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Developing a mammal monitoring programme for the UK

M.P. Toms, G.M. Siriwardena & J.J.D. Greenwood
(Part III.A.1 written by S.N. Freeman & G.M. Siriwardena)

July 1999

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M.P. Toms, G.M. Siriwardena & J.J.D. Greenwood
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Insectivores

Erinaceus europaeus	Hedgehog
*Talpa europaea**	Mole
Sorex araneus	Common Shrew
*Sorex minutus**	Pygmy Shrew
Neomys fodiens	Water Shrew
*Crocidura suaveolens**	Lesser White-toothed Shrew

Lagomorphs

Orcyctolagus cuniculus	Rabbit
Lepus europaeus	Brown Hare
Lepus timidus	Mountain Hare

Rodents

Sciurus vulgaris	Red Squirrel
Sciurus carolinensis	Grey Squirrel
*Clethrionomys glareolus**	Bank Vole
Microtus agrestis	Field Vole
*Microtus arvalis**	Orkney Vole
Arvicola terrestris	Water Vole
*Apodemus sylvaticus**	Wood Mouse
Apodemus flavicollis	Yellow-necked Mouse
Micromys minutus	Harvest Mouse
*Mus domesticus**	House Mouse
*Rattus norvegicus**	Common Rat
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Martes martes	Pine Marten
Mustela erminea	Stoat
Mustela nivalis	Weasel
Mustela putorius	Polecat
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Mustela vison	American Mink
Meles meles	Badger

Lutra lutra	Otter
Felis silvestris	Wildcat
*Felis catus**	Feral Cat

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*Sus scrofa**	Wild Swine
Cervus elaphus	Red Deer
Cervus nippon	Sika Deer
Dama dama	Fallow Deer
Capreolus capreolus	Roe Deer
Muntiacus reevesi	Reeves' Muntjac
*Hydropotes inermis**	Chinese Water Deer
*Capra hircus**	Feral Goat
*Ovis ammon**	Feral Sheep

Marsupials

*Macropus rufogriseus**	Red-necked Wallaby

Key References

For convenience, we refer throughout the text to the following key references by short titles. The full references are given at the end of the report.

Short title	Reference
The Atlas	Arnold (1993)
The Handbook	Corbet & Harris (1991)
The Populations Review	Harris *et al*. (1995)
The Field Guide	Macdonald & Barrett (1993)
MMR	Macdonald *et al.* (1998)
Yalden	Yalden (1999)

PART I. AIMS AND OBJECTIVES OF UK MAMMAL MONITORING

The purpose of this part of the report is to set the scene for the rest. It does so in three somewhat disparate sections. The first begins with a discussion of what we mean by monitoring and of its role in conservation, which it is crucial to understand if one is to design good monitoring schemes. We go on briefly to review the status of British and Irish mammals, why we need to monitor them, and the broad aims of such monitoring.

The second section begins with a brief reminder of the current state of UK mammal monitoring. It summarises the proposals of MMR (see front of this report for main references) and then presents our responses to each of them, except for those for which more detailed discussion is presented in later parts of the report. Section 3 briefly considers how the monitoring is different from that of birds, to ensure that both the authors and the readers of this report do not make unwarranted assumptions. The authors, with largely ornithological rather than theriological experience, are particularly likely to do so. Furthermore, the methods of bird monitoring are so well-known and well-developed that even non-ornithologists may translate them to mammals unless they carefully consider the differences.

It is perhaps worth remarking here that, in Part I of the report in particular, we have generally used BTO examples to illustrate points being made rather than examples from other monitoring work. While we have no doubt that examples could have been found elsewhere, it has been more efficient for us to stick to the illustrative examples with which we are most familiar.

1. WHY SUCH MONITORING IS NEEDED

1.1 What is monitoring?

Monitoring is more than surveillance (the documentation of changes over time in the distribution or abundance of species). It has three additional features (Baillie 1990; Hellawell 1991; Furness *et al.* 1993; Greenwood *et al.* 1993; Greenwood 1999):

1. Objectives and targets
2. Contribution to understanding
3. Stimulating and underpinning action

Effective monitoring involves applying the surveillance to management objectives. For example, the UK Biodiversity Action Plan (Anon. 1995) has as its overall goal:

> *To conserve and enhance biological diversity within the UK and to contribute to the conservation of global biodiversity through all appropriate mechanisms.*

On the basis of such broad objectives, specific targets need to be defined - such as the UK Biodiversity Action Plan targets for mammals (Table I.1.1). We do not address such targets in this report but note the need not only for them to be established but also for that establishment to be based on wide consultation. This is because, for many species, there is likely to be a wide range of people with legitimate interests, such as farmers, foresters, naturalists and shooters; furthermore, both the extent of their interests and the balance that has to be struck between them are value judgements that should not be made in a democracy without open consultation. The difficulties in reaching decisions are perhaps illustrated by the fact that the Brown Hare Action Plan envisages that the species' numbers are doubled by 2010; yet it is an introduced species that competes with a native species (the Mountain Hare), leading to an apparent conflict with both the Habitats and Species Directive and the Convention on Biodiversity (see below).

Surveillance provides the information to judge whether such targets are being attained. If they are not being met, the monitoring process should ideally: contribute to understanding of why not; contribute to the scientific advice underpinning remedial action; and provide alerts to those responsible for undertaking such action.

Fig I.1.1 identifies how monitoring supports management. It does so by contributing information and understanding that provide sound answers to the series of questions shown in Fig. I.1.1. Note that even if the answer is positive to the most basic question of all (which is whether the monitoring shows the target for the species to have been achieved), that is not the end of the matter; monitoring must be maintained (and the question constantly readdressed) in case of unforeseen changes. If the target is not being achieved, we need to ask whether we know why (question 2). There may be information external to the monitoring process that helps identify the reasons but if the monitoring programme has been well-designed, the monitoring alone may well provide the answer to that question. Whatever the answer, it will lead to a branching network of further questions and actions. Some of these must be informed by information from fields other than ecology or conservation (such as economics) or incorporate value judgements (such as the value people place on being able to watch Water Voles on their local brook) but all of them also require input of monitoring information. Note that the network is a closed one - all routes eventually lead back to the continuation of monitoring. This is essential, both to measure the effectiveness of deliberate management actions (such as legal protection) and to detect new problems (such as the impact of American Mink on Water Voles).

In the planning of a monitoring programme, it is important to remember that it is indeed a monitoring programme and not a research programme. Monitoring should, of course, contribute to our understanding of why targets are not being attained and of how management practices may be altered to improve the prospects of the population of interest. If too much ongoing research is built into the monitoring programme, however, this may divert resources from the more basic step of determining whether the population is being maintained at the target level and may result in much of the research not being focussed on the key issues. As with so many issues in respect of monitoring, striking the right balance is a matter of judgement.

1.2 The status of British and Irish mammals

The status and history of each species is summarised in Table I.1.2.

Further relevant information on ecology, life history, and behaviour is summarised for the 28 target species considered by MMR in their Appendix 1.1 and Table 1.4; for the other species it can be found in the Handbook and the Field Guide.

The conservation of a significant proportion of the UK's species of mammals is governed by domestic or European legislation (MMR, Chapter 1, Section 3). In more general terms, a very high proportion of species feature on the "long list" of the UK Biodiversity Action Plan (Anon 1995) (Table I.1.3), although, so far, there are species Action Plans for only a few of them (Table I.1.1).

1.3 Objectives of mammal monitoring

The Biodiversity Action Plan includes summary actions for monitoring the components of biodiversity, viz:

The Government and its agencies will:

- *examine and develop the integration of monitoring studies and seek to establish baselines for key components of biodiversity.*
- *develop UK monitoring schemes to take account of threats and impacts on biodiversity.*
- *develop thresholds for conservation action in relation to species population and habitat change.*

The UK Plan was a response to the Convention on Biological Diversity, Article 7 of which requires contracting parties to:

- *monitor through sampling and other techniques the components of biological diversity paying particular attention to those requiring urgent conservation measures and those offering the greatest potential for sustainable use.*
- *maintain and organise by any mechanism data derived from such monitoring activities.*

There is thus an administrative and statutory requirement for monitoring key elements of biodiversity. The administrative requirement is, of course, only there to fulfil deeper objectives, which are hinted at by the Convention's stating that particular regard should be paid to species that are of social, cultural or scientific importance, that are threatened, or that are important for research into biodiversity and its sustainable use. Broadly speaking, there is an objective of conservation management, to which monitoring has important contributions to make. The species listed in the Action Plan (see Table I.1.3) must therefore be prime candidates for monitoring. Indeed the individual species Action Plans (see Table I.1.1) can only be undertaken sensibly if monitoring is in place for those species.

Conservation management also underlies the requirement under the Habitats and Species Directive to maintain or restore the favourable conservation status of nominated species (comprising, for the UK, Mountain Hare, Common Dormouse, Pine Marten, Polecat, Otter and Wildcat).

A high proportion of the UK mammal fauna is non-native (Table I.1.2). The Convention on Biological Diversity requires contracting parties to take action against alien species that threaten native species. Since all communities are invasible, since the success and impacts of invading species are unpredictable, and since those impacts on other organisms may be great (Williamson 1996), all aliens pose potential threats. Furthermore, the establishment of any alien reduces the component of biodiversity contributed by biogeographical differences (γ-level diversity in technical terms). Thus the conservation of biodiversity requires that aliens in particular are managed and hence (for the management to be soundly-based) that they are monitored, even if the management comprises doing nothing unless the alien population begins to grow to a threatening extent.

Mammals need to be managed (and therefore monitored) for reasons other than their own conservation. Many, at least sometimes, can cause significant economic damage. Some represent an economic resource to be exploited, such as the Red Deer that attract both tourists and hunters to the Highlands. Even more broadly, mammals are important because they may have ecological impacts that affect other species of animals and plants. Their impacts may tend to be greater than those of many other animals because mammals are individually large; compared with birds, they are, furthermore, numerous for their sizes (Greenwood *et al.* 1996).

The most developed wildlife monitoring in Britain and Ireland is that of birds (Greenwood *et al.* 1993; Greenwood 1999). One value of bird monitoring is that birds can be useful indicators of environmental conditions (Furness & Greenwood 1993). This is not so much because individual species indicate particular conditions but because whole suites of species can provide information on problems in particular habitats (such as the now well-known problems in farmland, Baillie *et al.* 1997) or about the effects broad-scale environmental changes (such as climate change, Crick *et al.* 1997; Crick and Sparks 1999). Mammals are less useful in this respect since there are fewer species and since it is impossible to apply a single monitoring system across more than a few of them. Furthermore, many mammal species are subject to direct control (or are recovering from past control), so their status reflects the direct impact of man rather than other environmental factors. Even so, some mammalian species may be useful indicators - Moles perhaps of ground invertebrates, Water Shrews and Otters of water quality, Dormice and Yellow-necked Mice of habitat fragmentation, and many species as monitors of climate change.

In contrast, some mammals are key prey for a range of predators (birds and other mammals) and some have major impacts on vegetation; they are significant components of ecosystems. Furthermore, many species are economically important as pests or as game.

Thus, the objectives of mammal monitoring are to provide management information in respect of individual species of conservation or economic significance and to provide a contribution to the ecological information that is needed for the conservation of biodiversity.

1.4 Aims of mammal monitoring

1.4.1 Information

Monitoring schemes should aim to provide information, not data. The data are simply the means to the end, which is the information about changes in status in relation to target and about the likely reasons for those changes. There are two reasons why we need to be clear on this point. The first is that the monitoring needs to include provision not just for the collection and curation of data but also for the interpretation of the data and the reporting of the results, i.e. turning the data into information.

The other reason for making clear the need for information rather than data is that the data can be used for purposes additional to the provision of monitoring information. They may be used for other conservation purposes. They may be used for scientific studies. They may be used for work of a commercial nature that not only provides employment for staff of the organisation doing the work but also produces surplus monies that can help support the other work of the organisation. They may simply be sold (though in BTO's experience, while some data are commercially valuable most are not and the overall cost of a data-provision service is greater than the income it generates). Mammal monitoring in the UK is likely to involve a number of different organisations (and very many different individuals). For their collaboration to be effective, they will need to recognise not only that their roles in the monitoring scheme are different but that so may be their interests in subsidiary uses of the data. Those who need the conservation information but not the data need not insist on access to the latter.

1.4.2 Geographical scope

Mammal monitoring must aim to provide information at UK level. It is also desirable that information is available at national level, i.e. separately for England, N. Ireland, Scotland and Wales, not only because this is the level of government that is mainly relevant but also because the ecological circumstances of the four countries are generally different. It would not, however, be cost-effective generally to run separate schemes in the four countries. Not only would the cost of doing far exceed the cost of running a UK scheme but insights would emerge less readily from separate analyses at the country level than from integrated analyses of the data that build on differences that there may be between the countries. (As examples of the latter approach from BTO studies, we can quote the understanding we are getting of changes in Welsh wintering wader populations from analyses at the UK level and insights into farmland bird problems that come from comparisons between east and west Britain). Thus, UK monitoring needs to cover each of the four countries adequately but through common rather than separate schemes.

The provision of information at the UK level is a broad aim that does not necessarily mean that the immediate focus of attention should be the UK population rather than local populations. Some mammals have such disjunct populations that it is not biologically meaningful to speak of a national population; greater insight is gained by focussing on the separate local populations. It may even be convenient and effective to use different methods for monitoring such separate populations. Nonetheless, for administrative and practical purposes it is important that the local information is drawn together at country or UK level. Furthermore, ecological insights may be gained from comparisons between populations in different regions. It is therefore important, even for these species, that the local monitoring fits into a broad national framework. It will generally be helpful if similar methods are used in different regions, though we acknowledge that there may be reasons for using different methods that override this general guideline.

Monitoring information is needed at a local level in some cases - for the management of deer populations in specific areas, for example. The uses of such information may be specific to each locality, so the information required may also be specific. For this reason and because the detailed monitoring required in these places is not required nationwide, it is not appropriate to conduct nationwide monitoring at the intensity sometimes needed locally. This is not to say that local intensive monitoring cannot feed into the national programme; it would be wasteful if it did not.

Mammal monitoring will produce site-based data. These data are valuable for local planning purposes. For example, although the whole country is not covered by Badger Groups, the National Federation of Badger Groups reports that records of Badger setts influence well over 100 planning cases a year in Britain (Pat Williams, in Sargent & Morris 1997). Although monitoring schemes should be set up in ways designed to best fulfil the monitoring aims, we recommend that consideration should be given to how the data may be made available for site-based work, the value of doing so, and the additional cost involved. This is likely to involve The National Biodiversity Network (see Part VI).

Northern Ireland is a special case. It is politically important for monitoring there to fit in with that in Great Britain, so that a UK overview is possible. Equally the management of Northern Ireland's animals will most effectively take place in an all-Ireland context. It would therefore be useful if the monitoring within the two administrations were comparable (just as, in the bird world, the Irish Common Birds Survey uses identical methods to the UK Breeding Birds Survey and there is close co-operation between the Irish Wetland Birds Survey (I-WeBS) and the Wetland Birds Survey (WeBS)). We recommend that contact be made with Irish agencies at an early stage, in the hope that at least some of the monitoring that will be established (or continue) in UK may be extended to (or parallelled within) the Republic of Ireland.

Northern Ireland also has its own landscape characteristics and culture that may mean that monitoring schemes that are effective in Great Britain are less appropriate there. Time has prevented us paying much attention to this issue but it needs to be addressed when plans for particular monitoring schemes are being drawn up.

1.4.3 Habitat information

The interpretation of population data may be considerably enhanced if relevant habitat data are available, especially if they are gathered at the same time as the population data. We recommend that this be considered for any mammal monitoring scheme, although the advantages of gathering habitat information need to be weighed against various possible disadvantages. These could include putting off volunteer data-collectors and the greater costs of gathering, collating, processing and analysing the data.

An important question is whether to use a common habitat classification for all species or to use different classifications, appropriate to each species. This issue must be explored when decisions have been taken about what mammal monitoring is to be undertaken. (To aid integration, BTO now uses a common habitat classification across most of its schemes (Crick 1992); however, because many bird species can often be covered by a single method, BTO runs relatively few schemes). Whatever new habitat classifications are used for mammal monitoring, it is important that they are as compatible as possible with existing classifications, especially those particularly relevant to the species in question (e.g. The Environment Agency's *River Habitat Survey* scheme, for riparian species). The key aspect of compatibility is the mapping of classifications on each other: one-to-one, one-to-many, and many-to-one mappings are useful; many-to-many mappings are not.

1.4.4 Monitoring range

The collation of distribution records in the past has been valuable in demonstrating changes in range, which have focused conservation attention on problem species. However, with important exceptions (see below) we agree with MMR that biological recording as currently practised provides only approximate information on range, especially on range change, mainly because there is little or no control over the amount of effort devoted to it. Even the breeding bird atlases, which have both managed to obtain almost complete coverage over just a few years, have to be used with caution as sources of information on change in range (Gibbons *et al.*1993; Greenwood *et al.* 1997; Donald & Fuller 1998). It will be possible to assess such changes better in future because the second atlas used a more formal protocol that can be used again. The success of this approach depends, however, on the ease with which birds may be detected and the great number of observers available to take part in the fieldwork. It seems unlikely that such complete coverage could be achieved for mammals, although useful distributional surveys of some species (especially the more apparent ones and those of more restricted distribution) could be achieved. There are some mammals for which it is important to monitor range but, in general, we do not believe that it would be wise to devote resources to the promotion of biological recording that could be used to mount focused schemes to monitor abundance.

Fortunately, monitoring of range generally adds little to monitoring of abundance (providing the latter is achievable). Indeed, the evidence from birds is that overall abundance is more sensitive to changing conditions than is range (Donald & Fuller 1998). This is a logical consequence of the tendency for there to be a correlation between mean abundance at the sites that species occupy and the number of sites occupied (see, e.g. Holt *et al.* 1997). Since national abundance is the product of local abundance and range size, range will necessarily be correlated with national abundance. The latter is thus generally a better, and largely sufficient, measure of status.

These considerations do not preclude all monitoring of ranges. Indeed, for species that are (or could be) rapidly expanding their range, monitoring the extent of the range may be significantly more sensitive, and therefore more important, than monitoring total abundance. For some other species, range may be so much easier to measure than abundance that it is better to monitor range. For yet others, useful information on range may be obtained at little extra cost during the monitoring of abundance. Furthermore, biological recording may provide a useful stop-gap if there are species for which formal monitoring schemes are unlikely be set up in the foreseeable future but this can only be assessed after decisions have been taken about what schemes should be set up.

Recent work by Chamberlain *et al.* (1999) is relevant to the interpretation of changes in range. They found that, while changes in the abundance of declining farmland birds had been most marked in regions of predominantly arable agriculture in England and Wales, local extinctions (losses of birds from 10x10km squares) had been most common in regions of predominantly pastoral agriculture. They proposed two explanations for this, both predicated on pastoral areas having been less suitable for the species in question, not just in recent years but form the start of the period that their study covered. The simpler explanation is that the abundance of these birds has declined in all areas but that this has led to local extinction more in the pastoral areas because the birds were initially less abundant there. Under this scenario, reductions in range would be a sensitive indicator of problems which affect entire ranges. (It would, however, be misleading to associate the range losses closely with the features of the squares from which species were lost: such features would at most be correlates of low abundance rather than a local extinction). The second possibility is that at the start of the study period the pastoral areas were already so poor for these species that their populations there acted as sinks, maintained only by immigration from the comparatively better arable areas. As conditions worsened in the latter the supply of immigrants to the pastoral areas dwindles and the species therefore disappeared. Under this scenario, the losses of range in the pastoral regions depended on conditions elsewhere, making them poor indicators of problems locally. Thus the interpretation of changes in range under either scenario is not straightforward, a further reason for generally concentrating on changes in abundance where possible.

1.4.5. Monitoring abundance

The prime aim of monitoring the status of UK mammals is thus to monitor their abundance. Whether one conducts a complete national census or estimates national abundance by taking samples, there are various measures of abundance (Sutherland 1996). Most obviously, one can count the animals directly. Alternatively, one can count things that are correlated with the number of animals, such as the number of nests, droppings, footprints, or calls, to obtain an index of abundance (Greenwood 1996). If one needs an estimate of the numbers of the animal, such indices must be calibrated (see Greenwood 1996 for further details). For monitoring, where one is mainly interested in relative change in numbers rather than absolute numbers, calibration is unnecessary; all that one requires is that the relationship between the index and numbers should not vary systematically with time, should be monotonic and, indeed, should be approximately linear. Linearity is the condition most likely to be broken. Non-linearity will only have a significant practical effect if it is marked. It can be checked and corrected for by calibration, though it is not necessary that the calibration is carried out before the monitoring is instituted. We recommend that monitoring programmes should be set up as a matter of urgency, with calibration conducted later if deemed necessary. Even without calibration, indices that are not strictly linearly related to absolute numbers can be useful, so long as one bears in mind their likely non-linearity (Greenwood 1996). A somewhat non-linear index that is affordable is preferable to a strictly linear one that is too expensive to measure with the resources available.

The relationship between an index and actual numbers may differ between habitats. This presents no problem if population changes are the same across habitats but if they are not then simply combining the data from all localities will give an estimate of national population change that is biased towards the change in the habitat that has the index that rises and falls more steeply in relation to population change. In these circumstances, it is better to calculate habitat-specific rather than national indices.

Indices are often preferable to absolute counts because they are much easier to obtain. Similarly, indices that are less accurately related to absolute numbers may be easier to obtain than more accurate indices. In practice, one must choose the method that provides the information at the level of accuracy required for the least expenditure of resources. Thus the Breeding Birds Survey will provide better monitoring of widespread species in the UK than the Common Birds Census has done, despite the greater accuracy of the mapping method used by the CBC relative to the line transect method used by the BBS. This is because this greater accuracy is achieved at the cost of much greater effort, so it is possible to sample only about one-tenth of the number of sites in the CBC than is possible in the BBS, resulting in lower precision of the national CBC index. An even more dramatic contrast is provided in the Republic of Ireland, where there were insufficient resources to mount a CBC-like scheme but where a BBS-like scheme is now successfully established.

Gibbons *et al.* (1993) used frequency of apparent occurrence (for example, the proportion of 2x2km squares within each 10x10km square) as a measure of abundance, having found good correlations between this index and direct counts for a wide range of bird species (Gibbons 1987). Such an index is not useful for species that are so common that they are found almost everywhere (though this problem can usually be overcome by using smaller units within which to record presence or apparent absence, like 1x1km rather than 2x2km squares). Frequency of occurrence is also not useful for highly aggregated species, since these may vary much in abundance while continuing to occupy the same number of sites. Nor is it useful for species that are so difficult to detect in a locality (because they are either scarce or cryptic) that they are detected in few places; this is because there will be considerable statistical error in measuring year-on-year change (Box 1). There is no such problem when the species only occurs in relatively few of the subunits but is readily detectable; in that case, the index of frequency of occurrence will be low but not subject to great sampling variance.

In using presence/absence records as indices of abundance it is important to bear in mind the problems of interpreting changes in range (subsection 1.4.4, above). These problems generally do not affect the interpretation of the proportion of occupied sites in an area as being an index of average abundance in that area (they may even strengthen it). They do, however, indicate the need for caution in interpreting losses at individual sites or comparisons of losses between suites of sites.

Monitoring abundance by changes in proportion of subunits in which a species is detected: the importance of detectability

Consider a species that occurs in every one of 10 subunits in a study area. Suppose that its detectability is 50% of the subunits every year (on average). If in two successive years its abundance has not actually changed, there is a 47% chance that the ratio of the numbers of subunits in which it is recorded in those two years will lie between 0.75 and 1.33.

In contrast, if the detectability of the species were only 10%, then there is only a 12% chance that the ratio for two successive years will lie in the range 0.75-1.33. Indeed, there is a 22% chance that the species will be recorded in one or more subunits in the first year but none at all in the second (and conversely), suggesting substantial changes.

Box 1

If counts of absolute numbers are attempted, the methods must be strictly defined in order to avoid bias. If bias is inevitable, then it should be kept constant by the adoption of equally strict protocols, so that the biased count obtained can be taken as a good index of actual numbers. Indeed, all index methods require strict protocols in order to avoid a drift in standards through time; such drift could create apparent trends in the population being monitored or mask real trends. For example, if animals are detected by spotlighting at night then it is important to control the specification of the spotlights; if detectability requires a particular level of skill, then attention must be given to observer skills. Problems of drift in standards are most likely when the monitoring is as crude as simply asking people to score the abundance of a species in their locality on some scale from absent to extremely common or (rather more useful in terms of monitoring) to score its recent population changes in some equally subjective way. Nonetheless, even such methods can be useful if more rigorous ones are unavailable, as shown by surveys of Rabbit infestation on Scottish farmland (Kolb 1994) or of the trends in bird populations across Europe (Tucker & Heath 1994).

The validity of crude indices may be tested by checking a subset of the data against parallel work by specialists, particularly if the specialists use more rigorous methods (and if they work in the same places). For example, nationwide monitoring of a species might be based on a combination of rigorous (but expensive) studies at a few sites and cruder (but cheap) surveys at many sites. Alternatively, one may use more than one simple index method; if the biases of the different methods are different and unlikely to drift in the same way, they provide checks on each other. These two forms of cross-checking are useful if the different types of survey suggest similar trends. Unfortunately, if they do not then one may have no way of deciding which to believe.

Cost aside, unbiased estimates of absolute abundance are preferable to indices. For this reason, those contemplating population monitoring may favour the use of Capture-Mark-Recapture methods. Unfortunately, estimates so obtained are extremely sensitive to the assumptions of the underlying statistical models and these assumptions are generally unrealistic. This means that, unless it can be proved that Capture-Mark-Recapture estimates for a particular population are accurate (by checking against intrinsically more reliable estimates), these estimates themselves must be treated just as indices. We are not aware of any reason to suppose that they are better indices than the simple total number of animals captured. Since the latter is more transparent and requires no calculation beyond counting, we recommend against the use of Capture-Mark-Recapture unless there are specific and demonstrated reasons for using it in particular cases.

1.4.6 Demographic rates

BTO's Integrated Population Monitoring programme involves the monitoring of demographic rates, not just numbers, particularly the productivity of individual nests and the survival rates of fully-grown birds; as a result, it provides deeper insights into the causes of population changes (Baillie *et al.* 1997; Crick *et al.* 1998; Greenwood *et al.* 1993). However, this depends on some of these rates being relatively easy to measure in birds, on a large and experienced network of nest-finders and bird-ringers, and on 60 or more years of development. We recommend that the monitoring of demographic rates is not initially taken as a primary aim of the mammal monitoring programme. Nonetheless, attention should be paid to such information when it arises from local monitoring work (as it often does in the case of deer, for example) and demographic data should be obtained where it is easy and cost-effective to do so in the course of monitoring of numbers (for example, the reproduction data gathered in the National Dormouse Monitoring Programme).

2. THE BACKGROUND TO THE CURRENT PROJECT

2.1 Current mammal monitoring in the UK

MMR give a full account of current monitoring. We do not even attempt to summarise it here, as the picture is so complex. Its chief features are:

1. *Many different organisations are involved.*

   There is very little national co-ordination, sometimes not even between bodies working on the same species or between projects funded by the same organisations.

2. *Not all species are covered*

   Even for species that are covered, cross-species co-ordination is not common.

3. *Some of it is not at the UK, GB or all-Ireland scales*

   Some projects are restricted to single countries of the UK or to only one administration in Ireland; others are restricted even more, to just a few much smaller areas.

4. *Much is not annual*

   Some is at longer than annual intervals but fairly regular but much is irregular - including some schemes that are apparently set up to provide regular monitoring, which may run for a few years but then close down.

5. *Level of refinement varies widely*

   At one extreme, irregular questionnaire surveys of respondents' opinions on status (which provide little hard information); at the other, careful estimates of national population size (which may provide more than is strictly necessary for monitoring).

6. *Reporting is disparate and scattered*

   Some surveys result in detailed and comprehensive reports; others in no publication at all. Each project reports separately. The reports appear in a variety of different publications.

7. *The role of volunteers varies widely*

   Given the diversity of methods appropriate to mammal monitoring, this is inevitable; but there are some species where volunteers could contribute but do not currently do so.

2.2 MMR proposals

Note that our responses to these proposals are given in Section 2.3, using parallel sub-subsections for ease of cross-reference.

2.2.1 What species?

MMR were asked to consider only a restricted list of species - those without asterisks in the table of species at the front of this report.

2.2.2 What is to be measured?

MMR propose particular methods suitable for individual species. Many of them involve the use of indices of relative change but there is also considerable emphasis on estimating absolute population sizes where possible.

2.2.3 Integration across species

MMR propose a scheme (the MaMoNet) in which all species are monitored in the same 10x10km and 1x1km squares of the OS grid.

2.2.4 The three-tiered structure and the Master Squares

To maximise effectiveness, MMR propose a three-tiered structure for the MaMoNet: Master Squares, Rich Interest Kilometre Squares, and Focus Zones.

The Master Squares form the core of the MaMoNet. They are 10x10km OS squares. On the basis that the sampling intensity used in the Water Vole and similar surveys has proved satisfactory, MMR propose that 18% of the squares should be sampled. The sample squares would be chosen at random.

Within each of the Master Squares, five 1x1km squares would be the basic survey units. Within each, methods appropriate to each species would be used to measure numbers or an index of abundance. For example, using a standard protocol, a 1x1km square could be completely searched for Badger setts, whereas one might search only a fixed length of river-bank for Water Voles. If other than a complete search is conducted, MMR recommend placing the actual survey location randomly within the square (or within suitable habitat).

To improve effectiveness, MMR recommend that the location of the 1x1km survey units is stratified. Stratifications suggested are: habitat (e.g. woodland, riparian, rough grassland, other), historical versus new survey sites and random versus systematic components of the Master Square sample (see 2.2.10).

2.2.5 The seven-year cycle

MMR recommend that the monitoring takes place on a seven-year cycle. In the first two years, surveys would be conducted of woodland squares (using methods appropriate to that habitat and to the species within it); the next two years would be devoted to riparian sites; the next two to other sites; the seventh to intensive analysis and writing up of major reports. “Mandatory rapid turn-around of customised feed-back material from the Central Office to the field workers and collaborating organisations” would take place throughout the cycle.

2.2.6 Rich Interest Kilometre Squares

These would be sites that have been surveyed in the past (particularly those covered in formal nationwide surveys) but which do not fall within the random sample of Master Squares. MMR propose that some at least of these should be surveyed as part of MaMoNet, to provide comparison with the past.

2.2.7 Focus Zones

The third tier of the MaMoNet would comprise sites where intensive investigations should be carried out. MMR suggest two sorts of Focus Zones:

intensive studies of local populations, providing detailed ecological understanding;

more intensive surveys than provided by the network of Master Squares in regions of particular significance, such as the region bordering the current main distribution of the Polecat (into which the species may be expected to spread).

As MMR remark, Rich Interest Kilometre Squares and Focus Zones grade into each other, especially in respect of the class into which historical study sites should be placed.

2.2.8 Manpower and costs

MMR envisage a professional team of staff, operating in two groups: a central office staff of three scientists and managers (plus a half-time secretary) and a peripatetic team of five full-time and five part-time fieldworkers (who would also do much of the data entry).

In addition, MMR envisage volunteer participation in the work of MaMoNet, suggesting two sources in particular: unemployed graduates, vacation students, and gap-year students; Mammal Society members and others recruited through 'The Look Out For Mammals' and similar projects. However, they conclude that: "for the foreseeable future professional Mammal Monitors comprise the metaphorical skeleton of the MaMoNet, to which ever more volunteers add increasing muscle bulk". They suggest that professionals would mainly cover the Master Squares, with volunteers being used mainly for RIKS.

Finally, MMR suggest an Advisory Panel to provide input from all the collaborating parties and from technical experts.

Box 2 shows the cost of the MaMoNet, based on figures provided in MMR.

2.2.9 Utilising existing and ancillary schemes

MMR consider how periodic national surveys (such as the Water Vole survey) could be moulded into the MaMoNet (see below). They appear to envisage, however, that existing monitoring effort will contribute only in so far as the personnel might be redeployed to participate in MaMoNet - e.g. stalkers who currently contribute to the various deer-monitoring programmes could carry out deer surveys in Master Squares.
MMR appear to see little role for data from ancillary schemes, such as the game bags surveys and the mammal records from the BTO/RSPB/JNCC Breeding Bird Survey.

Box 2

Costing the MaMoNet

We have used the figures quoted by MMR to come up with the following annual expenditure. We have inflated the MMR figures by 6%, to turn them from 1997 values into 1999/2000 values. All the figures are in £000s.

2.2.10 Setting up the MaMoNet

MMR propose that the first seven-year cycle be regarded as an Exploratory Cycle, in that results obtained during it should be used to modify the methodology.

They also propose that, to provide continuity with existing surveys, the Master Square sample is not randomised at the start of the MaMoNet scheme. Rather, the first cycle would use the "QQ grid" that was used in the Water Vole survey. (The QQ grid is a systematic grid of 10x10km squares, with randomly located 1x1km squares within it). Subsequently, a proportion (e.g. 20%) of the QQ squares would be randomly substituted in each cycle by the same number of squares drawn at random. Once the substitution had reached a certain stage (e.g. 60% of the squares being random), there would be no further substitution, so that long-term continuity would be conserved.

2.2.11 Sampling with partial replacement (SPR)

MMR recommend that the random Master Squares should neither all be reselected during each survey cycle nor all be retained in perpetuity. Rather, they recommend that most are retained from one cycle to the next but that there is a 20% (for example) turnover in each cycle, with 40% retained in perpetuity.

In respect of 1x1km survey squares within each Master Square, MMR recommend that the same ones are used throughout the period for which that Master Square is retained in the MaMoNet sample.

2.3 Aims of the current project

2.3.1 General aims and species to be considered

The MaMoNet is a carefully thought-out scheme that would deliver high quality information on Britain and Ireland's mammals were it to be implemented. It is, however, expensive and it is in the form of such an integrated package that it is not clear how it could be modified (say by dropping some components, by relaxing statistical rigour, or by making more use of ancillary data) to be less expensive but still provide effective monitoring. We have been asked to provide a series of costed options that would allow the conservation authorities to pick out a set that would provide them with what they believe to be the most cost-effective mammal monitoring that would satisfy their needs.

We have also been asked to consider all the mammals living at liberty in the UK, not just the restricted list that MMR has asked to address.

In the rest of Section 2.3, we briefly review the design issues raised in Section 2.2 (using corresponding subsection numbers, for ease of cross-reference). More detailed considerations of the statistically formal design are covered in Part II and of volunteer input in Part V.

2.3.2 What is to be measured?

The bedrock of the monitoring must be the surveillance of status - primarily abundance but range in certain circumstances (Sections 1.4.4 and 1.4.5. above). Surveillance does not, however, require absolute measurement of abundance, merely measurement of relative change, which may be easier (Section 1.4.5). As MMR demonstrate, measuring absolute abundance allows one to build spatial, habitat-related models of mammal distribution (using the powerful tool of GIS if appropriate). This is not the chief aim of monitoring but is a useful piece of associated research that may help illuminate some of the key questions that arise if management targets are not attained (Fig. I.1.1). If absolute abundance can be measured with little more effort than measuring relative change it is therefore worth measuring it. Otherwise, it may be better to concentrate on relative change and to mount special surveys or research projects when the monitoring reveals problems.

Absolute abundance estimates are also required for Population Viability Analysis, also considered by MMR. We are unconvinced of the value of PVA for the conservation of the native mammal fauna of the UK, given that long before a species had declined to such an extent that it was threatened by the stochastic processes to which PVA is relevant (demographic stochasticity, loss of genetic variation, environmental catastrophe) we would expect the conservation authorities not only to have been alerted (by the monitoring) but to have taken the necessary measures to have reversed the decline. Furthermore, the history of various mammals in Britain, which have recovered from low numbers or expanded from very small numbers of introduced individuals, leads to some doubt as to the applicability of the available PVA models. We note that MMR consider that one of the primary roles of PVA "will be for providing insight into the relative benefits of alternative population or habitat management strategies". We believe that direct studies of the effect of habitat management on the species in question are more likely to provide useful guidance.

2.3.3 Integration across species

It can be useful to monitor different species in the same sites, as one can then conduct site-by-site analyses of the influence of species on each other (e.g. the demonstration that Sparrowhawk *Accipiter nisus* and Magpie *Pica pica* predation is not generally the cause of declining songbird populations in Britain, Thomson *et al.* 1998). Indeed, developing a series of representative 1x1km squares to provide a general sampling framework for the UK has been a subject of much discussion. There are potential practical benefits to using the same squares for all species. For example, permission has only to be sought once; the corresponding disadvantage is that a landowner who is faced with (or fears being faced with) people coming back time and time again to monitor one thing after another may be more inclined to refuse access than one who is asked for permission simply to monitor one species. Another potential advantage is that the fieldworkers will become familiar with the area, which may be advantageous; conversely, they may get bored and either do the work less well or not do it at all.

Using the same places for different species has the particular disadvantage for British mammals that several species have already been subject to national surveys using different sample sites; to move them all onto a common series of sites would lose the considerable advantages of historical continuity of sample sites (see Part II). A more generally practical problem is that different species may require sampling on different scales (e.g. 40x40m trap grids for mice, 10x10km squares for deer) or in different habitats (e.g. riparian, reedbed and woodland specialists). Further, the optimal pattern of sampling over the UK will differ between species; Badgers, e.g., may need to be sampled everywhere, whereas Polecats need to be sampled intensively on the margins of their range, perhaps less intensively within their core range and scarcely at all in the rest of the country. Finally, landowners may change management practices if they perceive that their land is in some way special, thus rendering it no longer an unbiased sample of the countryside.

For these reasons, we would not generally support using the same sample locations for all mammals, though we acknowledge that there may be value in having common locations for species that are likely to interact directly.

2.3.4 The Master Squares

We take up issues of sample distribution, intensity of sampling and stratification in Part II.

2.3.5 The seven-year cycle

A seven-year cycle is too long for smaller mammals, which may show considerable short-term fluctuations. If the number of Weasels is 20% lower in 2010 than it was in 2000, how do we now that this is a long-term decline rather than a short-term hiccup, perhaps caused by peculiar weather? We need annual monitoring both to be able simply to distinguish long- from short-term changes and to be able to estimate the effects of weather and similar variables (Baillie 1990).

It is true that, if a change can be assumed to be constant, then the most effective way of measuring it is to study large samples of sites at long intervals rather than just a few sites every year, but the assumption of constancy flies in the face of our knowledge of the natural history of many British animals. We recommend that monitoring should be annual for species that are likely to show short-term fluctuations.

There may sometimes be other reasons (such as keeping a team of observers together) that favour annual surveys. Equally, for some species, practical reasons may make it desirable to undertake major surveys at infrequent intervals rather than to attempt annual surveys. If so, this has to be considered alongside the desirability of annual monitoring and a decision reached about the relative cost-effectiveness of different frequencies of monitoring. This will be a species-specific (or, at least, scheme-specific) decision. To impose the same frequency of survey on all species would be inefficient.

Note that the interval between surveys may be adjusted in the light of experience. Where there is doubt about the appropriate interval, it is perhaps best to err on the side of caution starting with a relatively short interval at first and extending it if experience shows a longer interval to be permissible.

In working on this project, we have been alert to the possibilities of hybrid approaches, i.e. major surveys at long intervals combined with smaller-scale annual surveys, the former to give long-term precision, the latter to provide information on short-term variation.

2.3.6 Rich Interest Kilometre Squares

Our considerations of sampling design (Part II) cover these.

2.3.7 Focus Zones

We recommend that special intensive study sites should be included in the monitoring scheme only if monitoring is the prime focus of the study. If the prime focus is demographic or other ecological investigation, the methods may not be appropriate for monitoring. It would not usually be cost-effective to constrain the methods of the intensive study in order to fit it into the monitoring scheme (or vice versa).

In contrast, we support the suggestion that monitoring may need to focus on particular geographical regions for some species.

2.3.8 Manpower and costs

We consider that the cost figure derived from MMR (Box 2) is only *c*.80% of the true cost of employing the number of staff involved, despite the salaries proposed by MMR for fieldworkers being higher than we believe is necessary. The reason is that MMR propose overhead rates that are unrealistically low - only 26% even if everything but the direct costs of running the vehicles and the Advisory Panel costs are excluded. This is substantially less than is charged by any organisation we know that has to cover its costs, as well as being substantially less than government guidelines to universities. In addition, we believe that MMR have underestimated the true cost of running the vehicles.

Note, furthermore, that we have made no attempt to estimate whether the man-power estimates listed by MMR are correct but we suspect that they are too low. We note, in particular, that their seven-year cycle involves two years' fieldwork on riparian habitats, two on woodlands and two on other habitats; yet the latter comprise the bulk of the country and may be expected to demand far more fieldwork.

We consider other ways of monitoring mammals, particularly the use of volunteers, later in this report. These have significant impacts on costs.

2.3.9 Utilising existing and ancillary schemes

Those conducting existing or ancillary schemes may have their own reasons for continuing to conduct them in much the same way as they do at present. For example, The Deer Commission for Scotland has a specific remit, for which it needs to conduct its current surveys of deer; it is presumably unlikely to abandon its current surveys in order to participate more directly in a UK monitoring scheme. The information from its work is, however, considerable and it would be unwise not to use it as part of the overall UK monitoring of deer. It may not be easy to combine it with information from other schemes, such as these conducted by the Forestry Commission, by The British Deer Society, by MoD, by BASC etc. (and then with information from any new scheme designed to cover the gaps); and the combination of such disparate sets of information may not provide a simple index of the state of the nation's deer. Nonetheless, bringing all this information together will be more cost-effective than to base our monitoring on some new scheme that ignores all these continuing sources of information.

Of course, even greater cost-effectiveness may be achieved if it is possible for existing schemes to modify their procedures with the aim of improving their contribution to the national monitoring programme.

2.3.10 Setting up the mammal monitoring programme

We agree with MMR that the early stages of any new programme should be regarded as exploratory. In terms of methodology for individual schemes, we urge that such exploration occurs as quickly as possible, so that the work can settle into long-term protocols that deliver reliable monitoring within a very few years. More broadly, we advise that it would be inadvisable to set up the entire suite of desired monitoring schemes all at once. There are three reasons for this. First, some new schemes (and, indeed, some continuing schemes that require substantial modifications to existing practices) will probably demand more resources at first than they need later, especially if volunteer-based (because of the effort needed to recruit participants). Second, some schemes may need to be preceded by pilot work to ensure that the best methods and design are chosen. Third, the extent to which volunteers are prepared to participate is likely to increase with experience. It would thus be wise to begin an overall programme with fewer schemes than it is intended eventually to run, building in new schemes as the original ones get established.

2.3.11 Sampling with partial replacement

The issue of Sampling with Partial Replacement is taken up in Part II.

3. HOW THE MONITORING OF MAMMALS IS DIFFERENT FROM THAT OF BIRDS

3.1 Mammals are less easily detectable than birds

Because mammals are less easily detectable than birds, simple counts may reveal only a small proportion of the population present in an area. Thus, they provide an index that may be less closely linked to the true population than would be a count of, say, singing Whitethroats *Sylvia communis* on a warm morning in early May.

If people go out to record mammals they may see none at all, resulting in a loss of motivation. To boost the frequency of observations, it may be necessary to trap mammals or to substitute observation of the animals themselves with observations of their signs. Trapping is generally more demanding of human and financial resources than is simple observation. The use of signs may demand special training and raises the problems of standardisation common to almost all index methods (see Section 1.5.6).

3.2 Identification

Apart from some groups of small mammals and mustelids, mammals are generally at least as easy to identify as birds. Indeed, a rather higher proportion may be identifiable by the non-specialist than is the case for birds, raising the possibility of drawing relatively inexperienced observers into the monitoring of some species.

3.3 More species-specific techniques are needed for mammals than for birds

A high proportion of terrestrial bird species can be covered by the Breeding Bird Survey (BBS), of freshwater and estuarine species by the Wetland Birds Survey (WeBS), and of seabirds by general counts at colonies. In contrast, most potential monitoring surveys for mammals cover only single species or a small group of species. In designing such surveys, one must try to find ways of including as many species as possible in each, without unduly compromising the quality of the data for individual species.

3.4 Availability of personnel

There are far fewer amateur mammal enthusiasts than there are birdwatchers, so there is a smaller pool of potential volunteer recruits for survey work. This problem may be rather less severe than one might imagine at first sight, however, because amateurs who regard themselves as interested in mammals tend to have a rather more scientific (or, at least, committed) interest than do many birdwatchers; "twitching" has not distracted mammal-watchers. Furthermore, it is clear that there is considerable potential for building up volunteer network for mammal monitoring (Part V). (It is true that Burnett, Copp and Harding (1994) reported that there were *c.*100 times more biological records referring to birds in the UK than those referring to mammals, suggesting a huge imbalance of observer effort. However, a large proportion of the bird records result form there having been three atlases of bird distribution and from bird-ringing. The latter alone produces almost a million records each year).

In contrast, a significant proportion of the admittedly small number of academic theriologists still feel able to engage in survey and monitoring as part of their academic work. Unfortunately, retirements and the relentless pressure to engage in theoretically more exciting work may quickly deplete the ranks of this group of scholars.

3.5 Diversity of existing inputs is greater for mammal monitoring

Most bird monitoring is organised by BTO, WWT, RSPB and JNCC, between whom there is close liaison. Thus bird monitoring is well integrated. As is made clear elsewhere in this report, recent and current mammal monitoring is conducted by a great variety of organisations: some do national work on one or a few species, others work only locally; individual bodies may conduct one-off surveys but not repeat them, or may mount schemes that last just a few years. Some effort may be needed to pull this diversity of interest together (as is essential if UK mammal monitoring is to be developed properly) but we do not believe that this will be a major problem.

3.6 There is no commitment to long-term monitoring of mammals

Whereas the ornithological bodies have managed to build up a level of commitment to long-term monitoring (including some commitment to the funding that makes it possible to keep schemes going in practice), this has not been the case for most mammal monitoring. Some guarantee of funding is essential if cost-effective monitoring is to take place. Otherwise, we will continue to waste resources (both human or financial) on a series of short-term initiatives that do not provide the long-term monitoring that is needed.

3.7 Mammals are generally less mobile than birds

Birds are sufficiently mobile for it to be useful to think of a “British population” for many species. For mammals it will often be more illuminating simply to draw together the monitoring information for different regional populations rather than to combine it into some sort of national index, since the regional populations are affected by regional management and environment and since they exchange few individuals. There may, of course, be an administrative need to report at UK (or country) level but for actually managing the animals we need the regional information. This presents no problems for species that are already well-monitored for management purposes, such as Red Deer. Indeed, given that such species may be monitored differently in different places (by different organisations!), it is an advantage, because formally combining the regional data into a national index may not be easy. For other species, it may be difficult to obtain enough data to provide reliable indices at scales less than the whole UK; if we have to accept that, then we must still remain alert to the likelihood of regional differences in population trends.

Lower mobility may mean that mammals treat the environment as more ‘fine-grained’ than do birds, so that populations may vary more from place to place within a habitat than do those of birds of corresponding size. This may be particularly important for surveys of small mammals based on trapping, where a sample area may typically be one hectare or less; larger sample areas would smooth out the spatial variation in small mammal numbers but may be practically inconvenient.

3.8 Many mammals occur in many different habitats

This has several consequences. First, it is especially important to ensure that all habitats are adequately represented in the national sample, since population changes may differ between habitats. Unfortunately, because mammals are difficult to detect, it may be necessary to use different field methods in different habitats. For example, deer in open country may be assessed best by direct observation but in woodland by signs, whereas birds can be directly observed (by sight or sound) in both habitats, using methods such as distance sampling to correct for the difference in detectability between habitats this may mean that monitoring information for deer in the different habitats cannot be formally combined.

If there are economic reasons for focusing attention on a species in some habitats (for example, Grey Squirrels in forestry but not in gardens), this may result in a disparity between habitats in levels of work and, therefore, in level of information.

PART II. CONSIDERATIONS OF DESIGN AND STATISTICS

1. INTRODUCTION

1.1 Why revisit these issues?

MMR cover many of these issues in some detail. Our purposes in revisiting them are: to remind readers of key points, to introduce some points not covered by MMR, and to make a closer connection between some of the matters of statistical nicety and those of practical possibility. Some of the points we make are elementary; we make no apologies for this, because getting the design of surveys right is so important.

1.2 Statistical nicety or practical pragmatism?

The purpose of scientific investigations is to draw conclusions about the natural world. The purposes of survey design and statistical analysis are to maximise the efficiency of that process and to minimise the possibility of the wrong conclusions being drawn. In simple situations, the statistical design and analysis may almost completely remove the need for the scientist to make subjective judgements. For example, if one were to count all the individuals of a highly conspicuous and easily identifiable species in a truly random sample of 1ha plots in Great Britain, one could arrive at an unbiased estimate of the total GB population (with reliable confidence limits) simply by applying standard statistical techniques. In most real cases, however, the investigator would have to make judgements about the extent to which individuals may have been missed in the counts (or counted twice), the extent to which such counting problems differed between plots, the extent to which randomly chosen plots that could not be counted because of access problems were likely to have more or fewer animals than the average, etc. Such judgements will determine how accurate the investigator judges the population estimate to be - i.e. how close it is likely to be to the true population size. Accuracy thus defined is affected by two consequences of the methods used - whether they give biased results (i.e. whether the estimates are systematically different from the true values in one direction or the other) and whether they give precise results (i.e. whether repeating the study would produce a closely similar estimate). In general, it is impossible simultaneously to minimise bias and maximise precision. We make these elementary points because so much attention is usually paid to minimising bias, both during the education of ecologists and in the design or interpretation of ecological fieldwork, that there is a tendency to neglect the simultaneous need to maximise precision; the overall need is to achieve the most accurate estimates possible (given the resources available), by striking the optimum balance between minimising bias and maximising precision.

The point can be illustrated by example. Suppose that one is monitoring a species and has decided that action should be taken to conserve it if its numbers fall by 25% over 25 years. Suppose that one adopts a monitoring method that estimates the population size after 25 years to be 90% of its original size and that this estimate is absolutely unbiased; but suppose further that the lack of bias has been purchased at the cost of low precision, so that the confidence limits of the estimate are 60% and 150%. This information is of limited practical use. In contrast, if one had adopted an admittedly biased method that gave confidence limits of 87% and 93% and had good reason to suppose that the bias was unlikely to be more than a few percent, then one could conclude that it was unlikely that the 75% alert limit had been exceeded, a useful conclusion. As Yates (1981) wrote: "The investigator must also avoid attaching exaggerated importance to minor sources of bias which, in fact, can only produce errors which are trivial relative to the random sampling error".

Unfortunately, bias is rarely measurable in practice, so the balance between bias and precision is a difficult one to strike and generally depends on subjective judgements. So long as the judgements about bias are based on the best information about the natural history of the subject species and are made explicit to those involved in using the results, one is justified in using methods that are not completely unbiased.

Recommendation:

* **Be prepared to abandon absolutely unbiased methods if practical considerations dictate that overall accuracy is higher for somewhat biased methods - but make explicit the likely sources and magnitudes of bias. To avoid post hoc controversy, seek wide agreement about the likely sources and magnitudes of bias before finalising plans for the monitoring scheme.**

2. THE SPATIAL DISTRIBUTION OF SAMPLING

2.1 Generalising from samples

To know the population size of an animal in Britain, we would ideally count every individual directly - i.e. conduct a census. This is usually impossible in practice, if for no other reason than cost. Instead, we count sample areas and generalise from them to the whole country. The process of generalisation is straightforward when the samples are taken through a formal, properly randomised design. If they are not, the reliability and extent of the generalisation are a matter of judgement. The worst case occurs when, for practical reasons, it is only possible to study a single site: not only may this site be atypical but one has no direct knowledge of how atypical it might be, having to rely on knowledge of the species, the habitat and of similar cases to judge the reliability of conclusions drawn from just the one site. Sometimes the conclusion may be that knowledge of one site is better than no knowledge at all; sometimes one may reach exactly the opposite conclusion, in that the cost of being misled by information derived from just one site is so great that it is better to have no knowledge at all.

The reliability of information derived from a single site depends on how representative it is of the whole country. This has to be a matter of careful judgement. Unfortunately, naive judgements about how typical is a site may be seriously awry: a "typical" oak woodland is more likely to resemble some sort of idealised oak woodland (rarely observed in real life) rather than an average oak woodland. Assumptions and assertions of typicality thus need particularly critical examination.

Even if a site is not truly representative, there may be good reasons for studying it. Thus the sites in the Environmental Change Network (ECN) are mostly not typical of the British countryside: some were chosen for study because they had special features or were ideal examples of a particular habitat; most are managed differently from the wider countryside, sometimes because they are long-term ecological study sites! Nonetheless, the view was taken that, for the purposes for which ECN was set up, the sites were sufficiently representative of the rest of Britain that the information derived from them would be sufficiently capable of generalisation. The benefit of establishing a set of truly representative sites for the ECN, rather than using the existing long-term study sites, was judged not to be sufficient to justify the cost of doing so. Similar practical considerations must illuminate the establishment of mammal monitoring.

Multiple sample sites, as in ECN, have the advantage that the differences between them provide information on how atypical each is likely to be of the whole population and therefore how reliable one's generalisations are likely to be. Formally, provided the samples are truly random, one can place confidence intervals on statistical estimates derived from multiple samples. Thus, where possible, monitoring should be conducted at more than one site.

2.2 Sources of imprecision in sample surveys

Generally speaking, the precision with which population means are estimated will increase with the square root of the number of samples, but precision of the overall mean also depends on the precision with which measurements are made at each sample site. There is often a trade-off: more effort devoted to improving the precision of counts at individual sites means that there is less effort available for covering more sites. Texts on survey design provide methods for optimising the distribution of effort in such cases (e.g. Greenwood 1996). It has been suggested that such cost-benefit analysis in survey-design may often not be worth the effort, at least unless one pays careful attention to the design of the pilot studies that are used to provide information for the cost-benefit analysis (McArdle & Pawley 1994). However, the extent to which the recently-developed BTO/JNCC/RSPB Breeding Bird Survey (many sites, relatively undemanding work at each) provides better bird-monitoring at the national scale than the Common Birds Census (comparatively few sites, each studied intensively) shows the value of choosing the right design. For some mammal monitoring, rather little background information is available on which to base design judgements; it may be necessary to conduct pilot studies to provide the necessary information or to treat the first few years of a new monitoring scheme as a trial. (See also Part I, Subsection 2.3.10).

A great imponderable for surveys that use volunteers is the level of participation to be expected. One has little alternative but, having decided what level of participation is the minimum to make the planned survey effective, to use the experience of those involved in organising similar surveys in the past to judge whether that level of participation is likely to be attained.

2.3 What population is of interest?

Design texts lay great stress on the need to define what is the statistical population about which one is wishing to make inferences. Unless one does this, one's survey is likely to be both inefficient and misleading.

It is possible in principle to design surveys that will provide efficient and unbiased estimates of population change at the national level - i.e. the focus is on the national population. Paradoxically however, there are several reasons why having the national population as the immediate focus of the survey design may not be efficient for the monitoring of that population. The first we have covered in Part I, Subsection 1.4.2: where populations in different parts of the country are rather isolated from each other, greater insight is obtained by treating each as a separate entity than by aiming to obtain some measure that relates to the "national population"; the national perspective that is required can be obtained from drawing together the information about the individual populations.

There may be some geographical regions or habitats that contain so few of the species in question that the effort involved in surveying these places is not worthwhile as, for example, Badgers in urban areas (Cresswell, Harris & Jefferies, 1990). If so, it is best to omit those regions or habitats from the sampling programme. Given the extreme fragmentation of habitats in much of the UK and the fact that the smaller mammals in particular do not move far, selectivity of sampling may need to be fairly fine-grained. The information one gets from such selective sampling is, of course, relevant only to that part of the national population that lives in the parts of the country included in the survey; but if this is clearly most of the national population, that is enough for practical purposes. There is a proviso, however, in respect of surveys that are undertaken for monitoring purposes, since monitoring is concerned with change rather than with absolute numbers and change may, in some circumstances, be more marked in places where a species is scarce than where it is abundant. It is true that because such places hold only a small proportion of the national population the changes occurring in them (unless hugely different from the changes elsewhere) will have little impact on the national population index. However, knowing that there have been marked changes in such places may well be of much more relevance to conservation than knowing that the national population has changed rather little. For example, a species may be more sensitive to environmental change in marginal rather than in core areas, or we may need to assess how well a species, such as the Polecat, is reoccupying its former range, or we may need to assess how rapidly a species such as the Grey Squirrel is spreading and thus increasing its impact on other species. Thus whether or not to leave places with few of the species out of a survey must be a case-by-case decision as to whether such places are of special interest - Focus Zones, in MMR terms.

It may be necessary to leave out some places because they are difficult to work in or to access. This is acceptable for monitoring if one knows that the animal is relatively scarce in the excluded areas or if one can reasonably assume that the changes in those areas are unlikely to be markedly different from those in the rest of the country; otherwise, one simply has to admit ignorance of the excluded sector of the population. If the excluded places are left out according to clear criteria that can be related to habitat, the effect of leaving them out can be explicitly and clearly addressed. If they are left out on a more *ad hoc* basis, there is often a tendency to gloss over the possible effects; this should be avoided. For example, it may be reasonable to assume, in some circumstances, that places to which observers are refused access are representative of the countryside as a whole, so the exclusion does not bias the results. The refusal may, however, be linked to land-management practices that may affect the mammals being monitored (such as Pheasant-rearing) or, indeed, to the fact that illegal methods of control are being practised; if so, one has to accept that the population being studied is not that of the countryside as a whole but only a (rather ill-defined) part of it and that the results may not accurately reflect the population in the areas excluded from the survey.

Another situation in which one monitors only parts of the national population is when one is using existing schemes that are designed to provide monitoring of local populations (such as much deer monitoring) or of particular habitats (such as surveys of rodent infestation of houses). The extent to which it is appropriate to rely on such schemes depends on how representative are the populations they cover of the national population and on the expense of mounting surveys that would be more representative.

Appropriate monitoring techniques may differ between habitats. If so, it is sensible to design one's monitoring programme as a set of surveys, one for each of the habitats; each provides information on the population in that habitat. The way in which that information is brought together and used for national monitoring will depend both on statistical constraints and on needs; if the index in habitat A has gone up by X% and that in B by Y%, one can only produce an index of change in the national population if one knows the relative sizes of the populations in A and B - but that index is probably less revealing than are the separate indices for the two habitats.

For some species, useful information may arise from more than one monitoring scheme. For example, Grey Squirrels might be monitored by presence/absence in volunteers' gardens, through presence/absence in Woodland Trust reserves, through numbers seen on Breeding Bird Survey transects, and by frequency of occurrence of signs in hair tubes in plantations. None of these provides an index for the national population (or even that of a well-defined geographical region or habitat). Furthermore, the population to which each relates may be rather ill-defined (such as: "Grey Squirrels that use gardens at the times of day when volunteers are observing and that are bold enough to be observed") and may overlap with the populations covered by other schemes. Nonetheless, if the suite of schemes is taken as a whole and interpreted carefully, it will provide useful information for conservationists.

Finally, the interpretation of indices (rather than true counts) in terms of the population being studied is important. If Red Foxes in forests are monitored by counting scats along the edges of rides, one is monitoring not the Red Fox population in the forests but that proportion of the population that defecates along rides; the extent to which such Red Foxes are representative of the whole population must be explicitly considered not only when the survey is being designed, but also when the data are interpreted. The consideration must not only involve knowledge of Red Fox behaviour but also of the external factors that may be relevant, such as the likely impact of ride management on defecation behaviour. (In addition, as with all indices, one must consider how the relationship between the index and the population that is being monitored varies. For example, the number of ride-defecating Red Foxes may stay the same but the index may change because the defecation rate varies seasonally or because the detectability of scats by observers varies according to vegetation growth.)

Recommendations:
* **Treat isolated populations as separate targets for monitoring.**
* **Leave areas sparsely populated by the species in question out of the study, unless changes occurring there are likely to be of special interest.**
* **Be prepared to leave out areas that are difficult to cover but make as explicit as possible the criteria for omission and the likely resultant biases.**
* **Use existing local schemes as part of the national programme if this adds useful information, even if they use non-standard methods.**
* **Treat the populations in various habitats as separate targets for monitoring if different methods have to be used in the different habitats.**
* **Especially if no one scheme provides unbiased information on the national population, be prepared to use multiple schemes for monitoring a single species.**
* **Be particularly aware that indirect indices may refer to only part of the total population.**

2.4 Randomisation

It is well-known that the only way to obtain a sample that is truly representative of the population as a whole is to select which areas to sample by a formal randomisation process. Informal, haphazard processes are rarely truly random. Selecting “typical” sites is usually grossly non-random, suffering both from the misapprehensions about what is truly typical and from the failure to include a representative range of sites.

Unfortunately, many practical constraints make randomisation difficult or at least costly. Many of these have been considered in the last section - places or habitats where the species is scarce, difficulties of access, etc. If these practical difficulties interfere with full randomisation, one must carefully consider what exactly is the population that is being studied and then consider how typical it is likely to be of the wider population that is the true focus of interest. In other words, what bias is involved in using the non-random sample to estimate the changes going on in the wider population?

Recommendation:
* **If practical problems rule out proper randomisation, make the likely biases as explicit as possible.**

2.5 Species restricted to special habitats of limited extent

Riparian species present particular difficulties. It is not practically effective to choose study sites completely at random, since the majority of them will then not contain riparian habitat nor, therefore, the species in question. For example, the pilot Waterways Breeding Bird Survey achieved markedly better coverage than the Breeding Bird Survey of many riparian species, e.g. 36% of WBBS sites occupied by Dippers compared with 2% of BBS sites, 31% vs 4% for Common Sandpipers, and 41% vs 6% for Grey Wagtails (Marchant & Gregory 1999). There were similar differences for mammals, although the mammal data were collected incidentally to the bird data and are therefore perhaps less reliable: e.g. Otters on 14% of WBBS sites, Water Vole on 9% and American Mink on 8%, with almost none of these species being recorded on BBS sites (Marchant & Gregory 1999 and Part III).

It is easy enough to randomise at a coarse scale - for example, by choosing a sample of 10x10 km squares within which to survey the species in question. The difficulty lies in defining and identifying riparian habitat within such areas - when is a ditch too narrow or too dry to be included? Whatever method is used to pick which stretches of waterway to survey, one must consider carefully how this will bias the results. Another problem is how large a sample one should take within each 10x10km square; in principle, one should sample the same proportion of available habitat in each square, not the same absolute quantity. If one does not sample the same proportion and if the density of animals per km of habitat varies according to the amount of habitat available, then one's sample will provide a biased estimate of population size. Even if density does not vary according to the amount of habitat available, sampling that is not proportionate to the amount of habitat available may result in substantial inflation of the error variance of one's estimates of mean numbers or changes in numbers (Cochran 1977, section 11.2). In this respect, the methodology of Otter surveys, sampling at 5km intervals along every waterway in the selected 10x10km squares, has been superior to that of Water Vole surveys, in which exactly five samples were taken in each selected square.

