy or can be applied after the sample has been collected using appropriate criteria (Cochran 1977). To maximise precision, strata need to be constructed such that across-strata differences in population changes are large whereas within-strata differences are small. In ecological terms, it is likely that the greatest difference in species abundance and in the ecological processes acting on populations, occurs between areas of different landscape and climate type. One landscape and climate-based stratification system already in use for strategic assessment in Great Britain is the ITE land classification system (Box 4.2).

Box 4.2: ITE land classification system

Over the last 20 years, the Institute of Terrestrial Ecology (ITE) has developed a system of land classification for the strategic assessment of ecological stock and change. This system defines the range of variation in the environment of Great Britain using parameters such as altitude, topography, geology, climate and habitat cover, and divides the land into units known as land classes. The system assigns every 1km square in Britain to one of 32 land classes, which can be grouped hierarchically into 17, ten, or four major landscape types (Bunce *et al.* 1996). The framework provides a structure for modeling potential environmental change. A separate system has been devised for Northern Ireland.

During the NBMP's lifetime, the ITE land classification system has been revised such that there is a national division between Scotland and England/Wales (Howard *et al.* 1999) and this now forms the basis of the sampling strategy for Countryside Survey 2000 (Barr 1998). There are now 40 national land classes, which can be grouped into six Environmental Zones. (The ITE is now known as the Centre for Ecology and Hydrology (CEH).)

In the National Bats and Habitats Survey (Walsh & Harris 1996 a,b), a stratified survey of over 900 1km squares was completed, utilising the 32 ITE land class system as a stratification system. Land class was found to be a significant factor influencing abundance, and was therefore selected as a sensible choice of strata for the NBMP. In addition, this would facilitate the creation of Countryside Information System (CIS) import files; an output requested by DETR.

Other choices of stratification scheme exist which may be of value in analysing bat data collected in the NBMP. Of

Table 4.2 Comparison of observed, proportional and optimal sample allocation based on data of square root transformed mean number of bat passes collected for the National Bats and Habitats Survey 1990-1992. Estimate of total population is 1142808 passes, (se 29540). Sample size if even in all land classes would be 28

Land Class	Land Area	Estimate	Sd	Sample size = n			% of		
				Obs	Prop	Opt	Obs	Prop	Opt
1	14159	83181.25	3012.29	86	53	41	9.71	5.97	4.68
2	14463	83397.72	3704.84	66	54	45	7.45	6.1	5.04
3	15452	85554.56	3472.34	58	58	39	6.55	6.51	4.43
4	9012	52184.96	3507.64	36	34	31	4.06	3.8	3.53
5	3873	23722.48	2398.84	23	14	17	2.6	1.63	1.93
6	10360	54917.93	3322.44	57	39	37	6.43	4.37	4.2
7	2532	12543.19	1235.93	23	9	9	2.6	1.07	0.99
8	4412	25164.56	2297.53	25	16	17	2.82	1.86	1.92
9	11781	73136.26	4121.59	48	44	42	5.42	4.97	4.78
10	13905	75935.73	4349.93	49	52	45	5.53	5.86	5.1
11	8895	42295.40	2936.37	34	33	25	3.84	3.75	2.87
12	3543	15559.15	3370.24	4	13	10	0.45	1.49	1.13
13	7266	42449.57	3211.85	42	27	31	4.74	3.06	3.49
14	933	2124.46	1396.67	3	3	4	0.34	0.39	0.41
15	4195	25909.49	1548.85	45	16	15	5.08	1.77	1.74
16	3089	19952.79	1815.50	27	12	14	3.05	1.3	1.58
17	12999	61208.28	3944.41	37	49	36	4.18	5.48	4.02
18	6732	30777.37	4388.14	13	25	23	1.47	2.84	2.65
19	5421	28269.31	5107.51	13	20	27	1.47	2.29	3.09
20	2508	10409.14	1787.79	4	9	5	0.45	1.06	0.6
21	9717	39807.33	6578.77	15	36	38	1.69	4.1	4.27
22	12549	40989.85	6672.81	29	47	53	3.27	5.29	6.02
23	6951	0	0	1	26	0	0.11	2.93	0
24	7207	31331.33	17232.0	3	27	44	0.34	3.04	5
25	10552	39703.05	5629.51	52	39	60	5.87	4.45	6.8
26	6876	34638.99	6895.52	35	26	61	3.95	2.9	6.83
27	6881	30220.73	5691.84	32	26	48	3.61	2.9	5.39
28	7464	29062.82	4958.59	19	28	32	2.14	3.15	3.62
29	5465	20087.59	1526.49	3	20	4	0.34	2.3	0.44
30	4254	9512.23	0	1	16	0	0.11	1.79	0
31	3018			0	0	0	0	0	0
32	3779	18760.76	11856.4	3	14	30	0.34	1.59	3.44
Total							886	885	883
Estimated % CV							2.58	1.93	1.76
Treating the data as the true stratum variability for this attribute, then for a total sample size of N , the % errors for each type of sample allocation can be estimated:									
Sample Allocation	%CV (N)	$N= 300$	400	500	600	700			
Equal	$76.94/\text{SQRT}(N)$	4.44	3.85	3.44	3.14	2.91			
Proportional	$57.48/\text{SQRT}(N)$	3.32	2.87	2.57	2.35	2.17			
Optimum	$52.32/\text{SQRT}(N)$	3.02	2.62	2.34	2.14	1.98			

Table 4.3 Relationship between original 32 land classes and new national land classes 1-40. The letters e, w and s represent England, Wales and Scotland respectively.

(Old) land class	(New) national land class in relation to old	(New) national land class (New) number 1-40	Environmental Zone 1-6
1	1e	1	2
2	2e	2	1
3	3e	3	1
4	4e	4	1
5	5e	5	2
6	6e	6	2
7	7e	7	2
	7s	25	4
8	8e	8	2
9	9e	9	1
10	10e	10	2
11	11e	11	1
12	12e	12	1
13	13e	13	2
	13s	26	4
14	7e or	7 or	2 or
	7s	25	4
15	15e	14	2
16	16e	15	2
17	17e	16	3
	17w1	17	3
	17w2	18	3
	17w3	19	3
18	18e	20	3
18s	27	5	
19	19e	21	3
	19s	28	5
20	19e	21	3
	19s	28	5
21	21s	29	6
22	22e	22	3
	22s	30	6
23	23e	23	3
	23s	31	6
24	24s	32	6
25	25e	24	1
	25s	33	4
26	26s	34	4
27	27s	35	4
28	28s	36	5
29	28s	37	5
30	30s	38	5
31	31s	39	5
32	32s	40	5

bat abundance to improve precision, these land classes tend to be the marginal upland and upland land classes, where observer density is low and the difficulty and cost of surveying sites is high. If these factors were added into

the equation for optimal sample calculation they would have the opposite effect, reducing the number of sites to be surveyed within these land classes. Thus there is not much of an advantage in using an optimal scheme.

particular note is the European land classification developed by ITE and the Climate Research Unit in Norwich as part of the Natural Environmental Research Council's Terrestrial Initiative in Global Environmental Research (TIGER) programme on 'Landscape dynamics and climate change'. Ten major groups corresponding to recognisable divisions of European climate have been derived based on climate, altitude and locational data, but at present the classification is at a half-degree resolution (D. Howard pers comm). However, it offers a future opportunity to model climate change scenarios and expand the NBMP into Europe.

In the BTO Breeding Bird Survey, the distribution of sample plots is stratified by the availability of observers. In the NBMP, we opted to stratify by ITE land classes as described above. It should be noted that observer distribution was not known *a priori* but *post hoc* stratification by observer density may be applied if required.

4.1.3.c Sample allocation

In general, without detailed prior knowledge of the variability of bat abundance involved, it is best to allocate sampling effort so that strata are sampled in proportion to their size (Cochran 1977). When variability information is available, strata can be sampled optimally, allocating more samples in the more variable strata as well as weighting by strata size to increase precision. If the individual strata are of importance, then an eye also has to be kept on maintaining a minimum number of samples in each stratum to produce acceptable abundance estimates. The original ITE GB field survey selected eight sample squares as a minimum to estimate land class characteristics. Figures obtained for bat

abundance within land classes by Walsh (1996) suggest a minimum number of ten–20 sample squares is required for accurate abundance estimation in most land classes.

An analysis was carried out of the data collected for National Bats and Habitats Survey (Walsh & Harris 1996 a,b) by David Howard of ITE Merlewood. Three sample allocation regimens were compared: equal, in proportion to the land area of land class types and optimally (accounting for bat abundance variance between land class types). Figures for the observed pattern of samples collected in the survey are given. (Table 4.2, produced by David Howard, ITE Merlewood). In allocating sites, we opted to follow a simple proportional regimen. The rationale for this is:

- In allocating sites to volunteers, it is difficult to adhere to a precise stratification system. Examining the participation rate of observers, return rates of allocated sites ranged from 47% to 67%. Thus, even with the best of intentions, adhering to a strict stratification is not possible, and only approximations to the numbers of sites in each strata are likely to be achieved.
- In examining the coefficients of variation (CV) in Table 4.2, there is a significant reduction in CV when either proportional or optimal sample allocation is used over equal sample allocation. However, there is little difference in CV between using either proportional or optimal sample allocation, indicating their performance is similar.
- While optimal sample allocation suggests an increase in the number of sites in land classes with high variation in

Table 4.4 Descriptions of Environmental Zones 1-6. See Map on back page for distribution

Environmental Zone no.	Description
1	Lowland arable in England/Wales – Easterly lowlands
2	Lowland pastoral in England/Wales – Westerly lowlands
3	Uplands in England/Wales
4	Lowlands in Scotland
5	Marginal uplands in Scotland – Intermediate & Islands
6	True uplands in Scotland – Highlands

Table 4.5 Total number of 1km squares by the original Landscape types based on the 32 land class system and by the new Environmental Zones based on the 40 land class system.

Landscape Type	New Environmental Zone						Total
	England and Wales				Scotland		
	Arable 1	Pastural 2	Upland 3	Lowland 4	Marginal 5	Upland 6	
Arable	66297	632		14277			81206
Pastural		61642		8807			70449
Marginal Upland			21621		16368		37989
True Upland			4390		13498	32034	49922
Grand Total	66297	62274	26011	23084	29866	32034	239566
% of GB	27.67%	25.99%	10.86%	9.64%	12.47%	13.37%	

While we aimed to spread sites proportionally between individual land classes, an overall goal was to maintain a roughly proportional sample allocation between major groups of land classes, and ensuring there were sufficient samples in each major grouping to permit comparative analyses. Seven major land class groups were considered at the outset, based on hierarchical classification groupings. In 1999, data were re-stratified using the 40 ITE land class system and six Environmental Zones were considered (see Tables 4.3, 4.4 and 4.5).

Treating the data as the true stratum variability for this attribute, then for a total sample size of N , the % errors for each type of sample allocation can be estimated.

4.2 MATERNITY COLONY COUNTS (SUMMER)

Many research studies using survey or monitoring methods to estimate bat numbers have focussed on summer roosting aggregations of female bats, termed maternity colonies. Monitoring techniques employed fall into two broad categories: monitoring bats from inside the roost site, which entails a small to large degree of disturbance to the animals, and monitoring bats from outside the roost, which minimises or avoids disturbance. While internal counts have some advantages from a research perspective, they are generally impractical for large-scale monitoring. In addition to the disturbance factor, two main constraints are the inevitable restriction of roost site coverage caused by the limited number of licenced bat workers who may enter roosts, and the variability of counts caused by the preference of many bat species to select roosting sites in cracks and crevices, hidden from view.

Monitoring from the outside can be achieved via electronic counting devices, capture of bats and photographic/video recording techniques, but the least disruptive, cost effective and simple method that permits large-scale coverage of roosts and wide-scale participation by volunteer observers is to make visual emergence counts of bats at dusk.

Sample statistics measured in emergence counts of bats in previous long-term roost studies include:

- Emergence counts of adult bats pre-birth. Both the mean of several counts and the peak count of adult bats were used as a sample statistic
- Emergence counts of adult bats at the time of weaning. Both the mean of several counts and the peak count of adult bats were used as a sample statistic
- Some monitoring techniques have counted the emergence peak of bats both pre-birth and post-weaning to obtain estimate of the peak adult numbers and then adult plus young numbers. The peak proportion of adults producing young is used as a sample statistic

The NBMP selected the first model. Methods of estimat-

ing fecundity, such as the third bullet point, may be unreliable if the measure used does not relate to the recruitment rate into the breeding population. Studies in the UK suggest that counts made pre-parturition (shortly before young are born) provide a less variable and hence more accurate estimate of colony size.

4.2.1 Colony sampling strategy and counting protocol

Key components of the sampling strategy and counting protocol are:

- Visual emergence counts of bats at maternity colony roost sites made pre-parturition
- Sample units are maternity colony roost sites (e.g. houses)
- Sampling strategy is non-random: known sites are selected by volunteers
- Stratification of the site sample by ITE national land class is *post hoc*
- Two counts are made. In an examination of pilot data, Prof. Buckland advised that little loss of information would occur using two counts, and that if this increased roost coverage and encouraged consistency in counting, it would improve the dataset for analytical purposes. Using three or four counts was unpopular with volunteers and led to inconsistency in counts (see Chapter 6)
- Counts are annual
- There is no overlap of species monitoring under this strategy, with a single species monitored at each roost site. Sometimes there are mixed species colonies, but species are generally easily distinguished due to differences in size, behaviour, emergence time and echolocation calls

A basic description of the counting protocol is given in Box 4.3. Example survey forms are given in Appendix 3.

Schemes are in progress for *E. serotinus*, *R. hipposideros*, *P. pipistrellus* and *P. pygmaeus*. A *M. nattereri* roost monitoring scheme was piloted in 1995 and 1996, but due to the difficulties involved in surveying this species and the low number of known roost sites, the survey was discontinued. The most frequently encountered problem was the accuracy of counting bats given their erratic flight on emergence in low light levels. Further effort on roost surveying schemes for these bats was planned for 2000 and the results of this has not been entered onto the database for assessment.

4.2.2 Factors affecting colony counts

In addressing potential sampling bias it is evident that all surveys suffer from bias to a lesser or greater degree. The main question to be addressed is whether the potential bias in this case is likely to lead to drastically erroneous conclusions or whether it is acceptably low. This must be

Box 4.3: Maternity colony counting protocol

Standard method for a roost count

- If an unfamiliar roost site is surveyed for the first time, a visit is made prior to the official survey evenings to determine where and how many exit points are being used.
- If more than one exit point is being used, additional volunteers are recruited to help.
- Two emergence counts are made in May–June (pre-parturition). For *Pipistrellus* sp. and *E. serotinus*: one count is made between 6–15 June, a second count made between 16–25 June. For *R. hipposideros* one count is made between 29 May – 7 June, a second count is made between 8 June–17 June. Counts are made a minimum of four days apart.
- Observers are requested to be in place at least 15 mins before sunset or known emergence time.
- A full emergence count is defined as the net number of bats leaving a roost, starting with the first bat to be observed and ending when the net number of bats emerging is zero. This point is reached when either there is no further bat activity or activity has ceased for ten minutes, when it becomes too dark to see bats exiting or entering the roost or when returning bats and the swarming of bats around the exit makes it too difficult to assess whether more bats are emerging.
- For late emerging species, a torch with a red filter may be used to illuminate roost exit points.
- On **each survey** evening, observers record the total bat count, weather conditions at the start of the count : ambient temperature (degrees Celsius), cloud cover, wind speed and rain status, their reason for stopping the count and whether they used a bat detector. Observers are requested not to conduct counts in poor weather conditions (strong winds, heavy rain, very cold temperatures).
- **Each year**, observers record their name and address and the survey details onto a proforma. If no bats were present during the survey dates, but they were present at other times, observers are requested to make a single count on any night when the bats were present and to circle dates when the bats were present at the roost. If no bats were present at all that year, observers are requested to tick the relevant box and return the form anyway. Surveys are conducted annually

Roost site and habitat details

- For all new roosts entering the scheme, site details and habitat details around the site are recorded **once**. Site details include: OS grid reference, name, address and county of site, site type (e.g. house), species and verification status, number of roost exits, a simple sketch of the roost site and exit points or photograph. Habitat types that fall within a visual radius of approximately 500m around the roost are recorded. Selection is from a list of the 17 broad habitat types recorded in the Countryside Survey. Observers give the approximate % of each habitat type or simply mark its presence if linear or a small amount of the habitat is present.
- Simple written descriptions of site and habitat changes are requested each year.

considered on a species by species basis. A secondary question is whether an improved knowledge of roost dynamics gained through intensive studies would aid the interpretation of population trend data collected via roost counts such that population trends could indeed be adequately modeled and monitored.

Main sources of variability in the counting procedure include the emergence behaviour of the bats, contribution of observers and survey dates/environmental conditions. Whilst it is recognised that not all bats leave the roost site every night, internal validation of counts conducted post emergence have demonstrated that the majority of *R. hipposideros* do so on fine nights (Smith 1993). Counts are therefore only made in fine weather conditions, avoiding nights of heavy rain, wind or cold when a higher proportion

of bats might remain within the roost. In an analysis of pilot data, while the additional use of a bat detector, or a tally counter did not significantly increase lesser horseshoe counts, validation and a qualitative measure of observer experience increased counts (Witter 1998). Large variation in counts due to inexperience was also reported in *R. hipposideros* by Smith (1993), suggesting training of new volunteers to be advisable for this species. An experimental study was carried out by Aberdeen University honours student Joanna Guest at two roosts of *Pipistrellus pygmaeus* in north-east Scotland. During emergence, a sequence of bursts of red torchlight (using a red filter), white torchlight and periods of darkness were used during emergence counts. The study showed a significant drop in bats emerging when a white torchlight was used. However, there was no significant difference between darkness and periods of illumination

using a red light, indicating that red light did not disturb the bats. To reduce count variation therefore, a torch with a red filter can be used to illuminate roost exits to aid the counting of bats when it is too dark to see them.

Analyses presented in Chapter 9 of this report demonstrate that roost type, presence of other species, temperature, cloud cover, wind speed, rain status, reason for stopping the count (excluding sites where confusing bat activity stopped the count), the number of exits and use of a bat detector, did not have a significant effect on numbers emerging, once the influence of country, national land class and survey date were taken into account. When survey date was excluded, temperature was highly significant however. Many sites have missing temperature data and, in an attempt to reduce this, the NBMP has offered free thermometers to regular colony counters. Every effort should be made to ensure that ambient temperature is routinely recorded on every visit.

To monitor trends in numbers, it is not critical that a colony is counted at its peak size (although it should be noted that in proposing sites as Special Areas of Conservation, it is important to have a record of the peak count). There is little to gain from repeated visits, other than to cover for the possibility of a particularly low count on one visit. Standardisation across years and colonies is more important. Thus two visits per year, within a relatively narrow window of dates each year, carried out at a high percentage of surveyed roosts, will allow more reliable and precise quantification of trends in the population that the roosts represent than does a scheme that aims for three or four visits per year. It also allows greater flexibility in the dates of the visits, and for various reasons only delivers one count or even no counts at a significant proportion of 'surveyed' roosts. However, there should be no relationship between date and roost size over time. While there is a likely cline in birth dates with latitude, and annual fluctuations of birth date will occur due to prevailing weather conditions (Ransome & McOwat 1994), a radical shift in phenology over the longer-term seems unlikely, unless climate changes are severe. Predictive modelling of birth dates may help identify any such shift in response to climate change.

The policy of monitoring known colonies probably overestimates negative changes in abundance. Colony 'extinctions' (which includes movement of the colony to another (unknown) roost site) will be monitored, but colony formation will be unobserved, so that in species that fairly readily establish new colonies, estimated trends will be subject to considerable bias. The magnitude of bias depends on colony dynamics however, and there are little data available ascertaining whether bats do readily establish new colonies or not. Although this is likely to be the dominant bias, there is also potential for bias in the other direction. Larger colonies are more likely to be discovered, and survey of larger colonies is more likely to be maintained over a long time period. Thus if a species is in decline, but in a density dependent way, so that small colonies become smaller or become extinct while large colonies maintain their strength, roost counts may fail to quantify the extent of the decline.

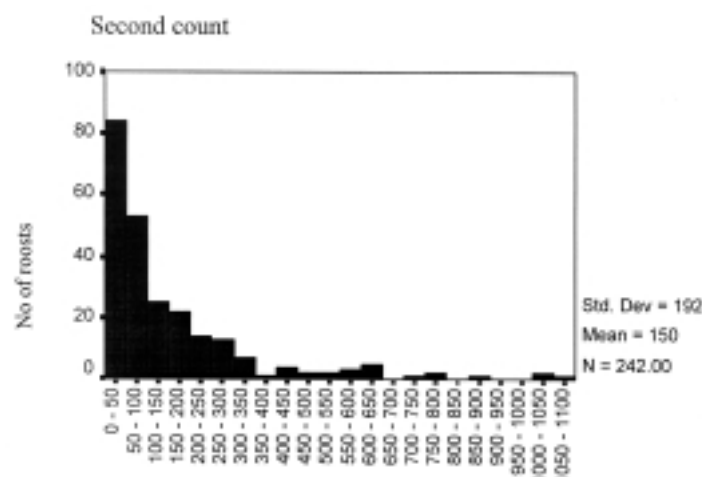
Another possibility is that as a population declines, the proportion of non-breeding females decreases as a density-dependent response. In that case, the decline observed in breeding colonies would be smaller than the true decline in the population. Two simple scenarios illustrate this:

1. Suppose a species tends to form new colonies fairly readily, and these initially expand rapidly, followed by a slow decline. Then most known (and hence monitored) colonies will show decline, even if the population itself is increasing rapidly.
2. Suppose colonies are stable in size, unless a site is lost through development or demolition. In that event, suppose the bats find an alternative location. Monitoring based on known sites will suggest stability for some colonies and extinction for others, so that on average, there appears to be decline, even though the population is stable.

In summary, colony counts are likely to be effective for monitoring change only in the following two cases: (a) nearly all colonies are known and monitored; or (b) it is rare for new colonies to be established, and a representative sample of colonies is monitored.

Within the NBMP schemes, colony count distribution ranges from below ten to 1,500, with 75% of roosts containing 194 bats or less (Figure 4.1). In a study of randomised bounded areas, where roost sites were searched for and found, the building size, age and distribution did not differ significantly from roost sites held on a database reported to English Nature (Battersby, 2000). The NBMP sample is similar to the reported roost sample, and thus it also may not differ greatly from a randomised sample. New sites are added to our sample each year, through new sites being discovered, and some element of colony turnover is therefore encompassed. In NBMP schemes, our assumption is therefore that (b) is not violated to a large extent for the species we are monitoring. However, this is based on very little autecological information, and effort needs to be concentrated on validating roost counts and on carrying out pertinent autecological research to aid the interpretation of population trend data.

Figure 4.1 Size distribution of pipistrelle roosts in 1999



A validation proposal to carry out randomised surveys of 4km- and 1km-square bounded areas to identify and monitor all potential roost sites proved difficult to achieve using a voluntary work force. In theory, results from 40 such areas could be compared with results from the main colony counting scheme. In the trial, extensive surveys of 4km² areas were carried out by mailing all occupied buildings, followed by an intensive search of a single 1km area within this block. Field visits were made to potential roost sites to search for bats and attempts made to track flying bats back to roost sites. The method was based on a highly successful systematic survey completed in the Netherlands. However, the results of the study were discouraging. Of 60 sites allocated to volunteers who had expressed their willingness to carry out this survey only 18 sites were surveyed. The majority of observers taking part in the survey found it too time consuming and expressed a reluctance to repeat the survey. This is understandable since many observers attempted the survey "solo". Confirming the presence/absence of roosts was found to be more difficult than expected. In some cases, even when roosts were known to exist, the householders did not return the mailed survey cards.

4.2.2.a Roost validation study statistics

- Sites allocated to volunteers who expressed an interest: 60
- Sites completed/returned to the office: 18, a return rate of 30%
- Number of letters posted per site averaged 88.8 (min eight, max 300)
- Total time spent surveying a site averaged 15.1 hours (min two, max 44)

Roost discovery: 12 of the 18 sites were identified as having no bat roosts present. However, in several of these sites, roosts were known about previously but not reported in the survey. Confirmation of whether the roosts were still in existence was either not carried out or not apparent in the returned notes for the sites. Within the six sites where the presence of roosts was confirmed, the surveyors already knew the majority of roosts identified although the numbers of bats present was in most cases not given. Only two new maternity roosts were discovered and confirmed as a direct result of the study.

On further consultation with Prof S. Buckland and Dr S. Langton (Central Science Laboratory), it was agreed that the scheme was not logistically feasible with the resources we have.

4.2.3. Colony count validation and research recommendations

Recommendation 22: No major changes to the protocol are recommended. If feasible, guidelines should be issued on the training of inexperienced observers, which should include some counts

made in the presence of an experienced observer.

Recommendation 23: Experiments of simultaneous but independent counts carried out by a second observer to assess accuracy and precision. A project using an infra-red imager, or any other aid to help get a more accurate 'true' count at a sample of sites would be of value.

One of the key biases in roost monitoring schemes is the unknown rate and pattern of colony turnover and the representativeness of a sample of known roost sites. Three options have been identified to measure or help reduce this bias:

Recommendation 24: An assessment of the relationship between the sample of colonies counted to that occurring in nature and of the movement of colonies and the formation of new colonies.

A discrete autecological study, involving radio-telemetry of bats collected in the field, could identify all used roosting sites within a bounded area. Movements of bats into and out of this area as well as between sites within this area could be followed, and counts at all sites made over a number of years. There are a number of long-term study sites within the UK, and the data available from these sites could be capitalised on if such autecological studies were based there.

Recommendation 25: Run parallel transect surveys for all roost-monitored species for a minimum of ten years or until trends between the two monitoring schemes can be compared.

Transect surveys might prove valuable for validating trends in roost counts. For example, the range of plausible rates of change for the *R. hipposideros* roost counts turns out to be quite narrow even for just three years of data: -3.3% to 7.5% (Prof. Buckland) and 0.05 to 9% for seven years of data. A transect-based approach in the same region might within just a few years allow assessment of whether there is a discrepancy between the two methods large enough to have management implications. This issue is more critical than whether the roost counts are accurate. When estimating trends in relative abundance, large biases in the counts can be tolerated, provided there is no trend in the biases over time.

Recommendation 26: Develop and test a stratified dawn transect survey to locate bats swarming on their return to maternity roosts at dawn. This will provide: 1) incorporation of new roost discovery into roost sampling monitoring schemes already in place:

- 2) location of roosts of less obvious species; and, 3) location of better samples of tree-roosting bats.

The bias resulting from colony turnover will be reduced if a component of new roost discovery is incorporated into roost monitoring schemes. It has been demonstrated by Dutch bat workers that new previously unknown roost sites can be more readily located at dawn (rather than dusk), when bats may swarm outside roost sites or are easily visible in the dawn light returning along familiar routes (often linear corridors such as hedgerows or treelines) to roost sites.

4.3 HIBERNATION SITE COUNTS (WINTER)

Traditionally, the assessment of populations in hibernation sites has been the most consistently and widely employed technique for population monitoring throughout Europe. While there are constraints on the reliability of such data, this information has been successful in highlighting declines and local extinctions (e.g. Daan *et al.* 1980). As a highly multispecies approach it also provides a valuable comparison between species and has provided data on species not currently targeted by the NBMP. In the UK, hibernation site sur-

veys can only be carried out under the guidance of a licensee with an appropriate endorsement.

The choice of sample statistic is straightforward – either the mean count or peak count of bats present during the surveys.

4.3.1 Hibernation site sampling strategy and counting protocol

Key components of the sampling strategy and counting protocol are:

- Visual counts of inactive bats at hibernation sites made in January and February
- Sample units are hibernation sites (e.g. mines, caves)
- Sampling strategy is non-random: known sites are selected by volunteers
- Stratification of the site sample by ITE National Land Class is *post hoc*
- Two counts are made. More counts may cause

Box 4.4: Hibernation site counting protocol

Standard method for a hibernation site search

- The majority of hibernation sites are known sites where previous visits have ascertained the form/internal structure of the site.
- One surveyor leading the search must have a hibernation site visitor's licence issued by the relevant Statutory Nature Conservation Organisation.
- **Two** counts are made of all species present at sites, one in January and one in February. Counts are made during the day, a minimum of one week apart.
- Observers are requested to search the whole accessible area of the site, or use standard search patterns such as transects in larger sites.
- If more than one main chamber is surveyed within a single location, counts are made on the same day and submitted for individual chambers, but treated as one site for database input purposes.
- On **each survey**, observers record the total bat count for each species, temperatures outside and inside at the warmest and coolest point, the numbers of surveyors and number of surveyors holding a licence and the time taken to complete the survey.
- **Each year**, observers record their name and address and the survey details on a proforma.
- Surveys are conducted annually

Hibernation site and habitat details

- For all new sites entering the scheme site details and habitat details around the site are recorded **once**. Site details include: OS grid reference, name, location and county of site, site type (e.g. cave), site size, surveyability and number of crevices, number of entrances, whether linear habitat or dense habitat cover is near the main entrance, a simple sketch of the site and routes surveyed. Habitat types that fall within a visual radius of approximately 500m around the site are recorded. Selection is from a list of the 33 habitat types recorded in the Countryside Survey. Observers tick the habitats present.

unacceptable disturbance to bats

- Counts are annual
- There is a high degree of overlap of species monitoring under this strategy, with several species monitored at each hibernation site. All species present (including non-target species) are recorded

A basic description of the counting protocol is given in Box 4.4. Example survey forms are given in Appendix 3.

4.3.2 Factors affecting counts of bats in hibernation sites

A number of human-induced factors may influence counts at particular sites. These may range from disturbance through activities or uses of the site causing bats to vacate at a critical time, to the efforts of conservationists to protect or improve sites specifically for bats and resulting in increased use by bats. Other factors which influence the numbers of bats and the ability to monitor the populations of bats using the sites relate to the nature of the site, the weather at or near the time of the count and the nature of the bats themselves. For the most part these are fairly constant factors that will even out with data collected over time. Most key sites and a wide range of lesser sites are monitored at least once per year so that natural fluctuations in counts, due to say weather, can be accommodated.

The size of a site will influence the number of bats using it. Larger sites will usually offer a wider range of environmental conditions and roosting opportunities, although few bats range more than a few hundred metres from an entrance. This will, however, relate to the number and size of entrance(s). A large site with a single small entrance will offer only rather uniform conditions once the threshold zone has been passed and may be less attractive to a range of species and larger numbers. While small sites may not provide for large numbers of bats, they will be used by almost all species and can be of considerable value for distribution monitoring and their importance to bats may be underestimated because of the small number of bats found in each site. Apart from their use during hibernation, such small sites may also be important at other times of year, e.g. as male mating territories. The rates of loss of such sites is high in some areas and the monitoring of the loss of the sites themselves should also be considered.

The surface structure will also influence the use by bats. A smooth well-mortared brick tunnel or even a smooth-walled natural passage will provide a poor substrate for roosting bats. Weather may significantly affect the occurrence of bats in underground sites. Particular species, such as *M. nattereri*, *Plecotus* sp. and *B. barbastellus* are more likely to occur in increased numbers in sites which remain frost-free during periods of prolonged very cold weather. These species may also be found in icy environments, but usually where they can maintain a microclimate above freezing. The NBMP survey forms include basic information on the nature of the site and weather at the time of survey.

Identification difficulties will also affect counts. The separation of *M. brandtii* and *M. mystacinus* can rarely be made with confidence without handling the animal. Since the general policy in hibernation site monitoring is to discourage the handling of bats, these two species are usually combined in survey results. Species of *Myotis* as a whole may present difficulties in identification if the key features of the bat cannot be seen clearly or for observers with less experience. Even separation of the two *Rhinolophus* sp. may be difficult to distinguish on the roof of a high cavern. However, most hibernation site surveys are carried out by groups of people where the range of experience can achieve accurate identification for most bats. The number of unidentified or questionably identified bats can be accounted for in the survey results and are unlikely to affect the general trend over time.

As a whole the above factors can be accommodated in the long-term monitoring of underground sites to give reliable data on population changes, but the ability of bats to conceal themselves in spaces that cannot be inspected (such as gaps behind brickwork, natural rock or boulder formations, within rock scree on the floor) means the number counted may be an unknown proportion of the number of bats present. An assumption is made that even where the majority of bats may be hidden from view (as was shown for one site by Baagoe *et al.* 1988), the bats that are visible are representative and that that representativeness remains constant from year to year. It is possible that in some weather conditions in some sites (e.g. particularly cold weather in a disused open-ended railway tunnel) more bats will be concealed in deeper crevices and out of view, but even that should not affect the longer-term assessment of population change.

4.3.3 Hibernation count validation and research recommendations

- Recommendation 27:** Encourage the monitoring of small sites and their rate of loss within the sampling strategy.
- Recommendation 28:** Some measurement of the relationship between numbers of bats visible, the complexity of the site and numbers of bats actually present is needed, but is very difficult to achieve. The potential of using endoscopes to search for hidden bats should be explored further.
- Recommendation 29:** Measurement of dispersal of bats between sites via long-term ringing studies and potentially short-term radio-tracking field research.
- Recommendation 30:** Detailed autecological study of factors affecting numbers of bats in hibernation sites.

Box 4.5 River Habitat Survey (RHS)

River Habitat Survey (RHS) is a method for assessing the physical character and quality of river habitats: it has been developed by the Environment Agency to help the conservation and restoration of wildlife habitats along rivers and floodplains.

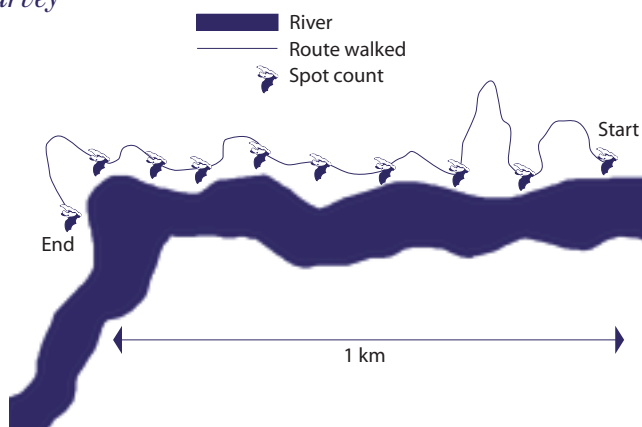
The RHS system is based on information from a major baseline survey of rivers and streams in the UK and the Isle of Man. Habitat and other data were collected from a network of randomly selected reference sites (each site being a 500m length of river channel), and more than 5,600 such sites were sampled during 1994–1997. The RHS provides a unique snapshot of the state of riparian habitats.