Similar considerations apply to other special habitats, some of which may be of very limited extent. Small mammals that occupy field margins, but not the cropped area of farmland, may pose particular problems.

Recommendations:

* **For surveys limited to special habitats, make as explicit as possible both the criteria used to define the places to be sampled and the potential biases.**
* **The number of samples of a special habitat to be taken within higher level sampling units (such as 10x10km squares) should preferably be proportional to the amount of that habitat present in the higher units.**

2.6 Systematic surveys

Systematic surveys comprise those surveys in which the country is covered by a grid and cells of the grid are included in the sample not at random but in some sort of pattern. MMR consider the problems resulting from systematic sampling at some length. Our aim is briefly to review and assess the magnitude of these.

The most obvious problem is that the pattern of the sampling may coincide with a pattern in the distribution of the organisms being monitored. This could easily happen, for example, if one studied soil invertebrates on a hillside that had been subject to periglacial sorting of the soil, producing some sort of patterned ground, but we believe that mammals are unlikely to show regular patterns in distribution or numbers at scales that would coincide with sampling patterns based on the national grid.

A more subtle problem, to which MMR pay much attention, is that estimates of the error variance of population means that are based on the assumption of random sampling are likely to be wrong if sampling is systematic. The direction and extent of the biases in the estimates of error and ways of obtaining unbiased estimates have been addressed in the technical literature (e.g. Bellhouse 1988; Murthy & Rao 1988). Unfortunately, they depend very much on the type of geographical trends and patterns present in the study population and how the pattern of the sampling relates to these (which determines the spatial correlation between samples), about which we are likely to know little in practice. However, both theory and simple simulations suggest that when the total number of potential sample units (e.g. 1x1km squares of the national grid) is large then the bias in estimating the error variance is likely to be small.

MMR also point out that the fact that the "false origin" of the Ordnance Survey grid was not randomly located raises difficulties in statistical theory, although these are unlikely to be other than trivial in practice.

To test out the effects of systematic versus random sampling, MMR used Countryside Survey data on habitat distribution taking the latter as an example of a spatial distribution comparable to that of mammals. They found no obvious biases in estimation of either means or standard errors when comparing systematic with random sampling. We agree with their conclusion that the theoretical reasons for preferring random sampling are unimportant in practice.

Advantages of systematic sampling pointed out by MMR are that it is easier for the layman to understand and that the sample units are easier to locate. Perhaps even more important, a regular grid makes the description and analysis of geographical patterns easier. Such patterns may be important in understanding population changes in distribution or abundance.

Note that, in refusing to follow statistical purists in condemning systematic sampling, we follow one of the masters of sampling methodology, who recognised that it would generally prove satisfactory except for material that had periodic features (Yates 1981).

Recommendations:

* **Generally choose random sampling but adopt systematic sampling if this is practically more convenient or if information about geographical patterns is required.**

2.7 Study sites chosen by the observers

Study sites chosen by observers are likely to be unrepresentative: they may be "typical" (i.e. atypical, see Section 2.1 above), chosen for reasons (such as accessibility) with which the abundance of mammals may be linked, or chosen because they have good populations of the species in question. In principle, such biases are undesirable. In practice, however, it may be better to get information from such sites than to get none at all.

Note that schemes in which observers choose where to go within a randomly chosen 10x10km square (for example) may be less biased than those in which there is absolutely free choice - but they cannot be bias-free.

Recommendation:

* **Be prepared to use study sites chosen by observers (rather than randomly allocated) if this is the only way to achieve enough sites but explicitly address the biases that may result.**

2.8 Sampling at more than one level

Suppose that traps are difficult to transport long distances but relatively easy to transport short distances. If one decides to set traps in a 40x40m grid at each sampling location, one could have such sites scattered across the country; but this would involve long distances between the sites. Alternatively, one might choose a set of 1x1km squares to which to take traps and then choose a set of 40x40m squares within each to be the sites at which one does the trapping; the 1x1km squares would still be at long distances apart but the small squares within each would be within easy distance of each other. This is an example of two-level sampling, which may be adopted for various practical reasons. If sampling is random at both levels, statistical interpretation is straightforward. The principle can be extended to more than two levels. The relative number of sample units to take at each level in order to maximise efficiency depends on relative costs (see e.g. Cochran 1977; Greenwood 1996).

If the sampling is non-random at any level, then the total sample is non-random - the randomisation at other levels does not compensate for the non-randomness at the one level. As always, judgement about likely bias must be made before one adopts non-random choice.

If non-random choice is at the lowest level, it may be circumvented simply by combining the data within each of the low-level groups, which are now treated as "clusters" rather than as sets of independent samples. In the trapping example for instance, moving the traps between five (say) random 40x40m squares within a 1x1km square may be too burdensome; as an alternative, one might choose one such 40x40m square as the starting point, then set the traps during the next four successive weeks in four squares 100m away from the first one, to the north, east, south and west. To analyse the data, one then lumps the results from each of these clusters of five. Such cluster-sampling allows more data to be gathered without expending the effort that full randomisation may require; the benefit is achieved at the cost of having rather broader confidence limits on one's results than if the design were fully randomised.

Recommendations:

* **If practical considerations suggest that it may be appropriate to sample at more than one level, pure random sampling or cluster sampling should be adopted if possible. Beware of bias entering at any level.**

2.9 Many small samples or fewer larger ones?

Since the samples in a cluster are lumped, each cluster is effectively one sample. Thus cluster sampling is an example of taking fewer larger samples than many small ones. Another example might be sampling 100 2x2km squares rather than 400 1x1km squares. To get the same area covered, taking fewer, larger samples (and clusters) is generally practically more convenient than taking many small ones - travel costs are likely to be lower, for example, but there is a cost to this, in that (because of the spatial autocorrelation between the parts of the larger samples, or the components of the clusters), the standard errors of the statistics that are estimated from the data will be higher. Cochran (1977) shows how to optimise cluster-sampling designs for a given cost (i.e. how many clusters of what size) and similar considerations apply when optimising the balance between number and size of samples.

For volunteer-based surveys, optimising the distribution of sampling effort will be more difficult because it will depend on predicting the responses of potential volunteers to various possible designs. For example, suppose that volunteers can easily walk several 1km transects. For the same total distance walked by a volunteer, precision will be greatest if his or her transects were part of a completely random sample; it would be less if they were randomly distributed within a fixed 10x10km square (itself randomly chosen, one hopes), even less if they were randomly distributed within a 5x5km square, and least if they were in adjacent 1x1km squares, but volunteers would rate these four designs in reverse order in terms of ease, so one would be able to recruit more people to the statistically less effective designs. Given that the likely reactions of volunteers to different designs are likely to be unknown in advance (unless some sort of opinion poll is undertaken), this aspect of survey design may depend largely on the judgement of those with good previous experience of organising such work and on their ability to balance theoretically probity with practicalities.

Recommendation:

* **Try to optimise the distribution of survey effort, in terms of number and size of samples, even though this may be difficult to predict for volunteer-based work.**

2.10 Stratification: general

In the most recent national Badger survey, OS grid squares were each assigned to one of seven land class groups; sampling was random within each group, not over the total set of squares (Wilson, Harris & McLaren 1997). A similar procedure has been used in surveys of Brown Hares, Red Foxes and bats. This is an example of stratified sampling: the potential sample units are divided up into sets (strata) and randomly sampled from within each set rather than from the entire population. The sets may be defined according to any relevant criteria, such as geography, land class, habitat, or observer availability, depending on the purpose of the stratification. Because stratified sampling adds to the complexity of organising a survey, it is important not only to be aware of its potential benefits but also to assess the likely magnitude of those benefits.

One purpose of stratification may be to ensure that all administrative divisions are adequately covered by the sample. For surveys involving hundreds of sample sites across the UK, adequate samples of each of the four countries (and of the English government regions) will be obtained without stratification. For smaller regions (should it ever be necessary to focus on such fine scales), stratification would be needed to ensure adequate coverage of each.
Stratification may also be needed to ensure adequate coverage of all habitats or land classes, which may be important if one wishes to use between-habitat differences to explain changes in abundance or distribution. Again, if the size of such strata is not too small, adequate sampling of each will happen without stratification. Since the most efficient distribution of sampling effort for exploring differences between strata is similar to that for precise estimates of the national statistics, the guideline that Cochran (1977) provides for the latter can be used here: if non-stratified sampling is likely to provide samples of 20 or more in each habitat, stratification is not needed at the sampling stage; post-stratification (Section 4.3, below) will be sufficient. Thus it is only likely to be needed if some of the habitats cover less than 10% of the country.

Another reason for stratification arises from the need to replace some of the sample sites over the years because, for example, land-owners decide to withdraw permission. To keep the characteristics of the sample as constant as possible, one could replace sites that drop out with other sites from the same strata, as has been done in Badger surveys (S. Harris, pers. comm.). This is likely to be important if the turnover of sample sites is large or is concentrated in some strata.

Stratification also allows sampling to be more efficient as a means of assessing the national population size or population change. By concentrating sampling effort where variation is greatest (which for monitoring means spatial variation in changes in abundance over time), greater precision is obtained per unit effort; the same is achieved by concentrating it where sampling is easiest (cheapest). The ways of optimising the distribution of sampling between strata according to differences in variation and in cost are well known: sampling should be concentrated more on strata that have large between-locality, within-stratum variance in numbers and that are relatively cheap to sample (e.g. Cochran 1977; Yates 1981; Greenwood 1996). However, McArdle and Pawley (1994) point out that one needs good information on within-stratum variation to achieve the optimum design and they suggest that it may often not be worth the effort. Unless strata differ markedly in the magnitude of the between-locality variance in population size or change or in the cost of taking samples, optimum stratification produces relatively little gain compared either with including the same proportion of each stratum in the overall sample (as has been attempted with several recent mammal surveys) or with pure random sampling combined with post-stratification (Section 4.3, below).

If stratification is used to improve the efficiency with which the national mean is estimated, it is probably unnecessary to use more than about six strata (Cochran 1977). We suggest that a similar number is appropriate if the focus is on using between-stratum differences to understand a species' ecology: to use more would run the risk of obscuring major patterns with incoordinate detail, as well as of having sample sizes for some strata that were too small to provide precise enough statistics.

Decisions not to sample areas, habitats or land classes that hold few animals or that are particularly difficult of access (see 2.3, above) are an extreme case of stratification - they involve identifying strata that provide so little information relative to the cost of getting it that there is little point in sampling them at all.

If habitat-related stratification is to be used in mammal monitoring, it is important to use relevant strata. If stratification is being used because of major differences between strata in variance or cost (so that stratification is needed to optimise efficiency), then the distribution of samples between strata needs to be species-specific. Furthermore, different stratum divisions may be appropriate for different species. On the other hand, it would be practically convenient to use the same system for most species; this would also make the analysis of species interactions easier. Several surveys of mammals have already used the ITE Land Classes as the basis of stratification, generally on the four or seven aggregate landscape groups rather than the 32 basic Land Classes, the latter rightly being considered to be too finely divided for the purpose. The ITE system underpins the GB Countryside Surveys, thus allowing monitoring based on these Land Classes to be linked to the data that they provide. Unless there are particular reasons for using other stratifications for other species, it would be appropriate to continue to stratify by aggregated Land Classes, such as the ten of ITE's Division 3 or the four of Division 4 (Bunce 1992).

Note that, for administrative reasons, these 32 Land Classes have now been modified somewhat differently in Scotland and in England and Wales, in that Land Classes that are scarce in

Scotland have been combined with similar but commoner Land Classes for Scottish purposes and similarly for England and Wales (Barr 1998). Furthermore, the Northern Ireland Countryside Survey used a different landscape classification from that used in Great Britain. Thus stratification will need in future to be at two levels: first by geography (three - or perhaps four-strata), then by Land Classes that are somewhat different in the different countries. We understand that analysis of CS2000 may use three aggregate Land Classes in England and Wales (two lowland, one upland) and a different three in Scotland (one lowland, two upland). There are enough data from previous mammal surveys to test whether this level of aggregation is sufficient or whether it would be better to use more strata for mammal monitoring schemes.

Recommendations:

* **Adopt stratification for mammal monitoring if there are good reasons for doing so for the species in question (This may need some simulation work relevant to individual species, based on existing data and realistic assumptions). If there are no particular reasons for stratifying, and it is easier not to do so, then do not bother.**
* **Unless there are particular reasons for doing otherwise, stratify by aggregate ITE Land Classes.**

2.11 Focus Zones may be strata

A particular form of stratification arises for species where Focus Zones have been identified. To pursue the example in Part I, Subsection 2.3.3, Polecat sampling could be conducted on the basis of three strata: one, regions with no Polecats (sampling intensity zero); two, regions on the edges of the Polecat's range (Focus Zones - high intensity of sampling); three, core Polecat range (moderate sampling intensity). However, if it is appropriate to use different methods in different regions, the latter can no longer be considered to be strata in a single survey; rather, they are subdivisions of the national population for which different monitoring schemes are being operated.

2.12 Stratification by observer availability

Concentrating sampling effort where there are relatively more volunteer observers (see above) is another example of stratification. The costs of sampling in the different parts of the country may not be explicit in this case, since they are chiefly the indirect costs of drumming up support, but these certainly differ according to the availability of volunteers (with the complication that within any one region the costs rise disproportionately with the number of observers required - the 21st observer is more difficult to recruit than the first). If one were simply to choose potential sample sites at random across the whole country and then only use those for which it is possible to recruit observers, bias will creep in at two levels. First, whole areas of the country (e.g. the Scottish Highlands) will be under-represented; second, places within local areas that are closer to peoples' homes are likely to be over-represented. These problems have both been addressed in the BTO/JNCC/RSPB Breeding Bird Survey. First, the country is divided into regions and the sampling intensity in each adjusted to the availability of observers; by appropriately weighting the data from each region, an unbiased national index can be obtained. Second, potential sample sites within regions are randomly ordered and are allocated to observers in that order, so that a site that is close to potential observers cannot be included until all sites before it in the list have been included, even if some of these are distant. Difficulties are still encountered in large, sparsely-populated regions: it may be impossible to persuade anyone to cover a remote square that is early in the list, even though there are plenty who are prepared to cover less remote squares. Once again, if the patchy distribution of observers cannot be fully overcome by using methods such as used by BBS, one has to consider carefully the likely biases that will result.

It is, of course, important not just to take steps to overcome the problems arising from variation in availability of observers but to take steps to reduce that variation. Recruitment efforts should be particularly intense in poorly populated regions. Volunteers may also be supplemented with professionals in such regions but we regard this as a last resort if the scheme is meant to be volunteer-based: it adds significantly to costs and sets an undesirable precedent.

Recommendation:

* **In schemes that are largely volunteer-based, consider stratifying by observer availability as an effective means of avoiding bias while achieving large sample sizes in those regions where it is possible.**

2.13 Statistical power

Many of the recommendations above are designed to maximise statistical power (the ability to detect important changes in numbers). The matter should also be looked at the other way round: For a given cost and sampling design, what is the power of the scheme to detect changes in numbers of a certain magnitude?

MMR present considerable discussion of the issues of statistical power to detect trends and validation of survey methods. They generally fail, however, to justify the choice of sampling design and recommended sampling size for individual species in terms of the power that these will have to detect trends that are considered important to conservationists. This can only be done formally by using species-specific data on the scale of geographical variation in the magnitude of temporal changes and on the extent of short-term fluctuations, since both of these determine the variance of any estimate of trend. Where the requisite data are not available, informal estimates based on scraps of relevant data, on related species, and knowledge of the species' natural history can be made. We have not had time to conduct the necessary analyses. Instead, we have used our experience in avian monitoring, knowledge of species' natural history and population ecology, and expert advice to come up with suggestions for suitable sample size for each species. This will allow decisions to be made as to what schemes it would be useful to attempt to run. After that, it would be wise to undertake more formal statistical analyses to confirm the suggestions that we have made for the species that it has been decided to cover.

As a general guideline in discussions on the size of schemes to run, one should note that precision will generally increase according to the square root of sample size. Thus, to halve the width of one's confidence limits, one would need to quadruple the sample size. More optimistically, if one can tolerate confidence limits twice as wide as have been (or may be) obtained with an existing (or planned) survey, one can reduce the sample size to only 25% of the current (or planned) number.

3. THE TEMPORAL DIMENSION OF SAMPLING

3.1 The importance of historical continuity of sample sites

Monitoring necessarily entails taking samples repeatedly over time. There are two extreme possibilities, to choose the sample locations independently on each occasion (Fig. II.3.2A) or to use the same locations on each occasion (Fig. II.3.2B). (We consider intermediate cases in the next section). Using the same localities has three advantages. The first is concerned with avoiding bias. Suppose that, however carefully the protocol for choosing sample sites is defined, there is a subjective element in it. If different sites are chosen on each occasion, there is no guarantee that the subjective element will remain constant; thus a change in the sample mean over time may not, not because there has been a change in the population mean but because the bias is changing. This problem is circumvented if the same sample sites are used on every occasion. It can probably also be circumvented in most cases by using careful and consistent protocols for choosing study sites, so it is not a strong reason for sticking to the same sites on every occasion.

Much more important is the value of historical continuity for increasing the precision of one's estimates of change. This is because the error variance of the estimate of change contains two components if one uses independent samples - that due to differences between sites in average numbers and that due to differences between sites in the change in numbers. The former, which is typically large, is removed if one uses the same sites on each occasion, so the change in numbers is estimated more precisely. An illustrative example of the effect on precision is given by Greenwood (1996). The number of breeding territories of Chaffinches *Fringilla coelebs* were counted in each of two years on 65 English farms; in one simulation exercise, an independent sample of 20 was drawn from the population of 65 farms in each year (five squares falling in both samples by chance); in another, the same sample of 20 farms was used in the two years; in both cases, the sample data were used to estimate the change in mean numbers between the two years. The confidence limits of these estimates were five times wider for the independent samples than for the constant sample. In a national programme, it is likely that there would be much less (if any) overlap between independent samples drawn in different years, so the confidence limits of the estimate of change under that protocol would be even greater. If the Chaffinch result is typical, it means that historical continuity delivers an improvement in precision equivalent to more than doubling the sample size. This is a powerful advantage.

The third advantage of historical continuity is that (unless the sampling intervals are greater than a few years) it requires less time to be spent in seeking access permission. In our experience, the time taken in getting initial permission is an order of magnitude greater than the time taken in renewing that permission annually.

There could be a corresponding disadvantage to historical continuity: that land owners may be less prepared to grant access for a survey that will continue indefinitely into the future than for a one-off survey. We do not believe that this is generally the case.

Another disadvantage to long-term continuity is that land-owners may change their management as a result of the regular visits of those conducting the monitoring. They may, on one hand, manage the land more sympathetically for the wildlife; on the other hand, through having their attention drawn to a species that they may consider to be a problem, they may take steps to control its number or even to eliminate it from their land. If these steps are illegal (or likely to attract public opprobrium), they may then deny access to the land! We do not believe this problem to be a general one but it needs to be considered for a few species, of which Badger is perhaps the most obvious.

A final disadvantage of revisiting the same sites, especially for single-species surveys, is that observers know what to expect. They may be more persistent in looking for the species because they know it was seen there on a previous occasion. If there was no corresponding lessening of effort in sites from which the species had not been previously recorded, this would bias analyses of change.

Wilson *et al.* (1997) checked for both of the latter two potential biases by comparing the numbers of Badger setts in revisited and new squares (and found no evidence of bias). Given that some turnover of sites is almost inevitable, similar checks could be carried out in most repeat surveys even when the aim was to revisit the same sites

Drawing new samples on each sampling occasion gives more information on geographical variation in abundance. This provides better estimates of the mean abundance (or index of abundance) of animals, averaged over the whole country and over all the years of the study, but knowledge of actual abundance is of limited value for monitoring, which must focus on changes in abundance - which are better estimated using an historically continuous sample.

Geographical information is directly useful for modelling distribution in relation to environmental factors, which may help to understand what determines the distribution and abundance of the species. However, given the extent to which the distributions of mammals in Britain are dependent on direct management by man (current or historical), this is likely to be less illuminating than studying temporal changes. In any case, the increase in precision of the geographical models that is obtained by taking new samples every year is likely to be less than the corresponding decrease in precision of the temporal monitoring.

Geographical information is useful for planning and similar purposes: the presence of Common Dormice or Badgers in a wood may affect the decision as to whether it should be turned into a housing estate, but even if new monitoring samples are drawn every year for many years, the overall proportion of the country covered will be small. Site-based information is much more effectively delivered from Atlas surveys, local biological recording, and specific surveys of threatened sites.

Recommendation:

* **The general case for using the same sites from year to year is overwhelming, except possibly for species that may be persecuted by landowners.**

3.2 Partially replacing samples

It is not always possible to keep sampling the same sites: permission may be withdrawn, or fieldworkers may not be able to carry on. The available methods for analysing monitoring data can cope with the inexorable slow turn-over of sites that results (see 4.2, below).

MMR consider in detail more formal designs for Sampling with Partial Replacement (Fig. II.3.2C); their proposed MaMoNet incorporates these ideas. The rationale of such designs is that they provide information on both geographical and temporal variation, providing estimates of both overall means and temporal change. There are situations where this combination may be more useful than either the mainly temporal information provided by sampling the same localities on every occasion (Fig. II.3.2B) or the much greater spatial information provided by drawing independent samples on each occasion (Fig. II.3.2A) (see, e.g., Skalski 1990). We do not believe that these apply to the monitoring of mammals in the UK. Sampling with as little replacement as possible remains the method of choice.

There is one exception to this recommendation, which we see applying to cases where there is an individual or group of observers working in an area that is too large to be covered in one year but small enough to be covered over a few years. In this case, particularly if the species is one where trends in numbers are likely to be fairly slow, Rotational Sampling may be appropriate. This means that observers cover a different part of the area every year until they have covered the whole, when the same cycle of coverage is begun again (Fig. II.3.3). Such a strict cycle will give much more useful information for the level of effort expended than will the rather haphazard variation in coverage that generally happens in such studies. We do not see Rotational Sampling as being directly relevant at the national level but it may be relevant to local studies that feed into the national monitoring.

(Note that the protocol we present, in which each part of the population is sampled only once per cycle (Fig. II.3.3A), is a special case. More generally, Rotational Sampling involves each group of sample units staying in the sample for a certain number of years, then dropping out for the rest of the cycle (Fig. II.3.3B). The statistics of the general case have been considered by Rao & Graham, 1964).

Recommendation:
* **There is no advantage in sampling with Partial Replacement for mammal monitoring.**
* **Rotational Sampling may be useful for local studies (which may form part of the national programme) but is unlikely to be useful at the national level.**

3.3 Building on previous surveys

Setting up long-term mammal monitoring in the UK does not take place on a clean slate: several species have been the subject of previous surveys. Given the extent of the changes that have occurred in the countryside in recent decades, it is important to be able to compare the status of these species now and in the near future with what it has been in the past. Does this mean that the methods of previous surveys should be adopted without any changes for future monitoring? For methods that produce indices, the answer is clearly "Yes", since the relationship between an index and absolute abundance depends on the methods used. Where past surveys have determined absolute abundance, the naive answer is "No", at least if the future monitoring is also based on absolute abundance. Suppose, however, that either the past or the future estimates are biased (whether or not we realise it): unless the bias is identical, the comparison of future estimates with the past is undermined, so even in this case there is an advantage in continuing to use the methods used in previous surveys.

The advantage of sticking with the same methods does, however, need to be balanced against any advantage to be gained from the greater efficiency or greater accuracy of other possible methods. This is a different judgement to make, as it entails weighting the short-term advantages of continuing with the same methods against the long-term advantages of making a change. If such decisions have to be made, it is worth investing time in getting them right. It is also important to make them now, since the longer that suboptimal methods are used the more disruptive will be a shift to better methods. Where changes are to be made, it is important to calibrate old and new methods against each other if one wishes to retain long-term comparability of the data.

It is somewhat easier to avoid disruption if one wishes to change the sampling design rather than the field methods. MMR suggest moving from one design to another by gradual modification, which has the benefit of providing some historical continuity but allowing a better design to be used in the long-term. Where such changes are contemplated, it would be worth simulating alternative designs and ways of moving between them, to aid judging what is best.

An easy modification to design is to change the intensity of sampling (through it may need some ingenuity to do this in the case of systematic sampling unless one envisages changes in intensity) that are particularly large. If previous surveys indicate that the sample sizes used are providing estimates that are more precise than needed, then reducing the sample size may be justified to save resources. It is probably wise to err on the side of caution and to retain a larger sample size than appears theoretically necessary, making further downward adjustments in future if the evidence from the data confirms that this is justified. If one reduces the sample too much, sites can always be drawn back into the sample in future, since modern analytical techniques can cope with sites being temporarily missing; it is however, better to avoid this if possible. Note that changes in intensity may be stratified, whether or not previous surveys have been stratified. For example, regions or land classes judged unimportant may be sampled less intensively.

Recommendations:
* **Use the same field methods as have previous surveys of the same species, unless others are clearly more efficient.**
* **Use the same sampling design as have previous surveys of the same species or change gradually to better methods.**
* **Invest enough time in judging whether or not to change methods or design.**
* **If changes appear desirable, make them now.**

3.4 Within-year variation

Mammal numbers at a site typically vary (often markedly) during the year, generally showing season patterns. There are two ways of dealing with this problem (to avoid within-year variation being added to the short-term between-year variation that interferes with the detection of long-term trends). One is to sample repeatedly over a sufficient period (or on a sufficient number of occasions) throughout the year that seasonal variation is averaged out. The other is to sample at a fixed time each year, though this is not so useful if the seasonal pattern itself varies between years. If one chooses to sample at a fixed time of year, it should be a time when between-year differences are least influenced by year-to-year changes compared to long-term trends: one should not choose times when behaviour or numbers are likely to be highly influenced by weather, for example.

For multi-species schemes, the optimum sampling time may differ between species. An obvious way to overcome this problem is to sample repeatedly over a sufficient span of time that one includes the optima for every species. Generally speaking, it will not then be sensible to ignore the data for each species that come from the suboptimal times, though if these produce very variable data it might be. The decision is best made by analysing the data, to find whether the error variance is lower for analyses based on the whole data set or for those based just on data from the optimal season.

4. NOTES ON STATISTICAL INTERPRETATION

4.1 Estimation and hypothesis testing

Too little attention is generally paid to how monitoring information should be used to trigger conservation attention. In practice, decisions about the conservation status of species based on trends in their abundance or distribution are often simply based on the best estimate of the magnitude of the trends, with little discussion of the reliability of the trend data. If there is any discussion, it is often more concerned with bias rather than precision. This is satisfactory for better-known species, such as many birds, where confidence limits for long-term trends may lie only a few percent around the mean. For other species, concerns may justifiably be raised about the reliability of the estimate: if a species has declined by an estimated 40% but the confidence limits on that figure range from a decline of 63% to an increase of 7% (confidence limits will always be asymmetric on a proportional scale), are we justified in turning conservation concern on to that species?

There are two approaches to judging the significance of monitoring trends. The more traditional is to test them against the null hypothesis of No Trend. Conservation concern is only raised if the actual trend indicates a decline significantly stronger than this. (If the interest is only in declines, a one-tailed test would be applied.) The other approach follows the Precautionary Principle: assume that there is a problem unless the trend is either an increase or a decline that is significantly weaker than the value agreed to be critical - say 25% over 25 years. In this case, a one-tailed test of the null hypothesis that there has been such a decline (or greater) is appropriate. In practice, for species where the monitoring provides only rather imprecise estimates of trends (which will often include the rarer species), the traditional view will result in important declines being missed, the precautionary view in alarms being raised unnecessarily. The best way around this dilemma is to place confidence limits on one's trend estimates. These immediately indicate whether each of the two null hypotheses may be rejected. (90% limits are appropriate if one wishes to apply one-tailed tests at the traditional 5% significance level). If neither test is rejected, one then has a "most likely" scenario (the trend estimate) a "worst case" scenario (the lower confidence limit) and a "best case" scenario (the upper confidence limit); considering the costs and benefits of taking or not taking conservation action under each of these three then allows the conservation manager to decide on the best course.

Recommendation:

* **Rather than testing null hypothesis of No Trend unthinkingly, place confidence limits on trend estimates.**

4.2 Remarks on appropriate statistical models

Considerable attention has been given to methods for modelling animal abundance and presence/absence data over the last few decades, much of it based around data on birds held by organisations like the BTO. Clear recommendations can therefore now be made as to the best modelling approaches with which to analyse monitoring data on mammals.

In general, the methods currently in common use for analysing population trends can be classified as forms of Generalized Linear Model (GLM) (McCullagh & Nelder 1989). These models are flexible, allowing choices of error distribution and link function which are most appropriate for the data being tested. The framework also allows indexing, hypothesis testing and statistical controls to be implemented through the estimation of categorical or continuous predictor effects and tests akin to regression and analysis of variance. The approaches applied to bird count data are reviewed by ter Braak *et al.* (1994) and Thomas (1996); Fewster *et al.* (in press) describe how Generalized Additive Models (GAMs) can be used in similar ways to estimate smooth but non-linear population trends (GLMs are limited to the estimation of linear (on the scale used) or categorical effects). The appropriate link function for count (abundance) data is the logarithmic link, used with a Poisson error distribution, whereas a logit link with binomial errors is appropriate for presence/absence data (McCullagh & Nelder 1989).

4.3 Post-stratification, regression and other modelling as means of increasing precision and understanding.

Suppose that one estimates the change in national abundance over a period. The standard error of the estimate will reflect both sampling error and the differences between sites in the extent of population change. If the samples are divided into categories, such as land-classes or regions, after sampling has taken place (post-stratification) and if there are differences between the categories, then the variation ascribable to between-category differences can be removed using standard analysis-of-variance techniques, thus reducing the standard error of the national estimate. If the differences between categories are small, the removal of this component of the variation may be outweighed by the reduction in the number of degrees of freedom associated with the estimate, so post-stratification should not be undertaken blindly. However, sample sizes for national monitoring schemes are likely to be so large compared with the number of categories used that there is unlikely to be much effect on the degrees of freedom.

An alternative approach is to identify relevant continuous variables that can be measured at each sample site (or are already available in national databases). These may explain part of the between-sample variation in the population change. If so, this component can be removed using appropriate regression techniques.

Both stratification and regression have a further benefit: the differences between strata (or the correlation with the regression variables) may aid understanding of the causes of observed population changes. For example, if Wood Mouse populations remain stable in woods but decline in farms, this may suggest that it is changes in farmland management that are driving the population changes. At the very least, such pointers may guide further research, allowing the causes of decline to be confirmed more quickly than if the habitat difference had not been identified. Modelling may go beyond the simple approaches of stratification and regression to provide even deeper insights into the factors influencing the numbers and distribution of a species (Buckland & Elston, 1993).

Recommendation:

* **Sufficient resources should be available in monitoring programmes to allow refined statistical analyses to be conducted that extract the maximum information from the data.**

PART III MULTI-SPECIES SCHEMES

INTRODUCTION

In this section we review existing and potential multi-species monitoring schemes for British mammals. Schemes which provide data on large numbers of species are unlikely to be ideal for any single species but can nevertheless contribute useful information, especially if several are run in parallel. Multi-species schemes are particularly suitable for use by volunteers because they allow all interesting encounters to be recorded, adding to the personal rewards that volunteers perceive. An important benefit is that areas peripheral to a species' range or where its abundance is low can be monitored without a loss of volunteer motivation when other species are also included in the target group. Multi-species schemes also provide monitoring data cost-effectively (given that the data are of sufficient quality) because the costs of central organisation, data processing, newsletter production, etc., can be shared across budgets allocated to a range of species. Running several multi-species schemes in parallel would provide effective checks for each individual scheme and help guard against problems due to the inadequacies of any one approach for a given species.

Mammal monitoring data are already collected under two national schemes: the Breeding Bird Survey (run by the BTO under a consortium including the RSPB and JNCC) and the National Game Bag Census (run by the Game Conservancy Trust). We review the potential these schemes have as parts of a unified UK mammal monitoring programme in Part III.A. We then outline proposals (for discussion) for five new national multi-species programmes, each of which can add important information cost-effectively to the spectrum of current monitoring schemes, by broadening species and/or habitat coverage. We stress that the schemes we consider should not be taken as alternatives to one another: they would contribute complementary information (but are, equally, not inter-dependent and any number or combination could be selected for further development). Our accounts of the multi-species schemes should be read in conjunction with the individual species accounts (Part IV), in which they are referred to where they can contribute usefully to monitoring in individual cases. The ways in which we envisage single and multi-species schemes contributing to the monitoring of each species are summarised in Part VII.

A. EVALUATION OF EXISTING SOURCES OF DATA

1. MAMMAL MONITORING UNDER THE BREEDING BIRD SURVEY

1.1 Introduction

A trial mammal survey was instigated in 1995 as an adjunct to the BTO/RSPB/JNCC Breeding Bird Survey (BBS) as a result of interest from BBS volunteers in recording the mammals they saw while counting birds. This trial has continued into the 1999 field season and has produced encouraging detection rates and/or sample sizes for a range of mammal species, suggesting that the BBS has the potential to contribute significantly to the monitoring of mammal populations in the UK. Although it is clearly not designed specifically for the monitoring of mammals and thus is not organised as would be ideal for that purpose, the BBS has the benefit of being an extant, national scheme with a large sample size (over 2,200 sites currently surveyed annually). The scheme draws on a pool of volunteers which is likely to be largely different from that tapped by mammal organisations such as The Mammal Society. In this chapter, we describe the background of the BBS and its methods, and then assess its potential value for monitoring mammals.

1.2 The background of the Breeding Bird Survey

The British Trust for Ornithology (BTO) has organised standardised, volunteer-based and national surveys of British breeding bird abundance since the early 1960s. For more than 30 years, the principal national survey was the Common Birds Census (CBC), which has served both to highlight a range of important changes in the British avifauna (see, e.g., Marchant *et al.* 1990; Gregory & Marchant 1996; Siriwardena *et al.*1998) and to provide a basis for the development and testing of new and better statistical methods for the identification of population trends (see, e.g., Mountford 1985; Peach & Baillie 1994; Fewster *et al.* in press). Although the CBC provides good data on bird populations breeding in farmland and woodland, and the farmland plot sample (at least) is representative of the wider habitat in south and east Britain (Fuller *et al*. 1985), its methods are labour-intensive (limiting the likely total plot sample size) and it has large gaps, nationally, in its habitat and regional coverage.

The Breeding Bird Survey (BBS) was introduced in 1994 as a replacement for the CBC (although the two continue to run in parallel for calibration purposes) which avoids the sampling biases associated with the latter while incorporating simpler fieldwork methods and maintaining statistical power. The method used by the BBS is described in detail below, but basically consists of two counts of a 2km line transect, within each of a *random* sample of 1km grid squares, along which all birds seen or heard are recorded. The size of the sample of BBS survey squares has now exceeded that shown by simulation studies to be sufficient to provide the same statistical power as is provided by the CBC, and it continues to grow annually (Gregory & Baillie, *in press*). Another important feature of BBS is the habitat data that are collected along the survey transects according to standardised methods and which are computerised routinely. These data allow bird abundance to be related to habitat characteristics so that a range of environmental hypotheses can potentially be tested.

1.3 The methods of the BBS

BBS survey design and methods are described in full elsewhere (Gregory & Baillie *in press*; Gregory *et al. in press*), so we only summarise them here. The BBS is based on a formal sampling strategy under which 1km squares to be surveyed are selected as a random sample, stratified by regions defined by observer density. Observers are distributed with human population density and are therefore harder to recruit in more remote areas; the stratification allows for this without introducing bias. Survey squares are allocated to observers showing interest in the BBS through staff at BTO headquarters and the BTO's national network of volunteer regional representatives.

Volunteers visit their survey squares three times in each year: one visit to record habitat and (re-) establish a transect route and two visits on which birds are recorded. Bird-recording visits are made in each of an early (April to mid-May) and a late period (mid-May to June), with at least four weeks between them, and visits begin between 6.00 and 7.00am to coincide with maximum bird activity while avoiding the daily peak of birdsong. Transect routes ideally comprise two parallel lines within a square, each 1km long, although terrain and access mean that deviations from the ideal are common. Each 1km transect is divided into five 200m sections which form the units for bird and habitat recording. Visits each tend to take around 1½ hours.

All birds seen and heard while walking transects are recorded using three distance band categories (<25m, 25-100m and >100m on either side of the transect); birds in flight are assigned to a separate category. Habitat is recorded annually using an hierarchical coding scheme (Crick 1992) which is used (with minor modifications) in all BTO monitoring schemes. Space is provided on the recording form for both a primary and a secondary habitat to be recorded for each 200m transect section.

1.4 Mammal recording within the BBS

To date, mammal recording in the BBS has proceeded only on a trial basis: the approach in use is therefore subject to revision and there is scope for improvements to be incorporated. The BBS approach attempts to take account of the fact that mammals are generally harder to observe than birds (in particular, they tend to be more silent, are often more cryptic and are often less tolerant of the presence of human observers). Currently, counts are solicited for the 17 species which are most likely to be seen and for which useful data are most likely to be collected (see Table III.A.1.1). Space is also allowed on the recording form for additional species to be recorded (which we do not consider further here). Volunteers are asked to provide one of two forms of data: numbers of individuals seen during the early and late transect surveys and an additional qualitative assessment of whether a species is "known to be present in the square". The latter encompasses any identifications made which are not on the formal transects, for example, identifiable field signs seen during transect surveys and sightings made during the habitat recording visit to the square. Zero returns, where no evidence of mammals was found, are encouraged, because these are essential for unbiased monitoring, but their rates of submission could still be improved. More than 75% of BBS volunteers have provided information on the mammals in their survey squares since the inception of the trial survey.

1.5 The Mammal Species Recorded

Three years of BBS mammal data, from 1995-1997, were computerised and available for analysis as of spring 1999. Restricting ourselves to considering species' presence or absence for simplicity, we investigated the sample sizes provided by the survey. A square was assumed to have been surveyed for mammals if either at least one species of mammal was counted (or known to be present) or a return reporting no evidence of mammals was received. A species was treated as present if either a count was provided in either of the two survey visits or the species was recorded as "known to be present". A species was recorded as absent if mammal data had been submitted for a square (including zero returns but not including squares surveyed for birds from which no mammal forms were received) and the species was not reported. Note that "absence" here refers to non-detection rather than, necessarily, to true absence from a square (or from the habitat through which a transect passes).

The BBS is intended to survey the same squares year-by-year, but there is some inevitable turnover as volunteers are recruited, drop out or move. A total of 2,231 squares yielded some information on the presence or absence of mammals during the period 1995-1997, annual contributions rising from 1,334 in 1995 to 1,874 in 1997. The numbers and proportions of squares occupied in each of the three years are tabulated, for seventeen species, in Table III.A.1.1 To quantify the precision of the estimated proportions presented, we computed their standard errors (s.e.) using the following standard equation (assuming

that the number of squares occupied is a binomial variable with probability *p*: Cochran 1977):

$$s.e. = \sqrt{\frac{p(1-p)}{(n-1)}}$$

where *n* is the total number of squares surveyed.

Rabbit was easily the commonest species, being reported as present in about 70% of squares for which information on mammals was given. Other species reported in more than 10% of the squares were Mole, Brown Hare, Grey Squirrel, Red Fox and Roe Deer. Small insectivores, rodents and mustelids, although likely to be widespread were reported only from a small proportion of squares, almost certainly because of their inconspicuous nature. The commonness with which the various species are detected within the BBS sample has important implications for the utility of the survey for the detection of changes in their populations: within the range of values found here, higher proportions of the total number of squares are better. These issues are explored in detail under "Statistical Power" below.

Geographical patterns in the occurrence of mammal species across Britain are often of interest, especially for species whose ranges are believed to be increasing (e.g. Reeves' Muntjac: Corbet & Harris 1991) or contracting (e.g. Red Squirrel: Corbet & Harris 1991). As a random sample of the landscape in Britain surveyed using standard methods, the BBS presents a powerful tool with which to examine the national ranges of British mammal species and a significant advance on the collation of opportunistic records used previously (Arnold 1993). Using DMAP For Windows mapping software (Morton 1993-1996), we plotted the spatial distribution of mammal records, contrasting examples of which are contained here. The Rabbit (Figure III.A.1.1) is shown to be almost ubiquitous, the Scottish highlands being the only large area in which most squares lack recorded presence. This is no doubt a major contribution to the significant spatial variation found in the generalized linear model fitted to the data for this species (see below). The scarcer Brown Hare was also not recorded from much of Northern Ireland, south-east and south-west England (Figure III.A.1.2). Reeves' Muntjac was first introduced to Bedfordshire but has since spread widely, both naturally and through many additional releases (Figure III.A.1.3). The distribution of the Red Squirrel records shows clearly that it is more widespread in eastern Scotland and northern England, but in all three years considered, only isolated locations elsewhere are found to contain the animal (Figure III.A.1.4).

1.6 Estimating Population Changes and Population Trends

Simple measures of changes in reported presence

Several possible options exist for identifying changes in BBS mammal data, each addressing subtly different questions with varying statistical sophistication, but all being generally definable within the framework of generalized linear models (GLMs: McCullagh & Nelder 1989). Using numerical count data would extract the maximum amount of information on mammal population changes from the BBS, provided that the number of animals counted is related to true abundance, but the sample size of squares available is maximized if we consider only the estimation of presence and absence. For such analyses, count records are thus considered to be simple "presences" and combined with the "known to be present" data. The proportions of squares where a species is present can be compared between years (or between regions or habitats) using a contingency table approach and referring the test statistic to χ^2 tables. Alternatively, in a GLM formulation, we can test whether the variation between years is significant by comparing a model with annual proportions and one with a single, time-invariant estimate derived by combining data across years, using a likelihood ratio test. Since the data to be modelled are proportions, we employ GLMs with a binomial error distribution and a logit link function.

Applying the likelihood-ratio test approach to data from 1995, 1996 and 1997, we found that proportions had varied significantly between years (at the 5% level) for nine of the 17 mammal species named on the recording form: Hedgehog, **Mole**, Common Shrew, Grey Squirrel, Brown Rat, Red Fox, Stoat, Weasel and Badger (Table III.A.1.2). Many of the smaller animals in particular were reported noticeably less frequently in 1995. This may be due to increasing effort by observers to record signs of mammals as the BBS has developed or to subtle changes in the recording instructions during the trial survey (see Discussion), so we repeated our analyses restricting our attention to 1996/1997. The analyses omitting the 1995 data gave rise to similar results for most species, but the inter-annual differences became non-significant for Mole, Rabbit, Brown Rat, Stoat, Weasel and Badger (Table III.A.1.2), suggesting that the effects identified previously for these species could have been artefacts of the change in survey methods. Note, however, that fewer significant results would be expected *a priori* from comparisons of two years as opposed to three.

The analyses of proportions described above are crude in the sense that they take no account of the matching of BBS survey squares between years: they assume that independent random samples of squares are drawn in each year. However, although there is some turnover in the BBS sample, the majority of squares *are* sampled in consecutive years. Analyses of the data can therefore make use of this to remove the need for the statistical consideration of square-specific effects (i.e. random biases caused by habitat-specific and geographical variations in density) which is inherent in the simple comparison of proportions. A method for doing this for pairs of years is presented by Cox (1970): data from any two years to be compared (not necessarily consecutive ones) are matched by square and squares where a species has been reported as either present or absent in *both* years are omitted. The remaining squares all therefore experienced a change in the reported status of the species, either from present to absent or from absent to present. The relative numbers of squares of these two types form sufficient statistics for the estimation of the difference in detection rates between years (Cox 1970, p. 56). A significant change in the overall proportion of squares reported to be occupied is indicated if significantly more than half of the squares where status has changed experienced change in one or other direction. Specifically, this test is based on the following observation: if the probabilities of detection at site j in the two years under consideration are p_j and $p_j+\Delta$, then N_{pa} has a binomial distribution (m, p) with binomial denominator $m=N_{pa}+N_{ap}$ and probability $p=e^{\Delta}/(1+e^{\Delta})$, where N_{pa} and N_{ap} are, respectively, the numbers of squares changing from present to absent and from absent to present (Cox 1970).

To evaluate the effects of the difference in approach, we used the matched squares method to conduct analogous analyses to those described above comparing the data from 1996 and 1997 for each species. The results are presented in Table III.A.1.2 . The results for most species were more significant than had been found in the unmatched analyses and inter-annual differences for seven (as opposed to four) species were significant at or around the 5% level (Mole, Common

Shrew, Brown Hare, Grey Squirrel, Red Fox, Badger and Roe Deer: Table III.A.1.2). The variations between analyses in the species identified as having significant inter-annual differences in numbers of occupied squares show where a difference or a lack of difference identified by the unmatched analyses could reflect the influences of spatial biases in the sample of survey squares.

The number of squares in which changes in status had occurred varied from 30 (Red Squirrel) to 382 (Red Fox) (Table III.A.1.2). Clearly, the utility of the square-matching approach depends on the number of squares which have been surveyed in both of the years compared: survey square turnover means that this will fall as the years compared are moved further apart in time. Note, however, that long-term turnover should be less of a problem (notwithstanding any observer effects) than has been the case for the CBC because new surveyors for particular squares will be sought to replace any who drop out.

The potential of Generalized Linear Models for presence/absence data

Extending the methods applied within the GLM framework and using likelihood-based testing would permit the fitting of a range of more flexible models, and therefore the testing of various hypotheses of interest. A logical extension of the pairwise square-matching approach is the linking of data from several years via square identity (together with enough flexibility to allow squares not to have to have been surveyed in all years). This can be done in GLMs incorporating the estimation of a set of square-specific probabilities of species presence in addition to year-specific probabilities: the prediction of the model for a given square in a given year is then the sum of the "location effect" and the "time effect". Analogous models now routinely form the basis for analyses of population trends in CBC and Wetland Bird Survey data, as well as in other bird monitoring schemes worldwide (ter Braak *et al.* 1994; Thomas 1996). Under such models, the probability of detection of a species in a survey square varies between locations, but this proportion fluctuates between years in a parallel fashion in each location.

In the methods currently used to analyse CBC data, location or site effects are usually fitted as a categorical variable, i.e. survey sites are not assumed to be inter-related (Mountford 1985; Peach & Baillie 1994; Fewster *et al*. in press). An alternative is to characterise sites by means of a few biologically meaningful variables such as latitude, longitude, altitude, area of woods, etc.; i.e. to assume that site-specific variation derives from a combination of these influences, and therefore to estimate far fewer parameters during model fitting. This approach, using geographical and habitat covariates in place of categorical site effects, may be obligatory for the application of GLM-based indices for mammal monitoring under the BBS: with currently available computing resources, it would be prohibitively time-consuming routinely to conduct long-term analyses incorporating over 2,000 separate "location" effects. The covariate approach also provides greater numerical precision. It is also important to note that formal statistical methods such as likelihood-ratio tests allow the significance of any relationships with covariates in GLMs to be assessed. This permits both the identification of a parsimonious model to explain any spatial variation and the testing of covariate-based hypotheses.

As an example of the application of GLMs incorporating both spatial and temporal variation, we analysed BBS Rabbit data using the county in which a survey square was found (as a categorical variable) as the spatial component. Each presence/absence record was categorised both by year and by county: survey squares were located in a total of 74 counties. Both "year" and "county" were then fitted as categorical predictor variables in a Generalized Linear Model and the significance of their effects tested by comparing models omitting each in turn with the full model using likelihood-ratio tests. Spatial variation, expressed at the county level, explained a significant proportion of the variation in the probability of detection for Rabbits (χ^2_{73} = 773.27, p<0.01). However, temporal variation was not significant at the 5% level (χ^2_2 = 4.84, p=0.09), although the annual indices of rabbit presence suggest that a decline may have occurred: on a logit scale, the indices were 0.1807 (1995), 0.0542 (1996) and zero (1997: the point relative to which the other years are scaled).

The GLM framework allows a range of additional models to be fitted; for example, interactions between year and geographical category could be added, permitting a test of whether proportions of squares occupied vary differently between regions, rather than in parallel as assumed above. As implied earlier, relationships between distribution and climatic or habitat variation could also be explored using either continuous or categorical variables.

Analysing changes in abundance

The GLM approaches applied to BBS and CBC data have focused on the estimation of changes and trends in abundance (see, e.g., Field & Gregory 1999). Similar methods can be applied to mammal data from the BBS, although rather fewer species can be meaningfully approached in this way than was the case with analyses of presence/absence data. However, where the data *will* support models of abundance and counts of mammals from BBS transects are likely to be good measures of true abundance, these models would provide much more sensitive methods for revealing population changes than would the presence/absence method. GLMs used for modelling variations in abundance are generally formulated using a logarithmic link function and a Poisson error distribution (ter Braak *et al.* 1994; Pannekoek & van Strien 1996), but otherwise the principles are consistent with those applied to presence/absence data as described above. We have investigated models of the abundance data collected by BBS volunteers for Brown Hare: this is probably the species to which the BBS methods and sample of survey squares are best suited (see Part IV.5).

We fitted a GLM with log link and Poisson errors to BBS Brown Hare data for 1995-1997, allowing for categorical year and county effects (as with the model of presence/absence data for Rabbit, this approach was much less demanding of computer resources, reducing the number of independent location effects to be estimated from around 2,000 to around 70). Counts were taken as the total of early and late counts to avoid problems with non-integer mean values. Likelihood-ratio tests showed that both the year and county effects were highly significant, revealing both temporal and spatial variation on Brown Hare abundance. Abundance indices (antilogs of the fitted year effects) for the three years were as follows: 3.78 (95% confidence interval 3.41-4.18: 1995), 3.31 (2.99-3.67: 1996) and 3.86 (3.49-4.27: 1997); from the relevant likelihood-ratio test, χ^2_2=363.9, P<0.01. These results therefore show no sign of a trend in Brown Hare numbers, but that abundance underwent a transient fall in 1996. Note, however, that we have made no attempt here to compensate for any effects of changes in survey methods.

1.7 Statistical Power

A fundamental issue in the design of any monitoring scheme is the power with which it is able to detect the changes that are of interest: sample sizes of survey data points must be large enough for change of the magnitude required to be detectable in the appropriate period of time. Equally, an efficient monitoring scheme would not expend effort collecting more data than is required to meet its objectives.

Presence/absence data

We have used standard formulae and simulation analyses to investigate the power of the analyses of BBS presence/absence data outlined above, under scenarios with various postulated population trends and survey square sample sizes. Sokal & Rohlf (1995, p. 768-769) provide a formula for the estimation of the sample size required to detect, with a given power, a given difference (at a predetermined level of significance) between two proportions. The method applies to random samples of the proportions compared, so is applicable to the "unmatched" survey squares approach. We applied this formula to simulated changes (declines) of 10, 20 and 30% in the "true" proportion of squares where presence is detected, varying the postulated power of detection and investigating a range of starting proportions from 0.05 to 1.00. The results, given a required *P*-value of 0.05, are shown graphically in Figures III.A.1.5 - III.A.1.7. The current BBS sample size of around 2,000 squares (more have been surveyed for birds in recent years but fewer for mammals) would detect 10% declines in reported presence with a power of between 60% and 90% given starting proportions of (approximately) between 0.3 and 0.5 (Figure III.A.1.5). (Note that, for a given starting proportion, there is higher power associated with the detection of "true" increases than declines since power increases as a function of the magnitude of both proportions being compared, irrespective of their temporal order.) These figures correspond roughly to or are exceeded by the proportions of squares where Rabbit, Brown Hare, Grey Squirrel and Red Fox have been reported as present in recent years. A decline of 20% can be detected given the current BBS sample size and starting proportions (approximately) between 0.1 and 0.2 across the range of powers tested (Figure III.A.1.6). A postulated 30% decline can be detected with still smaller starting proportions (below 0.1 for powers of 90% or less) (Figure III.A.1.7). The observed BBS sample sizes for different mammal species (Table III.A.1.1) therefore suggest that the survey could provide useful monitoring data at least for Hedgehog, Mole, Badger and Roe Deer in addition to the four more frequently reported species. In addition, any increases in the BBS sample size in the future can only increase the power of the survey to detect smaller changes.

The above process considers the significance of change between two chosen years. To assess the power of BBS data (with squares unmatched) to detect a gradual, long-term decline, we used a simulation approach based on 10% declines over 10 years in the proportions of squares with reported presence from starting values 0.3, 0.1 and 0.03. The proportion 0.3 corresponds approximately to that in which Brown Hares were found, and the others represent values from which we would expect the detection of declines to be progressively more difficult *a priori*. We then extended the analyses to consider a 25% decline from a starting proportion of 0.03 over periods of 10 and 25 years, as described below.

We simulated artificial mammal presence/absence records for 2,000 BBS survey squares over periods of 10 or 25 years, as appropriate. Given a pre-determined linear decline over the one of these time periods, each square was recorded, at random, as having a species "present" or "absent" with the probability for each year which would provide the overall decline required. A GLM containing a linear trend in the probability of detection was then fitted to the simulated presence/absence data. This process was repeated 100 times, generating 100 data sets from the same hypothesized model. To investigate the power with which the pre-determined linear decline could be identified, we tested the significance of the linear time trend term in each replicate analysis. The proportion of the 100 replicates in which a decline significant at the 5% level was found provided a measure of the statistical power of this modelling approach. The results are summarised in Table III.A.1.3.

The results show that the power of the simple GLM approach to detect a 10% decline over 10 years is high, given a starting proportion of 30% (similar to that found in real BBS data for Brown Hare, Grey Squirrel and Red Fox). However, the power declines rapidly as the starting proportion is reduced (Table III.A.1.3). Nevertheless, a larger, 25% decline was successfully detected in the majority of cases even from a very low starting proportion (3%), especially over a longer time period (25 years: Table III.A.1.3). We have suggested elsewhere that this is a key level for the detection of trends, and it is one which has been adopted for the generation of lists of Birds of Conservation Concern (Gibbons *et al.* 1996): it is extremely encouraging that BBS data could have the power to detect such changes for almost all of the species listed in Table III.A.1.1.

However, BBS presence/absence data seem to have limited utility for the detection of shallow population trends from low probabilities of detection (below 0.2) such as have been found for many species (Table III.A.1.1). Clearly, however, the key issue is the magnitude of population change that is of interest, and therefore that which the BBS would be required to detect. In this context, a 10% decline over 10 years may not be a significant cause for conservation concern for common or widespread species.

Abundance data

We also carried out a rough assessment of the power of BBS data to detect changes in abundance, rather than presence, using a simulation approach. Our simulations were based on a log-linear Poisson regression model fitted to 1995-1997 BBS data for Brown Hare. This GLM included categorical county and year effects: we used the fitted county effects and the year effect for 1997 as the basis for our simulation. We assumed that the squares visited in 1997 were visited in each of the ten subsequent consecutive years, and generated randomised data (counts of hares) for each square in each year. To do this, we assumed that the county effects remained at their estimated values throughout, but made the year effect decline annually by a constant amount, such that it had declined by 10% at the end of the tenth year. We ran this simulation 100 times, producing 100 replications of a scenario in which the population varies spatially but declines at the same rate throughout. The results showed that we could detect the 10% decline at the 5% level (via a likelihood-ratio test) in all 100 of our replicates, showing that with a data set of the size of the Brown Hare one, the BBS has very high power to detect a population change of this size. We should note, however, that the scenario we modelled featured a linear decline, which is highly unlikely to occur in practice: one might be able to *fit* a linear trend to population change, but the real changes will not be smooth because of inter-annual variation due to sampling error and effects which are independent of those driving the long-term trend. This means that we have estimated power under the best of all conditions. Nevertheless, the 100% success rate is encouraging, and it suggests that more detailed simulation work would be worthwhile.

1.8 Waterways Breeding Bird Survey

The line transects used by the BBS, being random in orientation with respect to the landscape, are not optimal for the monitoring of birds in linear habitats such as rivers and canals. The recognition of this fact led to the organisation of a pilot Waterways Breeding Bird Survey (WBBS) in 1998, in which BBS methods were adapted for use on linear waterways (Marchant & Gregory 1999). The key differences between WBBS and BBS were that WBBS sites were selected at the tetrad (2x2km square) rather than the 1km square level, that transect sections were 500m rather than 200m in length (to match the Environment Agency's River Habitats Survey) and that total transect lengths were allowed to vary up to a maximum of 5km (ten 500m sections). Routes within tetrads followed the course of the waterway and habitat recording was extended to allow recording of the characteristics of the waterway itself as well as the surrounding terrestrial habitats. Mammal recording was conducted exactly as in the BBS: either presence/absence or a pair of counts (early/late).

Observers surveyed 103 random WBBS stretches in 1998, returning mammal data on 93 of these stretches. The mammals recorded on more than 1% of survey stretches are listed in Table III.A.1.4. The species found most commonly on WBBS stretches were similar to those reported most commonly under the BBS, but the comparatively small scale of WBBS means that it is unlikely to be able to contribute significantly to the monitoring of such species (except, perhaps, populations specific to riparian habitats). Of more interest is the potential for WBBS to monitor three key riparian species: Otter, American Mink and Water Vole. The proportions of squares from which these species were reported (Table III.A.1.4) were large enough to suggest that WBBS could contribute to their monitoring. To check this, we ran further simulation analyses of the kind summarized in Table III.A.1.2, investigating the power to detect a 25% decline over 25 years from a starting proportion of stretches with a species present of 0.1 (i.e. approximately the figure found for Otter, American Mink and Water Vole). Taking a significance level of 5% and putative WBBS sample sizes of 100, 200 and 400, the trend was detected in 8%, 17% and 29% respectively, of the simulations conducted. Therefore, even with a significantly increased WBBS sample size, trends of the magnitude which are likely to be of interest are unlikely to be detectable in a majority of cases.

1.9 Discussion

The suitability of BBS field methods

Our exploratory analyses show that mammal monitoring through the BBS has the potential to provide a wealth of data which are *statistically* adequate to contribute significantly to a national monitoring scheme. The principal asset of the BBS in this context is that a large number of randomised sites are being surveyed regularly already using standardised methods, allowing mammal data of a high statistical quality to be collected at minimal cost. However, as described above, the BBS was designed for bird monitoring and its methods do not represent the ideal for any mammal species. Transect methods, in general, represent efficient and readily standardised approaches to the sampling of many habitats for many taxa, and we have recommended them for British mammals elsewhere in this report (see Part III.B.3, III.B.4 and III.B.5). Visual counts of individuals are not, however, appropriate as a means of surveying many mammal species, so considering mammals, in general, effectively as supplementary bird species (in terms of field recording) is unlikely to be feasible. Doubts may also exist as to the reliability of birdwatchers as identifiers of mammals, although these might be eased by the provision of a simple identification guide. Nevertheless, more visible species which are commonly detected where they occur by BBS observers, such as Brown Hare, Grey Squirrel and Reeves' Muntjac, could yield useful abundance data from BBS counts. In addition, standardised recording of presence/absence through signs or off-transect sightings (see below) can add further information for the less visible species. The BBS clearly cannot provide count data for these species.

The principal weakness of the BBS for mammal monitoring, even for visual species such as Brown Hare (for which line transect sighting methods can be recommended as the best monitoring tool: see Part IV.5), is that the timing of the survey is sub-optimal. Vegetation growth is substantial by May and (especially) June, making the detection of cryptic and silent animals more difficult, both on the ground and in trees. A second, potentially more serious problem, is that mammal productivity can vary greatly between years, and distinguishing the adults and juveniles of species, including Brown Hare and the squirrels, can be difficult by May. This means that apparent changes in abundance from BBS counts could just represent fluctuating productivity, masking the true trends in the abundance of adults. For each of these reasons, winter or early spring transect surveys would be preferable (see Part III.B.3). However, neither problem makes BBS mammal data invalid. Provided that problems with detection caused by vegetation growth do not affect the form of the relationship between detection rates and true abundance, lower rates will have no effect on population indices: any inter-annual biases caused by weather can be controlled for in GLMs using variables such as temperature or rainfall. Differences between annual counts or probabilities of detection, which are due to variation in annual productivity, will essentially only produce noise around any long-term population changes, thus making these underlying changes in adult numbers harder to detect. This will, therefore, only be a problem if this noise prevents the detection of “true” trends of the magnitude and with the power required. The effects of variable productivity will vary from species to species and will be greatest for the less visible species which cannot be counted effectively. Winter Transect Surveys (see Part III.B.3) run in parallel with the BBS would help to show for which species the BBS provides data which are not severely influenced by the effects of annual productivity and vegetation growth.

Presence/absence monitoring

As we have already stated, surveys of animal abundance provide more powerful monitoring tools than do those of changes in status (presence/absence), all other factors being equal. However, direct counts of many species are not feasible and the BBS allows useful direct counts to be made for only a few species.

The utility of BBS presence/absence data clearly depends on how the data can be interpreted. An obvious, but important, point is that “absence” reflects non-detection, which is not necessarily true absence. It is then critical to what extent detection rates reflect abundance within BBS squares: ideally, detection of presence would occur at a certain, fixed density of a given species. In reality, visual detection will vary with vegetation and productivity as discussed above, and will also incorporate a strong stochastic component, especially for rarely seen species such as Stoats and Weasels. The extent to which presence/absence data are useful then depends on how much of the variation in detection rates is due to real changes in adult abundance. Given a sufficiently large sample size, these real changes should be detectable, but we have no data to determine whether the current and achievable BBS sample size approaches this goal. Calibration of the BBS against other survey schemes which can be considered to provide more reliable information for particular species could be used to indicate whether changes in the BBS data reflect real population changes. The winter and sign transect approaches we discuss elsewhere (see Parts B.3 and B.4) could provide the relevant information for many species. Rarely seen

species might need calibration work based on intensive Capture-Mark-Recapture work in a sample of BBS squares.

Key issues in interpreting records of presence in BBS data are the criteria by which it is assessed and what it is that these criteria really mean. The wording of the instructions for volunteers changed after 1995, giving greater emphasis to the potential use of signs to assess presence, and this may explain the relatively low detection rates for many species in 1995 (Table III.A.1.3). However, the instructions have remained consistent in general, asking for records of species which were "present, but not on transect" (revised to "known to be present in square" for 1998 and 1999). These records can include animals which were "seen on a reconnaissance visit to the square" or for which the observer has seen "obvious signs of presence during fieldwork" (including tracks and signs). The principal problem with these methods is that there is considerable scope for variation in interpretation. For example, not all observers will be able to recognise Red Fox scats and others may not consider scats to be "obvious". More seriously, "known to be present" could be taken not to require direct evidence within the current calendar year. The level of interest observers have in mammals will also influence the extent to which they look out for signs, although this will cause only noise, not bias, unless this interest changes with time. A further problem is that the methods for reconnaissance visits are not standardised in the same way as those for bird recording. Opportunities for mammal recording could therefore vary from a cursory visit to check for changes in habitat to an in-depth assessment of changes in, say, agricultural field uses, perhaps with special attention being directed towards looking for mammal signs.

All of these problems could be solved by improvements to the instructions for volunteers and/or the recording form used. Several non-exclusive courses of action are available. First, the data solicited could be restricted to sightings and signs which we can be confident volunteers can recognise (such as fresh molehills). Second, information on the type of evidence used to assess presence could be requested (sightings, scats, roadkills), ideally also incorporating an indication from the surveyor as to whether they looked for each type of evidence. Third, estimates of the time spent on habitat recording visits would assist interpretation. Fourth, tighter controls on the sources of evidence that are admissible, such as sightings during reconnaissance visits but not on other occasions that surveyors might (for example) drive through the square, would help to standardise the data. Whatever improvements are incorporated, it is important that they do not increase the complexity of the BBS unduly: its primary purpose will remain the monitoring of bird populations and any additions which would affect its efficiency in this role should be avoided.

Developing trend analysis methods

Substantial amounts of research have been conducted into methods of analysing trends in CBC and other bird abundance data, generally focusing on methods which are related to the GLM approaches described above (Mountford 1985; Peach & Baillie 1994; ter Braak *et al*. 1994, Thomas 1996; Field & Gregory 1999; Fewster *et al*. in press). These methods include sophisticated uses of covariate modelling to test hypotheses and the modelling of non-linear trends which allow realistic long-term population trajectories to be estimated (James *et al.* 1996, Fewster *et al.* in press). The wealth of options available and the flexibility of GLM-based approaches mean that the brief explorations of analyses of BBS mammal data presented above only scratch the surface of what is possible. If it is considered that BBS data can contribute significantly to UK mammal monitoring, its potential will be greatest if time and resources are made available for detailed

investigations of the usefulness of the various modelling options to be conducted. Three months of staff time for a biostatistician to explore the possible methods ought to be sufficient.

Extensions to the BBS

We have already identified that the BBS has failings as a monitoring scheme for most (if not all) mammal species and that winter and sign transect surveys could be valuable, both in their own right and for the calibration of biases in the BBS data. These new survey options are discussed in detail in Parts B.3 and B.4, but it may be worth considering extending the BBS or building on the framework it provides to contribute to such new schemes. Three potential extensions are: (1) to add mammal-only survey squares to the BBS sample to improve sample sizes by recruiting volunteers who are not birdwatchers; (2) to ask volunteers to make an additional recording visit to their squares in late winter to record mammals; (3) to ask volunteers to make specific mammal sign-recording visits to their squares. The second and third potential extensions would depend on the willingness of bird volunteers to increase their efforts; the likelihood of them actually doing this might best be assessed by a questionnaire survey. Some winter visits to existing BBS squares are likely to be conducted in the future as a part of separate bird monitoring schemes, and so could be used to provide a limited amount of control mammal data.

Conclusions

We believe that the BBS has the potential to contribute significantly to the monitoring of many UK mammal species. It would have particular potential value if it were combined with other multi-species schemes run by a dedicated mammal monitoring organisation. The results of our analyses of its statistical power for mammal monitoring are encouraging. It is very likely to provide useful information for species such as Brown Hare, Grey Squirrel, Roe Deer and Reeves' Muntjac and may play a central role in their future monitoring (see individual species accounts). It should also at least provide ancillary information for many other species since the large sample size of survey sites and wide geographical coverage argue in its favour against any methodological failings. There are important issues in terms of the sensitivity of presence/absence monitoring to changes in abundance and in biases which the bird recording design might induce, and these should be addressed using alternative, more robust survey methods, but they do not invalidate BBS mammal monitoring in principle. The WBBS may also contribute data for key riparian species, but as yet it has no guaranteed long-term funding and the sample size it can generate is unlikely ever to be large, so it would be wise not to plan mammal monitoring schemes around the WBBS at present.

The additions or improvements to mammal monitoring under the BBS that we discuss above will need formal development, and the administration of data collection and collation additional to that already done for the bird data will need to be funded (see Part VII.2.1). Annual data management work ought to take no more than about 35 days of additional staff time; we would suggest that the development work ought to take no more than 55 days. We suggest that this work would best be done by the BTO staff who currently run the scheme, but that all interpretation of the data, which would be done in conjunction with data from other schemes, should be done by mammal specialists, hopefully within a dedicated mammal research organisation. The design of the final recording form for BBS mammal surveying and the details of the methods to be used, species coverage, etc., would also best be designed and organised in conjunction with the input of mammal specialists.

2. GAME BAGS

2.1 Introduction and background

Over the many years for which British country estates have been managed for shooting and hunting game, many of the gamekeepers and managers responsible have kept records of the animals killed both as quarry species and in the course of predator control. Game Bag records therefore are among the earliest long-term ecological time-series data, and as such their potential importance for monitoring contemporary environmental changes in an historical context has long been recognised by the game research community (Tapper 1992). In this section, we consider the contribution that bag return data can make to mammal monitoring in the UK, reviewing the pros and cons of the data in their current form and suggesting amendments which would increase the utility of the information collected.

A concise history of bag recording in the UK is given by Tapper (1992). The Game Conservancy Trust (and its forerunner organisations) masterminded the collation of shooting and gamekeeping bag data into a National Game Bag Census, which has been in operation since 1961. The census has been improved over time, with computerisation being introduced in the late 1970s, at which time the scheme was also expanded to provide better coverage of the uplands, especially in Scotland. Historical data from before 1961 have also been solicited from estates with long-term records of their own, and these have been integrated with the more recent data, extending the time series back to 1900 for many species. Such long runs of well-documented data on many predatory and game species clearly make Game Bag returns an important potential source of future mammal monitoring information.

Additional bag record data are collected by The British Association for Shooting and Conservation (BASC), primarily through one-off surveys of the organisation's gamekeeper and deer-stalker membership. These data do not provide long-term or continuing information, but could contribute to the meeting of monitoring objectives through repeat, "snapshot" surveys. BASC's membership also represents a valuable potential source of volunteers who might contribute to monitoring both through their bag records and through specific survey work.

2.2 The case for Game Bag data as a mammal monitoring tool

There are two principal reasons why Game Bag records could make a valuable contribution to mammal monitoring: the long runs of historical data and the fact that the data are already being collected according to established protocols (in the National Game Bag Census). The former will provide continuity and an historical context in which future monitoring information can be viewed. Such a context could be vital: historical population levels can provide us with targets for conservation action; they also allow the severity of recent population trends to be assessed in the light of conditions before the onset of any environmental changes causing contemporary concern. Integrating an established monitoring programme into future plans would allow data to feed directly into the consideration of policy and the development of conservation and management objectives without the need for pilot studies or trial surveys testing proposed methods. It might also be expected to be continued independently of any additional funding.

Mammal recording via Game Bags has several other key advantages. The National Game Bag Census already covers Great Britain effectively (but not Northern Ireland), including recording from estates in more remote areas such as the highlands of Scotland. Other forms of survey will always be more difficult in such areas, either because it is more expensive to survey them professionally or because volunteer densities are correspondingly low where human populations are sparse. Problems with access can occur for wildlife surveying if the surveyor does not have the confidence of the landowner or if the latter perceives that a conflict of interest exists between the survey and his or her shooting or agricultural interests. The use of records directly connected to game interests should avoid this problem and therefore maximize the likely cooperation from landowners. It is also notable that landowners who exploit game populations commercially have a vested interest in effective monitoring and so should, in principle, be cooperative.

The National Game Bag Census includes a record of the number of gamekeepers working on estates and it should be possible to enhance this recording of keepering effort. It is also possible that some of the concern about variable effort in the "sampling" of game populations (see below) does not represent a serious problem, at least for quarry species, because the numbers killed will tend to represent (more-or-less) a constant proportion of the population (40% has been suggested for Brown Hares: Tapper & Stoate 1992, but see Hutchings & Harris 1996) if a viable population is to be maintained by management. Game managers will use approximate judgements of game population sizes to determine the number of days' shooting that can be supported, improving the likely correlation between the sizes of Game Bags and abundance. However, improved recording of zero yields (no shooting) would be required if this approach were applied in population monitoring. Further expansion of the national census could perhaps be achieved by targeting individual shooters (for example, members of BASC) as well as gamekeepers and estates, and by developing coverage in Northern Ireland.

In summary, the following factors recommend the use of Game Bag data for mammal monitoring:

- long runs of historical data provide an important historical context that is unavailable elsewhere;
- data collection protocols are established and a national scheme is already funded, promising future continuity at low cost;
- the National Game Bag Census already covers much of Great Britain effectively, including some general problem areas;
- game and landowner interests are close to the data recording process, avoiding problems with cooperation and access which could affect other schemes;
- improvements to the recording of "sampling" effort and coverage (i.e. in Northern Ireland) may be possible.

2.3 The case against Game Bags

There are various problems with Game Bag data as they have been (and currently are) collected, some of which could be remedied easily and some which are more fundamental. The biggest general problem with the current bag record database is that the effort expended in shooting or control has not been recorded. In practice, this means that any apparent trend in a time-series of bag data could reflect changes in "sampling" methods or intensity as well as changes in the abundance of the species concerned. This is conceded tacitly by Tapper (1992), who wrote of the inclusion of predator records in the Game Bag Census that they "*...could provide a useful guide not only as to the efficiency of predator control, but also an insight into the changing abundance of predators*". In fact, these two types of information are confounded in the data. The significant changes in the methods used by gamekeepers to kill foxes documented by Reynolds & Tapper (1994) would be expected *a priori* to produce an upward trend and are probably sufficiently important to explain the increase in bag returns that these authors nevertheless ascribe to an increase in abundance. In addition, McDonald & Harris (in press) have recently shown that long-term declines in the bag returns for Stoat and Weasel can be explained as well by changes in trapping effort as by changes in abundance. It is highly likely that some changes in the sampling effort on which the Game Bag time-series are based have occurred for most species since 1961.

It is important to realise that “sampling effort” as we are referring to it here includes qualitative as well as quantitative factors. Thus, while a critical influence on shooting bags will be the number of man-days spent shooting, the efficiency of the guns and other equipment used (e.g. spotlights) and the skill levels of the shooters will also have important influences. Likewise, gamekeeper effort includes the nature of the method used for control (traps versus poison versus shooting), the efficiency of the method (which could vary with, say, type of poison) *and* the time expended by the keeper(s). The seasonal timing of control measures (which is likely to vary more than that of shooting harvests) is another feature of sampling effort which can affect kill rates via changes in the population sampled. For example, shifts in the timing of the peak effort in fox control have led to more dispersing animals being killed in addition to residents (Reynolds & Tapper 1994), a factor which has probably contributed to the rise in bag returns. Although it is unimportant for monitoring purposes whether sampling effort differs between estates (or gamekeepers, or whatever the sampling unit is chosen to be), it is critical either that it is constant over time or that the variation is quantified (see Part II). We would also note that amount or efficiency of effort may not be closely related to the numbers of individuals killed, because of interactions with features of species' social organisation. Once territory holders are removed, a virtually limitless pool of immigrant individuals may be tapped, such that the local abundance of breeding animals is not reflected well by the numbers of individuals killed. The extent to which this occurs is likely to depend on the time of year at which trapping is conducted, but it can certainly be a problem for foxes (Reynolds & Tapper 1994) and mustelids (McDonald & Harris, in press).

Even if attempts are made to standardise recording effort, a key problem is likely to stem from changing fashions in gamekeeping and game rearing. As the aims of game management change, for example from providing a shootable stock of wild Grey Partridges *Perdix perdix* to producing hand-reared Pheasants *Phasianus colchicus*, the gamekeeping measures thought to be necessary will change. As a result, the sampling effort underpinning the Game Bag record is likely to change qualitatively or quantitatively in response to strong commercial influences. It is difficult to see how gamekeeper effort could remain constant under such circumstances.

Another serious problem with Game Bag data is that they are, inevitably, drawn from shooting estates which are unlikely to be representative of the wider countryside. Management for game species will produce artificially high densities, especially where predator control is practised, and animals such as Brown Hares are sometimes moved to restock areas which have been hunted out or to create densities which are sufficiently high for driven shooting (Hutchings & Harris 1996). Within estates, shoot locations can also vary from year to year, if abundance is patchy, such that only areas with high densities are sampled to produce Game Bags, thus masking temporal variations in overall abundance (S. Harris, pers. comm.). These factors will limit the relevance of trends in Game Bag data to those of populations in the wider countryside. In addition, the removal of a large percentage of a species' population in the course of “sampling” means that the sampling method has a major impact on the population which, therefore, it cannot measure. For Brown Hares, as much as 69% of a local population can be removed in a year (Stoate & Tapper 1993): such a rate of killing probably represents the major mortality factor in the population, so an independent (preferably non-destructive) sampling regime would be required to measure its effects.

Changes in the sample of estates included in the Game Bag data set may also produce biases leading to the overestimation of abundance. Estates where shooting becomes poor over time are more likely to drop out of the survey altogether (if shooting ceases) than estates with better shooting, while new estates joining the scheme will probably be relatively good. In addition, zero records are not returned in the current National Game Bag Census, i.e. no data are obtained when no shooting has occurred in a given year because game numbers were too low to permit it. Each of these effects will bias abundance indices upwards. There is also a potential problem in that shooting and gamekeeping interests would have close control over the data collection for any Game Bag-based survey. Such individuals and organisations will have a commercial interest in having particular population levels of prey and predators perceived by the public at large, by conservation bodies and by government, especially if the results of the survey were to feed into policy. It would be preferable if monitoring could be conducted by an independent organisation.

A final problem with Game Bag data is specific to the information collected about predators. Such data are critically sensitive to changes in legislation: persecution of predators may continue after protection has been put in place, but gamekeepers and landowners are highly unlikely to report animals killed in such circumstances, even if anonymity is assured. This problem affects the data collected for Wildcat, for example: the Game Bag time-series ceases when full protection under the Wildlife and Countryside Act was granted to the species in 1988 (Tapper 1992). Partial protection for Hedgehog under the same Act has also reduced the number of estates reporting data on this species (Tapper 1992).

In summary, the following factors argue against the use of Game Bag data for mammal monitoring:

- probable historical changes in sampling effort and methods, both qualitative and quantitative, tend to devalue historical Game Bag data;
- some recording of effort or some commitment to standardisation is needed to make monitoring data from Game Bags reliable, but the extent to which the data collection can be extended is limited;
- the main influences on gamekeeping and shooting, such as commercial factors and game rearing fashions, will always be external to a monitoring scheme, so the need for standardisation under the latter is unlikely to be a guiding influence;
- shooting estates are unlikely to be representative of the wider countryside;
- shooting pressure will respond geographically to local variations in density, masking population variation;
- shooting can remove large proportions of local populations, thus becoming a major mortality factor, the effects of which shooting bags cannot measure;
- zero bag returns are not reported and estates entering into the Game Bag Census will tend to report larger bags than those leaving the scheme, creating bias;
- political and commercial considerations may influence the accuracy of the reporting of Game Bag statistics;
- legislation can change over time, leading to unavoidable changes in effort or to a species dropping out of the scheme altogether.

2.4 Conclusions and future priorities

It is important to remember that, whatever the problems with the historical Game Bag data set are, many of the historical weaknesses are irrelevant in terms of the potential utility of such data for future monitoring. Thus, in principle, efforts could be made to include the recording of shooting and gamekeeping effort and to improve the recording of zero returns in the National Game Bag Census. However, the principal asset of the Game Bag data is the historical context it provides, and any large scale changes would remove continuity from the data: the Game Conservancy would probably be unwilling to do more than include some ancillary recording forms in the census as an add-on, preserving the structure of the data (S.C. Tapper, pers. comm.). It is also the case that, once it is acknowledged that changes need to be made to the collection of bag data to make them more useful, the historical data have been devalued implicitly. In turn, this process weakens the case in favour of using bag returns in the first place.

Given the addition of sufficient recording of sampling effort (which will depend, ultimately, on the amount of information that contributors of Game Bag data are prepared to record) to the national census, Game Bag trend data could be modelled in the same way as CBC and other bird abundance data are modelled. This form of analysis would consist of models of bag sizes which incorporate year effects (estimates of the temporal variation) and categorical estate effects which change when sampling effort changes, i.e. treating estates where methods (say) change as new estates (see ter Braak *et al.* 1994; Thomas 1996). This would not work if changes in effort are too frequent, so standardisation over time would need to be encouraged: effort for a given species would have to remain stable over runs of several years (say, 5-10) at each site (estate) and then not change across all or most estates at the same time. Such developments of the Game Bag data would need to be funded as specific, contracted research projects.

Even without any improved recording of effort, the utility of bag data will vary between species because it will be much more reliable for some species than others. The data might be better for quarry species which are managed sustainably, representing a constant proportion of the population, and they might be particularly poor for generalist predators with only a peripheral impact on game, such as Brown Rats, Hedgehogs and Grey Squirrels, for which control measures might vary considerably in space and time. We have discussed the utility of bag data for each species group in the individual species accounts, but another general consideration is that sampling effort will be more variable for species for which it is easier for gamekeepers to assess abundance (S.C. Tapper, pers. comm.). For example, years with higher frequencies of Red Fox sightings are likely to lead to higher intensities of control, but such clues are not available as to variations in the abundance of small mustelids, so gamekeepers are more likely simply to expend the same effort (i.e. to set the same number of traps) every year. The diversity of possible methods for the control or hunting of a given species will also influence the variation in effective effort that occurs both spatially and temporally: more choice is likely to lead to more experimentation. Nevertheless, it is at least possible for trends in Game Bags apparently to reflect real changes in abundance: the trends revealed by the data for Grey Partridge match those shown by the CBC (Tapper 1992; Siriwardena *et al.* 1998), lending support to both surveys. (Unfortunately, no such national, potentially corroborative data yet exist for British mammals.)

We conclude that Game Bag data can provide a useful contribution to the monitoring of mammals in the UK, but that they should not be considered as a central part of future monitoring policy. The value of the data will depend, to some extent, on the other monitoring options available for a given species. Where other survey schemes can be established which will provide alternative sources of population trend information, similarities after 5-10 years between the changes over time shown by these schemes and the changes shown by the National Game Bag Census will give a clearer idea of the conclusions that we can draw from historical bag data. Meanwhile, we recommend that efforts should be made to encourage contributors of bag data to record as much ancillary information on sampling effort as is feasible. Such efforts would best be focused on the species for which Game Bag data are most likely to be valuable. We suggest that these species should be Stoat and Weasel: other schemes are unlikely to monitor them well and there is reason to believe that the bag data for these species are relatively reliable (see above).

The potential value of the long-term historical data sets that Game Bags provide also means that it would be worthwhile to investigate further how they might be interpreted. A key issue is the calibration of changes in sampling effort: monitoring the effects of future changes in effort via comparisons with independent measurements of abundance would calibrate not only that particular change but also shed light on the likely implications of past changes. Experiments mimicking past changes in effort which are regarded as being particularly important would also be valuable for calibration purposes. A further topic for investigation is the relationship between bag sizes and true abundance for many species: this is known to be non-linear for some gamebirds, but has not been investigated for mammals (S.C. Tapper, pers. comm.). Last, some data which are supplementary to the central Game Bag records are also currently collected and computerised, and explorations of these data could also clarify some of the biases which are believed to exist in the data (S.C. Tapper, pers. comm.). We recommend that the funding of studies such as these should be considered: the potential of Game Bag data to supply a valid historical context for mammal monitoring should be explored in detail.

B. FURTHER POTENTIAL MULTI-SPECIES SCHEMES

3. WINTER TRANSECT SURVEY

This scheme would use volunteers to carry out visual transects during the late winter period. The exact protocol to be adopted will require further discussion, although two approaches (the two extremes) are outlined here. In the more formal approach (based on the BBS protocol) volunteers would walk two predetermined 1km transects within a 1km square and record the number of individuals encountered of each selected species. The less-formal approach (used specifically in upland areas and primarily for Mountain Hares) would ask volunteers to walk a transect (with location and length selected by the volunteer) once each winter or early spring with the aim of counting the number of individuals of the selected species seen.

3.1 Advantages and disadvantages of this approach

Advantages
- It would cover several species for which other monitoring schemes were deemed less suitable and/or for which the species' is more visible in winter thereby maximising detection rates (e.g. Rabbit, Brown Hare, Mountain Hare, Red Fox and to a lesser extent Grey and Red Squirrels and deer).
- It would provide information on some species for which monitoring at other times of year would contain a significant productivity component masking long-term trends (e.g. Rabbit, Brown Hare, Mountain Hare). In this way it could act as a control for the BBS data.
- Volunteers might have fewer conflicting demands on their time during late winter.
- Visual transects would be better for volunteer involvement than more demanding techniques requiring greater identification skills.

Disadvantages
- The possibility of poor weather conditions.
- Difficulties in getting volunteers to participate in some areas (especially the more remote areas)
- Shorter day length, meaning that most fieldwork would have to be carried out at weekends, rather than early mornings on weekdays.

This scheme should be used in conjunction with other schemes (notably Sign Transect Survey and BBS) to determine its effectiveness and to help reveal patterns in long-term trends. Following examination of the data from concurrent schemes it may be possible to reduce the number of schemes being operated.

3.2 Which species could be monitored under this scheme?

All non-marine, non-Chiropteran species could potentially be recorded through this scheme where visual identification can be determined. This would allow volunteers to record everything they could see and identify, thus increasing their morale and providing some useful data on distribution. However, the target species for this scheme should be:

- for monitoring population trends (main spp): Rabbit, Brown Hare, Mountain Hare.
- for monitoring population trends (other spp.): Grey Squirrel, Red Squirrel, Stoat, Weasel, all deer species.

- for monitoring distribution: Pine Marten, Polecat, Feral Ferret, American Mink, Otter, Wildcat, Wild Swine, Chinese Water Deer, Reeves' Muntjac.

All the included species should be printed on recording forms. Observers should be asked to write in any other mammals that they come across, both to allow them the pleasure of doing so and to provide records of escaped aliens.

3.3 Examples of previous surveys using winter visual transects

National Brown Hare Survey - (see Part IV.5). The national population estimate for this species of 817,520±137,521 individuals was based on a winter transect survey of 738 1km squares over three winters. Counts of Brown Hares are best made between October and March, when detection rates are high and sward height is low. However, heavy persecution through driven shoots during February and March suggests that survey work should be completed by the end of January, thereby avoiding the influence of this important annual mortality factor Stephen Harris (pers. comm.).

Various Rabbit surveys - The five Rabbit surveys documented by Trout *et al. (*1986) were all carried out during the first third of the year (typically January to March). This is a time of year when the population is made up of overwinter survivors, thus reducing the influence of annual productivity on the monitoring estimate. It should be noted that visual transects for Rabbits carried out during the late winter may not provide as much information of value for monitoring (e.g. index of abundance) as transects involving the winter recording of field signs (see Part III.B.4).

Mountain Hare Walks - Several local natural history societies carry out less formalised walks along standard routes in upland areas, along which the numbers of Mountain Hares are recorded. (See Part IV.5).

3.4 What a Winter Transect Survey could offer

The use of volunteer recorders would allow the accurate visual recording of a small number of mammal species, although recorders should be allowed to gather information on all mammal species seen, even if this were not used in the same way for monitoring (e.g. records of Pine Martens could provide useful distributional data but would not contribute to any attempt to monitor population trends for this species). Allowing volunteers to record all species encountered should also improve participation rates and maintain motivation. An essential part of the management of the volunteer effort would be the provision of an annual newsletter, sent out prior to the fieldwork season and/or the inclusion of other taxa.

3.5 Alternative approaches

There is a continuum of possible methods with: (a) formalised transects based on the BBS protocol of observers following as closely as possible 'ideal' transect lines at one extreme and (b) less-formal 'walks' by volunteers along standard routes chosen by themselves at the other. The former adopts a more rigorous, statistically acceptable protocol while the latter is more likely to find favour with volunteers. The lack of a rigid protocol need not necessarily reduce the monitoring potential of winter 'walks'. It is felt that the winter 'walks' would be particularly suited to the monitoring of population trends in Mountain Hares. Such walks have been undertaken by local natural history societies in northern England specifically for this purpose, albeit at the local level. The choice of approach to adopt will depend on the required rigour and potential volunteer involvement. Consideration should also be given as to whether a particular approach should be adopted nationally. There could be good reasons for using different approaches in different regions (related to volunteer availability) or for different species/habitats.

3.6 The data recording forms

Form complexity will depend on the approach adopted and the type of data required.

Formal approach - We suggest that the forms can be read using an optical-mark-reader, allowing the rapid input of voluminous but fairly simple data. Recorders would simply count the number of individuals seen for each species, with no attempt to estimate density through distance sampling, and score through the appropriate box on the recording form. All the species likely to be encountered would appear on the form, with space for others to be entered by hand. Details on other species would have to be input by hand if these data are to be used, although they need not be used. Each transect should have a numeric code, as should each fieldworker. Fieldwork effort, as denoted by the amount of time spent in the field, should also be recorded. One form should be used for each of the two visits. A further form could be used to allow the recording of habitat details using a simple hierarchical approach.

Less formal approach - A single form would be required for this approach, with a reduced set of species and effort targeted towards recording Mountain Hares. Again the aim would be to use a form that can be optically-mark-read, containing information on the site, observer and habitat in addition to the species count data.

3.7 Organisation of the Winter Transect Survey

A single individual should be able to co-ordinate the scheme, producing fieldwork material, helping with the analysis of data and preparing regular newsletters. Additional inputs would be required at the graduate scientist, or more likely post-doctoral level, when data analysis takes place. It is suggested that this individual would also co-ordinate the Sign Transect Survey, working for the umbrella mammal monitoring body which would also run the other multi-species schemes and collate data from them and the mammal data generated by the BBS.

3.8 Other considerations

A discussion on the potential for the various forms of winter transect should cover the following points:

- Integration of components from sign transects may be appropriate for some species covered by the winter visual transects (e.g. Rabbit and Mole).

- Late winter may be a difficult time of year in which to recruit volunteers and carry out fieldwork, although fieldworkers may have fewer alternative commitments. The effects of short daylength and poor weather need to be considered.

- Feedback to volunteers would need to be an important component of the scheme, ensuring that continuation rates are maintained, with an annual newsletter.

- Consideration should be given to the points raised in Part III.A.2 on the power of BBS data to detect long-term trends in mammal species.

- Determination of appropriate transect lengths and survey design need further evaluation, using a modelling approach and existing datasets on mammal density and distribution within a range of habitats. 'Winter walks' may be best in upland areas (e.g. for Mountain Hare with the more rigid protocol used in other habitats.

3.9 Resource Requirements

Set-up costs - see Part VII.2.3

Ongoing costs - Were the scheme to be run centrally (apart from the initial recruitment of participants) and assuming co-ordination of this scheme with the Sign-Transect Survey and the Mammals on Roads Scheme, we estimate the annual requirements to be as outlined in Part VII.2.3.

We anticipate that the establishment and operation of a single scheme (in isolation) would require approximately half of the sums shown in Part VII.2.3: running all three schemes together would allow certain economies of scale

4. SIGN TRANSECT SURVEY

This scheme would use volunteers to carry out a search for easily recognisable mammal field signs along transects of standardised length and location. A protocol for the number of visits and their timing requires further consideration.

4.1 Advantages and disadvantages of this approach

Advantages

- It would permit the monitoring of a number of species that are difficult to observe directly in the field, but which have easily identifiable field signs (e.g. Hedgehog, Mole, Red Fox and Badger). Several of these species may already be covered by species-specific schemes or other multi-species schemes and data from the proposed scheme could provide an ancillary role.
- Where there is a known relationship between field sign density and population density it would be possible to monitor changes in abundance directly. Where the relationship is not clear, then it would still be possible to monitor population change through changes in the field sign index. Complications caused by any differences between habitats (see Rabbit species account) could be overcome by maintaining the same field sign transects over time, coupled with basic habitat recording.

Disadvantages

- Fieldworkers need basic skills in identifying particular field signs (but note the success of Look Out For Mammals: Part V.6).
- The field signs of some species cannot be readily separated in the field except by very experienced fieldworkers.
- Different searching may be required for different species' field signs, resulting especially from where they are located (e.g. squirrel dreys in trees, Mole hills on the ground).

This scheme could be used in conjunction with other schemes (notably Winter Transect Surveys and BBS) or in parallel to them (and to other single-species schemes) as a means of providing ancillary data to support those gathered by the different approaches. If several schemes are operated in parallel it should be possible to determine which one(s) offer the best power while being the most cost-effective and to make judgements about future funding and continuation of individual schemes.

4.2 What species could be monitored under this scheme?

Only a limited number of species should be covered by this scheme, so professional fieldworkers with experience of the more difficult species and their field signs would not be needed. The target species for this scheme and their acceptable field signs should be:

Hedgehog (droppings), **Mole** (mole-hills), **Rabbit** (warrens, droppings), **Red Squirrel** (dreys and cones in areas where the two species do not overlap), **Grey Squirrel** (dreys and cones in areas where the two species do not overlap), **Red Fox** (droppings), **Badger** (active setts, latrines, droppings)

4.3 Previous surveys using field sign transects

Field signs have been widely used in a number of monitoring and census schemes. These have been dealt with under the individual species accounts and so will not be further reported here. (See Rabbit, Water Vole, Harvest Mouse, Common Dormouse, Otter, Mink, Pine Marten, Badger, and various deer species.)

The National Fox Survey which is currently in progress (see Part IV.17) is a volunteer-based scheme involving searches for fieldsigns, so will potentially provide both a useful baseline for the monitoring of one key Sign Transect Survey species and useful clues as to effective methodologies. The latter will include successful field methods (transect routes and lengths, etc.), ideas as to volunteer skill and motivation and data on likely fieldsign encounter rates in different areas. Preliminary analyses following the Fox Survey's pilot year show encouraging levels of participation and of fox scat detection.

4.4 What a field sign transect scheme could offer

The use of volunteer recorders in this manner is likely to offer the best opportunity for monitoring Mole, Rabbit and Red Fox, as well as providing important ancillary data for a number of other species. Some additional information would also be generated for other species where the monitoring of distribution is considered important, although such records would typically be of individuals seen during fieldwork, rather than their signs. However, volunteers should be allowed to record field signs of all mammal species where they felt confident enough to do so. Allowing fieldworkers to record all mammal signs encountered should also improve participation and retention rates and allow them to 'opt out' of some species. An annual or seasonal newsletter should also be produced to further increase motivation.

4.5 The data recording forms

We suggest that the forms can be read using an optical-mark-reader (OMR) to allow the rapid input of voluminous but fairly simple data. Recorders should simply count the number of field signs encountered for a given species along the transect route, with no attempt to estimate field sign density from established methods - i.e. no consideration need be given to the accumulation rates for droppings and the effects of weathering, particularly if the same sites are used in future years. All the species likely to be encountered should appear on the form with counts scored through within boxes. Information on additional species would be added by hand within a section for other records, mainly to prevent observers being frustrated by being unable to submit records that they found to be interesting. These data would require computerisation by hand rather than by OMR if it was felt advantageous to analyse them. Habitat information should be entered on the same form along with details about transect location and observer code.

4.6 Organisation of Sign Transects

A single individual should be able to co-ordinate the scheme, producing fieldwork material, helping with the analysis of data and preparing regular newsletters. Additional inputs would be required at the graduate scientist, or more likely post-doctoral level, when data analysis takes place. It is likely that this individual would also co-ordinate the Winter Transect Survey, working for the umbrella mammal monitoring body which would also run the other multi-species schemes and collate data from them and the mammal data generated by the BBS. Transects should follow linear features (including hedges, roads, rivers, paths, etc) on the basis that higher encounter rates are likely to be encountered along linear features than random lines (see National Fox Survey account and Pine Marten account).

4.7 Other considerations

A discussion on the potential for this method should cover the following points:

- Volunteers will vary in their ability to identify different mammal field signs, with the level of ability likely to improve through training workshops.
- Support to volunteers should allow the provision of training workshops, guidance notes and verification of any field signs sent in.
- Volunteers should be allowed to record all mammal field signs encountered so long as they are confident of a correct identification.
- Sightings-based data should also be allowed to be submitted, providing useful distributional data and some supporting evidence for those field sign records submitted.
- Integration of Sign Transects with other transect schemes (notably Winter Transect Survey) may be appropriate (e.g. fieldworkers could walk a transect in one direction recording animals seen and on the return record field signs). This would provide the fieldworker with something to do on the return route and enable two sets of data to be gathered at the same time.
- Feedback to volunteers should take the form of a regular newsletter sent out prior to the commencement of fieldwork.
- Detailed consideration should be given to the points raised in Part III.A.1 on the power of the BBS transect approach to detect long-term trends in mammal populations.
- Determination of appropriate sampling protocols should be undertaken alongside those for other potential transect methods, thereby maintaining consistency in methods and allowing overlap in participation.
- Timing of transects is important and needs to be considered on the basis of temporal patterns in field sign occurrence for individual species and the timing of other studies. The number of visits each year, together with transect length and degree of stratification should be determined through pilot fieldwork and simulation studies.
- Fieldworkers from the National Fox Survey could be recruited into the scheme.

4.8 Resource Requirements

Set-up costs - see Part VII.2.3.

Ongoing costs - Were the scheme to be run centrally and assuming co-ordination of this scheme with the Winter Transect Survey scheme and the Mammals on Roads Scheme, we estimate the annual requirements to be as outline in Part VII.2.3.

We anticipate that the establishment and operation of a single scheme (in isolation) would require approximately half of the sums shown in Part VII.2.3: running all three schemes together would allow certain economies of scale.

5. MAMMALS ON ROADS

This scheme would monitor a small number of mammal species recorded (alive or dead) along routes regularly travelled by volunteers. The recording of wildlife road casualties in particular has been used to calculate national estimates of annual mortality (attributable to road traffic) for a range of bird and mammal species (Finnis 1960; Hodson 1965; Bourquin 1983; Morris (pers. comm.); Shawyer 1999). This approach can be modified to produce indices of occurrence based on the presence of individual species along standard routes. Alive or dead individuals would be recorded separately, to allow the production of either separate or combined indices.

5.1 Advantages and disadvantages of this approach

Advantages

- The scheme would permit the monitoring of a number of species that are difficult to observe directly in the field, but which are often encountered crossing roads or found dead on them.
- A similar method has been successfully applied to a range of bird and mammal species for monitoring purposes.

Disadvantages

- The species covered would be limited by those that are readily identifiable as they cross the road or when they have been hit by cars.
- The survey will need to be simple to carry out safely, thus reducing the range of species that can be covered and the amount of data that can be collected.
- Fieldwork would need to be restricted to the summer months when days are sufficiently long to allow successful recording.
- The frequency of carcass removal (particularly of large carcasses) along some roads may cause a problem, since this is likely to vary on an annual basis depending on local government spending priorities. Some roads are cleared every two days (Colin Shawyer, pers. comm.).
- Live sightings may not provide many data.

5.2 What species could be monitored under this scheme?

Only a limited number of species could be monitored under this scheme, given the practicalities of recording mammals while driving a predetermined route. The target species for monitoring population trends through this scheme should be: Hedgehog, Grey Squirrel, Red Fox, Stoat, Badger, Fallow Deer, Roe Deer and Reeves' Muntjac.

Several other species could perhaps also be included, namely: Rabbit, Brown Hare, Weasel and Red Deer.

Those species for which this approach could generate useful data on distribution include Polecat, Pine Marten, Feral Ferret, Otter, Wildcat, Reeves' Muntjac and Chinese Water Deer.

5.3 What a Mammals on Roads Survey could offer

The use of volunteer recorders in this manner is likely to offer a good opportunity for monitoring a number of mammal species, providing ancillary data to that gathered by other multi- and single species schemes. Additional information on distribution is also likely to be generated for several species as a result of this scheme.

5.4 The data recording forms

We suggest that the forms can be read using an optical-mark-reader (OMR) to allow the rapid input of voluminous but fairly simple data. Recorders should simply count the number of individuals encountered for a given species along the transect route (with live and dead recorded separately). All the target species should appear on the form with counts scored through within boxes. Information on additional species would be added by hand within a section for other records, mainly to prevent observers being frustrated by being unable to submit records that they found to be interesting. These data would require computerisation by hand rather than by OMR if it was felt advantageous to analyse them. The fieldwork instructions should also stress the value of collecting corpses of certain species: those for which genetic monitoring work is being undertaken (Polecat, Pine Marten, Feral Ferret), although the safety element should be stressed.

Information on road type, adjacent landscape, route length and traffic density should also be recorded, with the latter being derived through a simple count of oncoming traffic during a journey on which mammals were not being counted. This will allow for changes in traffic density over time to be examined, with the road death data being adjusted accordingly.

5.5 Organisation of Mammals on Roads

A single individual should be able to co-ordinate the scheme, producing fieldwork material, helping with the analysis of data and preparing regular newsletters. Additional inputs would be required at the graduate scientist, or more likely post-doctoral level, when data analysis takes place. This scheme could be co-ordinated alongside the Winter Transect Survey and the Sign Transect Survey, under an umbrella mammal monitoring body which would also run the other multi-species schemes and collate data from them and the mammal data generated by the BBS.

5.6 Other considerations

A detailed analysis of the advantages and disadvantages of this approach (when applied to road deaths) is provided in MMR. There are a number of other considerations:

- The safety of observers is paramount and fieldwork methods, choice of roads, etc. should all be evaluated against safety aspects. Motorways and dual-carriageways should not be used.
- Fieldwork should only take place during late spring through to early autumn.
- Details of traffic density, class of road and main habitats along the route all need to be recorded, though not during the monitoring visits
- Volunteers should be able to select the location and length of their route.

- Timing of recording should be ideally limited to the morning commuter period or some other consistent time of day.

- Feedback to volunteers would need to be an important component of the scheme, ensuring that continuation rates are maintained.

5.7 Resource requirements

Set-up costs - See Part VII.2.3.

Ongoing costs - Were the scheme to be run centrally and assuming co-ordination of this scheme with the Winter Transect Survey scheme and the Sign Transect Survey, we estimate the annual requirements to be as outlined in Part VII.2.3.

We anticipate that the establishment and operation of a single scheme (in isolation) would require approximately half of the same shown in Part VII.2.3: running all three schemes together would allow certain economies of scale.

6. MAMMALS ON NATURE RESERVES

In this scheme the wardens of nature reserves would send in records of having observed (or not) mammals on their reserves.

6.1 Advantages and disadvantages of this approach

Advantages

- There are a large number of reserves.
- They have a good geographical spread, especially being better spread than the human population.
- They cover a good range of semi-natural and natural habitats.
- Those wardening them are committed to nature conservation: some are paid, others have taken on the role in a voluntary capacity but in a sufficiently formal way for the commitment to be explicit.
- Most of those wardening reserves are highly competent field naturalists.
- Since reserves are mostly permanent, they provide better security for long-term continuity of observations.

Disadvantages

- Reserves tend not to include agricultural land (which makes up the majority of the UK) or 'human sites'.
- Reserves are usually places of particular nature conservation interest, making them unrepresentative of the countryside in general.
- Reserves are generally managed to maintain or enhance their nature conservation interest, so trends observed on them may not be representative of those in the wider countryside.

The last point is particularly important but may be less significant than might at first sight appear. Reserves are generally small, so that for medium and large mammals at least their populations are unlikely to be self-sustaining; they are generally so isolated that immigration from other reserves cannot be relied upon to re-establish mammalian populations that have become extinct on one reserve (an important difference between mammals and birds - the latter appear to be able to find almost any patch of suitable habitat). Thus, except for small species, mammal populations on reserves, while they may be denser, are likely to be correlated with those in the surrounding countryside.

We believe that the advantages of this approach outweigh the disadvantages and that such a scheme could make a valuable contribution to the monitoring of a number of species.

6.2 Which species could be monitored under this scheme?

All species of non-marine mammals (excluding bats) could be included. All could be the subject of reports of having been directly observed, alive or dead. These records could be supplemented by separate records of signs: these should only be signs that are fairly reliably identifiable. The records of signs should be separated from those of direct observations, to allow both finer analysis and inspection of the data for evidence that ability to detect signs is changing over time. To reduce the chances of observers being put off by the scheme appearing unduly difficult, the list of signs should be modest. We suggest that the following may be appropriate:

- Droppings and latrines: Hedgehog, Water Vole, Red Fox, American Mink, Badger, Otter.

- Nests: Harvest Mouse.
- Active setts: Badger.
- Feeding signs: Common Dormouse? (Should involve suspect nuts being submitted for confirmation, at least until the observer's reliability has been established).

Note that this scheme could be valuable in documenting the potential spread of several species whose distributions are currently restricted and for which any data at all may be difficult to get - i.e. Wild Swine and Chinese Water Deer. It could also be useful in picking up the spread of Wild Goats into new areas.

We have considered whether certain other species of very restricted distribution should be excluded from this scheme, as the number of sites providing positive records will be too small to be useful. The exclusions might be: Lesser White-toothed Shrew, Orkney Vole, Ship Rat, Fat Dormouse, Feral Sheep, Red-necked Wallaby. We have concluded that excluding them would frustrate those few observers who recorded them, so that it would be better to include them.

Note that we recommend that *Felis catus* be included in this scheme. Although there is no way in which observers can distinguish between Feral Cats and those that are attached to people, recording the occurrence of cats on reserves could be one of the few practicable ways of monitoring the occurrence of this widespread species.

All the included species (and signs) should be printed on the recording forms. Observers should be asked to write in any other mammals that they come across, both to allow them the pleasure of doing so and to provide records of escaped aliens. (Though, for the benefit of pedants, Dog and Man should perhaps be mentioned on the form as species not to be bothered with).

6.3 Participating organisations

It would be sensible to start with organisations that each currently manage large numbers of reserves. This will ease the setting up of the scheme. We suggest that likely candidates are:

- The statutory country conservation agencies
- Plantlife
- RSPB
- The National Trust
- The Wildlife Trusts
- The Woodland Trust

Between them, these bodies own thousands of reserves (and the number continues to increase). Not all would be recruited into the scheme. We suggest that the following criteria be used to prioritise candidate reserves initially:

- Is there a warden who is prepared to participate? Many reserves (perhaps an increasing proportion) have professional wardens (though a single person may have several reserves to care for); it may be that all the participating organisations would be prepared to include any of their reserves that had professional wardens. Other reserves are cared for by volunteer wardens, whose participation in the scheme would be a matter of persuasion, rather than instruction (we assume).
- Is the warden (or a colleague) able to identify a fair proportion of the mammals included in the scheme? So long as the observers were asked to indicate which species (and signs) they did not feel sufficiently reliable with, it would not matter if they could not deal with

all the species on the list; but there would be no point in including a reserve if the observers were only capable of identifying a handful of species - unless these were species of especially high priority.

- How often is the reserve visited?
- Is the reserve in a region that is comparatively poorly covered for mammal monitoring?
- Does the reserve contain priority habitats?
- Is the reserve in a part of the country that is of special interest (a Focus Zone) for any species?

Note that the last three criteria do not mean that sites that do not fulfil them should not be accepted (since we need good geographical and habitat coverage) but that sites fulfilling these criteria would be particularly acceptable.

6.4 Setting the scheme up on each reserve

When a reserve is taken into the scheme, it should be formally registered and various information placed in a database. Relevant information would be:

- Name of reserve
- Organisation managing the reserve
- 10km square in which the reserve falls (if in more than one, perhaps the parts in the different squares should be recorded separately?)
- Area
- Habitat composition - some broad habitats should be used, with simple classes of the areas of each - such as 0, <5%, 5-33%, 33-67%, 67-95%, >95%
- Name and address of observer responsible for submitting the records for the reserve

Observers should be supplied with a form on which to record (and submit) any changes in the above details, so that the database can have the new information added to it. Observers should be reminded from time to time of the need to submit such changes.

When a reserve is registered in the scheme, it should be given a unique number, which can be used in future to identify it on recording forms. Since the latter should be optically readable forms (using marked boxes) this number will be the way in which the data on recording forms are identified to locality, so it is important that observers get it right. We suggest that the number should have a part that identifies the organisation managing the reserve and that the whole number should contain enough simple devices that most wrong numbers can be picked up automatically when record sheets are being read.

6.5 The data recording forms

We suggest that the forms are optical-mark-read forms. These have proved very useful in Garden BirdWatch, for the rapid input of voluminous but fairly simple data - though data that are more complex than what is being contemplated here.

We suggest that each form should cover 13 weeks of the year (it is difficult to fit more onto an A4 sheet), with a box for each week against each species (and each species-sign), to be marked if the species (sign) is observed in that week. There should also be a set of boxes to be filled in for each week, recording the amount of time spent on the reserve that week, in broad classes - say, 0, 1-4, 5-16, 17-64, >64 man-hours. This will provide a means for checking long-term drift in recording effort and, indeed, of correcting for it.

There will need to be a careful description of what man-hours to include. It should cover all the hours on the reserve when mammals might be seen, even if the person is doing some task not directly concerned with recording - e.g. making fences. It should cover everyone who has been asked specifically to look out for mammals, not just the warden (or nominated observer). Perhaps there might be value in having a separate row of boxes for each species for casual records - e.g. reports by members of the public; this would broaden the recorder base for the species that are more difficult to observe; on the other hand, it would raise serious problems about the reliability of the data.

It may be useful to ask observers to write in whether there has been any unusual level of effort put into recording any species that week - for example, a periodic survey to estimate deer numbers or an occasional trap-survey of small mammals.

6.6 Organisation of the scheme

Forms should be submitted quarterly. The data should be input quickly, routine analyses run, and a report produced for the observers. The report should be sent out during the subsequent quarter, together with the survey forms for the quarter after that. This will give the observers prompt feedback and remind them to continue with the work. This is a routine that works well with Garden BirdWatch and it fits in with the design of the recording forms (13 weeks).

Routine analyses should cover such things as seasonal patterns, long-term trends, and geographic patterns, as well as unusual records (the latter are useful for lightening the tone of the reports). The report should comprise four A4 sides and contain news about the scheme and announcements, some of the results from the routine analyses, etc.

Most of this work should be undertaken by one organisation, preferably one that can integrate the results with those of other schemes. Contact with the observers might, however, be better undertaken by the organisations managing the reserves, to whom the wardens owe their primary allegiance. So they might be responsible for sending out the newsletters and recording forms to observers and for collecting up all the data emanating from their reserves. There is always a danger of delay in such a two-tiered approach to contact with the observers but if it helps participation rates then that is a risk worth taking.

The participating organisations should perhaps receive summary data for their reserves quarterly and should certainly be provided with an electronic copy of the data from their own reserves annually.

6.7 Data analysis

The accuracy with which changes in populations would be indexed by this scheme could be affected both by differences between reserves (such as size and habitat) and changes in recording effort (number of weeks per year in which the reserve is visited and number of hours per week spent on the reserve). However, if these are recorded as we suggest, statistical analyses based on

General Linear Models and General Additive Models can allow for them. Furthermore, the effect of differences between reserves is reduced by retaining the same reserves in the sample indefinitely.

6.8 Resource requirements

Were the scheme to be run centrally (apart from initial recruitment of participants), we estimate the annual requirements to be as outlined in Part VII.2.4.

Were the scheme to be run in a more devolved way, with participating organisations taking on more of the responsibility for communication with the reserve wardens, the central costs would be diminished but the total costs may be rather higher.

Set-up costs would be 1.5 man-months post-doctoral scientist, for design and programming

7. GARDEN MAMMAL WATCH

7.1 Introduction

A scheme in which volunteers recorded the occurrence (or apparent absence not) of mammals in their gardens would have the following benefits:

- It would cover significant parts of the populations of some species that would not be covered so well by other schemes (e.g. Hedgehog, Grey Squirrel, Red Fox - 14% of the British population of the latter live in urban areas (The Populations Review)).

- It would provide information on species that were difficult to cover by more formal surveys.

- Because large numbers of people might participate, it would provide coverage even in areas of sparse human populations, which may not be covered by other schemes.

- It would introduce people to monitoring who might go on to more demanding schemes.

- An associated newsletter would be a good medium for seeking casual records (outside peoples' gardens) of species for which these would be valuable - e.g. Polecat, Pine Marten.

- It would draw more citizens into direct participation in science-based conservation.

The disadvantage of garden-based recording is that gardens are a peculiar habitat, of marginal importance for most mammals. Urban and suburban gardens, in particular, are unlikely to reflect closely the status and trends of mammal populations in the country in general; rural gardens may do so, though some are so large that for smaller mammals they may form almost self-sufficient islands of habitat distinct from their surroundings. Thus, except for species with significant populations in gardens, such a scheme should only be used in conjunction with other schemes, to provide a suite of information on species that may be difficult to monitor otherwise.

7.2 Previous garden mammal surveys

Look what the cat's brought in - a one-off, five-month survey run during spring and summer 1997 by The Mammal Society. This produced capture records for 964 cats, comprising a wide range of mammals (up to the size of Grey Squirrels and Rabbits), birds, amphibians and reptiles.

The Garden Mammal Survey - a one-off survey run during the autumn and winter 1998-99, by The Mammal Society and The People's Trust for Endangered Species. The data have not yet been analysed but we understand that about 2,000 gardens were included and that these provided records of about 40 different species (bats included). A book on garden mammals was made available to participants at a modest price.

7.3 The BTO/CJ Garden BirdWatch (GBW)

The scheme we have in mind would be similar to GBW, instructions and recording forms for which are provided as an Appendix 2. This has run since 1995 and currently has 11,000 registered participants, of whom about half supply data. (The number of participants increased by *c*.40% during 1998). About 75% of the participants remain in the scheme from one year to the next.

Participants supply details of their gardens when they register. Thereafter, they record birds weekly, submitting their records quarterly. These records comprise: semi-quantitative data on 10 species, presence/absence records for 31 species, and records of the provision of water and various foods. Species other than the 41 printed on the main survey form may be recorded on a "Scarcer Species Form". Records are requested for each of the 13 weeks in the quarter; observers indicate in which weeks they were actually recording, so that weeks with active recording but nothing seen (which are theoretically possible) can be distinguished from weeks with no active recording.

The main survey form and the Site Registration Form are optically-read mark-sense cards, so can be processed quickly. (The main value of the Scarce Species Form, from which it is more laborious to extract data, is that is prevents participants being frustrated by being unable to submit records of these species).

Forms are sent out quarterly, in advance, together with an 8-page A4 newsletter.

Participants pay an annual fee which, with sponsorship from CJ Wildbird Foods Ltd., covers the cost of running the scheme - printing, postage, staff time and office overheads.

7.4 What Garden Mammal Watch could cover

Participants in Garden Mammal Watch are likely to vary considerably in their ability to identify mammals: some may be capable of identifying only a few species from direct observations; others may be able to identify almost all mammals they see and a range of signs. To maximize both participation rates and the value of the data, we suggest that a fairly long list of species is listed on the recording form, with each participant asked to indicate those that she or he wishes to cover (thus allowing observers to participate who do not feel able to identify all the species or their signs).

Species to be included should be decided after the Garden Mammal Watch data have been analysed. The following points are relevant to that decision.

- All obvious and easily identifiable species should be included, even if we do not really need the data; otherwise, participants may be frustrated at not being able to record them.

- Animals brought in by cats should be included, even if they may have originated outside the garden; this will not only avoid participants' frustration at not being able to record such animals but will greatly increase sample sizes of some species.

- Observers should be encouraged to record everything - even pests that have been killed or removed.

- More difficult species may be included, provided observers are reassured that they can opt out of recording them and provided that identification guidance is given.

- Species of restricted distribution should be included because all records of them outside their current range will be useful.

- Signs commonly left in gardens and relatively easily identifiable should be included.

- There should be opportunity to submit records of species additional to those listed.

- Observers should record the presence of non-resident cats and whether or not a cat is in residence - since these will influence whether some mammals occur in the garden and whether they are recorded if present. (Perhaps dogs should also be recorded).

- Houses should be included as part of the garden - to encourage records of House Mouse, Fat Dormouse, etc.

We suggest that observers are asked to record the presence of each species in each week, with a 13-week (i.e. quarterly) cycle of form submission, which has proved successful in GBW. A quarterly cycle allows the form to be of manageable size, reminds participants about the survey, and provides important opportunity for feedback through the newsletter.

7.5 Should other taxa be included?

We suggest that, if a Garden Mammal Watch is planned, serious consideration be given to the inclusion of reptiles and amphibians. Particularly in view of the serious declines of amphibians, even data not precisely identified to species (e.g. frog, toad) may be valuable. The add-on costs would be trivial.

7.6 Organisation of Garden Mammal Watch

There are two main options: as a stand-alone project perhaps run by The Mammal Society (or similar voluntary body) or as a bolt-on to Garden BirdWatch (which is run by BTO, but would need input from mammal experts if mammals were to be bolted on to it). We are hesitant to mention the second, as this possibility has not been assessed either by BTO or by the GBW sponsor; furthermore, it may appear to be a bid for BTO to reserve a high-profile element of mammal monitoring itself. However, we estimate it to be a much cheaper option. Our current estimates of approximate costs of (£000s per annum) of a GMW are as follows (they would need to be refined if this scheme was thought worth discussing further).

Number of participants	Stand-alone	Part of GBW
1000	85	20
2000	87	21
5000	90	25
10000	95	30

Note that there would be some additional cost for the second option, in the form of a few weeks per year for the input of time from mammal experts in interpreting the results and helping with feedback; it would probably be inappropriate for BTO to take on those tasks.

In addition, under either option, 2-4 man-weeks should be allowed for setting up the scheme and a further 4 man-weeks p.a. for any but the most routine analysis of the data (e.g. long-term trends, regional analyses, mapping, feeding records through into NBN; routine analysis would be confined to gross reporting rates in each quarter). These additional weeks would be at post-doctoral graduate scientist level.

The circulation of identification materials should be considered; the cost of this is not included above.

We do not believe that such a scheme could be funded through participants' subscriptions, since the mammals have fewer devotees than birds and generally provide less entertainment to garden-watchers than do birds (because there are fewer species - five per garden on average in the Garden Mammal Survey - and they are less commonly seen). We believe that most GBW participants would not pay more if asked to do so simply in order to include mammals on this project.

PART IV SCHEMES FOR INDIVIDUAL SPECIES

INTRODUCTION

In this part of the report, we review the options for monitoring each species of mammal found in the UK in turn. These accounts should be read in conjunction with the accounts in MMR, because the latter present much important background information (based on wider consultation). Within the constraints of readability, we have tried to avoid repeating material already presented in MMR. We have treated species individually, except where common monitoring concerns, approaches and/or interests make this illogical (for example, squirrels). For each species, we note current status in the UK (including range, abundance and known population trend) and review any recent and ongoing monitoring work on that species. We then suggest objectives for the monitoring of each species, but we would stress that we supply these only as points for discussion and to put our subsequent remarks in context: decisions on the aims of monitoring (including the quantitative power required of survey schemes) should be made by consensus between mammal specialists and government.

We review the techniques potentially available to monitor each species (with particular consideration as to their suitability for use by volunteers) and then consider how these techniques can be combined into effective monitoring schemes. Where possible, we suggest more than one alternative scheme (or combination of schemes) and we review the proposals in MMR critically. For many species, our suggestions include the use of the multi-species schemes described in Part III, so the species accounts should be read in conjunction with the outlines of the relevant schemes provided there. We end each species account with a set of recommendations as to future priorities and practices for monitoring. Again, these should be taken as points for discussion which are subject to revision after input from government and mammal specialists.

1. HEDGEHOG *Erinaceus europaeus*

Native and widespread (probably introduced to Ireland). May have declined in last 50 years.

1.1 RECENT AND ONGOING MONITORING WORK

None.

1.2 MONITORING OBJECTIVES

Hedgehogs, though their numbers are probably influenced by interactions with Badgers and Foxes, are probably good indicators of the availability of ground invertebrates. They also resonate with the public, so are a valuable means of drawing wildlife issues to the attention of the public. For these reasons it is important to monitor them.

The objectives of monitoring should be to be able to detect population changes of 25% over 25 years, at the level of individual countries.

Intensive work may be needed on islands to which Hedgehogs have been (recently) introduced; our recommendations cover monitoring at the national scale.

1.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Live-trapping of Hedgehogs is laborious, as the traps are large and the capture rate is low.

Game Bags - Game Bag data on Hedgehogs have been collected since 1961 by Game Conservancy Trust. We do not consider, however, that these provide reliable index data for Hedgehogs since this is a generalist species, subject to variation in effort of both control measures and recording, and since the change in its legal status consequent on The Wildlife and Countryside Act 1981 has led to fewer estates recording Hedgehog kills (Tapper 1992) - see Part III.A.2.

Direct sightings - Direct observations require many hours to be spent in the field per Hedgehog observed, though the frequency of observation is greater by night if a spotlight is used. Morris *et al.* (unpublished) worked in a high density population on Alderney and in habitats in which Hedgehogs were easily spotlighted - an airfield and a golf course. Even so, only two or three animals were detected per km walked. Dr Pat Morris (pers. comm.) estimates that 4-5 hours per site would be required to detect enough Hedgehogs for monitoring purposes.

Field signs - Hedgehog droppings are easily recognised, though are only conspicuous in short vegetation.

Road-deaths - Dead Hedgehogs are commonly seen on roads and are easily recognisable from a moving car. There have been various surveys of Hedgehog road-deaths and The Mammal Society is about to undertake analyses of extensive volunteer-based surveys conducted by Dr Pat Morris during 1991-1994.

1.4 POTENTIAL MONITORING SCHEMES

Spotlighting transects - MMR propose surveying at least 2000 sites on three consecutive nights every five years, each site covered by a 1km spotlighting transect. It would not be possible to recruit volunteers in the required numbers to conduct a survey, given the demanding nature of the work and the low success rate: given the results of Morris *et al*. (above), 0.5 animals/km is probably a generous guess of the likely mean sighting rate which suggests that even in three visits a high proportion of observers would see none at all, making it very unrewarding. To cover the sites professionally would take 400x3=1200 nights' work, even if the sites were sufficiently clumped for five to be done each night, which equates to at least five man-years - or one man-year/year averaged over the cycle of five years. We do not believe this to be cost-effective, nor that modifications to this basic design could produce a substantially cheaper option.

Note that MMR suggest applying capture-mark-resighting techniques to the spotlighting data. The numbers seen per sampling occasion would be too low to give reliable results using this technique, judging from the results of Morris *et al.*(unpublished) in ideal conditions on Alderney.

Breeding Bird Survey - Hedgehogs appear to be encountered sufficiently often on BBS squares for this scheme to contribute usefully to their monitoring (see Part III.A.1).

Sign Transect Survey - These could provide useful information on Hedgehogs (see Part III.B.4).

Mammals on Roads - MMR recommend 2000 transects of 1km length, driven at least three times at weekly intervals, every five years. We believe Mammals on Roads transects would provide useful data, though would adopt a different protocol in detail (see Part III.B.5).

Mammals on Nature Reserves - We believe that Hedgehogs and their signs are commonly enough observed, and readily enough identified, for records on reserves to provide useful monitoring information (see Part III.B.6).

Garden Mammal Watch - Hedgehogs were the second most commonly recorded species in The Mammal Society's Garden Mammal Survey, so Garden Mammal Watch could provide useful data (see Part III.B.7).

1.5 RECOMMENDATIONS

A combination of two more-or-less existing surveys (BBS and Garden Mammal Watch) and two others that could be mounted with relatively little further piloting (Mammals on Road and Mammals on Reserves) should provide sufficient information to detect major changes in Hedgehog numbers, though further quantitative analyses of the likely power of these schemes should be undertaken.

2. MOLE *Talpa europaea*

Native and widespread in Great Britain; absent from Ireland and most islands.

2.1 RECENT AND ONGOING MONITORING WORK

None. Moles are so difficult to count that there seem to have been no serious demographic studies.

2.2 MONITORING OBJECTIVES

We suggest that the Mole is probably a good indicator of soil invertebrate populations and that it should therefore be monitored throughout its British range. A decline in abundance (or in an index of abundance) of 25% over 25 years would be regarded as serious, so the monitoring programme should aim to detect this.

2.3 POTENTIAL MONITORING TECHNIQUES

Direct sightings - Moles are rarely seen on the surface, so this method is not useful.

Road-deaths - Haeck (1969) found that large numbers of young Moles were killed on roads in The Netherlands in June and July, as they dispersed from their natal territories. We believe that this species is too inconspicuous, however, for sightings of dead mammals to be included in the Mammals on Roads scheme (see Part III.B.5)

Owl pellets - Southern (1954) found that moles comprised 15% of the vertebrates taken by Tawny Owls *Strix aluco* in the midsummer dispersal period. However, they were much scarcer at other times of year. Barn Owls *Tyto alba* take Moles much less often, so such records are of little or no value for monitoring.

Trapping - Friesian live-traps have a fair success rate but are laborious to transport and set. In any case, both they and the various traps that kill Moles (and which are less laborious) need to be set in tunnels - which themselves provide an indication of the presence of Moles.

Field signs (fresh tunnelling activity) - New Mole hills are seen from midwinter onwards, as the animals repair damaged tunnels; since damage depends on soil structure and weather, so does the number of Mole hills. Surface tunnels are often conspicuous but are disproportionately dug in newly cultivated fields, very light soils and very shallow soils. Tunnelling activity is not always conspicuous in woodland, which is important Mole habitat. In addition to these habitat differences, tunnelling activity varies seasonally, not only in relation to winter weather damage but particularly in relation to the reproductive cycle: Moles burrow very actively in spring in the search for receptive females. Thus the observation of tunnelling activity is not a good indicator of Mole density. However, particularly if observations are made in the same places year after year and if habitat details are recorded, it can be used as a long-term monitoring index. The major caveat is its weather dependence. Given that there is no other easy way of monitoring Moles, we suggest that schemes based on observations of fresh tunnels should be used for monitoring; there is sufficient variation in weather from year to year for the potential impact of weather on the index to be examined as data accumulate, which will help in the interpretation of the index against the background of long-term climate change.

2.4 POTENTIAL MONITORING SCHEMES

Breeding Bird Survey, Winter Transects, **Sign Transects, Mammals on Nature Reserves, Garden Mammal Watch -** Observations of fresh Mole tunnels in these schemes are likely to provide a good long-term index of Mole numbers. For their own satisfaction, observers should also be allowed to include records of Moles seen dead or alive but these are unlikely to be numerous enough for monitoring purposes.

Mammals on Roads - We recommend against observers being asked to record Moles seen dead on the road but suggest that observations of fresh tunnelling activity beside the road might be trialed.

2.5 RECOMMENDATIONS

1) Moles should be monitored through a series of multi-species schemes, incorporating records not only of Moles directly observed (dead or alive) but also of fresh tunnelling. The schemes are:

Breeding Bird Survey;
Winter Transects;
Sign Transects;
Mammals on Nature Reserves;
Garden Mammal Watch.

2) Observations of fresh tunnelling within sight of roads could be included in Mammals on Roads on a trial basis.

3. LESSER WHITE-TOOTHED SHREW *Crocidura suaveolens*

Introduced. Occurs on the Isles of Scilly and is believed to be widespread within most habitats offering adequate cover. There are few data available for this species, although it is believed that the population is currently stable.

3.1 RECENT AND ONGOING MONITORING

None.

3.2 MONITORING OBJECTIVES

Although populations of this species are thought to be stable, there is no empirical data either to support or to refute this claim. In view of this, periodic monitoring should be instigated initially with a view to producing baseline data against which future changes can be examined.