By building quantitative models of Daubenton's bat abundance with parameters such as channel structure, flow rate bank vegetation and water quality – it will be possible to identify factors influencing the presence of bats and predict what changes in river catchment management would most benefit Daubenton's bats.

4.4 BAT DETECTOR FIELD SURVEYS (SUMMER)

The availability of heterodyne bat detectors at an affordable price has increased the number of volunteers able to identify and record free-flying bats. This was demonstrated by the UK National Bats and Habitats Survey (Walsh *et al* 1995), which surveyed over 900 1-km squares nationwide using volunteer input throughout the country. Although field surveys are labour intensive, they provide an opportunity for monitoring species simultaneously and validating roost count or hibernation count data. Surveyors require a minimum amount of training to differentiate between the species monitored by the NBMP, and this training is being carried out through bat detector workshops organised by the

Figure 4.2 Transect route for Daubenton's bat field survey



Box 4.6: Daubenton's bat field survey protocol – Standard method for a Daubenton's waterway survey

- Surveyors are allocated a six figure grid reference of an RHS site along a waterway (river) within a 1km square. Some canal sites (not surveyed by EA) are also randomly selected.
- During the day, surveyors identify a roughly 1km route along the waterway, which includes the grid reference. Along this route, ten stopping points by the side of the river are identified, a minimum of 100m apart, and spaced equally where possible.
- Two surveys using heterodyne bat detectors are made in August, one count is made between 1–15 August, a second count made between 16–30 August.
- Observers are asked to start surveys approximately 40 mins after sunset.
- On each survey, the detector is tuned to 35 kHz, a torch is used to scan the water surface, and Daubenton's bat passes are recorded for four mins at each of the ten spots along the waterway. Thus the number of Daubenton's bat passes per 30 mins in total are recorded.
- Daubenton's bat passes are identified only if heard and seen skimming the water surface. The number of "unsure" bat passes, that are heard but may be another species are also recorded.
- On each survey evening, observers record the total bat count and weather conditions at the start of the count : 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, very cold temperatures).
- Each year, observers record their name and address, which bat detector they used, and the survey details on a proforma.
- Surveys are conducted annually.

Waterway site and habitat details

- For all new sites entering the scheme, site details and habitat details are recorded once. Site details include: county, waterway type, water channel width, water flow, and the degree of bank shelter. Habitats types that fall either side of the waterway within a visual distance band of approximately 20m are recorded. Selection is from a list of the 23 habitat types and typical waterway features. Observers tick boxes of habitats present.
- Simple written descriptions of site and habitat changes are requested each year.

NBMP. As expertise and equipment develops, the use of bat detectors is likely to become an increasingly important monitoring technique.

Four basic techniques can be applied:

- Continuous counts of bats along randomly placed transect lines of fixed or variable length
- A fixed number of spot counts for a set time period spaced systematically along randomly placed transect lines
- A fixed number of spot counts for a set time period within a range of specified habitats
- Counts of bats using either spot count or transect lines through known seasonally exploited (optimal) habitats.

Key sample statistics measured in other studies include:

- The presence or absence of a bat species.
- The total number of bat passes recorded per area or length of route surveyed or per time period (per km², per km or per minute etc)
- The maximum number of bats estimated to be present with the aid of a bat detector and torch-light when encountered along a transect or at a stationary point
- The proportion of time bat activity was recorded per time period e.g. two out of ten mins = 0.2

In NBMP schemes, a mixture of the first two techniques and sample statistics respectively were used

4.4.1 Field survey sampling strategies and count protocols

In identifying suitable sampling strategies and counting protocols for NBMP target species, the first step was to review the potential for multi-species surveys using heterodyne detectors. Potential overlap areas in detecting species with heterodyne bat detectors are:

- **Noctule/serotine:** since their echolocation calls are both below 30kHz on the detector. However in most situations it is possible to differentiate their calls with confidence on the detector
- **Common pipistrelle/soprano pipistrelle/Daubenton's bat:** since their echolocation calls are all circa 45–55kHz. However trained surveyors can differentiate pipistrelles from Daubenton's with confidence by a combination of listening to the sound types and rhythm of each species and by use of the tuning dial. A percentage (~70%) of the two pipistrelle species can be differentiated with confidence by trained surveyors. Appropriate identification rules are issued for each field survey

When consideration is given to appropriate sampling frames, overlap areas change thus:

- **Noctule, serotine, common pipistrelle and soprano pipistrelle:** all of these species occur widely in the countryside, making the choice of stratified random 1km-squares a suitable sampling frame
- **Daubenton's bat:** unlike the other species, this bat is largely associated with water, and although it also forages away from water, it is extremely difficult to identify in such circumstances and can easily be confused with other *Myotis* species. Therefore a more appropriate sampling frame of water bodies was selected

Based on the above information and the need to minimise field-worker effort and costs, two separate field surveys were planned. One was a single species survey for Daubenton's bats (referred to as the Daubenton's waterway survey), and a second was a mixed species survey for noctule, serotine, common pipistrelle and soprano pipistrelle (referred to as the NSP survey).

4.4.1.a Daubenton's waterway survey

Key components of the Daubenton's waterway survey area:

- Sample units are stretches of waterway approximately 1km in length
- Sampling strategy is stratified-random: sites are selected from a pool of River Habitat Survey (Box 4.5) sites and proportionately by ITE national land class (Table 4.2)
- Counts of bat passes heard over a heterodyne bat detector made at ten stopping points or "spots" spaced along a roughly 1km stretch of waterway
- At present the scheme covers linear waterways – canals, rivers and streams only. In the future, different survey designs might be needed for rivers and for ponds, and an assessment made of whether trends are the same in the two cases
- Two survey counts are made during August
- Counts are annual
- There is a no overlap of species monitoring under this strategy at present. However, with the use of broadband bat detectors in the future, overlap with all other species present may be feasible

In the initial year of this survey (1997) random sites were selected proportionately from the ITE land class strata, as described in section 4.2. In 1998 and 1999, a different approach was taken – by selecting sites that had previously been surveyed in the Environment Agency's River Habitat Survey (Box 4.5), but also proportionately from ITE land class strata. This allowed bat data to be integrated with the detailed level of habitat data collected within the RHS scheme.

Figure 4.3 Environment Agency officer Richard Green prepares for a Daubenton's field survey. The Environment Agency was an important partner in this work



A basic description of the counting protocol is given in Box 4.6. A diagram of a survey route and photograph of a field-worker in action is presented in Figures 4.2 and 4.3.

Example survey forms are given in Appendix 3.

4.4.1.b Noctule, serotine, common pipistrelle and soprano pipistrelle (NSP) field survey.

Key components of the NSP survey are:

- Sample units are 3km length transects within 1km-squares.
- Sampling strategy is stratified-random: sites are selected proportionately by ITE National Land Class (Table 4.2).
- Counts of bat passes heard over a heterodyne bat detector are made at 12 stopping points or "spots", and 12 walking sections, spaced equally along the 3km transect.
- The location of transect lines and stopping points within the square are predetermined, and if these should prove impossible to follow, the closest negotiable route is identified and noted.
- Two survey counts are made during July.
- Counts are annual.

- There is overlap of species monitoring under this strategy. More species may be recorded with the use of broadband bat detectors in the future.

The idealised route within a sampled square was selected so that the observer finishes at the starting point. Because the idealised route is a closed loop, the observer can start at whatever point provides easiest access.

A basic description of the counting protocol is given in Box 4.7. A diagram of a survey route is given in Figure 4.4

Example survey forms are given in Appendix 3.

4.4.2 Factors affecting counts of bats using bat detectors

Randomised sample survey methods avoid many of the difficulties associated with roost and hibernation site counts, but are by no means problem free. Acoustic line transect surveys have potential as an inexpensive method of estimating trends in relative abundance. In principle, trends over time within a species can be estimated purely from the number of passes detected; precisely how many *animals* were detected is not needed. However, the following requirements need to be met:

- There should be no immeasurable trend over time in the sensitivity of the equipment

Box 4.7 Noctule, serotine, pipistrelle (both species) (NSP) field survey protocol

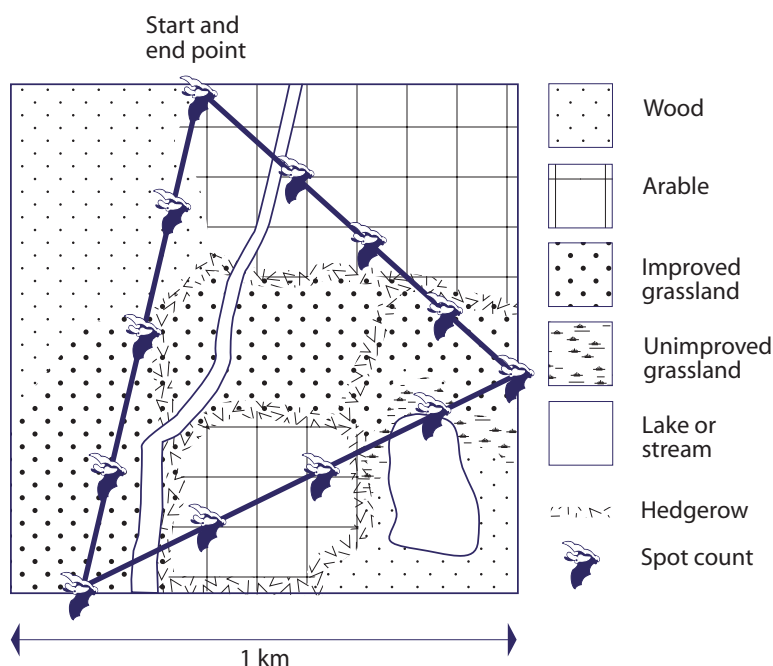
Standard method for an NSP survey

- Surveyors are allocated a 1-km square, randomly selected from ITE National Land Class strata, in proportion to land class availability.
- A predetermined 'ideal' triangular transect route, roughly 3km in length, is printed onto a map of the 1-km square. Twelve stopping points, four on each side of the triangular route are also printed onto the map.
- During the day, surveyors identify a walkable route around all of the stopping points, attempting to follow the ideal route. Where stopping points cannot be reached, points close by in the same habitat are selected by surveyors.
- Two surveys, using a heterodyne bat detector, are made in July, one count is made between 1–15 July, a second count made between 16–30 July.
- Observers are asked to start surveys approximately 20 mins after sunset.
- On each survey, surveyors walk between spots, with detectors tuned to 25 kHz to record serotine and noctule bat passes, then when each spot is reached, the detector is re-tuned to 50 kHz, and the observer record common pipistrelle and soprano pipistrelle passes for two mins while stationary.
- On each survey evening, observers record the start and end time of the survey, total bat count and weather conditions at the start of the count: 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, very cold temperatures).
- Each year, observers record their name and address, which bat detector they used, and the survey details on a proforma.
- Surveys are conducted annually.

NSP site and habitat details

- For all new sites entering the scheme, site details and habitat details are recorded once. Site details include: county, the site and descriptions of each spot. Habitats types present in the 1-km square are recorded. Selection is from a list of the 33 habitat types. Observers tick boxes of habitats present.
- Simple written descriptions of site and habitat changes are requested each year.

Figure 4.4 Example transect route for NSP field survey



- There should be no immeasurable trend in detectability of bats over time

- Detected passes should be reliably identifiable by species. Alternatively, a proportion of passes should be identifiable, and there should be no trend over time in this proportion

- Transect lines should be placed according to a randomised design. Failing that, they might be placed in the same, non-random locations each year, in which case trend estimates will apply to the locations covered, and not necessarily to a wider area of interest

Perhaps the most problematic requirement is the first; as technology improves, it would be difficult to justify retaining inferior equipment. If better detectors are

introduced, calibration will be required for each species against the old detectors. Alternatively, if a measure of the effectiveness of a detector can be recorded, the analyst can adjust for it. Changes in equipment should only be initiated only when it is demonstrated they will increase the sensitivity of present statistical analyses significantly.

For monitoring relative abundance, it does not matter if it is impossible to determine whether a count of say five bat passes corresponds to five different animals, or to just one animal passing five times. Provided the average number of passes per bat does not show a trend over time, number of passes can be taken as an index of number of bats: if the number of passes halves in five years, and other factors are unchanged, we estimate that the number of bats has halved. (If an estimate of absolute abundance was required, we would need to know number of bats rather than number of passes, and their locations relative to the line.)

In areas of high activity, it can be difficult to count the number of bat passes. If observers cannot reliably estimate the number, there is the potential for bias in estimated trends. It does not matter if the counts are subject to error, provided that observers do not consistently estimate high or low. If for example there was a tendency to underestimate the number of passes at high density, then any decline in numbers of bats would also be underestimated.

4.4.3 Field survey validation and research recommendations

Recommendation 31: Experiments with independent, simultaneous counts by different observers to assess observer differences in estimating numbers of bat passes and species identification success and assess observer accuracy in identifying species.

Recommendation 32: Experiments to measure detectability of bats in different habitats should be attempted or site habitat included as a covariable on trend models.

Use of the electronic bat developed by the NBMP in open, edge and cluttered habitats would give comparative results.

Recommendation 33: The degree to which the idealized route (NSP) was compromised can be recorded from maps submitted of survey routes, and an assessment made of whether apparent trends are a function of this degree.

Recommendation 34: Data from the NSP survey need further review and possible changes to the protocol (see Chapter 6).

4.4.4 Bat detector technology

4.4.4.a Types of bat detectors

All NBMP field surveys currently rely on the use of heterodyne bat detectors. The use of heterodyne detectors is relatively inexpensive, since many surveyors own their own detector (they cost around £150), and the simplicity of their use opens up participation in these schemes to a wider number of potential surveyors.

However technology is advancing rapidly, and it is likely that a move towards using "broadband" detection systems will be advantageous to the NBMP, in that they will:

- increase species identification accuracy
- increase the number of species that can be monitored simultaneously, thereby reducing the need for separate surveys and complicated protocols

To understand how technology is developing and the confounding effects of advancing technology can be minimised, it is first necessary to understand the three main systems of ultrasound conversion that have led to the three main types of bat detector currently available on the market.

Heterodyne This system is the one used on present surveys. Heterodyne detectors convert ultrasound to audible sound in real time but have to be tuned into the frequency of the bat echolocation call – this limits their effectiveness on multi-species surveys. They provide limited frequency information and hence recordings cannot be used to produce sonograms via computer programs. Bat identification rests with the abilities of the surveyor.

Time expansion (broadband) These detectors work by sampling a portion of bat ultrasound then slowing that portion down, usually by a factor of ten. The sound is recorded and can be transferred to a tape-recorder or mini-disk. Some detectors are automatically triggered by ultrasound which triggers recording, while in others the surveyor has to listen in heterodyne or time expansion mode and on hearing a bat echolocation call must then press a button on the detector to record the sound. Time expansion detectors are good for multi-species surveys because they are triggered by any bat ultrasound – no tuning is required. The disadvantage of time expansion is that it does not work in real time and any ultrasonic triggers (bat or non-bat) cause the device to become 'blind' whilst it processes the sound. However, because they capture all frequencies, recordings can be used to produce high-quality sonograms.

Frequency division (broadband) works by only sampling every tenth sound wave. As frequency is related to the number of waves per second, taking every tenth wave reduces the frequencies by ten. Like time expansion, no tuning is required but frequency division has the advantage of working in real time. Sonograms can be produced from recordings. However, because only one tenth of the original sound waves are used, the quality of sonograms is considered poor and may lead to a higher mis-identification rate.

4.4.4.b Bat detectors as identification and survey tools

Identifying bats on field surveys with heterodyne detectors is difficult, partly due to the wide repertoire of calls produced by each species but also by the experience required by each surveyor. To limit the proportion of misclassified bat passes, the NBMP's field surveys concentrate on species where simple rules can be used for identification and where differences between species are marked. Further, the NBMP targets identification training at all levels from beginners to more advanced fieldworkers. In anticipation of future changes, the NBMP also runs time expansion courses.

In the long-term, the use of broadband system may enable the separation of surveying from identification via post-survey computerised analysis of recordings. In this scenario, the user does not then have to have any high level skill and the need for training will be reduced. Recently, measurements of parameters from recorded echolocation calls of 14 sympatric species of bat in Britain were used to train an artificial neural network to distinguish between the species. The system achieved an overall 87% correct classification rate (Parsons & Jones 2000), and even *M. brandtii* and *M. mystacinus* were correctly identified to species at a rate of just over 60%. Other similar developments have been made (Obrist *et al.* 2000, Burnett & Masters 1999), and it is likely that computerised identification of calls will improve in the near future, to a point where a commercial program may become available to analyse calls to species level. One problem at present remains that classification of calls based on parameter measurement relies on examining only the "good" calls recorded, and discarding significant numbers of calls that cannot be used in the analysis. From a monitoring perspective, this is unacceptable, since all calls need to be counted and identified.

Thus, although detectors are an invaluable tool for monitoring bat species, there are many factors that need to be considered to optimise their use in the NBMP:

- Detector system: Heterodyne, Time expansion, Frequency division
- Price
- Sensitivity
- Ease of use

Heterodyne detectors are inefficient tools for multi-species surveys such as the NSP survey. Their limited frequency bandwidth means the tuning dial has to be rotated constantly to encounter all species or kept at a specific tuned frequency to encounter a selection of species. To enable them to survey four species on a single survey, the NSP survey uses a rather complex protocol whereby the detector is tuned to two different recommended optimum frequency settings during different parts of the survey. In contrast, for single species surveys such as the Daubenton's field survey, heterodyne detectors are a cost-effective tool, relatively cheap (about £150 or kit at £30) and easy to use.

Currently, there are two main problems associated with the use of broadband systems: identification is not instantaneous and the resultant computer analysis of sonograms generates extra hours of post-survey work. The first problem could be addressed by using a detector that uses both heterodyne and broadband systems. Thus the surveyor identifies bats in the field and their data can be verified later. This system has the advantage of correlating the two techniques and so allows continuity of data collection. The second problem could be addressed by developing a program that automatically analyses recordings or by training volunteers to analyse recordings themselves.

In addition, the two types of broadband systems (time expansion and frequency division) have various advantages and disadvantages:

Ease of use Frequency division is the easier technique to use because it works in real time. Time expansion is more difficult to use because once the detector is triggered the machine becomes 'blind' whilst it processes the sound. Thus if the machine is triggered by non-bat ultrasound, e.g. grasshoppers or jangling keys, then it is not surveying for bats during this period.

Cost The components for frequency division detectors are cheaper than for time expansion. It would be feasible to produce a cheap frequency division kit that would cost less than £50, whereas this would not be possible with time expansion detectors.

Sonogram quality Time expansion results in much higher quality sonograms than frequency division. However, the sonograms derived from frequency division are of sufficient quality to identify present NSP species with reasonable confidence.

Future proofing To meet monitoring objectives, sites require annual surveying over a long time period (20 years plus), and it is likely that the use of different technologies will become more of a problem and may confound results. Looking into the future, there are already systems available using ultrasonic microphones attached to lap/palm top computers with high processing power, and thus permitting the productions of high-quality sonograms in real time, although the cost is prohibitive at present.

A final consideration in comparing different detector types as survey tools is the sensitivity of the microphone used in the detector. Three types of microphone are used in detectors:

- Piezo
- Electret
- Capacitance

The **PIEZO** microphone is particularly sensitive around 40–45kHz but sensitivity drops off markedly away from this frequency range. Because of this sensitivity peak it is

unsuitable for producing sonograms.

The **ELECTRET** microphone has a flatter frequency response than the piezo up to ~60kHz after which sensitivity drops off markedly. Sensitivity in the 40–45 kHz range is less than the piezo.

The **CAPACITANCE** microphone is expensive. It has a flat frequency response up to 100+ kHz although sensitivity in the 40–45kHz range is poorer than the piezo. Capacitance microphones are not functional in humid conditions which limits their use in damp conditions.

Standardisation on electret microphones for future detectors would offer the best compromise between sensitivity, frequency response and price. However, recommending one type of microphone will not stop volunteers using others.

4.4.4.c Future NBMP bat detector technology recommendations

Changes in bat detectors will inevitably be confounded with long-term trends in abundance, and must be accounted for at the analysis stage.

Making changes in the design of surveys to incorporate new detectors use is difficult, since both systems require to be run simultaneously over several years to allow re-correction of datasets. Therefore any proposed change needs to significantly enhance the statistical sensitivity or reduce survey effort before its use should be considered.

Recommendation 35: The use of heterodyne detectors should be retained for a minimum of seven years to permit a data series wherein trend estimation is possible without too many confounding factors. Also, no changes should be made to field survey protocols during this time.

Recommendation 36: The phasing in of new bat detector technology should be gradual and any changes in the monitoring protocol design made at the same time. In this way, all sites may be analysed together with covariates to adjust for the change in design.

Recommendation 37: Calibration of all different detector types being used in the NBMP should be carried out regularly, and weighting factors incorporated into trend estimation models to account for sensitivity differences. Sensitivity tests of the detectors can be carried out in the field and in the laboratory (see Waters & Walsh, 1994).

5: Data handling

5.1 OPERATIONAL MANAGEMENT OF DATA RECORDING

A key long-term goal of the NBMP is to minimise the handling of data and to maximise the throughput. Data recorded by volunteers on field sheets must be transferred for storage and analysis quickly and efficiently.

The current system is labour intensive, but automation has not been possible during what has been a rapid development phase of the programme. Pilot tests of schemes have been conducted, and as a result protocols and forms to capture data have been altered during the five-year period. It has been necessary to observe and process hand written information as an aid to programme development. However in the future, such information will be minimal and a more automated process should be possible.

Recommendation 38: Review and test systems for web-based and email based automated data entry to allow large amounts of data processing with low level staff input.

The programme is currently exploring web-based and email-based systems that will automate large amounts of data collection and input. Two alternative methods are being assessed:

- A web-based system – users will log onto a password protected web page and will be presented with a web form that mimics the paper forms as used today. This form will have a degree of "intelligence" and will detect inconsistent or obviously incorrect entries according to agreed rules. The data will either go into a live "holding" database from where information will be extracted onto the "real" database or will be emailed to the project in a form suitable for import into the database
- An email based system in which a Word form (or similar) is mailed to surveyors who can fill it in and mail it back to the project. A simple program will automate the extraction of data from the form and post it into the database. Note that Word forms can also be built with a degree of "intelligence".

5.2 DATA SCREENING AND ENTRY

Data are submitted by the observer to The Bat Conservation Trust office, London, on original field sheets. Each datasheet is checked for transcriptional, mathematical and biological errors on arrival. Data are then entered onto a database and each new site allocated a unique catalogue site number.

Data are entered by temporarily employed office assistants, and sometimes by NBMP staff. All assistants have been graduates, with a sound knowledge of ecology. Whenever possible, assistants have been re-recruited for more than one year to maintain consistency. At the data entry process, the majority of data entered onto the database passes through certain validation rules e.g. temperatures must fall within the range minus ten and plus 30 degrees Celsius. Data are coded and poor quality records can readily be excluded in subsequent analyses.

Manual data inputting will always entail an error rate (as does computer readable data entry). All data are currently screened by the project co-ordinator, taking a three stage approach. First, all records are scanned through quickly on the computer and obvious mistakes corrected. Second, all data are printed out, scanned visually and obvious mistakes corrected. Third, data are imported into a statistical package and data tabulated in different groupings, frequency histograms and graphs of the data are constructed and outliers identified. Unusual figures are checked by a phone call to the observer. This system is currently too labour intensive and data need to be checked using specialised computing routines in future.

Recommendation 39: Improve validation of data at the entry stage to reduce data errors. Develop specialised computing routines to check data automatically.

Annually, the bulk of data from summer roost counts undertaken in June is returned by the end of August of each year. The bulk of the data from winter hibernation counts undertaken in January and February is returned by the end of May. The bulk of data from bat detector field surveys undertaken in July, August and September is returned by the end of October. Freepost envelopes are included in survey packs to encourage prompt return of data and reminder letters are sent out approximately 1-2 months after the completion date of each survey scheme. Given the data return dates of late August/early October, the inputting of data collected in summer schemes can only realistically be started in September/October each year. This is because the bulk of the data is required before an assistant can be employed to input the data on a short contract basis.

5.3 DATA STORAGE: DATABASE MANAGEMENT SYSTEMS

Often in monitoring programmes, a large number of variables are stored which are unlikely ever to be utilised in any statistical analysis of the data. The design aim of the NBMP was to collect and store only those variables required in relation specifically to monitoring programme schemes.

5.3.1 Database software

Microsoft Access was selected as an appropriate and flexible relational database management system (RDBMS) with which to develop a database application for storing both monitoring data and volunteer details. Access is not only an RDBMS, but is also a complete database application development system and therefore it has been used to build an application that is tailored to the NBMP's specific data management needs.

Access97 databases have developed to store data generated by the monitoring schemes by Blue-Bag Ltd. (George Boobyer: George@blue-bag.com).

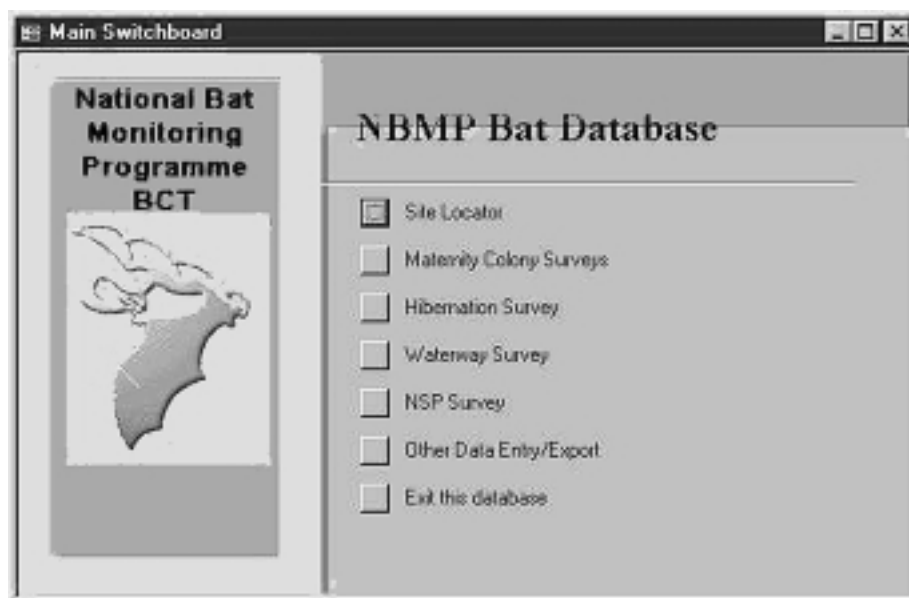


Figure 5.2a The NBMP database 'switchboard'

5.3.2 Database model

The NBMP database consists of a suite of Access 97 datafiles. The database has been implemented as a relational model and the implementation splits the data access and management functions from the user interface. The NBMP suite consists of:

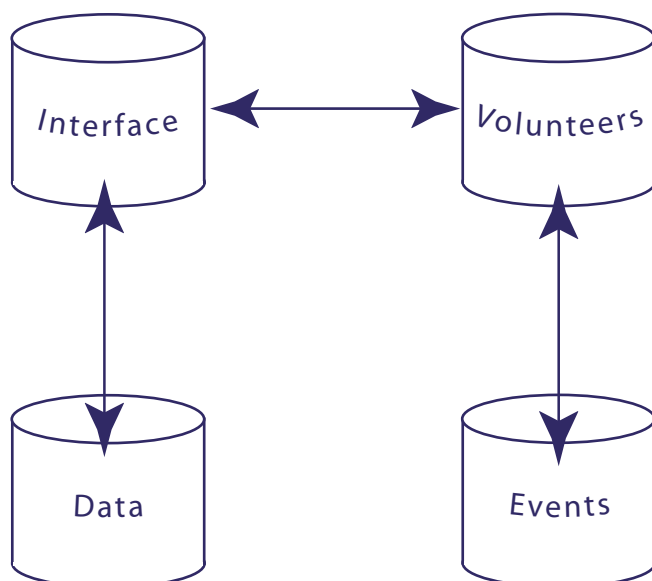
NBMP Survey Database:

- BatInterface.mdb
- BatData.mdb

Volunteers Contact Database and Events module:

- Volunteers.mdb
- Eman.mde

Figure 5.1 NBMP Database Suite



Thus, the suite consists of three distinct access database files. The first of these (BatData.mdb) contains the data tables that store the survey data. The second database file (BatInterface.mdb) contains the data entry screens and entry validation routines. A third database (Volunteers.mdb) manages contact details for the surveyors and details of interaction with them (provision of forms, receipt of data etc). The Interface manages all survey data entry and links to these databases. The Volunteers database contains interface forms for entry of contact details and can be used in isolation of the main survey database for this purpose. An additional module (Event Manager – Eman.mde) has been provided for managing 'events' or interactions with volunteers. Links between the datafiles are shown in Fig 5.1.

5.3.2.a Database management – linking

The links between the various databases are managed by the Interface and the Volunteers databases. If the associated files have been moved, the application requests that the user re-locate the database. This has the advantage of enabling the Volunteers database to be held on a separate computer and managed independently day-to-day from the NBMP Survey database.

5.3.2.b NBMP Survey Database

The NBMP Survey Database follows a relational model and consists of the three databases 1, 2 and 3 in Fig. 5.1. The "back-end" database file (BatData0.mdb) contains the data tables with the stored NBMP survey data, while the "front-end" database file (BatInterface.mdb) contains all the other database objects (queries, forms, reports, macros, modules) and links to the tables in the back-end database. To function, BatInterface.mdb is also linked to the observer table in the Volunteers Contact Database (Volunteers.mdb).

Interface forms The database has a user-friendly switchboard on opening (Fig 5.2a), and separate interface forms have been constructed for each monitoring scheme type because different data are collected in the different schemes

(Fig 5.2b). Interface forms have been constructed to be uncrowded and highly user friendly by the use of tabbed pages. In addition, there are interface forms to locate sites readily, to optionally edit coding systems and lists, and to produce data export tables. When a new scheme is run, a new interface can be added as a discrete unit without making any major changes to the underlying database structure.

Configuration A configuration utility is provided that manages the links between the component databases and enables the selection of standard operations for data entry. These options cover aspects of user warnings when editing records, grid reference validation and other 'business' rules. An example of such options is 'data entry validation warnings'. These can be optionally suppressed when data are being edited by the survey manager (facilitating faster data entry) and enabled when data are being entered by other users to ensure data quality.

Dictionary data Standard terms are used where they exist or existed at the time of the development of the database in 1997. Table lists, such as modern counties and the bat species list, were compiled to maintain compatibility with Recorder (pre-2000 edition). A standing data utility enables the entry and editing of standard terms used throughout the database. This enables the management of controlled lists and allows the user to change the order of terms that are displayed in drop down edit boxes to facilitate rapid access to frequently used terms

Macros Many of the variables recorded do not require manual entry and are computed by macros. For instance, country is determined by the county entered, and once a grid reference has been entered, the 1km square plus individual easting and northing are automatically calculated. This particular feature will facilitate the export of data into CIS format.

Validation rules At present basic data entry validation rules have been added to the database, e.g. on entering a date for a survey, the year given is checked to see if it is the correct year. Once a record has been saved, if accidental changes are made when scrolling through the data, a warning appears and cancellation of accidental changes is possible. Further refinements to validation rules are being made as possible areas for concern are identified.

Figure 5.2b Interface form for pipistrelle colony count data

The NBMP Survey Database model and catalogue is presented in Appendix 4.

5.3.2.c Volunteers Contact Database and Events module

A separate database, which can be linked to the NBMP Bat Data database was constructed to store volunteer names and addresses, data relating to previous bat fieldwork experience and event data relating to survey forms sent to or received back from volunteers. The application consists of a single relational database (Volunteers.mdb) containing data tables and all other database objects. A separate module, the Events Manager (Eman.mde) is linked to the tables in Volunteers.mde, and is used to automate the tracking of survey scheme information. For instance, an event may be set up such as "Daubenton's survey forms sent out" for a selected group of volunteers, such as "everyone who has signed up a form to join the NBMP". A mail out list for these people is created and their records within the database automatically updated for this particular event – avoiding the errors associated with adding this event to each person manually. The automation of such information checking is vitally important in a large-scale monitoring programme. It greatly enhances the efficiency of running surveys involving large numbers of volunteers and multiple projects.

Recommendation 40: Review database model and improve the structural design such that the volunteers component and data component are more closely linked.

5.4 DATA ACCESS AND EXCHANGE AGREEMENTS WITH RECORDERS AND OTHER ORGANISATIONS

Monitoring data for each target species should be complete and easily accessible for decision-making, education, research, conservation and other public-benefit purposes. For monitoring data to be complete, data has to be collated by the NBMP from both recorders participating in NBMP projects and other data collecting organisations, requiring exchange agreements to be drawn up between relevant parties. For monitoring data to be easily accessible to users, access agreements need to be formulated by the data owners/holders/managers.

5.4.1 Data collection – from individual recorders and bat groups

Individual recorders are both suppliers and users of the data. Consultation with JNCC and BTO at the start of the programme in 1996, resulted in the following sentence being added to the back of all NBMP data forms issued to recorders:

"Use of surveillance data without the permission of the owner is a breach of copyright law. In the collation process, reasonable steps should be taken to obtain authorisation for use from originators of the surveillance data. Informing relevant people that a collation is being created and making it clear how the data owners and managers intend to use the data, and obtaining copyright permission either through a signature or allowing time for people to comment or withhold their data are recommended. (National Biodiversity Network (NBN) Data Exchange: a framework of principles – consultation draft on the web)."