3.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Lesser White-toothed Shrews can be caught using Longworth live-traps set in suitable habitat, ensuring that the treadle weight is set accordingly for an animal of its size (Churchfield 1990). A density of 10/hectare was reported in The Populations Review for populations in natural vegetation. This figure, coupled with home range sizes of 50-80m^2, suggests that a grid of traps covering 1ha should be used, with a 10m trap spacing. However, the suitability of this approach needs to be evaluated in the field across the range of habitats occupied by this species. The use of shoreline habitats further complicates the development of a standard method for trapping this species.

Field signs (faeces) - This species is the only shrew to occur on the Isles of Scilly, thus making it possible to use dropping boards or bait stations to collect faeces (see similar approach for Water Shrew - Abyes & Sargent 1997). This will provide information on the distribution of the species, together with a basic index of abundance. The suitability of this method would need to be evaluated during pilot fieldwork.

3.4 POTENTIAL MONITORING SCHEMES

Both the use of live-trapping and faeces counts at bait stations may potentially be used for monitoring this species. However, both need to be evaluated in the field and the two methods may be calibrated against each other during the initial stages of monitoring, with one being dropped if it were found not to be cost-effective. Populations of this species may fluctuate over the short-term and annual monitoring should be implemented for the first 10 years to examine short-term trends. If these prove to be absent then monitoring could take place periodically rather than annually, although this needs to be evaluated further.

The biggest difficulty with either of the two approaches is how to ensure that there is sufficient coverage of the diverse range of habitats the species uses. A suitable sampling design to cover all habitats needs to be discussed, possibly after some pilot work examining densities of the species in different habitats.

3.5 DEVELOPMENT AND VALIDATION STUDIES

A research study needs to be undertaken over a couple of field seasons in order to determine the habitat associations of this species. This information can then be used to establish a suitable sampling protocol for the use of either live-traps or faecal signs.

3.6 RECOMMENDATIONS

Pilot fieldwork needs to be carried out to establish the best way in which to monitor this species (live-trapping or faecal signs) and how to sample the diverse range of habitats used. Once this has been determined, monitoring should take place on an annual basis for the first 10 years and then periodically if short-term fluctuations prove to be insignificant.

4. RABBIT *Oryctolagus cuniculus*

Introduced. Widespread and abundant, with numbers highest in the east and south-east of England. Can cause damage to farming and forestry interests, although Rabbit grazing is beneficial in maintaining chalk grassland habitats.

4.1 RECENT AND ONGOING MONITORING

A full review of Rabbit surveys up to the early 1980s is provided by Trout *et al*. (1986).

Forestry Commission Surveys - Four surveys of Rabbits (and other wildlife) on Forestry Commission land have been carried out by the Wildlife Section of the Forestry Commission since 1968, at approximately five-year intervals. The data are sent in by foresters in response to a questionnaire and the accuracy of responses is '*..inconsistent since the knowledge and interest of the respondents may vary.*' (Tee *et al.* 1985). However, since Rabbits and Rabbit damage are relatively straightforward to identify, the results for Rabbit are likely to be reliable.

Environmental Change Network (ECN) - MMR report that the ECN have selected the Rabbit as an indicator species to be monitored by winter pellet counts in selected sites, although this scheme has encountered statistical difficulties and only covers less than 20 sites.

Game Conservancy National Game Bag Census - The National Game Bag Census has recorded the numbers of Rabbits killed by keepers on many shooting estates since 1961. The general disadvantages of Game Bags are addressed in Part III.A.2. Additionally, the diverse ways in which Rabbits are controlled, together with changes over time in the favoured methods of control, make the Rabbit Game Bag data more difficult to interpret.

British Association for Shooting and Conservation (BASC) - Since 1980, a random sample of BASC members have recorded the number of Rabbits shot during the year. A basic index of abundance (number shot/km^2) can be derived, although this contains a component of hunting effort, which would need to be separated before the data could be used to determine Rabbit abundance itself.

Ministry of Agriculture, Fisheries and Food (MAFF) and Scottish Office Agriculture and Fisheries Department (SOAFD) Surveys - Since 1969, MAFF has operated three consecutive types of Rabbit survey on farms. This work has been restricted to England and Wales and the different survey approaches are not directly comparable. Similar work has been carried out in Scotland (Kolb 1994) with surveys by SOAFD, formally DAFS, in 1969, 1970, 1973, 1974 and 1991. See Trout *et al.* (1986) [Table 1] for detail of the methods employed. Of the MAFF surveys, all three provide data of value for monitoring Rabbit distribution, but only the two most recent surveys allow calculation of Rabbit abundance. With the Scottish survey work, there was a problem in that there was a subjective element involved in judging the severity of infestation.

4.2 MONITORING OBJECTIVES

Rabbits should be monitored because of their economic importance (as pests of agriculture and forestry), their influence on vegetation structure and their importance to other bird and mammal species (Sumption & Flowerdew 1985). The widespread distribution of this species negates the need for distribution based monitoring, but monitoring of abundance would appear to be an important objective.

4.3 POTENTIAL MONITORING METHODS

Game Bags - Bags of Rabbits taken from estate records are prone to variation stemming from differences in the control measures employed. For this reason they are more difficult to interpret and less useful in a monitoring context. Rabbits may be taken by a number of different means, sometimes as part of a day's shoot, sometimes through ferreting, others through spotlight shooting or snaring. Some control measures may not be reported as part of the Game Bag records. However, a long term average trend has been produced from the Game Bag data by Tapper (1992) suggesting a recovery in the population following the increase in genetic resistance to myxomatosis. It has been established that the different methods of taking Rabbits have resulted in samples of different age and sex structure (Smith *et al.* 1995). These biases may have had an influence on the monitoring value of Game Bag data, as different methods for taking Rabbits have changed in popularity.

The British Association for Shooting and Conservation have information gathered between 1980-1983 on the number of Rabbits shot by a sample of its members. There is no information on whether this type of data will be gathered on a more regular basis using a more structured approach.

Twilight counts - Counts taking place at dawn and dusk reveal about 15-20% of the population during winter and 40-60% of the population during the summer. Trout & Tittensor (1989) note that at least three counts are required to attain sufficient accuracy.

Spotlighting - Like hares, it is possible to detect Rabbits at night by using a spotlight to produce eyeshine. Barnes & Tapper (1985) developed a method to count Brown Hares using this approach and this could be re-evaluated to allow the production of population estimates for Rabbits. The method was found to be most appropriate (in the case of Brown Hares) when applied to the assessment of large differences between Brown Hare populations in extensive studies.

Field signs (warren entrances) - The number of active warren entrances has been demonstrated by some authors to be related to the number of Rabbits using the warren (Parer & Wood 1986). However, this relationship '.. *is likely to be highly variable, and in high-density populations the relationship may be non-linear..*' (Parer & Wood 1986). In some habitats entrances will be more difficult to find than others, while in a few instances Rabbits may not use burrows at all. Collectively this suggests that the use of warren entrance counts may be of little value for long-term monitoring, even though it has the advantage that it is quick and relatively easy to record such features.

Field signs (pellet counts) - Counts of faecal pellets may be used to determine the presence of Rabbits at a site, although there may be some confusion with those produced by Brown or Mountain Hares. The density of Rabbits may be calculated from counting pellets within a specified area. This approach has been widely used for deer (Bennett *et al.* 1940; Bailey & Putman 1981) and potential problems with the method have been reviewed (see Neff 1968). The technique has been used for Rabbits (Taylor & Williams 1956; Trout & Tittensor 1982; MAFF 1982; Wood 1988).

While consistent relationships between Rabbit density and pellet density have been found within some sites (overseas), or across sites with similar characteristics, Angerbjorn (1983) points out [from work on hares] that separate factors are necessary to convert pellet density to hare density for habitats which differ substantially. While it may not be possible to compare Rabbit densities between habitats, it should be possible to monitor trends in abundance within sites, so long as the same monitoring sites are used year-on-year. Variability in pellet production and pellet decay rates may result from a number of factors. Production rates may be influenced by changes in the quality of vegetation (Arnold and Reynolds 1943), which in turn may be related to season (Lockley 1962) or climatic differences between years. Consideration should be given to these effects if a monitoring protocol based on pellet counts is to be implemented. The successes of the MAFF scheme and ongoing work by Roger Trout suggest that Rabbit abundance may be monitored through the use of pellet counts along transects.

4.4 POTENTIAL MONITORING SCHEMES

Garden Mammal Watch - Rabbit may be recorded as part of the proposed Garden Mammal Watch scheme (see Part III.B.7), although it is not clear how often Rabbits will be recorded in gardens and to what extent those that are recorded are representative of the population in the wider countryside.

Mammals on Roads - Rabbits are likely to feature quite prominently in those species seen dead on the roads. However, encounters with dead Rabbits may be too frequent to be of value to the index approach outlined in Part III.B.5. To overcome the problem of a lack of stability in the Rabbit population during the summer months, road-transects would need to be covered in the winter, something that may be impractical.

Breeding Bird Survey - Rabbits were reported from about 70% of those transects for which BBS mammal data were received, suggesting that the BBS approach may be suitable for this species. However, the BBS count data need evaluation and the BBS presence/absence data needs evaluation against other schemes.

Sign Transects - (see Part III.B.4) Rabbits can be recorded through a field sign survey providing a simple index of abundance without the need to determine a relationship between pellet density and Rabbit density. This approach should be carried out during the winter months when the Rabbit population is more stable. It is not thought that Game Bags, BBS transects or other datasets could be used successfully for the monitoring purposes outlined.

4.5 DEVELOPMENT AND VALIDATION OF STUDIES

Work should be carried out to determine the relationships between Rabbit density and pellet density for a range of regions and habitats. This can then be used to calibrate data from the sign transects.

4.6 RECOMMENDATIONS

1) The abundance of Rabbits at a series of fieldsites should be determined annually through Sign Transects (Part III.B.4).

2) Ancillary data should be gathered through Garden Mammal Watch (Part III.B.7) and Mammals on Roads (Part III.B.5) schemes. The value of such data should be evaluated

against that derived from sign transects. Data from BBS can also be fed in to the monitoring programme.

5. HARES

MOUNTAIN HARE *Lepus timidus*: native to Britain and Ireland, southern British populations introduced; in Britain, restricted to Scottish uplands, the Isle of Man and the Peak District but locally common, widespread in Ireland and found in many habitats; stable but vulnerable, especially with respect to global warming.

BROWN HARE *Lepus europaeus*: introduced to Britain in Roman times or earlier, introduced to Ireland in the 19th century; common and widespread in Britain but abundance variable, scarce and localised in Ireland; has declined considerably but now perhaps stable.

5.1 RECENT AND ONGOING MONITORING WORK

National Brown Hare Survey - A winter transect survey, using distance sampling, of 738 1km squares forming a random sample stratified by ITE Landscape Region, conducted in 1991-1993 (Hutchings & Harris 1996). Consideration of more than one winter minimized the impact of inter-annual fluctuations in numbers on population estimations. A statistically sound and unbiased survey giving a baseline national population estimate of 817,520±137,521 Brown Hares, to which future survey results can be compared. The survey has been repeated in 1997-1999 and preliminary analysis suggests that Brown Hare numbers have fallen slightly in arable and pastoral habitats, despite the presence of set-aside land which was expected to benefit the species (S. Harris, pers. comm.).

National Game Bag Census - Long-term data (1961 onwards) on Brown and Mountain Hare shooting bags taken from keepered estates in Britain.

Game Conservancy Trust Spring Census - Twilight counts of Brown Hare numbers at 34 different sites in Britain since 1989.

British Field Sports Society - Counts of sightings by beagle packs and harriers since 1983-1984.

The Mammal Society - A national questionnaire survey for Brown Hares aimed at past trends and current status. Analysis is incomplete as yet, but county-specific trends tend to have shown increases between the 1960s and 1970s and declines between the 1980s and 1990s.

Sorby Natural History Society - An annual, set winter walk of *c.* 20km: effectively an annual transect survey for Mountain Hares in one part of the Peak District (east of the Pennines) (D.W. Yalden, pers. comm.). Typically, 60-100 Mountain Hares are recorded.

Derbyshire Wildlife Trust - Another annual winter walk on which Mountain Hares are counted, this one in the Western Pennines and *c.* 10km long. Typically, 30-50 Mountain Hares are recorded (D.W. Yalden, pers. comm.).

5.2 MONITORING OBJECTIVES

As with other quarry species, it may be important to monitor hares both to determine their conservation status and to indicate whether current hunting pressures are sustainable.

Under the JNCC Brown Hare Species Action Plan, two points for *Future research and monitoring* are relevant to objectives of monitoring for the species:

5.5.1 Promote further research to assess the effects of different agricultural practices (e.g. crops planted, cutting dates and cutting methods) on Brown Hare populations.

5.5.3 Repeat the National Brown Hare Survey at regular intervals.

The second point clearly represents one complete option for the monitoring of Brown Hares in the long term (see below). While not necessary for monitoring changes in numbers, detailed habitat recording during survey work could allow studies to be conducted which contribute to the first point. Hare numbers are known to be very variable, so annual monitoring is needed for the two species: surveys at long intervals could give false impressions of long-term trends.

Although Mountain Hares are native and both rarer and more vulnerable than Brown Hares, no Species Action Plan has been prepared for the species. It would seem logical that the monitoring of Mountain Hare populations should be given a higher priority than that of Brown Hare populations.

Special consideration needs to be given to Mountain Hares in Northern Ireland, where they occur in lowland areas and may interact with Brown Hares: data collection and/or interpretation would therefore have to be different.

By analogy with current monitoring practices for birds, the detection of trends leading to population changes of 25% over 25 years could be taken as the target for hare monitoring.

5.3 POTENTIAL MONITORING TECHNIQUES

Line transect counts - Transect methods allow populations to be sampled quickly and efficiently using standardised methods. Recording in distance bands allows density to be estimated. Habitat recording along transects can also be standardised. For hares, counts would best be made between October and January when vegetation is low and detection rates are high (although the animals are still visible at other times) and before most hare shooting (which will increase the variance of counts) occurs (Harris, in press). Timing is less critical if simple counts are used instead of distance sampling. Late spring/early summer counts (as in the BBS) are likely to overestimate numbers of breeding adults because the year's juveniles can have been born as early as January and be difficult to distinguish from adults. Such counts could then be heavily affected by variations in productivity from year to year, obscuring variations in adult abundance. Daylight counting probably underestimates true densities because hares are less active than at twilight or after dark.

Standard winter walks - Effectively surveyor-designated transect routes, annual or twice-annual winter walks of (say) 2-10km with standardised mammal and habitat recording methods could be an efficient way of managing volunteer surveyor input. Data collection would best be simple counts, rather than distance sampling. Such a method is used by the Sorby Natural History Society and Derbyshire Wildlife Trust to monitor Mountain Hares and it may be particularly suitable for this species and upland habitats. A disadvantage is

the lack of randomisation of transect routes with respect to habitat, but this has no necessary serious effect on the method's potential for detecting population changes.

Direct counts (total or sample, daylight, twilight or spotlight) - Direct counts aim to account for all individuals within an area or a sample of an area. Considerations for the timing of counts are the same as for line transects. While direct counts measure true density if they are accurate, they also require more intensive coverage of an area than do transects, so any gains may be outweighed by the extra time taken. Spotlight counts are very specialised, difficult to standardise and best analysed only on a site-specific basis (S. Harris, pers. comm.).

Drive counts and dragline counts - Total populations can also be counted by driving with beaters or dogs or by using draglines. However, as with direct counting, considerable effort is required: in these cases, teams of individuals for each survey plot.

Capture-Mark-Recapture - Hares can be caught in nets and tagged, allowing population sizes to be estimated by CMR. However, netting is difficult, costly and time-consuming.

Hunting and Game Bag records - Long time series of historical game bag and hunting records exist and these data are likely to continue to be collected. These data can therefore at least provide a valuable historical context for future survey data. However, hunting and bag record data are subject to important biases which severely limit their potential as a front line monitoring method. First, they are derived mostly from estates and areas that are managed for hares, (supporting (often artificially) high hare densities), and so are unlikely to be representative of the wider countryside and of any areas where densities are low or falling. Second, they will depend critically on the hunting effort (which includes method (driven shooting versus culling with rifles) and gun and shooter efficiency, as well as man-days) and, which is rarely recorded. Third, numbers of Brown Hares are regularly trapped in high density areas and moved to restock other areas where high densities are required by coursing interests, thus weakening any relationships there might have been between game bags and the environment. Fourth, no counts are returned by estates where shooting does not occur in a given year because of low population levels, so population indices based on national game bags will always be biased upwards. Tapper & Parsons (1984) considered that estates will generally manage annual bags to be a fixed proportion of the Brown Hare population (around 40%), but this has been questioned (Hutchings & Harris 1996) and is also unlikely to be true for the less managed Mountain Hare. The issues of representativeness will apply equally to other count schemes run by hunting interests.

Counts by beaglers - Numbers of hares seen by beagling packs are collated by the Game Conservancy. As well as problems with representativeness as discussed above, beaglers choose areas for hunting, and therefore sampling, to have an optimum density which is neither too low nor so high that dogs are confused (S. Harris, pers. comm.).

Field signs - Field signs are difficult to distinguish between species and can also be confused with those of Rabbits. Such indirect methods will inevitably be less accurate than visual count methods for open habitat species as visible as hares, so are not preferable.

Questionnaire surveys - Simple questionnaires have the advantage that they can reach much larger samples of people, but data quality will be variable and subjectivity is a

problem. Again, this is not a priority method for species like hares which can easily be censused in other ways.

5.4 POTENTIAL MONITORING SCHEMES

All of the following schemes would provide information on changes in abundance and in range.

Repeats of the National Brown Hare Survey - This is the approach recommended by the Species Action Plan for Brown Hare. Repetition need not be at fixed intervals, but could occur as a response to external stimuli whenever it were considered necessary. The methods used are strong, leading to the collection of high quality density and habitat information. However, the scale and intensity of the National Brown Hare Survey is such that it is unlikely to be economically feasible for it to be repeated annually (and it was never designed for such a purpose, running over several winters).

Breeding Bird Survey - The BBS transect approach is described in detail in Part III.A.1. It has several disadvantages specific to hare monitoring, primarily because of the timing of the survey: counts in spring and early summer will be subject to potentially large fluctuations as a result of both variable annual productivity and changes in shooting pressure. Despite these problems, the BBS may provide useful and reliable information on changes in (especially) Brown Hare numbers, as a result of its wide geographical coverage and large sample size, and the ease with which the animals can be seen by BBS surveyors (see III.A.1). The extent and seriousness of any problems with the BBS method would need to be investigated before the survey were adopted as a central contributor to UK hare monitoring. Calibration against a full or trial Winter Transect Survey (Part III.B.1) ought to supply the necessary information.

MMR recommended approach: Hare Survey transect methods applied within the MaMoNet grid - This approach describes a scheme which is more than three times the size of the National Brown Hare Survey (2,700 sites). The survey would therefore be more expensive (at least if conducted in isolation) and still more difficult to repeat annually than the Hare Survey. Such a sample size is also much larger than would be required to obtain enough count data for the effective monitoring of Brown Hares, so would not be cost-effective (S. Harris, pers. comm.).

Breeding Bird Survey - The BBS transect approach is described in detail in Part III.A.1. It has several disadvantages specific to hare monitoring, primarily because of the timing of the survey: counts in spring and early summer will be subject to potentially large fluctuations as a result of both variable annual productivity and changes in shooting pressure. Despite these problems, the BBS may provide useful and reliable information on changes in (especially) Brown Hare numbers, as a result of its wide geographical coverage and large sample size, and the ease with which the animals can be seen by BBS surveyors (see Part III.A.1). The extent and seriousness of any problems with the BBS method would need to be investigated before the survey were adopted as a central contributor to UK hare monitoring. Calibration against a full or trial Winter Transect Survey (Part III.B.1) ought to supply the necessary information.

Winter Transect Survey incorporating upland standard walks - Mid- to late winter is likely to be the best time of year to survey most mammals using visual methods, so a multi-species, standardised winter transect survey could be a widely applicable and useful

method (see Part III.B.1). Hares would be key "flagship" species for such a survey scheme and would perhaps be the group for which we would expect the highest quality data to be collected. Carefully chosen squares offering a partial repeat of the National Brown Hare Survey would allow the linking of future data to an historical context. The optimal timing for hare monitoring might be different to that for other species and compromise may be required. Upland areas present special problems because of weather and access, so the option of surveyor-designated standard walks would be a useful one in such areas. The organisation of such a scheme would most efficiently be done as an offshoot of the more formal Winter Transect Survey.

5.5 RECOMMENDATIONS

1) We suggest that a combination of BBS summer transect data and Winter Transect Survey data should form the core national monitoring schemes for Brown Hare. BBS methods are not ideal for mammals (see Section III.A.1) but the sample size of survey sites is large (over 2000) and running a Winter Transect Survey in parallel should identify any major biases and perhaps supply annual correction factors. At least, pilot winter transect data from the same squares as sampled by BBS will be required to calibrate BBS data. The design of a Winter Transect Survey is dealt with in detail elsewhere (Section III.B.1), but the options include a standard walk approach and more standardised transects.

2) Multi-species transect surveys may be sufficient for the monitoring of Mountain Hare populations, but their geographical distributions in Britain are likely to mean that sample sizes will be small as a result of local volunteer densities. The importance of Mountain Hare as a vulnerable, native species means that effective monitoring could be a priority. We therefore suggest that the standard winter walk approach be developed to sample areas representative of the whole of the species' range, building on the Sorby Natural History Society and Derbyshire Wildlife Trust walks.

3) To provide historical context, attempts should also be made to calibrate Game Bag data against BBS and Winter Transect Survey data. A key issue is the relationship between data from shooting estates and from the wider countryside, which should be investigated. However, it is important that the possibility that Game Bags will provide no useful information at all is acknowledged prior to any attempts at calibration.

6. SQUIRRELS

RED SQUIRREL *Sciurus vulgaris*: native to Britain but probably introduced to Ireland; locally common in Scotland, scarce and localised (some populations re-introduced) in England and Wales but widespread in Ireland; declining.
GREY SQUIRREL *S. carolinensis*: introduced; common throughout most of England and Wales and central Scotland, more restricted than Red in Ireland; increasing and spreading.

6.1 RECENT AND ONGOING MONITORING WORK

NPI Red Alert North West - A developing survey of Red Squirrels in north-west England. Sightings data have been solicited from the public, volunteers and foresters since 1995 and have been useful in documenting the spread of Greys. Visual transect methods using volunteers are in development, working from three repeat surveys in each of spring and autumn. Basic volunteer training is included to allow the use of distance-sampling methods and to promote consistency. Hair tube methods are also in development for areas where visual transects are less useful (small and dense woodlands), but will require more professional input than the transect approach. A transect-based hair tube survey of squirrel distribution in Cumbria is currently being written up.

Biological Recording in Scotland Campaign (BRISC): Scottish Red and Grey Squirrel Survey - A current survey of Scottish squirrels which began in 1994. BRISC collect records opportunistically or from sightings-based questionnaires. Sightings data are collected centrally and stored in a database administered by SNH. BRISC have also organised specific surveys in known Red Squirrel areas, visiting different sites on different occasions. Following recommendations from SNH, the surveys consist of parallel transects (100m apart) walked by teams of volunteers looking for Red and Grey Squirrels themselves (not field signs) (A-.M. Smout, pers. comm.). The lack of repeat visits under the current survey design clearly limits this survey to the generation of “snapshots” at present.

Forestry Commission - Records of presence and absence at the 10km square scale on Forest Enterprise land, together with data on the extent/severity of tree damage and the amount of Grey Squirrel control practised, for 1960-1994. This monitoring has since ceased, to be replaced with a scheme to monitor abundance of both species as well as presence/absence in the context of the Red Squirrel Species Action Plan (see below). The protocol for the new scheme has yet to be finalised, but recommended methods will include time-area counts, hair tube surveys and line transects looking for feeding signs. It is intended that data collection will be volunteer-based and managed by local squirrel groups and wildlife trusts.

Institute of Terrestrial Ecology - Annual monitoring of Red and Grey Squirrel abundance in a small number of woods.

Northern Ireland Distribution Survey - Presence/absence and crude abundance data from sightings, field signs and interviews organised by the Ulster Wildlife Trust and the Forest Service of the Department of Agriculture for Northern Ireland in 1993.

Isle of Wight Red Squirrel Survey - A standardised presence/absence survey using field signs, conducted in all woods of more than 1ha.
Encroachment by Greys into Red Squirrel habitat - Studies at the Universities of Oxford and Newcastle of selected populations where the species are interacting.

6.2 MONITORING OBJECTIVES

In the *Future research and monitoring* section of the Red Squirrel Biodiversity Action Plan, the following point defines the objectives of monitoring for the species:

5.5.2 Establish a survey method and Squirrel Monitoring Scheme to ascertain population levels, identify key sites and monitor range and population of Greys.

This appears to specify a need for the monitoring of the range and abundance of both Red and Grey Squirrels in the UK. However, Greys may not be considered the object of conservation interest and so could be given a lower priority, i.e. monitoring need not be able to identify such a small change in distribution or abundance: they are also not protected, so can be culled locally if it is deemed necessary for control purposes. Damage to timber and woodland biotopes as well as the prevention of the establishment of new woodlands are issues here (S. Gibson, pers. comm.). Intensive monitoring might best be focused on areas where Red and Grey populations are interacting.

6.3 POTENTIAL MONITORING TECHNIQUES

Visual transect counts - Transect methods allow populations to be sampled quickly and efficiently using standardised methods. Recording in distance bands allows density to be estimated in theory, but in practice problems with detectability and with the estimation of distances in a three-dimensional habitat invalidate the results (S. Harris, pers. comm.). Habitat recording along transects can also be standardised. For squirrels, differential detection rates with respect to habitat pose particular problems, such as in deciduous versus coniferous woods, but sampling or statistical controls could account for such differences in the indexing of population *change* (density estimates would be biased). Counts would be best made in early morning and, in early spring, would benefit from better visibility in deciduous habitats. Some observer training may be required to assist species identification because well-known features such as pelage colour and the presence of ear tufts are not reliable in all seasons. Early spring transects would maximise detection rates; spring/summer counts such as practised under the Breeding Bird Survey will suffer from variation due to inter-annual differences in productivity and detection problems due to vegetation growth (especially in deciduous woods) (see Part III.A.1). In general, visual transects are likely to be more reliable for Grey than for Red Squirrels: behaviour and population density mean that a higher proportion of the population will be encountered more frequently (S. Harris, pers. comm.).

Direct counts (total or sample) - Direct counts aim to account for all individuals within an area or a sample of an area. Variations in detectability are accordingly more of a problem than with transect counts. In addition, while direct counts measure true density if they are accurate, they also require more intensive coverage of an area than do transects, so any gains may be outweighed by the extra time taken. Standardised time-area observation counts (Gurnell & Pepper 1994) fall into this category.

Capture-Mark-Recapture (CMR) - Baited cage traps, checked twice daily, can be used to catch squirrels and individual ear tags or combinations of fur tags to mark them (Gurnell & Pepper 1994). Standard statistical methods then allow the estimation of population size. The disadvantages with this method are that it is labour-intensive and requires specialised equipment and training and (for Red Squirrels) government licences.

Field signs (cone cores) - Field signs such as pine cone cores can be searched for using standardised methods and then related to density, but species identification is a problem. Pine cone cores can be counted along standard transects which are raked clean after each transect count, giving information on squirrel habitat use, activity and perhaps abundance (although this requires verification) (Gurnell & Pepper 1994). The most important problem with this method is that cone cores left by Red and Grey Squirrels cannot be distinguished.

Field signs (winter drey counts) - Counts of dreys visible along line transects in February and March can be used to estimate density, based on published studies (Don 1985; Wauters & Dhondt 1988; Gurnell & Pepper 1994). Drey counting is most effectively done by teams of observers walking parallel transects 25m apart and it is important that dreys in current use are distinguished from derelicts and birds' nests (Gurnell & Pepper 1994): these factors make this technique less suitable for use by volunteers. It seems likely that relationships between drey and squirrel density will vary with habitat, as will drey detectability: this would bias estimates of squirrel density but would not necessarily affect a population index. Dreys will be difficult to identify reliably to species level, so would only be useful for monitoring in areas where the two species do not co-occur.

Hair tubes - Plastic tubes of 75mm diameter with adhesive tape placed just inside the entrance(s), fixed to branches at least 2m above the ground and baited, can be used to collect samples of hair which can then be identified to species level in the laboratory where necessary (i.e. where more than one species occurs in the study area) (Gurnell & Pepper 1994, Garson & Lurz 1998). Hair identification is best done by negative staining: Red Squirrel hair features a longitudinal groove in which dye collects (Dagnall *et al*. 1995). The presentation of hair tubes according to a standardised protocol (for fixed periods of time at a fixed density along a transect or in a sample plot) can be used to estimate density or to provide an index of abundance as well as indicating species presence (the adhesive tape with attached hair samples is removed at regular intervals). This method provides a useful intermediate between visual surveys and CMR: it is likely to be less biased than a visual approach, does not require licensing and is less labour-intensive than CMR. It should be noted that hair tubes measure activity rather than numbers of animals *per se*, so detection rates are likely to be related non-linearly to abundance.

Road-deaths - Standardised records of squirrel corpses on roads could be used as a monitoring tool, but information on abundance (at least) would depend critically on "sampling effort", i.e. traffic density and distances travelled in searching for corpses (see Part III.B.3).

Garden Mammal Watch - Squirrels are popular, visible animals in gardens, so reliable, simple presence/absence or abundance data should be readily obtainable from volunteers. This could be a low-cost method for the monitoring of Grey Squirrel populations and the species would be a key one in our proposed Garden Mammal Watch (Part III.B.5). Garden sightings may also provide information on changes in the ranges of each squirrel species.

Reports of presence/absence - Simple reports of squirrel presence or absence from well-watched and well-defined areas such as nature reserves or Forestry Commission woodlands might give the most reliable and earliest warnings of changes in the range boundaries of both species. Such a scheme would involve a regular collation of opportunistic sightings made by individuals such as nature reserve wardens during the course of their normal activities and is discussed in Part III.B.4.

6.4 POTENTIAL MONITORING SCHEMES

MMR Recommended Approach - Within the national MaMoNet QQ grid of 10km squares, MMR recommend that each selected 1km square be surveyed for dreys in winter, using a distance-sampling "crenellated transect" approach. Where both species occur (and in a buffer zone around these areas), the base method would be supplemented with direct counts in which individual squirrels are identified. Red Squirrel-only areas would be surveyed every three years, Grey-only areas every six years and areas where the species mix would form annually surveyed Focus Zones. The weaknesses of this monitoring package are that the principal method, drey counting, is far from ideal and possibly seriously biased as well as perhaps being labour-intensive (see above). There are also doubts about direct counts, but they may represent the best method for volunteer or non-expert involvement in squirrel surveys.

Combined, complementary surveys - Squirrels are difficult to survey accurately using simple methods. Our philosophy here is therefore that a number of complementary, simple and (individually) non-ideal multi-species surveys can be combined to give an overall picture of squirrel populations. Specifically, the Breeding Bird Survey (Part III.A.1) can potentially contribute considerable information on Grey Squirrels (in particular), a Winter Transect Survey would probably provide higher sighting rates and therefore more information still (see Part III.B.1), a Garden Mammal Watch would give information on suburban populations (see Part III.B.5), road-deaths would give information on distribution and perhaps abundance (see Part III.B.3), Mammals on Nature Reserves would give reliable information on changes in range, and Sign Transects could also contribute (see Part III.B.2). The relative importance of each of these schemes will depend on the uptake of each by volunteers and then on the detection rates found in practice. These schemes would be supplemented by more intensive work using hair tubes in and around the areas where the two species' ranges overlap. This work would best be done by professionals and/or trained amateur enthusiasts. Existing Red Squirrel monitoring schemes such as Red Alert North-West and the Isle of Wight Survey may already meet the requirements of this work or be easily adapted to it. In terms of organisation, this approach would require the establishment of the various new schemes listed above and annual central collation of the information collected. Separate surveys could be conducted by different organisations but it would be most efficient if they were run by the same body, which would then also collate information annually.

Current schemes directed towards Red Squirrel - A subset of our recommended methods for multi-species monitoring, sufficient to detect large changes in abundance or distribution (perhaps just the BBS), may be enough to monitor squirrels in conjunction with existing Red Squirrel monitoring. Threatened populations of Red Squirrels (especially) are often monitored already: additional work might only have to involve central collation and evaluation of the existing schemes. This would require guaranteed repeat survey or continuation funds for schemes such as Red Alert North-West, the Isle of Wight Red Squirrel Survey and the BRISC Red and Grey Squirrel Survey (perhaps with a standardisation of methods and expanded coverage where necessary). Funding *would* be required for the central collation of information from the various sources of monitoring data: within a dedicated mammal research organisation, this could be achieved with an annual input of no more than one or two months of staff time.

6.5 RECOMMENDATIONS

1) Consensus on the precise requirements of a monitoring programme for Red and Grey Squirrels must first be established, i.e. it must be decided whether Grey Squirrel populations are of intrinsic interest or of interest only in terms of their impacts on Reds.

Detection of a 10% decline over 10 years may be required for Red Squirrels (S. Gibson, pers. comm.). Decisions about monitoring should be made in consultation with the UK Red Squirrel group and with respect to the Red Squirrel Biodiversity Action Plan. Patterns of interaction also differ between Britain and Northern Ireland, so different strategies may need to be adopted.

2) Our proposed multi-species monitoring schemes would all contribute some information on Grey Squirrels, so a combination of them (managed centrally by a national organisation) gives a potentially valuable approach for monitoring this species.

3) If monitoring the species is deemed to be important, the existing monitoring schemes for Red Squirrels should be promoted and future funding guaranteed, perhaps on the condition that the methods used are standardised as much as possible. In general, it should be ensured that all monitoring schemes adhere to controlled protocols and a statistically sound sampling regime.

4) Given that the areas of expansion of Grey Squirrels and of contractions of Reds are of paramount importance for monitoring, professional hair tube studies of areas of interaction between Reds and Greys should be established where they do not already exist. These would best be done or coordinated by a national mammal monitoring body. Such work should require no more than one staff-year annually, but might most efficiently be divided between locally-based fieldworkers (who could be employed on short contracts or be drawn from the staffs of county Wildlife Trusts or the country agencies), together with a central collation effort.

5) Careful consideration of the integration of new volunteer-based schemes such as the incipient Forestry Commission survey with established schemes such as Red Alert North-West is needed. It would be desirable for different schemes to use the same methods and to be run in collaboration with one another, at least at a committee level. It is imperative that different surveys do not compete for volunteers.

7. ORKNEY VOLE *Microtus arvalis*

Introduced. Within the United Kingdom the species is found on only six of the Orkney islands (and Guernsey). The population has almost certainly declined as a result of substantial changes in land use.

7.1 RECENT AND ONGOING MONITORING WORK

Aberdeen University - Work has been carried out by Aberdeen University for a number of years investigating Orkney Vole populations and interactions with their predators (Gorman & Reynolds 1993).

7.2 MONITORING OBJECTIVES

The Orkney Vole is the only diurnally active rodent on the Orkneys and it is therefore extremely important as a potential prey item for Hen Harrier *Circus cyaneus*, Kestrel *Falco tinnunculus* and Short-eared Owl *Asio flammeus*. Recent changes to the landscape of the Orkneys have almost certainly reduced the population of Orkney Voles and an assessment of the current population size is urgently needed. Gorman & Reynolds (1993) provide density estimates for a range of habitat types and these may contribute to assessment of future monitoring requirements. Monitoring needs to be carried out on an annual basis to account for short-term cyclic behaviour in population trends. These should also be taken into account when the baseline population estimates are calculated by running fieldwork over several seasons.

7.3 POTENTIAL MONITORING METHODS

Live-trapping - Orkney Voles can be readily monitored within favoured habitats, notably along fence lines (Martyn Gorman, pers. comm.), using Longworth live-traps. The Capture-Mark-Recapture (CMR) method and its inherent biases have been discussed in depth by MMR and by Flowerdew (1976).

Field Signs - The value of field signs to the monitoring of Orkney Vole populations needs to be evaluated. The likely dramatic changes in density with the stage of the vole cycle may mean that such methods may be readily applied to determine short-term changes of large magnitude, but be less suitable for determining more subtle longer term trends.

7.4 DEVELOPMENT AND VALIDATION STUDIES

A formal trapping protocol should be established following discussions with Martyn Gorman and colleagues at the University of Aberdeen.

7.5 POTENTIAL MONITORING SCHEMES

A live-trapping approach is recommended for the monitoring of Orkney Vole populations on an annual basis. Following an examination of densities within different habitats and discussions with Martyn Gorman, a series of study sites should be selected reflecting the distribution of the species across habitats in the Orkneys. Each site should be trapped using a trapline of Longworth live-traps (see Development and Validation of Studies) twice a year (during trough and peak months of the annual cycle) to provide measures of density. Each site should be trapped for five days and is likely to involve 80-100 traps with a single observer covering four sites at a time. With a six-week trapping window for each of the two trapping periods this would allow four sites to be covered each week, or 24 sites in total, representing *c*.60 working days a year. Gorman & Reynolds (1993) covered 14 different habitats on the mainland with each habitat trapped for five days, four times a year. Work could be undertaken by professional fieldworkers from the University of Aberdeen or by volunteers co-ordinated by a single professional. The Orkney Field Club may be a suitable organisation to approach regarding volunteer input.

7.6 RECOMMENDATIONS

Orkney Vole populations should be monitored at a core of 20-30 sites within the range of habitats occupied by the species using a live-trapping approach and CMR methods. The exact trapping protocol should be determined through discussions with researchers at the University of Aberdeen. Monitoring must take place on an annual basis to allow for short-term fluctuations in abundance resulting from the cyclic behaviour of this species. Volunteer involvement (with a professional co-ordinator) could perhaps be mediated through the Orkney Field Club.

8. WATER VOLE *Arvicola terrestris*

Native. Widespread on mainland, but absent from most of Northern and Highland Scotland and from most islands. Dramatic and widespread decline, both in terms of numbers and distribution.

8.1 RECENT AND ONGOING MONITORING WORK

Nature Conservancy Council Enquiry - An enquiry into the changing status of the Water Vole was carried out using data from county mammal reports, supplemented by questionnaire responses from participants in the BTO's *Waterways Bird Survey*. The analysis suggested a long-term decline in the Water Vole population linked to the pollution of rivers by organochlorines from the 1950s and the spread of introduced American Mink from the 1960s (Jefferies *et al.* 1989). Although not 'monitoring' *per se*, this work does illustrate the possibility of collecting useful data from observers involved in other survey work within riverine habitats.

Vincent Wildlife Trust Survey 1989/90 - Baseline survey work was carried out by a single professional recorder using a systematic search of pre-selected sites chosen from within a grid of 10-km squares. This was supported by a search of sites for which there was historical evidence of the species. Of the 2,970 sites covered, 47.7% had signs of Water Voles (Strachan & Jefferies 1993; Morris *et al.* 1998). Reanalysis of the data by Morris *et al.* (1998) provided a population estimate of 7,236,000 individuals, although the confidence intervals for this estimate are very wide. It should be noted that the national survey fieldwork was carried out throughout the year. Therefore, the low number of latrines reported in some areas may be a consequence of the timing of fieldwork rather than a reflection of population size. Latrine use varies seasonally with little or no above ground latrine formation in the winter. This reduces the spatial quality of this component of the dataset, introducing bias into conclusions drawn about Water Vole distribution across catchments.

Vincent Wildlife Trust Survey 1997/98 - A repeat of the 1989/90 survey, again using professional recorders working at the same sites and using the original methodology. Field sites were revisited during the same season as for the previous survey, thus removing the bias associated with sampling date and allowing a comparison to be made between the two datasets. The data are currently being analysed and a report is due to be published at the end of 1999. When the results are published it will be possible to be much clearer about the future monitoring strategy for this species.

WildCRU - An ongoing study using *River Corridor Survey* methodology to record Water Vole distribution within seven river catchments (Bure, Isle of Sheppey, Isle of Wight, Itchen, Teifi, Thames, Tyne). See MMR for full description of methods. Also within the MMR is a detailed assessment of possible sampling regimes based on this approach and their application to a national monitoring programme for Water Voles.

Aberdeen University - Four projects concentrated within the River Don catchment initiated from 1995 onwards. The projects examine the behavioural ecology, conservation, metapopulation dynamics and phylo-geography of Water Vole populations. As with the WildCRU work, this project can potentially provide detailed information on Water Vole populations within a specific catchment and could contribute to an examination of suitable recording methods.

Environment Agency - The Environment Agency's *River Habitat Survey* documents the presence of Water Voles in conjunction with the collation of data on habitat and river features.

The detailed nature of the survey, coupled with the large number of sample sites, could provide useful information of the distribution and (with modification) abundance of Water Voles.

Wildlife Trusts - The *Water Vole Watch* project was established in 1997 by the Wildlife Trusts in collaboration with the Universities of Oxford and Newcastle. Volunteers were asked to survey stretches of river (selected by the volunteers themselves) for signs of Water Voles. A simple recording form allowed volunteers to note the presence of Water Voles and their signs and to record basic habitat information. No systematic selection of sampling areas was undertaken and in its current format, the survey provides little information of value to the monitoring of temporal or spatial trends in Water Vole populations.

National Water Vole Breeding Programme - Although not specifically a monitoring programme, consideration is being given to the efficacy of reintroduction and translocation as a conservation tool for Water Voles. Monitoring of released populations is being undertaken by Sparsholt College Hampshire, together with an examination of suitable release methods. A planned reintroduction at the Arundel Wetlands and Wildfowl Trust reserve is due to take place later this year (Mike Jordan pers. comm.). This will involve 80 individuals, half of which will be followed using radio-tracking for six months post-release. This will be followed by routine trapping carried out every 6-12 weeks. A further release of 100 individuals is planned for the WWT Barn Elms reserve at a later date.

Other projects - A number of other local projects involving the monitoring or surveying of specific catchments are being carried out across the United Kingdom. These are listed in The Mammal Society's *Current Projects* and include work examining the establishment of 'key sites' in England and Wales as the basis for long-term monitoring. This work is due to commence late in 1999 (Paul Bright, pers. comm.).

8.2 MONITORING OBJECTIVES

Within the '*Future Research and Monitoring*' section of the Water Vole Biodiversity Species Action Plan are two aims that point towards the type of monitoring required for this species (Anon 1995). These are:

> 5.5.3 *to seek to establish a National Water Vole monitoring scheme based on indices and regular survey of key sites in all counties.*
>
> 5.5.4. *to carry out a survey to determine the distribution of Water Voles throughout Britain, identifying key populations in all counties and regions.*

This suggests that a two-tier approach should be adopted, with periodic national surveys (ideally within the grid of sample squares already established), supported by annual monitoring at a number of sites across the UK. The lack of quality spatial data resulting from methodological problems with the current national survey suggests that the collation of distributional data should be a high priority. This does not necessarily require a completely new national survey: there is a lot to be gained from building upon the two surveys already carried out. Instead, an examination of potential spatial bias within the VWT data may determine whether a calibration exercise could be used to improve the spatial quality of the data. High quality data already exist for specific river catchments and efforts should be made to draw these together, identifying those catchments for which additional data is urgently required.

The 94% decline reported for this species (Don Jefferies, pers. comm.) highlights the immediate action that needs to be directed towards its conservation.

8.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Capture-Mark-Recapture methods may be used at 'core' sites where the majority of individuals present appear to be readily caught using wire mesh traps baited with mashed carrot and/or chopped apples (Stoddart 1970; Airoldi 1976; Woodroffe *et al.* 1990). Trapping at 'Peripheral' sites was found to be ineffective by Woodroffe *et al.* (1990) even when high levels of Water Vole activity were registered. Trapping at both types of site should be carried out between early spring and late autumn, with traps positioned as near to the water as possible. Traps placed on purpose built rafts may be equally or more effective as indicated by Water Vole responses to Coypu traps placed on baited rafts (Baker & Clarke 1988). Stoddart (1970) provides a suitable trap design. Trapping should involve a prebait period followed by three days of trapping with traps set at a 20m spacing (Mike Jordan, pers. comm.). This species can be readily caught during the breeding season, but is very difficult to catch between November and March.

Direct sightings - Direct counts of individuals are likely to be unreliable given the difficulties in approaching this species and because of colony structure.

Field signs - Various field signs may be used to detect the presence of Water Voles at a site, with breeding season latrine counts in particular potentially providing a measure of abundance (Woodroffe *et al.* 1990; Strachan & Jefferies 1993; Morris *et al.* 1998, MMR). The value of latrine counts in determining abundance relies on assumptions regarding the ratio of latrines to individual voles. Reanalysis of Woodroffe *et al.*'s (1990) data by Morris *et al*. (1998) suggests a roughly 1:1 relationship between the number of latrines and the number of voles and not the 6:1 relationship for the Yorkshire sample as reported in MMR. However, other radio tracking work undertaken by WildCRU suggested some six latrines per vole. Since latrines appear to serve a territorial purpose, the number produced per vole could be expected to vary with population density, season and site. This may reduce the effectiveness of the widespread application of latrine counts as a means of assessing abundance, unless more information can be gathered on the relationship between latrine production and vole density. Provision of dropping boards may improve the ease with which latrines can be found in difficult habitats. It should be noted that there is no latrine formation above ground in the winter and that the persistence of latrines is very dependent upon water level (Mike Jordan, pers. comm.).

Counts of burrows and runways, although they are readily identified, may be biased by the fact that these features may continue to exist after a colony has become extinct (Woodroffe *et al.* 1990). Only the presence of tracks provide an indication of Water Vole activity away from 'core' sites, although the difficulties in separating Water Vole tracks from those of Brown Rat make this method unsuitable for widespread or amateur use.

Mammals on Nature Reserves - Records of Water Voles on nature reserves could be collated according to the suggestions outlined in Part III.B.6.
Waterways Breeding Bird Survey (WBBS) - Water Vole, along with Mink and Otter, is one of the few species that could be monitored through the WBBS, although it should be stressed that this survey is currently still in its pilot stages and may not have funding for continuation beyond the end of the pilot period. Additionally, the survey is designed to survey a range of bird species

associated with riparian habitats and is therefore not ideal for the transect monitoring of Water Vole field signs.

Other alternatives - Questionnaires or Reporting Cards could be used to gather data on an *ad hoc* basis from anglers, Wildlife Trust members, river keepers and boat users. While such an approach may highlight those areas in which Water Voles occur, it will not provide the type of data required for monitoring purposes.

8.4 POTENTIAL MONITORING SCHEMES

The established grid of Water Vole survey sites, within which two national surveys have already been undertaken, provides a monitoring framework that has documented a 94% reduction in Water Vole occurrence (Don Jefferies, pers. comm.). To replace this scheme with an alternative would effectively remove what is an important historical dataset. As has been stressed elsewhere, such replacement should only be the preferred option where a current scheme fails to deliver suitable monitoring information or is prohibitively expensive. Although there is a degree of spatial bias in the Water Vole dataset, due to the manner in which the data is gathered, it does provide quality data on temporal trends in the population (see Recent and Ongoing Monitoring Work - VWT survey 1989/90). The rapid decline witnessed for this species may suggest that more regular monitoring work is undertaken and with a 94% decline already witnessed, there is urgent need for a coherent strategy to be put in place. Priority action may require that resources are targeted towards preserving the remaining populations, removing causal factors and investing in future captive breeding and release schemes. The nature of planned action will itself partly determine the monitoring structure required. It would be prudent to base monitoring decisions on the data published in the second Water Vole Survey Report (due end 1999) rather than to make and act on recommendations now.

Potentially there is a great deal to be gained from undertaking more detailed monitoring within specific catchments, either where measures to safeguard Water Vole populations are being implemented or where populations are to be reintroduced. Such monitoring work would need to be linked to the monitoring of those factors implicated in the decline, specifically Mink populations and habitat degradation. This work could be based on a transect approach, involving the location of field signs (specifically latrine counts) supported by detailed work in a range of habitats to determine the relationship between the number of voles and the number of latrines. An understanding of Water Vole abundance at study sites should be considered a priority over the recording of simple presence/absence data. Data showing a decline in abundance at sites will provide earlier indications of a decline than data merely showing presence or absence at a site. This will be especially important if existing sites are to be protected and their Water Vole populations stabilised. The evaluation of 'key sites' as a basis for monitoring in England and Wales is due to commence later this year. The success of this approach for the Common Dormouse suggests that it may be equally applicable for Water Voles.

While both the VWT national method and that proposed by MMR can provide broad-based monitoring data at the national level, it might be better to target the limited resources more towards priority catchments, long-term refuges and Water Vole/Mink interfaces. These catchments could be studied in detail, possibly involving local Wildlife Trusts and Environment Agency officers, in an attempt to undertake regular and detailed monitoring, additionally gathering other data on the presence of Mink, river quality and habitat structure. This additional data collation could be based on the Environment Agency's *River Habitat Survey* (Raven *et al.*

1997), a method recently adopted and linked to the recording of waterways breeding birds (Buckton & Ormerod 1997; Marchant & Gregory 1999).

Timing of fieldwork should be evaluated through pilot fieldwork or by drawing upon published data on the seasonality of latrine production. Similarly, the number of transects required and their length and placement, should be the subject of fieldwork trials, possibly using the validation work already undertaken by MMR, or expanding on that planned for the monitoring of 'key sites'. Data from the two national surveys could be used to model the best sample sizes, their distribution and periodicity of coverage.

8.5 DEVELOPMENT AND VALIDATION STUDIES

A data-modelling exercise (using data from the two national Water Vole surveys, once they are available) should be used to establish whether the number of sample sites can be reduced without reducing the power of the approach for detecting trends of say 25% over 25 years. This exercise could also be used to examine the ideal interval between surveys based on the power of detection and the costs of implementing the survey. This could be carried out at the same time as modelling data for other species (e.g. Badger and Otter). Such analyses are considered in Part VII.

8.6 RECOMMENDATIONS

1) No firm decision on monitoring should be taken until the second National Water Vole Survey report is published (end 1999) and the 'key site' approach (5) is evaluated. Once these data become available a study should be initiated to determine a suitable sampling protocol based on simulations, examining sampling interval and the number of sites used. The results of the simulations may demonstrate that a further degree of stratification could be introduced, that sample size could be reduced and that sampling interval could be altered.

2) Allowing for the outcome of simulations in (1), it would be sensible to base future monitoring of this species on the approach adopted for the two VWT surveys (transect search for field signs) and the existing grid of survey sites. However, the survey could be made more cost-effective through the use of trained volunteers to survey individual sites, rather than a single professional observer.

3) In view of the 94% decline due to be reported by the second national survey, work should be carried out using a shorter inter-survey interval than currently used, at least for the short-term. There may also be some value in targeting efforts towards priority catchments (i.e. those with remaining populations or those likely to be colonised by Mink in the coming years).

4) Ancillary data should be gathered through the recording of this species on nature reserves and possibly through the Waterways Breeding Bird Survey.

5) Evaluation of a 'key sites' approach is to be undertaken (Paul Bright, pers. comm.) and findings from this work should contribute to the development of the national monitoring strategy (1). Local monitoring may be an important component of the national strategy, possibly providing information on an annual basis to support the national data collected every five years.

6) Some attempt should be made to examine the level of spatial bias in the two VWT surveys (see Recent and Ongoing Monitoring Work: VWT Survey 1989/90).

8.7 RESOURCE REQUIREMENTS

Co-ordination of monitoring work on this species could be carried out by a single individual (full-time HSO grade - also acting as co-ordinator for Otter and Mink), supported largely by volunteer fieldworkers, with some professional input to the teaching of monitoring methods, validation of data gathered during the survey work and coverage of remote areas.

9. YELLOW-NECKED MOUSE *Apodemus flavicollis*

Native. Believed to be declining in range and abundance, although the rate and magnitude of the decline is unknown. Found predominantly in the south, south-east and west of England and in central and eastern Wales; absent from the southern Midlands.

9.1 RECENT AND ONGOING MONITORING

National Yellow-necked Mouse Survey - A 'snapshot' survey was undertaken by The Mammal Society and the University of Bristol during late 1998, using volunteers working with lines of Longworth live-traps (Chitty & Kempson 1949) on sites across England and Wales (Marsh 1999). Trapping was carried out between the start of September and the end of November within deciduous woodland sites greater than two hectares in size and selected by volunteers. Forty traps were operated for two nights to obtain a measure of relative abundance, together with the collation of data on habitat characteristics. The results showed the species to be widespread in suitable woodland within its natural range (occurring at 71% of sites). However, small mammal populations are prone to considerable inter-annual fluctuations (Mallorie & Flowerdew 1994) and this may have influenced some of the results, notably those relating to abundance.

Mammal Society planned work - The National Yellow-necked Mouse Survey report outlines future work planned by The Mammal Society on this species. This will look at habitat needs, edge of range densities and precise limits of distribution.

9.2 MONITORING OBJECTIVES

A better understanding of the range limits for this species is required, together with information on long-term population change and persistence of populations in habitat other than mature deciduous woodland. This approach is likely to require annual monitoring to overcome the influence of interannual fluctuations when determining long-term trends and delimiting range. Additionally, more intensive study work should be aimed at examining habitat use outside 'core' habitats.

9.3 POTENTIAL MONITORING METHODS

Live-trapping - Longworth live-traps can be used to catch Yellow-necked Mice, using rolled oats as bait and a trap interval of 15m on a grid or transect line. The exact grid arrangement needs to be established and to some extent will be dependent upon the ultimate aims of the monitoring work. A trap-line (or transect) approach will be less suitable for determining abundance than a trapping grid due to the 'edge' effect encountered when trapping (Pelikan 1968; Hansson 1969; Twigg 1975). However, if simple presence/absence is all that is required, then a transect line may be the most appropriate approach because it requires fewer traps.

Hair tubes - In practice it may not be possible to separate the hairs of *Apodemus flavicollis* from those of *Apodemus sylvaticus* and the suitability of this method needs further evaluation before consideration is given to its use as a monitoring tool.

Nestboxes - Yellow-necked Mice will use nestboxes erected for Dormice or cavity-nesting birds. Where large numbers of boxes are regularly checked (e.g. Pied Flycatcher *Ficedula hypoleuca* or Great Tit *Parus major* schemes) there is the potential for CMR techniques to be applied. The use of such boxes by Yellow-necked Mice is currently being investigated by Aidan Marsh with preliminary findings suggesting that capture levels in boxes may be too low for CMR techniques to be applied for most sites (pers. comm.).

9.4 POTENTIAL MONITORING SCHEMES

Live-trapping using woodland grids - The apparently rather specific habitat requirements of this species make it possible to monitor nationally occurring long term changes in abundance that would be impossible for most other small mammal species. That component of the Yellow-necked Mouse population using mature deciduous woodland is likely to represent the bulk of the population within the UK, although more work should be carried out to confirm this. Assuming that this is the case, so long as enough sites can be covered each year, it should be possible to monitor long-term trends and to remove the effects of differences between individual woodland sites (e.g. seed production, age, species composition). This is still likely to require a significant number of sites, certainly far more than the number covered annually as part of the study by Mallorie & Flowerdew (1994). The minimum number required should be investigated as part of a pilot study, in order to determine whether this approach is economically feasible (see also Part IV.15 - other small mammal species). The pilot work should also examine the number of traps required and the structure of the trapping protocol, although this may be based on either the methods of Marsh (1999) or Mallorie & Flowerdew (1994), although top grids should replace the use of trap lines.

Ancillary data - Information on distribution may be obtained from examination of the occurrence of Yellow-necked mice in nestboxes at a network of sites across the UK. This is likely to require increased co-ordination of ongoing schemes to ensure that bird ringers and nest recorders, together with those people working on Common Dormouse boxes, pass information on mice to the appropriate recorders. These people should also be provided with training into how to recognise Yellow-necked Mice and how to separate them from Wood Mice.

9.5 RECOMMENDATIONS

1) A series of woodland study sites should be trapped on an annual basis (to allow for short-term fluctuations with the aim of monitoring long-term changes in abundance as revealed by CMR techniques.

2) Field trials should be carried out to investigate the distribution of Yellow-necked Mice in other habitat types and to determine whether the trapping protocol used for the National Yellow-necked Mouse survey is the most cost-effective for repeated surveys to allow determination of a 25% change in abundance over 25 years.

3) The potential for collation of ancillary data from long-term nestbox schemes should be investigated further.

9.6 RESOURCE REQUIREMENTS

One person could oversee co-ordination of schemes involving the Yellow-necked Mouse, with this individual likely to be involved in the co-ordination of other projects as well. During the pilot phase, additional input is likely to be required as fieldwork trials are carried out. The National Yellow-necked Mouse Survey involved trapping at 168 woods surveyed over a 12 week period. Assuming one set of 40 traps could be used at a single site in any one week, some 14 sets of traps (560 traps - £16,800) would be required, involving *c.*1,700 hours fieldwork.

10. HARVEST MOUSE *Micromys minutus*

Native. The species shows a restricted distribution with the majority of records coming from England. Populations are thought to fluctuate between years and there is some evidence of a recent contraction in range.

10.1 RECENT AND ONGOING MONITORING

National Harvest Mouse Survey (1973-1977) - A national survey instigated by The Mammal Society in 1973 aimed to establish both the status and distribution of the species within Great Britain. Targeted media appeals were followed up by the collation of record sheets, noting the occurrence of Harvest Mice at various sites. Some 1,205 record sheets were returned by observers allowing a distribution map to be plotted. Records of Harvest Mouse nests accounted for 66.9% of reports, with 8% referring to trapped individuals and 7.6% to remains from Barn Owl pellets (Harris 1979). It was noted that *'.. on the fringes of its range, populations of Harvest Mice were extremely localised, and often difficult to find..'*.

***Look Out For Mammals* Survey (1996-1997)** - As part of The Mammal Society's *Look Out for Mammals* project some 800 sites from the 1970s survey were resurveyed to determine whether Harvest Mice still occurred at the sites and to assess the degree of habitat change. The results from this work are currently being analysed, although early indications are that only 29% of historical sites still show signs of activity.

10.2 MONITORING OBJECTIVES

The monitoring of population trends, together with the establishment of range limits should be considered a priority for this species.

10.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Live-trapping can be carried out using a grid of Longworth live-traps (Chitty & Kempson 1949). Although Harvest Mice can be caught on the ground between September and February, (when the vegetation dies or is cut back), they are more readily caught in the summer months by setting traps some 0.5 to 1m above the ground using bamboo canes (Perrow, pers. comm.). MMR note that seed-baited traps should be set in undisturbed grassland or along field margins using a 7x7 grid with a 15m trap interval, in keeping with home range sizes of 300-400m^2 (Trout 1978).

Hair tubes - Hair tubes (28mm diameter, placed 0.5-1.0m above the ground) have been used by Martin Perrow at the University of East Anglia for much of his work on Harvest Mouse populations. Attempts to calibrate hair tube data against live-trapping data suggest that the use of hair tubes is well suited to this species.

Field signs (nests) - The aerial breeding nests made by Harvest Mice are distinctive, typically placed in monocotyledons and are made from finely split and woven grasses. During the period when young are in the nest there is no obvious entrance, although the nest becomes more battered once the female has abandoned the young. The nests are usually spatially separated, so a cluster of two or three is likely to represent successive litters from one female (Trout 1978).
Artificial baiting nests (Warner & Batt 1976) - Artificial baiting nests have been developed from tennis balls with the aim of attracting Harvest Mice. A hole is made in the wall of the

tennis ball using a 15mm cork borer, before being waterproofed and mounted on a post at a height of 30 to 50cm. Once in position and baited with bird seed, the tennis ball can then be left for five days before being checked to determine if Harvest Mice have taken the bait. This period is thought to be long enough to reveal the presence of Harvest Mice at low population densities (Warner & Batt 1976). MMR note that this approach only provides presence/absence data and that recent countrywide trials by The Mammal Society have been largely unsuccessful.

Owl pellets - Harvest Mice occur in Barn Owl pellets (Buckley 1977) although the species is considered to be only a minor prey species (typically up to 3% of dietary intake by number). Analysis of Barn Owl pellets as part of a general pellet scheme could provide useful information on distribution of this species.

10.4 POTENTIAL MONITORING SCHEMES

There are two alternative approaches that could potentially be adopted (a) hair tubes - favoured by workers at the University of East Anglia and (b) nest searches - favoured by The Mammal Society. Both are discussed below.

a) Hair tubes - Hair tubes should be supplied to a volunteer network of people interested in helping with ongoing monitoring of this species during the summer months. Guidelines should be supplied on where and how to place tubes and tape from tubes should be sent back for analysis at the end of each annual sampling period. Survey work should take place each summer, the data being analysed during the winter and a report sent to all contributors prior to the commencement of the follow year's fieldwork. Each observer should get a mail-merged letter accompanying the material for the following season (new forms, tape, etc.) and the report from the previous season. This letter should contain information on the individual species recorded or presence/absence of *Micromys* by that observer.

It is difficult to predict how many volunteers would be willing to become involved in this project, but the likely number of sites requiring coverage could be determined through an analysis of data from the two Mammal Society Harvest Mouse surveys. Data from the most recent survey are currently being analysed and a sampling protocol should not be finalised until after these data are published. Participants in the most recent survey, together with nature reserve wardens, FWAG field officers, LOFM participants, etc. may be the logical groups to approach in the hope that such people could provide continuous monitoring at sites over time.

Analysis would be undertaken by a single person, not necessarily the person running the scheme, but possibly involved in other monitoring projects of a related nature. Initial inputs to the scheme would require development of guidelines and survey packs, targeted media appeals and general promotion of the scheme. Once established, the preparation of an annual report and analysis of the results should be considered a priority in order to maintain volunteer enthusiasm and recruit new fieldworkers. The proportion of tubes containing *Micromys* hairs could form the basis of an index and provide information on both distribution and abundance.

b) Nest searches - Searches for nests could also be undertaken at the sites being covered with hair tubes or as part of an unrelated scheme. Searches are likely to be quick, simple and effective with counts of breeding nests providing a quick and simple approach that can be included in transects for field signs in the autumn. This approach could allow more sites to be covered annually than would be possible with hair tubes. Detailed methods for finding sites should be based on The Mammal Society's *Look Out For Mammals* guidelines.

Ancillary data could come through the recording of presence/absence of Harvest Mice at those nature reserves involved in any monitoring scheme aimed at recording mammals on nature reserves (see Part III.B.6.).

10.5 DEVELOPMENT AND VALIDATION OF STUDIES

A series of live-trapping grids should be placed on a subset of the sites, allowing calibration of the data received from the hair tubes and nest searches. This should only continue for as long as necessary to allow determination of the effectiveness of the two approaches. Pilot work should be carried out to establish the number of sites that need to be covered, together with the number of tubes that should be used per site. It is recommended that either The Mammal Society or the University of East Anglia are approached regarding the pilot work.

10.6 RECOMMENDATIONS

Two alternative schemes (1) and (2) require further consideration and could be supported by ancillary data from other schemes.

1) Annual monitoring of this species could be based on the use of hair-tubes at a number of sites across the known range. Placement of tubes and data collection should be undertaken by volunteers, with tape from the tubes sent to a central co-ordinator for analysis. Results should be reported on an annual basis through a scheme newsletter sent out with the fieldwork material for the following season. The number of sites to be covered and the number of tubes to be used should be determined following discussion with The Mammal Society and researchers at the University of East Anglia.

2) Searches for nests could be undertaken at those sites detailed in (1) or as part of an unrelated scheme. Monitoring of those sites notified during the national Harvest Mouse surveys should continue, using nest searches as the primary fieldwork method. Data from The Mammal Society's evaluation of artificial baiting nests should be examined in detail to determine whether this method can be applied successfully and whether there are any implications for other monitoring methods.

3) Ancillary data could be gathered through the monitoring of this species on nature reserves (see Part III.B.6).

11. HOUSE MOUSE *Mus domesticus*

An ancient introduction. Widespread. Strongly commensal: most (but not all) populations outside buildings are probably sinks, dependent on continuing input from populations in buildings. Probably suffered big declines following loss of cereal ricks.

11.1 RECENT AND ONGOING MONITORING WORK

Housing Condition Surveys (DETR) - These have been conducted at five-yearly intervals in England and Wales although (the 1996 survey omitted Wales). They have covered a random sample of dwellings in the areas of participating local authorities (participation was complete in 1996 but voluntary before that). The 1996 survey (not yet published) gathered information on the percentage of dwellings infested by mice but we understand that earlier ones did not.

National Rodent Survey (MAFF) - Conducted annually during 1976-1979 and 1993, covering business premises as well as houses; the 1993 survey included agricultural premises but the 1976-9 surveys did not (Meyer *et al*. 1995). Covered England and Wales but not all local authorities participated. Recorded infestation rates. For many years prior to 1976, a less formal survey was used to monitor infestation rates roughly (Rennison & Drummond 1981).

Northern Ireland - Similar surveys to the Housing Condition Survey have been run.

Scotland - Similar surveys to the Housing Condition Survey have been run, but without gathering information on rodents.

Note on data quality in the above surveys
Questionnaires commonly refer simply to "mice"; it is furthermore, likely that many respondents would not distinguish between mouse species. Given that Wood Mice are common in houses, at least in rural and semi-rural locations, the above surveys are probably of limited value for monitoring House Mice.

11.2 MONITORING OBJECTIVES

House Mice are not good wildlife indicators because they are so commensal with humans and their numbers depend so much of the efficacy of measures taken to control them. They are probably of little significance in most natural and semi-natural ecosystems in the UK. Conservation of the species in its own right requires that we need to be aware of catastrophic declines in its numbers.

11.3 POTENTIAL MONITORING TECHNIQUES

Questionnaire surveys of local authorities - These are limited use because of the problem of species identification (see above).

Questionnaire surveys of pest-control companies - Company representatives have suggested to us that these would be of limited value because of the problem of species identification and because companies do not routinely collate data in a form that could be useful for monitoring.

Pest-control data from specific sites - At many commercial sites, mice and rats are routinely controlled in continuous programmes of work. Typically, contractors visit sites 2-8 times per year to determine whether pest species are present (and to take action to control them if they are).

The proportion of visits yielding positive records could provide an index of House Mouse and Brown Rat at each site.

Trapping - House Mice are relatively easy to trap, so trapping rates at a site could provide an index of numbers at that site.

Direct sightings - House Mice are too rarely observed (even in gardens) for most schemes based on direct observations to provide much useful data.

Owl pellets - House Mice are scarce in owl pellets.

11.4 POTENTIAL MONITORING SCHEMES

Questionnaire survey of local authorities - Despite the identification problems, this may be the only feasible way of getting some sort of measure of changes in the national House Mouse population. Local authorities might only co-operate if it was part of a broader survey of housing conditions.

Gathering pest control data from specific sites - There are several hundred pest control companies, each managing pests at many sites. Some may be prepared to provide data as a way to promote the industry's positive image. Client confidentiality could be a problem but there is not need to exact locations to be revealed. The British Pest Control Association could provide a link with some of the companies. Guidance on identification would be needed.

Trapping - Given the patchiness and great temporal variation of House Mouse populations, a scheme based on trapping animals would probably only deliver a useful national index if it involved some hundreds of sites. This would be very expensive.

Owl Pellets Scheme - House Mice would automatically be included in a scheme but the numbers of House Mice in the samples would probably be too low to be useful.

Garden Mammal Watch - House Mice should probably be included, to allow observers to record them, but the number of observations is likely to be too few to be useful (and there may be identification problems).

11.5 RECOMMENDATIONS

1) House Mice should be included in the Owl Pellets Scheme.

2) House Mice should be included in Garden Mammal Watch.

3) The value and best way of including rats and mice in future surveys like the Housing Condition Survey should be assessed after the report of the 1996 Survey is published.

4) If monitoring through the Housing Condition Survey is judged unfeasible, consideration should be given to gathering site-specific data from pest-control companies.

12. BROWN RAT *Rattus norvegicus*

Eighteenth century introduction. Widespread. Largely commensal but less so than House Mouse; as well as in buildings, it is common in refuse tips, in sewers and along urban waterways. Populations on arable land may move more into agricultural buildings after harvest. Natural habitats are occupied along the coast. Numbers have probably declined greatly this century, consequent on more efficient harvesting and storage of food and on highly effective poisons.

12.1 RECENT AND ONGOING MONITORING WORK

See House Mouse: all of the surveys listed under that species also covered Brown Rats, as did the 1991 Housing Condition Survey.

Note on data quality in these surveys
Although questionnaires commonly refer simply to "rats" and it is likely some respondents would not distinguish Brown from Ship Rats, the latter are so scarce that the information provided by the surveys is genuinely relevant to Brown Rats.

12.2 MONITORING OBJECTIVES

Brown Rats are poor wildlife indicators for the same reasons as House Mice. Populations in natural and semi-natural ecosystems may be important predators (especially of seabirds on islands) and they are sometimes significant in the diet of larger predators. Thus we need to be aware of substantial changes in numbers of Brown Rats.

12.3 POTENTIAL MONITORING TECHNIQUES

Questionnaire surveys of local authorities - Provide an index of how abundant and widespread Brown Rats are.

Questionnaire surveys of pest-control companies - Of limited use because companies do not routinely collate data in a form that could be useful for monitoring.

Pest-control data from specific sites - At many commercial sites, mice and rats are routinely controlled in continuous programmes of work. Data from such sites could provide an index of population levels at each one.

Game Bag data - The recording of rats in Game Bags is almost certainly too sporadic to be useful.

Trapping - Rat traps are more cumbersome than mouse traps and Brown Rats often difficult to trap, but trapping could be used to index their numbers at individual sites.

Direct sightings - Brown Rats are not infrequently observed in gardens and in the countryside, though they are generally shy and nocturnal.

Owl pellets - Rats occur not uncommonly in owl pellets.

12.4 POTENTIAL MONITORING SCHEMES

Questionnaire survey of local authorities - See House Mouse.

Gathering pest-control data from specific sites - See House Mouse.

Trapping - See House Mouse; because of the larger traps and the neophobia exhibited by rats (leading to smaller numbers of catches per trap-night), the costs would be even greater for rats.

Owl Pellet Scheme - Brown Rats would automatically be included in such a scheme; they may be recorded often enough for this to provide a useful index. Though most rats found in owl pellets are young ones, so their frequency is not a good indication of adult numbers.

Garden Mammal Watch - Brown Rats should be included; they may be recorded often enough for this to provide a useful index.

Mammals on Nature Reserves - Brown Rats should be included; they may be recorded often enough for this to provide a useful index.

12.5 RECOMMENDATIONS

1) Brown Rats should be included in the Owl Pellets Scheme.

2) Brown Rats should be included in Garden Mammal Watch.

3) Brown Rats should be included in the Mammals on Nature Reserves Scheme.

4) The value and best way of including rats and mice in future surveys like the Housing Conditions Survey should be assessed after the report of the 1996 survey is published.

5) If monitoring through the Housing Condition Survey is judged unfeasible, consideration should be given to gathering site-specific data from pest-control companies.

13. SHIP RAT *Rattus rattus*

Introduced. Established populations in Britain and Ireland reduced to a few on islands (Lundy, Shiants, Forth Islands) and one on the mainland (Tilbury); sporadic occurrences in ports (from ships) and supermarkets (from lorries).

(Note that there seems to be no published reference to the occurrence of Ship Rats on the Forth islands but Mr William Penrice of Fife Nature has told us that a specimen from Inchcolm was supplied by a rodent controller in 1998; there is a local belief that the species has been present on the island for some years, perhaps alongside Brown Rats as on Lundy; there are also suspicions that Ship Rats may be established on Inchmickery and Inchkeith)

13.1 RECENT AND ONGOING MONITORING WORK

We understand the Port of London Authority have good records for its area.

Both the Lundy and Shiants populations are the subject of sporadic investigation by university and similar groups (Smith *et al.* 1993; Key *et al.* 1998).

Dr Graham Twigg has surveyed Ship Rat distribution by questionnaire (Twigg 1992) and continues to collate reports of the species.

Fife Nature intend more fully assessing the species' status on the Forth islands.

13.2 MONITORING OBJECTIVES

We suggest that the national priority for this introduced species of limited distribution should be to monitor its range. Should it be considered appropriate either to eliminate the island populations or to take steps to maintain them, then appropriate local monitoring should be undertaken.

13.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Trapping (with or without mark and recapture studies) is an effective way of monitoring Ship Rats.

Field signs (fur smears and droppings) - Field signs can be distinguished from those of Brown Rats with experience.

Questionnaire surveys of pest control companies, local authorities, environmental and public health authorities and port authorities can provide some evidence of occurrence and infestation rates but there may be problems of distinguishing the two species of rat. Twigg (1992) was able to get useful information on the changing fortunes of Ship Rats in the UK from such a survey, though he attempted to gather records going back over three decades, with the result that the data for earlier years were sparser because of the passage of time.

13.4 POTENTIAL MONITORING SCHEMES

A. Island populations

Since these are isolated and of little relevance to the country as a whole, these populations can be treated as independent units.

MMR recommend standardised live-trapping for these populations but the monitoring that should be undertaken depends on the view that is taken of the way in which they should be managed and, thus, on the strategic conservation objectives for these populations. Broadly speaking, the possibilities are:

1. Letting nature take its course

In this case, monitoring is unnecessary. We would recommend, however, that the statutory agencies collate information on these populations as it becomes available.

Resource requirement: a few hours per year on top of the time input of those providing the information.

2. Eliminating the populations

This is feasible. Success could be determined on the Shiants by using the standard technique of bait sticks; on Lundy, where Brown Rats are also present, this would need to be supplemented by sign surveys or trapping if one wished to know whether Ship Rats had been eliminated even though Brown Rats had not. Similar methods could be used on the Forth islands.

Resource requirement: difficult to estimate; the monitoring of success would be an integral part of the control programmes.

3. Maintaining the populations

On Lundy, the population could be readily indexed by using a systematic programme of live-trapping, since there is a reserve warden on the island in whose duties such work could be incorporated. It would probably be useful to trap in late winter (when natural food is scarce, so that trapping rates will be enhanced, but numbers are likely to be low) and in late autumn (when numbers will be high but variable, depending on breeding success).

On the Shiants, which are difficult of access, standardised live-trapping (i.e. at the same time of year and in exactly the same sites) could provide useful data. A less-standardised programme of trapping would be much less cost-effective. Given the cost of getting people onto these islands, it may be preferable to undertake a major trapping programme every few years rather than to undertake a smaller programme annually, despite the likelihood of considerable annual fluctuations in numbers.

Rats are routinely trapped on at least some of the Forth islands. It would be possible, in principle, to collate data on numbers trapped and trapping effort; if Brown Rats prove also to be present, there might be identification problems.

B. Mainland populations

It may be possible to get useful information on Ship Rats at the same time as monitoring Brown Rats and House Mice. If such monitoring is not undertaken, or if gathering information on Ship Rats is considered too specialised to be included in the monitoring of these common species, then we suggest that a quinquennial questionnaire survey should be conducted of: the area offices of major pest control companies, local authorities, environmental and public health authorities, and port authorities. MMR recommend annual questionnaire surveys but, given that the majority of Ship Rat reports apply to occasional individuals or to ephemeral populations we believe that this is unnecessary. Such frequent surveys, for which the majority of responses were negative could alienate potential respondents.

13.5 RECOMMENDATIONS

1) Monitoring of island populations should depend on a clear decision being reached as to the strategy conservation objectives for these populations (see above).

2) Mainland populations should be monitored through quinquennial questionnaire surveys.

14. COMMON DORMOUSE *Muscardinus avellanarius*

The Common Dormouse population has undergone a pronounced reduction in range and abundance this century. Populations are threatened by loss and fragmentation of suitable habitats, and by the inability to respond quickly to environmental change.

14.1 RECENT AND ONGOING MONITORING WORK

Mammal Society Dormouse Survey (1975-1979) - The Dormouse survey was initiated by The Mammal Society in January 1975 and ran until April 1979 (Hurrell & McIntosh 1984). Details of the survey were circulated with record forms to all known natural history societies, county naturalists' trusts and museums in England, Wales and Scotland. Some of the areas from which relatively few responses were received were examined in greater detail through field visits. Four-hundred and seventy-four completed record sheets were received, allowing distribution to be determined. No information was available on the abundance of the species within its established range.

Mammal Society Dormouse Survey (1993-1994) - Termed the 'Great Nut Hunt' a national distribution survey was undertaken as part of an exercise to raise the public awareness of Dormouse conservation issues. Approximately 11,000 survey packs were distributed to schools, naturalists and the general public resulting in the return of 1,878 report forms. A total of 13,171 nuts were sent in for confirmation that they had been opened by Dormice, as recorded by the observers (Bright *et al.* 1996a). However, only 1,352 (10.3%) of these had been opened by Dormice, the majority (63%) having been opened by squirrels. This was possibly the result of the survey packs having been distributed to too wide an audience. Three-hundred and thirty-four individual Dormice sites were identified from the submission of nuts opened by Dormice. Some attempt was made to quantify the relative abundance of the species across the country on the basis of the submissions received, but the resulting measures may be unreliable because there was no indication of how search effort varied between observers.

General agreement between the two Mammal Society surveys, along with that from work in Wales (Bright 1995), appears to confirm the contraction in range of this species, although it fails to provide data allowing changes in abundance to be properly assessed.

National Dormouse Monitoring Scheme - This scheme collates data from 'Key Sites' within the known range of the species. It aims to gather long-term data on an annual basis, providing information on annual variation in breeding success and population density across habitats and regions. Those participating in the scheme do so on a voluntary basis and receive feedback in the form of an annual newsletter. Typically, three or four observers cover each of the 70 or so monitoring sites, with the observers coming from a general mammal background.

14.2 MONITORING OBJECTIVES

The Common Dormouse was included in the review of scheduled species (Whitten 1990) and the UK Biodiversity Steering Group Report (Anon 1995), and is the subject of a Species Action Plan prepared by English Nature. Action Plan objectives laid down by Bright *et al.* (1996b) contain recommendations for future monitoring of this species, namely:

(a) '*Collation of data from the National Dormouse Monitoring Scheme, its analysis and dissemination. The purpose is to study long-term effects of habitat change on population density* *and breeding success, and also climatic effects on yearly and geographical variation in population size and viability. More sites and observers should be recruited into the monitoring scheme. The target should be to maintain surveillance of Key Sites in at least 25 counties, recruiting at least three new sites per year until the year 2000 and beyond.*'

(b) '*Periodically (every 5-10 years), a survey should be undertaken of sites where dormice have been recorded in the past (using The Mammal Society Survey site list and the Great Nut Hunt of 1993 as the baseline data).* [The next 'Great Nut Hunt' is planned for 2001]. *The purpose will be to establish the rate at which sites are being lost and to ensure that widespread extinctions do not occur unnoticed.*'

Bright & Morris (1996) note that the Dormouse is likely to be '.. *a very sensitive indicator species for monitoring future changing environments and an excellent model for studying the effects of habitat fragmentation, climatic shifts and climatic stochasticity*'. To achieve these aims, and those mentioned above, annual monitoring of Key Sites should be a priority, coupled with an examination of Dormouse abundance within hedgerow habitats and periodic national surveys of distribution.

14.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Dormice can be trapped in purpose-built wire-mesh traps (Morris & Whitbread 1986). These should be baited with apple, contain a nestbox (typically a clean milk carton) filled with hay and be positioned between 1 and 4m above the ground, set against trunks or in suitable cover. MMR recommended that a grid of 7x7 traps is positioned with a 15m trap spacing. Traps should be run over a five-day trapping period and checked twice daily. Capture rates are low and the method is very labour intensive.

Hair-tubes - Hair-tubes can be used to record the presence of Dormice in an area and provide a simple measure of activity. Tubes should be 3-4cm in diameter, contain sticky tape on the upper surface, be baited with jam or peanut butter and fixed at 1-3.5m height to the trees. The best arrangement of tape within the tube is subject to some debate. Bright *et al.* (1996b) recommend tape be placed across two openings cut across the roof of the tube, while Jordan (pers. comm.) recommends (for general hair-tube use across species) that tape be placed length-ways along the tube roof. Correct identification of Dormouse hairs requires expert knowledge or formal training and access to a microscope.

Field signs - The way in which hazelnuts are opened by the Common Dormouse is characteristic and apparently relatively straightforward to identify, although it should be noted that many of the respondents to the 'Great Nut Hunt' failed to separate correctly squirrel- and dormouse-opened nuts (Bright & Morris 1989; Bright *et al.* 1996b). Five 10x10m quadrats placed within suitable habitat should be searched for 20 minutes each (Bright *et al*. 1994). If no positive nuts are found then it is likely that the species is absent from the site. Searches should be undertaken from about mid-September to the end of December. This approach cannot be applied to Dormouse populations utilising hedgerow habitats. However, work is planned to examine the relationship between Dormouse abundance and hedgerow characteristics at 60 sites in England and Wales (Paul Bright, pers. comm.).
Summer Dormouse nests are characteristic when freshly constructed, having tightly woven material (typically strips of Honeysuckle) bound together with leaves (Hurrell & McIntosh 1984). Nests are usually spherical, lacking any obvious entrance hole and are grapefruit-sized

(Bright *et al.* 1996b). The lack of an obvious entrance hole distinguishes them from the nests of Wren *Troglodytes troglodytes* and Harvest Mouse.

Nestboxes - From the work of Paul Bright it is clear that nestboxes can provide an important tool for monitoring Dormouse numbers and breeding success (Morris *et al.* 1990). A description of suitable nestbox designs is provided by Bright *et al.* (1996b). Inspection of nestboxes under licence should be carried out at least twice a year (mid-June and mid-October), although more regular checks will provide greater detail.

Nestboxes erected for other species, notably Pied Flycatchers *Ficedula hypoleuca*, may occasionally contain Dormice. The number of boxes occupied each year could provide a basic index of the species at sites where nestbox schemes are regularly monitored. This is currently being evaluated by Aidan Marsh primarily with regard to Yellow-necked Mouse use of bird boxes (Aidan Marsh, pers. comm.).

14.4 POTENTIAL MONITORING SCHEMES

National Dormouse Monitoring Scheme - The present National Dormouse Monitoring Scheme, with its emphasis on 'Key Sites' and periodic national surveys, already provides data of the type required for the successful monitoring of this species. The monitoring network has grown steadily since the mid-1980s and with continuing efforts to expand the number of sites covered annually (and the range of habitats), no alternative monitoring scheme would appear necessary. Work should continue to evaluate the success of the translocation programme (Bright & Morris 1993, 1994) and other aspects of Dormouse conservation (Bright *et al.* 1994): e.g. Morris (1993) stresses the need to establish what constitutes a minimum viable population for this species. Additional funding may be required to extend the range of habitats and regions covered further.

14.5 RECOMMENDATIONS

1) The current National Dormouse Monitoring Scheme already provides suitable data for monitoring this species. The scheme could be expanded through additional funding to cover sites in a number of other habitats and regions.

2) Ancillary data would be available on distribution from the proposed Mammals on Nature Reserves scheme (Part III.B.6).

15. FAT DORMOUSE *Glis glis*

Introduced into Tring Park, Hertfordshire in 1902. The population has steadily expanded its range since that time and now occupies a triangle of 260km^2 delimited by Beaconsfield, Aylesbury and Luton where it is locally numerous (Thompson & Platt 1964; Hoodless & Morris 1993; Morris 1997).

15.1 RECENT AND ONGOING MONITORING

In addition to the collation of sightings on an *ad hoc* basis:

DETR - Licences are required under the Wildlife and Countryside Act for the purposes of trapping *Glis*. Pest Control companies operating under such licences are required by law to submit details of where (and how many) animals are caught when carrying out pest control operations. This data could be made available for monitoring purposes, although some of the detail may be withheld (Kevin Rye (DETR), pers. comm.).

Study by Pat Morris and Paul Bright - Ongoing work is being carried out in a wood within the core range of *Glis* examining basic ecology and survival rates. One-hundred and thirty nestboxes, with additional nesting tubes (converted tree guards), have been positioned along lines in 20 hectares of woodland to allow sampling of different woodland compartments. Monthly visits are made between May and November and individuals caught are marked with implanted chips, allowing the application of CMR. To date over 170 individuals have been marked with tags, with others previously having been marked with ear tattoos. This information is being used to determine survival rates and additional information is available on productivity and recruitment.

15.2 MONITORING OBJECTIVES

Any expansion in range would be a cause for concern, especially given the potential damage that this species can cause to forestry and domestic properties. Although the population has yet to spread much further afield, this may simply be the result of it not yet having saturated the already colonised area (Lever 1994) and of difficulties in moving across areas of unsuitable habitat. Assessment of current distribution and some basic information on densities within the occupied range should be considered a priority. It is established that some individuals removed from properties have been released at some distance and this may have contributed to the expansion in range of this species.

15.3 POTENTIAL MONITORING TECHNIQUES

Line-transects - In early summer Fat Dormice are particularly vocal, emitting raucous chirring vocalisations soon after emergence at dusk. Transects can be walked at this time and the number of *Glis* heard can recorded (Pat Morris, pers. comm.) using a distance sampling approach. This approach was used by Hoodless & Morris (1993) to estimate population density, with 550m transects each walked a total of nine times between the hours of 2130 and 0100hrs over four separate nights. Transects should be walked on still nights to reduce the interference caused by background noise.

Live-trapping - The species is noted by Lever (1994) to be readily trapped. Commercially available squirrel traps can be used, under licence, to capture this species (Pat Morris pers. comm.).

Nestboxes - The work carried out by Pat Morris highlights the potential for monitoring through the use of nest boxes. *Glis* readily take, to nestboxes and nesting tubes and can be caught outside the hibernation period in such sites. Both nestboxes and nesting tubes appear to be equally suitable for this species (Morris & Temple 1998).

Infestation records - Licences are required for the purposes of trapping *Glis*. Pest control companies operating under such licences are required by law to submit details of where (and how many) animals are caught when carrying out pest control operations. This data could be made available for monitoring purposes, although some of the detail may be withheld (Kevin Rye (DETR*)*, pers. comm.).

15.4 MONITORING OPTIONS

Annual Monitoring - The restricted distribution of *Glis*, coupled with its habitat requirements suggests that successful monitoring of this species may be possible through annual monitoring of nestboxes at a small number of sites (possibly even one). *Glis* require high beech forest mixed with conifers, a combination that is untypical of much British forestry, but which does occur in the Chilterns. Monitoring of a grid of nestboxes and nest tubes within such habitat on an annual basis outside the hibernation period could be used, through the application of CMR, to derive an index of abundance. The manner in which data are currently gathered by Pat Morris (monthly visits May-Nov) additionally provides information on productivity, recruitment and survival rates, all of which are important if we are to understand the ecology (and possible control measures) of this species within Great Britain. The current scheme is unfunded and funds would need to be made available to secure the continuation of the work and its possible expansion to a limited number of other sites within the known range. The apparent synchronicity between the GB population and those elsewhere in Europe further supports the possibility of monitoring using just a small number of sites or a single site. It would make sense to have several study sites, thus reducing the risk of loss of monitoring following a change in access conditions.

Pest Control returns - The data generated by the above annual monitoring does not provide information on that component of the population utilising buildings for part of the year. Information gathered by pest control companies and reported to DETR through licence returns could be used to generate an index of *Glis* occurrence in buildings. This should be examined in relation to data from the wider countryside, although it is not clear at this stage whether the two components are likely to show positive correlations or negative ones (Pat Morris, pers. comm.). There are good biological reasons why either may occur.

Transects - Periodic transect surveys for *Glis* vocal activity can be carried out to examine the distribution, and to a lesser extent the abundance, of the species at a larger number of sites. The protocol for this approach needs to be evaluated through pilot fieldwork examining the best time for carrying out such work and the length of transect required (see Hoodless & Morris 1993).

15.5 RECOMMENDATIONS

The current monitoring work being carried out by Pat Morris should be formalised through the provision of specific funding, allowing extension of the scheme into a small number of other sites. This would provide sufficient detail to monitor population changes of 25% over 25 years through CMR techniques. Additionally it would provide important information on productivity and basic ecology, both of importance if the potential future control of the *Glis* population is to be effective.

16. OTHER SMALL MAMMAL SPECIES

(Common Shrew *Sorex araneus*, Pygmy Shrew *Sorex minutus*, Water Shrew *Neomys fodiens*, Bank Vole *Clethrionomys glareolus*, Field Vole *Microtus agrestis* and Wood Mouse *Apodemus sylvaticus*.)

The remaining small mammal species have a wider distribution and broader habitat requirements than species such as Yellow-necked Mouse and Harvest Mouse. Consequently they present particular difficulties with regard to monitoring. For this reason they have been grouped together and the structure of this section has been adapted accordingly to allow examination of the problems associated with monitoring these species and any potential monitoring strategy. For the purposes of explaining some of the difficulties in working with this group the Wood Mouse is used as an example. Specific problems associated with the other species are readily available within the wide-ranging literature on small mammals.

16.1 MONITORING OBJECTIVES

Small mammals are an important component of our mammal community. Some species are of economic importance (Wood Mouse), others of limited distribution or conservation interest (Water Shrew, Harvest Mouse) and all are important as prey species for some of our scarcer carnivores and predatory bird species. There is evidence of a widespread decline for species like Field Vole, Water Shrew and Harvest Mouse, with Action plans having been drawn up for some species (Churchfield 1997). Monitoring should be directed towards establishing long-term trends in abundance across a range of habitats.

16.2 DIFFICULTIES WITH THIS GROUP

Scale - The main difficulty in developing a suitable monitoring strategy for this group is one of scale. Most of these species will use a range of habitat types and all are widely distributed within Great Britain, although within habitats they often exhibit very clear microhabitat preferences. In the case of the Field Vole, the species can be found in unimproved grasslands, roadside verges, young conifer plantations and (at lower population densities) in woodland. In these habitats it shows a preference for areas with a lush growth of soft grasses, a high basal density to the sward and well-developed tussock structure (Ferns 1976, 1979).

The Wood Mouse is more of a habitat generalist, occurring in most habitats: woodland (Flowerdew 1985; Montgomery 1989), arable land (Rogers & Gorman 1995), sand dunes (Deshmukh & Cotton 1970), hedgerows and urban areas. The widespread occurrence of this species, coupled with its abundance, makes monitoring on the basis of simple presence/absence quite impractical. The only alternative is to look at abundance. However, this also presents problems in that there are various biases associated with the application of Capture-Mark-Recapture (CMR) methods and difficulties in selecting a sample of sites that represents the wider habitat use of the various species.

Trapping at a small number of sites (say 30 woodland sites) is unlikely to provide a realistic picture of what is happening to the Wood Mouse population at the national level. The abundance of the species at each site will depend on both the habitat type and the microhabitat features present on the trapping grid. This will lead to a high degree of variation between sites, as sites differ in age, food availability, the proximity of source/sink populations, etc. The only way to overcome the effects of this between-site variation (site-effect) is to sample at a large number of sites, across all utilised habitats. This may greatly increase the number of samples that need to be taken in order to obtain a suitably precise measure of the underlying trend (year effect). Mallorie & Flowerdew (1994) examined data from a series of 13 study sites in deciduous woodland employing standardised trapping in an attempt to determine whether there was synchrony between populations. Analysis of variance of the effects of trapping sites and year on $\log_e$ numbers of Wood Mice and Bank Voles showed both significant year and site effects, suggesting that it is possible to get at year effects, at least in similar woodland habitats, with this number of samples. However, the synchrony found by Mallorie & Flowerdew (1994) appears to be related to masting events (Flowerdew 1973) and similar synchrony is less-likely to occur in non-woodland habitats. It should be noted that synchrony has also been demonstrated in other woodland/forest habitats (Shanker & Sukmar 1999) This is further complicated by the influence of source/sink dynamics.

Number of samples required - To build up an accurate picture of what is happening to Wood Mouse populations at the national level it is important to sample a representative suite of habitats within which the species is known to occur. For a large species of mammal or bird the size of the sample unit (e.g. tetrad, 1km square) is typically large enough to ensure that a representative sample of available habitats can be covered within a reasonable number of units, enabling a national estimate to be produced - i.e. the sample is representative of the wider countryside (Toms *et al*. 1998). With small mammals, the sample unit is much smaller, typically a grid of less than a hectare in size. A larger number of these units would then need to be covered if they are to be representative of the wider countryside. In the case of a small mammal showing a restricted distribution (e.g. Dormouse, Harvest Mouse) this may be possible in that the species has specific habitat requirements, but for a habitat generalist like the Wood Mouse this is more difficult to achieve. The number of samples required may be prohibitively expensive in terms of the man hours required and the capital costs involved (see worked examples).

Biases relating to the trapping of small mammals - The biases associated with trapping small mammals and the CMR method have been well covered by MMR. Typically, such biases result from the number of traps used per trap point (Andrzejewski *et al*. 1966; Gurnell 1976), trap position, length of the trapping period (Andrzejewski & Glogowska 1962), weather (Vickery & Bider 1981), trap odour (Tew 1987) and density of the population under study (Janion & Wierzbowska 1970). In addition to those biases applicable across habitats, there will be other biases specific to individual habitats. Biases associated with small mammal trapping and the use of traps are reviewed by Flowerdew (1976) and Twigg (1975) respectively. The timing of sampling is another important factor due to (i) regular annual cycles witnessed in most small mammal populations (Stenseth *et al*. 1977; Anglestam *et al*. 1984; Flowerdew 1985) and (ii) multi-annual cycles witnessed in some species (Henttonen *et al.* 1989; Hanski *et al.* 1993).

Biases relating to habitat - There are two components to habitat-related biases; firstly, those resulting from differences in the dynamics of the study species in different habitats and, secondly, those relating to differences in trap efficiency in different habitats, mediated through the biases outlined in the previous section. Wood Mice populations in different habitats may behave differently, often as a result of source/sink dynamics and habitat preferences. If such biases influence the number of small mammals caught by trapping, and hence the estimate of abundance, then comparisons between habitats become less meaningful. This might suggest that trapping in different habitats should take place with the data from each habitat used independently to monitor population change. If there is evidence of synchrony between a population sampled in woodland and a population sampled in grassland then this may be taken as evidence of a real population change. However, it is more likely that source/sink dynamics may result in one population remaining stable while the other decreases, making the true pattern of population change more difficult to detect.

16.3 AVAILABLE METHODS

Snap-trapping - Snap or break-back traps kill the small mammals being sampled and careful consideration should be given as to the value and ethics of using them for monitoring purposes. Such traps should always be set undercover and ideally only operated at night to reduce the risk to non-target species. They are considerably cheaper than live-capture traps. Snap-traps have been widely used in the surveillance of small mammal abundance in Scandinavia (Myllymaki *et al.* 1977) through the application of the Small Quadrat Method (SQM).

Live-trapping - Live-trapping methods have been reviewed by Twigg (1975), Flowerdew (1976), Tapper (1976) and Gurnell & Flowerdew (1982). Traps can be arranged in grids or lines, the latter being of less value to most small mammal work, but allowing relative changes in catch to be measured and being simpler to operate. A grid approach would ideally involve 49 trap points with two traps per point and an interval of between 5-15m between trap points depending on the target species. Recent work on Yellow-necked Mice by The Mammal Society has employed a reduced grid of two lines of ten trap points with two traps per point. The length of the trapping period should be long enough to catch an adequate sample, but not so long as to introduce bias as assumptions about a closed population begin to break down. Field Voles require a period of 3-4 days prebaiting before the trapping is carried out (Toms, in prep.), although this is less important for other species. The choice of trap is also important with some considerably less effective than others (Toms, in prep., but see Lambin & Mackinnon, 1997). It is important that, for monitoring purposes, a single trap design should be employed, with no mixing of designs between sites. Similarly, the spacing and arrangement of traps used should also be held constant.

Hair tubes - Hair tubes have been successfully applied to the study of some small mammal species (e.g. Water Shrew, Mike Jordan; Harvest Mouse, Martin Perrow), although some species cannot be separated through this approach. An additional problem is that the perceived 'abundance' of a species derived from the use of hair tubes, will contain an activity component in addition to the abundance component. Whilst this also occurs when live-trapping, the effect with hair tubes is likely to be more significant. There is some evidence that, at least for Harvest Mice, there is a correlation between hair tube indices and those derived from live-trapping.

Field signs - Sign-indices have been derived for the examination of Field Vole populations (Hansson 1979; Village & Myhill 1990). Hansson (1979) found that grazing intensity and to a lesser extent, runways and faeces piles, correlated well with trap catches of *Microtus agrestis* on abandoned fields throughout the year. In forest habitats similar correlations were found between field signs and trap catches of *Clethrionomys glareolus*. Under some circumstances the faeces of these two species can be difficult to separate. Village & Myhill (1990) derived an index based on field signs for *Microtus agrestis* which enabled large differences in population size to be determined (but not necessarily smaller changes). Tapper (1976) used the number of active runways as a measure of abundance, although he also demonstrated this to vary seasonally.
The droppings of *Neomys fodiens* can be distinguished from other shrews (in most cases) because they contain aquatic invertebrate remains and it is possible to collect these droppings from baited feeding tubes or dropping boards at bait stations (Abyes & Sargent 1997). This approach has been used in a national pilot survey examining the habitat preferences of the species (Greenwood 1998). It should be noted that the diet of those Water Shrew populations

established away from water may not contain the diagnostic remains of aquatic invertebrates (Churchfield 1990), making this component of the national population more difficult to monitor effectively. Stephen Harris (pers. comm.) feels that this component of the population is likely to be transitory in nature, reducing the importance for its direct monitoring.

Pellet remains - The identifiable remains of small mammals found in the pellets of owls may allow changes in small mammal populations over time to be investigated. There are two potential problems with this approach. First, individual owls are not likely to hunt in a random fashion, i.e. they do not take small mammal prey in relation to their availability (Yom-Tov & Wool 1997). This means that the proportions of different prey recovered from pellets are not representative of the proportions of those same prey in the wider countryside (although see Glue 1970). Individual owls may select prey on the basis of its profitability, either directly or through some selection of the habitat over which they choose to hunt. Therefore, this problem relates to how representative the data are of small mammal populations in the wider countryside.

A second problem is that the prey species selected by an owl may change over time; either as a result of a changing prey availability (the target of monitoring) or because of changes in the habitats selected by the owls for hunting. Changes in those habitats selected for hunting may result from changing prey availability, or as a consequence of changes in the owl population itself. At high population densities a component of the owl population may be forced to hunt over sub-optimal habitats, taking a different range of prey species to those occurring in optimal hunting habitats. At low population densities all hunting may take place over optimal habitat, so changes in the proportions of individual small mammal species in owl pellets may result from either (1) real changes in the occurrence of small mammals or (2) changes in the habitats hunted by owls due to the population size of the owls themselves.

Even if individual owls (or owls depositing pellets at individual sites) do not take prey directly in relation to their availability, it may be possible to build up a general picture of large scale trends in small mammal populations by analysing pellet samples from a large number of sites and from different predator species. For example, regular analysis of pellets from Kestrels *Falco tinnunculus*, Little Owls *Athene noctua*, Long-eared Owls *Asio otus* and Barn Owls *Tyto alba* may all point towards a decline in the proportion of Common Shrews being taken, thus providing some evidence that something has happened to either the Common Shrew population or populations of the other small mammal species occurring in the diets of these three species. The potential of this approach has been highlighted by a recent study examining Barn Owl diet in the UK (Love *et al*., in press), a follow up to the previous national study (Glue 1974), which together show a shift in the proportion of Common and Pygmy Shrews being taken. This may indicate a genuine change in the populations levels of these two species or a shift in the habitats over which Barn Owls are hunting. Either way it is indicative of something happening and as such may provide support to some other monitoring approach to small mammals.

16.4 DEVELOPMENT AND VALIDATION STUDIES

A full protocol should be developed following more detailed discussions and pilot fieldwork, although there are several points that are worth raising here.

1) A period of three days prebait is required when trapping Field Voles (Toms, in prep.).

2) Shrew captures require that traps are visited at least twice a day, increasing to every six hours in extreme weather.

3) All small mammal populations show pronounced annual fluctuations usually resulting in a population peak during late autumn. Trapping should therefore be carried out twice a year (late spring and late autumn) to produce a measure of abundance of value to monitoring.

4) Many small mammal species show pronounced inter-annual fluctuations, with some cyclicity recorded for populations in some habitats.

5) Cyclic behaviour, activity, trap response, population density, etc., all vary between habitats and, with the influence of source-sink dynamics, a large number of sites across a range of habitats need to be covered.

16.5 RECOMMENDATIONS

1) Monitoring of Common Shrew, Pygmy Shrew, Water Shrew, Bank Vole, Field Vole and Wood Mouse should be undertaken as a pilot scheme at a small number of sites using live-trapping and a network of volunteers, co-ordinated by a single professional. The scheme should be evaluated after five years and, if found to be practical, expanded to a level where the power for detection is acceptable for monitoring purposes. We cannot say for certain just how many sites would be required for this purpose, but this is something that could be examined by running simulations from the data collected by Mallorie & Flowerdew (1994). The trapping protocol will need to be determined, but could involve volunteers setting traps for prebait on day 1 (Wednesday), setting for capture on day 3 (Friday evening) and trapping on days 4 and 5 (Saturday and Sunday, taking the grid up on the Sunday).

2) Ancillary data should be gathered through the analysis of predator pellets (Barn Owl, Tawny Owl, Little Owl, Long-eared Owl and Kestrel) collected from as many sites as possible.

3) Pilot studies using hair tubes and field signs should be evaluated in parallel to the live-trapping work in order to determine whether either of these approaches could have a monitoring role.

16.6 MONITORING COSTS

The costs of implementing a monitoring programme based on live-trapping at a sufficient number of sites to provide the required power of detection are outlined below. These are very rough figures designed to give an impression of what is involved rather than to specify particular sample sizes. The sample sizes required would need to be evaluated through a review process and possible modelling of existing datasets, notably that stemming from Mallorie & Flowerdew (1994).

EXAMPLE ONE - Allowing a period of pre-bait and three days trapping - PROFESSIONAL FIELDWORKERS

ASSUMING - (i) a grid of 49 trap points with two traps per point, with a period of three days prebait, three days trapping and one day for change over, would allow one trained fieldworker per grid.

(ii) two trapping periods a year (one in April and one in September) with each trapping period lasts six weeks, would allow one set of traps to be used at six sites during each trapping period.

(iii) one fieldworker can only operate one grid at a time to allow for the likely distance between sites and the time taken each morning and evening to remove trapped animals, mark and release them.

Based on these assumptions, a single, fully committed fieldworker could cover six different sites during the six-week sampling period. The six-week sampling window is required to ensure that different sites are sampled at a similar time to each other thus reducing seasonal bias. This would mean that:

(i) a sample of 50 sites would take 350 working days per trapping period (700 per year) and require nine fieldworkers using 882 traps (£26,460 for traps).

(ii) a sample of 100 sites would take 700 working days per trapping period (1,400 per year) and require 17 fieldworkers using 1,666 traps (£49,980 for traps).

(iii) a sample of 500 sites would take 3,500 working days per trapping period (7,000 per year) and require 84 fieldworkers using 8,232 traps (£246,960 for traps).

These calculations assume that fieldworkers would be fully committed during the six week period. This would almost certainly rule out volunteer involvement, although a different approach could be adopted to involve volunteers.

EXAMPLE TWO - no period of prebait and two days of trapping. VOLUNTEER FIELDWORKERS

ASSUMING - (i) two rows of 10 trap points with two traps per point, with the traps set on a Friday night and checked twice on the two following days. Allowing one trained fieldworker per grid.

(ii) two trapping periods a year (one in April and one in September) with each trapping period lasts six weeks, would allow one set of traps to be used at six sites during each trapping period.

(iii) one fieldworker can only operate one grid at a time to allow for the likely distance between sites and the time taken each morning and evening to remove trapped animals,

mark and release them. Traps would be passed to the fieldworker covering the next site during the intervening days.

Based on these assumptions, six different sites could be covered during the six-week sampling period. The six-week sampling window is required to ensure that different sites are sampled at a similar time to each other thus reducing seasonal bias. This would mean that:

(i) a sample of 50 sites would take 125 working days per trapping period (250 per year) and require a maximum of 50 fieldworkers assuming one fieldworker per site, using nine sets of traps (882 traps) (£26,460 for traps).

(ii) a sample of 100 sites would take 250 working days per trapping period (500 per year) and require a maximum of 100 fieldworkers assuming one fieldworker per site, using 17 sets of traps (1,666 traps) (£49,980 for traps).

(iii) a sample of 500 sites would take 1,250 working days per trapping period (2,500 per year) and require a maximum of 500 fieldworkers assuming one fieldworker per site, using 83 sets of traps (8,232 traps) (£246,960 for traps).

Other alternatives could be considered, varying the number of traps used, the number of sites to be covered, the inclusion of a period of prebait as part of the volunteer approach and the length of the trapping period.

16.7 RECOMMENDATIONS

1) Development of suitable monitoring methods for Common Shrew, Pygmy Shrew, Water Shrew, Bank Vole, Field Vole and Wood Mouse should form part of a specific study. Attention should be given to the value of live-trapping, pellet analysis, field signs and the use of hair tubes. Of these, only live-trapping will allow monitoring of all these species at the same time: field signs cannot be used for the two *Sorex* spp. or *Apodemus*, hair tubes likewise, and pellet analysis is best suited for determining broad changes in commonly taken prey species.

2) Volunteer involvement is likely to form the basis for long-term monitoring of these small mammal species, but only with the support of a number of professional co-ordinators, a ready supply of traps and good logistical support.

17. RED FOX *Vulpes vulpes*

Native; common and widespread in Britain and Ireland but absent from most small islands; population may be increasing, especially in urban areas.

17.1 RECENT AND ONGOING MONITORING

Game Conservancy National Game Bag Census - Game Bag records from a sample of shooting estates throughout the UK dating back to 1961 (with additional historical records). These data show a continuing, increasing trend which has been interpreted as showing an increasing population (Reynolds & Tapper 1994). The data are subject to severe biases, however, and have not been corroborated: sampling methods have changed over time as has the time of year at which control is typically practised. The sampling method has direct effects on the effort effectively expended, i.e. the combination of the time spent and the efficiency of the method, but the timing of control actions has had potentially even more serious effects by changing the population sampled from resident to dispersing and from older to younger (Reynolds & Tapper 1994). The apparent population increase could therefore be an artefact of changes in the "sampling regime". Greatly increased inter-annual variation in bag data from recent years (Reynolds & Tapper 1994) gives further cause for concern.

Long-term monitoring by gamekeepers (The Game Conservancy Trust) - Over sixty gamekeepers from around the country conduct twice weekly spotlight counts of foxes with, critically, a measure of survey effort. This is a recently established survey, but is intended to run in the long term. Cull data are also collected. To an extent dependent on its geographical and habitat range, this survey could provide an important contribution to the monitoring of rural Red Fox populations.

Direct distance sampling surveys by spotlight (The Game Conservancy Trust) - A professional survey to calibrate spotlighting by gamekeepers in four, geographically separated study areas over the period 1995-1997. The survey, using standardised methods, revealed consistent differences between regions which corroborate the gamekeepers' spotlight counts.

The National Fox Survey (The Mammal Society/University of Bristol) - A survey of scat density and replacement rates in rural areas in February and March, 1998-2001, based on up to 1,000 randomly selected 1km squares (a sample stratified by ITE Landscape Region). The aim is to collect scats from along all or at least 5km of the linear features found in the square (scats are then collected centrally for dietary analyses). "Linear features" are defined as hedgerows and other fence lines, roadside verges, worn footpaths or tracks, woodland edges and the banks of ditches, rivers, lakes and other water features. Estimates of the national population and of geographical variations in abundance will be made from the results of the survey.

Forestry Commission Kill Records - These records will be geographically limited and may suffer from a lack of effective measures of effort.

Fox Hunt Kill Records - Hunt kill records will vary in quality from hunt to hunt, but all will be derived from areas which support high fox populations and which may be managed for them. Hunting effort will be variable and difficult to quantify, and may not be recorded in any form.

Urban foxes - Stephen Harris and others at the University of Bristol have conducted detailed studies of the determinants of Red Fox abundance in British towns and cities which have generated models capable of predicting fox densities in any British conurbation from habitat and sociological data (Harris 1981; Harris & Rayner 1986a,b,c; Harris & Smith 1987). The survey work underlying these models was based on counts of litters and made use of the voluntary participation of schools (Harris 1981; Harris & Rayner 1986a).

17.2 MONITORING OBJECTIVES

The objective may be to measure trends in rural and urban Red Fox populations. Red Fox populations have intrinsic conservation interest, but monitoring may also be important with a view to the effects of hunting and control requirements perhaps, and there may be intra-guild competition issues with respect to Pine Marten. Population information could also feed into policy development for rabies control.

17.3 POTENTIAL MONITORING TECHNIQUES

Spotlight counts - The eyeshine of foxes is distinctive enough for it to be distinguished from that of other similarly-sized animals by experienced observers. Spotlight counts along standardised transects therefore represent a potentially useful survey technique. Counts should be made during February and March, between 2100 and 0300 hrs on clear nights, to estimate spring breeding density. Problems with spotlighting are that it is unsuitable for volunteers (it is labour-intensive, involves unsociable hours and requires considerable training), that counts are likely to underestimate fox populations because the animals learn to avoid lights under shooting pressure (so counts are seriously biased according to the intensity of shooting), that habitat access is severely biased by the need to use motor vehicles and that animals in woodland cannot be seen. Avoidance of lights due to shooting pressure further mean that counts are biased towards recording (young) animals which have yet to be shot at. It is also likely that the lights available for spotlighting will increase in power over time, affecting sampling efficiency (such issues have been considered with respect to improvements in bat detector technology).

Hunting and Game Bag records - Long time series of historical Game Bag and hunting records exist and these data are likely to continue to be collected. These data therefore might provide a valuable historical context for future survey data. However, hunting and bag record data are subject to important biases which severely limit their potential as a front line monitoring method. Game Bag data depend critically on the sampling effort, including the type of method (shooting, trapping or poisoning) and the efficiency of the method, as well as the man-days spent in control measures; these are rarely recorded. Assumptions must therefore be made about the constancy of methods which cannot be tenable in the long term. Bag or hunt records are also likely to be biased towards area of high fox density, so being unrepresentative of low density areas. These problems make bag records a poor monitoring tool for foxes. Game Bag data are discussed in detail in Part III.A.2.

Drive counts - Total populations can also be counted by driving with beaters or dogs. However, considerable effort is required: in this case, teams of individuals for each survey plot.

Fox hunt counts - Fox hunts could provide data on the numbers of foxes seen during hunting, as a crude transect-type method. However, hunts will only go where prior intelligence suggests foxes will be found, so counts are unlikely to track population abundance, among other problems (see MMR, p. 177).

Mammals on Roads - Fox carcasses are among the more easily identified road-deaths, so road-death data could give useful background information on distribution. Given measures of search effort and estimates of traffic density, as postulated for our proposed Mammals on Roads survey (Part III.B.3), information on abundance could also be obtained.

Live-trapping - Foxes can be trapped and tagged, allowing population sizes to be estimated by CMR. However, trapping is labour-intensive, costly and time-consuming. It is also especially difficult in rural areas and some individuals are extremely trap-shy (S. Harris, pers. comm.).

Field signs (faecal counts) - Fox faeces are easily identified, so volunteers could feasibly be used to collect data, especially after Mammal Society accreditation. The National Fox Survey is effectively providing a valuable baseline measure of rural Red Fox abundance to which future faecal count work can be compared. It will also provide valuable information on the effectiveness of the method and suggest where improvements could be made. Preliminary results indicate encouraging scat detection rates and responses from volunteers (S. Harris, pers. comm.). Fox scats would be a key target of the proposed Sign Transect Survey (Part III.B.2) and would be monitored as part of our proposed survey protocol for Pine Marten, particularly because of the interactions that occur between the two species.

Field signs (track counts) - Tracks can be identified and counted, but serious habitat biases and weather effects are likely unless specialised methods (sand traps or tracking plates) are used. Such methods effectively preclude any large-scale volunteer input. A further problem is that the tracks of foxes and small dogs can be difficult to distinguish in less than ideal conditions (S. Harris, pers. comm.).

Field signs (breeding den counts) - Several field signs allow the identification of Red Fox breeding dens in spring, especially if dogs are used. Data on abundance could be obtained from standardised searches for breeding dens, but encounter rates are likely to be low per unit search effort and searching could have to be very intensive, using teams of six to eight searchers for a 1km square (see Insley 1977). This may make the method unsuitable for volunteer input.

Bait discovery - This method is under development by MAFF and the Game Conservancy Trust and could provide robust estimates of density if the effects of learning can be controlled for. However, it will always be an intensive method for professionals only, requiring repeated visits to baits and standard bait preparation methods.

Visual transect counts - Sightings of foxes in daylight are probably too infrequent for monitoring via direct counts from transect surveys such as the Breeding Bird Survey, but presence/absence data based on controlled off-transect sightings and evidence from field signs such as scats could contribute usefully to national fox monitoring (see Part III.B.2). Sighting rates would be higher from winter/early spring transect counts (see Part III.B.1).

Questionnaire surveys/follow-up litter counts - This method has been used successfully to measure fox densities in urban areas, which are important yet difficult to survey in similar ways to rural areas. Casual sightings or questionnaire returns from the general public (i.e. not necessarily paid-up wildlife enthusiasts) backed up by professional input provide an efficient way of surveying urban areas.

Garden sightings - Red Fox is a key species which can easily be monitored by a garden-sighting based monitoring scheme and whose urban and sub-urban populations are important. Our proposals for a Garden Mammal Watch are detailed in Part III.B.5.

17.4 POTENTIAL MONITORING SCHEMES

MMR Recommended Approach - Within the QQ grid of 10km squares, MMR suggest that 1km squares should be surveyed for foxes by spotlighting along 1km transects covered by car. They also suggest supplementing this information with scat data collected in conjunction with sign surveys for other species, with questionnaire surveys of landowners and householders and with Game Bag data. We have outlined the major problems with Game Bag data and spotlighting above (see also Part III.A.2): we believe that these methods are unlikely to monitor foxes adequately. Surveys for fox scats fall under our proposed Sign Transect scheme (Part III.B.2).

Combined, complementary surveys - We suggest that separate survey approaches are required for urban and rural Red Foxes. For urban foxes, there are two options: regular questionnaire surveys (perhaps using school projects) backed up by professional checks for litters, using the work of Stephen Harris (Harris 1981; Harris & Rayner 1986a) as a model, or a less specific approach using records from a Garden Mammal Watch (see Part III.B.5). Recent changes in the UK's educational culture such as the development of the National Curriculum may limit the extent to which repeats of Harris' school-based work is practicable (S. Harris, pers. comm.). The latter might not monitor animals in more urban areas well, but should detect large changes in sub-urban populations. The regular questionnaire approach could target a random sample of urban areas and the sample could be rotated according to, say, a five-year cycle to maintain interest and broaden participation. Such a survey could have an additional benefit of introducing children in urban areas to wildlife and conservation issues.

For rural foxes, we suggest that a scaled-down version of the National Fox Survey would provide the best guide to *changes* in abundance and distribution. Such a survey would be provided by our suggested Sign Transect Survey (see Part III.B.2), within which Red Fox would be a key species. Scat numbers vary with diet (S. Harris, pers. comm.), so some periodical checks for changes in diet (say, using faecal analysis) would be necessary as controls to prevent misinterpretation. Ancillary information on fox abundance and distribution would also be forthcoming from the Breeding Bird Survey (see Part III.A.1) and our proposed Winter (visual) Transect Survey (see Part III.B.1). These surveys will be subject to different biases to those affecting sign transects, so would provide an independent check on the results. Mammals on Roads (Part III.B.3) could also contribute and further field sign data would be collected in the course of transect surveys for Pine Marten in habitats where the species co-occur (see Pine Marten species account).

17.5 RECOMMENDATIONS

1) For urban foxes, it may be considered that a specific monitoring scheme is unnecessary, in which case we recommend that a Garden Mammal Watch (see Part III.B.5) be set up, within which Red Fox would be a key species. This should detect large changes in urban and suburban fox range an abundance.
2) For rural foxes, we recommend that our proposed Sign Transect Survey (see Part III.B.2) forms the principal monitoring tool for the species. Using the National Fox Survey results as a baseline, this will provide information on changes in range and abundance. We suggest that visual counts of foxes from the Breeding Bird Survey (Part III.A.1) and a

Winter Transect Survey (Part III.B.1) will also contribute valuable information, as will Mammals on Roads.

18. PINE MARTEN *Martes martes*

Native. Population largely restricted to Scotland and currently recovering from a dramatic population collapse in the mid-Nineteenth Century. Several satellite populations appear to exist in England and Wales, although their viability has been questioned (Langley & Alden 1977; Bright & Harris 1994).

18.1 RECENT AND ONGOING MONITORING WORK

Lockie (1964) - Lockie (1964) examined the distribution of Pine Marten records in Scotland, based on the submission of sightings and trapping records. Local fluctuations in numbers were also studied at Beinn Eighe NNR, Wester Ross, providing evidence that there is a seasonal pattern to the occurrence of scats. This was demonstrated at least partially to be the result of differences in the rates at which scats disintegrated with season. Scats disintegrated more quickly in summer than in winter and Lockie was able to apply correction factors to his index of Pine Marten abundance.

Vincent Wildlife Trust Survey (1981-82) - Fieldwork, undertaken by a single fieldworker over 18 months, was based on transects recording the occurrence of Pine Marten faeces at 277 sites (Velander 1983). Two hundred and sixty people were interviewed regarding records of Pine Martens and 65% of reported sightings were followed up by site survey to verify reliability. A similar approach was adopted in the Republic of Ireland (O'Sullivan 1983). Positive records were noted from 155 10x10km squares. Fieldwork effort was concentrated towards the main Scottish population, although the work carried out in England failed to reveal any direct evidence of Pine Marten populations. Velander (1983) concluded that Pine Martens were still present in at least some of the satellite areas on the basis of local reports. It has been suggested that the method employed by Velander did not have a large enough sampling intensity to successfully locate Pine Martens at the very low population levels at which they are thought to occur in England and Wales (Don Jefferies, pers. comm.).

NCC Pine Marten survey of England and Wales 1987-1988 - Similar survey methods to those employed by Velander (1983) were used in a NCC study of Pine Marten populations in England and Wales. Sightings were gathered from a range of sources, these being used to identify 'core' areas where fieldwork should be carried out. Additional effort was targeted to those adjacent sites that contained 'likely' habitat. The fieldwork employed again involved transect sampling for field signs, although the sampling intensity used was increased over that used by Velander (1983). Fieldwork was carried out over a 19 month period by a single observer. Because of this, effort was directed to sites selected for the likely presence of Pine Martens, rather than on the basis of random selection.

Selected sites were resurveyed at a different time of year to (a) investigate those areas where available information suggested that martens were present but had not been detected, and (b) check on possible seasonal variation in either the ability to detect martens, their marking behaviour or in the use of certain areas for food resources (Strachan *et al.*1996). Because the 2km survey transects were chosen as likely positive sites, the number of survey sites examined per 10x10km square depended on the extent of apparently suitable habitat within that square. The survey found a mean density of 6.22 sites per 10x10km square (range 1-22). Three potential problems arise with the methodology especially when applied to Pine Marten populations occurring at low density:

(a) Pine Martens may alter their range at different times of year;
(b) Seasonal movement within established ranges may occur;
(c) Seasonal variation in the deposition of scats may occur.

The survey concluded that although all five of the main populations south of Scotland were still extant in 1988, they all existed at very low densities, with three at least contracting. Scats were only found in four of these regions (Northumberland, Cumbria, North Yorkshire and north Wales). Bright & Harris (1994) note that the partial resurvey of sites by Strachan *et al*. (1996) did not yield results consistent with the initial visits, and that only 8% of the 896 survey sites yielded positive results.

Ulster Wildlife Trust and Forest Service Study - A questionnaire approach was adopted in 1993 by the Department of Agriculture for Northern Ireland (DANI) Forest Service and the Ulster Wildlife Trust (Hughes 1993). A recording sheet was distributed through forest officers and other staff responsible for the various forest management units throughout Northern Ireland. Reports suggested a westerly distribution for this species, although there are likely to be difficulties in interpreting this type of data, given the habits of (Pine Martens).

English Nature study - Bright & Harris (1994) examined the feasibility of reintroducing the Pine Marten into parts of its former range. As part of this work, 91 2km transects were walked at a number of sites from the previous survey with the express purpose of determining whether marten populations were present. Scats were readily located on transects near Glen Trool, Galloway, but only two Pine Marten scats were positively identified from transect counts carried out elsewhere. The authors concluded that *'..Pine Martens are on the verge of extinction in England. There is no viable population in Cumbria, nor almost certainly in north Yorkshire.'* Comments from this work also serve to highlight the overlap in scat shape between Pine Martens, other mustelids and Foxes. This is supported by ongoing DNA analyses of faecal material, which '..*casts doubt on the validity of any survey technique based on scats alone..'* (Angus Davison, pers. comm.). It should be noted that surveys in the Lake District in 1993 and in North Wales in 1994, suggest that there have been further significant declines in numbers (Bright *et al.*, unpublished).

Scottish Natural Heritage Report (1994) - The survey work undertaken by Balharry *et al.* (1996) again utilised a two-tier approach, questionnaires and 1km transects. Effort was targeted to determine the expansion of the Pine Marten population from 'core' areas, with fieldwork restricted to those areas containing adequate woodland cover (see Balharry 1993). The questionnaire generated 256 returns on the presence or absence of Pine Martens with 620 grid references, covering 42% of the 10km squares in Scotland.

For the fieldwork component, four separate 1km transects (non-randomly selected) were walked in each area, with both Red Fox and Pine Marten scats being collected: those not identified were classified as unknown. The 82 areas searched revealed 404 Pine Marten scats, 754 Red Fox scats and 653 unknown scats. The results demonstrated that there was no significant difference in the frequency of scat deposition per kilometre of track walked between February and September. The results suggest that marten had recolonised parts of northern and western Grampian, Tayside, Central and Strathclyde regions.

Vincent Wildlife Trust - MMR note that the VWT continue to record details of Pine Marten sightings from England and Wales. As part of this work, detailed DNA analyses are being carried out on specimens sent in. During the last couple of years six specimens have been received from England and Wales, 20 from Ireland and over 40 from Scotland (Birks *et al.* 1997; Angus Davison, pers. comm.). Continued monitoring of the genetics of specimens can also be used to establish the presence of American Martens *Martes americana* and Beech Martens *Martes foina*, both of which have escaped from UK fur farms (Baker 1990; Don Jefferies, pers. comm.).

18.2 MONITORING OBJECTIVES

Despite repeated surveys, there remains uncertainty over the status of Pine Marten populations in England and Wales. There is some suggestion that Pine Marten populations are able to persist at very low population densities (Don Jefferies, pers. comm.) possibly indicating that 'relict' populations may remain undetected for long periods. Isolated populations of this species should be a priority for monitoring, alongside work examining the recovery of the Scottish population and some monitoring within the 'core' range to detect future changes.

18.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Pine Martens can be trapped using mesh traps, baited with raw fish or chicken. Traps should be set in areas of suitable habitat and checked daily, with trapping taking place between August and February to avoid trapping heavily pregnant females or those with dependent young (Bright & Harris 1996). Low rates of capture are to be expected, especially where population densities are low.

Direct counts - MMR note that sightings may provide information on the presence of Pine Martens within an area, but these would need careful evaluation. Direct sightings, followed up by intensive fieldwork have formed the basis of most Pine Marten survey work within the UK and Ireland.

Camera traps - Baited camera traps are recommended by MMR as a means by which the presence of Pine Martens in an area can be confirmed following the receipt of sighting records.

Road-kills - Although only small numbers of Pine Martens are killed on the road, road-kills can provide useful data on distribution, physiology and the genetic structure of the population.

Field signs (faecal counts) - Fresh Pine Marten scats typically have a characteristic smell, although this is lost as the scats age. To some extent, older scats can be identified on the basis of size and shape, although they are very variable and they overlap in size with Stoat at one end and Fox at the other. Shape is highly dependent on diet. Additionally, confusion may occur with Ferret and Mink scats. Scats are deposited along man-made tracks (usually dirt or stone, but not grass) and transects along these tracks (at least 1-2km in length) have been used for monitoring purposes. Work by Balharry *et al.* (1996) showed for areas with resident breeding Pine Martens that they would be '..*unlikely to find no scats if at least 2km of track [were] walked..*' and that '..*we can be 95% confident of finding four or more scats if we walk at least 3km of suitable track and seven or more if we walk 4km..*'. In areas with low population densities or containing only transitory individuals, the degree of scatting is likely to be greatly reduced, making it difficult to apply a transect approach based on field signs. Territorial behaviour in other mustelids has been shown to break down altogether at low population densities potentially making this method ineffective in some regions (Lockie 1966).

Field signs (tracking-stations) - Baited tracking stations have been used for a range of mustelid species (e.g. King & Edgar 1977) and the potential exists to employ their use in a similar manner to hair tubes and camera traps. All three methods should be evaluated during a pilot study carried out at various sites within the known Pine Marten range.

Hair tubes - The value of hair tubes is currently being evaluated by the Vincent Wildlife Trust. These would seem to be more cost-effective than live-trapping for the purposes of determining the presence of Pine Martens within an area, although their reliability needs to be established.

Mammals on Nature Reserves - Records of Pine Martens on nature reserves could be collated according to the suggestions outlined in Part III.B.6.

Garden Mammal Watch - Pine Martens may use some gardens within their Scottish range and it would be useful (for both the collation of distribution data and project profile within Scotland) to include Pine Marten on the list of mammal species to be covered by this scheme (see Part III.B.7).

18.5 POTENTIAL MONITORING SCHEMES

The 'core' Pine Marten population (with its front of range expansion) and the 'relict' populations in England and Wales should be treated in different ways. Primarily this relates to the different monitoring objectives for these areas, although apparent differences in population density would also require the use of different approaches for the different areas.