Box 5.1 Consent to release of records

The records collected by the NBMP project are sent to the BCT on the understanding that the information provided by the recorder will be entered onto a computerised database and will be accessible by the DETR, the monitoring programme contractor and any others subject to the approval of the Department for the purposes of repeating the survey, publication in summary form (at a resolution no greater than 1km) and will be available for public information for nature conservation, research and education.

The information remains the intellectual property of the recorder/compiler at all times.

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

☐

Signed :

.....(please sign)

Further, each computer record has the name and details of the original contributor attached. These data are protected under the Data Protection Act 1998, but it is permissible to use such data, to acknowledge the copyright holder, to administer the recording scheme and to provide contact data for use when data supplied on forms needs to be confirmed. However, it would be advisable to make this clear to everyone contributing data, and extend the section in Box 5.1 with appropriate wording.

In the development of the NBMP it has become clear that much data are being collected, but not transferred to BCT for incorporation into the NBMP. Concerns aired by volunteers and bat groups to NBMP staff include:

- ☐ Data submitted to BCT on specific sites will be published and credit for the work not given to the individual naturalists collecting data for those sites
- ☐ Data submitted to BCT are owned by the DETR and will be released to anyone who pays/asks for it – including developers, ecological consultants
- ☐ Data submitted to BCT on sites considered sensitive will be published or passed on to other parties, potentially angering site owners and resulting in the exclusion of bats/loss of the sites
- ☐ Data submitted to BCT will be stored but not processed adequately, with little/no information being filtered back to the people who submitted it
- ☐ Data submitted to BCT are owned by the DETR and may be used by MAFF to exterminate bats given a rabies epidemic scenario

These concerns are real and need to be considered in data access and exchange agreements. While free access is favoured, assurance needs to be given that data will be restricted when considered necessary. Of particular note, assurances should be given that data will only be published in summary form, and that the compilation of local data into a national data set can only increase knowledge of bat populations and benefit bat conservation.

Recommendation 41: Review the legal aspects of data collection and ownership by volunteers. Simple, standard guidelines on how to collect data from volunteers need to be drawn up for all societies collecting data on a large-scale.

A major problem with the hibernation site data in particular, is that while many licensed surveyors visit hibernation sites each year, data are either not submitted to SNCOs or are submitted to SNCOs and therefore NBMP forms are not completed and returned. Data returned to the SNCOs are filled in on forms bearing no reference to the NBMP.

Recommendation 42: Review SNCO licensing and re-

structure return forms to increase record return and compatibility for NBMP collation

5.4.2 Data collection – from other recording organisations

5.4.2.a Countryside Council for Wales (CCW) lesser horseshoe bat monitoring

Discussions with the team heading the Welsh lesser horseshoe bat monitoring project have been held throughout the period of the NBMP contract. The result of these discussions was standardised protocols that facilitate analyses of the pooled datasets. Ongoing discussions aim to draw up a data exchange agreement so that datasets can be merged electronically as opposed to the manual system at present. This will reduce possible data transfer errors and result in a more robust combined dataset. The proposed agreement on data exchange to share data strengthens the UK surveillance of this species by the NBMP and allows CCW to extend their monitoring of factors influencing lesser horseshoe bat populations.

Recommendation 43: Finalise data exchange agreement between CCW and NBMP to improve NBMP's UK-wide lesser horseshoe bat dataset. Consider developing one recording form for both surveys and enter data onto a common database to reduce costs

5.4.2.b The National Bat Colony Survey, The Robert Stebbings Consultancy Limited

Discussions were held with The Robert Stebbings Consultancy Ltd regarding a data exchange agreement and possible merging of the two projects. No agreement has been reached to date but future meetings are planned to build on previous discussions. At present data collected by the NBMP for the pipistrelle colony count is of sufficient quality and quantity to meet our statistical objectives over the long term. However the datasets held by The Robert Stebbings Consultancy Ltd include some long-term repeat counts of the same colony that are not present in the NBMP dataset. Suitable analysis of these counts would help to identify yearly variance in colony size over a long time period and this information would be useful to the NBMP.

5.4.2.c Greater horseshoe bat roost monitoring – VWT owned sites

The VWT send NBMP a copy of their annual report which includes summaries of their research on the greater horseshoe bat. Although VWT does not send raw data to the NBMP it does supply it to EN and CCW. An agreement with VWT and other holders of greater horseshoe bat data would help strengthen surveillance of this species in the UK.

Recommendation 44: Investigate all sources of data collected for the greater horseshoe bat, and propose a way forward for national collation of data.

5.4.2.d English Nature

Informal discussions held with Tony Mitchell-Jones of English Nature have assured the NBMP that all records held by EN may be freely exchanged subject to the agreement of the originator of the data. To facilitate this, a formal exchange agreement including data transfer standards and a data use statement from the NBMP is required.

5.4.3 Data ownership and access for users

A draft data usage agreement between the DETR and BCT was drawn up and supplied to DETR for review in October 1996. No comments were passed back to BCT, and thus no further progress has been made or formal access agreement compiled.

Many bat groups, and other users such as English Nature and the Environment Agency have already requested information on sites and surveys in their areas. No information has been released to date. Data-mining is an issue in need of attention; mining data in different required formats for different users requires staff time and funding.

Recommendation 45: A meeting and production of a formal access and data exchange agreements is urgently needed between involved parties: DETR (now DEFRA), BCT, JNCC, SNCOs.

5.5 DATA COMPATABILITY WITH OTHER RECORDING PROJECTS: NBN & RECORDER 2000, CIS

A number of groups are working to facilitate the technical transfer of data between recorders and recording organisations.

Early in 1996, bat records held by EN on the databases BatData and BatSites were reviewed and a list of variables obtained to ensure that data collected in the monitoring programme will have some degree of compatibility with SNCOs roost and hibernation site records. The design and data stored in other recording systems currently in operation was also reviewed. In particular, this included data stored by county recorders in various packages including the "Recorder" package and data stored on the new Mammal Society 'Look out for Mammals' recording package "Biobase".

5.5.1 National Biodiversity Network & Recorder 2000

The National Biodiversity Network (NBN) aims to make biodiversity data easily available to inform wise choices about the environment. An essential tool to achieve this aim is a widely accepted scheme into which data and relevant meta-data may be entered. In practice, appropriate software tools need to be developed to support this underpinning agreed schema. The redevelopment of Recorder was commissioned as the primary tool for the NBN data model implementing the underlying scheme. Recorder 2000 is now available as a "collect and collate" data management system.

The NBMP has worked closely with database experts involved in or aware of the issue addressed in the redevelopment of Recorder 2000 and associated data management issues (George Boobyer & Martin Newman pers comm).

Recommendation 46: A study to assess the problems of making NBMP compliant with emerging NBN standards. The suitability of Recorder 2000 as the primary data management tool will form a large part of this work.

As a result of this it may be that:

1. If suitable the data may be exported from NBMP for direct transfer to Recorder 2000 or into other agreed NBN compliant formats (e.g. XML using the NBN DTD – XML is the long standing extensible Mark Up language using DaTa Definitions which define its use for particular data. XML is at the heart of many leading-edge cross-platform software implementations and is at the core of Microsoft's NET strategy for the next decade)

2. If not, create an add-in to Recorder to extend it to allow easy entry and proper management of bat specific data.

5.5.2 Countryside Information System

The Countryside Information System (CIS) consists of software commissioned by the DETR, which allows map display and analysis of environmental data, summarised by 1km square of the National Grids for Great Britain or Northern Ireland.

Means and variances of variables for Land Classes may be inputted into CIS manually or an ASCII file imported for plotting. Also, values for individual 1km squares or 10km squares may be imported from an ASCII file. The format of ASCII files requires that the easting and northing of the square are given in numeric format.

Data stored within the NBMP database are on a 1km square basis (grid references for roost and hibernation sites, and grid references for field survey sites). Also, Land Classes are recorded. Means and variances of bat abundances for Land Classes can readily be calculated and inputted into CIS manually. Data can also be exported in ASCII format for importation. In particular, the NBMP Survey database calculates and stores numeric easting and northing references from the inputted letter-number grid reference format, making the creation of the correct ASCII file format possible.

Recommendation 47: Create a CIS transfer routine as an add-in to the NBMP Survey database.

5.6 DATA PRODUCTS AND INFORMATION DISSEMINATION

Much of the success of the NBMP as a surveillance programme will rely on the production and supply of quality-assured information to users.

The NBMP office has three recurrent annual production tasks:

- the processing of each year's data
- basic analysis to produce the latest figures on the site network and trends
- dissemination of these results to users

The NBMP disseminates information primarily to volunteers at the present time. Dissemination occurs through information published in an annual newsletter and posted on the BCT's web pages. Web page updates are carried out on an infrequent basis by a BCT volunteer. It is important that the production of information each year is timely to maintain enthusiasm amongst volunteers.

There is much scope to widen and improve information products and dissemination.

- Development of the NBMP web pages for information provision. To supply summary data tables for counties, regions or countries on sites surveyed and trends, with access for downloading this information. To supply information describing the general reliability and data constraints and more specifically providing warnings to the user when an analysis is based on low abundance or when variance is high. An important aspect is to invest in regular updating of the web pages
- To assist in the task above, development of the underlying data management software to ease the production of a range of statistics and other summary and particular data. Annual reports could be produced for groups on paper, and updated reports could be readily accessed on the web
- Production of articles in popular and technical magazines and newsletters. For example, information can be used to tell farmers about trends of bats over farmland in publications such as *Farmers Weekly*.
- Production of scientific papers. NBMP staff are currently working on the production of several papers to be published in the scientific literature in 2001. Data are currently under-used and there is the potential to extract a large amount of scientific information
- In the longer term access to data initiated by availability of appropriate meta-data on the NBN Gateway

Recommendation 48: Review how BCT could best act as a data-provider and improve information dissemination to stakeholders. Determine the funding needed.

6: Baseline datasets

6.1 SUMMARY OF NBMP DATASETS

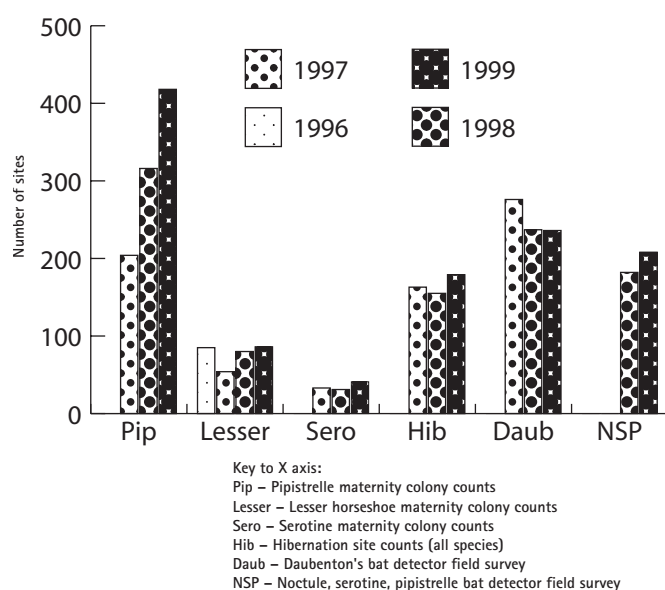
This chapter presents an overview of the structure of the data collected by the NBMP 1996–1999. In going to press, data for 2000 are currently being entered onto the database and thus are not presented. Data are tabulated and graphed for each NBMP monitoring project individually. The numbers of sites completed each year for each NBMP monitoring project is shown below for immediate reference (Figure 6.1). The distribution of all sites surveyed for all projects from 1996 to 1999 is shown in Map 6.1.

6.2 MATERNITY COLONY COUNTS

6.2.1 NBMP lesser horseshoe bat dataset 1993–1999

Prior to the start of the NBMP, a large sample of lesser horseshoe summer bat roosts had been counted in Wales

Figure 6.1 Number of sites completed each year by project



for three summer seasons (1993–1995) as part of a monitoring scheme being co-ordinated by CCW. This scheme has proved to be a valuable test-model of roost counting protocols for *R. hipposideros* and the information is also applicable to most other species of bat. A review of the data collected in the Welsh lesser horseshoe monitoring scheme 1993–1995 was carried out in the initial start-up phase of the NBMP. This led to two main recommendations regarding the collection of data: first that the number of counts should be reduced from four to two to improve consistency from year to year, and second that counts should be made over two ten-day periods towards the end of what was the four counting periods used in the initial Welsh scheme. These changes were initiated in 1995 when the monitoring scheme was extended into England by the NBMP. The changes have had no major effects on the continuity of the data, since two counts are available for the majority of roosts that fall within the newly defined ten-day counting periods. However it does mean that the dataset consists of Welsh roosts monitored between 1993 and 1999, and English roosts monitored between 1995 and 1999.

In 1997, the NBMP requested volunteers to concentrate their efforts on other species in their locality and miss a year of counts for the lesser horseshoe. This resulted in confusion amongst volunteers and a low rate of data return in the following year. Many volunteers continued with their counts, but did not send the data in to the office. An annual approach is therefore strongly recommended.

R. hipposideros roost sites surveyed from 1993–1999 are given by Environmental Zone (major land class groupings), country and region (Tables 6.1–6.3).

The number of sites surveyed each year is shown in Figure 6.2

○ An important finding is shown in Figure 6.3, which indicates the consistency in coverage of sites over a seven year monitoring period. While many roosts are surveyed in a single year, fewer roosts (28) have been surveyed every year for the full seven year monitoring period.

Table 6.1 *R. hipposideros* roost sites included in scheme by Environmental Zone 1993–1999

Environmental zone (EZ)	No. of sites	% of relevant EZ in GB	% of sites in relevant EZ
Lowland arable in England/Wales – Easterly lowlands (1)	21	36	13.4
Lowland pastoral in England/Wales – Westerly lowlands (2)	104	37	66.2
Uplands in England/Wales (3)	9	27	5.7
Data unavailable	23		14.6
Total	157		

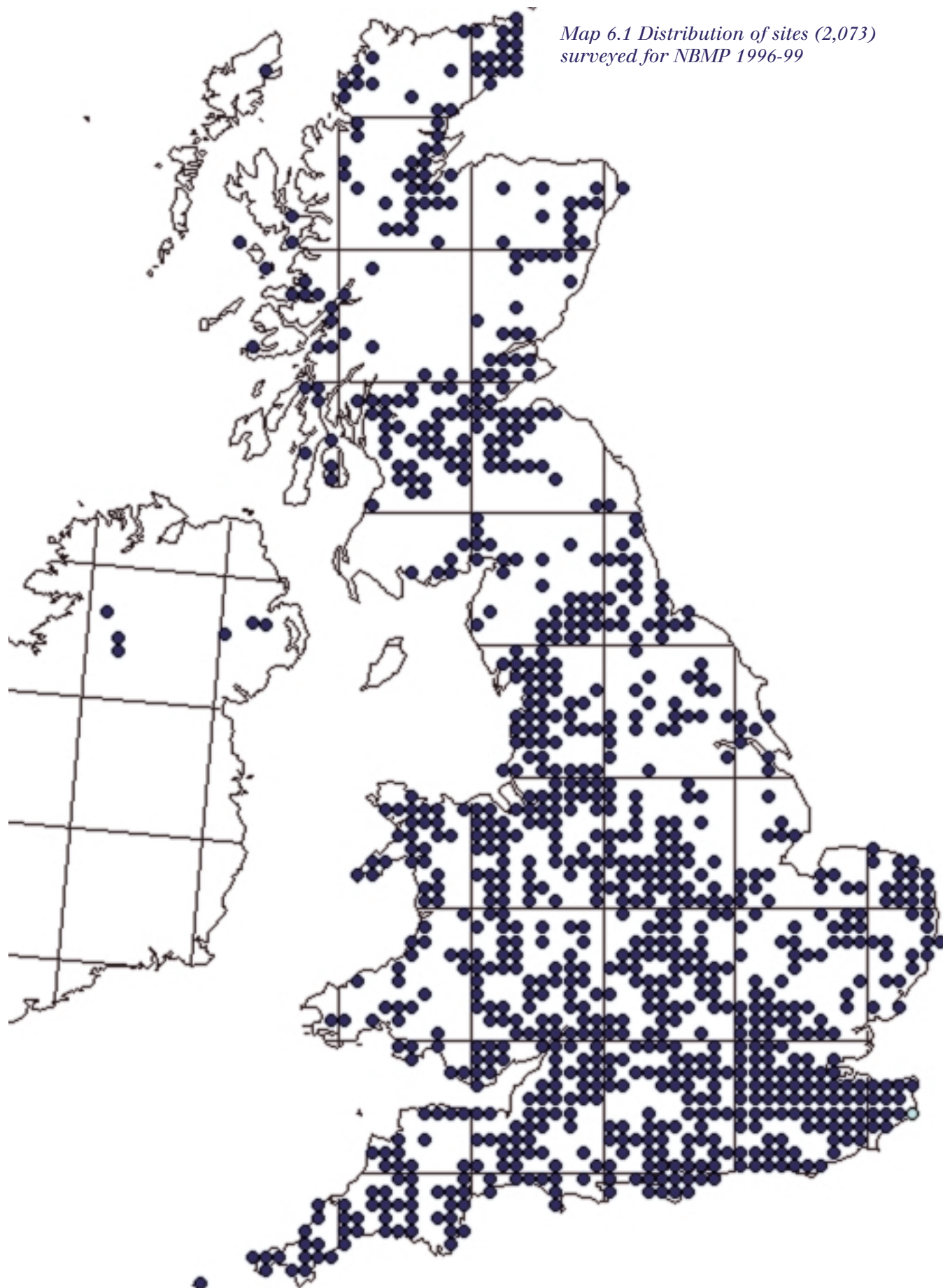


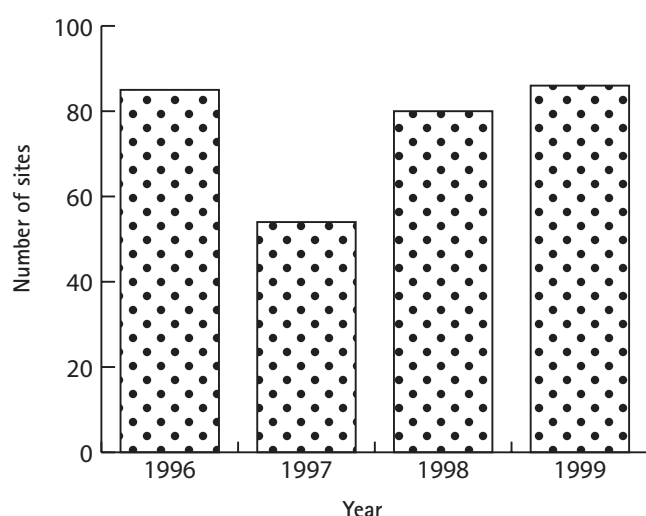
Table 6.2 *R. hipposideros* roost sites included in scheme by country 1993-1999

Country	No. of sites	% of sites
England	65	41.4
Wales	92	58.6
Total	157	

Table 6.3 *R. hipposideros* roost sites included in scheme by region 1997-1999

Region	No. of sites	% of sites
West Midlands	5	3.2
South West	60	38.2
Wales	92	58.6
Total	157	

Figure 6.2 *R. hipposideros* roost sites monitored:



6.2.2 NBMP pipistrelle bat dataset 1997-1999

See tables 6.4, 6.5, 6.6, 6.7 and 6.8, figures 6.3 and 6.4 and map 6.2.

6.2.3 NBMP serotine bat dataset 1997-1999

Low numbers of serotine roost sites are included in the NBMP monitoring scheme, in part due to the restricted distribution of this species. However, more effort is needed to incorporate further roosts into the scheme. See tables 6.9 and 6.10, figure 6.5 and map 6.3.

6.2.4 NBMP Natterer's bat pilot study dataset 1996-1997

○ 11 sites in total were surveyed, ten in England, one in Scotland.

○ *M. nattereri* study statistics:

Roosts surveyed 1995:	10
Roosts surveyed 1996 :	6
Sites surveyed 95 & 96:	5
Total unique sites surveyed:	11

Sample sizes were too small to calculate meaningful statistics. However, mean peak count for $n=10$ sites in 1995 was 27.8 bats.

Due to the difficulties involved in surveying this species and the low number of known roost sites, the survey was discontinued. The most frequently encountered problem was the accuracy of counting bats given their erratic flight on emergence in low light levels.

Further effort on roost surveying schemes for *M. nattereri* was planned for 2000 and the results of this have not been entered onto the database for assessment as yet.

6.3 HIBERNATION SITE COUNTS

The distribution of underground hibernation sites is not uniform throughout the UK but clumped e.g. where extensive limestone deposits are present or areas where

Table 6.4 *Pipistrellus* sp. roost sites, organised by Environmental Zone 1997-1999

Environmental Zone	No. of sites	% of sites
Lowland arable in England/Wales – Easterly lowlands	224	38.2
Lowland pastoral in England/Wales – Westerly lowlands	206	35.2
Uplands in England/Wales	28	4.8
Lowlands in Scotland	65	11.1
Marginal uplands in Scotland – Intermediate & Islands	28	4.8
True uplands in Scotland – Highlands	11	1.9
Missing (N Ireland)	24	4.1
Total	586	

Table 6.5 Pipistrellus sp. roost sites included in scheme by country 1997-1999

Country	No. of sites	%
England	423	72.2
Scotland	105	17.9
Wales	33	5.6
Northern Ireland	25	4.3
Total	586	

Table 6.6 Pipistrellus sp. roost sites included in scheme by bat group region 1997-1999

Region	No. of sites	%
North	34	5.8
North West	32	5.5
Yorks & Humberside	32	5.5
West Midlands	35	6.0
East Midlands	43	7.3
East Anglia	25	4.3
South West	65	11.1
South East	157	26.8
Wales	33	5.6
Scotland	105	17.9
Northern Ireland	25	4.3
Total	586	

Table 6.7 Pipistrellus sp. roost sites included in scheme 1997-1999 identified by species using mini bat detectors

Unknown	No of sites	%
Pipistrellus sp	374	63.8
Pipistrellus pipistrellus	124	21.1
P. pygmaeus	86	14.68
Total	586	

there has been extensive mining activity. The clumped distribution of surveyed sites also reflects, to some extent, the distribution of hibernation licence holders who submit data as they are not evenly spread throughout the UK. The NBMP will endeavour to improve distribution over the longer term through both encouraging data return from more existing hibernation licensees and by recruiting new licensees in appropriate areas.

6.3.1 NBMP Hibernation site dataset 1997-1999

See tables 6.11 and 6.12, figure 6.6 and map 6.4.

6.4 BAT DETECTOR FIELD SURVEY COUNTS

6.4.1 NBMP Daubenton's bat detector field survey dataset 1997-1999

M. daubentonii is found throughout the UK and there is evidence from elsewhere in Europe of an expanding population. It is an aerial hawk with a distinct habitat preference for water bodies, foraging mainly over slow moving or still water.

The NBMP monitoring scheme for this species surveys waterway sites (rivers/streams/canals). Bats are recorded at ten points along a 1km waterway route, and the data for all ten points summed. Bat passes distinctly identified as Daubenton's bat using torchlight in addition to call structure are recorded as well as "unsure " bat passes, where the observer may not have seen the bat and only heard it briefly, but it is likely to be a *M. daubentonii*.

- A total of 716 sites have been surveyed from 1997-1999, 325 of which are Environment Agency River Habitat Survey Sites.

No significant difference in bat abundance were detected between Environmental Zones. See tables 6.13, 6.14, 6.15 and 6.16 and figures 6.7, 6.8 and 6.9, and map 6.5.

6.4.2 NBMP Noctule, serotine, common pipistrelle & soprano pipistrelle field survey dataset 1998-1999

This mixed species survey involved a transect route split into "walks" – 12 sections of transect along which observers recorded noctule and serotine bats, and "spots" – 12 points at which observers stood and recorded common or soprano pipistrelles.

- A total of 367 1km sites were surveyed 1998-1999.

See tables 6.17, 6.18 and 6.19, figures 6.10, 6.11, 6.12, 6.13 and 6.14, and maps 6.6, 6.7, 6.8 and 6.9.

Table 6.8 Pipistrellus sp. roost sites counted by year

	1997	1998	1999
Total sites	197	330	412
New sites	197	213	166
Sites from 97	-	117	119
Sites from 98	-	-	127
Total sites repeated all three years is 88			

Table 6.9 E. serotinus roost sites organised by Environmental Zone 1997-1999

ENVIRONMENTAL ZONE	NO. OF SITES	%
Lowland arable in England/Wales – Easterly lowlands	43	79.6
Lowland pastoral in England/Wales – Westerly lowlands	11	20.4
Total	54	

All sites are in England.

Table 6.10 E. serotinus sites included in scheme by region 1998-1999

REGION	NO. OF SITES	%
East Anglia	3	5.6
South West	12	22.2
South East	39	72.2
Total	54	

Table 6.11 Hibernation sites, organised by Environmental Zone 1997-1999

ENVIRONMENTAL ZONE	NO. OF SITES	%
Lowland arable in England/Wales – Easterly lowlands	116	45.4
Lowland pastoral in England/Wales – Westerly lowlands	104	40.8
Uplands in England/Wales	26	10.2
Lowlands in Scotland	3	1.2
Marginal uplands in Scotland – Intermediate & Islands	4	1.6
True uplands in Scotland – Highlands	2	0.8
Missing (N Ireland)	0	0
Total	255	

Table 6.12 Hibernation sites included in scheme by country 1997-1999

COUNTRY	NO. OF SITES	%
England	209	82.0
Scotland	9	3.5
Wales	37	14.5
Northern Ireland	0	0
Total	255	

Figure 6.3 Consistency of counts made at *R. hipposideros* roosts in England and Wales over seven years from 1993-1999

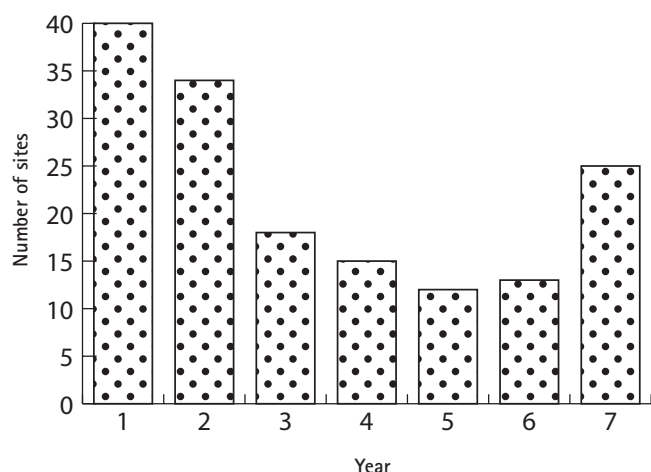


Figure 6.6 Sites monitored: serotine bat roost count

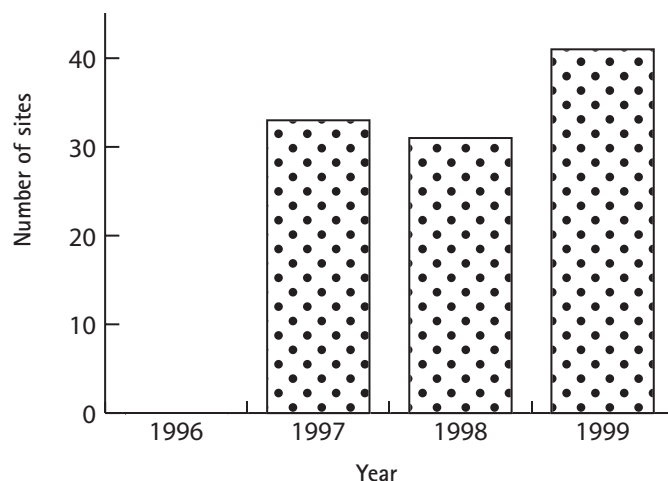


Figure 6.4 Sites monitored: *Pipistrellus* sp. colony count

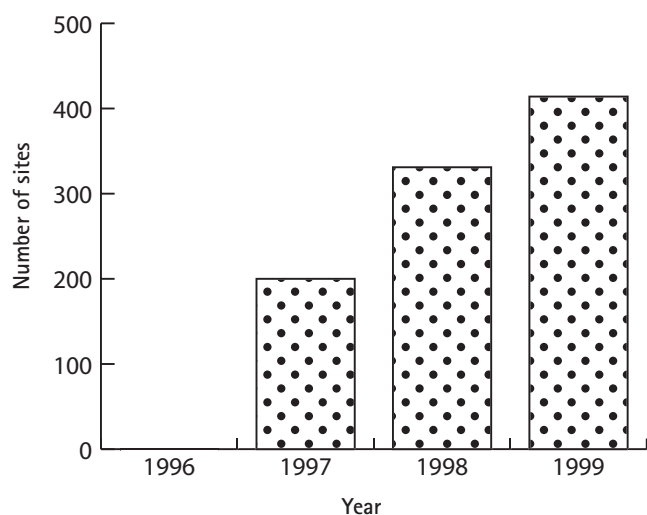


Figure 6.7 Sites monitored: hibernation site count

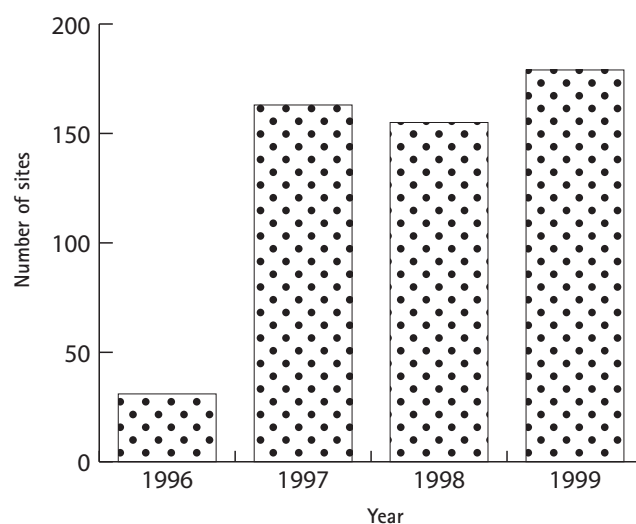
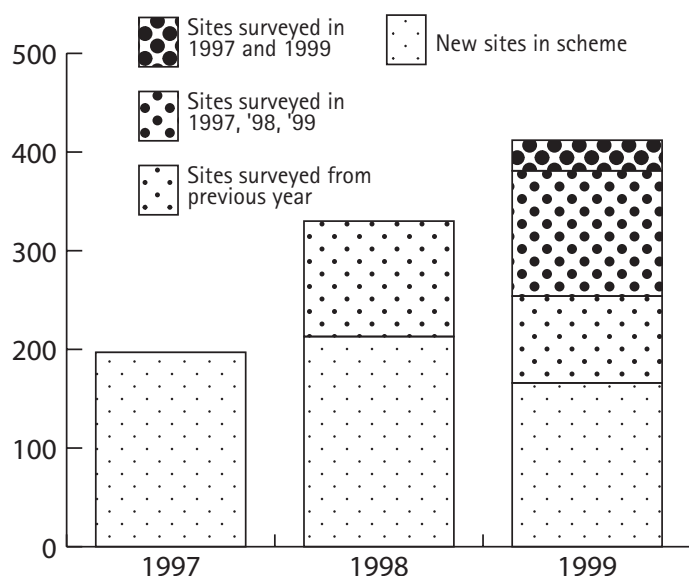
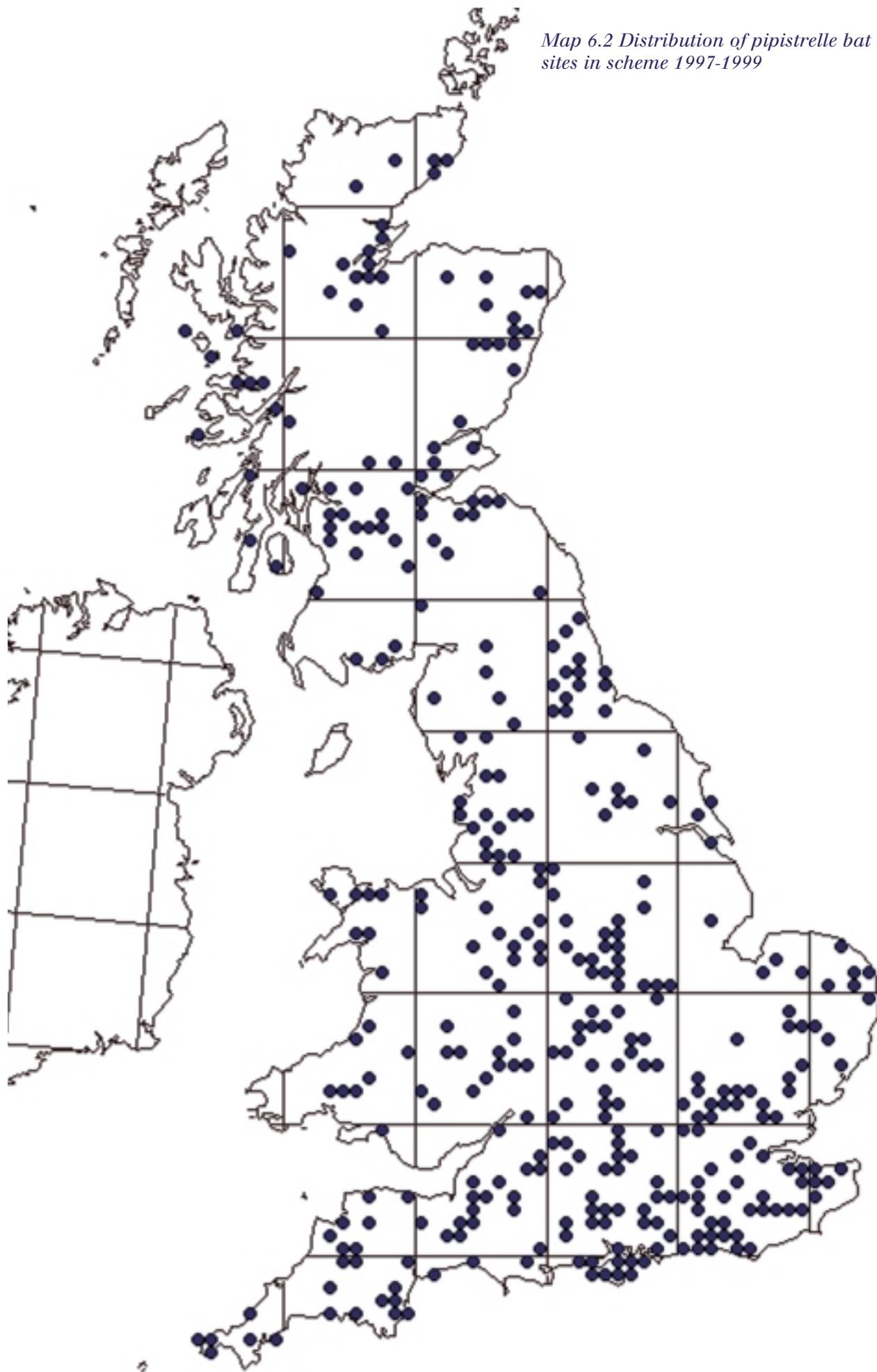
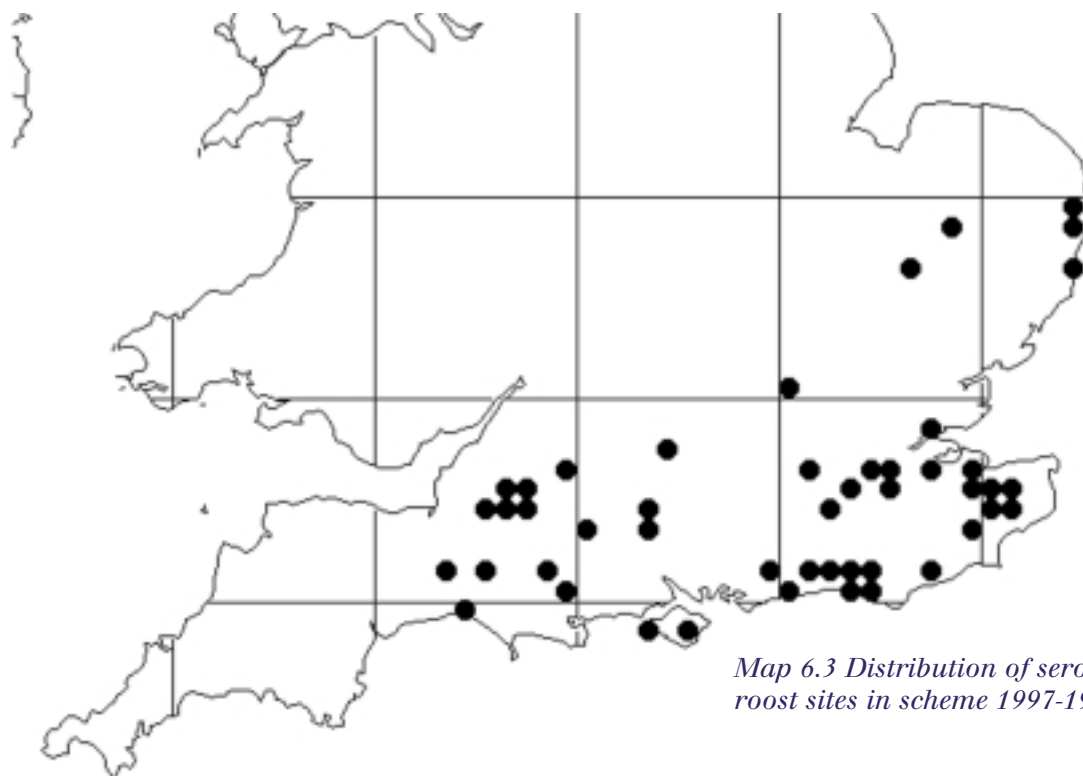