'Core' populations and front of range expansion - Sites within these areas should be monitored on a regular basis every five to seven years. Suitable habitat, as defined by Balharry (1993) and Balharry *et al.* (1996) should be surveyed within a grid of survey squares selected from the existing range in Scotland and those areas bordering the front of range expansion. The same sites should be revisited during subsequent surveys, thus providing a continuous dataset on range expansion and colonisation rates, together with the statistical benefits of repeat surveys at the same sites. Trained volunteer fieldworkers should walk 2-3km along predetermined transects, located along paths, rides and tracks within suitable habitat. All field signs (Pine Marten, Red Fox and unknown) should be recorded and collected, allowing the potential for validation work by experts or DNA analysis at a later stage. Fieldwork should be undertaken during the period when territories are thought to be most stable (February to September) and co-ordinated by a number of local organisers under the direction of a single scheme co-ordinator, presumably based at SNH. This approach would also allow the monitoring of Red Foxes within Pine Marten habitat, something that is considered important given the perceived interactions between these two species (Don Jefferies, pers. comm.). Information from other sources (e.g. road-kills) should be fed into the monitoring programme enabling the addition of new survey squares on a rolling basis, as the population continues to expand.
'Relict' populations in England and Wales - The status of 'relict' populations should be the target of focused work, with known sightings and other distribution records being followed up by intensive fieldwork using either live-trapping, camera traps, hair tubes or tracking boards, rather than field signs. In areas where Pine Martens are found to occur, there is the possibility of more detailed work (funded as separate projects) to ascertain population density, habitat use and likely population change.

Co-ordination of Pine Marten monitoring is likely to require the part-time involvement of single individuals each based at one of the four country agencies. These individuals would liaise at the national level ensuring that national work is consistent. It is thought that some professional fieldworkers would be required on a seasonal basis to undertake fieldwork when required.

18.6 RECOMMENDATIONS

1) The 'core' population and its expansion should be monitored every five to seven years using a grid of survey squares containing suitable Pine Marten habitat. These should be surveyed by trained volunteers, supported by professionals, to carry out transect counts of field signs. Transects should follow tracks and paths as detailed by Balharry *et al.* (1996) and be of 2-3km in length. Red Fox field signs should also be recorded along with those of unknown origin. A subset of collected field signs can then be examined by professionals to validate the survey results. Monitoring of the Red Fox population within areas of Pine Marten habitat would also be possible, and is desirable given the potential interactions between these two species.

2) The 'relict' populations in England and Wales should be monitored in greater detail, with recent sightings and other records being followed up by intensive fieldwork based on either live-trapping, camera trapping, hair tubes or tracking boards rather than field signs.

3) Work should be undertaken within the known Pine Marten range to evaluate the effectiveness of hair tubes, live-trapping, camera traps and tracking boards. This should be a priority, enabling application of these techniques to recommendation (2).

19. STOAT *Mustela erminea* and WEASEL *Mustela nivalis*

Stoat - Native. Widespread, major reduction in population size following the outbreak of myxomatosis in Rabbits. Population has recently undergone a partial recovery and reanalysis of Game Bag records, with trapping effort taken into account, suggests that the population is currently stable.

Weasel - Native. Widespread, population boomed after myxomatosis outbreak among Rabbit population. Game Bags indicate a decline since the early 1960s, but see McDonald & Harris (in press). Pronounced short-term fluctuations in some areas in response to availability of small mammal prey (Tapper 1979).

19.1 RECENT AND ONGOING MONITORING WORK

Game Conservancy National Game Bag Census - Potential conflicts between Stoats/Weasels and gamebird populations have led to their control on the majority of shooting estates (Day 1968; Moors 1975; Tapper 1976, 1992). Data submitted by gamekeepers on the number of Stoats and Weasels killed annually have, since 1961, been collated through the National Game Bag Census (Tapper 1992). Most of these will have been caught in tunnel traps, although a significant portion of the Stoats will have been shot.

Analysis of these data (Tapper 1992) suggests that the Stoat population underwent a period of recovery (through to 1976) as the Rabbit population recovered from the effects of myxomatosis. Since this time, the national Game Bag trend suggests a gradual population decline.

Game Bag data demonstrate two periods during the year when the number of Weasels trapped reaches a peak (March/April and August/September), with short-term annual fluctuations also evident, as Weasel populations respond to changes in the availability of Field Voles (Tapper 1979). The long-term trend in these data suggest a decline in the number of Weasels killed since 1961.

19.2 MONITORING OBJECTIVES

The monitoring of Stoat and Weasel populations is considered as being of High/Medium priority by JNCC; a result of our relatively poor understanding of the status and current population trend of these species (Paul Rose, pers. comm.).

19.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Live-trapping would allow the population census (at least of trappable individuals) and estimation of population size through Capture-Mark-Recapture (CMR) techniques (Cross *et al.* 1998). However, individual Stoats and Weasels can show selective responses to trapping, notably relating to sex (King 1975a; Buskirk & Lindstedt 1989), territory size, weather, activity and social status.

Stoats are very active and highly susceptible to damp and nervous exhaustion (King & Edgar 1977). Wooden, rather than metal or mesh traps should be used. A design (the Edgar Stoat Live-trap) is shown in King & Edgar (1977). The effects of trap position have been evaluated by Dilks *et al.* (1996).

Traps, set for at least four nights in a linear feature, should be baited with a dead mouse or chick and the entrance smeared with Rabbit gut. Traps will be most successful if operated during the mating season. Erlinge (see King & Edgar 1977) noted that, depending on population density, somewhere in the order of 30-40 hectares need to be trapped for each Stoat observed. If a CMR approach is applied then as much as 200 hectares may need to be covered with sufficient density of traps. This may require a significant amount of fieldwork effort to ensure that the traps are checked regularly (King 1975a, b)

Trapping for Weasels is most effective during the months of July and August (Rust 1968), with the traps themselves positioned along natural runways in hedgerows and ditches or, in the case of traps set in woodland, along specially-created features. Approximately one trap per 0.7 hectares is the spacing recommended by King (1973). Weasels can be trapped in a range of trap designs including wooden treadle traps, but should not be caught using traps made from wire mesh since Weasels chill readily and may damage their teeth on the mesh (King 1973).

From the published literature it appears that the only safe and humane way to handle live mustelids in the field is anaesthetisation (King 1973), although a method has been developed to mark Polecats without doing this (Birks 1997).

Kill-trapping - Kill-trapping, using tunnel traps, will provide an index of numbers caught per unit effort. However, it suffers from the same selectivity problems as seen for live-trapping. Additionally, there are other disadvantages, not least that you are killing a component of the population you are supposed to be monitoring as well as other non-target species (Hewson 1972). The removal of individuals from a population may stimulate a response in those untrapped individuals remaining, leading to a disruption of social status and dispersal behaviour. By removing territory holders a sink is created into which other individuals will move, changing the sampling of individuals from within a defined area to sampling over an unknown area. This is not ideal for monitoring purposes. King & Edgar (1977) recommend that to estimate population change by kill-trapping, a single straight line of traps, spaced at 400m intervals, should run for at least 16km through homogenous habitat (*i.e.* 50 traps).

National Game Bag Census - Essentially this approach is a form of kill-trapping, although there are clear differences in the way traps are employed by different gamekeepers, increasing variance in sampling protocol. There is currently no measure of trapping effort, making comparisons over time and between areas somewhat difficult. The value of using trapping records to monitor populations of Stoats and Weasels has been examined by McDonald & Harris (in press) who show that these records can be misleading if sampling effort is not controlled for. They found that the national decline in the numbers of Stoats trapped (Tapper 1992) was equally consistent with a reduction in trapping effort and a true population decline. Such long-term changes in trapping effort are quite likely to have occurred alongside changes in game rearing practice. There is also the question of whether Game Bag data are representative of populations in the wider countryside (see Part III.A.2).

Tracking - Tracking methods have been evaluated by King & Edgar (1977), with methods typically employing tracking stations (tunnels) containing an arrangement on the floor to record the tracks of visiting individuals. This approach provides a basic index of population status (*i.e.* proportion of tracking stations containing tracks of the study species), but this index is confused by an activity component. Because of differences in activity, one individual may visit many stations or many individuals may visit only one station, thus providing a false picture of population size. MMR recommend that tracking stations should have an entrance diameter of

8cm and should be placed in natural runways along linear features (as for live- and kill-trap placement). This approach is less-suited to habitats lacking linear features, notably upland areas. Additionally, poor weather can dramatically reduce the efficiency of tracking methods.

Hair tubes - Hair tubes are similar to tracking stations in that they record information on both population status and activity. This approach will not separate Stoat and Weasel (Stephen Harris, pers. comm.).

Camera traps - MMR note that these traps could be used to record animals running through tunnels. As with some of the other methods already mentioned, an index of population status may be confused by activity patterns, unless individuals can be identified. Individual Weasels can be identified in the hand (Linn & Day 1966) although this approach is not applicable to the current design of camera traps. It should also be noted that camera traps are expensive.

Field signs - Because of considerable overlap in faeces size and composition with other species, the use of field signs is not recommended. Additionally, the faeces are difficult to find.

BBS transect approach - (see Part II.A.1. - Mammal Monitoring under the Breeding Bird Survey). The presence of Weasels is reported from about 3-4% of BBS squares for which mammal recording forms are submitted annually, while the corresponding figure for Stoats is about 5% of BBS squares submitted annually. However, although Stoats and Weasels are thought to be widespread, they are unlikely to be encountered by fieldworkers even when present in an area. This means that there will be a strong stochastic component to the data submitted by BBS, making it unlikely that the scheme in its current form could be used for monitoring Stoat and Weasel populations. There may be the potential for BBS (or a modified mammal transect scheme) to provide ancillary data, but this requires further evaluation.

Winter Transects - (see Part III.B.3) - Compared to summer transects, the encounter rates may be increased through specific mammal visual transects operated during late winter (Stephen Harris, pers. comm.). Again, there may be a significant stochastic component in the data collected. Transects are likely to be a good monitoring technique (Stephen Harris, pers. comm.)

Sign Transects - Transects for field signs are likely to be impractical for this species, given the difficulties in separating the scats of small mustelids.

Mammals on Roads - The number of Stoats or Weasels recorded dead or alive on the road along regular survey routes could provide a basic index of population change (see Part III.B.5).

19.4 POTENTIAL MONITORING SCHEMES

For both species MMR recommend the use of camera traps at a minimum of 2,000 sites, calibrated by live-trapping at a subset of these sites. This is likely to be an extremely expensive option, given the equipment involved and the number of professional man-hours required. A far cheaper approach would be to develop the information gathered by the Game Conservancy's National Game Bag Census. As noted by McDonald & Harris (in press) this would require some measure of trapping effort to be recorded alongside the trapping returns. If this becomes possible, then Game Bag data may be available from the majority of estates contributing to the National Game Bag Census. There are other problems with Game Bags (see Part III.A.2), the most important of which (for future monitoring of Stoat or Weasel populations) is that changes in legislation regarding the control of the species' or game rearing in general may radically alter the amount of data contributed. The likelihood of such changes occurring must be considered in the context of the likely benefits of utilising the Stoat/Weasel Game Bag data at least over the short term.

Ancillary data for Stoats and Weasels may be obtainable from the BBS, road-kills and road-sighting surveys. These may not provide as detailed picture of population change, but taken together may satisfy the monitoring needs for this species. The use of hair tubes to monitor population change/activity could also provide useful monitoring data, although the feasibility of utilising this approach needs to be evaluated. Co-ordination of the road-based schemes should be carried out by a single individual, also responsible for co-ordination and development of other national schemes (see Parts III.B.2 and III.B.3).

19.5 RECOMMENDATIONS

1) Seek modification of the National Game Bag Census to allow recording of trapping effort, thus enabling trapping returns to be expressed *per unit effort*. This could form a readily applied and relatively cheap monitoring option. Monitoring of Weasels should take place on an annual basis to allow for the short-term fluctuations that result from variations in Field Vole populations (Tapper 1979).

2) Further evaluate the use of transects for monitoring purposes, notably the data generated by VWT and initially analysed by Simon Poulton.

3) Ancillary data for both Stoat and Weasel could be gathered through the Mammals on Roads scheme (Part III.B.5).

20. POLECAT *Mustela putorius*

Locally common throughout Wales with populations recorded in 12 to 15 counties within England. Population and range appear to be expanding.

20.1 RECENT AND ONGOING MONITORING

National Game Bag Census - The National Game Bag Census has a small amount of data (from 31 estates) on the numbers of Polecats shot by gamekeepers, although the species was not specifically added to the National Game Bag Census record until 1997 (Tapper 1992). The inclusion of the species on Schedule 6 of the Wildlife and Countryside Act means that even fewer records are now received. There is also potential confusion between Polecats and Feral Ferrets.

Vincent Wildlife Trust survey - Live-trapping was undertaken in selected 1km squares within a sample area covering 58 10km squares. The distribution of sample sites was not random, but selected for convenience of volunteers recruited through the Wildlife Trusts. The criteria used for selecting squares were (1) that they lay within the known range, (2) that they were predominantly rural and (3) that they avoided areas of ground-predator control. Trapping was carried out during the winter (1993-1996). Baited single-entry cage traps were used with each 1km square containing 16 traps set for seven consecutive nights. Volunteers were trained and initially accompanied by an expert. Eight thousand, seven hundred and twenty trap nights resulted in 96 captures of 76 individuals.

Road-deaths - Small numbers of Polecats are killed annually on the roads. These reports currently provide important distribution information and contribute to the monitoring of introgression between Feral Ferret and Polecat (see below).

Genetic Monitoring - Ongoing work on carcasses submitted to the Vincent Wildlife Trust is examining the introgression occurring between Feral Ferret and Polecat.

20.2 MONITORING OBJECTIVES

The restricted distribution of the Polecat together with its gradual colonisation of 'fringe' areas points to a targeted monitoring programme rather than its inclusion in part of a wider scheme. The low densities at which this species occurs (Blandford & Watson 1991; The Populations Review), and the range of habitats it occupies, makes it difficult to monitor without the commitment of significant resources. Distribution monitoring is a high priority as is the collation of detailed information on habitat preferences and the degree of hybridisation with Feral Ferrets.

20.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Polecats can be captured using single-entry cage traps baited with a dead-day-old chick. Each 1km square to be trapped should be divided into a grid of 16 250x250m cells with one trap placed within each cell. These should be left for seven consecutive nights with the bait being replaced on day four. Trapping should be carried out between October and March, a time of year when the Polecat population is likely to be stable. Although labour-intensive, Birks (1997) has shown that with training volunteers can operate the trapping grid and weigh, mark and release trapped Polecats without sedating them. The number of individuals caught per unit effort is low (0.01 captures per trap night) suggesting potential motivational problems in areas where Polecats are scarce.

Game Bags - As noted above, this approach is unsatisfactory for monitoring purposes. A recent questionnaire based study, centered on the main Polecat range, demonstrated that 88% of gamekeeper respondents had experience of Polecats (Packer & Birks, 1999).

Indirect counts - Identification of scats and tracks is difficult, making them unreliable for monitoring purposes. Additionally, there may be variation in scatting activity between seasons, habitats and population density as demonstrated for other mustelid species. Hansen & Jacobsen (1999) have demonstrated that faeces of Otter, Mink and Polecat can be separated using DNA analysis, although this approach would probably be prohibitively expensive for monitoring purposes.

Road-deaths - As MMR note, this technique is useful for monitoring the distribution and spread of this species. If carcasses are collected then they can be analysed using DNA extraction techniques to monitor the introgression between Ferrets and Polecats.

Mammals on Nature Reserves - Records of Polecats on nature reserves could be collated according to the suggestions outlined in Part III.B.6.

20.4 POTENTIAL MONITORING SCHEMES

A targeted monitoring programme concentrating on the boundary of the core range would appear to be the most cost-effective way in which to monitor the increase in range of this species. Other work should be undertaken within the core range to monitor any future impacts that may influence the population. Significant resources need to be committed to the monitoring of this species, given that intensive live-trapping is the only workable option. The approach outlined and tested by Birks (1997) should be used as the basis for future work and costs of fieldwork based on this approach, mixing a single professional organiser with volunteer fieldworkers.

20.5 RECOMMENDATIONS

1) Live-trapping of this species should be undertaken both within the core range and along the boundary of its current range expansion. This should follow the protocol outlined by Birks (1997).

2) Material removed from trapped animals, along with that from road-kills, should be analysed to determine the degree of introgression between Feral Ferrets and Polecats. This is currently being investigated by the Vincent Wildlife Trust.

3) Ancillary data may be available from the Mammals on Nature Reserves and Mammals on Roads schemes within the current range, although these alone may not be of sufficient detail or quantity to provide adequate monitoring for this species.

21. FERAL FERRET *Mustela furo*

Escaped individuals can be encountered across the UK making it difficult to detect established feral populations. Island-based feral populations have occurred on Mull, Lewis, Bute, Arran and the Isle of Man (Blandford & Walton: in The Handbook), Shetland, Islay, Harris, Mull and The Uists (The Populations Review).

21.1 RECENT AND ONGOING MONITORING

None.

21.2 POTENTIAL MONITORING TECHNIQUES

National Game Bag Census - Feral Ferrets are likely to be controlled on shooting estates as part of the general management of mustelid predators (Tapper 1992). Although the National Game Bag Census does not currently report on the number of Feral Ferrets killed annually by gamekeepers, the scheme could do so in the future. Confusion with the legally protected Polecat may reduce the number of individuals reported in some areas.

Vincent Wildlife Trust Polecat survey - Feral Ferrets may be caught during the live-trapping of Polecats providing some data on the occurrence of this species (see Polecat).

Road-deaths - Small numbers of Feral Ferrets are likely to be killed annually on the roads. These reports could provide important distribution information and contribute to the monitoring of introgression between Feral Ferret and Polecat (see below).

Genetic Monitoring - Ongoing work on carcasses submitted to the Vincent Wildlife Trust is examining the introgression occurring between Feral Ferret and Polecat.

Breeding Bird Survey/Winter Transects/Garden Mammal Watch - Although they are rarely encountered, validated reports of Feral Ferrets could contribute some ancillary information on distribution. However, it would not be possible to monitor population trends effectively by these methods.

21.3 MONITORING OBJECTIVES

The Ferret is an introduced species, fully interfertile with the Polecat and established in some areas. Information is needed on this species because of its potentially deleterious effects on native fauna. This is twofold:

- Competition and hybridisation with Polecats on the mainland.
- Predation, on islands from which Polecats are naturally absent.

We suggest that this leads to four monitoring objectives

- To determine trends in the frequency of occurrence of Ferrets at liberty on the mainland.
- To detect the establishment of Feral Ferret populations on the mainland.
- To report on occurrences of Feral Ferrets at liberty on islands which have no established populations.
- To establish trends in abundance of Feral Ferrets on islands on which they are currently established.

21.4 POTENTIAL MONITORING SCHEMES

The presence of escaped individuals over such a large area makes it difficult to monitor the general status of this species in mainland Great Britain. Information on the occurrence of Feral Ferrets should be gathered using all available schemes (e.g. road-kills, Garden Mammal Watch, Winter Transects, Polecat studies, etc.). If the National Game Bag Census is to be used in the monitoring of other mammal species, then it may be worthwhile asking estates to report on the numbers of Feral Ferrets killed annually.

Populations of Feral Ferrets established on islands could be monitored using a live-trapping approach similar to that devised for Polecat (see Polecat species account), although the density and ranging behaviour of ferrets on these islands may differ. Trapping for monitoring purposes should be considered alongside trapping for removal purposes.

21.5 RECOMMENDATIONS

1) Distribution data on Feral Ferrets should be gathered through other single species or multi-species schemes wherever possible.

2) The value of trapping island populations for monitoring, rather than for control should be considered before any decision to monitor such populations is made.

3) The National Game Bag Census should be extended to allow submission of records of Feral Ferrets.

4) Analysis of carcasses to examine introgression between Feral Ferret and Polecat should continue through work co-ordinated by the Vincent Wildlife Trust.

22. AMERICAN MINK *Mustela vison*

The American Mink population has been undergoing a general expansion in range and numbers across the UK, although recent evidence suggests that many populations are in decline, probably as a result of competition with a recovering Otter population.

22.1 RECENT AND ONGOING MONITORING WORK

Department of Agriculture and Fisheries for Scotland Enquiry - An enquiry into the changing status of American Mink in Scotland was carried out using data from mink farmers, gamekeepers, museums, naturalists, Government Pest Officers and Department of Agriculture trapping records. This analysis demonstrated the rapid spread of American Mink since the early 1960s and suggested that the existence of suitable habitat and abundant food supplies would allow further expansion in numbers and distribution (Cuthbert 1973).

Forest & Wildlife Service Enquiry - Data on the status of American Mink throughout Ireland (including Northern Ireland) were gathered from all available sources as part of an enquiry undertaken by the Forest & Wildlife Service. This information was supplemented by a survey carried out between 1984 and 1986. Trained fieldworkers visited selected 10km squares and walked a minimum 3km length of representative rivers, recording field signs of both American Mink and Otter (Smal 1988). Some 167 of the 312 watercourses surveyed (53.5%) showed the presence of American Mink. It should be noted that there were variations in the amount of effort expended in each square, and that this may have introduced some bias to the overall results.

Vincent Wildlife Trust National Otter Surveys - Field signs (scats) of American Mink have been recorded during each of the three Otter surveys carried out in England. The reports on these surveys (Lenton *et al.* 1980; Strachan *et al.* 1990; Strachan & Jefferies 1996) contain maps highlighting those 10km squares (within the survey grid) with American Mink present. Examination of the data suggests a continued expansion of the American Mink population into the Midlands and south-east England, with evidence of a decline in the south-west most probably linked to the recovering Otter population (Strachan & Jefferies 1996). During the initial survey, recording effort along the 600m transects was terminated once signs of Otters were found and this may have resulted in some stretches containing Mink not being recorded as positive sites, simply because the Mink field signs had not been reached in the linear transect. Transect length would have varied between sites depending upon the distance at which Otter spraints were found, thereby introducing an element of spatial bias into the Mink dataset in terms of sampling effort.

Vincent Wildlife Trust Water Vole Survey 1989/1990 - Evidence of American Mink was recorded as a component of the VWT Water Vole survey, enabling the distribution of this introduced species to be determined nationally. One thousand and twenty-two (34.4%) of the 2,970 sites examined for Water Voles showed evidence of American Mink presence (Strachan & Jefferies 1993).

Vincent Wildlife Trust Water Vole Survey 1997/1998 - A repeat of the 1989/1990 survey, again recording the presence of American Mink at sites being surveyed for Water Voles. The data are currently being analysed and a report is due to be published at the end of 1999.

Environment Agency - The Environment Agency's '*River Habitat Survey*' documents the presence of American Mink in conjunction with the collation of data on habitat and river features. Additional training may be needed to ensure that RHS recorders can identify field signs (see Part V).

Wildlife Trusts and other organisations - A number of projects examining the status and distribution of American Mink are being carried out nation-wide, many as components of projects on Otters and Water Voles.

22.2 MONITORING OBJECTIVES

The American Mink was first recorded breeding in the wild over 30 years ago, since when it has become an established part of the UK fauna (Birks 1990). It is only recently that researchers and policy makers have begun critically to examine the effects of its establishment (Birks 1990; Woodroffe *et al.* 1990). Consequently, there is a clear need to undertake detailed monitoring of the distribution, status and likely impact of the species within the United Kingdom. Specifically, information should be gathered by:

a) monitoring the distribution and spread of American Mink within individual catchments, especially where catchments contain populations of Water Voles or Otters;

b) monitoring how the distribution and abundance of American Mink is changing in relation to recovery in the Otter population and loss of Water Vole populations. If data can be gathered relatively easily and cheaply (possibly as a component of other work) then examination of the interactions between American Mink, Otters and Water Voles may be possible.

c) monitoring the distribution and abundance of American Mink on islands where they may constitute a threat to seabird colonies or other wildlife.

This would suggest that monitoring should be carried out through the proposed national Otter and Water Vole surveys.

22.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - American Mink can be trapped in commercially available baited traps (Dunstone 1993). These should be positioned close to the water's edge with the entrance facing downstream and some degree of camouflaging employed. Traps can be positioned at a density of one every 200m along a linear feature. Trapping success varies seasonally, with the greatest chances of capture being during the mating season (January to April) or when juveniles are dispersing (September to November). For monitoring purposes trapping should be restricted to the mating season to remove the effects of short-term variability in productivity. There are various sex and age biases in terms of the ease with which individuals can be captured (Dunstone 1993).

Direct counts - The direct sighting and correct identification of American Mink are difficult within riverine habitats, but may be more readily applied in the few areas where the species occurs in coastal habitats.

Indirect counts - As with Otters, the presence of American Mink at a site may be determined from field signs, specifically faeces. With a small amount of training these can usually be separated from those of Otter, but separation from Polecat can be more difficult in certain circumstances. The consistency and colour of Mink scats depends on diet and on how fresh the scat is (Lawrence & Brown 1973). Hansen & Jacobsen (1999) have demonstrated that faeces of the three species can be readily separated using DNA analysis. Mink scats are usually deposited at conspicuous sites around dens, on prominent rocks, under bridges and on fallen tree trunks. There is some evidence from the literature that scat deposition varies seasonally with scats significantly more likely to be found during the summer and autumn (Wise *et al.* 1981). This is likely to be a result of changes in Mink activity and scat decay rates with season.

Game Bags - Game Bags are not likely to offer a reliable monitoring option for this species, since it is difficult to standardise information on recording effort (see Part III. A.2).

Road-deaths - As MMR note, road kills could provide incidental records of distribution, indicating where Mink had moved into new areas before other monitoring methods showed them to be present.

Mammals on Nature Reserves - Records of American Mink on nature reserves could be collated according to the suggestions outlined in Part III.B.6.

Waterways Breeding Bird Survey (WBBS) - American Mink, along with Otter and Water Vole, is one of the few species that could be monitored through the WBBS, although it should be stressed that this survey is currently still in its pilot stages and may not have funding for continuation beyond the end of the pilot period. Additionally, the survey is designed to survey a range of bird species associated with riparian habitats and is therefore not ideal for the transect monitoring of Mink field signs.

22.4 POTENTIAL MONITORING SCHEMES

Current monitoring of the Mink population takes place through the existing Otter and Water Vole surveys. Given the interactions between these three species it makes sense to continue recording Mink distribution as a component of these two schemes. This approach would provide a greater level of detail regarding the species interactions than would be possible were Mink to be surveyed in isolation.

Monitoring of American Mink populations should therefore remain a component of the schemes developed for Otter and Water Vole, either as a continuation of the existing monitoring methods or with the incorporation of a greater volunteer component. The Mammal Society has demonstrated that volunteers can be trained to identify Mink scats and that a sufficient network of observers can be generated for most of the UK. Professional recorders would be required for the more remote regions and technical support would be needed to help with data analysis and the identification of problem scats. Co-ordination of Mink monitoring would depend on decisions made about the co-ordination of Otter and Water Vole.

22.5 RECOMMENDATIONS

1) Monitoring of Mink distribution and abundance (through an index of abundance) should be undertaken as components of the proposed National Otter and Water Vole Schemes.

2) Populations on islands should be monitored as a separate scheme with the objective of determining distribution and likely threat to seabird colonies or other wildlife.

3) Ancillary data should be collected through the proposed Mammals on Roads (Part III.B.5) and Mammals on Nature Reserves (Part III.B.6) schemes.

23. BADGER *Meles meles*

A general increase in numbers has been witnessed this century, with particularly noticeable increases in some local areas during the last two decades.

23.1 RECENT AND ONGOING MONITORING WORK

National Badger Survey (report based) - The National Badger Survey was instituted in 1963, with the aim of establishing the distribution of Badgers in Britain. County Badger Recorders were asked to submit details of all setts known to them, together with information on sett size, position and soil characteristics. Records of over 4,300 setts were received including additional information from the Forestry Commission and the Biological Records Centre. These data were then used to establish the total likely number of setts per 10km square, allowing some interpretation and mapping of regional variations in sett density (Clements *et al.* 1988).

The data used in the National Badger Survey were accumulated over many years, meaning that some of the earlier records would have been out of date by the time the analysis was carried out. This may have been a particular problem in this instance because of the upsurge in illegal persecution by Badger diggers in the 1970s and the TB control measures being carried out by MAFF in the south-west. A further problem results from the fact that different surveyors may have been working to different standards, specifically with regard to the types of sett being recorded and to the level of effort put into gathering records.

National Badger Survey 1985-1988 (fieldwork based) - The first fieldwork based national survey of Badgers was carried out between the end of 1985 and the beginning of 1988, covering 2,455 1km squares. These squares were selected using a stratified approach with squares allocated within strata based on the 32 land classes of the ITE's Land Classification Scheme (Bunce *et al*. 1996). Within each square, fieldworkers followed standard methods recording Badger setts and signs of Badger activity. The results suggested that there were 42,891 (±3,851 ((95% confidence limits) Badger social groups, with densities presented for each of the 32 ITE Land Classes (Cresswell *et al.* 1990). Additionally, the data were used to demonstrate regional variations in distribution (Cresswell *et al.* 1989).

It is worth noting that the data were reanalysed following changes to the ITE Land Classification, although this resulted in only a slight change to the estimate of the number of Badger social groups (Reason *et al.* 1993). Data from this survey were also used by MMR as part of an analysis to assess the power of this scheme to determine trends in different regions (MMR, p63-66).

Badger Survey of Northern Ireland - A similar approach to that used by Cresswell *et al.* (1990) was employed in Northern Ireland (Feore, Smal & Montgomery 1993), and in the Republic of Ireland (Smal 1995).

National Badger Survey 1994-1997 (fieldwork based) - Some 93% of the original 2,455 Badger survey squares covered between 1985 and 1988 were resurveyed as part of the second National Badger Survey (Wilson *et al.* 1997) allowing an estimate of change in the Badger population to be determined. This approach was adopted for two main reasons. Firstly, because Badger setts are not randomly distributed; '*.. resurveying the same 1km squares, rather than surveying a new random sample of 1km squares, is best suited for detecting change in data where there are large 95% confidence limits about the population means*.' (Wilson *et al.* 1997).

Secondly, repeatedly surveying the same squares allows the fate of individual setts to be monitored and those factors leading to sett loss or gain to be quantified. In addition to the 2,271 squares resurveyed, a further 307 new squares were included, enlarging the sample database for future resurveys.

Changes to the Land Classification Scheme (Bunce *et al*. 1996) meant that the data were analysed according to seven land class groups. The results produced an estimate of 50,241 (±4,327 ((95% confidence limits) social groups, an increase of 24% over the previous survey. Regional variations in both the number of social groups and levels of population change were also examined, as was the loss of individual setts.

23.2 MONITORING OBJECTIVES

Although the Badger population has been demonstrated to have increased within much of its existing range, there are substantial areas of seemingly suitable lowland Britain from which the species is absent. Even if the current degree of legal protection continues, it is likely that recolonisation of all suitable Badger habitat will take many decades. In view of this, and because of the susceptibility of Badgers to infection with Bovine TB (Cheeseman *et al.* 1981, 1989), persecution and habitat perturbations (Harris *et al.* 1992) it is important to continue regular monitoring of distribution and population size, the latter being based on the number of social groups. Such information should be considered as being of primary importance if changes in legislation are to be addressed in the future. Harris *et al.* (1992) outline the information required for Badger monitoring, namely:

(a) an estimate of the number of Badger setts in Britain;
(b) the distribution of setts per social group;
(c) the likely effects of land use change on Badger numbers;
(d) the potential effects of population perturbations on reproductive success;
(e) the effects of population density on group structure;
(f) the current rate of annual mortality.

In actual fact, much of this information has a modelling purpose, which could be considered additional to baseline monitoring. The baseline monitoring should consider changes in abundance and the number of social groups.

23.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Badgers can be caught using cage traps baited with peanuts, in snares or with hand-held nets, the latter being used when Badgers are foraging within open areas at night (Cheeseman & Mallinson 1980; Harris 1982). Trapping is labour intensive and would not be practical at the national level unless used as part of a calibration exercise.

Direct Counts - Direct counts of individual Badgers can be made by watching active Badger setts (MMR). These should be watched either at dawn or dusk, unless night-vision equipment is available allowing watching to be undertaken throughout the night. MMR evaluated whether the accuracy of the number of animals counted improves with (a) the number of consecutive nights on which counting occurs and (b) with the number of observers (MMR: p112-116). It was found that accuracy increased with the number of nights counted, but that the use of multiple observers opened up the risk of double-counting the same individuals. It should also be noted that Badger activity is influenced by weather conditions (Cresswell & Harris 1988) and that emergence times may differ between habitats (Harris 1982).

Direct counts of Badgers could also be employed as a component of a Garden Mammal Watch approach (see Part III.B.7), with the presence/absence of Badger sightings in gardens (or maximum counts) being used as a basic index.

Road-deaths - Records of Badgers found dead on the road have been examined by several researchers (Killingley 1973; Jefferies 1975; Neal 1977; Davies *et al.* 1987). Although there are some differences between the conclusions of these studies, there appears to be a bimodal distribution to the seasonal pattern of Badger road deaths. In a study of 984 carcasses from southern England, Davies *et al*. (1987) found a similar seasonal pattern for both males and females, with peaks in February-April and July-August.

Indirect counts - Various field signs can potentially be used to monitor Badger populations including setts, latrines and tracks (Harris *et al.* 1989; Wilson *et al.* 1997). Badger setts are perhaps the most conspicuous of the field signs, and have been used as a measure of the number of social groups (Clements *et al.* 1988; Wilson *et al.* 1997). Since a Badger social group can have more than one sett within its range (active or inactive) it is important that different types of sett and their function can be distinguished. The following guidelines to classifying sett type have been established by Wilson *et al*. (1997):

main setts - '.. *these usually have a large number of holes with large spoil heaps, and the sett generally looks well-used..*'

annexe setts - '.. *these are often close to a main sett, usually less than 150 metres away, and are usually connected to the main sett by one or more obvious well-worn paths. They usually have several holes, but may not be in use all the time even if the main sett is very active..*'

subsidiary setts - '..*these often have only a few holes .. They are at least 50 metres from a main sett, and do not have an obvious path connecting with another sett. They are not continuously active..*'

outlying setts - '..*these usually only have one or two holes, often with a little spoil outside the hole, have no obvious path connecting with another sett, and are only used sporadically..*'

The number of main setts in an area has been used to indicate the number of social groups. Attempts by MMR to relate the number of badgers using a sett to sett characteristics (see MMR: 112-116) suggest that it is not possible to use this approach to predict group size. However, other researchers state that there is a very strong relationship between group size and features of sett size and pattern of use (S. Harris, pers. comm.). A mean of 5.9 adult Badgers per social group was used by Cresswell *et al.* (1990) to approximate the size of the national Badger population. However, it was accepted that there is great variation in the number of Badgers making up a social group. Recent work has enabled the production of more precise estimates of social group size in different parts of the UK (Stephen Harris, pers. comm.).
Badgers regularly use a number of dung pits grouped at latrine sites. These have a territorial function (Kruuk 1978) and the number of latrines used by a group has been demonstrated to be related to group size. Even stronger associations can be detected where the number of individual dung pits or amount of faeces per kilometre of linear feature have been used (MMR, 115-116).

However, Stephen Harris believes the MMR data to be flawed and that this technique only works in areas with high Badger densities. At low densities Badgers do not use latrines or dung-pits.

23.4 POTENTIAL MONITORING SCHEMES

Several monitoring options could be successfully applied to the Badger population and each of these is dealt within in turn.

Periodic National Surveys - The pre-existing grid of Badger survey squares, with the two national surveys already completed, forms an ideal basis for future monitoring of Badger populations. The approach detailed by Wilson *et al.* (1997) employs a suitable sampling protocol, including an element of stratification, which delivers the ability to monitor population change with the required degree of power. However, considerable professional effort went into covering some of the more remote strata (containing fewer Badgers) and it should be possible to use a more effective stratification to reduce the level of coverage in these areas while maintaining power. Consideration should be given to running simulations based on existing datasets to determine to what extent the existing stratification can be modified to achieve better sampling efficiency. It may prove possible to reduce the overall sample size and distribution of samples between strata. The other distinct advantage of continuing with the approach adopted in the most recent survey is that resurvey of the existing sites provides greater statistical power and continuity of historical information on changes to individual setts.

The volunteer involvement in this work increases the cost-effectiveness of the monitoring, allowing a large number of squares to be covered. Reducing the number of sites covered is unlikely to increase cost-effectiveness significantly, although it could reduce the number of volunteers requiring training and thus some of the associated costs.

Further consideration should be given to refining our understanding of the relationship between latrine/dungpit counts and social group size. This could increase the predictive power of using such counts to estimate population size rather than relying on estimates of the number of social groups. Wilson *et al.* (1997) note that changes to the Badger population can occur in two ways, either (a) a change in the number of social groups or (b) a change in the number of Badgers within social groups. There is '.. *a general perception that the number of social groups only increases slowly, particularly in areas of high population density*.' Although such changes might be slow, they are likely to reflect a long-term increase in Badger population size. However, if it is possible to get an accurate estimate of the number of Badgers directly, through latrine/dungpit counts, then it could offer the opportunity to monitor shorter-term changes in group structure that may result from other factors (note the problems outlined above). Although this work may be at the cost of other monitoring options it does offer the potential to monitor any factors that may reduce the Badger population without a corresponding change in the number of social groups (e.g. some form of disease).

Badger road deaths - The Badger is one of the species considered for inclusion in the monitoring of animals seen crossing roads or found dead on roads, by recorders driving regular routes (see Part III.B.5). This approach could generate a basic index providing ancillary information on a more regular basis than that produced by periodic (10-yearly) national surveys.

Garden Mammal Watch - The Badger is one of the species considered for inclusion in the monitoring of mammals recorded in gardens (see Part III.B.7). An index based on presence/absence or maximum counts (gathered on a weekly or monthly basis), could be established following the approach adopted for the BTO's Garden Bird Watch. This could also allow the extended monitoring of this component of the national population. There are few Badgers actually using urban areas, although a few more use gardens on the edges of villages and small towns. Badger use of gardens varies seasonally, often in relation to rainfall (Stephen Harris, pers. comm.).

23.5 DEVELOPMENT AND VALIDATION STUDIES

Simulations based on existing datasets should be used to determine to what extent the stratification used for the most recent Badger survey can be modified to achieve better sampling efficiency. It may prove possible to reduce the overall sample size and distribution of samples between strata while still maintaining the required power to detect a trend of 25% over 25 years.

23.6 RECOMMENDATIONS

1) The current format of the National Badger Survey should be maintained with the resurvey of existing sites every 10 years. The survey interval could be adjusted if required, this being an issue that should be examined by modelling data from the two surveys to establish how sample size and sampling interval can be adjusted to maximise survey efficiency and the power to detect the required levels of change.

2) Work examining the relationship between social group size and latrine characteristics should be continued to establish whether this approach offers increased predictive power. The flaw with this approach highlighted by Stephen Harris (pers. comm.), i.e. that there is no latrine production at low population densities, requires further discussion. This problem may not preclude the collation of valuable data on established populations.

3) Ancillary monitoring data should be gathered through schemes based on the Mammals on Roads scheme (Part III.B.5) and Garden Mammal Watch (Part III.B.7), and on records of Badgers within gardens. Harris (Harris 1984; Harris & Cresswell 1987) has demonstrated the different territoriality of urban badgers and monitoring of Badgers in gardens may make an important contribution to the overall monitoring of this species. This ancillary data would provide more regular information than that from a 10-yearly national survey.

24. OTTER *Lutra lutra*

Widespread, but absent from much of central England and central belt of Scotland. Population recovering from historical decline, now showing expansion in range and numbers with consolidation most pronounced in areas with already established populations.

24.1 RECENT AND ONGOING MONITORING WORK

National Otter Surveys - England - Baseline survey work by the Vincent Wildlife Trust was carried out in England between 1977 and 1979, covering 2,940 full survey sites. These were distributed at approximately 5km intervals along each waterway, coast or lake/reservoir shore, within a grid of alternate 50km squares (north-west and south-east diagonals of each 100km square of the national grid. This gave a mean frequency of six sites per 10km square, with the sites themselves being 600m in length. Otter signs were found at 170 (5.78%) of these (Lenton *et al.* 1980). A second survey was undertaken between 1984 and 1986, rechecking the 2,940 original sites and an additional 248 sites (Strachan *et al.* 1990), during which Otter signs were found at 286 sites (8.97%). The most recent survey (1991-1994) examined the same 3,188 sites as in 1984-86, revealing Otters signs within 706 (22.15%) of them (Strachan & Jefferies 1996). A comparison of the results for those sites covered in all three surveys suggests a 304% increase in 14 years.

National Otter Surveys - Scotland - Survey work in Scotland has been carried out by the Vincent Wildlife Trust largely in parallel to that in England (1977-1979, 1984-1985, 1992-1994). The baseline survey work covered 4,636 sites (Green & Green 1980) with 57% of these sites being resurveyed during the second survey (Green & Green 1987). Sites surveyed during the second survey were those showing evidence of a suboptimal distribution from the baseline survey.

National Otter Surveys - Wales - Otter survey work in Wales again parallels that in England (1977-1978, 1984-1985, 1991) with baseline work suggesting that 20% of survey sites were occupied (Crawford *et al.*, 1979). Repeat survey work was carried out in 1984-1985 (Andrews & Crawford 1986) and 1991 (Andrews *et al.*, 1993) with the proportion of 'positive' sites rising to 38% and 53% respectively.

National Otter Surveys - Northern Ireland - Northern Ireland was surveyed as part of an all-Ireland sample survey between 1980-1981 (Chapman & Chapman 1982). Of the 2,177 sites covered across the whole of Ireland, Otter signs were found at 92%.

All these national surveys employed a similar methodology: 'full survey sites' were examined by a surveyor who walked one bank of a watercourse for up to 600m searching for Otter spraints. During the earliest surveys once a spraint was found the search was terminated. During successive surveys sites were revisited at approximately the same time of year to reduce potential seasonal bias.

National Water Vole Surveys - The presence of Otter signs was recorded as part of the survey work carried out during the two national Water Vole surveys (Strachan & Jefferies 1993). During the most recent Water Vole survey an attempt was made to determine whether Otter distribution could be adequately monitored using the Water Vole grid. This demonstrated that, although there were some similarities within the core Otter range, in most cases the differences were marked suggesting that the Water Vole sampling design was unsatisfactory for Otters (Don

Jefferies, pers. comm.). There is very little overlap between those sites selected for the Water Vole survey and those selected for the Otter survey. This is largely a result of the different habitat requirements of the two species.

Environment Agency - The Environment Agency's '*River Habitat Survey*' documents the presence of Otters in conjunction with the collation of data on habitat and river features. Additional training may be needed to ensure that RHS recorders can identify Otter spraints. In addition to this, the Environment Agency is currently funding another Otter survey of England, to be based on the existing grid of squares used during the VWT surveys. Fieldwork will be carried out by the Environment Agency's own Otter Officers (based regionally) with sites revisited at a similar time of year to that used in the previous studies.

Wildlife Trusts - A large number of projects examining the distribution and status of Otters have been established nation-wide. These employ a range of different methods, reflecting their different objectives, and are outlined in The Mammal Society's *Current Projects.*

24.2 MONITORING OBJECTIVES

A number of the objectives laid out in the JNCCs '*Framework for Otter Conservation in the UK 1995-2000*' require the input of data acquired through monitoring. This requirement for monitoring data is identified within the following action plan aims:

> 5.5.4. *to develop and implement methods to estimate Otter numbers and permit population modelling.*
>
> 5.5.5. *to monitor populations and distribution of Otters throughout the UK, including local survey to monitor the expansion of fringe populations.*
>
> 5.5.6. *to pass information gathered during survey and monitoring of this species to JNCC in order that it can be incorporated in a national database and contribute to the maintenance of an up-to-date Red List.*

Taken together, these aims suggest that monitoring should be targeted to towards (a) those populations on the edge of the current range of expansion and (b) those areas where population consolidation is being prevented by pollutant levels within specific catchments (Mason & Macdonald 1992). Additionally, the interactions between Otters and Mink suggests that attention should be given to areas where these two species occur together. Continuation of the periodic national surveys would provide information of value for (a), and to a lesser extent (b), but more detailed locally based work would be needed to examine the interactions between Otters, pollution and Mink.

24.3 POTENTIAL MONITORING TECHNIQUES

Live-trapping - Otters can be trapped in box traps (Kruuk 1995; Durbin 1998) baited with fresh spraints (MMR) placed near well-used sites. However, this method is time-consuming and not readily applied to a species living at low densities.

Direct Counts - MMR note that direct sightings may give a more accurate estimate of abundance than sign surveys on some islands, presumably stemming from the work of Kruuk *et al.* (1989).

Indirect Counts - The presence of Otters at a site may be determined from various field signs including sprainting sites, holts, tracks, runways and individual spraints themselves. Of these, spraints provide the best indication of Otter status within a given area (Jenkins & Burrows 1980; Mason & Macdonald 1987), having a territorial function. Otter spraints are characteristic and can be readily separated from Mink scats by observers with only a small amount of training (Gillie Sargent, pers. comm.). Additionally, it has been demonstrated that Otter faeces can be distinguished from those of Polecat and Mink through the use of DNA analysis (Hansen & Jacobsen 1999). Bas *et al.* (1984) found that most spraints were located in places that were densely wooded or well-wooded, with spraints deposited on boulders, under trees, on tree trunks and tussocks. However, sprainting behaviour appears to differ between habitat types and the implications of this for spraint decay rates should be considered (Jenkins & Burrows 1980; Kruuk *et al.* 1986; Kruuk & Conroy 1987; Mason & Macdonald 1987). The distribution of spraints appears to reflect centres of activity and points of contact with other Otters (Green *et al.* 1984).

Otter spraints appear to offer an ideal means by which the presence of Otters at a site can be established. The number of spraints (or spraint density) can be used to determine Otter abundance (or activity), although this approach may be less suitable in coastal habitats. Kruuk *et al.* (1986), working on Shetland, could find no correlation between sprainting and the frequency of use of an area by Otters and concluded that their findings cast '..*doubt on the use of spraint surveys as a method to assess habitat utilisation by Otters'*. However, coastal Otters may show different sprainting behaviour to riverine populations. Mason & Macdonald (1987) note that the demonstrated seasonal cycle in sprainting activity (Erlinge 1968; Mason & Macdonald 1986) may '..*invalidate any proposed relationship between spraint numbers and Otter populations*..' Importantly, these authors go on to assert that '..*the level of variation in sprainting at sites between catchments can be such that, providing the sample size is sufficient, the technique can be used broadly to define the status of an Otter population.*' Therefore, with large enough sample sizes, spraint density may provide a broad indication of population status and, as Mason & Macdonald (1987) note, '..*such data may become more valuable when part of a monitoring programme, rather than a single survey*.' These sentiments are echoed by Jefferies (1986) who later demonstrated correlations between spraint density and percentage occupancy of survey sites for the most recent Otter survey in England (Strachan & Jefferies 1996).

Kruuk *et al.* (1989) found that in coastal habitats there is a relationship between the number of holts and the number of Otters (see MMR for elaboration).

Game Bags - Hunting records from packs of otter hounds have been used to illustrate the historical decline of the Otter (Chanin & Jefferies 1978). However, the legal protection currently afforded to the Otter and the cessation of hunting by this method prevent the possibility of using bag records as a monitoring tool.

Road-deaths - Records of Otters killed on roads can provide some information on distribution (see objective 5.5.5. in *Framework for Otter Conservation on the UK 1995-2000*) and on various aspects of physiology and toxicology (Kruuk *et al.* 1997). Although this approach is not likely to provide information of the type required for monitoring purposes, it could be used to pick up records of Otters as they move into new areas, before the population establishes itself at a level where it could be detected through other monitoring methods.

Mammals on Nature Reserves - Records of Otters on nature reserves could be collated according to the suggestions outlined in Part III.B.6.

Waterways Breeding Bird Survey (WBBS) - Otter, along with Mink and Water Vole is one of the few species that could be monitored through the WBBS, although it should be stressed that this survey is currently still in its pilot stages and may not have funding for continuation beyond the end of the pilot period. Additionally, the survey is designed to survey a range of bird species associated with riparian habitats and is therefore not ideal for the transect monitoring of Otter field signs.

24.4 POTENTIAL MONITORING SCHEMES

Clearly, there are a number of options available which can be used to achieve the monitoring objectives. Given that a grid of survey sites is well-established and that three national surveys have been undertaken (with a fourth about to begin - Environment Agency), it would seem unwise to dismantle what is already an adequate monitoring system without good reason. The historical data available from the VWT sites provides information on population change as well as suggesting likely reasons for that change. The detailed information on Otter/Mink interactions that has come from revisiting the same VWT sites in each survey could not have been achieved had different sites been selected randomly each time. Continuity is important, not only for this reason, but also because it allows small changes in the Otter population to be monitored more effectively by reducing the variation associated with selecting a new sample of squares each time a survey is carried out (see Part II).

Therefore, a different monitoring scheme should only be used if the current scheme fails to provide sufficient data for monitoring or if it were not economically feasible to continue funding such a large multi-annual programme. The current scheme delivers information identifying trends in the Otter population with acceptable levels of precision, demonstrating the change in range and highlighting those areas where the population is not consolidating as effectively as elsewhere. It therefore satisfies the primary objective, although it is expensive to fund. Consequently, a replacement scheme could be argued for on economic grounds if it were able to deliver adequate monitoring data at a greatly reduced cost. This would also have to be offset against the loss of an already existing long-term dataset. It should also be noted that the low density of the Otter population in some areas would require sampling as intensive as that employed for the VWT surveys, potentially suggesting that a more economical approach may compromise data quality.

The replacement suggested by MMR has the potential to provide more detail than the current scheme, but this additional material is likely to be surplus to the basic requirements of a monitoring scheme for Otters in that a smaller sample size could be used without reducing the ability to detect trends of the required magnitude. Additionally, combining the Otter work with that for Mink and Water Vole (as suggested by MMR) may reduce survey efficiency, as fieldworkers require different 'search-images' for the different species. A combined survey might also fail to target fieldwork effort most effectively, notably because the three species often occupy different riparian habitats. The most recent Water Vole survey highlights this, with the grid of Water Vole survey sites providing a poor estimate of Otter population size (see above). This is the result of an inappropriate selection of study sites (for Otters) and sampling intensity (Don Jefferies, pers. comm.).

A volunteer-based transect method involving the recording of field signs (across the grid of existing sites) could provide a more cost-effective monitoring programme, while maintaining continuity of the historical dataset. The Mammal Society has demonstrated that volunteers can be trained to identify Otter spraints and, with technical support to help identify difficult spraints, there is no reason to expect any reduction in data quality with volunteer involvement. Use of multiple fieldworkers, rather than the single fieldworker employed on the VWT, has distinct advantages (see Part V), although the seasonal component of the existing methodology may need to be changed. It also appears that a sufficient number of volunteers could be recruited (Stephen Harris, pers. comm.). The use of trained volunteers could be tested during a pilot study or as a component of the forthcoming Otter survey of England. Professional recorders would be needed in the more remote parts of the country where observer coverage would otherwise be low.

Although trained volunteers fieldworkers could carry out much of the survey work, they would need to be supported by a professional national co-ordinator (also co-ordinating American Mink and Water Vole) and possibly local co-ordinators (such as the Environment Agency Otter Officers). A proportion of collected spraints could be sent in for validation and a proportion of the survey sites could be visited by professionals, again for validation purposes.

24.5 DEVELOPMENT AND VALIDATION STUDIES

A data-modelling exercise (using data from the national Otter surveys for England) should be used to establish whether the number of sample sites can be reduced without reducing the power of the approach for detecting trends of say 25% over 25 years. This exercise could also be used to examine the ideal interval between surveys based on the power of detection and the costs of implementing the survey. This could be carried out at the same time as modelling potential sampling protocols for other species (e.g. Badger: Cresswell *et al.* 1990; Wilson *et al.* 1997).

24.6 RECOMMENDATIONS

1) Monitoring work should build on the three previous national Otter surveys and there is a great deal to be gained by continuing a national Otter survey every seven years using volunteer input. The recommended interval of seven years is based on the balance between survey costs and the need to obtain regular monitoring data. The steady change in the Otter population is not so dramatic that more regular surveys are currently needed, although the sampling interval could be adjusted in light of the modelling exercise recommended in (4) or as a result of changes in the rate of Otter population change.

2) More intensive monitoring should be carried out at a reduced number of sites to provide a better understanding of the processes limiting recovery in certain areas. Such work should examine the relationship between population recovery and catchment characteristics (notably pollution) thus enabling aim 5.5.4 of the action plan to be addressed. Liaison with groups carrying out ongoing work at the local level may highlight appropriate study areas.

3) Work examining the feasibility of monitoring Otter populations using the VWT methodology and sites but with volunteers, rather than a single professional observer, should be investigated. The completion of this pilot work, together with that outlined in (4) should be completed prior to the implementation of recommendation (1).

4) A parallel monitoring approach would need to be developed for coastal populations, which, although seemingly more stable, are at risk from catastrophic events such as oil spills and the effects of sea-level rise.

5) Data from the previous Otter surveys should be used to establish whether the number of sample sites can be reduced without reducing the power of the approach for detecting trends of 25% over 25 years. The value of altering the survey interval should also be evaluated as part of this modelling process.

6) More effort should be targeted towards understanding and quantifying the relationship between Otter density and spraint density. As Otter numbers increase and the number of occupied sites also increases, so data on the occupancy of sites becomes less valuable for monitoring purposes. Abundance data will highlight where changes in numbers occur without a corresponding change in the number of occupied sites. This could be important.

7) Ancillary data should be gathered through Mammals on Nature Reserves (Part III.B.6) and Mammals on Roads data (Part III.B.5) both of which would contribute to the gathering of distribution data, with the former also providing a simple index of occurrence on an annual basis.

25. WILDCAT *Felis silvestris*

Native; rare and restricted to upland Scotland (extinct in Ireland, England and Wales); population probably stable but threatened by hybridisation with Feral Cats *F. catus*: genetic status in question.

25.1 RECENT AND ONGOING MONITORING

Game Conservancy Trust National Game Bag Census - Game Bag data were collected centrally by the GCT from 1960 until 1985, when the Wildcat was given legal protection. The data will suffer from the problems inherent in all Game Bag records (see Part III.A.2). More Game Bag data will not become available in the future because Wildcats are hugely unlikely again to be made legal quarry (although persecution certainly persists).

Wildcat Survey of Scotland - A questionnaire survey (1983-1987) involving interviews with gamekeepers, forest rangers, volunteers and others which solicited sightings information and was widely publicised in Scotland (Easterbee *et al*. 1991). Sampling was based on the 100x100km national grid squares, with several 10x10km squares sampled within each 100x100km square. Wildcats in blocks of 3x3 10x10km squares were then classified as rare/absent, rare, occasionally seen or established.

SNH survey of wild-living cats in Scotland - As part of a study investigating the definition of the Wildcat and the phenotypic variation found in the extant population of wild-living cats, Balharry & Daniels (1998) supervised trapping efforts across Scotland using baited cage traps (primarily for the purpose of collecting blood samples and morphological data). Formal attempts to estimate abundance or other population parameters were not made, but a total of 44 cats were caught over 5,558 trap-nights of effort (giving a mean of *c*. 130 trap-nights per cat). Comparable numbers of non-target species were also caught, most of which were Pine Martens.

Investigation of Wildcat genetics - Studies of the genetics of Wildcats, Feral Cats and their hybrids by SNH and the Wildlife Conservation Research Unit (University of Oxford) are currently in progress.

25.2 WILDCAT GENETICS

Wildcat morphology has traditionally been defined as being identifiable from that of Domestic and Feral Cats by means of a number of field characters. The typical coat is a tabby mixture of black and a grey-brown which varies in darkness. Key diagnostic features are large size, long legs, no dark stripe on the back at the base of the tail, fewer dark stripes on the body and fewer rings on the bushy, black-tipped tail (Kitchener 1995). Introgressive hybrids with Feral Cats are identifiable by various "domestic" features such as smaller size and unusual coat colours such as patches of white: colour variants in Wildcats are believed to be very rare (Kitchener 1995), although this could surely reflect a reporting bias against "hybrids".

Recent morphological analyses have suggested that there is no "genetically pure" population of Wildcats, derived from the native, ancestral stock, which can be distinguished from Feral Cats (Balharry & Daniels 1998). This suggests that introgression has proceeded to such an extent that the feral and wild populations are now effectively

integrated, and that the (single) type specimen from which Wildcat morphology was defined (in 1907) may have come from a population which already possessed feral genes. Balharry & Daniels (1998) found that two groups of cats ("group 1" and "group 2") could be identified by a linear discriminant function incorporating gut length and skull size. Other features, such as pelage colour and pattern and other morphological measurements did not allow any other groupings to be defined. Group 1 cats had larger skulls and shorter guts, as well as a higher ratio of tabby to other coat colours (but coat colours were far from exclusive). Records of group 1 cats also tended to be separated geographically from those of group 2 cats and tended to come from colder, drier areas. It is tempting to suggest that group 1 cats represent genuine Wildcats, but there is no evidence to support this conclusion. In particular, the possibility that the morphological differences between group 1 and group 2 cats in fact reflects the influence of natural selection on the same (wild mixed with feral) gene pool cannot be discounted.

Balharry & Daniels' (1998) analyses have been criticised (A.C. Kitchener, pers. comm.), but no written account of the relevant arguments was available at the time of writing. It is possible, for example, that Balharry & Daniels' analyses involved only hybrid individuals and that a true Wildcat population exists in areas that they were unable to sample. It would seem that the only way to resolve the discrepancy would be to investigate the genetic differences between the traditional Wildcat phenotype and those of Feral Cats and putative hybrids. The genetic investigations currently in progress should hopefully provide the necessary information.

25.3 MONITORING OBJECTIVES

Considerable confusion remains as to how a "Wildcat" should be defined. At present, opinion is divided on whether a genetically distinct and identifiable Wildcat, as opposed to a gradation from more wild to more feral genotypes, exists (Kitchener 1995, pers. comm.; Balharry & Daniels 1998). Identification of the characteristics of the population to be monitored is the first priority and must precede the establishment of any monitoring scheme.

It may not be necessary to identify a genetically and/or morphologically distinct Wildcat population to design an effective monitoring scheme. We suggest that monitoring should focus on cats in the niche of the ancestral Wildcat (insofar as it exists in contemporary Britain). If a distinct Wildcat population does exist, this will form some of the population monitored (along with hybrids which possess "wild" genes). If Scottish wild-living cats are a fully hybridised population, it suggests that Feral Cats and Wildcats cannot be regarded as different species in any biologically meaningful sense. It may be notable that domestication has selected cats primarily for exotic pelage colours and socialisation. If these form the principal differences between the wild and domestic genotypes, the distinction is likely to disappear rapidly from feral populations by natural selection: populations in the "Wildcat niche" should therefore become "wilder" over time (given that introgression is limited in the future). In addition, if the aim of the conservation effort is to preserve genes from the ancestral Wildcat population, these may now be found in many "hybrid" and "feral" individuals: trying to conserve (and monitor) any given phenotype would then merely be an exercise in aesthetics.

We suggest that the aims of monitoring could be (i) to monitor long-term changes in the genetic and morphological make-up of the wild-living cat population in Scotland

(concentrating on areas away from human habitation), and (ii) to monitor the range and abundance of wild-living cats in general. Areas considered as core ones for the Wildcat phenotype (with buffer zones around them) could be chosen as key areas for the monitoring of population trends and introgression by feral stock.

25.4 POTENTIAL MONITORING TECHNIQUES

Spotlighting - This method would allow visual transects to be conducted (at night), potentially giving standardised information. However, the method has important disadvantages (see Red Fox species account: IV.16). Identification is also likely to be a problem if phenotypic distinctions are to be made among wild-living cat types.

Road-deaths and other carcasses - Carcasses provide a cheap source of detailed information on morphology and (potentially) genetics which can be stored for reassessment in the light of future developments in Wildcat taxonomy or in policy. Specific solicitation of Wildcat carcasses is likely to be necessary since encounter rates will be very low and the species is unlikely to be monitored effectively by a generic Mammals on Roads survey (see Part III.B.3). Carcasses will be obtained more frequently from areas near towns and villages, so such biases would have to be taken into account.

Live trapping - This method is probably the only one that would allow unbiased sampling of all habitats and also allow morphological recording and genetic sampling, but it has important disadvantages. It requires very specialised training, licensing and considerable field effort. Landowner permission and free access may also be a problem, especially where cats are most abundant, because illegal control is most likely to occur on such land.

Questionnaire surveys - Both the general public and experienced professionals such as reserve wardens, gamekeepers and foresters could be targeted to supply sightings information with as much ancillary information as possible. Such an approach would provide information on changes in range and perhaps, crudely, on abundance, but would be highly dependent on the precise questions asked. A useful approach might be to ask not just for records of Wildcats, but of Feral Cats too, together with some record of the reason for the decision made (e.g. pelage colour, behaviour). As with most protected species which are considered a threat to gamekeeping interests, records (or a lack of records) from shooting estates would have to be treated with caution.

Field signs - Cat scats are deposited in exposed sites as territory markers, so could be used to assess presence or abundance. The scarcity and distribution of wild-living cats in Scotland means that sufficient numbers of cat scats are unlikely to be recorded by a generic Sign Transect Survey (see Part III.B.2) to monitor the population which is of conservation interest. Given suitable genetic markers, scats could also be used to monitor the genotypes of wild-living cats. As with carcasses, a central collection of scats would allow re-assessment of any classification in the future.

25.5 POTENTIAL MONITORING SCHEMES

Road-deaths and live-trapping - MMR recommend that Wildcats are counted by spotlighting and faecal counts in surveys also monitoring Red Foxes (which would be conducted every seven years), combined with the collection of road-deaths which could be

stored until genetic differentiations can be made. They concede that spotlighting for Wildcats has yet to be tested: given the problems with counts of foxes by spotlight (see Red Fox), it is unlikely that Wildcats (a still more wary species) will be counted easily, although they are shot by spotlight. Cats and foxes can also be difficult to distinguish at the edge of spotlight teams (S. Harris, pers. comm.). MMR also suggest that standardised live-trapping may present the most reliable monitoring technique, despite the effort and cost involved. However, live-trapping could well be biased by problems with access, so may not justify its high cost.

Combined Mammals on Roads, questionnaire and field sign surveys - We suggest that an ongoing scheme soliciting road-deaths and questionnaire data would be the best core approach, in accordance with the consensus of expert opinion in MMR (p. 180). Mammals on Nature Reserves (Part III.B.6) could also contribute. Collation (including report/newsletter production) could be via SNH or a central mammal monitoring body and would perhaps be annual for questionnaire data and five-yearly for road-deaths (whereupon the accumulated collection of corpses would be measured and DNA samples analysed). The collation ought to require no more than one month of staff time per year. Occasional scat surveys would then allow estimates of cat abundance and distribution to be made and these could be calibrated genetically via the road-deaths data. Such surveys would probably have to be conducted professionally because of the likely difficulty in volunteer recruitment in remote areas. Access problems could perhaps be reduced by the broadening of such a survey to include other, less contentious species, making the survey less sensitive politically, even if the additional data accumulated were of little value for the extra species.

25.6 RECOMMENDATIONS

1) Consensus on the characteristics of the wild-living cat population to be monitored must first be reached.

2) We suggest that the population to be monitored should consist of all wild-living cats found away from centres of human population. Road-deaths and questionnaire data could be used to monitor this population, with records categorised as wild or feral according to all available criteria (i.e. appearance, behaviour, measurements, etc.). Where possible, genetic reference material should be collected, stored and analysed periodically (provided that suitable genetic markers can be found) to monitor any spread of hybrids or Feral Cats. Such surveys would give information on changes in range and distribution.

3) Occasional scat surveys should also be considered. They would supply information on changes in the abundance of wild-living cats which could be calibrated by phenotype (and perhaps genotype), if desired, by the results of the monitoring suggested under point 2. Given suitable genetic markers, scat collection could perhaps also contribute to any genetic calibration.

4) The Mammals on Roads and Mammals on Nature Reserves schemes could contribute useful data to the monitoring of wild-living cats.

26. WILD SWINE *Sus scrofa*

Native but hunted to extinction. Current population of 100-200 in *c*.100km^2 of Kent and East Sussex originated from only two escapes, that of 20 or more in a smaller area of Dorset from just one escape. Widely kept in captivity and escapes not uncommon.

26.1 RECENT AND ONGOING MONITORING WORK

None but CSL (1998) has assessed the species' current status in England and CSL is currently studying the British population.

26.2 MONITORING OBJECTIVES

We note that Howells & Edwards-Jones (1997) concluded, on the basis of a simulation model of the Minimum Viable Population, that "the goal of establishing a self-sustaining population of Wild Boar in Scotland is unrealistic in the short-term". We also note that, in contrast, Feral Pig and Wild Swine populations have become established in very many parts of the world, often on quite small islands (Lever 1994) and that the two English Wild Swine populations seem to have established themselves readily. Given this practical experience, the analysis by Howells & Edwards-Jones should not be taken as an excuse for complacency in respect of Wild Swine.

It should be noted that there are strong views on the presence of Wild Swine in the British countryside. For example, Jackson (1999) argues that it is already far too late to eradicate the species and that it should be managed properly as a quarry species, whereas the Game Conservancy Trust argue that it can and should be eliminated (Dr Stephen Tapper, pers. comm.) Some welcome its return as a native animal, playing its natural part in British forests and providing an economic resource through hunting. Others point out that the ecology of Britain is now quite different from what it was before Wild Swine became extinct (in particular, predators such as Brown Bear *Ursus arctos* are no longer present and various other herbivores have been introduced); they point to potential problems of both economic conservation damage to woodlands, damage to crops and agriculture, predation on lambs, attacks on people and dogs, road traffic accidents, and the dangers (in the crowded British countryside) of using appropriately high-powered fire-arms to hunt Wild Boar. Given the potential economic impact of this species and the strength of the divergent views of how it should be managed, sound monitoring is particularly important.

26.3 RECOMMENDATIONS

We recommend that the monitoring of this species be considered promptly when CSL has reported on its current project. It will then be possible to define more clearly the nature of the problem (if there is one), the management objectives and the best monitoring methods for use in Britain.

27. DEER

As recognised by MMR (p. 38), deer are a special case among the groups of mammals found in the UK. They are of interest to people concerned with conservation, forestry, agriculture, animal welfare and field sports: these interest groups have each collected data on some aspects of deer .populations, but in ways both diverse and often less than ideal for monitoring (especially at the national level). A detailed assessment of current and historical deer monitoring is given by MMR, so we do not repeat it here. Instead, we focus on how new proposals can be combined with the high quality data which is already being collected, to allow deer populations to be monitored nationally. Following MMR, we deal with the monitoring of all UK deer species together: although they exist in a wide range of habitats and vary in behaviour, discussion of the pros and cons of monitoring approaches applies to all species. MMR were asked to consider only four deer species; we have broadened the species range to consider all species living wild in the UK.

RED DEER *Cervus elaphus*: native to Britain and Ireland; locally very abundant, but distribution patchy, rarer in Ireland and absent from the North; numbers stable either naturally or under control by culling; also subject to translocations and introductions.
SIKA DEER *C. nippon*: introduced to Britain and Ireland; widespread in Scotland, more localised in England, Wales and Ireland; not abundant, but increasing in Scotland. Hybridising with *C. elaphus* and may effectively be indistinguishable.
FALLOW DEER *Dama dama*: introduced to Britain and Ireland; widespread, especially in southern Britain and central Ireland, but patchily distributed elsewhere.
ROE DEER *Capreolus capreolus*: native with reintroductions in Britain, absent from Ireland; widespread throughout Britain except Wales and Midlands, abundance patchy; range is expanding, probably along with abundance.
REEVES' MUNTJAC *Muntiacus reevesi*: introduced; south and east Britain only, patchy distribution reflects introduction sites; rapidly increasing but may soon saturate some areas.
CHINESE WATER DEER *Hydropotes inermis*: introduced; uncommon, localised, primarily found near introduction sites in south-east England; not increasing significantly.

27.1 RECENT AND ONGOING MONITORING WORK (REVIEWED IN DETAIL BY MMR)

Historically, deer monitoring has been organised mostly only at a local scale, with a view to the management of local populations either for sporting interests or to control damage to agriculture and forestry. The best ongoing schemes monitoring abundance are as follows:

The Deer Commission for Scotland (DCS)/Scottish Deer Management Groups - annual and five-yearly total counts for Red and Sika Deer populations made when the animals are relatively concentrated on lower ground in late winter and therefore most easily counted. Complete censuses of Scottish populations are made. There is some doubt as to the genetic integrity of many Scottish Red Deer populations after possible hybridisation with introduced Sika Deer, but this may simply mean that effective monitoring cannot distinguish between the two "species" and their hybrids.

Services Branch of the British Deer Society - complete annual censuses of all deer found on Ministry of Defence land (all those listed except Chinese Water Deer) are made using the most appropriate method for each site: where complete, direct counts are not possible, population estimates are made using correction factors for unseen individuals.

Forestry Commission - the monitoring of all deer species on all Forestry Commission properties using locally appropriate methods is now being encouraged, and will be made more rigorous and standardised in future, with pellet counts and distance sampling by thermal imaging as the core approaches. Population indices, rather than complete censuses, are likely to be the goal of this monitoring.

Exmoor Deer Management Society - annual census data for deer on Exmoor.

The precise methods used by these surveys differ, but all aim to provide estimates of population size within designated areas. In each case, the surveying organisations have a vested (and often commercial) interest in promoting the accuracy and precision of deer monitoring which should only enhance the value of these surveys. Potential biases due to political pressures must, however, always be considered when information on politically sensitive issues is collated.

Other data collected under various schemes primarily comprise **cull data, bag returns and presence/absence surveys** (conducted nationally by the British Deer Society). The latter would clearly give information on changes in distribution, but may not be closely related to changes in abundance, especially in terms of relationships with habitat (Chamberlain *et al.* 1999). Relationships will also be weaker for species which live in large social groups, as do Red, Sika and Fallow Deer. As with all population sampling methods, the utility of cull data, bag returns and other mortality data, such as those from road accidents for monitoring abundance, depends on the recording of "sampling effort". Unless effort has been constant, the effects of changes in methods must be controlled for in indices of changes in population size. In cull and bag data, the time spent stalking, the quality of equipment, the ability of personnel, the methods used and the areas visited must all be recorded, together with information on the effects of variation in these parameters (see Part III.A.2). Changes in any of these could produce spurious apparent changes in a population index. Nevertheless, mortality data (if complete) can be used to assess population size and structure retrospectively and thus to check previous censuses (MMR). Such information can be vital for the management of local populations, because of the importance of population structure in the design of culling strategies.

27.2 MONITORING OBJECTIVES

Nationally, it may be desirable to monitor changes in range and abundance for each species to provide information on conservation status and biodiversity. Local monitoring may also be extremely important for deer because it is at the local scale that any management which aims to prevent habitat damage or to estimate the size of sustainable annual harvests must occur. Monitoring of range change may be important for the species which are believed to be expanding their ranges: Sika, Roe and Reeves' Muntjac. Deer are important economically and can have large impacts on their environments and on other wildlife: these factors suggest monitoring priorities in addition to those due to the monitoring of the health of the countryside.

27.3 POTENTIAL MONITORING TECHNIQUES

A comprehensive review of the methods available for the monitoring of deer is presented in Mayle & Staines (1998) (summarised in MMR), so we consider only the best of the methods here. The diversity of habitats occupied by deer mean that a single monitoring approach could not be recommended for all species, or indeed across the complete range of some individual species. Mayle & Staines recommend a different basic method for each of open hill and wooded habitats and also consider the use of more technologically sophisticated approaches.

Open hill areas (Red and Sika Deer): direct counts - Direct count methods as currently applied by the Deer Commission for Scotland are recommended by Mayle & Staines (1998). Counts might be made more often than is currently the case, but otherwise the approach used by the DCS could be adhered to. In Scotland, counts are made by teams of stalkers who use radio contact to avoid double-counting in each of 50 blocks which cover the whole range of red deer, and which each feature "fairly self-contained" deer populations. Animals are counted on open ground and, where necessary, flushed from cover. Some will nevertheless be missed, so the counts are regarded as minima. The counting system is designed to estimate total population size but might provide reliable information on population changes more efficiently if a randomised sample of blocks were covered using repeat visits. The nature and spatial distribution of counter effort within open hill areas outside Scotland would determine whether a sampling or total count approach would be most appropriate in each area.

Woodland and partially wooded landscapes: pellet-group counts - Mayle & Staines (1998) concluded that total and sample (plot or transect) counts are unreliable because deer are cryptic in these habitats and therefore difficult to detect. Of indirect methods, Mayle & Staines concluded that faecal pellet counts were the most suitable, made using one of two methods: faecal accumulation rate (FAR) or faecal standing crop (FSC), both of which are best conducted in winter when vegetation growth is low and decay times are long. FAR requires multiple visits to a sample plot or transect strip and involves the recording of the pellet groups present on each occasion. FSC requires only a single visit but depends critically on decay rates. Defecation rates and decay times vary with habitat, diet and season and need to be known if absolute abundance is to be estimated. However, the estimation of population *change* would require only that these parameters do not change over time *within plots*. Mayle & Staines (1998) suggest that FAR is best used where deer densities are high and FSC where densities are lower, but that FSC may also be the best option when observer time is limiting since fewer, less time-consuming visits to each plot are required. Pellet groups suffer from a potential identification problem where species of a similar size co-exist and/or where sheep and goats are also found. In such cases, data where species cannot be determined with certainty can be omitted from population indexing analyses: although this would bias estimates of absolute abundance, it should not affect relative indices unless identifiability changes with time. The identifiability problem may mean, however, that it is not feasible to use volunteers for pellet count surveys where more than one similarly-sized deer species occurs. Some experts consider that identifiability presents insurmountable problems that invalidate pellet-based methods (in practice) for deer monitoring (S. Harris, pers. comm.).

Other methods - Mayle & Staines (1998) discuss a range of further monitoring approaches. In terms of providing improvements on estimates produced using the methods described above, the most important of these are aerial transect counts for deer in open country (using helicopters or microlight aircraft) and transect counts with distance sampling done using thermal imaging. Both of these approaches will probably be too expensive to be practical for repeated, large-scale monitoring projects, but could perhaps be used for the purposes of calibration, either in a one-off national survey or in the repeated (annual) censusing of particular populations.

Visual transects - The line transect methods as used by the Breeding Bird Survey (see Part III.A.1) are not ideally suited to deer monitoring (Mayle & Staines 1998, MMR) but this survey produces presence/absence information at the 1km square scale together with standardised habitat data which could be useful. The chief advantage of BBS data in this context is that it is already being collected and is based on a random sample of the UK landscape. The BBS could also provide a useful independent check on presence/absence data collected by the British Deer

Society and the Institute of Terrestrial Ecology (see MMR Chapter 2, Section 3). Sightings data from Winter Transects (see Part III.B.1) may supply better data on deer because the animals will be more visible.

Specific, deer-focused transect counts form a monitoring technique recommended by some experts (S. Harris, pers. comm.): to be most effective, these counts would be conducted at first light or at dusk and would follow routes along the edges of woods and along rides. Easily identified field signs (such as tracks) could also be recorded at the same time.

Presence/counts in gardens - The occurrence of deer in gardens could provide important information, especially on range changes, for Reeves' Muntjac and Roe Deer, which commonly enter gardens where they occur.

Road-deaths - Road-death sightings, especially when combined with measures of sampling effort as recommended for our proposed Mammals on Roads survey (see Part III.B.3) could supply useful information, especially on distribution and changes in range. Again, the smaller species will be monitored best by such data.

Presence/counts from nature reserves - Reserve wardens could contribute valuable data, especially on presence/absence, which could be used to chart changes in range. Reserves are unlikely to be representative of wider land-use, so will be of less value as a source of count data (but see Part III.B.4).

27.4 POTENTIAL MONITORING SCHEMES

MMR recommended approach - As part of the QQ grid-based MaMoNet system, MMR recommend transect-based pellet-group or direct counts (with supplementary methods including vantage point counts, woodland edge counts and analyses of cull data as necessary or appropriate for particular species) for five randomly selected 1km squares within each 10km square to be surveyed (although the details of the method proposed are sometimes unclear). Transects would be "crenellated to cover the entire square". Where the 1km square may be too small a sampling area to produce repeatable data, i.e. for more mobile (less territorial) and more gregarious species such as Fallow and Red Deer, 5km squares are also suggested as the sampling unit if populations in entire 10km squares cannot be censused. Absolute densities would presumably be estimated for each survey square. Complete surveys are proposed every seven years, with additional, more intensive monitoring in the key areas for species' range expansion. Proposals gleaned from discussion with deer experts but not used explicitly in the MaMoNet (MMR, p.184) also include recommendations that at least 2000 1km squares which encompass the known range of each species plus a 50km buffer zone around the ranges of Roe, Sika and Reeves' Muntjac should be covered every five years using 1km transects, and that each square should contain at least one block of woodland of more than 1ha.

The MMR method has the advantage of being geographically unbiased and is therefore a sound basic sampling strategy to cover national populations. The statistically robust background to the design of the MaMoNet is a further advantage. The use of absolute densities as a "common denominator" also allows the results of disparate monitoring methods to be combined meaningfully. In practice, this could represent the only way in which an internally consistent national system for the monitoring of deer could be designed. However, there are several problems with the approach proposed, most of which are practical. First, the method ignores the large amounts of high quality data which are already being collected for deer populations in some habitats or regions (see above), which must at least be inefficient. Second, having methods which are not fully standardised but require a professional assessment of the action needed to measure the densities of all species found in a given 1km or 10km square restricts the survey work to highly qualified surveyors. Third, where good data are being collected, the available pool of surveyors (if professionals are not to be used) would be asked either to add to their existing work or to replace it; this is unlikely to be popular when the new data are likely to be of less use, locally, than those already being collected. Fourth, considerable concern has been expressed about the reliability of pellet count methods (S. Harris, pers. comm.). Fifth, the MaMoNet concept is centred on the idea of national monitoring and, ultimately, single species-specific figures for population changes. Like those of many other mammal species, deer populations are probably not mobile enough to mix to such an extent that the whole of Britain or of the UK can be meaningfully considered to hold a single, homogeneous population. It might therefore be more desirable to monitor deer species according to biologically meaningful divisions and to combine the results of such monitoring schemes if and when it is required politically. This would allow the needs of local and national monitoring to be combined.

Combining existing and new schemes - Although the MMR method may be the only way to obtain an internally consistent national survey of deer populations (subject to the methods being ratified), we suggest that this requirement could be relaxed. We consider that the objectives for UK deer monitoring can be met by using the existing monitoring schemes which generate high quality data and by supplementing them with new survey information which fills the geographical and species gaps in the current monitoring spectrum. Current deer monitoring probably covers most of the ranges of Red, Sika and Fallow Deer effectively through the schemes run by the Deer Commission for Scotland, Services Branch of the British Deer Society, Forestry Commission and Exmoor Deer Management Society. British Deer Society cull data provide further monitoring information on distributional changes.

Several options exist for the monitoring of the other species and areas. Most accurate would be dedicated deer surveys, which would have be species-specific and to be conducted in winter. For open hill species (almost always Red Deer outside Scotland), direct counts of large randomised survey areas (say, 2×2km tetrads) would be the best method and could be conducted by volunteers. For woodland species, expert opinion is divided, suggesting that further discussion and pilot work is necessary to identify methods which are widely acceptable. One option is to use faecal pellet count methods (either FSC or FAR methods according to the availability of resources and distribution of sample sites: Mayle & Staines 1998), working on small plots (a minimum of 10×10m) or transects (say, 1km). Different transect lengths or plot sizes would be most appropriate for species with different social behaviour (e.g. Roe and Fallow Deer), but compromise may be needed to allow such species to be monitored by a single scheme (such as an adjunct to our proposed Sign Transect Survey: Section III.B.2). The considerable difficulties with pellet identification mean that professional surveyors would probably be required to conduct these surveys; volunteers could be trained to make the identifications (perhaps with professional support by post in difficult cases) but deer pellets are not currently covered by The Mammal Society's Look Out for Mammals courses. However, even professional surveyors may be unable to identify a sufficient proportion of the pellets they find for monitoring to be effective, especially in areas with which they are unfamiliar. The alternative approach is to use a dedicated visual transect method, with routes designed to maximize encounter rates (i.e. concentrated in late evening/early morning and directed along woodland rides and edges). Such an approach would need research into the specifics of its design to optimise the monitoring of each species and the concerns with habitat-specific differences in detectability would have to be addressed.

Less accurate information, but sufficient at least to monitor changes in range, could be obtained at much lower cost from the general, multi-species schemes suggested elsewhere in this report: the Breeding Bird Survey (Part III.A.1), Mammals on Roads surveys (Part III.B.3), Winter (visual) Transects (Part III.B.1), Sign Transects (Part III.B.2) and Garden Mammal Watch (Part III.B.5). In addition, simple sightings data, solicited from key potential range expansion areas for Roe Deer, Reeves' Muntjac and Chinese Water Deer, through county Wildlife Trust magazines (for example), would give information on distributional change. None of these might be ideal individually, but each would be subject to different biases and sources of error such that patterns common to a number of survey schemes would be highly suggestive of genuine changes.

Before the implementation of such new schemes, the principal requirement for coordinated national deer monitoring is a body which can collate the data collected by the specialist deer organisations and combine them with information from the general mammal or deer-specific schemes. Such a body would also be best-placed to administer the latter. It might be most efficient for this overall monitoring organisation to form part of whatever body oversees general mammal schemes such as a Winter Transect Survey, and it could be as small as a single individual working within such a body. The coordinating work should be co-supervised by a committee drawn from the various groups interested in deer, or at least by a combination of Deer Initiative and Deer Commission for Scotland representatives, and significant input from scientists in the deer research community should be incorporated.

The coordination work would involve combining region and habitat-specific data from the modular system outlined above. It may not be biologically meaningful to combine data from disparate schemes monitoring different areas, so it should be acceptable to index populations from different habitats and/or regions separately. However, if a combined index is required (for example, for national biodiversity targets), the deer monitoring coordinator(s) could calibrate the individual surveys using habitat- or region-specific estimates of density and construct some kind of meta-index.

27.5 RECOMMENDATIONS

1) The amount and quality of information required from monitoring work on each species must be decided as a first priority. This will then determine the need for new survey schemes to be established and the extent to which existing schemes meet the objectives of monitoring.

2) The second priority is the establishment of a national coordinating body for deer monitoring, perhaps through collaboration between the Deer Initiative and the Deer Commission for Scotland. This body, ideally through staff within a national mammal research organisation, would collate the data collected under existing schemes, set up and administer any new surveys required and combine the information into indices or summaries addressing national deer monitoring aims. This work should require no more than one full-time post within an umbrella mammal monitoring organisation.

3) Significant proportions of the British populations of the larger deer species are already monitored well. Cost-effective and efficient national monitoring would best be served by promoting the continuation of these schemes and by making efforts to collate the information generated centrally. It is important that the needs of national monitoring do not impinge on extant, more local schemes which have been designed with the needs of local monitoring in mind.

4) New survey schemes will be necessary if the populations of deer (especially outside Scotland and of the smaller species) not found on land which is currently the subject of survey work are to be monitored effectively. These include much of the populations of Fallow Deer, Roe Deer, Chinese Water Deer and Reeves' Muntjac. We have outlined two possible general approaches for the monitoring of these populations. If detailed information on complete populations is required, then surveys based on direct counts (open habitats) and on either pellet group counts or deer-specific transects (woodland) should be established, sampling the countryside on a random basis stratified by habitat (say, using ITE Land Cover data). Identifying the best method for surveying woodland deer should be a priority: the conclusions of the most recent methodological review (Mayle & Staines 1998) and the consensus of expert opinion (*per* S. Harris) are currently at odds, so we cannot provide firm conclusions here. Any pellet-based surveys would require considerable professional input, at least in terms of support for the identification of difficult pellet groups and probably also directly to conduct fieldwork (professional input would not, however, guarantee successful pellet identification). Volunteer input to any survey would best be managed by a central mammal research organisation and could be drawn from the memberships of BASC, The Mammal Society and the British Deer Society. Three to five staff employed over the survey period (which would best be a period of several months in winter) ought to be sufficient to cover (with volunteer assistance) several hundred of each of woodland and open survey plots. A sample size of at least this order would be needed to provide useful information, but precise requirements can only be assessed through trial survey work.

5) If less detailed information than that specified under point 4 is required, data compiled piecemeal from the multi-species schemes we propose elsewhere and from sightings that solicited from key areas of range expansion could be sufficient. We would envisage that the BBS (Part III.A.1), Winter (visual) Transect Survey (Part III.B.1), Sign Transect Survey (provided that pellet identification is not considered too difficult for volunteers) (Part III.B.2), Garden Mammal Watch (Part III.B.5), Nature Reserve Monitoring (Part III.B.4) and Mammals on Roads data (Part III.B.3) could all contribute. Such a system would require significantly less staff time than specific deer schemes: no more than one to two months per year over and above the time needed to run the multi-species schemes themselves. Both this potential approach and that based on deer-specific monitoring would have to be piloted to assess their suitability and to suggest required sample sizes before either one were adopted wholesale.

28. FERAL GOAT *Capra hircus*

Introduced. Series of small (mostly a few hundred or less), isolated populations in the uplands of each of the four countries of the UK and on some sea cliffs. Abundance stable. Bullock (1995) provides much information on the status and management of this species.

28.1 RECENT AND ONGOING MONITORING

No formal monitoring at national level but managers of almost all land on which goats occur in UK monitor their animals to varying degrees of precision using various combinations of direct counts and observations of damage to vegetation. In Wales, CCW lead a formal management plan with the objective of preventing extinctions of goat populations whilst avoiding damage to oak woodlands.

28.2 MONITORING OBJECTIVES

Local monitoring has the objectives of signalling when unacceptable damage to vegetation has occurred or when numbers are increasing to a degree that is believed to threaten vegetation. Goats are easy to observe, to herd with dogs, and to cull, so management is also easy.

Goat populations are so limited in distribution and so widely managed that there is no reason to monitor them as indicators or (generally) as ecosystem components. Their social structure is such that national monitoring should concentrate on changes in distribution.

28.3 POTENTIAL MONITORING TECHNIQUES

Direct counts - Goat distribution, and even numbers, are easy to monitor by direct observation.

28.4 POTENTIAL MONITORING SCHEMES

Collation of data from local monitoring would provide sufficient monitoring at a national level.

28.5 RECOMMENDATIONS

We recommend that the conservation agencies ensure that the current informal system, whereby Dr D J Bullock (National Trust) collates information on Feral Goats is maintained and perhaps somewhat formalised. (The field observations are generally provided by those responsible for local land management.) Ongoing collation of readily obtained data would probably be five days work per year. More intensive reviews at perhaps decennial intervals may prove necessary of the annual accumulation of data is insufficient. Regional staff of the country conservation agencies should be encouraged to be alert to the possible establishment of Feral Goats in new areas.

29. FERAL SHEEP *Ovis ammon*

Introduced. Boreray Sheep restricted to Boreray (St. Kilda), unenclosed Soay Sheep to Soay and (through recent introduction) to Hirta (St. Kilda), Holy Island (Arran), Cardigan Island, Lundy Island and Cheddar Gorge.

29.1 RECENT AND ONGOING MONITORING WORK

The Hirta population has been studied in some detail since the 1950s. All other free-ranging populations of Soays, with the exception of that on Holy Island (about which there is no recent information) are managed closely on the basis of almost annual counts. Boreray Sheep are counted opportunistically, mainly by telescope from Hirta (which overlooks the main grazing slope.)

29.2 MONITORING OBJECTIVES

The demographic studies on Hirta have scientific objectives, based on this being such a detailed long-term study. More generally, local monitoring has the objectives of managing populations for the benefit of vegetation and of preventing animal welfare problems that could arise from overstocking. (Feral Sheep are not readily herded but they are easy to cull by shooting).

Sheep populations are so limited in distribution and so widely managed that there is no reason to monitor them as indicators or (generally) as ecosystem components. Their social structure is such that national monitoring should concentrate on changes in distribution.

29.3 POTENTIAL MONITORING TECHNIQUES

Direct counts - Feral Sheep live in open habitats and are easy to observe.

29.4 POTENTIAL MONITORING SCHEMES

Collation of data from local monitoring and scientific studies would provide sufficient monitoring at national level.

29.5 RECOMMENDATIONS

1) We suggest that individual country conservation agencies should routinely collate the data obtained about Feral Sheep populations and that appropriate regional staff should be encouraged to be alert to the possible establishment of new populations (given that Soay Sheep are widely kept in captivity).

2) Resource requirement: two or three man-days work per year for each country conservation agency to ensure that data are centrally collated and to alert regional staff to the possible establishment of new populations. (The latter should be combined with alerting them about the need to gather information on occurrence of various species beyond their known range.)

30. RED-NECKED WALLABY *Macropus rufogriseus*

Introduced. Frequently released or escapes. Populations have persisted for decades but 20-30 animals on Inchconachan (Loch Lomond) and perhaps 50 on the Isle of Man are the only currently viable populations. At least one animal has reached the mainland from Inchonachan. The reproduction rate is low, the animals are vulnerable to road traffic and hard winters, and they may not compete well with ungulates.

30.1 RECENT AND ONGOING MONITORING WORK

Dr D W Yalden has studied the Peak District population for *c.*30 years (Yalden 1988) and there has been one study of the Inchconachan population (Weir *et al.*1995).

There seems to have been no published work on the Manx population but Chris Sharpe (pers. comm.) has supplied the following information. The population inhabits an extensive area of "curragh" willow scrub (grid reference SC3694/95), largely owned by The Manx Museum and National Trust; it may number 50 animals (10 have been seen in a single group) and occupies an area of about $1km^2$; it may be increasing. It originated from escapes from a wildlife park, probably in the late 1960s. There is no formal monitoring, all the above information being derived from casual observations.

30.2 MONITORING OBJECTIVES

Assuming that the current aim is neither actively to eliminate nor to maintain wallaby populations in the UK, we suggest that the monitoring objectives for this alien species should be:

1. to record the establishment of any new populations;
2. to monitor the size and range of such populations, especially to detect any sustained increase.

30.3 POTENTIAL MONITORING TECHNIQUES

Direct counts - Wallabies are secretive (and small populations are therefore easily overlooked) but populations in small areas can be counted by sweeping the area with a line of counters - 45 people were used to cover the 45ha of Inchconachan.

Field signs (droppings) - Wallaby droppings are fairly easily identifiable and are thus a useful means of confirming continued presence in an area; but they are unlikely to be sufficiently noticeable to provide alerts to the presence of Wallabies in previously unoccupied areas.

Field signs (tracks) - Wallaby spoor is so different from that of any British animal that naturalists alert to the possibility of the species escaping or being released may notice it. It is a useful means, particularly after snow, of confirming the species' continued presence in an area.

30.4 POTENTIAL MONITORING SCHEMES

See below.

30.5 RECOMMENDATIONS

1) Inchconachan - There is no need to devote resources to monitoring this population but SNH should collate any information that is obtained about it. Resource requirement: a few hours per year.

2) Loch Lomond - Local SNH staff should be aware of the possibility of animals emigrating from Inchconachan. They should know what wallaby droppings and spoor look like. They should collate all reports of sightings and signs. They should follow up such reports, to establish the number and exact locations of any animals observed.

Resource requirement: virtually none, unless reports need to be followed up, which may take a few man days.

3) Isle of Man - The Manx Museum and National Trust could perhaps take the lead in systematically collating sightings of these animals. Local ornithologists maintain a systematic programme of work on part of the site and could perhaps maintain systematic records of wallaby sightings. The extent of the area occupied should be assessed every few years by a survey using sightings and field signs. It would be useful to have a base-line assessment of numbers, by organising a large team of drivers to cover the area thoroughly, as was done on Inchonachan (Weir *et al.* 1995).

Resource requirement - depends on scale of work but collation of sightings should take no more than a few hours per year and surveys of the area occupied only a very few man days each.

4) Other established populations - Assuming, as is likely, that other populations of wallabies are occasionally established, their size and range should be monitored. We suggest that, given the slow reproductive rate of the species, surveillance at intervals of, say, five years would be adequate, consisting of surveys to determine the area occupied (by means of searching for animals, droppings and tracks), followed by intensive sweeps of the area by a large team during a single day, to determine numbers.

Resource requirements: perhaps two-man-months of professional time to organise and report on each survey; some dozens of volunteers would be needed for the sweep of the occupied area.

5) Alien mammals scheme - This should be used to monitor occurrences of this species.

31. UNESTABLISHED ALIENS

Large numbers of alien species (and sub-species) are kept in captivity in Britain, as exotic pets as exhibits in zoos and wildlife parks, and as farmed animals. Escapes and deliberate releases are not uncommon (Baker 1990). In addition to the non-native species that are currently established (and which are individually considered in this report), this has resulted in the establishment of populations of Muskrat (*Ondatra zibethicus*), Himalayan Porcupine (*Hystrix trachyura*) and Coypu (*Myocastor coypu*); all were eliminated, though in two cases at great cost.

In order that the potential establishment of aliens should be properly managed, monitoring should be conducted of the occurrence of all alien mammals at liberty in the UK. Dr Simon Baker (FRCA) currently runs a low-key monitoring scheme for MAFF, for all alien mammals except common small pets such as Golden hamster *Mesocricetus auritus;* most of his records come from FRCA colleagues and Mammal Society members. Some occurrences probably go unrecorded because of the low level of publicity afforded to this scheme.

31.1 RECOMMENDATIONS

The FRCA scheme should be strengthened, through a systematic publicity programme to a target audience (too wide publicity could result in large numbers of dubious and unverifiable records of "The Beast of Bodmin" sort). This would include more frequent publication of results.

Resource requirements: a few man-weeks per year.

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PART V BUILDING THE VOLUNTEER NETWORK

1. INTRODUCTION

The UK has the most highly developed system for conservation-related research and monitoring of birds in the world. This is largely because of the substantial input of fieldwork by volunteers. Similar work is also undertaken for other taxa, albeit on a smaller scale. In respect of the monitoring of mammals, the key question is whether the volunteer input can be developed enough to enable the UK to put into place an effective and affordable programme.

From earlier parts of this report and from MMR, one gains some appreciation of the major contribution that volunteers have already made to the study of mammals in Britain and Ireland. Most of the major surveys have involved a considerable input from the volunteers. Another impressive example comes from surveys of vespertilionid bats (scarcely the easiest group of mammals to study). Volunteers covered 1,030 1x1km squares stratified by Land Class; and the result was two major papers in the *Journal of Applied Ecology* on the foraging habitat preferences of the bats and on the relationship of their abundance to geographical factors, to Land Class and to habitat (Walsh & Harris 1996 a, b). There is clearly a lot that volunteers can do.

We begin this part of our report by briefly reviewing why one should use volunteers for wildlife monitoring and the potential problems with doing so. We consider the support needed from professionals, given that volunteers cannot do the whole job. We review how many volunteers there might be for the monitoring of mammals and we discuss how the volunteer network can be developed through training and through good systems of communication and feedback to volunteers on the work that they do. The volunteer input has to be organised: we make the case for this to be done by a membership organisation, to which many of the volunteers would belong (or, to put it another more important way) which would belong to many of the volunteers. We address how to organise the volunteers and their work at local level, and the special problems that there are in sparsely populated areas. Finally, we address the question of payment to volunteers, sometimes seen as a way of overcoming difficulties of recruitment especially in the sparsely populated areas.

2. WHY USE VOLUNTEERS FOR WILDLIFE MONITORING?

2.1 Citizen participation

There is great value in a democracy in citizens actively participating on a voluntary basis in work that is for the benefit of the whole community.

2.2 Building up a body of committed enthusiasts

The involvement of citizens in conservation-related fieldwork gives them an understanding and commitment to wildlife conservation that is deeper and more soundly based than that they are likely to get simply from reading or hearing about conservation problems.

2.3 Large numbers

Because volunteers are available in large numbers, it is possible to carry out surveys over a wide geographical area potentially in a short period of time. Thus, 1,000 volunteers can easily deliver five man-years of work in a single weekend. The concentration of work into a short time frame may often be necessary in monitoring and can be impossible to deliver with professionals simply because not enough of them are available.

2.4 Knowledge of local areas

Volunteers can build up an intimate knowledge of their local areas in a way that professionals covering much larger areas cannot. Furthermore, they can provide long term continuity in those local areas, which may be important for effective monitoring.

2.5 Reduced dependence on individuals

If a monitoring programme depends on a single professional, it can be seriously interrupted at short notice should the professional fall ill or move to a different job. Because there are a large number of volunteers there is an overall continuity of effort, even though individuals might drop out of a work programme. Furthermore, there is a long term continuity of expertise in the body of volunteers even though there may be a gradual turnover of individuals. In contrast, if an individual professional carries out a survey of a species, that same person is unlikely to be available in five or ten years time when the repeat survey is conducted, leading to a loss of the experience that is important in long term monitoring work.

2.6 Guaranteed commitment

"The best assurance that the fieldwork shall be accurate is that the investigators are thoroughly trained in their work, are capable, conscientious, and keen." (Yates, 1981)

We deal with training and ability below. Here we point out that volunteers, by their very nature, are bound to be conscientious and keen. This means that if they do the work at all then they can be relied upon to do it to the best of their ability. It is true that a proportion of volunteers in a survey may fail to do the work because unexpected commitments interfere with it or because it turns out to be more arduous than they anticipated. They are unlikely, however, to pretend to do the work to the required standard when they have not. In contrast, while the majority of professionals are at least as conscientious and keen as the volunteers, there is always the possibility that a small proportion of them are not conscientious and, in order to maintain their employment, pretend to have done work that they have not actually done (or at least pretend to have done to standards higher than those that they actually operated). While we have no reason to suppose that this has ever undermined the integrity of national surveys of wildlife, the risk is always there.

2.7 Saving in costs

Volunteers do not need to be paid. Most of them live close to where they conduct the fieldwork and are willing and able to cover their travel costs. In contrast, professionals need to be paid and may have to travel long distances in order to undertake fieldwork. As a result, surveys in which the majority of the fieldwork is conducted by volunteers can achieve many times the level of work for a given expenditure on professional organisation than can surveys which are wholly dependent on professionals. This is an obvious advantage of using volunteer fieldworkers, but it is important not to over emphasise it in relation to the other benefits of using volunteers that we have covered here.

2.8 Establishment of protocols

"In order that common standards shall be achieved throughout the survey (which means that over the course of time of monitoring work) it is important that all the survey forms and explanatory material that are to be used by fieldworkers are carefully designed and thought out" (Yates, 1981). This is just as true for professional fieldworkers as for volunteers. Our experience with using volunteers is that one is forced to pay particular attention to these issues because the volunteers quickly come back with questions if the forms or the instructions are unclear. As a result, if another takes over the survey in later years, they may be unaware of procedures adopted by their predecessors because these procedures were in their predecessors heads rather than being recorded on paper. Thus volunteer based surveys, by forcing one to be more explicit about instructions, have a long-term advantage in ensuring that common protocols are adhered to.

3. POTENTIAL PROBLEMS WITH USING VOLUNTEERS

3.1 Level of expertise

Some volunteers may have less expertise than professional surveyors. It must not, however, be forgotten that some volunteers in national wildlife surveys and monitoring are professional ecologists carrying out these surveys in their spare time. Nor must it be forgotten that many amateurs have very considerable field experience with skills equalling, or indeed exceeding, those of many of their professional colleagues. The key issue is field skills and since these are rarely taught as part of the education of professionals, academic qualifications, however sound, are no guarantee of requisite field skills.

Training can overcome the problem of insufficient field expertise for amateurs, just as it can for professionals. Of course, since individual amateurs do less work than those professionally employed to carry out surveys, the training of amateurs tends to result in fewer man-hours of subsequent fieldwork per hour of training than does the training of professionals. However, the *Look Out For Mammals* project (Section 6) shows that training of amateurs can be carried out at relatively low cost. Indeed, amateurs are prepared to pay often significant fees in order to obtain training in the work for which they have so much enthusiasm.

3.2 Numbers

It may not always be possible to recruit enough volunteers, especially in sparsely populated areas, to undertake the level of survey work that is required. Recruitment can, however, be considerably enhanced by investing professional time in building up a team of committed volunteer fieldworkers for the monitoring work. This is one of the reasons why a professional infrastructure is needed for a monitoring programme where much of the fieldwork is carried out by volunteers (Section 4).

3.3 Cost-effectiveness

Given the need for training and for the building of teams of volunteers which take professional time, some survey work is certainly more cost-effective if done largely by professionals rather than largely by volunteers. The cost-effectiveness of an amateur versus a professional approach must be assessed on a case-by-case basis.

3.4 Availability

Survey organisers sometimes worry that volunteers may not always be available at the times when they are needed. After all, volunteers are carrying out the work in their spare time on which there are often many competing demands. BTO experience is that this is a minor problem. It is certainly outweighed by being able to concentrate many man-hours of volunteer work into a short period because of the availability of large numbers of volunteers. This is a major problem with conducting surveys using professional fieldworkers since the best time of year for conducting a survey may be a relatively short season so that it is simply impossible to recruit enough professionals to do the work within that short time.

3.5 Reliability

Some people who have volunteered to cover an area in a survey may not do so. In our experience, this is usually a very small proportion. This disadvantage is compensated for by the fact that those who do go out to do the work will do it to the best of their ability.

4. THE NEED FOR A PROFESSIONAL INFRASTRUCTURE

The history of the BTO is that the amount of work conducted by the organisation increased rapidly after the number of professional staff that the organisation employed had built up to a level that allowed them to provide the requisite support to the volunteers. There are several jobs that need to be done in running survey and monitoring programmes for which professional input is important. They are as follows:

- **Planning** - Professional expertise is needed to carry out the detailed work of planning surveys and to make sure that the best principles of design are used. The professionals may also be needed to carry out trials of alternative methods before a survey is launched.

- **Training** - Training by professional organisers is a good way of ensuring common standards across fieldworkers.

- **Organisation** - There is a great deal of routine office work in organising surveys, from arranging that the necessary coverage is indeed obtained, to producing and distributing the recording forms. Much of this work is not the sort of thing that volunteers wish to do, and much of it demands sustained and intensive input at particular times.

- **Publicity** - Publicity may be needed on a large scale during the launch of a scheme. This demands both time and expertise.

- **Answering fieldworker queries** - Even in the best planned surveys, fieldworkers are likely to come up with queries when they begin to apply the methods in the field because it is difficult to cater for every eventuality in instructions that have been put together before a survey is actually carried out. The value of a professional organiser is that she, or he, can be available constantly to answer these questions and can ensure that the answers to them are the same for all fieldworkers.

- **Collating data -** The collation of large amounts of survey data (including their input into appropriate computer databases) is a much more demanding task than might be thought. For long-term work the data have to be stored such that they can be used without ambiguity in future. This requires both professional expertise and experience if it is to be done properly.

- **Analysis** - The analysis of data arising from monitoring work requires considerable statistical and computing abilities that almost inevitably require professionals to carry out the work.
- **Feedback to the volunteers** - This is an important aspect of building the volunteer network (see Section 7). It is important that it is done well, and that it is done promptly. Volunteer survey organisers often do not have enough time available to give the feedback as quickly as is desirable.

A few volunteers have the expertise, the competence, and the time to carry out the sort of full time organising work for which one might otherwise employ a professional. The majority of volunteers, however, either have jobs that prevent them devoting sufficient time to organising surveys or, if they are retired, they do not wish to undertake such demanding tasks and would rather concentrate on fieldwork.

Other advantages of professional organisers arise if they work for a body that is responsible for a suite of mammal monitoring and survey work. Even though there may be turnover of individual staff in such organisations, there is a build-up of corporate expertise and the development of the necessary long-term continuity of approach that is needed for successful monitoring. It should also be noted that, at the corporate level, it is easier to manage professionals than volunteers, particularly if performance is not up to standard.

5. HOW MANY MAMMAL VOLUNTEERS MIGHT THERE BE?

Sources of volunteer manpower for mammal monitoring are various. The chief ones are probably the established voluntary bodies: The Mammal Society has a growing membership of *c.*2,000 and The Bat Conservation Trust *c.*3,000. Both of these have been able to mobilise many hundreds of volunteers for some of the national surveys of mammal species (as have other people organising such surveys).

In addition, there are special interest groups who may be able to provide substantial input for certain species - the 80 groups who belong to The National Federation of Badger Groups, The British Deer Society, The Game Conservancy Trust, and the British Association for Shooting and Conservation. BASC, in particular, have a large membership (around 125,000), which includes the majority of the UK's professional gamekeepers and many others who are active in the countryside, such as professional and amateur deer-stalkers. BASC members are perhaps particularly likely to be interested in (and to possess the appropriate skills for) monitoring key quarry species, but no formal attempt to gauge this interest has yet been made. Overlap in membership between BASC and other organisations such as The Mammal Society and the British Deer Society would have to be considered if volunteer input were solicited from several bodies.

Some mammalian species or their signs are identifiable by relatively inexperienced naturalists, especially if good identification materials and training are provided. It is likely that there are large numbers of potential mammal surveyors who could be contacted via the Wildlife Trusts, local naturalists societies, etc. Even if such people have no particular commitment to mammal monitoring in general, their interest may be enough for them to participate in an individual survey (perhaps one of the less-demanding). Providing they get the right encouragement, training, and feedback, this may lead on to further surveys and to taking up membership of relevant bodies such as The Mammal Society.

The fact that some mammals are relatively easy identifiable means that it may be possible to recruit a wide range of people working in the countryside into mammal monitoring. The easiest groups are those that work for large agencies, such as The Forestry Commission, The Environment Agency, and SEPA. Such people may well be prepared to participate in surveys of species such as deer, Red Fox, Badger, Wildcat and Pine Marten.

In summary, there are enough potential volunteers for a good national programme of mammal monitoring to be run, provided the professional infrastructure is in place to develop the network.

6. DEVELOPING THE VOLUNTEER NETWORK THROUGH TRAINING

6.1 Why train?

Training improves people's skills, so improving the quality of their work. Furthermore, it builds their self-confidence, so making them more prepared to participate in surveys and monitoring.

Follow-up questionnaires to 1997 participants in LOFM training courses (see below) showed that in the subsequent year, over 60% had submitted records to their County Mammal Recorders compared with 18% the previous year; over 60% had used new search methods; and 50% had made records of mammal groups that they had not previously recorded.

6.2 *Look Out For Mammals* Courses

The Mammal Society has run this training project during 1996-9, mounting 60 weekend courses over that period in all parts of the UK. To date, *c.*500 people have attended and it is anticipated that the final number will be almost 700 - double what was planned for the project.

These weekend events include:

- talks and practical training on finding, identifying signs and making sightings of mammals, particularly distinguishing difficult groups.
- hands on experience of Longworth trapping
- owl pellet analysis of identification of mammal remains
- demonstration of the new mammal recording software
- training in identifying mammal calls
- access to an extensive collection of skins, feeding remains, droppings and other mammal signs enabling participants to develop recognition skills.

Participants in the courses have the objectives clearly laid out for them and are tested on their level of achievement at the end of the course. Those who successfully graduate from the course are awarded a certificate (accredited jointly by The Mammal Society and the Field Studies Council). This is a good system for producing a cadre of fieldworkers, trained to consistently high standards.

As part of this programme, a team of trainers has been set up. A standardised programme has been developed for training such trainers.

The courses are evaluated by participants and 70% of participants in the 1997 courses said that they would now like to receive more advanced training.

6.3 Further benefits of the LOFM project

- Publication of *How to Find & Identify Mammals* training manuals. Over 1,000 have been sold.

- National Mammal Recorder workshops co-ordinated by the *Look Out For Mammals* project, have provided a forum for debate on Mammal recording issues.

- New versions of specially developed mammal recording software; the LOFT Recording Package, have been circulated. Over 70 systems are now in operation.

- Improved the UK coverage of County Mammal Recorders from 60% to 95%.

- A LOFM national survey of Harvest Mice revealed alarming declines over the last twenty years. This information forms the basis for future targeted surveys and a successful media campaign has targeted farmers who are in a unique position to manage Harvest Mouse habitat sympathetically.

- An additional investigation into survey techniques for recording Water Shrews has tested and established new and effective methods for collecting records of this elusive species.

- Where training courses involve people mostly from one area, they serve a valuable role in building the local team.

6.4 The future

The Mammal Society is now seeking funding to take LOFM forward and to develop courses in monitoring as such, going beyond the simple identification and recording covered in the courses run so far. An Atlas may be produced to focus interest and raise the profile of mammal surveying by volunteers.

7. DEVELOPING THE VOLUNTEER NETWORK THROUGH COMMUNICATION AND FEEDBACK

It is important to give volunteers feedback on the results of their work, both in terms of straightforward descriptions of how many animals have been found and where and in terms of the use that is being made of that information. The chief value of that feedback is to maintain the level of enthusiasm and commitment that is required in order for the volunteers to continue the work that they do.

Feedback is also important in building up the expertise of volunteers. As organisers discover the problems that volunteers are having and the ways in which their work can be improved, they can pass on the necessary messages as part of the feedback.

To obtain both of these benefits, it is necessary to give specific feedback on individual surveys, but more generalised feedback on mammals and their monitoring is also valuable, not only for these purposes, but also for creating a general climate of interest in the monitoring work, and thus for recruiting new participants.

Feedback can take a variety of forms. Newsletters that reach the people who have participated in a survey and potential recruits are perhaps the most important way of reaching a large number of people for a relatively modest outlay of resources. It is important that all participants get newsletters about their work. This can be difficult if people work in groups, only one member of which is known to the national organiser. A web site can also be valuable (particularly for reaching participants whose names and addresses are unknown to the national organiser). Unlike a newsletter, however, it does not force itself on the attention of participants or potential recruits. Nor may it give the same sense of belonging as does a newsletter sent to participants in the survey, a sense of belonging that may be very important in maintaining volunteers commitment to the work (It is true that one can operate a web site with access restricted to the survey participants, but this tends to defeat the publicity objective which is important in terms of recruiting new volunteers).

Meetings between the volunteers and survey organisers are especially important in developing enthusiasm for monitoring work. These may take the form of informal gatherings, with groups of volunteers in a region or more formal workshops. Presenting lectures to local natural history societies, local mammal groups, Wildlife Trusts etc. is valuable for recruitment and can also be used as an effective means of thanking and meeting survey participants as they are likely to be members of such audiences. Short conferences are another effective way of developing the commitment of the volunteers.

Face-to-face contact between professional organisers and volunteers is easier if the professional organisers are not all concentrated in a single office, but are spread across the country. We would urge that serious consideration is given should a body be set up to promote mammal monitoring to having offices in the different countries of the UK. Compared with having a single office this has many disadvantages, such as losing out on economies of scale and on ease of interaction between the staff. It reduces the extent to which the organisation is seen as a focus of interest and to which it becomes a centre of expertise, it can interfere with the integration of and mutual support within the monitoring team. It may also mean, unless the matter is fairly carefully managed, that volunteers in different parts of the UK may be getting slightly but significantly different advice on how to conduct their survey work. Such disadvantages need to be carefully weighed against the advantages of the organisers being seen to have a local commitment and to them being able to meet a greater cross-section of the volunteers on a much more routine basis.

8. THE IMPORTANCE OF A MEMBERSHIP-BASED ORGANISATION

We believe that membership-based organisations are the most effective way of developing a volunteer network for wildlife monitoring.

An obvious advantage of conducting much of the monitoring through a membership-based organisation is that such bodies, through their membership, have good contacts with volunteers. In practical terms, it is very important to have an up-to-date database of the names and addresses of potential volunteers. The law on data protection makes it increasingly difficult to keep lists of people who have not given consent to their names and addresses being held, especially if reasonable effort is not made to keep those lists up-to-date. Membership organisations, by necessity, have to have the arrangements in place both for dealing with data protection issues relating to names and addresses and for keeping their records up-to-date.

The main advantage that membership-based organisations have in running volunteer surveys is that the members of an organisation have ownership of the work that the organisation carries out. This is not only true in a formal sense but also in an informal sense: the members not only have legal ownership of the organisation but they also feel such a commitment to the organisation that they feel that the work that is done is truly theirs. Developing and maintaining this level of commitment requires focused and sustained attention to members concerns. Nonetheless, it is much easier to do where the organisation running the work is one to which the volunteers have made a membership commitment rather than if it is merely some body that has simply asked the volunteers to assist it.

The feeling of ownership is important for three chief reasons. First, it helps to prevent the organisation being seen as some sort of remote body separate from the volunteers themselves. Second, it reinforces the motivation that the volunteers have for the work because they have made a commitment to the organisation through their membership. Third, in a well run membership organisation, the members should be able to have their views heard. This is always true in principle, since the members will be responsible for electing the board of governance of the organisation. If that board works properly, along with its various specialist committees, it should provide an important channel of communication between the members and the staff. It is important that members feel that they are able to make their views heard, both in strengthening their commitment to the work of the organisation and also in broadening the base of expertise that feeds into the organisations work. It is too easy for professional organisers sitting in offices to lose contact with the problems of fieldworkers. In a well run, membership-based organisation, however, the concerns of the fieldworkers can be fed through the proper channels so that they influence the way in which future work is organised.
If the professional organisers of surveys do not respond to the concerns of fieldworkers, then fieldworkers are likely to stop participating in survey work. We believe that, in a membership-based organisation, they will generally make their views clear through the usual channels before they reach the stage of resigning. Furthermore, if they do resign from membership, it will quickly become apparent that the organisation is not satisfying the wishes of its members. This is a powerful form of feedback. In contrast, if a survey is organised by an institution that is not membership-based, then the support of volunteers can slip away almost unnoticed until it is too late.

We believe that the lessons from the ornithological world, not only in Britain but throughout the world, are that wildlife monitoring works best if it is carried out by a membership-based organisation and less well if it is carried out by private research institutes, universities or governments that try to recruit volunteers without a membership base. Our interactions with amateur naturalists suggest to us that government bodies are at a particular disadvantage in this disregard, being perceived as remote, unresponsive to the concerns of amateur naturalists, unduly influenced by political interests, and as trying to get their monitoring work done "on the cheap".

9. ORGANISATION AT THE LOCAL LEVEL

From early in its history, the BTO has benefitted from having a network of Regional Representatives. These are volunteers who undertake to organise the Trust's work at local level.

They are usually responsible for a single county, though in sparsely populated areas a Regional Organiser may take on more than one county, and in heavily populated areas it is sometimes advantageous to split a county between more than one Regional Representative.

It is not the function of BTO's Regional Representatives to organise surveys as such. Rather, they implement the survey organisation at local level. The value of their input is as follows:

- They know the local volunteers, not only those who are members of the organisation but also non-members who are potentially interested in participating in the survey and monitoring work.

- They know which of the local members are reliable because they know many of them personally and, indeed, have often been in the field with them.

- They provide contacts with local groups such as local natural history societies, local bird clubs and county Wildlife Trust branches.

- They know their local areas. This can be important for some surveys, if effort has to be focussed in particular sorts of places or if particular large land-owners need to be approached in a certain way in order to allow access to their land for wildlife surveys.

- They can deal with some of the questions and worries of volunteers and so take pressure off the national organisers of surveys (though it is important to regulate this element of their work to ensure that the same advice is being given by Regional Representatives across the country.

- They provide a focus for feedback to the volunteers and for contact between the volunteers and the organisation as a whole, helping to prevent the organisation as being seen as a remote. professional driven body.

- In some cases, local organisers can be useful in screening survey returns before they are submitted to the national centre. They have the local knowledge to pick up errors that might not be spotted by national organisers and they know more about the ability of individual fieldworkers so that they can judge whether data are likely to be correct. They are also often in a better position to discuss with fieldworkers the quality of their records than would be a national organiser sitting in an office remote from the fieldworkers.

We believe that a similar network of local organisers would not only be valuable for mammal monitoring work, but would also be relatively easy to set up. There is already an almost complete network of County Mammal Recorders. In addition, there are local mammal groups in some areas which provide a particular focus for volunteer mammal studies. It is true that some of the County Mammal Recorders are not particularly active but, given the lack of official support for their activities, it is remarkable that they are as active as they are. In any case, we believe that these sorts of problems can be overcome if sufficient resources are put in to supporting the network. Resources are not only needed to ensure that individual local organisers are effective (by enthusing existing incumbents and by recruiting replacements for ineffective individuals) but they are also needed to support the work of the local organisers. That support may range widely from the provision of office back-up and of such things as display materials, to the training of local organisers in effective ways of carrying out their role.

10. THE SPECIAL PROBLEMS OF SPARSELY POPULATED AREAS

It is almost inevitable that there are likely to be fewer volunteers available in sparsely populated parts of the country. In practice, the problem seems to be smaller than might be thought. In Scotland, for example, where large parts of the country are very sparsely populated, the membership of The Mammal Society is disproportionately large in relation to the population as a whole (and levels of participation in almost all BTO schemes are also disproportionately greater). Similarly, in Northern Ireland where we (and we understand others) have sometimes had problems in recruiting enough volunteer fieldworkers, The Mammal Society has found a particularly strong demand for training courses. It may be that, in the more sparsely populated parts of the UK, people appreciate the need to get involved themselves and not to leave such volunteer work to others. In addition, in these smaller communities people with common interests tend to know each other better than they do in heavily populated parts of the country, so that there is more interaction and mutual encouragement to take up volunteer work of the sort we are discussing. Nonetheless, there is often a problem in getting enough volunteers in the sparsely populated parts of the country and any plans to set up a programme of mammal monitoring must address how this problem can be dealt with.

It is important, in such areas, to demonstrate to people that the work one wishes to carry out is useful in a local, as well as a UK, context since people often have greater commitment to their local area or to their own country than they do to the UK as a whole. This needs to be remembered throughout the process of interacting with volunteers and it is one of the reasons why it is valuable to have contacts at local level and not just through newsletters and conferences that cover the whole of the UK.

The key to recruiting volunteers is persistent encouragement to participate. The means are through meetings with local natural history societies and similar groups, through notices in the magazines of the Wildlife Trusts, through training courses, and so on. This sort of encouragement can best be delivered at a local level, underlining the importance of having regional meetings around the country and events associated with National Mammal Weeks, as well as a good system of regional organisers and, if possible, professional staff located in offices in various places around the UK rather than in just one place. Given that this sort of encouragement to participate is delivered at local level, it is possible to concentrate these activities in those parts of the UK where volunteers are most needed. Doing so can have an important impact on the level of recruitment.

Concentrating recruitment and publicity efforts in the areas of sparse population is unlikely to overcome the problem entirely. One way of mitigating its effects is to stratify the sampling programme for surveys according to the availability of observers. This allows the variation in intensity of sampling in different regions to be allowed for in the analysis. It does not, however, solve the problem that the intensity of coverage in sparsely populated regions may be too low to give satisfactory information on the regional populations of animals.

To attain better coverage in sparsely populated regions than the local volunteers can provide, it is necessary for people from other areas to help out. One way in which this can be done is by mounting expeditions of teams of volunteers from elsewhere in the country. “Earthwatch” is a global example of the way in which volunteers are often prepared not only to participate in working holidays but to pay the costs of doing so, particularly where there is an element of training involved. Since sparsely populated areas of the UK tend to be areas that naturalists from elsewhere find particularly attractive, there are considerable possibilities of covering such areas with visiting teams of observers. We suggest that such arrangements may work best when the organisation responsible for monitoring is able to bring together potential visitors and local volunteers. The latter, with their local knowledge, can undertake tasks such as getting access permission and finding accommodation, so that the visiting volunteers can concentrate on getting the fieldwork done. Even simply putting individuals from elsewhere into contact with the regional organisers in sparsely populated areas can be a useful contribution to increasing the volunteer effort in the sparsely populated regions.

The obvious solution to coverage in sparsely populated areas is to employ professionals to survey them. We believe that this should be a last resort because the response of volunteers may be that their time is obviously not needed, since the survey organisers can afford to pay professionals. If professionals are put into the field, they should have close contact with the local regional organisers so that they are very much seen as part of the local team and not just as professionals drafted in from outside.

It is often advantageous for survey organisers to undertake some of the fieldwork involved in their survey in order that they should understand the practical problems which the fieldworkers encounter and to provide a quality control against which to evaluate the results submitted by volunteers. If this is to be the case, then it is clearly best for their efforts to be especially concentrated in the sparsely populated regions of the country, not only because that helps to fill the gaps in the coverage, but because if they interact well with local volunteers and potential volunteers, then they can build up the enthusiasm that is so important for recruiting and retaining members of the volunteer network.

11. SHOULD DIRECT FINANCIAL SUPPORT BE PROVIDED FOR VOLUNTEERS?

There is no doubt that providing financial support for volunteers could help recruitment, although, depending on the sort of financial support offered, they might no longer be volunteers in the strict sense. Many of the advantages that stem from using volunteers would persist, such as the number of people that could be involved in a survey over a short period of time, and the local knowledge that volunteers have of their areas. The major disadvantage of supporting volunteers financially would be the costs, even if only travel costs and a modest fee were to be paid, this could increase the overall cost of a monitoring programme many fold, even to the point where it might be more cost-effective instead to conduct the survey wholly through professional staff.

Even if it should be judged that the costs involved of providing financial support for volunteers are justified by the likely improvement in recruitment for a particular survey, it is important that the issue is very carefully considered before it is decided to go down the route of making payments. This is because any such system of payment sets something of a precedent with wider implications for wildlife monitoring generally. Payments made in respect of one monitoring scheme may be a cost-effective way of running that scheme but they may, through undermining volunteers' willingness to participate in survey work without financial support, cause problems for other wildlife monitoring schemes.

It is also worth pointing out that developments in employment law are such that one has to be extremely careful in making payments to volunteers. It is very easy to get into a situation where they are legally to be treated as employees. This may lead to problems in relation to conditions of employment, health and safety, minimum wage and dismissal on the grounds of unsatisfactory performance, or indeed of redundancy.

The arguments against providing direct financial support for volunteers are therefore strong. In general, the equivalent funding spent on providing them with encouragement, support and feedback is likely to be more cost-effective in building up a team of dedicated volunteer wildlife surveyors.

There is one exception to this generalisation, which is that coverage of remote areas may be improved if some funding is available to assist with the travel expenses of volunteers. Even here, however,
it is important to be seen to be providing such funds as a special case, with the funding available to support fieldwork requiring special efforts in remote areas. The payments should never be seen to be matters of routine.

PART VI. POTENTIAL RELATIONSHIPS BETWEEN MAMMAL MONITORING AND THE NATIONAL BIODIVERSITY NETWORK

1. THE CURRENT BIOLOGICAL RECORDING NETWORK

Some biological recording is organised through national bodies but much of it takes place through Local Records Centres (LRCs). The distribution of these is, unfortunately, very patchy; the number of effective LRCs is perhaps only 20% of what is required; some parts of Britain have never had an LRC; others have had one in the past but not now. The effective LRCs feed data into the national Biological Records Centre (run by ITE); others do not.

Another important element of biological recording comprises the County Recorders, usually volunteers but sometimes employees of bodies such as county museums, squeezing their recording work into gaps they make between their other duties. Some counties have recorders for a wide range of taxa (sometimes co-ordinated through a county naturalists' society); some taxa (including, now, mammals) have recorders in almost all counties. As with LRCs, the effectiveness of County Recorders varies widely. Effective County Recorders work closely with effective LRCs, exchanging records systematically.

Ulster, with a Biological Records Centre that covers the whole province, is in a unique position. We address this briefly in section 9.

2. THE PROPOSAL FOR A NATIONAL BIODIVERSITY NETWORK (NBN)

The NBN is currently under development, with the objective of improving the provision of biodiversity information to all those who need it, through better collection, collation, and dissemination. The vision is of a complete network of LRCs (to gather and disseminate data locally), linked with national societies, organisations and schemes that gather or use such information.

Much thought, planning and preparatory work has gone into the proposal but its progress depends on how quickly three things can be achieved: first, completing the LRC network; second, building the links between the elements of NBN in such a way that information is as freely available as possible but with safeguards against its misuse (and with protection of ownership rights); third, funding for the building and operation of what will be an expensive system. It is currently not clear what the time-scale is likely to be, though the wish is to begin expansion from a demonstration phase in 2000 and to complete the national network with comprehensive local coverage by 2010.

This part of our report addresses the part that NBN might play in mammal monitoring. We concentrate on one area in particular: the potential role of the LRCs.

3. THE ADVANTAGES OF BUILDING FROM LOCAL TO NATIONAL

Many naturalists have particular commitment to their local areas. Building up national programmes of recording and monitoring from the local level has the advantage that such local commitment is harnessed. Many volunteers in national schemes, however, also take a pride in making their contribution to something of national significance, so it is important that the local elements are seen to be part of the national programme, not as independent entities.

The enthusiasm of volunteers can also be boosted through direct contact with the organisers of surveys, which is clearly easier if those organisers are locally based. Local centres can, however, only provide a limited range of expertise. Furthermore, it is likely that many, if not all, surveys will need a national co-ordinator if they are to be effective at national level. Thus personnel of local record centres may be seen as no more than intermediaries, with the “real” organiser still being a faceless person based in a distant town.

It should be noted that both of the above advantages of local organisation can be delivered not only through the federation of local work into a national programme (the “bottom-up” approach) but also through the establishment of local contacts for a national scheme (the “top-down” approach).

Local Records Centres could provide an opportunity for volunteers to help with the inputting of data into computerised databases. Not only are more volunteers close to LRCs than to single national centres but volunteers are generally more likely to be interested in inputting their own area’s data into a database managed in that area than in inputting data from unfamiliar areas into a central repository. (Note that we have not addressed the technical issue of whether the packages currently available for biological recording would be appropriate for managing the data from monitoring schemes).

Finally, a bottom-up approach ensures that the projects undertaken are appropriate, both in nature and scale, for local priorities. Suppose, for example, that a county had put the monitoring of Brown Hares into its Local Biodiversity Action Plan but found that Brown Hares were only recorded on a handful of those sites within the county that were included in the sample for the national monitoring programme. If this was so, the national programme would be unable to deliver the information regarded as of local priority. If the national programme was a federation of local schemes, each county could (in principle) ensure that its local needs were fulfilled.