Figure 6.5 Turnover of colony roost sites counted within the *Pipistrellus* sp. monitoring scheme 1997-1999



Map 6.2 Distribution of pipistrelle bat roost sites in scheme 1997-1999





Map 6.3 Distribution of serotine bat roost sites in scheme 1997-1999

Figure 6.8 *M. daubentonii* abundance (1998/1999 data) in different Environmental Zones for identified *Daubenton's* (A) and identified plus unsure bat pass data (B)

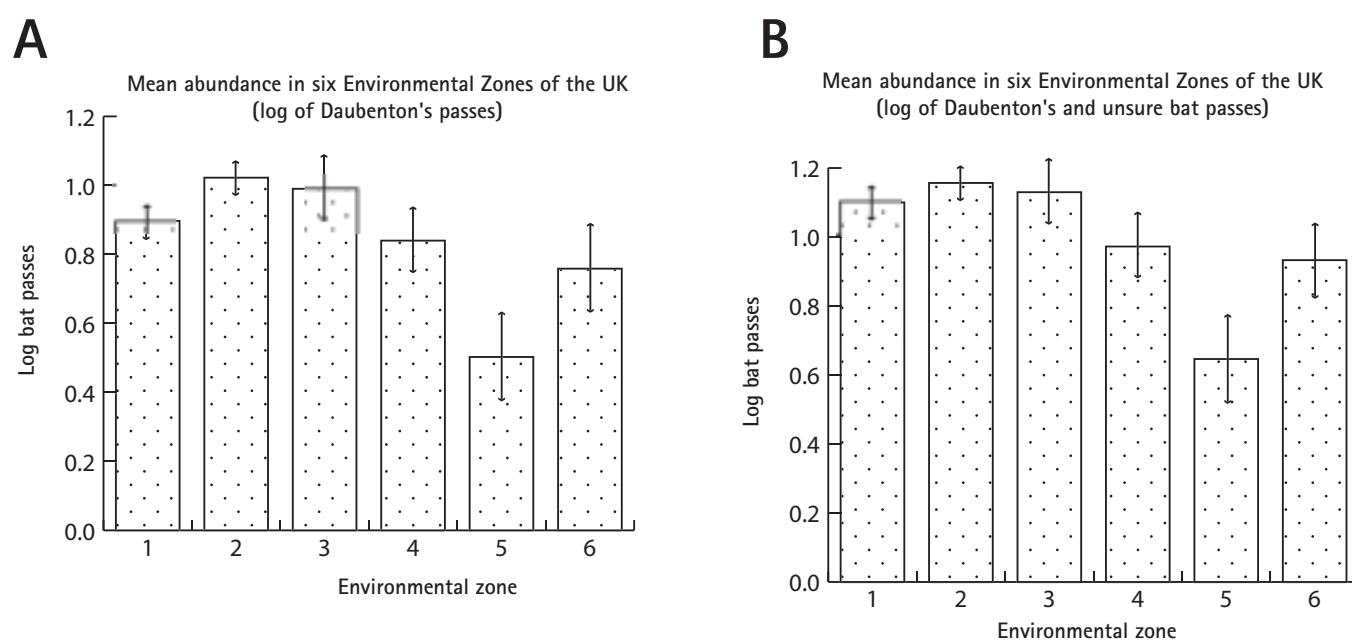


Table 6.13 M. daubentonii field survey sites included in scheme by Environmental Zone 1997-1999

Environmental Zone	No. of sites	% of sites
Lowland arable in England/Wales – Easterly lowlands	266	37.1
Lowland pastoral in England/Wales – Westerly lowlands	275	38.4
Uplands in England/Wales	54	7.5
Lowlands in Scotland	60	8.4
Marginal uplands in Scotland – Intermediate & Islands	37	5.2
True uplands in Scotland – Highlands	17	2.4
Missing (N Ireland)	7	1.0
Total	716	

Table 6.14 M. daubentonii field survey included in scheme by country 1997-1999

Country	No. of sites	% of sites
England	529	73.9
Scotland	115	16.1
Wales	65	9.1
Northern Ireland	7	1.0
Total	716	

Table 6.15 M. daubentonii field survey sites counted by year

	1997	1998	1999
Total sites	275	237	236
New sites	275	213	212
Sites from 97	-	8	5
Sites from 98	-	-	19
Total repeated site sample	-	8	24

Table 6.16 Kruskal Wallis test for differences in M. daubentonii abundance (1998/1999 data) between Environmental Zones. The test uses raw count data of all Daubenton's bat passes including unsure bat passes

Chi-square	8.006
Df	5
Asymp.Sig	0.156

Table 6.17 NSP field survey sites included in scheme by Environmental Zone 1998-1999

Environmental Zone	No. of sites	% of sites
Lowland arable in England/Wales – Easterly lowlands	126	34.3
Lowland pastoral in England/Wales – Westerly lowlands	116	31.6
Uplands in England/Wales	36	9.8
Lowlands in Scotland	47	12.8
Marginal uplands in Scotland – Intermediate & Islands	28	7.63
True uplands in Scotland – Highlands	10	2.72
Missing (N Ireland)	4	1.09
Total	367	

*Map 6.4 Distribution of hibernation sites in scheme
1997-1999*

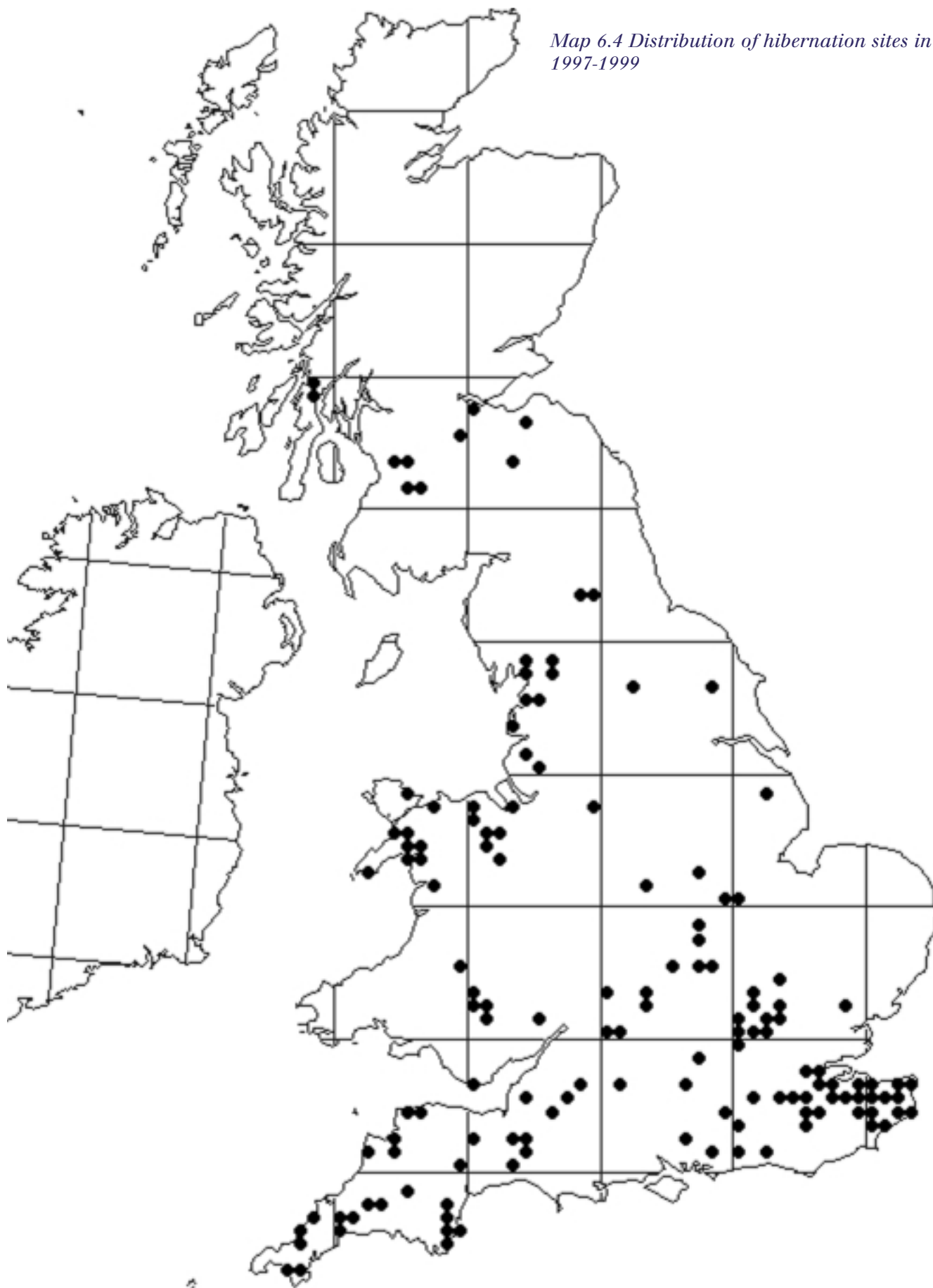


Figure 6.9 Sites monitored: Daubenton's bat survey

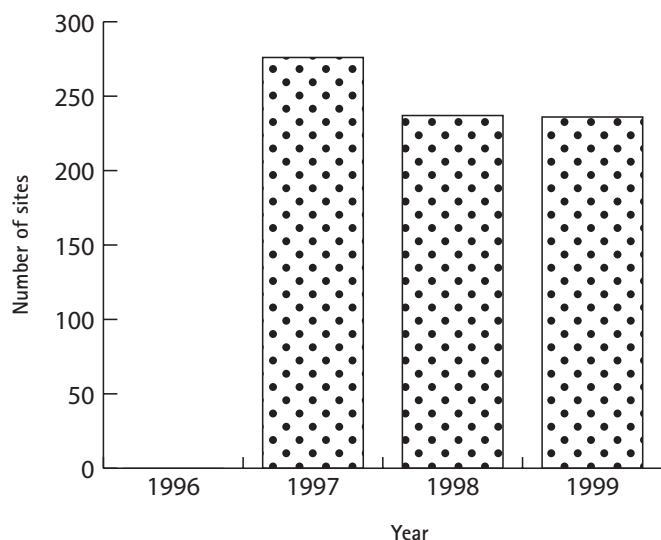


Figure 6.10 Sum of Daubenton's bat passes at each spot for all survey nights in 1999 (197 sites)

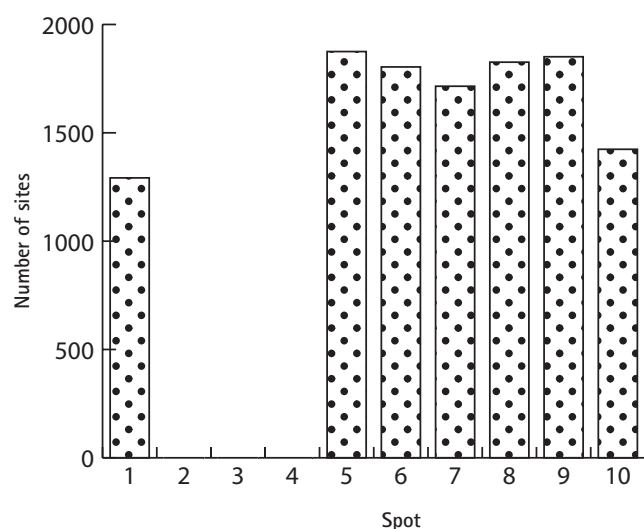


Figure 6.11 Sites monitored: NSP survey

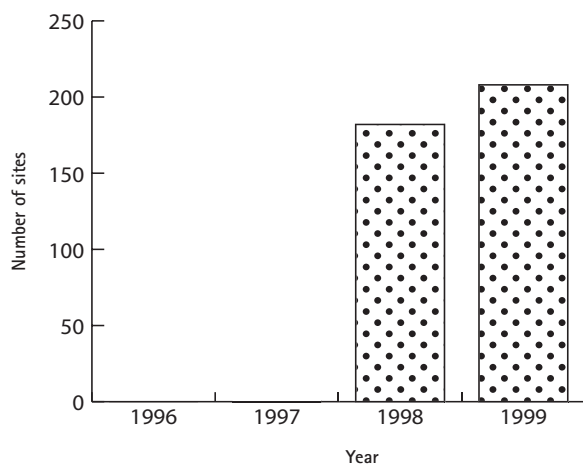


Figure 6.12 NSP walk counts

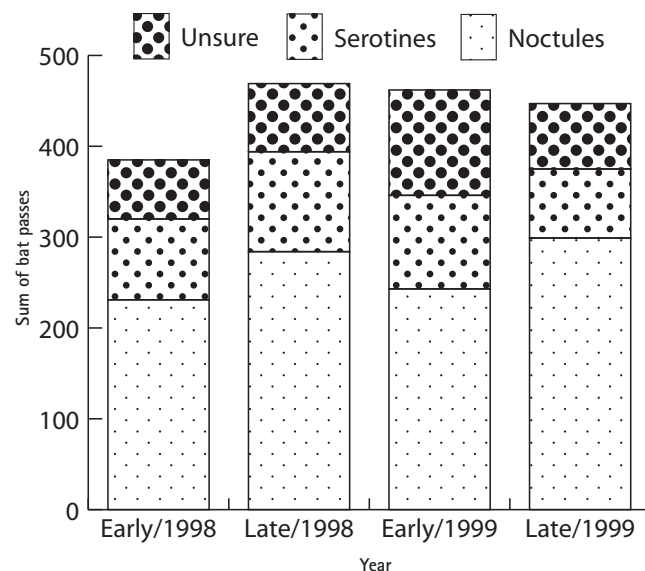


Figure 6.13 NSP spot counts

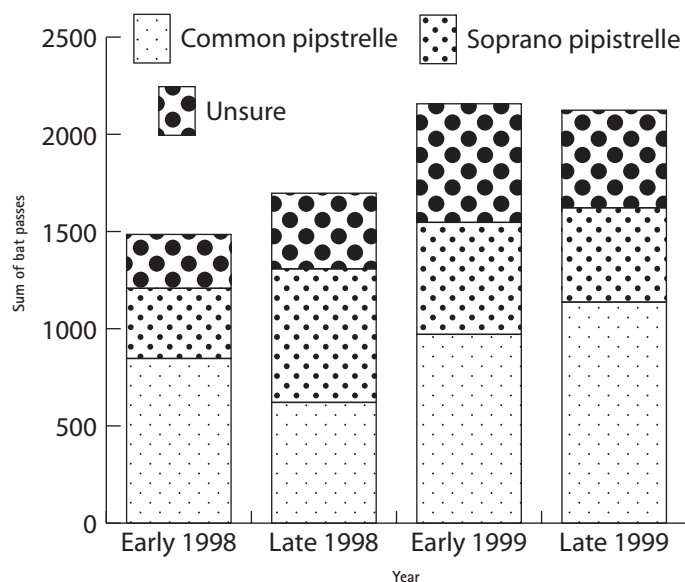
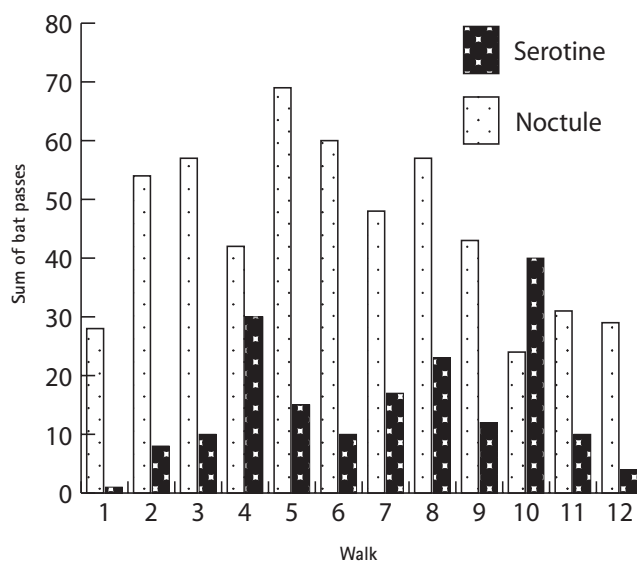


Figure 6.14 Sum of nocturnal and serotine passes on each walk section for all survey nights in 1999 (197 sites)



Map 6.5 Distribution of Daubenton's bat survey sites 1997-99

- = Daubenton's present
- = Daubenton's absent

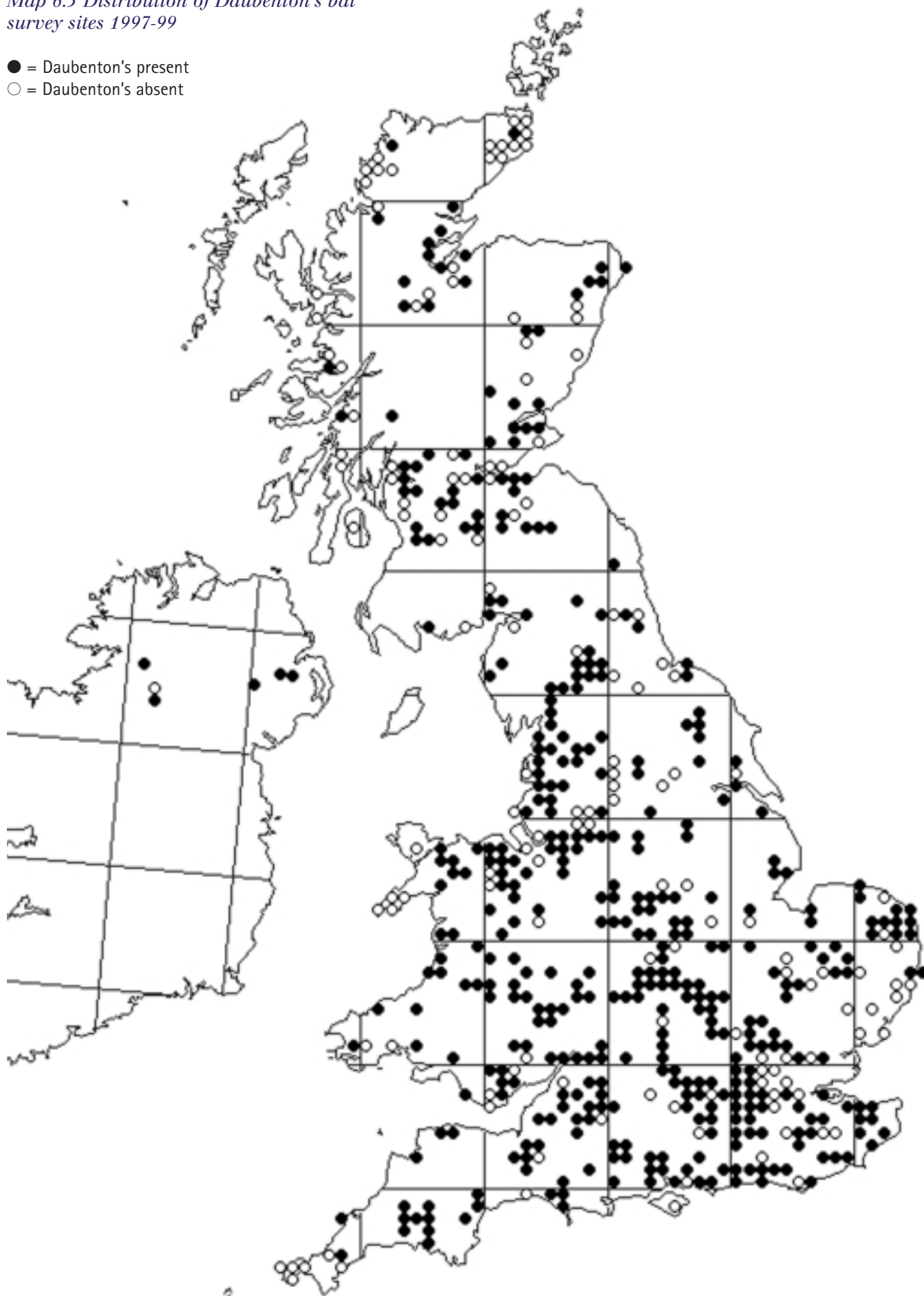


Figure 6.15 Sum of common and soprano pipistrelle passes at each spot for all survey nights in 1999 (197 sites).

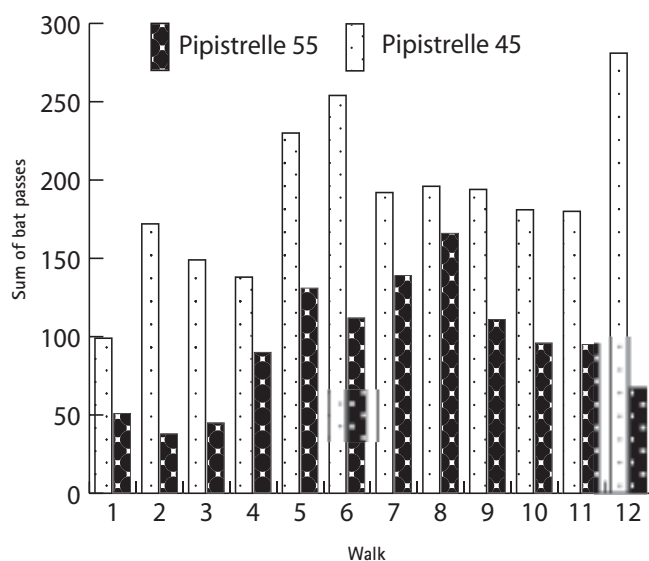
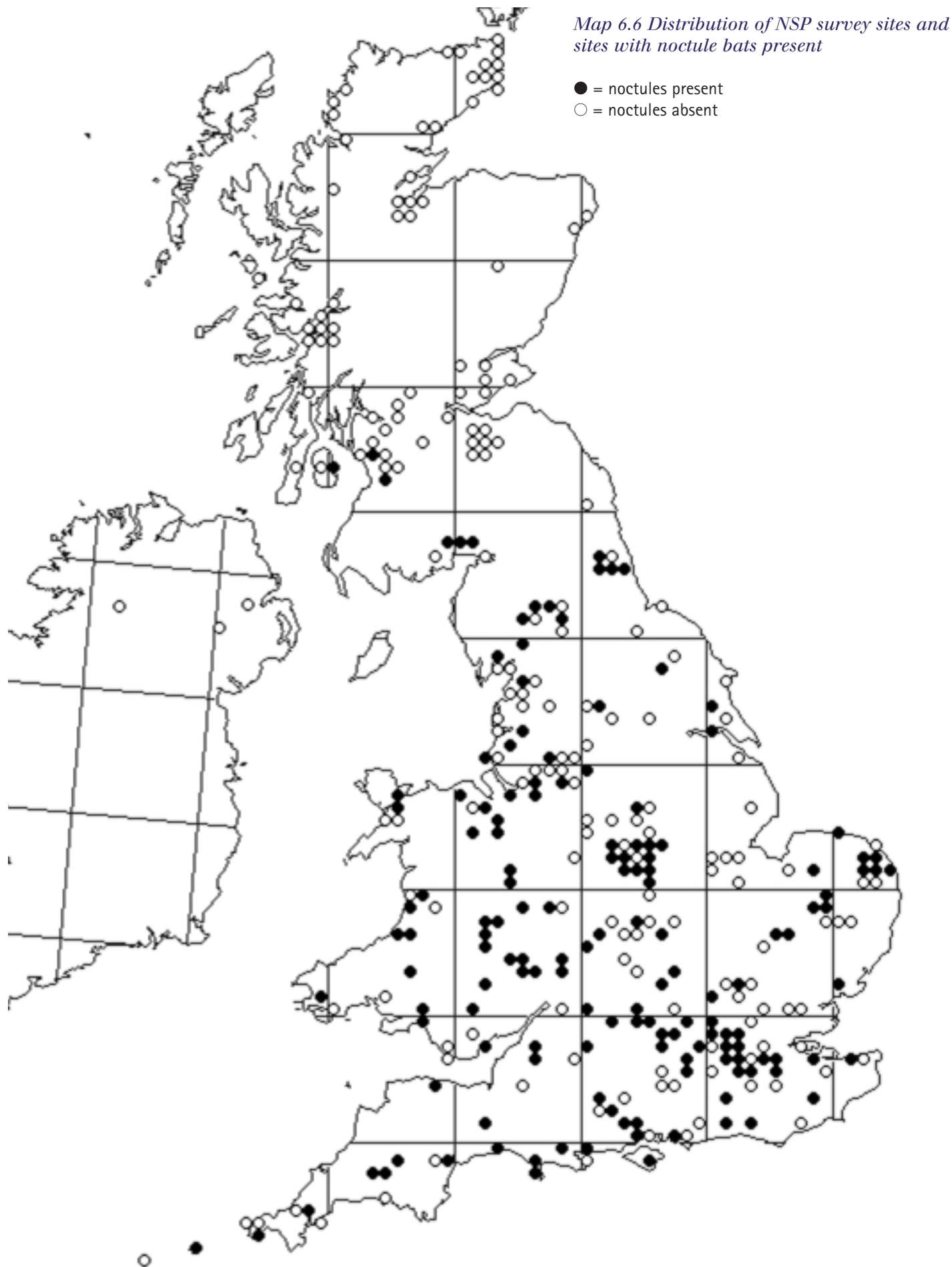


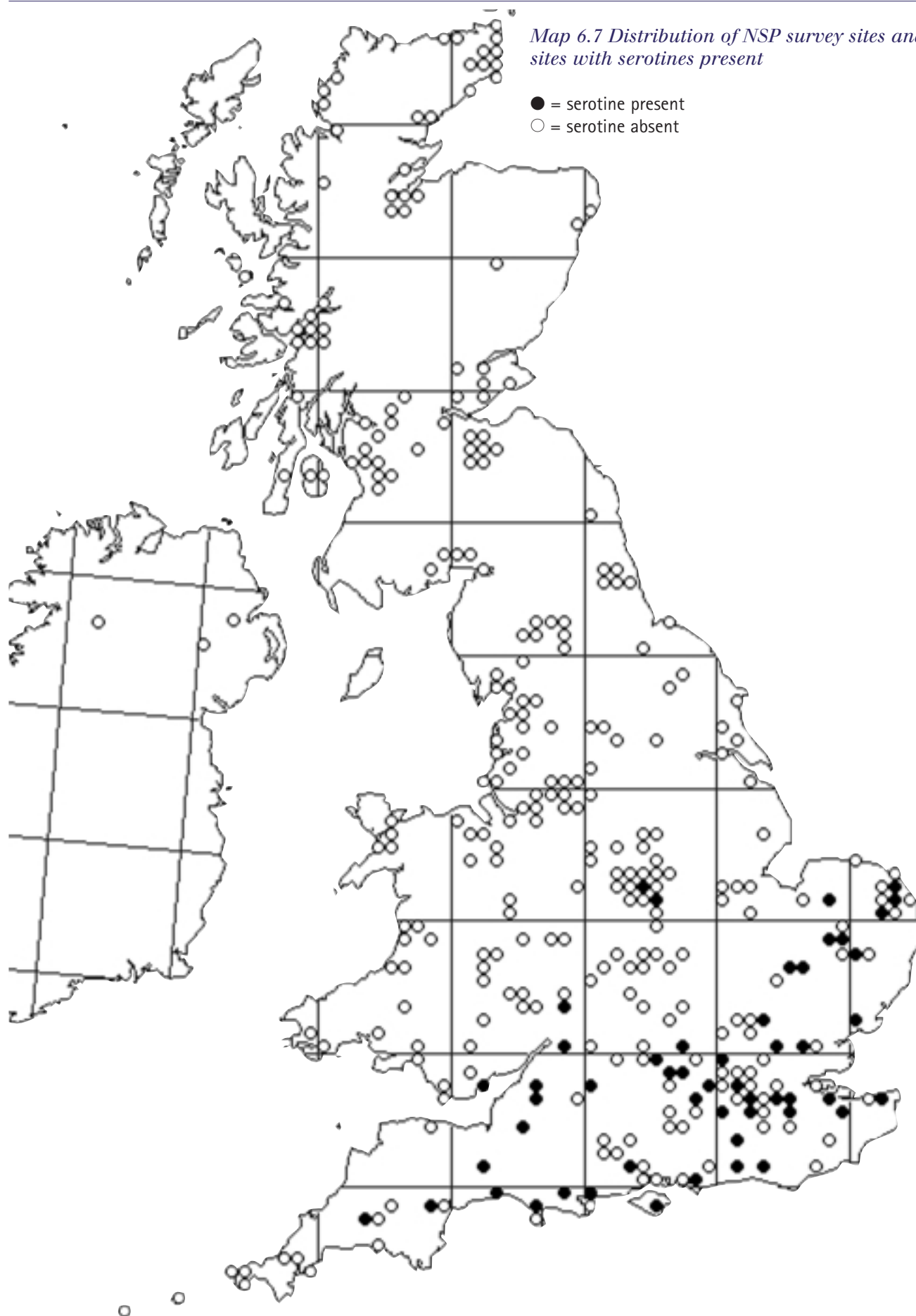
Table 6.18 NSP field survey sites included in scheme by country 1998-1999

Country	No. of sites	% of sites
England	254	69.21
Scotland	80	21.8
Wales	29	7.9
Northern Ireland	2	0.5
Channel Islands/ I.O Man.	2	0.5
Total	367	

Table 6.19 NSP field survey sites included in scheme by region 1998-1999

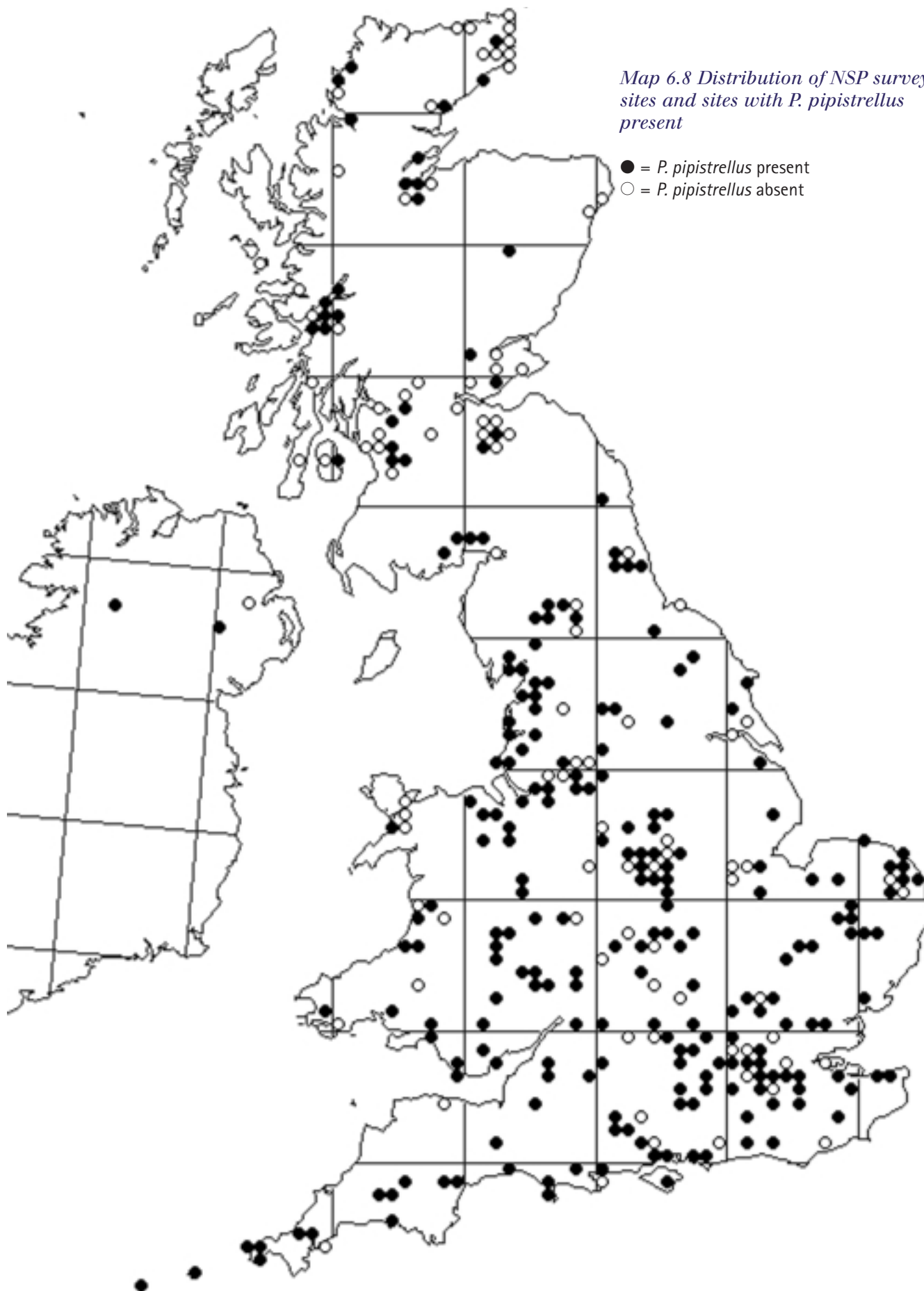
Region	No. of sites	% of sites
North	21	6
North West	23	6
Yorks & Humberside	10	3
West Midlands	19	5
East Midlands	29	8
East Anglia	24	6
South West	33	9
South East	85	23
Wales	29	8
Scotland	80	22
Northern Ireland	2	0.5
Channel Islands/ I.O.M.	2	0.5
Total	367	

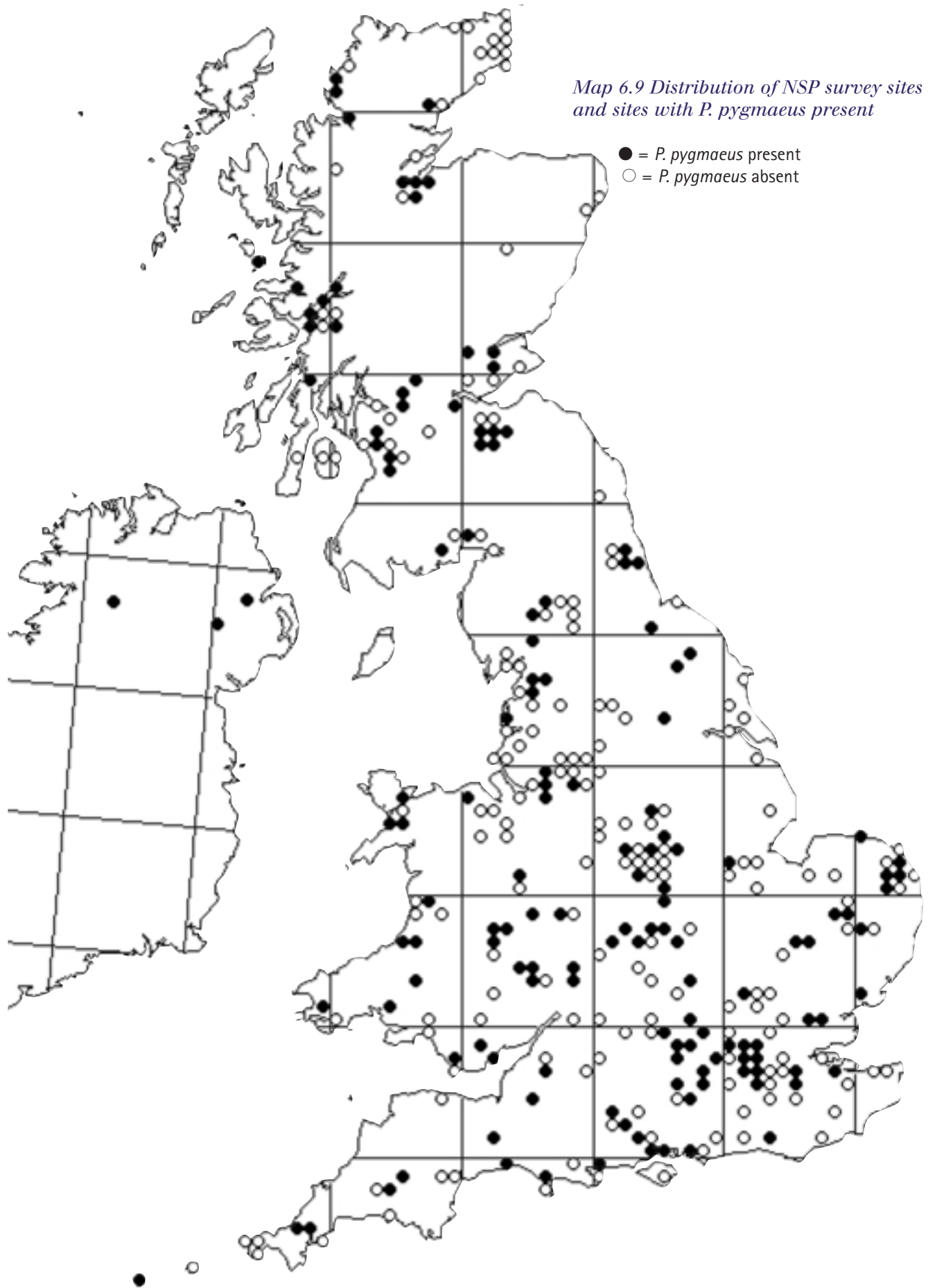




*Map 6.8 Distribution of NSP survey sites and sites with *P. pipistrellus* present*

● = *P. pipistrellus* present
○ = *P. pipistrellus* absent





7: Power and study design

7.1 INTRODUCTION TO POWER ANALYSIS

The purpose of a monitoring program is to draw accurate and correct conclusions about what is happening in the natural world. The design of surveys for monitoring must therefore aim to maximise accuracy and minimise the possibility of the wrong conclusions being drawn about trends. However, there is also a need to reconcile these aims with practical possibility and available resources.

The statistical measure known as “power” reflects the ability of a monitoring scheme to correctly identify an ongoing population trend. The population trend of interest represents the sustained patterns in count data that occur independently of cycles, seasonal variations, and irregular fluctuations in counts. Ideally, monitoring information should be correct. In the real world however, there are two possible scenarios when information may be incorrect. First, a significant trend could be identified in the population, when in fact it does not really exist. Second, it is possible that a real trend existed in nature, but that no significant relationship was found. Both errors could result from bias in the data collection and sampling methods, or could arise due to random fluctuations in the data obscuring the true trend. Power is a measure of the second error, and is expressed as the percentage chance that a particular design will detect a trend of the specified magnitude. In conservation biology, it is the second error that is more serious, since failure to detect an ongoing decline could result in delays in dealing with conservation problems and lead to local extinction of a species.

Power is influenced by many factors, including the magnitude of change (trend) in the population over time, the magnitude of stochastic year to year fluctuations in population size, the length of time a population is monitored, the number of survey sites sampled and the sampling error associated with surveys. Calculating the power of a monitoring scheme in relation to different combinations of these factors can help to identify an appropriately balanced design that takes into account the substantive goals of the programme and the resources available to accomplish these goals. For example, the more variable the bat counts are, the more difficult it is to correctly detect a population trend, and “power” is decreased. However, this can be offset by changing other aspects of how surveys are carried out, such as the number of visits made each year and the number of sites at which counts are made. Evaluating the power of a scheme can also aid programme planning by identifying whether sufficient funds are available to reach an adequate sampling effort level or whether funds are being wasted in the collection of data beyond that needed to achieve significant results.

Key questions in designing a monitoring programme are: How many years of counts do we need to detect a biologically significant trend? How frequently do we need to make counts, between years and within years? How many samples do we need to obtain significant results?

7.2 NBMP DATASETS AND POWER ANALYSIS METHOD

7.2.1 NBMP datasets

Real data on bat counts gathered during the first three years of the NBMP were used to simulate variation in bat numbers and assess the probability that population changes of a given magnitude will be detected under differing sampling designs.

Datasets investigated were

1. Roost count data for pipistrelle bats at a total of 458 sites over two years (1997,1998) with repeat sites each year.
2. Roost count data for lesser horseshoe bats at a total of 134 sites over three years (1996,1997,1998), repeat sites each year, with a subset of Welsh sites repeated since 1993.
3. Field survey bat detector counts for Daubenton's bats at a total of 712 sites over three years (1997,1998, 1999), different sites each year with a subset sites repeated 97/98/99.
4. Field survey bat detector counts for noctule, serotine, common pipistrelle and soprano pipistrelle bats at a total of 367 sites over three years (1998,1999, 2000), different sites each year, with a subset of repeat sites.
5. Hibernation site counts for a mixture of bat species at a total of 249 sites over three years (1997,1998,1999), repeat sites each year with a subset of sites repeated over ten years.

Factors investigated were

1. Numbers of sites (50 up to 500)
2. Number of years surveyed with annual counts (five up to 25 years)
3. Cycle of years surveyed by varied frequency of counts (biennial, and two year pairs with longer gap periods)
4. Rate of population change that we want to detect i.e. annual trends (1% up to 5%).

Table 7.1 For each survey, summary of number of sites repeated with different combinations of years

	Pipistrelle	Lesser horseshoe	Daubenton's	NSP	Hibernation
1997 only	48	1	255	-	25
1998 only	72	0	125	129	17
1999 only	84	28	134	98	9
2000 only	85	9	83	65	14
1997&1998	23	2	6	-	5
1997&1999	16	1	3	-	12
1997&2000	1	0	3	-	0
1998&1999	51	15	6	9	3
1998&2000	13	1	80	16	5
1999&2000	82	17	76	86	18
1997&1998&1999	91	51	0	-	101
1997&1998&2000	6	-*	2	-	4
1997&1999&2000	16	-*	2	-	13
1998&1999&2000	75	6	13	16	29
1997&1998&1999&2000	56	-*	0	-	94
1997 total	200	59	273	-	165
1998 total	331	77	235	185	164
1999 total	414	109	230	209	185
2000 total	333	33	262	198	182

* Awaiting data

7.2.2 Power analysis method

One question with these data is whether to include all sites that have been surveyed, or exclude some where the species is never seen. Clearly sites outside a species range should be excluded, but it is difficult to know what to do about others, particularly since the presence of many zeros will make the log normal distribution unrealistic. Fortunately, the omission of sites where the species is never seen does not have a large impact on the variance components; with more zeros included site variability is slightly higher but with slightly lower residuals. However, in all field surveys and hibernation site counts, figures were calculated excluding sites where a particular species was never seen, to reduce the number of zeros. For roost counts, data from all sites were used.

Raw count data were log-transformed, and analysed using REML – Residual Maximum Likelihood (Robinson 1987, Verboom 1998) – in order to estimate the different sources of variability in the data.

Four sources of variability were examined:

- Year: variations between years that are consistent across sites – these might be due to long-term trends or short term annual effects (on either the bats or the methods) which affect all sites
- Site: variations between sites (roosts or hibernacula or field sites) that are consistent between years. This reflects the fact that some sites have consistently higher numbers than others

- Site by year: year to year variation in the relative numbers at different sites. For example where a roost which generally has very high numbers has no bats in one particular year
- Residual: variation between pairs of counts at the same site in the same year

Power was calculated using a simple form of route regression, considering only linear trends. This is similar to the approach used in a program called "MONITOR". All sites were weighted equally and two-sided tests (to examine either upward or downward trends) were used, with a more liberal alpha level of 10% ($p < 0.10$) (see MacDonald et al. 1998). The variabilities from REML analyses were used to calculate the expected variation in the estimate of linear trend using the standard rules for calculating the variance of a linear combination of random variables (see for example Bulmer 1979). The probability of detecting the trend (the power) was then assessed using the t-distribution function. These results were confirmed for a subset of the factor combinations by direct simulation of data from a log-normal distribution with variances equal to the REML estimates at each level of variation.

7.2.3 Analytical constraints

Since real bat data are not a perfect fit to the log-normal distribution, particularly for low counts, the power figures produced will be an approximation, but are accurate enough to make informed choices about the best design to adopt. Approaches other than using the log-normal distribution for power analyses would involve extensive simulations, and it

would be difficult to cover the full range of parameter combinations. Further, results based on other distributions may be particularly sensitive to the distribution and shape-parameter chosen, whereas log-normal distributions are widely used for all sorts of population data and should be robust against minor departures from the distribution.

Power estimates presented are based solely on the numbers of years for which we have repeat data, and it should be noted that at this stage year-to-year variability is estimated with relatively poor precision for field surveys due to the limited number of years of repeated sites currently available. Further analysis, incorporating more repeat sites is recommended to improve estimates.

The route regression approach used provides only a simplistic test of trend based on large-sample approximations. Route regression involves establishing whether the trend is greater than would be expected by chance on the basis of site-to-site variability. This means that the method will be sensitive to any sort of year to year variability rather than just a consistent trend over time.

The models presented take no account of covariates such as weather conditions or biases associated with sampling and counting methods.

7.3 JUDGING WHETHER TARGETS ARE BEING ACHIEVED AND RAISING ALARMS

The purpose of a monitoring programme is to apply monitoring information to conservation objectives. Conservation objectives relevant to bats at a national scale

Box 7.1 Biodiversity Action Plan targets

B. barbastellus and M. bechsteinii

- Maintain the known range and populations
- Increase the total population size of this species by improving woodland age structure, (particularly in wooded river valleys for barbastelle), to increase roosting and foraging opportunities

R. hipposideros

- Maintain the current range and populations
- In the long-term, expand the current range through natural recolonisation and landscape enhancement, into areas where research shows climatic and landscape features are suitable

R. ferrumequinum

- Maintain all existing maternity roosts and associated hibernation sites
- Increase current population by 25% by 2010

Pipistrellus sp

- Maintain existing populations and range of pipistrelles
- Restore populations to pre-1970 numbers

Myotis myotis

- Maintain and enhance any extant populations discovered in the UK
- Ensure maximum conservation effort should the species re-establish

are either broad and qualitative such as "conserving biodiversity" or can be more quantitative targets defined for individual species, such as the targets set for BAP species (Box 7.1)

Such conservation targets demand the setting of **alert levels** to trigger action when objectives/targets are not being met i.e. when a population decline that is considered of conservation concern is identified and hence populations are not being maintained.

To set meaningful alert levels, identified trends require interpreting not only to identify statistical significance but also to assess their biological significance. This can be complicated because long-term declines may take the form of slow gradual declines or sudden crashes and are set against a back-drop of natural fluctuations in population size due to stochastic factors such as weather conditions or density-dependent feedback. In addition, estimates of population size/trends will fluctuate with biases associated with sampling and counting methods such as biased site selection (maternity roost/hibernacula) and unequal detection probabilities among observers (all monitoring schemes), equipment and habitats (field surveys). Unequal detection probabilities between bat species is not a problem, since trends are only assessed for each species separately and we are not attempting to get absolute estimates of population sizes. Incorporating these factors into models when testing for trends would go some way to remove many of the ephemeral fluctuations in the data and improve power analyses. However, we have insufficient information to make quantitative assessments of these issues at present and none of these sampling and measurement issues is easily solved.

There are no precise definitions to judge at what population size a bat species becomes vulnerable to extinction. Similarly there are no definitions to judge at what rate of population decline does a species become vulnerable to extinction. Many of the population parameters required to calculate the intrinsic rate of natural increase of populations and to carry out population viability analyses are uncertain for bats. Rates of change deemed important for other species may be used as estimates however. As guidance, conservation alerts defined by a BTO Research Report (No. 200) entitled "Enhancements for monitoring of opportunistic bird populations" were applied to NBMP data. In this document, the BTO defined an Alert Level system that can be used to identify population declines of conservation concern. In this system, species are categorised as high conservation priority (Red Alert) if their populations have declined by 50% or greater over 25 years and as medium priority (Amber Alert) if their populations have declined by 25–49% over 25 years. These criteria are based on levels defined for animal populations by the IUCN and represent decreases that have already occurred. A second criterion involves predicting future population levels based on the current rate of decrease. Species can be given a Red or Amber Alert if their current population change rate is such that a 50% or greater, or 25–49% change is predicted to occur over a 25 year period. A 50% and 25% decline over 25 years translates into an annual decline rate of 2.73 % or 1.14 % respectively. Thus if a 1.14 % decline rate is observed over a shorter time

Table 7.2. Overall population change for different rates of decline over different numbers of years

Population change (% decline per year)	Cumulative % change over number of years				
	5	10	15	20	25
1%	4.9%	9.6%	14.0%	18.2%	22.2%
2%	9.6%	18.3%	26.1%	33.2%	39.7%
5%	22.6%	40.1%	53.7%	64.2%	72.3%
10%	41.0%	65.1%	79.4%	87.8%	92.8%
Amber 1.14%	5.6%	10.9%	15.9%	20.6%	25.0%
Red 2.73 %	12.9%	24.2%	34.0%	42.6%	50.0%

Table 7.3 Variance component estimates for field surveys from REML

SPECIES	Daubenton	Common pipistrelle	Soprano Pipistrelle	Noctule
Component				
site	0.2504	0.0724	0.0478	0.0160
site.year	0.0593	0.0219	0.0855	0.0347
residual	0.0981	0.1588	0.1312	0.1066
No. of sites	561	230	137	137
No. of observations	1015	548	334	326

Table 7.4 Variance component estimates for roost counts using REML

SPECIES	L. horseshoe	Pipistrellus sp.
Component		
Year	0.000	0.012
site/roost	0.164	0.544
site.year	0.022	0.148
Residual	0.034	0.200
No. of sites	123	394
No. of observations	759	1022

period, say five or ten years, the species should be given Amber alert status. A 5% annual decline rate is also of value to examine to represent a sudden crash scenario (see Table 7.2).

7.4 RESULTS

7.4.1 Variance estimates

Results from REML are shown in tables 7.3–7.5.

Table 7.5 Variance component estimates for hibernation site counts from REML

SPECIES	Whiskered	Daubenton's	Natterer's	Brown long-eared	Greater horseshoe	Lesser horseshoe
Component						
Year	0.000	0.005	0.004	0.001	-0.003	0.009
Site	0.098	0.126	0.149	0.048	0.306	0.304
site.year	0.024	0.017	0.023	0.009	0.026	0.007
Residual	0.020	0.035	0.034	0.034	0.018	0.039
No. of sites	47	99	116	110	34	79
No. of Observations	287	601	714	678	115	211

The total count variability is very large for Daubenton's bat and this is largely due to the site to site component – there are some sites where hundreds are always present and some where there are very few. On the Daubenton's bat survey passes identified as 'unsure Daubenton's bat' counts were included in the analysis. This is because the means of passes identified as Daubenton's bat correlate with the means of all bat passes recorded (i.e. including those thought to be Daubenton's bat but recorded as "unsure Daubenton's bat").

Variance component estimates for serotine bat counts in field monitoring did not converge properly due to insufficient data. Therefore, these results have not been included in the presented analyses. Serotine bats are present at very few sites and occur at low densities. In the roost monitoring schemes for this species, less than 50 roost sites are currently being monitored and the sample of repeated sites is small leading to potentially unreliable variances estimations for power estimation. However, given that the required sample sizes for other roost monitoring schemes fall to below 50 roosts over the long-term (20 years plus, Figures 7.1–7.12), it is likely that sufficient roost data are being collected to estimate trend adequately. This has identified the need to put effort into finding roosts/increasing the number of serotine roost sites within the network and to increase the sample size of sites surveyed as part of the NSP scheme within the range of this species (southern England).

7.4.2 How many years?

At the outset, the major point to consider is the dominating effect of time over most survey variables. A key question to ask therefore is how much time one is willing or able to wait for conclusive results. For all schemes, examining trends over a time period of less than five years is inadvisable since short-term population fluctuations may be confounding.

The difference in power of monitoring schemes to detect annual population trends of 1.14%, 2.73% and 5% with increased years of monitoring is shown in Figures 7.1 to 7.12. Schemes compared are:

- Roost monitoring for pipistrelle and lesser horseshoe bats
- Field monitoring for Daubenton's, common pipistrelle, soprano pipistrelle and noctule bats
- Hibernation site monitoring for whiskered, Natterer's, greater horseshoe, lesser horseshoe, Daubenton's and brown long-eared bat

The required sample sizes to achieve 90% power are illustrated, and it should be noted that these are repeat site samples. Power graphs for all schemes are presented so that estimates for different sample size – time – trend magnitude combinations can be read directly from the curves.

- Selecting the lesser horseshoe bat roost counting scheme as an example; after seven years, a sample size of around 25 roosts is adequate to detect a large annual change in the population of 5%, while a sample of around 100 roosts is adequate to detect a red alert change of 2.73%. At this stage it is unlikely that smaller changes will be detected in short time periods, because the roost sample size required is too large to be practicably achievable (over 500 roosts). However, after a series of 13 years' data have been collected, a sample of just under 100 roosts will then be adequate to detect an amber alert change of 1.14%
- All graphs demonstrate the general principle that the longer monitoring is carried out, our ability to detect smaller and smaller trends increases and required sample size reduces

Table 7.6 Number of years of monitoring at which required sample size falls below 100 for identifying different rates of population change.

Monitoring scheme type	Species	Years to detect	Years to detect	Years to detect
		5%	2.73%	1.14%
Roost schemes	<i>R. hipposideros</i>	5	8	12
	<i>Pipistrellus sp.</i>	9	13	25
	<i>E. serotinus</i>	–	–	–
Field schemes	<i>P. pipistrellus</i>	7	10	18
	<i>P. pygmaeus</i>	7	11	20
	<i>N. noctula</i>	6	9	18
	<i>E. serotinus</i>	–	–	–
	<i>M. daubentonii</i>	7	10	18
Hibernation scheme	<i>M. nattereri</i>	5	9	18
	<i>M. daubentonii</i>	5	7	12
	<i>M. mystacinus</i>	7	10	18
	<i>R. ferrumequinum</i>	5	7	12
	<i>R. hipposideros</i>	5	6	11
	<i>P. auritus</i>	5	6	9

- All graphs also demonstrate that after 25 years of monitoring, all monitoring schemes can detect Amber (1.14%/yr) and Red (2.73%/yr) trends at powers of over 90%, and satisfy monitoring targets

To compare schemes and gain an estimation of how long schemes need to run before trends can be statistically detected, Table 7.6 summarises the number of years of data required at which the sample size needed to detect trends falls below 100 sites. The figure of 100 was selected as an arbitrary threshold, as in practice few schemes are likely to achieve a repeat sample size above this.

- Thus, for the majority of monitoring schemes, the earliest point in time that large declines can first be statistically detected is after a period of 5–9 years. Similarly, the earliest point in time that a Red Alert decline can be statistically detected will be after approximately 6–13 years, and to detect an Amber Alert after approximately 9–25 years. These figures vary depending on the sample sizes and schemes but they give some indication of the ability of monitoring schemes to detect changes over time
- The roost monitoring scheme for pipistrelle and lesser horseshoe bats demonstrate the difference in power between the two schemes. The *Pipistrellus* sp. roost monitoring scheme is less powerful than the lesser horseshoe scheme and hence requires larger sample sizes to monitor trend effectively. This corresponds with what might be predicted: that roost monitoring schemes are less powerful for more mobile bat species

In comparing different types of scheme for the same species, the roost and hibernation counting schemes for *R. hipposideros* appear to be similar in their performance, so too do the field and hibernation monitoring schemes for *M. daubentonii*. However, differences at this stage may be an artefact of the current analysis, since variances for the hibernation and lesser horseshoe roost schemes are lower, being based on a longer run of repeat years data, and this has the effect of increasing their power slightly.

7.4.3 How many counts?

The decision on how many visits/counts should be made annually must consider costs and practicality i.e. availability of trained volunteers/staff to carry out monitoring, in addition to objectives concerning accuracy/power.

Figures 7.13 to 7.17 illustrate the difference in power of monitoring schemes when either a single count or two counts are made at sites/transects each year. Schemes compared are:

- Roost monitoring scheme for *R. hipposideros* and *Pipistrellus* sp
- Field monitoring scheme for *M. daubentonii* and *N. noctula*
- Hibernation site monitoring scheme for *M. nattereri* bats

In all schemes, two visits yield greatest power.

- The changes in power follow a similar pattern for other species
- Selecting an example, in the *Pipistrellus* sp roost monitoring scheme, after ten years of monitoring taking a single count each year, an additional 72 sites are required to reach the same level of power as when two counts are taken each year. After fifteen years, this difference is reduced to 21 sites, and after 20 years the difference is nine sites
- The reduction in power when a single visit is made is more pronounced when smaller declines are to be detected, when sample sizes are smaller and when shorter monitoring time periods (<10 years) are considered

A reduction from two counts/visit per year to a single visit per year is an option to be considered in the long-term, but would necessarily result in a loss of power and requirement for larger sample sizes. The advantages of reducing to a single count may be an increase in the numbers of sites covered in schemes and more consistent coverage of sites from year to year. For hibernation site counts, a single count would also reduce disturbance of bats. One option might be to maintain two counts in all schemes for a minimum period of ten years and then to reduce to a single count if deemed appropriate. However, the disadvantages are likely to outweigh these benefits. Two counts do not put much more pressure on observers/cost much more than a single count, and will minimise variation in counts between years. Where a large number of hibernation sites are surveyed by few people then a reduction to one count can be considered justifiable as often there is simply not enough time to cover all sites twice.

7.4.4 What frequency of monitoring?

The decision on how frequently to count populations between years must consider the intrinsic rate of population change, risk from extrinsic factors (e.g. risk from habitat change), required reporting frequency, costs and practicality, i.e. availability of trained volunteers/staff to carry out monitoring in addition to objectives concerning accuracy/power.

Figure 7.18 illustrates the difference in power of the Daubenton's bat field monitoring scheme following three distinct survey patterns: annual, biennial and once every five years.

- A reduction in survey frequency of monitoring from annual to once every five years reduces power significantly, such that a run of at least 23 years is needed before a 2.73% trend can be detected with under 100 roost sites in the scheme
- A reduction in frequency to every other year (biennial) also reduces power significantly over the short-term. However this reduction in power is less pronounced over the long-term (20 years plus). After seven years of monitoring

toring, taking two counts every other year, additional 92 sites are required to reach the same level of power when two counts are taken annually. After fifteen years, this difference is reduced to 15 sites

- The changes in power follow a similar pattern for other species

A reduction in frequency of monitoring from annual counts to biennial is an option to be considered in the long-term. While this may be logistically practical for field surveys, it is considered impractical for roost and hibernation site schemes. In a test year, the NBMP requested lesser horseshoe roost observers to take a gap for a year, and to count at the roost of a different species instead. However, this resulted in confusion, and many observers continued counting at their lesser horseshoe sites, but did not return the data to us. The confusion also carried forward into the next year, with observers unsure whether they were supposed to count at their site or not, resulting in a loss of continuity.

Advantages of surveying less frequently in field surveys might be a reduction in effort for volunteers and the concentration of efforts into a single field scheme each year thereby causing an increase in site coverage and year-to-year consistency of coverage. Also, a cycle of schemes may provide variety for volunteers and time would be freed for them to participate in verification and other research pilot studies initiated as part of the NBMP. Disadvantages of spacing surveys out over time might be that the network of volunteers may fragment and reduce in number.

7.4.5 How many samples?

Re-examining Figures 7.1 to 7.12, the difference in increasing sample sizes on power to detect trends of different magnitude may be estimated from the curves for all monitoring schemes.

Minimum required sample sizes to detect a Red Alert decline rate of 2.73%/yr with 90% or above power were estimated from these curves for a run of seven, ten and 20 years monitoring, and are summarised in Table 7.7 below.

For the serotine bat best estimates, based on other species which behave in a similar manner or are recorded with a similar low frequency, are given in brackets ().

- For all monitoring schemes, very large sample sizes would be required to monitor smaller trends (less than 2.73% annual trend) over shorter time periods (less than seven years)
- For all survey scheme species (with the exception of the serotine), yearly figures of sites surveyed to date (1997, 1998, 1999) meets the minimum target listed in Table 7.6 above
- A major consideration is whether regional or major land class group estimates of trend are required. If they are, sample sizes would need to be raised approximately to the same level within each country/land class group. For example where a sample size of 20 is required, this would need to be 80 if consideration of trends within England, Scotland, Wales and Northern Ireland were estimated separately

Table 7.7 Estimated minimum sample sizes to detect Red and Amber alert decline rates in the UK population in the medium to long-term for each monitoring scheme

Monitoring scheme type	Species	Core sample size to estimate a UK annual trend of 1.14 & 2.73% over ten and 20 years of monitoring			
		2.73%		1.14%	
		10 years	20 years	20 years	25 years
Roost	Lesser horseshoe	<20	<20	22	<20
	Pipistrelle	66	24	130	67
	Serotine	(<20)	(<20)	(22)	(<20)
Field survey	Common pipistrelle	75	<20	54	29
	Soprano pipistrelle	110	<20	80	42
	Noctule	65	<20	47	25
	Serotine	(65-110)	<20	(65-80)	(<20-42)
	Daubenton's	80	<20	58	31
Hibernation	Natterer's	59	<20	49	29
	Daubenton's	27	<20	20	<20
	Whiskered	91	<20	66	35
	Greater horseshoe	27	<20	20	<20
	Lesser horseshoe	21	<20	<20	<20
	Brown long-eared	21	<20	<20	<20

- If sole interest is in making national trend estimates, then as long as sites are well dispersed between regions and land classes, fairly small sample sizes are adequate

7.5 RECOMMENDED STUDY DESIGNS FOR MONITORING SCHEMES

In all analyses, the significance (alpha) level used in tests for trend was set at 10% ($p < 0.10$). This is because the system is designed to be an early warning system. It might be preferable to raise the alarm about the status of populations early, and spend some time following up false leads, than to set such stringent statistical aspirations that populations are in severe difficulty by the time statistical significance is attained. If a more stringent test level of 5% ($p < 0.05$) is used, this will have the general effect of raising the required sample sizes to achieve 90% power. Increases should not be of a large magnitude however, as demonstrated in the lesser horseshoe roost scheme in Figure 7.19.

In all analyses two-way tests were used, because for most species possible upward as well as downward trends might occur. If one way tests are used, and only a decline is tested for, this will have the general effect of reducing the required sample sizes to achieve 90% power.

In all analyses, the assumption was made that the desired minimum sample size required will be collected within a single year. If the desired minimum sample size can only be achieved through data collection spread over a two-year period, then this will have the effect of reducing power, and raising the required sample sizes. However, this may be beneficial if the sample sizes required to make country level estimates of trend are so large that they are unattainable in a single year. One problem in spreading data collection across years is that any year effect would get more critical, because a bad year would only affect half of the sites. In addition, normal statistical design ideas would suggest that it would be unwise to use a simple scheme of doing the same 50% of sites together each time – it would be better to design a scheme whereby different combinations of sites were done in each year. Obviously this is a logistically difficult practice to achieve when relying on volunteers, and the benefits would need to be weighed against the benefits of a simple scheme of alternate years.

Recommendations for study design in the short-term are:

- Recommendation 49:** At this stage, no reduction in count number or reduction in survey frequency between years is recommended, and all schemes should remain annual with two counts.
- Recommendation 50:** Re-assessment through further power analyses when more data are available is recommended.
- Recommendation 51:** Production of table detailing desired and achieved sample sites for all surveys divided into UK,

country and Environmental Zone. This will identify areas where more survey effort is required and allow the development of statistically defensible surveillance targets for each country of the UK.

- Recommendation 52:** Ensure a core sample of 30-40 sites for each scheme are consistently covered from year-to-year to enable UK estimates of trend. This may require employment of paid work.

- Recommendation 53:** It is important to state that at this stage, all power analysis results are preliminary. Further power analyses should be carried out when more data are available from different years to re-assess required sample sizes and survey designs.

Figure 7.1 Effect of trend size and time on required sample size: *R. hipposideros* maternity colony counts

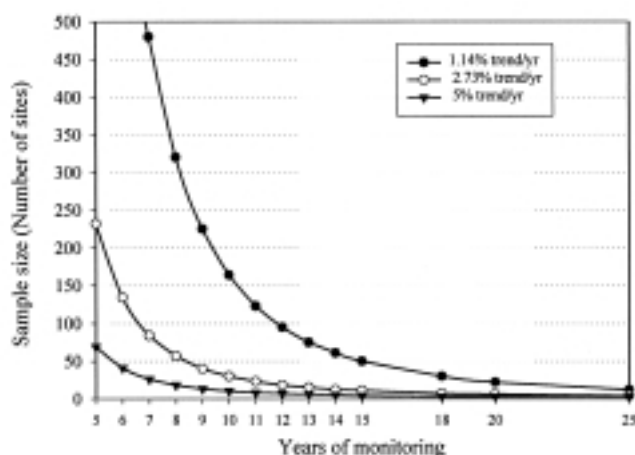
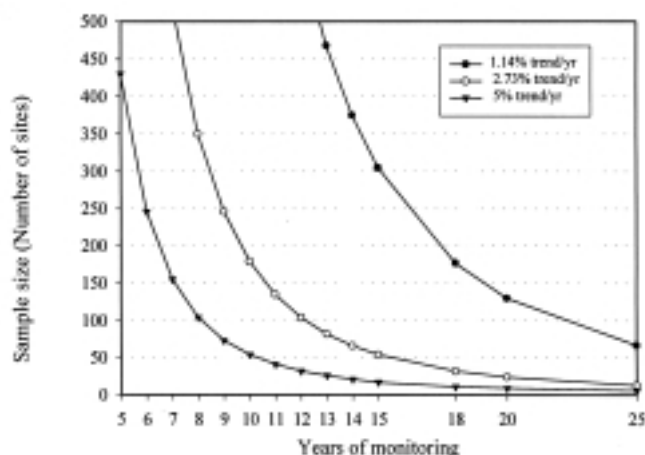


Figure 7.2 Effect of trend size and time on required sample size: *Pipistrellus* sp maternity colony counts



○ Figures 7.1 & 7.2 Minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.73 and 5% per year, given length of monitoring in years and two counts per site per year. Power was calculated using route regression, $p < 0.10$.

Figure 7.3 Effect of trend size and time on required sample size: *M. daubentonii* field survey

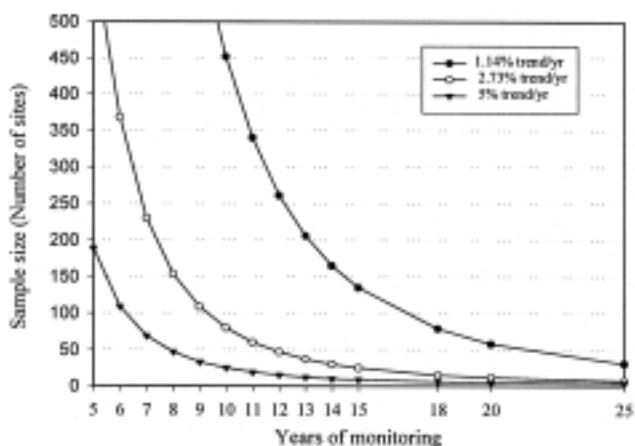
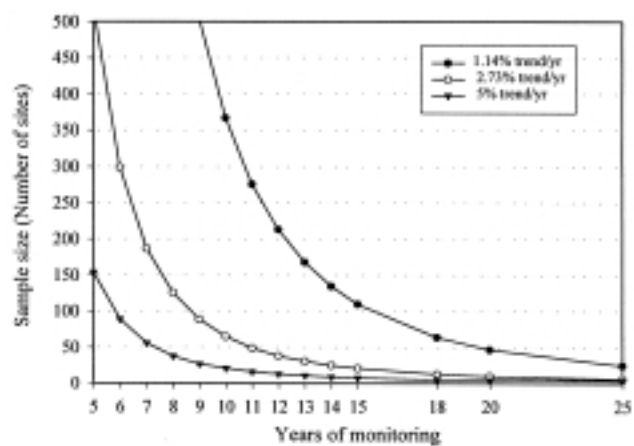


Figure 7.4 Effect of Trend size and time on required sample size: *N. noctula* – NSP field survey



○ Figures 7.3 & 7.4 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.73 and 5% per year, given length of monitoring in years and two counts per site per year. Power was calculated using route regression, $p < 0.10$.

Figure 7.5 Effect of trend size and time on required sample size: *P. pipistrellus* – NSP field survey

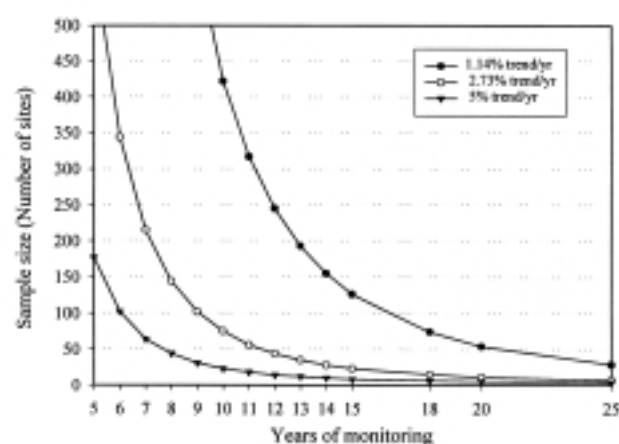
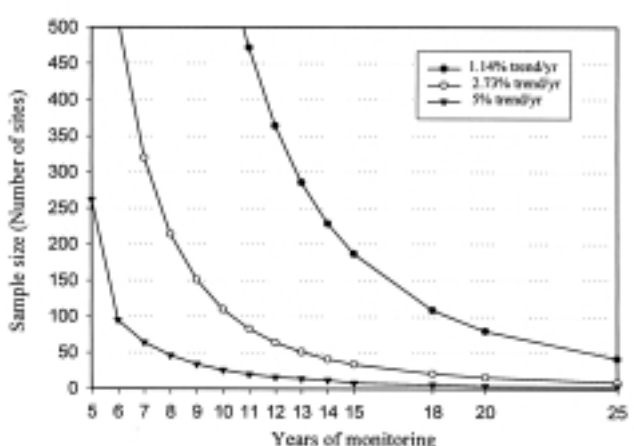


Figure 7.6 Effect of trend size and time on required sample size: *P. pygmaeus* – NSP field survey



○ Figures 7.5 & 7.6 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.72 and 5% per year, given length of monitoring in years and two counts per site per year. Power was calculated using route regression, $p < 0.10$.

Figure 7.7 Effect of trend size and time on required sample size: *R. ferrumequinum* hibernation site counts

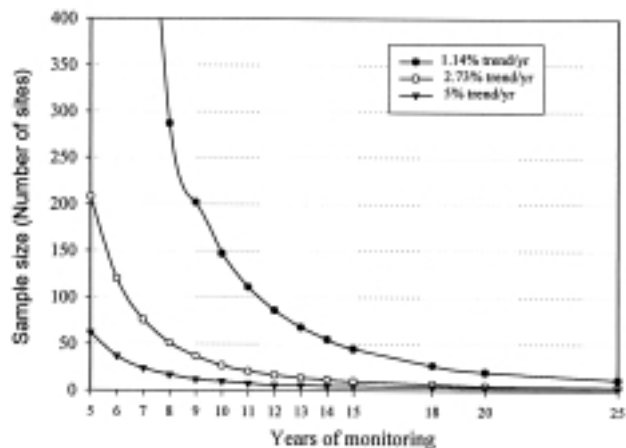
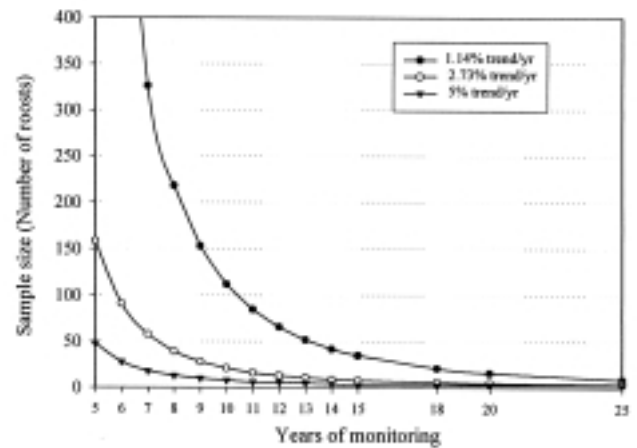


Figure 7.8 Effect of trend size and time on required sample size: *R. hipposideros* hibernation site counts



○ 7.7 & 7.8 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.72 and 5% per year, given length of monitoring in years and two counts per site per year. Power was calculated using route regression, $p < 0.10$

Figure 7.9 Effect of trend size and time on required sample size: *Plecotus auritus* hibernation site counts

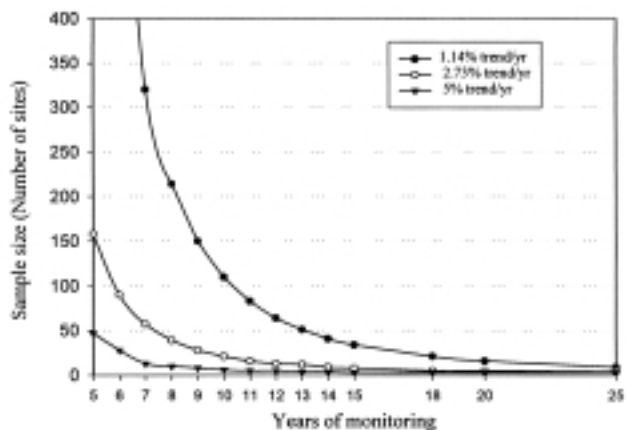
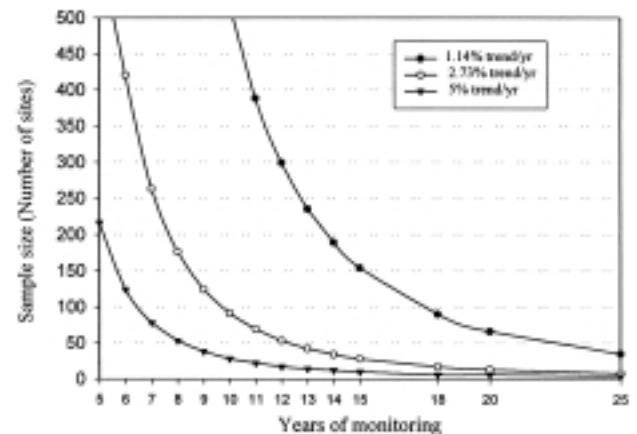


Figure 7.10 Effect of trend size and time on required sample size: *M. mystacinus* hibernation site counts



○ Figures 7.9 & 7.10 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.72 and 5% per year, given length of monitoring in years and two counts per site per year. Power was calculated using route regression, $p < 0.10$.

Figure 7.11 Effect of trend size and time on required sample size: *M. daubentonii* hibernation site counts

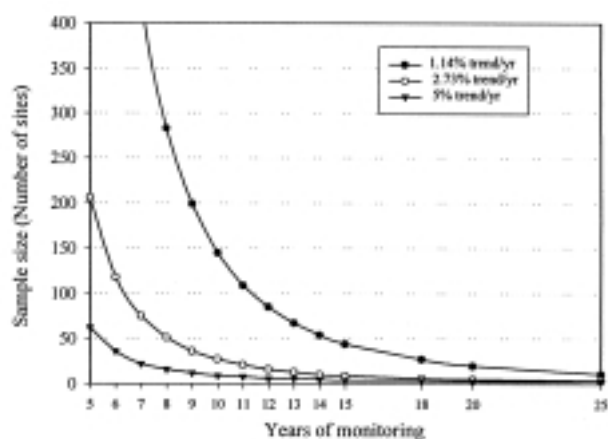
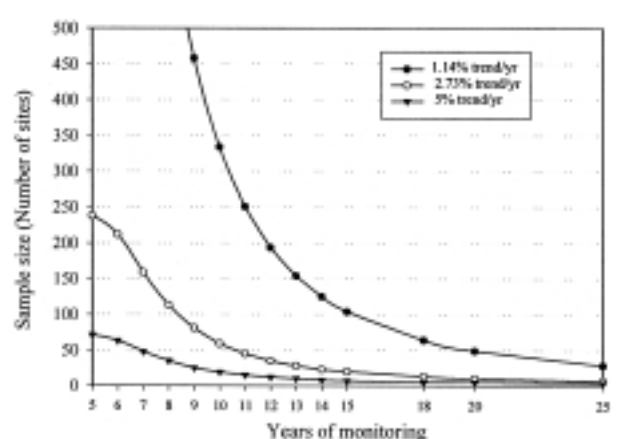


Figure 7.12 Effect of trend size and time on required sample size: *M. nattereri* hibernation site counts



○ 7.11 & 7.12 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.72 & 5% per year, length of monitoring in years and two counts per site per year. Power was calculated using route regression, $p < 0.10$

Figure 7.13 Effect of trend size and time on required sample size: *R. hipposideros* maternity colony counts

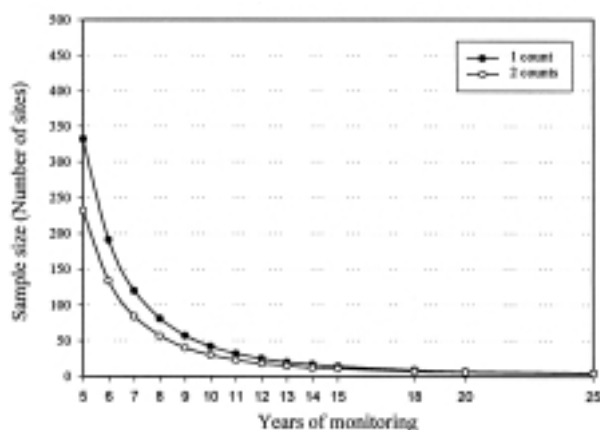
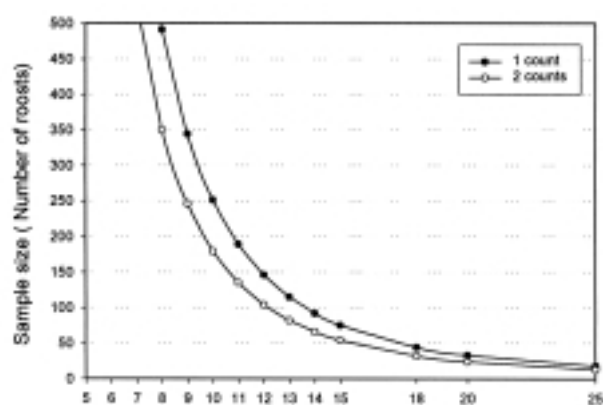


Figure 7.14 Effect of trend size and time on required sample size: *Pipistrellus* sp. maternity colony counts



○ Figures 7.13 & 7.14 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 1.14, 2.73 and 5% per year, given length of monitoring in years and number of counts per site per year. Power was calculated using route regression, $p < 0.10$.

Figure 7.15 Effect of counts per Year and time on required sample size: *P. pygmaeus* – NSP field survey

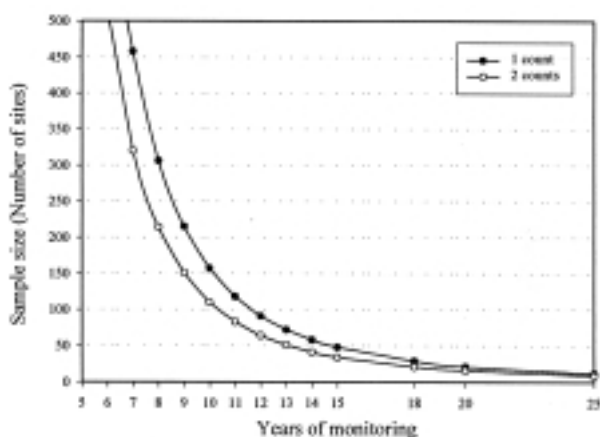
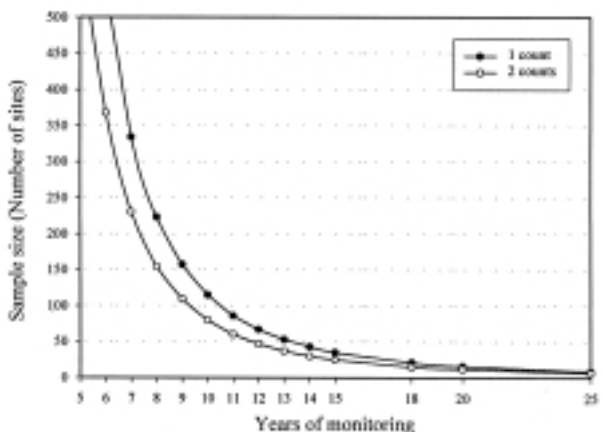
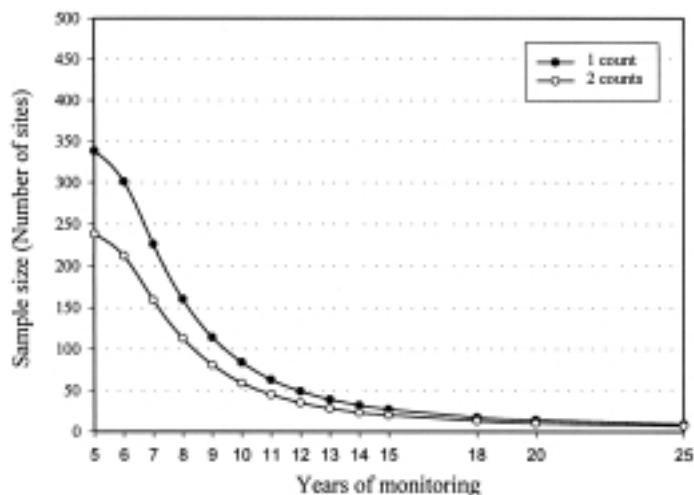


Figure 7.16 Effect of counts per year and time on required sample size: *M. daubentonii* field survey



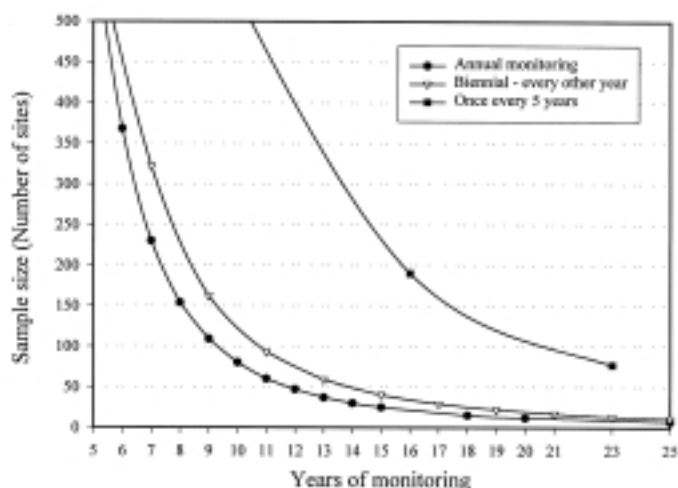
○ Figures 7.15 & 7.16 refer to minimum number of sites needed to obtain at least 90% power to detect existing declines of 2.73% per year (Red Alert), given length of monitoring in years and number of counts per site per year. Power was calculated using route regression, $p < 0.10$.

Figure 7.17 Effect of counts per year and time on required sample size: *M. nattereri* hibernation counts



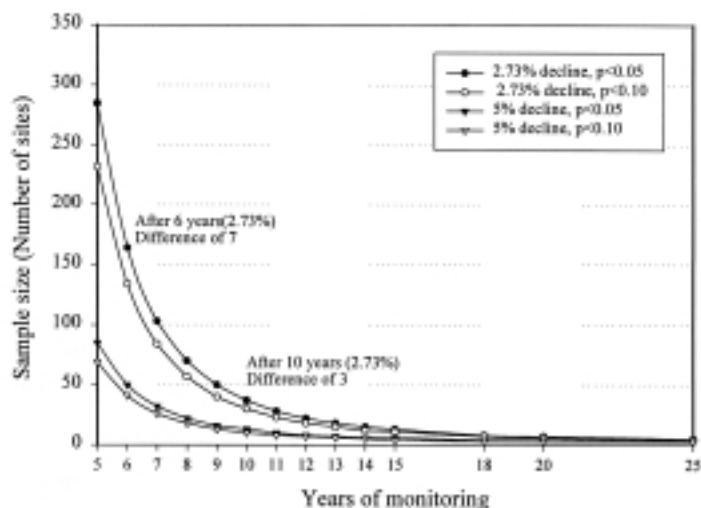
○ Figures 7.17 refers to minimum number of sites needed to obtain at least 90% power to detect existing declines of 2.73% per year (Red Alert), given length of monitoring in years and number of counts per site per year. Power was calculated using route regression and variances obtained from pilot data.

Figure 7.18 Effect of survey frequency between years and time on required sample size: *M daubentonii* field survey



○ Figures 7.18 refers to minimum number of sites needed to obtain at least 90% power to detect existing declines of 2.73% per year (Red Alert), using two counts per year and given length of monitoring in years and survey frequency between years (annual, biennial, once every five years). Power was calculated using route regression and variances obtained from pilot data.

Figure 7.19 Effect of alpha level on required sample size in power calculations *R. hipposideros* maternity colony count



○ Figures 7.19 refers to the minimum number of sites needed to obtain at least 90% power to detect an existing decline of 2.73 and 5% per year, given length of monitoring in years and power calculated using route regression, for $p < 0.01$ and 0.05.

8: Species distribution maps

8.1 ATLAS MAPPING

The Biological Records Centre (BRC) has promoted the grid-based natural history mapping of flora and fauna throughout the British Isles. The last distribution atlas of bats in Britain was included in the BRC's publication "Atlas of mammals in Britain" (Arnold, 1993). It did not include any records for Ireland. Since then there has been an upsurge in recording by local bat groups aided by new user-friendly computer programs, and a number of groups have published distribution maps for their areas. At the end of a millennium it was decided to pull together existing data for Britain (including the Channel Islands and Isle of Man) and Ireland to see the present state of bat distribution so that comparisons can be made in the future.

The National Bat Monitoring Programme is just completing its first five-year cycle and so the production of an atlas provides an opportunity to incorporate some of projects findings alongside traditional records.

8.2 BAT ATLAS RECORD COLLECTION, GRID SIZE AND STANDARDISATION

A provisional collection of records and production of the distribution atlas has been organized by Phil Richardson of the BCT in close collaboration with the NBMP staff.

8.2.1 Format of records

Three categories of records were collected:

1. Summer roosting sites
2. Records away from roost sites (this to include bat detector records, grounded bats, bats trapped indoors, dead bats)
3. Hibernation sites

It is known that these are broad categories and that there are no clear-cut definitions that take into account all cases. Summer roosts may be nursery sites, all-male gatherings, spring gathering sites, single male sites, autumn dispersal roosts or a single bat in a bat-box in summer. Bats trapped indoors and grounded bats are often from a nearby roost yet were recorded here as being away from a roost site unless the roost was discovered. In autumn, bats may go to winter hibernation sites, but not begin to hibernate so such sites could be classed as summer roosts. Hibernation records were meant to give an impression of where bats were likely to be found in those cold months when activity is relatively low. Long-eared bats, however, are well-known for lingering in summer roost sites well into December, and becoming torpid. Nevertheless, overall, most records fitted well into

one of the three categories. A few county recorders were unable to separate their records into the three categories and these have been recorded as hollow circles (records away from roosts) although some are known to be roosts and hibernation site records (mainly Norfolk and Suffolk).

Recording was based on 10km squares and did not take population density into account. For a general distribution atlas this scale of recording was adequate.

Records from 1980 to 1999 were gathered. This was believed to be enough time to provide adequate numbers of records of the more scarce species, and to have an up-to-date set of data.

8.2.2 Numbers of records and their sources

Once duplicate records had been removed a total of 12,382 10km square records were collated and converted into distribution maps.

The major contributors were the bat groups around Britain and Ireland. This included the Channel Islands and the Isle of Man and, for the first time, included records from Ireland. Most groups have a recorder who provided and validated the records, but in some cases the records came via local museum services, wildlife trusts or the statutory nature conservation organizations. In addition major contributions were received from the NBMP, the Vincent Wildlife Trust, the Forestry Commission, the National Trust and the National Parks and Wildlife Service of Ireland. In all cases the organisations have methods of checking the accuracy of the records. We are indebted to all of these people for their efforts.

8.2.3 The maps

● Full circles represent roosts in summer, or hibernating bats.

○ Hollow circles represent bats away from roosts.

As an example, maps for *Pipistrellus pygmaeus* and *Pipistrellus pipistrellus* are shown here (Figures 8.1 and 8.2). These represent the first maps ever produced of the two species' separate distributions in the UK.

The detail is important: although some species have previously been reported as having a distribution across a large part of Britain we can now see that the distribution is often not complete, with areas having no records of certain species even though it has been actively sought. Whiskered bat, for example, is rare or non-existent in the eastern counties of Essex, Norfolk and Suffolk although many texts show its range across the whole of England.

Figure 8.1 Example map from the Bat Atlas for winter hibernation distribution of *Myotis daubentonii* 1980-1999

● Hibernation site

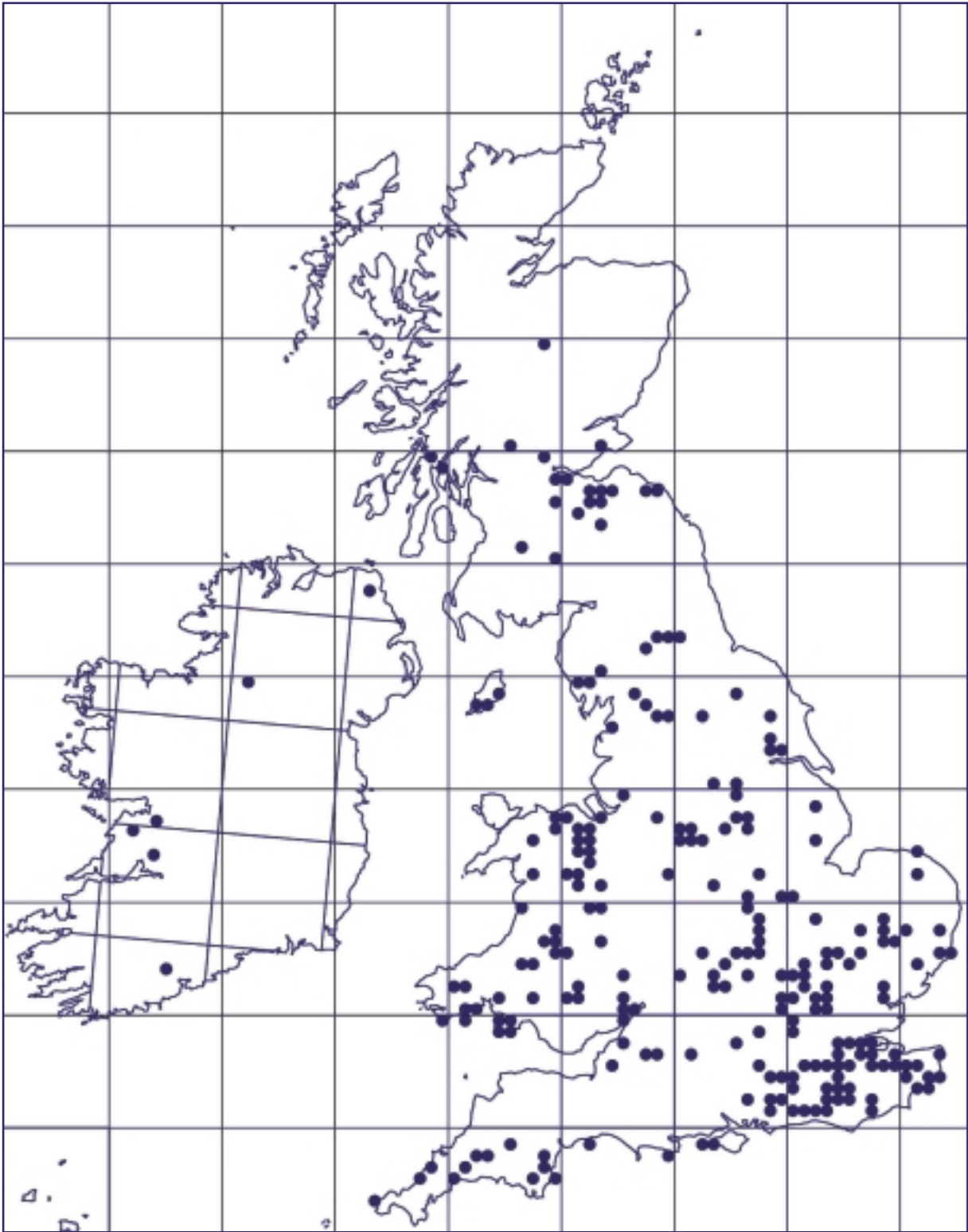
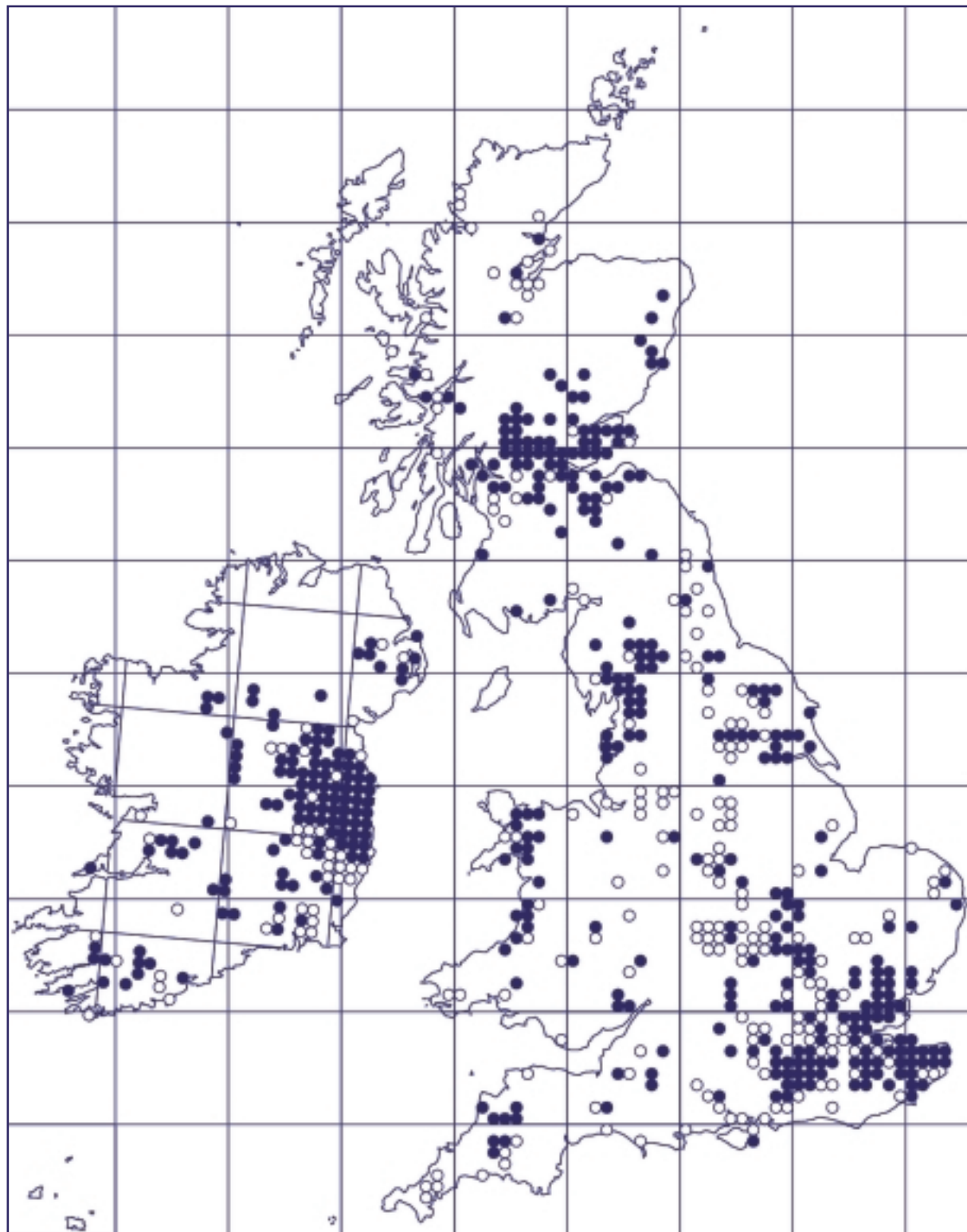


Figure 8.2 Example map from the Bat Atlas for summer roost distribution of *Pipistrellus pygmaeus* 1980-1999

● Roost

○ Occasional record



The full set of provisional maps can be found in a supplement to this report, entitled *Distribution atlas of bats in Britain and Ireland. 1980 – 1999*, compiled by Phil Richardson, Bat Conservation Trust, 2000.

8.3 CONSTRAINTS OF THE BAT ATLAS MAPS

As with any distribution mapping the maps need to be interpreted with caution. Records of roosts and hibernation sites have been collected on an *ad hoc* basis, coverage is incomplete, and it is certain that regions vary in the amount of time and effort spent on searching for sites. This source of bias has important implications – since data for different areas are not directly comparable. In short, the extent to which the distribution maps are representative of the species rather than the methods used to record them is not known. Information about the way in which data have been collected and allowance for sampling intensity is needed before monitoring distributional changes can be considered reliable. An example of this is the new *Atlas of breeding birds in Britain and Ireland: 1988–1991* (Gibbons *et al* 1993).

A more detailed list of constraints specific to this Bat Atlas are :

- There is a natural tendency to have clusters of records around recorders' home areas because that is where most fieldwork is carried out
- There is also an unevenness of recording effort between areas – some counties have a large number of active fieldworkers whereas others have few. Changes in county boundaries have resulted in some areas lacking any recording by bat groups. In addition, Surrey, Sussex, West Yorkshire and Glamorgan bat group recorders submitted no records, although some of these groups are known to be actively collecting records for imminent submission. Some counties have carried out special surveys on certain species resulting in a large number of records for those species
- There is also a bias towards recording roosts that are relatively easy to find – those in residential buildings – whereas tree roosts are less often encountered and so tree-roosting bats are likely to be under-recorded. Bat box schemes are redressing the balance to some degree, but roost records tend to concentrate around human habitation
- Similarly some bat species are relatively easy to detect (such as pipistrelles and noctules) whereas others need special techniques of detection (such as barbastelles and Bechstein's)
- Some roosts were known to have been abandoned during the two decade period covered by this Atlas – in some cases the bats had moved and were then represented by a second spot on the map. This gives rise to the possibility of some over-recording

Nevertheless the maps give a "rough guide" to the ranges of different species of bats across Britain and Ireland.

8.4 USE OF ATLAS MAPS TO MONITOR DISTRIBUTION CHANGE AND OTHER MAPPING APPLICATIONS

The maps, collected over a relatively short time span, give a snapshot of the ranges of bats resident in the UK. Future maps may enable us to compare and note changes in the ranges of some species e.g. if future records of horseshoe bats occur well outside the present known distribution this may indicate an expanding population. Changes in ranges are usually associated with population changes. Local areas can now combine records with neighbouring areas to view the region's distribution of a species. Regions containing key species can be easily identified for combined work in conserving certain species.

Map data can be imported into Geographical Information Systems and factors influencing distribution such as habitat, isotherms, altitude and land-use investigated and monitored over time. Although the maps do not record abundance they certainly provide a frequency index when similar areas of different species are compared.

It should be remembered, however, that the range of all of these species of bats extends into mainland Europe, and thus their overall distribution in the context of Europe should be monitored. The UK is on the northern or western edge of the distributional range for many bat species (see Mitchell-Jones *et al.* 1999), and trends occurring within Europe are likely to influence the species composition and population status of bats within the UK.

The data collection methods for the distribution maps produced mean they are highly likely to be biased. In addition to this, care is required when using information on known colonies to assess factors that affect bat distribution. The distribution of known colonies might not represent well the true distribution of the species. For example, a species might be most abundant and widespread in remote areas, but known colonies might be predominantly in or near conurbation's, simply because colonies are more likely to be found where there are more people to find them. The monitoring of known colonies may provide unreliable information if used to quantify changes in distribution. If all known colonies within an area become extinct, then that is circumstantial evidence of a contraction in the distribution. However, it may be that the lifetime of colonies in that area is short. Even if new colonies enter the scheme as they are discovered, it is not possible to ensure that new colonies are discovered at a rate that ensures reliable estimation of changes in distribution. For species whose colonies are predominantly in easily identified locations, such as houses, a sample survey might be implemented. For example, houses could be selected according to some random (probably multi-stage) sampling scheme, then checked each year, to determine whether they are being used (e.g. recording presence of emerging bats, or mailing a short questionnaire to householders, with a follow-up to determine species

where the householder indicates that bats are present). However, transect surveys are likely to prove more effective at quantifying changes in distribution.

8.5 IMPROVING RECORDING – FUTURE RECOMMENDATIONS

The project proved popular with many bat workers, both amateur and professional (comments from many quarters were that they were pleased that someone had shown an interest in their records and their work was going to be of use nationally). The maps will be published and made available to all interested parties.

In the immediate future it is hoped that these provisional maps will stimulate more recording to fill in the gaps so that future maps are more complete. In addition, it is hoped that a number of hollow circles will become filled as roosts are discovered.

By studying the maps conservationists can decide which areas to survey for best effect: for example, the northern edge of serotine bat distribution could be a fertile area to survey to see any population changes that may affect distribution, or the areas between concentrations of lesser horseshoe roosts could be areas where special conservation measures need to be taken to improve the habitat. Studying the maps also shows problems with some species such as Daubenton's bat and noctule bat in that they are regularly recorded across large areas of Britain but the roosts are rarely discovered. This highlights the sorts of problems that conservationists may need to concentrate on.

Recommendation 54: Publish the maps in Bat Atlas form and disseminate to bat groups to stimulate searches for roost and hibernation sites in all areas.

Recommendation 55: Aim to produce a new set of maps in ten years time to assist in identifying distributional changes.

This project highlighted a number of problems with the logistics of recording across the country: everything from

recorders going missing with all the records (in one case 20 years of hard-won records were completely lost) to new databases that could not be questioned by the group to extract the records. It is hoped that the usefulness of an easy-to-use data retrieval system operated regularly in each area will improve the way records are held and enable record transfer to a national database.

An approximate quantitative estimation could be obtained through measures of numbers of licensed bat workers and the relative size and activity of local record centres within each area.

Methods used to record distribution data require significant revision. As an interim measure, recommendations to improve the quality of records are:

Recommendation 56: Encourage bat groups to maintain records in a standard form that allows easy transfer to regional/national recording centres. The use of a standard recording package – Recorder 2000– should be encouraged. Such a system should conform to NBN recommendations.

Recommendation 57: Make a basic assessment of sampling intensity in different regions. Use this information to define recording targets for areas and thereby improve the evenness of recording.

Recommendation 58: Encourage groups to record sampling intensity measures and in the collation of data for any new maps, collect information relating to sampling intensity.

9: Analyses for conservation

9.1 ANALYSIS OF COUNTS AND TRENDS IN COUNTS

NBMP surveys assessing the abundance of bats produce data in the form of counts of either actual bat numbers or bat passes. Large numbers of sites with zero counts exist within some of these datasets, skewing data away from a normal error distribution pattern. In collecting data to assess trends it is critical that these data can be analysed in a robust way, and if they cannot then the design of how data are collected may need to be altered to accommodate alternative analytical techniques.

A frequently used method of analysing non-normal data, is to transform counts (using either a square root or log-transformation, adding a constant to all counts to avoid the problem of zero counts) and to apply standard linear modelling (route regression or ANOVA) with/without co-variables (see for example Blake *et al.* 1994, Walsh & Harris 1996a,b, Vaughan *et al.* 1997). Log-normal distributions are widely used for all sorts of population data and should in general be robust against minor departures from the distribution. Figures 9.1 and 9.2 show an example of the distribution of raw and transformed (log transform and square root transform) colony count data and bat pass count data collected in the NBMP lesser horseshoe bat colony and Daubenton's bat field monitoring schemes respectively. The distributions are shown for a single year (1999) and single count period. Distributions for hibernation count data (when sites where bats were never present are excluded) follow a similar pattern to the colony count distribution. Data for other similar colony and field schemes and other years or count periods follow the same basic pattern. Thus we are dealing with two basic distribution patterns.

Examining colony count data, transformation appears to produce a distribution of values not far from normal. Transformation to approximate normality followed by standard parametric analyses is therefore considered reasonably robust for NBMP colony and hibernation count data. Examining bat pass count data, a higher proportion of sites with zero counts are present, and the data still show a departure from the normal distribution after transformation. A reduction of sites with zero counts improves this, and can be achieved when examining trends in counts of field surveys by excluding sites where bats have never occurred. However, exploration of techniques with less strict assumptions about the distribution of the data may be more appropriate.

An increasingly popular tool for the statistical analysis of count data is Poisson regression, which is generalized linear modelling (GLM) with a Poisson error distribution and log-link function (McCullagh & Nelder 1989, Braak *et al.* 1994). The log link ensures that the fitted values are all positive, as counts must be. The Poisson error function takes account of

the data being integer and having variances that are equal to their mean. Counts of bats in colonies and bat passes analysed using Poisson regression display varying levels of overdispersion (Verboom 1998, Table 9.1 below). This may be because the underlying distribution is non-Poisson or because it does not allow for co-variables, such as temperature, which might influence the observed counts. Counts of bat passes are a mixture of counts of commuting bats, where each bat pass is different, and counts of feeding bats, where each bat pass may be the same or different bats flying over a different number of times, and thus the distribution is likely to be more complex. If dispersion is not too great, models can be re-scaled to allow for overdispersion, by estimating the dispersion parameter (quasi-likelihood method; see McCullagh & Nelder 1989). Alternatively it may be more appropriate to assume a different error distribution, such as a negative binomial error distribution. (see for example Wilson, Grenfell & Shaw 1996). For long sequences of counts, say over six years or more, the log linear assumption might be dubious, and a generalized additive model (GAM) – again with a Poisson or negative binomial error distribution and log link function – may be worth investigating (S. Buckland, pers comm.). The application of two-stage models to bat pass data may also be a useful approach. In this approach, presence/absence is firstly modelled as a binary process, followed by a GAM fitted to bat abundance conditional on presence. Time can be treated as a continuous variable and bat abundance modelled as a function of location, allowing greater flexibility for modelling spatial and temporal trends, and permitting the production of abundance maps with respect to spatial and other explanatory variables. A relatively new approach, of which there are few examples, is the use of mixed models (models with fixed and random explanatory variables), in which linear modelling is generalized to REML (Residual Maximum Likelihood). Verboom (1998) applied mixed models to log transformed counts of bat passes.

Most NBMP sites have had gaps, and are likely to have future gaps, in coverage from year to year. Gaps occur when observers are unavailable or if a completed survey is excluded from analyses due to quality problems. Trend analysis of the count data therefore requires care because of the relatively large amount of missing data. Simple yearly means can produce deceptive results, especially if data are missing from sites/routes with very high or low densities of the species being analysed (Gesissler & Saur 1990). Additionally, all schemes have had, and are likely to have, new sites/routes added and old ones discontinued, further adding to the problems of unbalanced data.

Any analysis of count data makes assumptions about variation in the proportion of animals counted. Temporal and spatial differences in the proportion of animals counted can lead to misinterpretation of differences in population size, and it is important that temporally or geographically varying

factors that affect counts are incorporated as covariables in the analysis of population parameters from count data (Link & Saur 1998). Determination of which factors significantly affect variation in counts is therefore required initially.

Recommendation 59: Continue efforts to determine the strengths and weaknesses of alternative methods of trend analysis. Organise a technical meeting to discuss appropriate methods.

9.1.1 Preliminary analysis of Welsh lesser horseshoe bat colony counts 1993, 1994, 1995

In preliminary analyses of three years of Welsh lesser horseshoe colony counts, a Poisson regression was carried out by Prof. Buckland, using GLIM (3.77, update two (copyright) 1985 Royal Statistical Society, London). Counts were overdispersed, with dispersion parameter around 4.4. In this case, year was entered as a factor at three levels, corresponding to years 1993, 1994 and 1995. In the models investigated, year failed to reduce the deviance significantly, so that these data do not provide evidence of any trend in numbers at the monitored colonies in the three-year period. If year is entered as a covariate, then a log-linear trend over time is assumed. This analysis yields an estimated annual rate of increase of 2.1% with approximate standard error of 2.8% and 95% confidence interval of (-3.3%, 7.5%). That is, the data are consistent with rates of change from a decline of 3.3% per annum through to an increase of 7.5% per annum.

In this particular analysis, only the maximum count from between one and four visits per year per colony was analysed. This maximum count seldom occurred in May, suggesting that there may be little benefit in counting these colonies before June. Trend might be better assessed by tak-

ing the mean count from visits in June say, although this may cause bias if some counts are carried out in unsuitable weather.

There was clear evidence that trends differed between colonies, necessitating inclusion of colonies as a factor at 58 levels. (Colonies for which there were no counts in the three years were excluded.) Given inclusion of this factor, there was no benefit to retaining vice counties as a factor.

9.1.2. Analysis of lesser horseshoe bat colony counts England and Wales 1993-1999

A second analysis of colony count data for lesser horseshoe was carried out in collaboration with Steve Langton, Central Science Laboratory, York. All analyses were conducted using Genstat Version5 (release 4, 1993).

Two approaches were used:

1. *An examination of co-varying factors affecting counts:* A mixed model (REML) was fitted, using square root transformed count data. Counts were used for all dates, thus there was more than a single count for each colony in each year.

2. *Trend estimation in counts:* Generalised linear models (GLM) were fitted to raw count data, and different models examined for estimating year-to-year change. Patterns between land classes and countries in trend were also examined. The maximum count from each colony in each year was used, thus there was a single count for each colony in each year.

Both approaches excluded counts where the reason for stopping was difficulty in counting due to confusing bat behaviour or deteriorating weather.

Table 9.1 Results of fitting log-linear models (GLM with log-link and Poisson error) to NBMP bat counts. Mean deviance is the ratio of the deviance to the number of residual degrees of freedom. Expected mean deviance is 1.00 if Poisson. p is the significance of difference from 1.00

Species	Data type	Years of data	Terms allowed for*	Mean deviance	p	Analysis by**
Daubenton's	Bat passes	1997,1998	Site (colony), year, and site.year interaction	8.50	<0.001	S. L.
Lesser horseshoe	Colony count	Eng+Wales 1993-1998	Site (colony), year, and site.year interaction	5.56	<0.001	S.L
Pipistrelle	Colony count	1997,1998	Site (colony), year, and site.year interaction	23.63	<0.001	S.L.
Lesser horseshoe	Colony count	Wales 1993-1995	Site (colony), year and site.year interaction	4.4	Sig.	S. B

* note: other terms were included in models such as date of count, then excluded due to non significance, however key terms were kept in the models

** S.L= Steve Langton, CSL, York. SB =Steve Buckland, St Andrews University, Scotland.

Figure 9.1 Transformation of lesser horseshoe bat colony count data. Percentage of sites with zero counts: 2.3%

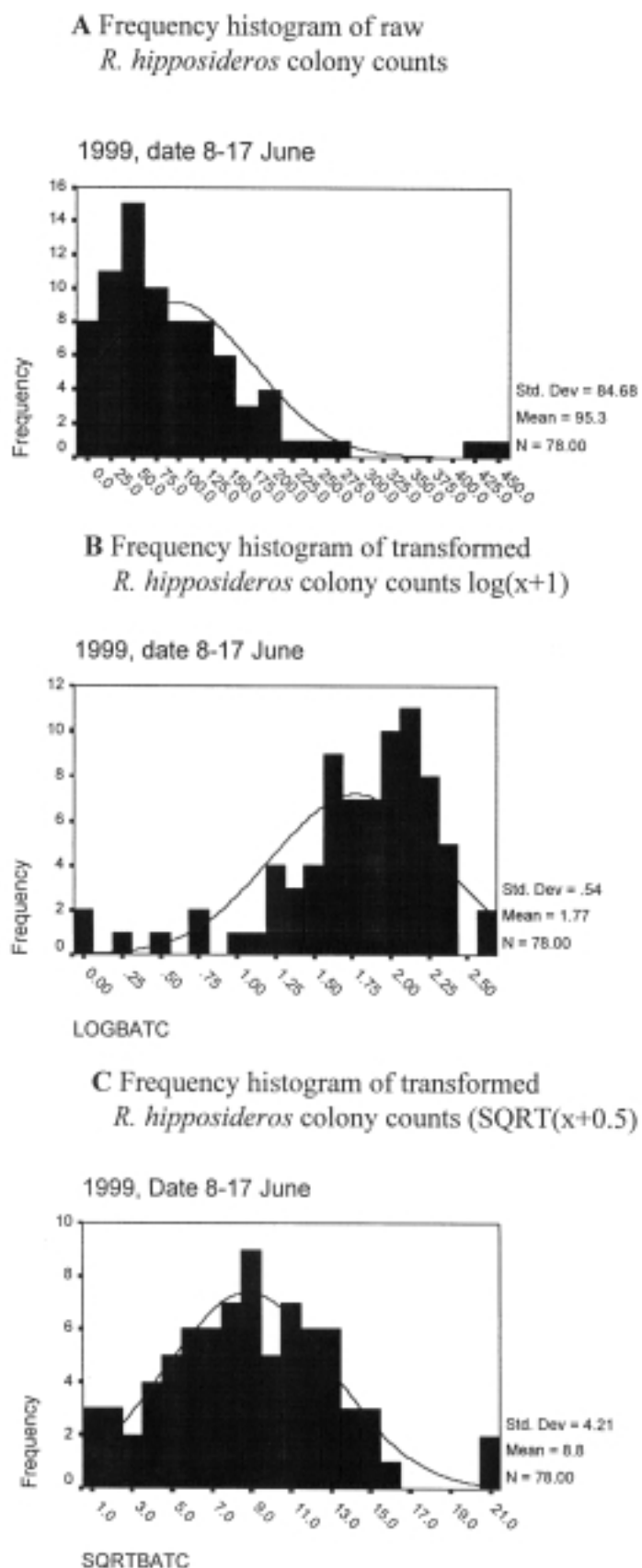
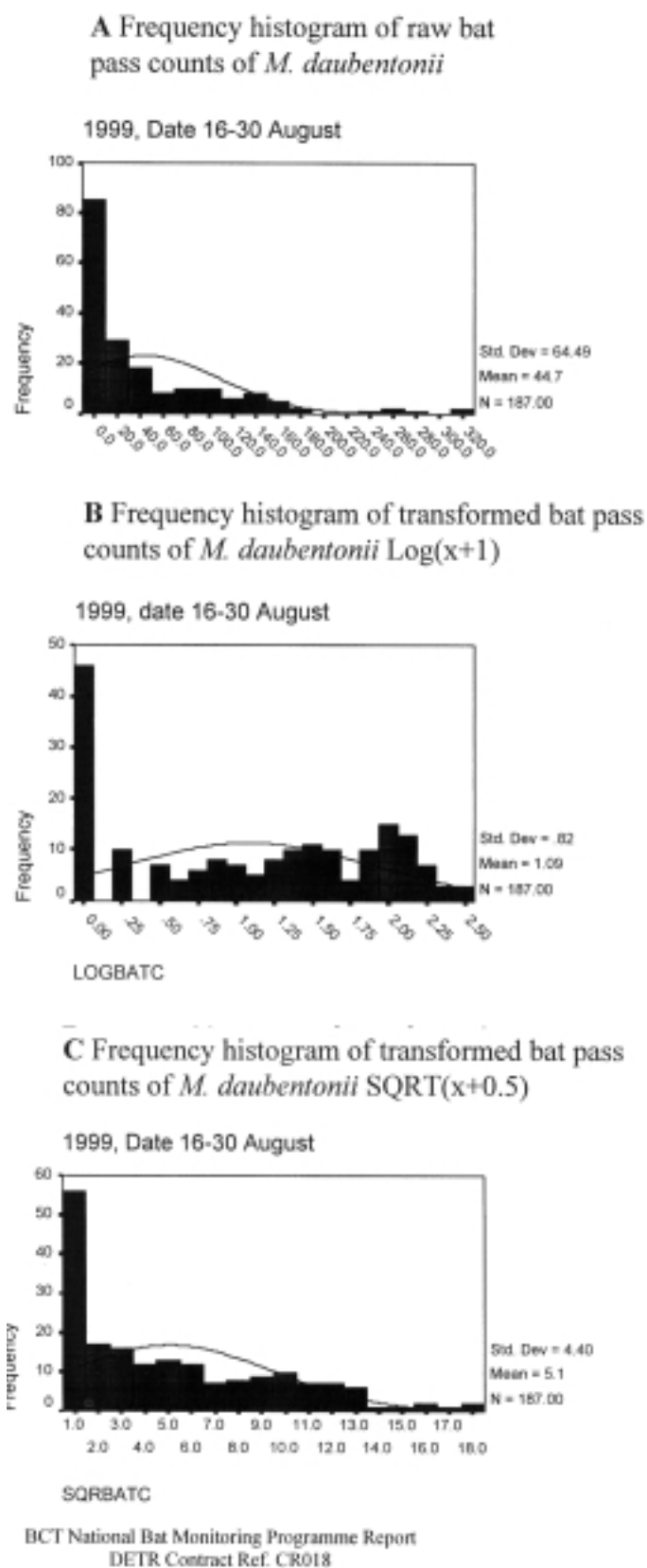


Figure 9.2 Transformation of Daubenton's bat pass count data. Percentage of sites with zero counts: 24.6%



9.1.2.a An examination of co-varying factors affecting counts: A mixed model (Residual Maximum Likelihood -REML)

In the REML model, three steps were involved in model specification:

1. Colony, year and their interaction, plus date as random effects were fitted.
2. A stepwise model fitting process was used to examine the other factors. Co-variables that were tried and were non-significant were county, roost type (e.g. house), environment zone, other species presence, weather variables: cloud cover, rain fall, wind speed, internal counts and reason for stopping the count. The number of bat exit points, region and bat detector use were all significant when originally tested, but were non-significant after allowing for significant terms: country, national land class and day number. Temperature was highly significant initially and borderline significant after fitting day number, but it was excluded from the final model as it has a very high number of missing values. Ordnance Survey northings and eastings were also tested in the model, but country remained significant, suggesting it is more than just a simple linear north/east effect.
3. The significant factors of country, national land class and date (day number within a year) were fitted in the final fixed model.

The magnitude of the random effects is given in Table 9.2, and the significance of the fixed effects in the final model in Table 9.3.

Table 9.2 Estimated variance components:
Random model: colony+year+colony.year+date

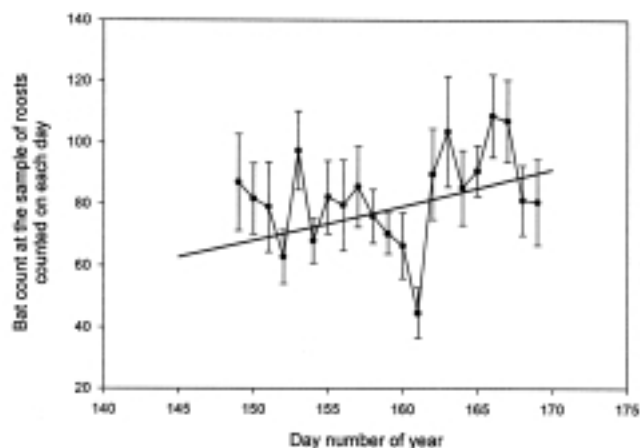
Random term	Component	se
Colony	9.5770	1.4141
Year	0.2321	0.1645
Colony.year	1.6715	0.1881
Date*	0.0847	0.0494
Units	0.9866	0.0827

*Where date has a different value for each survey date in each year.

Table 9.3 Wald tests after a REML analysis for the fixed model: constant + country + national land class + day no.

ChiSq	DF	Prob.	Term
4.61	1	0.032	Country
28.09	17	0.044	National land class
81.76	1	0.000	Day no. (Day number within a year)

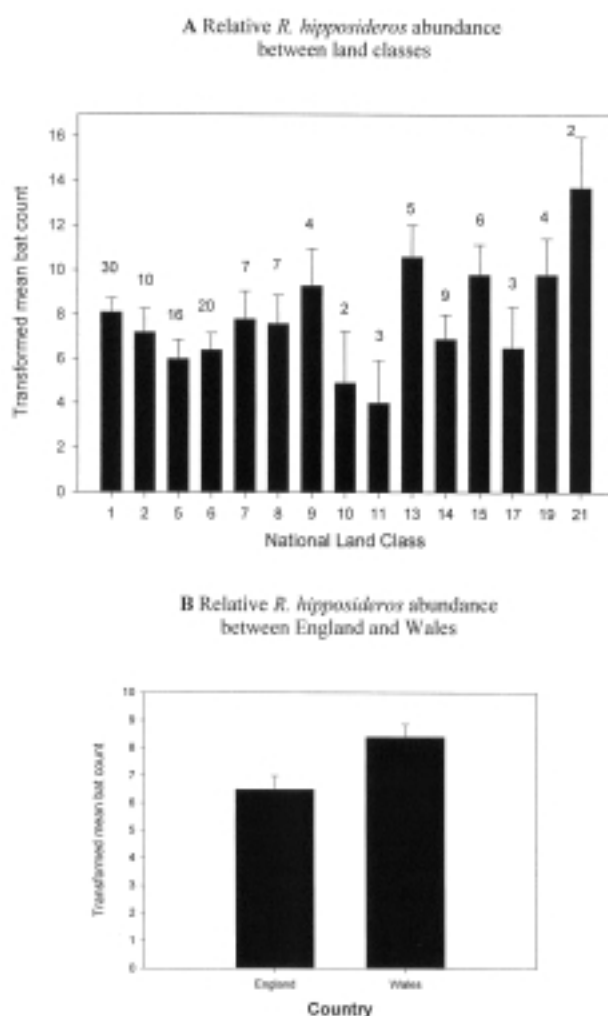
Figure 9.3 Relationship between date and bat count with REML fitted line



As would be expected the colony component is by far the largest, and even the rather small date component is reasonably large compared to its standard error.

The day number effect seems to be adequately described by a simple linear effect (Figure 9.3) – neither polynomials nor a spline model (a generalised additive model) – improve the model fit significantly. There is a lot of random variation but on average the means increase with time.

Figure 9.4 Relative *R. hipposideros* bat abundance



The effect of country and land class are shown in plots of the transformed means (Figure 9.4)

REML Model Conclusion

Country, land class and date all significantly affect variation in lesser horseshoe bat counts. These factors should be incorporated as spatially and temporally varying factors into trend estimation models where appropriate.

9.1.2.b Trend estimation in counts: Generalised linear models (GLM)

Examining trends in counts using GLMs with log-link and Poisson error distribution gave results indicating that models were still heavily overdispersed. The use of a negative binomial error function instead of Poisson, reduced overdispersion, and was used instead.

Different models were used to examine year-to-year change. Models tested used: a factor with a level for each year (which therefore fits each year perfectly), a linear trend, a polynomial trend and a GAM-type spline. Land class and country were included as covariates in the models but made no significant difference to the model fits, since a highly significant term for site which takes out land class and country effects was included. Day number was not included because the GLM models are fitted to the maximum count and so there will not be the same simple relationship with day number.

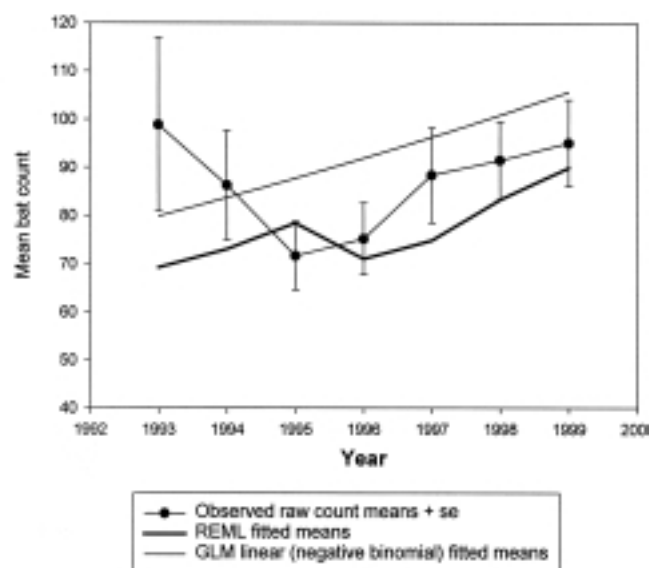
Polynomials and the GAM gave similar results and they are both a slight improvement over the simple linear fit, however the improvement is not significant ($F=1.86$, $2, 320$, $p=0.157$). The factor approach also gave no improvement and was similar to the GAM approach.

In many ways, the GAM model approach is best and most flexible, but on statistical grounds a linear model is adequate and thus the results of this model are presented. While the linear model is likely to be an oversimplification, it is more easily interpreted.

The linear trend GLM model (applied to seven years of lesser horseshoe colony count data 1993-1999), significant differences were found between years. If year is fitted as a factor with six degrees of freedom, year effects are very highly significant ($F=4.18$ with six and 317 d.f., $P<0.001$, note: F-tests rather than χ^2 were used as the model is slightly overdispersed).

The observed raw bat count means and their standard errors, fitted means from the generalised linear model with

Figure 9.5 Predicted means compared with raw means



linear trend and negative binomial error distribution, and the back-transformed fitted means obtained in the previous REML are shown in Figure 9.5 for comparison. Raw means and fitted negative binomial means are based on the maximum of each pair of counts, whereas the REML means use all observations and are therefore lower.

If a linear trend is fitted across all years, the fitted negative binomial model gives an annual increase in the population of 4.8% (95% confidence interval from 2.6% to 6.9%). If however, the upward rate of the fitted negative binomial means for 1997-1999 are examined, the rise during this period is equivalent to around 9% per year. Further, if the model is just fitted for those years (1997-1999), then the annual increase, corresponds to an 11.4 % increase. (95% confidence interval from 5.3% to 17.8%). (see Table 9.4)

The final stage in any model fitting process is to compare the predicted means estimated from the model with the raw means from the real dataset. Examining these in Figure 9.5, there is a marked difference between the pattern of the observed raw means from the real dataset and the predicted means estimated from the GLM and REML models. All three sets of means agree on the rise from 1997-1999 however.

The observed means show a decline over the first three years (1993 to 1995), and while the fitted means indicate an overall rise in the population, the observed mean count in

Table 9.4 GLM linear trend (negative binomial) model coefficients

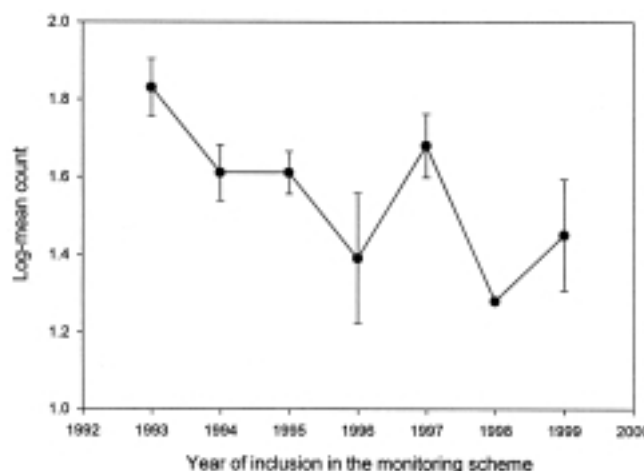
Years fitted	Year coefficient	se	coefficient antilog	se antilog	% rate of change (se)	95% confidence interval
1993-1999	0.0466	0.0105	1.0477	1.0105	+4.8% (1.1%)	2.6 % – 6.9%
1997-1999	0.1081	0.0286	1.1142	1.029	+11.4% (2.9%)	5.3% – 17.8%

(df is 300+, thus 95% confidence intervals are 1.96 *se in either direction)

1993 was higher than in later years. If the log-mean of the colony in the year it joined the study is tabulated against year of joining, there is a significant linear decline ($F=8.48$, $p=0.004$), suggesting that the colonies included at the start were on average larger ones, with smaller ones being incorporated into the monitoring scheme later (Figure 9.6). This gives the reason for the discrepancy between raw and fitted means – the raw mean in 1993 is high because the programme started with relatively large colonies, whereas later raw means are lower because they include lots of smaller colonies that were incorporated later. It also demonstrates that care should be taken when interpreting simple raw means of counts, since they may give a distorted picture of the overall trend.

Both the GLM and REML models include terms for individual colonies. This effectively means that they work out trends by examining changes within colonies. Thus a colony monitored from 1993–1997 provides evidence on changes in that period, whilst one monitored from 1995–1999 gives evidence for changes in the later years. The models then

Figure 9.6 Log mean against year of joining



integrate this information from individual colonies to provide the overall trend over the whole period. Because the models examine changes within colonies in this way, trend estimation should not be affected by non-random colony selection to as great an extent as might be thought. As representative a sample as possible is desirable but not critical. Thus the findings about sizes of new colonies included in the monitoring scheme over time does not in any way invalidate either of the models – they already allow for it.

To investigate whether the pattern of trend over time differed between national land classes or countries, interactions between these factors and the linear component of year were added to the models (using both the GAM and linear trend approach). After allowing for the interactions, the improvement in fit of a non-linear model (polynomial or GAM) becomes closer to significance ($F=2.78$, $p=0.064$). However, results for the linear fit model are presented here in keeping with the previous results. The interaction between the trend and either country or national land class are both significant in the models. However, the interactions seem to relate only to the linear component (i.e. the year-to-year pattern is basically the same but with different linear trends for different countries or land classes). In the case of country interaction, which is highly significant ($F=11.15$, $p<0.001$), England has an overall linear trend which is slightly downward, whereas Wales is upward (Table 9.5).

The interaction with national land class is also highly significant ($F=3.45$ with 17 and 302 d.f., $p<0.001$, after allowing for the country interaction), with land classes 7, 14, 17 and 21 showing the biggest positive trend and 11 showing the biggest negative (Table 9.6). However, sample sizes are very small for most land classes, and results in Table 9.6 should be treated with extreme caution.

Land classes 1, 5 and 6 fall into lowland pastoral areas of England/Wales and show only low levels of increase or decreases. Land class 2 falls into lowland arable in England/Wales and shows a marked increase.

Table 9.5 GLM linear trend (negative binomial) model coefficients for country-trend interaction. Rates of decline or rise when the model is fitted without national land class are given

Interaction with year	coefficient	se	coefficient antilog	se antilog	% rate of change (se)	95% confidence interval
England	-0.0321	0.0266	0.9684	1.0269	-3.2 (2.7)	-8.1 – +2.0
Wales	0.0597	0.0112	1.0615	1.0112	+6.2 (1.1)	3.8 – 8.5

Table 9.6 GLM linear trend (negative binomial) model coefficients for national Land Class-trend interaction. Rates of decline or rise for land classes with sample sizes (n) of ten or above colonies are given

Interaction with year	coefficient	se	coefficient antilog	se change (se)	% rate of interval	95% confidence interval
LC 1 (n=30)	-0.0216	0.0215	0.9786	1.0217	-2.1 (2.2)	-6.2 – +2.1
LC 2 (n=10)	0.0686	0.0659	1.071	1.068	+7.1 (6.8)	-5.2 – +21.1
LC 5 (n=16)	.0154	0.0405	1.0155	1.0413	+1.6 (4.1)	-6.2 – +9.9
LC 6 (n=20)	0.0060	0.0231	1.006	1.0233	+0.6 (2.3)	-3.9 – +5.3

GLM (linear fit, binomial error) Model conclusion

Analysis of seven years of lesser horseshoe colony counts (1993 to 1999) indicates that there has been a significant overall rise in the total population of around 4.8% (between 2.6% and 6.9%). The upward trend in the population is mainly due to a rise of around 11% over the previous three years (1997 to 1999). Differences exist between the English and Welsh populations; an overall decline of around 3.2% (between a decrease of 8.1% and an increase of 2.0%) is evident in the English population, in contrast to a 6.2% rise (between 3.8% and 8.5%) in the Welsh population from 1993 to 1999. These figures are tentative, because the upward trend does not follow a wholly linear pattern and the time span over which trends have been examined is relatively short. A longer run of data is needed to establish whether these trends are sustained.

9.2 ASSOCIATIVE HABITAT AND DISTRIBUTION ANALYSES

The main purpose of NBMP is to provide representative monitoring data for a range of bat species across the UK. The objective is to use these data to inform and influence conservation decisions, both regionally and nationally. One of the major factors influencing bat populations is changing land use – a critical question therefore is how to relate bat population and distribution data to habitat data, and at what scale, in order to inform, influence and predict the outcome of land management policies. The most commonly used approach is to attempt to link collected distributional and abundance data to measures of habitat and other environmental factors that are considered potential drivers of change. Once a formal mathematical link has been identified, this can be used to predict distributions elsewhere and environmental change scenarios.

9.2.1 Habitat recording: GIS and scale dependency

In many studies, habitat recording is conducted alongside the collection of population data. The benefits of ground-collecting of habitat data alongside population data has been demonstrated in bird monitoring schemes by the BTO (see for example Gregory and Baillie 1998). However, the expense and logistical problems of conducting exhaustive habitat surveys need to be weighed against the benefits, and alternative solutions considered, such as utilising extant habitat data for sites available through other strategic monitoring schemes.

Geographical Information Systems (GIS) have been used in many studies of animal and plant conservation. GIS can be regarded as the high-tech computerised equivalent of the map. The systems store spatially referenced information, such as habitat cover information, and enable users to relate information from different sources to model and predict animal distributions and the likely impact of any habitat change. Through a function known as visualization, a GIS can be used to produce animated images of observed and modelled changes over time. The primary requirement for all source data to be fed into a GIS is that the spatial location

of each variable is known. Thus many different forms of habitat and animal data – ground collected data, data scanned in from maps or digital data from satellite images – may be stored and analysed.

The distribution of bats has been investigated on a large-scale, at the land class level, in Great Britain (Walsh & Harris 1996) and these data have been used to derive general management prescriptions at the land class level. However, the distribution of bats in the landscape is dependent upon an interaction of processes operating at many different scales. Work in Wharfedale in North Yorkshire (Waters *et al.* Submitted ms.) has shown that bat distributions can be predicted from habitat features as small as individual trees. A critical question is therefore at what scale of habitat information can bat distributions be accurately predicted and hence used for specific management prescriptions. Configuration of habitat features locally may be just as important to bats as a simple quantitative measure of habitat availability.

Three main options for associating bat population and habitat data exist:

1. Simultaneous ground habitat data collection
2. Integration of monitoring sites with extant ground-collected habitat data
3. Integration of monitoring sites with extant map-derived habitat data

9.2.1.a Simultaneous ground habitat data collection

In NBMP surveys, habitat data may be collected by the volunteers carrying out the surveys. The main restrictions to field data collection imposed by volunteers are:

- Habitat definitions of a complex nature are generally not discernible by volunteers, and only basic habitat types may be recorded.
- Invariably, changes recorded are either due to the change in the observer or simply mistakes and incorrect estimations on a second survey. In a study examining inter-observer variation in the application of standard Phase 1 habitat survey mapping, professional ecologists surveying the same area produced widely differing results. Habitat types recorded ranged from 13 to 21 types, and the agreement between all surveyors regarding the area covered by different land types was only 7.9% of the study site. (Cherrill & McClean 1999). This is a complex habitat mapping survey, however the reliability of the surveys was inadequate at a basic classification level, and therefore it seems unlikely that volunteers will record habitats and changes in habitats accurately (unless they are very simple habitat classifications).
- Recording of habitat is time-consuming. A full habitat map of a site may deter volunteers recorders, who do not have enough spare time to carry out such a survey.

In all NBMP survey schemes, two trial systems for ground habitat data collection have been implemented:

- Initially, volunteers were requested to tick boxes of habitats present at their sites. A selection of 30 habitats were listed, and volunteers were also requested to circle the dominant habitat. For each scheme, some individual habitat features relevant to the scheme were recorded e.g. amount of smooth water in the Daubenton's survey
- All data were collected at the 1km square level
- In analysing trends, this data could be used to split groups of sites into a few broad categories, such as sites with or without woodland and water present
- However, the majority of volunteers failed to circle the dominant habitat type
- Part way through the NBMP, field surveys for the new Countryside Survey 2000 were started
- In an attempt to standardise NBMP habitat-data collection with the strategic monitoring by CS2000, the system of habitat data collection was changed for one scheme as a second trial (the pipistrelle colony scheme)
- In this system, volunteers were provided with a description of the 17 broad CS2000 habitats. Volunteers were asked to fill in a box with a simple measure of % cover of the major habitats present (of which there are generally one, two or three) and record only the presence/absence of habitats with very low coverage or linear habitats
- In both trial systems, habitat data were not collected at the individual bat recording points/segments along transect routes, because it was considered too time-consuming to enter such fine detailed information
- Part way through the NBMP, the decision was taken to halt the inputting of all habitat data and prioritise inputting of count and survey data. This was due to the lack of funds, insufficient staff available for data entry, the lack of time available for analysis of such data, and the general poor quality level of the data being collected

9.2.1.b Integration of monitoring sites with extant ground collected habitat data

- In a third habitat system trial, an informal collaboration was established with the Environment Agency team in charge of the River Habitats Survey (RHS). Sites selected for the Daubenton's bat field survey were sites included in the RHS, which holds detailed habitat data and water quality data for over 4,000 river sites. RHS sites were used in the second and third year (1998 and 1999) of the Daubenton's bat waterway survey
- The intention was to extract habitat and water quality

data from the RHS database to integrate with the bat data and produce detailed habitat-distribution models

- Progress on extracting data from the RHS database has been hampered by its unavailability. However, an informal exchange of data was organised with EA staff, and collaborative work to produce habitat models is ongoing

9.2.1.c Integration of monitoring sites with extant map-derived habitat data

Integration with strategic habitat data on a 1km square level is likely to be a cost effective and accurate way of identifying broad habitat changes in the long-term. Volunteers would no longer have to decipher between habitat types or measure % cover changes. Data capture, putting the information into the system, is the most time-consuming and high-cost component of using GIS

The main drawback with using GIS data may be the scale at which data can be extracted and used. Certain habitat features may be of scale significance to bats and may be important drivers of distributional and population change. They may also be confounding factors that need accounting for in estimates of trend. These features may be accurately recorded by volunteers on a local bat recording point scale, e.g. features such as individual trees, linear connections close to colony/hibernation sites, tree cover along waterways

Recommendation 60: Assess GIS needs and spatial referencing of NBMP survey routes/sites. Assess GIS habitat data and scale of data available, the costs-benefits of data capture and the potential of a central GIS for use by all mammal monitoring programmes.

9.2.2 Predictions using CIS

The Countryside Information System (CIS) is software commissioned by the DETR, which allows map display and analysis of environmental data, summarised by 1km square of the National Grids for GB or Northern Ireland. CIS is equivalent to a GIS – in that spatially referenced census data are stored – however, it does not have the advanced modelling analytical capabilities of most GIS. It may be used to produce comparative and overlay maps, and data may be extracted from the system and imported into a statistical package for use in distribution modelling.

Data from species maps can be used to model habitat occupancy, that is, presence in or absence from 10x10km grid squares using information on climate and land use extracted from CIS or other external data set sources (see for example with birds, Gates *et al.* 1994, Gibbon's *et al.* 1995). Data consisting of means and variances of bat abundance can be used to plot distribution maps. However, time limitations and prioritisation of trend analysis has meant that little work has been done using CIS to date.

10: Programme evaluation and future directions

10.1 PROGRAMME ACHIEVEMENTS 1996–2000

The NBMP is best placed to become the primary source of trend information for bats in the UK. In order to monitor the performance of the programme and assist in future developments and improvements, it is important to review the achievements and scientific quality and operations of the NBMP at this stage of its development.

In fulfilling the requirements of a monitoring programme, the NBMP depends on effectively balancing the immediate need for information to guide management with the need for technical improvements and long-term strategic information to understand and predict emerging patterns and trends in bat populations. There is no doubt that full and effective implementation of a monitoring programme for bats requires considerable improvements in our knowledge and understanding of bat populations. Accordingly, it is essential that schemes are supported by research projects so that they can be improved and assessed as new scientific knowledge is obtained. It is also essential to put in place adequate mechanisms to ensure that the results of monitoring and research are rapidly disseminated and incorporated into current and future management actions.

The primary achievements of the NBMP's first phase 1996–2000 are set out in relation to key progress markers defined in the original contract (Table 10.1).

10.2 SCIENTIFIC QUALITY AND RESEARCH RECOMMENDATIONS

Scientific strengths of the NBMP include standard data-collection protocols, stratified random sampling schemes and extensive geographic and species coverage. The primary scientific function of the NBMP is to establish a national co-ordinated programme of long-term ecological monitoring to detect patterns of change and to understand the causes and impact of such change. As such, the NBMP will act as a basis for assessing multidisciplinary ecological research to support monitoring techniques and improve our understanding of long-term and event-driven processes.

In each chapter of this report, discussion of the scientific quality of the programme methods, their strengths and problem areas are discussed and resultant recommendations for areas of improvement listed. These have been drawn together and organised by general area of activity below. Numbers against the recommendations given here refer to individual or groups of recommendations as they appear elsewhere in the text of this report. Consideration should be given to prioritising these recommendations and setting time

limits within which results of the recommendations are expected.

10.2.1 Bat biology and monitoring technology issues

Research in the following areas would assist in improving the reliability of monitoring data and advancement of future monitoring methods:

- Review progress of autecological studies on swarming within the next two years to assess its potential as a national survey and monitoring or surveillance technique. (Recommendation 3, Chapter 2)
- Review the advances made in automatic recording devices in the past few years to assess whether reductions in cost and improvements in technology have made the use of such equipment a feasible option. (Recommendation 4, Chapter 2)
- Promote the steerage of bat detector technology developments towards improving standardisation of data, wider multi-species capabilities and assisting confident field identification either through active or remote field operation or later analysis. (Recommendation 5, Chapter 3)
- Start developing a broad band multi-species field survey protocol. (Recommendation 6, Chapter 3)
- Develop better techniques of locating bat colonies in trees / other non-building habitats and surveying for woodland bat species. (Recommendations 7, 8, Chapter 2)

10.2.2 Programme planning – methods/protocols

Implementation of the following recommendations would assist in meeting monitoring targets for the species currently included in the NBMP as presented in Table 10.2. Non-target species should be incorporated over the next five or more years as in Table 10.3.

10.2.2.a Maternity colony roosts

- No major changes to the maternity colony count protocols are recommended. If feasible, guidelines should be issued on the training of inexperienced observers, which should include some counts made in the presence of an experienced observer.

(Recommendation 22, Chapter 4)

Table 10.1 Progress against key markers

Original progress marker	Progress against original set markers
"Efficient monitoring methods designed for each selected species".	○ Achieved. Three key monitoring methods have been developed and implemented by a volunteer network following standardised protocols ○ Sampling designs of surveys have been formally assessed using power analysis. ○ All eight selected species are currently being monitored annually using one or more methods.
"Baseline data for each selected species"	○ Achieved. Baseline monitoring data have been collected for all eight selected species. ○ For some species, baseline data have been collected using two different methods to allow comparison in method accuracy.
"Improved distribution maps for each selected species"	○ Achieved. Up-to date 10km2 records have been collated from bat groups and other record sources in conjunction with the Chairman of BCT. ○ Distribution maps have been produced for all eight selected species, and in addition for all other UK species. ○ A Bat Atlas will be published and distributed to provide feedback to bat groups and other recorders.
"Identification of methods suitable for monitoring other species of bat"	○ Achieved (given current technological restrictions). The potential application of current methods and development of new monitoring methods for species currently not targeted has been summarised.
"Timetable in which selected species should be monitored over the long-term"	○ Achieved. Continuous annual survey regimens are recommended for all selected species to maintain volunteer continuity and the statistical power of the survey results. ○ Mechanisms for integrating non-target species into the programme over the short and long-term have been proposed. Monitoring objectives for target and non-target species have been proposed. ○ A 5-year (2001-2005) project timetable has been proposed.
"Costed options for monitoring each selected species. Costed options for a national monitoring strategy for all resident species"	○ Achieved. During the course of the programme it was evident that costing surveys on a species-by-species basis was inappropriate. Thus the fixed costs for core survey delivery, plus additional costings for inclusion of additional non-target species and associated research and development study costs have been estimated.
"Draft data model and data catalogue for database"	○ Achieved. A customised Access database (Bat Survey Database) has been developed and data model produced in conjunction with Blue-Bag Ltd. ○ The JNCC has issued a contract (2001) to investigate and improve data transfer capabilities.
"Draft data usage and exchange agreements for key suppliers and users"	○ Partly achieved. A data usage and exchange agreement was drafted in 1997. A formal review and updating of this agreement is needed.
"Preliminary analyses of environmental factors affecting bat distribution and abundance"	○ Achieved to a significant extent. Analysis of land class, weather and other factors affecting maternity colony counts of lesser horseshoe bats has been undertaken as a case example. Further analyses incorporating additional environmental factors are underway.
Additional BCT progress markers	Progress made beyond original set objectives
A countrywide network of skilled volunteers and training techniques to support recorders.	○ Achieved. Recruitment of over 800 active volunteers has been reached. ○ A rigorous skills training programme of over 60 talks and bat identification workshops has been conducted making use of new training techniques and resources.
Initial trend results from monitoring schemes.	○ Achieved. A statistically significant trend in lesser horseshoe bat populations has been identified, demonstrating the efficiency of the NBMP.
Greater awareness of UK bats and their conservation needs.	○ Achieved to a significant extent. Implementation of the NBMP has involved collaboration with a wide range of other organisations. There has been widespread publicity about the project and results have been disseminated via conferences, meetings and articles in newsletters.

- Experiments of simultaneous but independent maternity colony counts carried out by a second observer to assess accuracy and precision. A project using an infra-red imager, or any other aid to help achieve a more accurate 'true' count at a sample of sites would be of value.
(Recommendation 23, Chapter 4)
- Assess the relationship between the sample of colonies counted to that occurring in nature and of the movement of colonies and the formation of new colonies.
(Recommendation 24, Chapter 4)
- Continue parallel bat detector transect surveys for all roost-monitored species where applicable until trends between the two monitoring schemes can be compared.
(Recommendation 25, Chapter 4)
- Develop and test a stratified dawn transect survey to locate bats swarming on their return to maternity roosts at dawn. This will provide: 1) incorporation of new roost discovery into roost sampling monitoring schemes already in place; 2) location of roosts of less obvious species; 3) location of better samples of tree-roosting bats.
(Recommendation 26, Chapter 4)
- Investigate all sources of data (summer roost and winter hibernation) collected for the greater horseshoe bat, and propose a way forward for national collation of data.
(Recommendation 44, Chapter 5)

10.2.2.b Hibernation sites

- Encourage the monitoring of smaller hibernation sites and their rate of loss within the sampling strategy.
(Recommendation 27, Chapter 4)
- Some measurement of the relationship between numbers of bats visible and numbers of bats actually present in hibernation sites is needed, but is very difficult to

achieve. Explore the potential of using endoscopes to search for hidden bats.
(Recommendation 28, Chapter 4)

- Measure dispersal of bats between hibernation sites through long-term research studies.
(Recommendation 29, Chapter 4)
- Initiate detailed autecological studies of factors affecting numbers of bats in hibernation sites.
(Recommendation 30, Chapter 4)

10.2.2.c Bat detector field surveys

- Initiate experiments with independent, simultaneous counts by different observers to assess observer differences in estimating numbers of bat passes and species identification success and assess observer accuracy in identifying species.
(Recommendation 31, Chapter 4)
- Initiate experiments to measure detectability of bats in different habitats should be attempted or site habitat included as a covariable on trend models.
(Recommendation 32, Chapter 4)
- Further statistically assess the data collected in the NSP survey scheme, and consider making changes to the protocol to improve data quality. However, benefits must be large to outweigh the benefits of retaining the present protocol and thus maintaining the current baseline.
(Recommendations 33, 34, Chapter 4)
- The use of heterodyne detectors should be retained until absolutely proven that gradual phasing in of new technologies will not confound factors. The phasing in of new bat detector technology should be gradual and any changes in the monitoring protocol design made at the same time. In this way, all sites may be analysed together

Table 10.2 Targets and Mechanisms for current NBMP target species

Species	Target	Mechanism
<i>Rhinolophus ferrumequinum</i>	Detect population change at minimum level of 25% over 25 years. Meet BAP workplan requirements.	Centralise and unify current monitoring data from summer and winter roosts.
<i>Rhinolophus hipposideros</i>	Detect population change at minimum level of 25% over 25 years. Meet BAP workplan requirements.	Centralise and unify current monitoring data from summer and winter roosts.
<i>Myotis daubentonii</i>	Detect population change at level of 25% over 25 years.	Maintain NBMP targets of sites/counts for field and hibernation survey.
<i>Myotis nattereri</i>	Detect population change at level of 50% over 25 years.	Maintain hibernation site monitoring; develop summer [roost] monitoring.
<i>Pipistrellus pipistrellus</i>	Detect population change at level of 25% over 25 years. Ref to BAP workplan.	Assess distribution and abundance in relation to <i>P. pygmaeus</i> . Maintain summer roost and field monitoring.
<i>Pipistrellus pygmaeus</i>	Detect population change at level of 25% over 25 years	As for <i>P. pipistrellus</i> .
<i>Eptesicus serotinus</i>	Detect population change at level of 25% over 25 years	Maintain and increase summer roost and field survey participation.
<i>Nyctalus noctula</i>	Detect population change at level of 25% over 25 years	Maintain summer field monitoring, increase summer roost monitoring. Initiate mating roost monitoring.

with covariates to adjust for the change in design.
(Recommendations 35, 36, Chapter 6)

- Calibration of all different detector types being used in the NBMP should be carried out regularly, and weighting factors incorporated into trend estimation models to account for sensitivity differences. Sensitivity tests of the detectors can be carried out in the field and in the laboratory (see Waters & Walsh 1994).
(Recommendation 37, Chapter 6)

10.2.2.d General sampling design for monitoring schemes

- At this stage, no reduction in count number or reduction in survey frequency between years is recommended, and all schemes should remain annual with two counts.
(Recommendation 50, Chapter 7)
- Ensure a core sample of 30–40 sites for each survey are consistently covered from year-to-year to enable UK estimates of trend. This may require payment to surveyors.
(Recommendation 52, Chapter 7)

- It is important to state that at this stage, all power analysis results are preliminary. Further power analyses should be carried out when more data are available from different years to re-assess required sample sizes and survey designs.
(Recommendations 51, 53, Chapter 7)

10.2.2.e Integration of non-target species into the programme

- Initiate a maternity colony monitoring and field survey scheme for Leisler's (*Nyctalus leisleri*) bat in Northern Ireland, within the next two years.
(Recommendation 1, Chapter 2)
- Initiate a UK maternity colony monitoring scheme for the brown long-eared bat (*Plecotus auritus*), within the next two years.
(Recommendation 2, Chapter 2)

Table 10.3 Targets and mechanisms for population monitoring of species not currently targeted by the NBMP

Species	Target	Mechanism
<i>Myotis bechsteinii</i>	Develop appropriate monitoring methods and sample size Ref BAP workplan	Maintain and enhance current relevant autecological studies. Maintain centralised database of records
<i>Myotis brandtii</i>	Detect population change at level of 50% over 25 years. See <i>M. mystacinus</i>	Hibernation sites (where generally not separated from <i>M. mystacinus</i>), initiate summer roost monitoring, develop broadband field survey
<i>Myotis myotis</i>	Maintain 'surveillance'	Maintain centralised record of occurrence in UK
<i>Myotis mystacinus</i>	Detect population change at level of 50% over 25 years	As <i>M. brandtii</i> .
<i>Pipistrellus kuhlii</i>	Maintain 'surveillance'	Maintain centralised record of occurrence in UK
<i>Pipistrellus nathusii</i>	Maintain 'surveillance'. Assess potential for survey	Maintain centralised record of occurrence in UK. Survey to establish summer status, distribution and abundance, develop broadband field survey, develop mating roost protocol
<i>Pipistrellus savii</i>	Maintain 'surveillance'	Maintain centralised record of occurrence in UK.
<i>Eptesicus nilsonii</i>	Maintain 'surveillance'	Maintain centralised record of occurrence in UK
<i>Vespertilio murinus</i>	Maintain 'surveillance'	Maintain centralised record of occurrence in UK
<i>Nyctalus leisleri</i>	Detect population change at level of 50% over 25 years	Initiate summer roost/field monitoring in Northern Ireland
<i>Barbastella barbastellus</i>	Detect population change at level of 50% over 25 years	Ref BAP workplan. Develop broadband field survey. Maintain centralised record of occurrence in UK
<i>Plecotus auritus</i>	Detect population change at level of 25% over 25 years	Initiate summer roost monitoring.
<i>Plecotus austriacus</i>	Assess range and abundance and potential for monitoring	Review available data. Maintain centralised record of occurrence in UK. Check <i>Plecotus</i> roosts within known range of <i>P. austriacus</i>

10.2.3 Distribution mapping

Distribution maps should be published at regular intervals to identify changes.

- Publish the maps in Bat Atlas form and disseminate to bat groups to stimulate searching for roost and hibernation sites in all areas. Aim to produce a new set of maps every ten years to assist in identifying distributional changes.
(Recommendations 54, 55 Chapter 8)
- Encourage bat groups to maintain records in a standard form that allows easy transfer to regional/national recording centres. The use of a standard recording package (Recorder 2000) should be encouraged. Such a system should conform to NBN recommendations.
(Recommendation 56, Chapter 8)
- Develop a process for estimating sampling intensity in different regions to improve map interpretation.
(Recommendations 57, 58, Chapter 8)

10.2.4 Trend and habitat/distribution analyses

- Continue efforts to determine the strengths and weaknesses of alternative methods of trend analysis. Organise a technical meeting to discuss appropriate methods.
(Recommendation 59, Chapter 9)
- Assess GIS needs and spatial referencing of NBMP survey routes/sites. Assess GIS habitat data and scale of data available, the costs-benefits of data capture and the potential of a central GIS for use by all mammal monitoring programmes.
(Recommendation 60, Chapter 9)

10.3 STRATEGIC MANAGEMENT/RECOMMENDATIONS

The support of a large volunteer workforce motivated only by their enthusiasm, while maintaining the production throughput needed for operational effectiveness, is a demanding task critical to the success of the NBMP.

In each chapter of this report, programme management issues are discussed and resultant recommendations for areas of improvement listed. These have been drawn together and organised by general area of management activity below. Numbers against the recommendations given here refer to individual or groups of recommendations as they appear elsewhere in the text of this report. Consideration should be given to prioritising these recommendations and setting time limits within which results of the recommendations are expected.

10.3.1 Volunteer network and field work organisation

The availability of a volunteer network of adequate size and

quality is essential to the continued success of the NBMP. There is a clear need to promote interest and enthusiasm among volunteers, both to recruit new volunteers and to retain experienced volunteers. Successful promotion and recruitment has already been achieved during the first phase of the NBMP, and it is recommended that the practices already in place be continued. In addition the implementation of the following recommendations would be of value:

10.3.1.a Recruitment, publicity, maintenance

- Invest in marketing, publicity and recruitment in order to maintain and expand the NBMP volunteer network to ensure adequate geographical coverage. The BCT has identified that there is a large demand from the general public to take part in the surveys. Resources are required to tap into the demand and to build on the services offered to the volunteers – to become more customer focused. Areas of low volunteer density should be targeted.
(Recommendation 9, Chapter 3)
- A periodic review is recommended (once every five years) to maintain the balance of survey schemes operated within the overall programme. They should provide enough activity to maintain interest and involvement without overloading volunteers.
(Recommendation 10, Chapter 3)

10.3.1.b Training

- Continue to improve the quality of NBMP observers by further development of resources and programmes to train observers to a consistently high standard (including developing an accreditation scheme). Use the synergies with other BCT training courses.
(Recommendations 11, 12, 13, 14, Chapter 3)
- Monitor changes in observer skill levels over time.
(Recommendation 12, Chapter 3)

10.3.1.c Support

- Further develop volunteer-based (buddy systems, NBMP representative in bat groups) and computer-based systems to improve communication processes between volunteers and the office, and to improve consistency of volunteer site coverage (including gap coverage) for all NBMP schemes.
(Recommendation 15, 16, 17, 18 Chapter 3)
- Begin discussions with bat group representatives about recruiting an NBMP representative in each bat group responsible for site liaison and recruiting/maintaining an NBMP workforce on a local level. Work closely with BCT bat group development officer. Discussion could also cover the potential for regional co-ordinators.
(Recommendation 17, Chapter 3)

10.3.1.d Feedback

- Promote greater outreach to NBMP stakeholders, especially volunteers. Elements of this should include increased frequency and prompt delivery of results to volunteers/other organisations and increased contact with

volunteers via annual regional gatherings to discuss NBMP issues.

(Recommendations 20, 21, Chapter 3)

- Explore the storage of scanned maps (with transect routes marked on them) on computer to reduce effort spent on map photocopying for all NBMP schemes in consultation with Ordnance Survey.

(Recommendation 19, Chapter 3)

10.3.2 Data management, information access, dissemination and use

10.3.2 a Data processing

- Review and test systems for web-based and email based automated data entry to allow large amounts of data processing with low level staff input.

(Recommendation 38, Chapter 5)

- Improve validation of data at the entry stage to reduce data errors. Develop specialised computing routines to check data automatically.

(Recommendation 39, Chapter 5)

- Review database model and improve the structural design such that the volunteers component and data component are more closely linked. Ensure all edits to the database are clearly documented.

(Recommendation 40, Chapter 5)

10.3.2.b Data usage agreements

- A meeting and production of a formal access and data exchange agreements is urgently needed between involved parties: DETR, BCT, JNCC, EN, CCW, SNH, DOE (NI).

(Recommendation 45, Chapter 5)

- Review the legal aspects of data collection and ownership by volunteers. Simple, standard guidelines on how to collect data from volunteers need to be drawn up for all NGOs collecting data on a large-scale.

(Recommendation 41, Chapter 5)

- Review SNCO roost/hibernation licensing and re-structure return forms to increase returns of records and compatibility for NBMP collation.

(Recommendation 42, Chapter 5)

10.3.2.c Information transfer

- Assess how to ensure NBMP data and the NBMP database is compliant with emerging NBN standards. The suitability of Recorder 2000 as the primary long-term data management tool should be assessed in conjunction with any proposals to standardise SNCO data management systems. In the short term, the creation of data transfer routines from the NBMP database to Recorder 2000 and CIS should be a priority.

(Recommendation 46, 47, Chapter 5)

- Review how BCT could best act as a data provider and improve information dissemination to stakeholders.

Determine the funding needed for feasibility studies.

(Recommendation 48, Chapter 5)

10.3.3 Additional management recommendations

Annual NBMP tasks are currently carried out by two key members of staff, with occasional temporary help from volunteers or paid assistants. However, the resources to perform the increasing annual volume of work during the first five years of the programme have been so stretched that some areas of work critical to the long-term success of the NBMP have received less attention than desired in the face of more immediate issues.

Recommendation 61: Ensure adequate staff support is available to carry out routine seasonal NBMP procedures, such as map copying, mailouts etc.

10.4 COSTS, SPECIES, METHODS, TIMING, STAFF: AN OPERATIONAL MATRIX

Components of the proposed continuation of the NBMP include:

- Implementation of core annual monitoring schemes
- Integration of additional species surveillance schemes
- Continued monitoring against BAP targets
- Validation of existing and development of new surveillance schemes
- Continued volunteer and data management
- Streamlining of volunteer and data management systems
- Further development of centralised record collection for all UK species
- Integration with wide-scale mammal monitoring partnerships and other ecological monitoring data
- Provision of information on bat populations

Since the inception of the National Bat Monitoring Programme, BCT, the DETR and other partners – including the network of volunteers – have made a considerable investment in this programme. The primary responsibility of the BCT is to continue to build on this investment and ensure value for money.

To achieve this, the core project requires two qualified permanent staff with adequate resources. New research and development projects, as new partners are engaged and resources secured, can expand the core programme.

At this stage in development it is not useful to cost individual species surveys separately, since the fixed costs in delivering the surveys are on such a scale that such an exercise is inappropriate. Annual fixed costs have been estimated currently at roughly £125,000. More detailed costing plans are currently being discussed by BCT and JNCC.

The BCT has a proven record in delivering value for money. The NBMP has benefited from other BCT projects, which add value to the programme, e.g. the bat group Development and Support Programme and the National Bat Helpline. Both projects provide resources and opportunities to the NBMP.

10.5 FUTURE DIRECTIONS

Given that bats constitute over one third of the UK's mammalian biodiversity, the NBMP aims to promote and co-ordinate a united strategy for the conservation monitoring of bat populations. This will incorporate surveillance of bat populations, education and training of a skilled volunteer force and the wider public, dissemination of information to all interested groups and research into novel monitoring techniques, species ecology and causative factors of population change, through partnerships. The NBMP will thereby provide a network of collaboration for bat conservation: improving communication and information transfer between amateurs, professionals and policy makers.

The NBMP was created out of the need for a co-ordinated approach to address monitoring of bat populations at a UK level. While the main goal of the programme is to provide information at a UK level, we also recognise that a great deal of conservation action takes place at local, regional and country levels. The NBMP must therefore act to promote and facilitate communication of information between all levels. A liberal exchange of information is essential for groups at all levels to reach consensus on appropriate priorities and action for the conservation of bat populations.

We envisage the NBMP as a specialised data and information provider working as a quasi-independent unit that feeds data into a national mammal monitoring partnership. Bats are unique amongst mammals and present technical challenges to those attempting to sample them in the field. Bats are volant, nocturnal, highly mobile, difficult to identify, often colonial and active only during a short summer period. The NBMP has met this challenge by developing a specialist skilled volunteer work force and novel standardised monitoring protocols, which have enabled the collection of baseline data for target bat species. The NBMP intends to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of all UK bat populations.

Box 10.5.1 Short (2001-2005) and long-term NBMP aims

The overall, long-term objective is to promote an integrated approach to monitoring bat populations that is applicable to the wide range of user community needs. The programme will produce information to enable targeted prioritised conservation and thus value for money. The vision is based on the ethos of information provision to all those who value wildlife, therefore making bats accessible and tangible to a wider audience.

10.5.1 Short (2001-2005) and long-term NBMP aims

In the long term, the BCT aims to rationalise the monitoring process, working in parallel to and also in collaboration with any composite national mammal monitoring partnership, to enable effective use of resources.

In the short-term (2001-2005), we need to build on the investment made in the NBMP over the previous five years to ensure continued success and value for money which the project provides.

Programme aims 2001-2005:

- To implement a multi-species surveillance programme, using standardised protocols and developing new protocols, to detect changes in UK bat populations.
- To provide the best information currently available through research, development, and validation of current and novel monitoring techniques.
- To maintain and develop the specialist volunteer network through marketing and training strategies.
- To make information available to the general public and land managers and thereby raise awareness of bat conservation issues and clearly inform policy-makers at all levels towards conservation action.
- To feed quality assured data into a composite national mammal monitoring initiative and work with others to provide an integrated monitoring programme: assessing the causative factors influencing bat populations (climatic and habitat).
- To provide the relevant information to monitor performance against the targets outlined in the National Biodiversity Action Plan/SAPs.
- To continue to meet obligations under the Habitat and Species Directive and the Eurobats Agreement.

Table 10.4 Strategic Infrastructure NBMP: Mammal Surveillance Network

	Knowledge of bats required	BCT	MSN
Scientific quality			
Planning	High	✓	(✓)
Protocol design, trials, verification.		✓	
Associated research involvement		✓	✓
Training/direction of professionals/gap fillers		✓	✓
Liaison with wider mammal monitoring		✓	
Strategic management			
Organisation	Medium	✓	(✓)
Organising coverage		✓	(✓)
Produce/distribute forms		✓	(✓)
Prepare maps/photographs			✓
Define habitat classifications		✓	✓
Volunteer requirements	High	✓	
Recruitment, publicity		✓	
Structured training		✓	
Outreach/feedback, support materials		✓	
Data queries from local groups, database report management		✓	
Data management	Low	✓	✓
Data input		✓	(✓)
Data verification at form filling/data input stages		(✓)	
Database systems design			✓
Data queries from organisations, data transfer management		✓	
Data analysis- information production	Medium		
Summary reporting		✓	
Trend analysis, habitat and distribution associations		✓	
Assessment of improvements needed/wanted		✓	✓
Publicity	Medium	✓	✓
For recruitment/feedback		✓	✓
Raising awareness, conservation action		✓	✓
Integration of results with other monitoring			
Bats elsewhere (e.g. Eurobats)	High	✓	
Other fauna/flora	Low		✓
Data usage agreements	Low	(✓)	✓
✓ = Lead partner, (✓) = Contributing partner			

10.5.2 Relationship to wide-scale mammal monitoring and surveillance

The BCT has the skills and organisational structure, including a committed and skilled volunteer network, already in place. Information available as a result should be capitalised upon during the start-up phase of any composite national mammal surveillance partnership.

We propose that BCT continues to co-ordinate the NBMP

as a quasi-independent monitoring unit over the next five years (2001- 2005), with close links to the new mammal surveillance programme through meetings and shared information/expertise. The NBMP represents a valuable data source for the newly developing programme and should be consulted for information. Statistics on volunteer recruitment rate/loss and computer programmes designed to aid information tracking and random site selection may be valuable in new programme planning.

Data from all NBMP schemes can be made available at any point in time to be fed into a centralised mammal sur-

veillance database (given appropriate data usage agreements). It appears likely that the new mammal surveillance network will have the statistical expertise on board to carry out detailed analyses of animal population data in combination with other datasets such as habitat, climate, other species. We therefore anticipate that trend analysis and relational analyses for prediction and monitoring management scenarios may, in time, be based with them. However, this should not restrict the NBMP carrying out similar in house analyses if required. Further, the potential exists for the new mammal surveillance network being responsible for ensuring that the statistical requirements of monitoring are being met by "umbrella" projects such as the NBMP. This may take the form of shared professional field staff to survey under-represented areas and other shared resources such as GIS maps.

Table 10.4 defines one view of the strategic infrastructure of the NBMP and the areas where integration with a central mammal surveillance network may be beneficial.

10.5.3 An integrated bat population monitoring strategy

- In five years, the NBMP has built a monitoring programme that works, despite the many challenges imposed by the behaviour of bats. It is already providing valuable population trend information

- Examples of significant investment in non-governmental organisations to undertake such work are rare. This report demonstrates the investment was well placed and that the NBMP has delivered value for money
- The partnership approach has enabled the collection of data from a wide range of sources and the ability to share knowledge and resources. The NBMP has gained from, but also encouraged, the enthusiasm and good will that the general public has towards wildlife. It has taken the dedication of the volunteers, steered by skilled staff to develop a highly innovative programme
- The existing programme provides the best basis for developing an integrated ecological research programme aimed at improving our understanding of long-term and event-driven ecological processes affecting bats. A general view of how the NBMP might incorporate or promote further aspects of population research into an integrated population monitoring strategy are shown in Figure 10.2

Figure 10.2 NBMP Integrated Population Surveillance Strategy