4. THE DISADVANTAGES OF BUILDING FROM LOCAL TO NATIONAL

For most wildlife, especially wide-ranging species like mammals, monitoring is needed at the national level; their conservation management requires policy decisions (and the right administrative and legislative framework) at national level - and thus also require monitoring at national level. While local action may be as, or even more, important for some species it is generally the case that this needs to be set within the right national framework of policy and legislation. What is needed, therefore, is a national programme, adapted to local circumstances as appropriate. Even if a national monitoring programme is required, it would be possible to build this up from the local level. We have presented above the advantages of doing so. There are, however, a number of disadvantages, which we judge to be overwhelming.

A major problem with the bottom-up approach is that different areas may have different priorities, so that the coverage of an individual species (or group of species) may turn out to be patchy nationwide. It may be appropriate, in terms of national priorities to have more intensive efforts in some regions than in others but such appropriate distribution of effort is unlikely to emerge simply from adding together local schemes.

This problem would disappear if the financial and human resources were sufficient to allow good coverage of all species in every county, or even to allow each county both to put in the concentrated effort that was felt locally to be needed on local priority species and to provide coverage of other species adequate for contribution to the national monitoring programme.

Unfortunately, resources are limited. A county that concentrates enough effort on riparian habitats to be able to monitor riverside species precisely at the local level is less likely to be able to find enough further volunteers to do all of the general mammal monitoring needed nationally.

A third problem with the bottom-up approach is that the data can only be interpreted readily at national level if they are gathered using uniform protocols and common data standards. Such are unlikely to emerge without an overarching national organisation.

5. CONCLUSION: MAMMAL MONITORING SHOULD BE CENTRALLY ORGANISED

We believe that a national programme of monitoring can only be delivered effectively if it is centrally organised; the disadvantages of the alternative bottom-up approach (4, above) strongly outweigh the advantages (3, above). Ornithological experience across Europe supports this conclusion. Bird monitoring has been effectively developed in many European countries but not in those where the organisational structure is divided regionally.

Our conclusion specifically with reference to NBN is that it cannot provide the means for collecting data for a national monitoring programme. If the organisation of a survey is the responsibility of a national centre, then the data can be collected satisfactorily without NBN being involved, whether the fieldworkers are professionals or volunteers, though indirect support of fieldworkers may usefully be provided by LRCs (see Section 7, below).

6. CAN NBN CONTRIBUTE IN ANY WAY TO DATA COLLECTION FOR NATIONAL MONITORING?

Our general conclusion does not mean that NBN has no part to play in data collection for national monitoring. In particular, the national monitoring of some species may require intensive local work (e.g. local studies of the more southerly populations of Red Squirrels). There may also be cases where local enthusiasm results in intensive studies that complement the extensive national work (e.g. the new Water Vole study in Somerset). LRCs may be important in either circumstance, providing a focus for local organisation, technical expertise and back-up, and a connection (via NBN) with the national programme.

Should intense local work be planned, it is important (in terms of effectiveness) that it fits in well with the national programme and that it does not detract from national priorities. It is also important, as with all monitoring work, that it has some guarantee of continuity, to avoid resources being wasted. Given the history of so many LRCs, this last point should not be forgotten.

LRC personnel (whether staff or volunteers) can also contribute significantly to national monitoring by encouraging volunteers to participate and by stressing the value of local efforts being drawn together at the national level, to provide the monitoring feedback that will ultimately drive national policy and, thus, eventually, the fate of local wildlife. LRC personnel can also be in the vanguard of training, perhaps going on special training courses themselves and then passing on the skills to local volunteers. Demonstration collections of skins and “signs” would be particularly useful for training potential mammal recorders.

LRCs may also assist national programmes by providing office facilities for volunteers (both fieldworkers and regional co-ordinators). Computing facilities and local data collation (Section

3, above) are obvious examples but even such simple things as photocopying may be useful to some people. For monitoring schemes that involve significant quantities of data being generated by individual observers, it may be cost-effective to ask observers to submit the data electronically; more generally, regional organisers might usefully submit their regional data electronically. In such cases, LRCs may be able to provide the appropriate facilities for the input and transmission of data.

7. USING LRCs AND NBN FOR DISTRIBUTION RECORDS

Rejecting a bottom-up approach to building a mammal monitoring programme does not mean rejecting any role for LRCs. They have a part to play, especially through NBN and especially in terms of distribution records. Such records are useful for identifying locally significant wildlife sites, which is often important for local planning. LRCs are the most effective means of collecting and collating such information; NBN will be an effective means of delivering distributional information collected at the national level to the LRCs.

Even though there are severe problems of interpretation caused by the unsystematic nature of most biological recording, such records have been used both to model the distributions of animals and plants (thus helping us to understand what controls them) and to monitor changes in distributions. LRCs are important for drawing in general distribution records, particularly because they can harness local enthusiasm in a way that a national centre cannot. Those parts of mammal monitoring that require distribution to be monitored will therefore benefit greatly from the involvement of LRCs.

Where the recording of distribution needs to be based on a more systematic approach, as in recent atlases of birds, central organisations is appropriate, to maintain uniform protocols and common standards. LRCs have a role to play even here, however, as one means of linking volunteer observers into the national programme of work.

8. DISSEMINATION OF INFORMATION THROUGH NBN

This is the central objective of NBN. Even if a mammal monitoring programme is organised centrally, NBN will be a highly effective means of delivering information from the central system to LRCs. Site-based records would form the bulk of such information (Section 7, above) but it would be appropriate for LRCs also to be the point of contact between NBN and the public in respect of monitoring results for local populations. This would be important both for the development and promotion of the monitoring programme and for the use of its results at local level.

9. ULSTER: A SPECIAL CASE

The Ulster Biological Records Centre covers the whole province and is well-founded. Furthermore, the ecological, land-use and cultural differences between Ulster and GB are sufficiently great that it might be useful to modify national monitoring programmes for local application there, even at the expense of abandoning the uniformity of approach that is generally so important in national monitoring schemes. Furthermore, there may be advantages in some of the work in taking an all-Ireland approach in Ulster, even if this interferes with a UK approach: in terms of the effective delivery of conservation science, biogeography may be more important than administrative protocol.

We do not have the expertise to do more than raise these issues and to recommend that they be seriously addressed as part of the planning of a mammal monitoring programme.

10. SUMMARY

1. NBN would not be appropriate as the chief means of data gathering for the national mammal monitoring programme but has important roles in drawing intensive local studies into the national programme and in encouraging and supporting volunteer participants.

2. NBN has an important role in gathering distribution records locally for use centrally.

3. NBN has a major role in disseminating monitoring results.

PART VII PROPOSALS FOR A UK MAMMAL MONITORING SCHEME

1. SPECIES AND SCHEMES

The proposals set out in MMR are based around a single, three-tiered grid design, to which the recommended monitoring techniques are applied. We have not attempted to create a single monitoring scheme for all UK mammals, since we recognise that it is unlikely that a comprehensive scheme will be an affordable option. It would also lead to a lack of flexibility in incorporating pre-existing data collection and in adaptation to constraints such as the available density of volunteers. Instead, we have indicated species-specific monitoring options, combined into multi-species schemes where possible to maximize cost-effectiveness, as described in Parts III and IV. Table VII.1.1 summarises the available monitoring options for each species (as we see them), and the range of species for which each multi-species scheme can contribute useful information. We then indicate likely approximate costs for the various individual schemes and discuss briefly practical considerations for the organisation of our proposed composite mammal monitoring programme.

2. COSTS OF THE PROPOSED SCHEMES

We now present approximate costings for the multi-species schemes proposed in Part III and for a single example of a species-specific scheme, which should be generally applicable to all such schemes described in Part IV and referred to in Table VII.1.1. All costings are based on the experience of the BTO in setting up and operating each type of scheme and of the various staffing requirements that the schemes will incur. They should be taken as estimates: running several schemes in parallel under the control of a single organisation would be likely to lead to economies of scale and some costs are necessarily unpredictable until the details of survey design and the numbers of volunteers participating are known.

These estimates are costed at 1999/2000 rates and all figures exclude VAT.

The total costs are summarised in Section 2.8.

Note that we have not addressed the costs of running some of the more specialised single-species schemes.

2.1 Likely Costings- Additional Data Collation Through the Breeding Bird Survey

The figures presented below are the projected costings associated with the collation of mammal data as a formalised component of the Breeding Bird Survey. The recurrent costs represent approximately a 10% increase on the existing Breeding Bird Survey annual budget.

Detail	**Days**	**Grade**	**Cost (£)**
Setup costs			
Development of methods	55	HSO	11,000
Programming	30	HSO	6,000
		Total Setup Costs	**17,000**
Recurrent costs			
Inputting/Printing			3,000
Data Validation	15	SO	3,000
Data Analysis	20	HSO	4,000
Feedback/scheme promotion	20	SO	3,000
		Total Recurrent Costs	**13,000**

Notes:

1. Programming includes simulations on existing data to evaluate sampling requirements and the development of programs to check and analyse the data gathered.

2.2 Likely Costings - Additional Data Collation Through the National Game Bag Census

The figures presented below are the projected costings associated with the collation of data on sampling effort as a new component of the National Game Bag Census. It is assumed that secretarial support and other associated costs are already met as a component of the existing National Game Bag Census protocol.

Detail	**Days**	**Grade**	**Cost (£)**
Setup costs			
Form design	10	HSO	2,000
Analysis for setup	20	SSO	5,000
Promotion of the scheme	40	SO	7,000
		Total Setup Costs	**14,000**
Recurrent costs			
Promotion of the scheme	20	SO	3,000
Annual reporting	20	HSO	4,000
		Total recurrent costs	**7,000**

2.3 Likely Costings - Combined Scheme with Winter Transects, Sign Transects and Mammals on Roads

The three schemes (Winter Transects, Sign Transects and Mammals on Roads) could be co-ordinated most cost-effectively by running them in parallel rather than in isolation. This would require the establishment and introduction of schemes on a rolling basis, with one new scheme being established every year until all three were operating in parallel. The costings presented below assume this approach is adopted and include set-up and running costs. The costings are for ***all*** schemes together rather than per scheme. We anticipate that the establishment and operation of a single scheme (in isolation) would require approximately half of the sums shown: running all three would allow certain economies of scale.

Detail	**Days**	**Grade**	**Cost (£)**
Organiser/Publicity	220	HSO	44,000
Data Manager/Analyst[1]	220	SO	37,000
Secretarial support	110	SEC	12,000
Scheme workshops			*c.*10,000
Travel			*c.*5,000
Data inputting			*c.* 7,000
Mailing/Printing Costs (report)			*c.* 6,000
	Total Annual Cost		**121,000**

Notes:

1. Some consultancy on analysis techniques and statistical design may be considered appropriate, in which case this would need to be costed into this budget.

2.4 Likely Costings - Mammals on Nature Reserves

The costings presented below assume that a sample of 3,000 nature reserves are included in the scheme. The costs presented are recurring annual costs (30-50% on top of this is envisaged during the initial year).

Detail	**Days**	**Grade**	**Cost (£)**
Promotion of the scheme & feedback	55	SO	9,000
Data analysis and interpretation	20	HSO	4,000
Secretarial support	20	SEC	2,000
Data inputting[1]			*c.* 1,000
Mailing/Printing Costs (report)			*c.* 9,000
		Total Annual Cost	**25,000**

Notes:

1. - Assumes that data are input using an Optical Mark Reader.

2.5 Likely Costings - Owl Pellet Survey

The figures presented below are the projected costings associated with the processing of mammal data from a standardised analysis of pellet material. This would involve collection, analysis and submission of material by volunteers, with co-ordination and some validation carried out centrally.

Detail	**Days**	**Grade**	**Cost (£)**
Co-ordination	20	SO	3,000
Promotion/Feedback	20	SO	3,000
Data analysis	20	HSO	4,000
	Total Annual Cost		**10,000**

2.6 Likely Costings - One Year Single Species Survey

The costings presented below assume that a single year of fieldwork is required to carry out a survey for an individual species.

Detail	**Days**	**Grade**	**Cost (£)**
Setup costs			
Determination of sampling protocol[1]	10	SSO	2,000
Determination of sampling protocol[1]	75	HSO	15,000
		Total Setup Costs	**17,000**
Running costs			
Overall running of the project	15	SSO	4,000
	50	HSO	10,000
	110	SO	19,000
Secretarial Support	30	SEC	3,000
Expenses (Travel, Inputting Data, Printing Costs)			5,000
		Total Running Costs	**41,000**

Notes:

1. This includes examination of suitable methods, simulation of stratification required and associated analyses.

2.7 Likely Costings - National Co-ordination of Mammal Schemes

The costings presented below represent the likely requirement for linking the various schemes at the national level, thereby providing a nationally coherent approach to mammal monitoring. The co-ordinator would also be responsible for the collation of data from existing schemes such as those currently carried out on deer and squirrels. These figures could potentially be reduced by 50% if the national co-ordination was integrated directly into the co-ordination of the three schemes (Winter Transects, Sign transects and Mammals on Roads) approach outlined previously.

Detail	**Days**	**Grade**	**Cost (£)**
Co-ordination of schemes, publicity, etc	220	HSO	44,000
Secretarial Support	50	SEC	5,000
		Total Cost	**49,000**

2.8 Likely Costings - Total Costs for All Schemes

Setup Costs (where calculated)

	Cost (£)
Additional Data from the Breeding Bird Survey	**17,000**
Additional Data from National Game Bag Census	**14,000**
Mammals on Nature Reserves	**Not costed**
Owl Pellet Survey	**Not costed**
Total (where costed)	**31,000**

Annual Recurrent Costs

	Cost (£)
Additional Data from the Breeding Bird Survey	**13,000**
Additional Data from National Game Bag Census	**7,000**
Combined Schemes (Winter Transects, Sign Transects,	**121,000**
Mammals on Roads, Mammals on Nature Reserves)	**25,000**
Owl Pellet Survey	**10,000**
Single Species Survey (includes setup costs)	**58,000**
National Co-ordination	**49,000**
Total Recurrent Costs	**283,000**

3. ORGANISATIONAL PRACTICALITIES

There are several issues that need to be addressed, or at least borne in mind, during the development of a mammal monitoring scheme.

3.1 Long-term guarantees

There is no point in setting up any monitoring scheme without some commitment to its long-term continuity. Schemes that are discontinued after a few years are a waste of time and money. They also seriously undermine the enthusiasm of participants, especially volunteers. If a mammal monitoring scheme is set up then those who have undertaken to fund it must be prepared to give guarantees about its future that are sufficiently firm that it would at least cause them severe embarrassment were the funding to be withdrawn. For this reason, it would be better to start with a modest scheme that costs relatively little than a more ambitious and more expensive scheme. A modest scheme can be expanded as it becomes established and if funding is available, whereas an expensive scheme is likely to be more subject to the vagaries of the financial climate.

Another aspect of long-term security is that those responsible for the work should be corporate bodies rather than individuals, so that there is a better guarantee of continuity.

3.2 Security of data

However the programme is organised, raw data and the supporting documentation should be copied and stored in more than one place. The most effective way to do this is to computerise the data, or at least to store its image on CD-ROMs. It is essential to set up the right data curation systems from the start. Indeed, as a one-off investment, data from previous surveys should be computerised where this has not already been done.

3.3 Developing the system

It would be unwise to set up all components of the system at once. Rather, there should be a phased approach, beginning with the most urgent schemes and introducing others after the most urgent are established.

3.4 Comprehensiveness

Consideration should be given to including bats and marine mammals in the overall mammal monitoring system.

3.5 Design and Statistics

A critical part of the design of any monitoring programme is the method of statistical analysis proposed to deliver information with the precision and power required. We have considered these issues with respect to the BBS in Part III.A.1, but many of our remarks there also apply to other monitoring schemes. All of the entries in Table VII.1.1 assume that sufficient sample sizes and effective analysis techniques are in place: these must be dealt with during the initial organisation of any survey and could have large impacts on the time and effort required (for example, to recruit volunteer effort from more sparsely populated areas). Where multiple surveys are to be considered, the quality of information which is likely to accrue from the *combination* of surveys must be assessed. This presents a different statistical problem which is considered briefly in Part VIII.4.

3.6 Organisation

There may be large numbers of organisations with potential interests in mammal monitoring, as producers or as users of information; some may be able to provide financial support or staff manpower; others may be able to muster teams of volunteers. All of them need to be drawn together, their different interests recognised, and an overall organisation put in place. We advise against setting up bureaucratic structures; what is need is clear agreement as to what is each body's role and how these various roles should work together in making the whole system work.

If the decision is taken to base much of the system on volunteer fieldworkers, one or more membership-based NGOs needs to be supported to take the lead in organising the volunteer-based work.

3.7 Geographic aspects of organisation

Thought should be given to whether schemes should be run centrally or from centres in each country (or even in regions of countries).

3.8 Professional/volunteer interface

We have covered many aspects of this in Part V. A further point is that some organisations may have such a particular interest in a species that they are prepared to put time from their own staff into the fieldwork or into its local organisation. If, as a result, these staff are essentially doing work that might otherwise have been done by volunteers and especially if they are covering only some of the work for a survey (with volunteers providing the rest), it is important that they are seen by volunteers as part of the same team as themselves. How this is done will vary from scheme to scheme but its importance should not be overlooked.

PART VIII. DETERMINING THE LIMITS OF CHANGE

1. INTRODUCTION

In Part I of this report we have considered why conservationists should wish to monitor British and Irish mammals. In Part II, we have considered the design of monitoring programmes. These broad issues now need to be brought down to the practicalities of putting together a practical programme for monitoring, based not only on this report and on MMR but on the views of all of those who have an interest in such work. This is not a task for us but in this final part of the report we raise issues that need to be addressed during the planning of a mammal monitoring programme: how one decides what are the priority species, what information is required for each (in terms of both type and precision), and the sorts of pilot work that should be done before the programme of work is finalised.

To set the scene, we quote from Buckland (1993) who, although he was addressing narrower and more local management issues, illustrates clearly how the definition of management requirements is an integral part of conservation science, determining exactly what science and monitoring needs to be done:

> *To determine appropriate methods for counting deer, or for estimating deer density, it is necessary to define and list management objectives. These objectives should be specific, and tolerances should be specified that determine maximum acceptable departures from the desired objectives. Only then can the value to management of competing methodologies be fully and objectively compared, and experiments carried out to aid this comparison. A strict definition of management objectives enables subsidiary requirements to be identified. For example, if an objective is to ensure that deer population size is maintained below some limit, that limit or "target population" must be determined. This in turn requires that the term target population is precisely defined. For example, it might be that population which maintains current diversity of habitat, or allows habitat diversity to reach a pre-determined level. This then necessitates modelling habitat diversity as a function of deer numbers, if possible by detailed modelling of deer requirements in different habitats, otherwise or additionally by monitoring habitat change and incorporating a feedback mechanism, so that cull sizes are adjusted to ensure convergence to the desired habitat diversity. The detailed "process" modelling allows target populations to be estimated, whereas the feedback approach by default yields an estimate only when habitat stability at the desired diversity has been reached, and the deer population is therefore at the target level. In practice, a combination of these approaches, with greater initial dependence on the process models, and increased use of feedback over time, allows faster achievement of the target population with adjustment of that target if feedback suggests that the initial estimate is poor.*
>
> *Tight definition of management objectives can lead logically to sophisticated research requirements, as outlined above. However, by specifying tolerances for these objectives, it may become clear that approximate rules of thumb can sometimes replace the process modelling step. For example, data from a number of sites and from various sources may suggest acceptable deer densities by type of forest with adequate accuracy. It is then necessary merely to estimate density periodically (with precision, and hence survey effort, determined from the specified tolerances), and to adjust cull levels if required.*

2. HOW SHOULD WE DECIDE WHAT ARE THE PRIORITY SPECIES?

Other things being equal, the species to which most monitoring effort should be devoted are those most in actual or potential need of active management. Of course, other things are not equal: some species may be very easy to monitor, so may be worth a little effort even if of low conservation priority; others may be so difficult to monitor that, even if they are of high conservation priority, it is better to devote the monitoring resources to other species. Nonetheless, determining priorities for conservation management is an essential next step in establishing a mammal monitoring programme. We list here matters that need to be taken into account when priorities are determined. Our list is not in order of importance.

1. Legal and administrative status

If there is a legal or administrative requirement to manage the population of the species, monitoring is essential.

2. Can the species be managed effectively?

Suppose it were to be concluded that the population of American Mink on mainland Britain could not be controlled given the resources available. (We are not arguing that this is, indeed, so). Then there is a little point in monitoring that population for its own sake. There might, of course, be reasons for monitoring it in order to understand its interactions with other species or as an indicator, but those are different matters; it is important to be clear about the issues and not to confuse them.

In contrast, it might be concluded that American Mink populations on many islands could be controlled; if there were reasons for implementing such control, monitoring of these populations would be needed.

3. Taxonomic status

Some conservationists argue that taxonomically more isolated species are more important than those with many relatives, since their extinction would result in a greater loss of total biodiversity. At the species level, this may not be an important criterion for British and Irish mammals. At the intraspecific level it is: many would wish to conserve Soay Sheep and Feral Goats because they are ancient breeds now scarce and rather distinct from modern domestic sheep and goats; however, they are not full species and should therefore perhaps be accorded relatively low priority.

4. Is the species alien?

The introduction of species outside their natural range has had many ecological and economic impacts; it has often reduced biodiversity by bringing about the extinction of native species. Even without such impacts, however, introduction of aliens results in loss of biodiversity - that part of biodiversity (γ - diversity in technical terms) comprising the biotic differences between different parts of the world that depend not on modern ecology but on the accidents of history, such as the absence (before man interfered) of marsupials from Europe or of Fat Dormice from Britain and Ireland.

Note that whether the species is alien does not always have a simple answer. For example, some might argue that the introduction of *Microtus arvalis* to Orkney by Neolithic people should be considered "natural"; we might wish to be more tolerant of House Mice than of Brown Rats because they have been here for a few thousand, rather than a few hundred, years; we might be more tolerant of the Brown Hare than of the American Mink because it has long ago settled into Britain's ecology, whereas the mink is still causing disruption.

5. Are the species' numbers dangerously low?

We doubt whether any species of mammal native in Britain and Ireland is so scarce that it is likely to become extinct through demographic accidents or inbreeding. The evidence from the establishment of so many species from small introductions and from the persistence of others on islands is that our mammals are able to persist at very low numbers.

6. Are numbers expectedly low?

The relationship of animal abundance to body size is one of the most persuasive of ecological generalisations (Peters 1991). It applies to British mammals (Greenwood *et al.* 1996). Harris *et al.* (in prep.) point out that some species of British mammals (e.g. Pine Marten) are less common than one would expect on the basis of their body size, while others (e.g. Rabbit) are more abundant than expected. They suggest that these departures from expectation should be used to identify species of particular conservation concern, and species interactions that should be considered, to take prioritisation beyond simple rarity and population change.

7. Current and historical population changes

If a species is currently declining in numbers, or has undergone a marked decline in the past, then (especially if the decline can be ascribed to human activities) many would argue that the decline should be reversed. People feel that the species' numbers should be restored to their "natural" level. Given the ecological transformations that man has wrought in Europe over the last 10,000 years, defining what that level should be is impossible in both practice and principle; that does not, however, weaken people's views that we "ought" to have more Pine Martens, Brown Hares and Water Voles.

Equally, people become concerned if populations are increasing beyond what they regard as desirable or natural.

These views are strongly value-laden but they are also often strongly held. Even when they do not lead to a decision to take action to modify the decline or growth in the population, they may require that the population is monitored, so that the need for management action can be kept under review.

8. International status

In addition to domestic issues, international status may be a reason for giving a species priority: Is the species generally rare in Europe? Does Britain hold a high proportion of the European population? Such considerations are often reflected in legislation but the latter should not be the only criterion.

9. Quarry species

Species that are hunted should usually be monitored (if only at the level of the individual exploited populations), to ensure that their numbers are not reduced to levels either that threaten the economic viability of the hunting or that are unacceptable to the public.

10. Health and economic impacts

Some mammals are vectors of human diseases and many others cause economic damage. In contrast, other species are of economic benefit, not just as quarry species but as tourist attractions, for example. It is not always necessary to monitor such species directly. For example, if damage to trees by Feral Goats is monitored and the goats are culled when the damage reaches unacceptable levels, the situation can be well managed - better managed, indeed, than if one monitored the goat population itself and managed it to some target that was considered, perhaps mistakenly, to be appropriate in terms of vegetation damage. In other cases, direct monitoring would be appropriate.

11. Ecological impacts and species interactions

The American Mink is an important predator of the Water Vole and may have been the key factor in the massive decline of the latter. If the Water Vole is to be conserved, we need to understand its ecology and be aware of the changing pressures on it; monitoring mink is thus important for Water Vole conservation, even if not for any other reason. Equally, the impact of grazing by Field Voles and Rabbits and their status as prey of many birds and mammals is an argument for monitoring their numbers.

12. Is the species a useful indicator of the state of the environment?

The way in which the declines of farmland birds have focussed conservation and political attention on the need to reform agricultural policy shows the potential value of using wildlife as indicators of environmental problems.

13. Cultural significance

Some species are culturally important: the Red Fox has played a major part in rural life and economics for many years; the Ship Rat was responsible for the outbreaks of bubonic plague that had so much impact on our history. Some would argue that these species should be conserved for that reason, just like the Magna Carta and great buildings.

14. Public resonance

Some species arouse more public sympathy and interest than others. In a democracy it is right that this should influence conservation action. Furthermore, species that resonate with the public will act as more effective alarm signals than others, if their decline is an indicator of wider problems. For these reasons, the resonance of the species with the public is an appropriate criterion to use when judging the priority of species for conservation monitoring, alongside the other criteria we have listed.

3. WHAT INFORMATION IS REQUIRED?

For some species, we have clearly indicated in Part IV the different monitoring programmes that would be appropriate for different management objectives. In general, however, there is a considerable range of possible objectives, so we have not considered alternative monitoring strategies in detail. It is important that the objectives should be determined for each species before monitoring programmes are defined; otherwise, inappropriate assumptions may be made.

Broad questions to be asked include:

- Do the management objectives require only an overall national monitoring programme or should the work be regionally focussed?

- Do the management objectives make the monitoring of distribution (at least in some areas) more useful (cost-effective) than monitoring numbers?

- How precisely do changes need to be measured?

The last question may perhaps be recast as "What change would be great enough to trigger concern?" but even in this form it is almost impossible to answer other than arbitrarily, especially in the absence of historical records showing the extent of past variations. A key level used in the Biodiversity Action Plan and elsewhere for the purpose of identifying species of conservation concern is a 25% decline over 25 years. Perhaps this should be regarded as a general guideline for the present.

Perhaps, however, 25 years is too long. Should we aim to be able to detect a 10% decline over 10 years?

Suppose that, given the resources available, a potential monitoring scheme is unlikely to be able to deliver the precision required. What should one do? One answer is that there is no point in wasting money on monitoring that is not precise enough. This is, however, too simple. Suppose that one mounted the monitoring anyway and discovered a decline of 20% over the next 10 years; one would be very glad not to have turned down the scheme on the grounds that it would not have reliably picked up a smaller decline. On the other hand, very imprecise monitoring is unlikely to be useful, since declines that are so large as to be detectable by very imprecise schemes are unlikely to occur. Thus the judgement as to whether a scheme is worth mounting depends not only on its precision and its cost but also on the likelihood and likely magnitude of untoward changes. It also depends on how bad these changes would be in conservation and other terms - a 50% decline in Field Voles might be considered to be worse than a 50% decline in Yellow-necked Mice (or perhaps not so bad!). We raise these issues not because we have answers but because they should be explicitly addressed by those who set up the monitoring programme.

4. TRIAL AND POWER ANALYSES

There are two issues which are critical in the design of all monitoring schemes: first, that the measure or index of presence or abundance is related to true presence or abundance in a known way and, second, that the survey sample size is sufficiently large for population changes of the magnitude required to be detected with the required statistical power. (If we are to consider cost-effectiveness, the latter can be extended to include the avoidance of over-powered designs.)

The trial work required to determine relationships between survey methods and population parameters will vary with method and species. At one extreme, direct counts of large proportions of a population (e.g. for Feral Sheep) may require no trialing at all; at the other extreme, detailed investigations of the factors influencing the detection of field signs such as Pine Marten scats may be necessary. Visual count methods can be heavily influenced by factors such as the activity of individuals and vegetation density, whereas the detectability of faecal signs can vary in complex ways with population density (see, e.g., Water Vole species account). In each case, the necessary extent of any trial survey work (calibrating proposed methods against other techniques) should be determined by expert opinion and by consultation of any previous work which has already been done using the method concerned. Educated guesses about the efficiency of some methods may be possible given the results of other work using related techniques: for example, the results of the current National Fox Survey will inform the design of our proposed Sign Transect Survey.

Four parameters need to be known to calculate the sample size of survey sites required for the detection of a population change with a given statistical power: the size of change/trend to be detected, the sampling interval to be employed, the variance which exists between sites in (changes in) abundance (or presence) and the extent to which short-term fluctuations occur around long-term trends. The former two are set (and can be altered at will) by the monitoring body; the latter two need to be measured or estimated. The best approach to investigating the implications of these unknowns is to conduct simulation analyses, informed by as much relevant information as possible.

Information on spatial variation in abundance or detectability will be available from the results of any one-off or longer-running survey. In this way, we ran simulations of future trends in BBS data (Part III.A.1) using estimates of current survey-square-specific abundance and presence effects. Data from past or existing Badger, fox or hare surveys (for example) could be used in the same way (although they would need, in practice, to be computerised). Information on (annual) fluctuations in abundance under a given long-term trend is harder to come by, and can strictly only be measured with long-term survey data (or at least repeated surveys) in which an underlying trend can be determined. In practice, it will be necessary to run simulations on a range of plausible levels of short-term temporal fluctuation and spatial variation where little useful data are available. Clearly, any simulations will be of higher quality and more reliable if more real data are employed: results on the power of future, repeated Badger surveys would be stronger than any on the power of the Mammals on Roads scheme (for which we do not even know mean detection rates as yet).

As well as variations in trend magnitude and sampling interval, simulations might also take into account issues of stratification and the degree of randomisation of survey sites. The former would form a key part of the design of many of our proposed surveys to maximize their efficiency (Part III) and simulation would be a useful approach for the exploration of stratification strategies. Randomisation may also be worth exploring: power is affected if survey sites are not selected randomly (as they were assumed to be in our BBS: Part III.A.1). A scheme such as our proposed Winter Transect Survey, which would probably include an (as yet undetermined) proportion of surveyor-selected transect routes (Part III.B.1), would benefit from simulations investigating the effects of this lack of randomness.

A further issue with respect to statistical power arises if multiple schemes as considered for the monitoring of the same species. Conceptually, it is clear that we would have more confidence in a population change suggested by one scheme if a consistent change were shown by an independent, parallel scheme. Statistically, however, consideration of the relative value of each scheme and how to quantify it may be necessary. Such consideration could be informed by the literature on “meta-analysis”, which refers to the combination of multiple, independent studies in searches for patterns at a larger scale (Osenberg *et al*. 1999a & b; Gurevitch & Hedges 1999).

We suggest that each potential scheme for the monitoring of each species should be assessed with respect to the need for trial field survey work, and particularly important areas are identified in the scheme and species accounts (Parts III and IV). For analyses of statistical power, many of the schemes we suggest are based on essentially similar data, so could be addressed by the same simulations, or at least by minor modifications of a basic simulation framework. We suggest that a suite of power analyses which would provide comprehensive coverage of potential mammal monitoring schemes (given that the data required are made available) should be achievable in *c.* 2 man-months of the time of a statistician.

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Table I.1.1 Action Plan objectives and targets for UK mammals (Anon. 1994).

Species	Objectives and Targets
Water Vole (*Arvicola terrestris)*	Maintain the current distribution and abundance of the species in the UK.
	Ensure that water voles are present throughout their 1970s range by the year 2010, considering habitat management and possible translocation of populations to areas from where they have been lost.
Brown Hare (*Lepus europaeus)*	Maintain and expand existing populations, doubling spring numbers in Britain by 2010.
Otter (*Lutra lutra)*	Maintain and expand existing otter populations.
	By 2010, restore breeding otters to all catchments and coastal areas where they have been recorded since 1960.
Dormouse (*Muscardinus avellanarius)*	Maintain and enhance dormouse populations in all the counties where they still occur.
	Re-establish self-sustaining populations in at least 5 counties where they have been lost.
Red Squirrel (*Sciurus vulgaris)*	Maintain and enhance current populations of red squirrel, where appropriate, through good management.
	Re-establish red squirrel populations, where appropriate.

Table I.1.2 The status and history of British and Irish mammals. Taken from The Population Review, The Handbook and Yalden, with additional information from The Atlas, The Field Guide and MMR.

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
Hedgehog	1,555,000	Widespread on mainland and (often through introductions) on islands.	General, up to tree-line, including in gardens; scarce in conifer woods, marsh, moorland and cereal crops.	Native. May have declined in last 50 years.	Probably introduced but now widespread.	Predator on eggs and chicks of ground-nesting birds; currently causing severe problems on Outer Hebrides (where recently introduced) for machair-breeding waders. Killed by game-keepers. Many killed on roads. Perhaps particularly susceptible to pesticides because they lay down hibernation fat.
Mole	31,000,000	Widespread on mainland but absent from most islands.	General, up to 1000m, except where soils too shallow. Uncommon in conifer woods, moorland and sanddunes.	Native. No evidence for changes in numbers or distribution.	Absent.	Molehills can cause problems by damaging farm machinery or by causing soil to be taken up by combine harvesters, so moles are widely controlled.
Common Shrew	41,700,000	Widespread on mainland; absent from Shetland, Orkney, Outer Hebrides, Isle of Man, Scilly Isles and some Inner Hebrides.	General, though scarcer where ground-cover is sparse. Range into arable crops from field margins.	Native. Population trends unknown.	Absent.	May be sensitive to use of insecticides.
Pygmy Shrew	8,600,000	Widespread on mainland and (perhaps through introductions) most islands, except Shetland and Scilly Isles.	General, especially where there is plenty of ground-cover.	Native. Population trends unknown.	Similar to British.	May be sensitive to insecticides.
Water Shrew	1,900,000	Widespread in most of mainland but patchy in N. and W. Highlands. Absent from Shetland, Orkney (apart from 3 records from Hoy 1847-1964).	Habitat preferences poorly known. Mainly found near clean, fast-flowing waterways but also near ditches. Frequently use deciduous woodlands and farmland hedgerows, but probably not permanently.	Native. Population trends unknown.	Absent.	May be sensitive to water quality and stream-bank management.
Lesser White-toothed Shrew	14,000	Scilly Isles (except smaller ones).	Tall herbaceous vegetation and woodlands. Boulder beaches.	May well have reached Scilly Isles by chance introduction rather than wholly naturally.	Absent.	A widespread species in S. Europe and Asia. Former subspecific status of Scilly population not now recognised.
		Widespread up to the treeline; on	Short grassland and heathland preferred.	Introduced by Normans.		A major agricultural pest, though

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
Rabbit	37,500,000	most islands.	Live in field margins in arable landscapes.	Expansion out of managed warrens was not marked until 18th and 19th centuries. British population probably 60-100 million, perhaps more, in first half of 20th century; myxomatosis reduced population by 99% but there has been a steady recovery of the national population since, with considerable local fluctuations.	Similar to British.	important for maintaining chalk grassland in places. Important food supply for some avian and mammalian predators and scavengers.
Brown Hare	817,500	Widespread but absent from NW and W. Highlands and Shetland; introduced to many other islands.	Commonest in open grassland and farmland below 500m, especially cereal-dominated arable landscapes.	Introduced in Iron Age or Roman times. Numbers appear to have declined from 1920s until now, with some recovery in the late 1950s and 1960s.	Widely introduced in late 19th century but remains scarce and localised (only in Fermanagh, Derry & Donegal).	Minor agricultural pest. Minor game species.
Mountain Hare	350,000	Scottish Highlands, Southern Uplands, Peak District, Isle of Man, some other islands.	Heather moorland (especially grouse moors).	Native to the Highlands; introduced to more southerly regions and islands. Numbers appear to have fluctuated at scales of one to a few decades.	Native. Occupies wide range of habitats, similar to those occupied by both hare species in Britain.	Similar to issues relating to Brown Hare. Well-marked subspecies in Ireland.
Red Squirrel	160,000	Still present in much of mainland Scotland (except N. and NW.) but only a few relict populations in England and Wales (including Isle of Wight).	Large tracts of conifer forest are prime habitat but also occupy smaller and deciduous woodlands.	Native (though reinforced with introductions). Major fluctuations occurred in Scotland in 19th century. Massively declined in England and Wales during 20th century as a result of competition from Grey Squirrel (especially in deciduous woods) but in Scotland impact of latter mitigated by increased area of forestry. Continuing to decrease as Grey Squirrel spreads.	Probably introduced. Reintroduced in early 19th century, following 18th century extinction. Widespread except in extreme N. and W. but declining as Grey Squirrel spreads.	Causes forestry damage but fully protected.
Grey Squirrel	2,520,000	Most of England and Wales (not Scilly Isles or Isle of Wight); central Scotland; parts of E. Scotland.	Woodland, especially mature deciduous, extending out along hedgerows; urban and suburban areas with large deciduous trees.	Introduced widely during half century after 1876. Continuing to increase.	Introduced in 1911. Now occupies about 20% of the country.	Major forest pest. Horticultural and agricultural damage occurs. Has caused massive decline of Red Squirrel. Some householders resent Grey Squirrels taking food put out for birds but many other people in urban and suburban areas gain much

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
						pleasure from observing Grey Squirrels. Not a game species in Britain and Ireland, unlike in its native range of N. America.
Bank Vole	23,000,000	Widespread on mainland but absent from most islands.	Mature deciduous woodland with thick shrub or field layer; also in grassland, hedgerows, conifer woods, deciduous plantations.	Native. No evidence of major population changes, though populations fluctuate nationwide in short-term, perhaps dependent on masting of trees.	Probably introduced accidentally to the south-west, *c.*1950. Now found in *c.*20% of the island; still spreading.	Important prey of Tawny Owl *Strix aluco*, some other birds, and mammals. Populations on Skomer, Mull and Raasay are considered to be subspecifically distinct.
Field Vole	75,000,000	Widespread on mainland but absent from Shetland, Orkney, many Hebridean islands and Isle of Man.	Mainly rough (especially ungrazed) grassland, including forestry plantations.	Native. There have probably been major population declines as a consequence of loss of preferred habitat; probably as a result, major short-term fluctuations now no longer occur in Britain. Populations rose in 1950s and 1960s, as myxomatosis reduced Rabbits, leading to increased grass growth.	Absent.	Major prey of Weasels, Kestrels and other mammals and birds. Forestry and agricultural damage occurred when numbers were high but is now uncommon. Of the various island forms once considered subspecifically distinct , only that on Islay is currently recognised.
Orkney Vole	1,000,000	Orkney	Occupy dense grassland, moorland, marsh, plantations and gardens but largely absent from arable land and short pastures (except for field margins).	Introduced by Neolithic people (around 3500 BC or earlier). Has probably declined during recent agricultural intensification, now being confined on farmland largely to linear features (where numbers can be very high).	Absent.	Subspecifically distinct from populations on mainland Europe. Of 5 subspecies formerly recognised on various islands in Orkney, 2 are still considered useful.
Water Vole	1,169,000	Widespread on mainland, but absent from most of N. and Highland Scotland and from most islands.	Densely vegetated banks of slow-moving permanent waterways; less common on ponds. Uncommon in uplands. In a few localities live subterraneously, away from water.	Native. Long-term decline during this century; especially rapid in north and west in 1940s/50s and in 1980s/90s (probably because of acidification of streams following acidification and predation by American Mink, respectively, though pollution, habitat destruction, and disturbance may have played a part).	Absent.	None.
Wood Mouse	38,000,000	Very widespread, even on many small islands.	Rare above tree-line or in very wet places; otherwise fairly ubiquitous, including arable land.	Native. Population trends unknown, though there are short-term fluctuations.	Similar to British.	Susceptible to poisoning by various pesticides and sensitive to herbicide use (which reduces both vegetable and

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
						invertebrate food resources). Can cause damage to pelleted seed of sugar beet and to stored food.
Yellow-necked Mouse	750,000	S. and SE England and border counties of Wales.	Mature (perhaps especially ancient) deciduous woods; less commonly in hedgerows.	Probably native. Certainly present from Neolithic onwards. Archaeological evidence suggests a wider distribution in Neolithic and Roman times; reduction probably result of clearance of woodland. May have declined further during this century.	Absent.	Sometimes damages stored food.
Harvest Mouse	1,425,000	Most of English mainland except NW and some coastal areas of Wales; scattered colonies elsewhere (probably recent introductions).	Areas of tall, dense vegetation outside woods - long grass, reedbeds, grassy hedgerows and ditches, bramble patches, cereals and some other crops.	Origin uncertain: not recorded archaeologically until Roman times but total archaeological records are few. May have declined in late 19th century with advent of close-cutting reaping machines. Agricultural changes have removed large areas of suitable habitat during 20th century and recent switch to winter cereals means that crops are harvested before peak of breeding season; but no direct evidence of reductions in range or abundance.	Absent.	Vulnerable to agricultural intensification and loss of non-agricultural habitats. MMR suggest that Harvest Mice may be "particularly sensitive to climatic changes at the extreme of their range"; however, that range extends from Japan, across a broad sweep of C. Asia, through most of Europe (not Mediterranean) to Finland, Denmark and N. Spain, with the western bounds apparently determined by the sea.
House Mouse	5,192,000+	Widespread across the whole of Britain, including inhabited islands (less common on uninhabited; St. Kilda subspecies died out following human abandonment of island).	Essentially commensal in Britain, in dwellings, farm buildings and food stores. Populations in arable land do best if sustained by reservoirs from grain stores.	Almost certainly introduced but present in Iron Age (perhaps Bronze Age). Formerly commonest mammal in S. English arable land but probably declined considerably following loss of cereal ricks (consequence of combining) and more effective pest control in buildings. Numbers can fluctuate hugely in short-term, as they build up rapidly when food is plentiful.	Similar to British.	A major pest of stored food. Widely controlled by poisoning.
Brown Rat	6,790,00+	Widespread, even on small islands.	Commensal, found in farm and other buildings, food stores, refuse tips, sewers and other urban waterways; widespread in arable land, especially in summer. Occupy natural habitats along the coast.	Introduced around 1728. Spread rapidly. More effective harvesting and food storage, combined with modern poisons, have probably reduced numbers dramatically during 20th century though numbers may have increased recently.	Similar to British.	A major pest in food stores. Damage also caused by gnawing. Disease risk, especially leptospirosis (Weil's disease). Widely controlled (especially in urban areas) by poisoning, though genetic resistance is widespread.
Ship Rat	1,300	Confined to ports and to Lundy	Warehouses, etc., in dockland areas.	Introduced in Roman times and	Only in ports.	Where common, at least as important

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
		Island (Bristol Channel) at least the three larger of the Shiant Isles (Key *et al* 1998), and Inchcolm and possibly other Firth of Forth islands (William Penrice pers. comm.).	Rocky shores and cliffs on Lundy and Shiants.	continuously since then from ships and (more recently) lorries. Widespread and common before arrival of Common Rat but then declined rapidly; largely restricted to ports by 1900, with further declines since. Most port populations probably dependent on reintroduction.	Probably extinct except for sporadic accidental introductions.	a pest as Common Rat. Plague and typhus vector in eastern tropics (and formerly in Europe).
Common Dormouse	500,000	Widespread but local from mid-Wales, Leicestershire and Suffolk southwards; scattered populations in N. England.	Deciduous woodland with good shrub layer; coppice.	Native. More widespread in N. England in 19th century than now. Appears to have declined in range and abundance in 20th century.	Absent.	None.
Fat Dormouse	10,000	Confined to an area around the Chilterns approx. 20 x 30 km.	Deciduous and mixed woodland (does not require dense shrub layer); orchard and gardens.	Introduced to Tring Park, 1902. Range and numbers slowly increased; continue to do so.	Absent.	Can cause serious forestry damage; locally may be orchard pests. Cause damage in lofts of houses by eating and fouling stored food and by chewing.
Red Fox	240,000	Widespread on mainland but absent from most islands.	Almost ubiquitous.	Native. Reduced in numbers and range (especially in the east) by game-keeping during the 19th century; has recovered, especially in the second half of this century. Now widespread in urban and suburban areas.	Similar to British.	Widely regarded as a pest (mainly because of incorrect view that foxes kill many lambs but also because they take free-range domestic birds and ground-nesting wild birds) but also as a sporting quarry: 100,000 or more probably killed by man each year in UK. Great adaptability and breadth of diet probably make it a poor indicator of the general condition of the countryside.
Pine Marten	3,650	NW Highlands; patchily in E. and S. Scotland, N. England and Wales. Absent from most islands.	Various: higher densities in woodland but also occurs in pasture, scrub, moorland and coastal sites.	Native. Hunting for sport and pelts, and probably deforestation, made it rare in much of Britain and Ireland by 1800. Continued decline in 19th century (under intensive game-keeping) but recovery in 20th, with continued increase in numbers and range in recent decades in Scotland, NE England and Wales but evidence of recent (post 1960) decline in NW England and N. Midlands.	Patchily distributed. History probably similar to that in Britain.	A predator of rodents, gamebirds, wildfowl and domestic poultry; almost half farmers and one-third of foresters and game-keepers regard it as a pest but others have positive views.

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
Stoat	462,000	Widespread. Absent from Orkney, Outer Hebrides and some Inner Hebrides.	Ubiquitous, provided there is some cover (uses cover in field margins in open agricultural landscapes).	Native, though probably introduced to most of the islands on which it occurs. Major reductions occurred consequent on Rabbit decline caused by myxomatosis; at least partial recovery subsequently but game bags of Stoats have declined again during past quarter century.	Similar to British.	Widely persecuted (though probably ineffectively: >75% need to be removed annually to reduce population). Rabbit is main prey in Britain. Irish population regarded as subspecifically distinct.
Weasel	450,000	Widespread on mainland but Skye, Anglesey and Isle of Wight are only major islands on which it is present.	Ubiquitous, though less common where small mammals scarce.	Native. Population boomed after myxomatosis, dependent on large numbers of small mammals living in grass that was freed from constraint of Rabbit grazing. Game bags indicate decline since early 1960s, especially in E. England.	Absent.	Widely persecuted as perceived enemies of gamebirds (of which they take chicks, though main prey are small rodents). May be indicator of healthy populations of small mammals. Irish population regarded as subspecifically distinct.
Polecat	15,000	Most of Wales; border counties of England; spreading into Midlands.	Widely distributed in woodland, forests, farmland, marshes and coasts; less common on high ground.	Native. Probably once widespread in Great Britain but by 1915 persecution had reduced to an area around Aberystwyth of about 60 km radius. Gradual recovery since, especially in last 50 years, as persecution relaxed.	Absent.	Takes a wide variety of vertebrate prey (including poultry and Pheasants).
Feral Ferret	2,500	Established on Shetland, Harris, the Uists, Islay, Mull, Isle of Man and in a few mainland sites - though mainland populations tend to be ephemeral.	Little studied. Occupies moorland on Mull.	Repeatedly introduced, largely by accidental escapes.	Apparently absent.	Diet similar to that of Polecat, so is a potential pest, especially on islands (where it seems to flourish). Hybridises with Polecat, from which it is derived.
American Mink	110,000+	Most of mainland Britain and many islands, though not yet Orkney and Shetland (Mike: the latter needs checking).	Wide range of aquatic (including coastal) habitats but may move away from water if terrestrial prey abundant.	Introduced through escapes, though not establishing until 1950s. Spread rapidly through natural increase and deliberate releases. Spread north in Scotland has slowed but continues; still increasing in East Anglia.	Similar to British.	Thought to be largely responsible for decline of Water Vole. Devastating impact on seabirds that nest on flat grounds, such as terns. Local pest at fish-farms, on poultry farms, and Pheasant pens. Probably competes with Otter but actual impact of each species on the other is the subject of debate.
Badger	250,000	Widespread but absent from much of N. Scotland, Shetland, Orkney, Hebrides and Isle of Man.	Fairly ubiquitous but less common in open country and on high ground.	Native. Reduced by persecution in 19th century; general increase in 20th century, with some local setbacks as a result of dieldrin poisoning in 1960s.	Similar to British.	Can be a nuisance to farmers and horticulturalists. May be important reservoirs of bovine TB, though some argue that cattle are the reservoirs for Badger TB; experimental culling in progress.

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
Otter	7,350+	Widespread but absent from much of central England and central belt of Scotland and from Anglesey, Isle of Man, Isle of Wight.	Inland and coastal waters of all sorts.	Native. Reduced by persecution and hunting in 18th and 19th centuries; some recovery in first half of 20th century. Massive drop in numbers and reduction in range after 1950s in England and Wales (less so in Scotland) as a result of organochlorine poisoning.	Widespread. Similar history to Britain in terms of persecution but, as in Scotland, largely escaped pesticide problems.	An indicator of pesticides and pollution of waterways. Probably much less of a fisheries pest than was formerly believed. Irish population may be subspecifically distinct.
Wildcat	3,500	Scottish Highlands.	Relatively low altitudes in the Highlands. Woodland, forest, open hill ground.	Native. Has potentially interbred with Feral Cats for hundreds of years, so present-day genetic status is in question. Whether a morphologically distinct "Wildcat" can actually be identified today is in dispute (Balharry & Daniels 1998, Daniels *et al.* 1998; Kitchener 1995). Formerly widespread in mainland Britain. Extinct in much of England by 1800; extinct in Wales by 1862; reduced to remnant in NW Scotland by 1915. Subsequently expanded to current range but little evidence of further change in last 40-50 years.	Native but became extinct during Neolithic.	The most northerly population of this species in the world. May be threatened by hybridisation with Feral Cat.
Feral Cat	813,000	Widespread, even on some currently uninhabited islands (e.g. Monach Isles).	Various, especially close to human dwellings.	Introduced. Given difficulties of distinguishing archaeological remains from those of Wildcat, time of introduction unclear; possibly Roman, more likely Norman. History of population equally unclear.	Similar to British.	Perhaps largely dependent on Domestic Cat population as source of recruits in some areas. Given numbers, probably an important predator in the countryside. (Have caused major problems on many oceanic islands).
Wild Swine	200+	Kent/East Sussex; Dorset	Deciduous Woodland, moving onto agricultural land to feed.	Native but probably extinct in 13th century. Recently re-established from escapes.	Native but extinct by historic times.	Major game species on continent. Agricultural damage can be severe; disease risk to domestic pigs.
Red Deer	360,000	Scottish Highlands, Hebrides, SW Scotland, Lake District, SW England, Breckland; small scattered population elsewhere in England and Wales.	Probably originally a species of open woodland and forest edge but Highland, Hebridean and SW English populations occupy open moorland; conifer plantations widely colonised.	Native but populations widely translocated or boosted by introductions.	Native but numbers have always been small in historic times; may have become extinct. Various reintroductions	Important sporting species in the Highlands (and source of venison). Upland populations often so numerous as to cause serious impact on vegetation, especially in preventing forest regeneration. Cause damage to vegetation in both planted

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
					from Britain. Now restricted to a few small areas (none in N. Ireland).	and native woodlands unless numbers controlled. Numbers in most places depend on management by man.
Sika Deer	11,500	Scattered populations in various parts of England and S. Scotland; more extensive in Argyll and N. Highlands. Absent from islands.	Dense woodland, scrub, thicket stage of conifer plantations; less adaptable to tree-less areas than Red Deer.	Introduced in late 19th century, with some subsequent translocation. Some populations are stable or only slowly growing. Rapid expansion of range continuing in N. Scotland.	Introduced at same time as in Britain. Established in three main areas (one in N. Ireland).	Causes forestry damage. Shot for sport and as source of venison. Substantial hybridisation with Red Deer (population in Co. Wicklow fully hybridised).
Fallow Deer	100,000	Most of England, except NW and N. Wales; scattered populations elsewhere in mainland Britain. Absent from most islands but established on Mull.	Mature woodland; scarcer in coniferous forests. Forage on agricultural land near woods.	Introduced, probably by Normans (perhaps by Romans). Largely confined to parks until 17th century, after which escapes created wild populations, though numbers remained low until 20th century. Currently appears to be increasing slowly, if at all.	Similar to British. Found over much of central Ireland. Scattered populations in N. Ireland.	Causes damage to both trees and ground flora in forests and woodlands; also to agriculture culling produces venison.
Roe Deer	500,000	Widespread on Scottish mainlands (and some Inner Hebrides), N. England, S. and SW England, parts of East Anglia; scattered populations elsewhere.	Various woodland; agricultural areas if small woods available; open moorland in parts of Scotland.	Native but become extinct in England in 18th century and re-established by introduction. Still increasing in range in England.	Absent.	Causes forestry, agricultural and horticultural damage. Increasing interest in sporting and meat value.
Reeves' Muntjac	40,000	Established over much of S. and Midland England; scattered populations to N. of main range and in Wales.	Dense habitats such as neglected coppice, unthinned plantations, scrub, plantations with ground cover.	Introduced via escapes from 1920s onwards; spread assisted by both deliberate accidental releases. Number and range increasing rapidly.	Absent.	Has dramatic impact on ground flora and shrubs in woods; increasingly recognised as a major conservation problem.
Chinese Water Deer	650	Population established in band from Bedfordshire/Hertfordshire to N. Norfolk.	Woodland and reed beds.	Introduced via escapes from parks during 20th century. Some populations eventually died out. Increase, if any, slow.	Absent.	Thought to pose little threat to forestry or agriculture.
Feral Goat	3,565+	Various mountains in England, Ireland, Scotland and Wales and many islands.	Mainly hills with cliffs, above 300m; may use woodland.	Introduced through escapes of domestic stock, which have been in Britain for *c.*4,500 years. No evidence of major changes in numbers.	Similar to British.	Goats cause devastating overgrazing in many parts of the world and do some damage to flora in British and Irish woodlands, but populations are generally small and limited in

Species	Approx. British Population	British distribution	British habitat	British history and trends	Irish status	Further relevant issues
						distribution; they are widely managed. Britain and Ireland hold more Feral Goats than any other W.European country except Crete (whose goats are very close to the wild ancestor, *C. aegargus*).
Feral Sheep	2,100	Soay sheep, from island of that name (St Kilda), now introduced to other offshore islands. Boreray sheep confined to island of that name (St Kilda).	Grassland.	Sheep introduced about 5,500 years ago. Soay is considered a primitive domestic breed, perhaps descended from the sort of sheep introduced by Neolithic people (though possibly introduced by the Vikings). Boreray sheep are a relatively modern breed. Both St Kilda populations fluctuate, with no long-term trends.	Apparently absent.	Of some scientific interest because subject of long-term study. Soay sheep of interest as a rare breed. These forms are endemic to Britain.
Red-necked Wallaby	50?	Inchconachan (Loch Lomond) and Isle of Man.	Scrub.	Introduced. Escapes and releases have established populations. One in the Weald survived 1940-1972. One in the Peak District, established 1940, is now reduced to two females (D.W. Yalden, pers com.). Loch Lomond population now *c.*30) deliberately established 1975. Escapes on Isle of Man (probably late 1960s) led to current population of *c.*50 (Chris Sharpe, pers. comm.). No others survive.	Absent.	A pest of forestry in parts of Australia. Frequently liberated in Britain, since it is easy to keep in captivity, but has yet shown little propensity to increase. Individuals from Inchconachan have reached the mainland.

Table I.1.3 Conservation assessment of species considered in this report. Single asterisks indicate that the species is included in the UK Steering Group's Biodiversity long list (Anon. 1995) and double asterisks that this is in the short list of species of greater concern. (There are no mammals on the medium list). The conservation criteria are as used for that list (explained here on the next page)

Species	Int. threat	Int. Import	Decline	Local.	EC Annex	Bern App.	Bonn App.	UK Act Sched.
Hedgehog*	0	0	0	0				
Mole								
Common Shrew*	0	0	0	0				
Pygmy Shrew*	0	0	0	0				
Water Shrew*	1	0	0	0				
Lesser white-toothed Shrew*	0	0	1					
Rabbit								
Brown Hare**	0	0	1	0				
Mountain Hare*	1	0	0	0				
Red Squirrel**	0	0	1	0				5(b)
Grey Squirrel								
Bank Vole								
Field Vole								
Orkney Vole								
Water Vole**	0	0	1	0				
Wood Mouse								
Yellow-necked Mouse								
Harvest Mouse								
House Mouse								
Brown Rat								
Ship Rat								
Common Dormouse**	1	0	1	0	IVa			5
Fat Dormouse								
Red Fox								
Pine Marten*	0	0	0	0				5(b)
Stoat*	0	0	0	0				
Weasel*	0	0	1	0				
Polecat*	1	0	0	0				
Feral Ferret								
American Mink								
Badger*	0	0	0	0				(b)
Otter**	2?	0	-1	0	IIa IVa	II		5(b)
Wildcat*	0	0	0	0	IVa	II		5
Feral Cat								
Wild Swine								
Red Deer*	0	1	-2	0				
Sika Deer								
Fallow Deer*	0	0	0	0				
Roe Deer*	0	0	-2	0				
Reeves' Muntjac								
Chinese Water Deer								
Feral Goat								
Feral Sheep								
Red-necked Wallaby								

The following provides a key to interpret abbreviations used in Table I.1.3

International Threat:

2	**Species of global conservation concern**
2?	**Status uncertain - possibly 2**
1	**Unfavourable conservation status in Europe**
0	**Favourable conservation status in Europe**

International importance:

3	**75+% of the world population in the UK**
3*	**Believed endemic**
3*?	**Possible endemic**
2	**50-74% of the world population in the UK**
1	**25-49% of the world population in the UK**
0	**0-24% of the world population in the UK**

Decline:

2	**50-100% decline in numbers/range in GB in last 25 years**
1	**25-49% decline in numbers/range in GB in last 25 years**
0	**0-24% decline in numbers/range in GB in last 25 years**
0	**0-24% increase in numbers/range in GB in last 25 years**
-1	**25-49% increase in numbers/range in GB in last 25 years**
-2	**50+% increase in numbers/range in GB in last 25 years**

Localisation:

2	**Currently occurs in 1-5 10km squares in GB**
1	**Currently occurs in 6-15 10km squares in GB**
+	**Currently occurs in 16-100 10km squares in GB**
0	**Currently occurs in 101+ 10km squares in GB**

EC Directives **Birds Directive Annex 1 (native species only)**
EC Habitats Directive Annex II and/or IV (native species only)

Bern Convention **Appendices I and II (native species only)**

Bonn Convention **Appendices I and II (native species only)**

UK Act Scheds.	**1 Schedule 1}**		**(a) Schedule 1}**	
	5 Schedule 5}	**Wildlife & Countryside**	**(b) Schedule 5}**	**Wildlife (Northern**
	8 Schedule 8}	**Act 1981**	**(c) Schedule 8}**	**Ireland) Order 1985**
	5* Schedule 5 but protection against sale only			

Table III.A.1.1 Summary of the numbers of BBS survey squares in which each of the principal 17 mammal species was reported to be present in each year of the trial mammal survey, 1995-1997.

Species	Number of Squares "Present" in Each Year			Percentages of Squares "Present" in Each Year (s.e.)		
	1995	1996	1997	1995	1996	1997
Hedgehog	26	138	162	1.95 (0.38)	8.54 (0.7)	8.64 (0.65)
Mole	95	284	292	7.12 (0.7)	17.59 (0.95)	15.58 (0.84)
Common Shrew	26	100	90	1.95 (0.38)	6.19 (0.6)	4.80 (0.49)
Rabbit	966	1117	1297	72.41 (1.22)	69.16 (1.15)	69.21 (1.07)
Brown Hare	496	594	648	37.18 (1.32)	36.78 (1.2)	34.58 (1.1)
Mountain Hare	39	53	68	2.92 (0.46)	3.28 (0.44)	3.63 (0.43)
Red Squirrel	15	30	33	1.12 (0.29)	1.86 (0.34)	1.76 (0.3)
Grey Squirrel	399	570	602	29.91 (1.25)	35.29 (1.19)	32.12 (1.08)
Brown Rat	23	78	64	1.72 (0.36)	4.83 (0.53)	3.42 (0.42)
Red Fox	423	527	477	31.71 (1.27)	32.63 (1.17)	25.45 (1.01)
Stoat	37	86	86	2.77 (0.45)	5.33 (0.56)	4.59 (0.48)
Weasel	19	69	71	1.42 (0.32)	4.27 (0.5)	3.79 (0.44)
Badger	82	152	156	6.15 (0.66)	9.41 (0.73)	8.32 (0.64)
Red Deer	85	100	102	6.37 (0.67)	6.19 (0.6)	5.44 (0.5)
Fallow Deer	47	57	57	3.52 (0.5)	3.53 (0.46)	3.04 (0.4)
Roe Deer	249	294	298	18.67 (1.07)	18.20 (0.96)	15.90 (0.84)
Reeves' Muntjac	61	67	76	4.57 (0.57)	4.15 (0.5)	4.06 (0.46)
Total Squares	1334	1615	1874	-	-	-

Table III.A.1.2 Results of likelihood-ratio tests of the significance of inter-annual differences in the proportion of survey squares in which species were recorded as present. The sample size N for the matched squares tests refers to the numbers of matched squares where changes in status occurred (see text for details).

Species	Likelihood-ratio tests: χ^2, *P* (N)		
	1995, 1996 & 1997 Unmatched	1996 & 1997 Unmatched	1996 & 1997 Matched
Hedgehog	84.78, <0.01	0.01, 0.92	0.07, 0.79 (129)
Mole	82.14, <0.01	2.52, 0.11	9.63, <0.01 (207)
Common Shrew	35.49, <0.01	3.24, 0.07	4.11, 0.04 (96)
Rabbit	4.83, <0.1	0.00, 0.98	1.16, 0.28 (220)
Brown Hare	2.88, <0.3	1.83, 0.18	5.79, 0.02 (222)
Mountain Hare	1.25, <0.6	0.31, 0.58	0.61, 0.44 (41)
Red Squirrel	3.07, <0.3	0.05, 0.86	0.00, 1.00 (30)
Grey Squirrel	9.92, <0.01	3.91, 0.05	14.2, <0.01 (248)
Brown Rat	22.78, <0.01	4.43, 0.4	2.76, 0.10 (70)
Red Fox	25.72, <0.01	21.8, <0.05	23.6, <0.01 (382)
Stoat	12.80, <0.01	1.00, 0.32	1.24, 0.26 (80)
Weasel	24.33, <0.01	0.53, 0.47	0.62, 0.43 (58)
Badger	11.09, <0.01	1.27, 0.26	3.08, 0.08 (104)
Red Deer	1.47, <0.6	0.89, 0.35	0.53, 0.47 (47)
Fallow Deer	0.845, <0.7	0.65, 0.42	0.31, 0.65 (43)
Roe Deer	5.17, <0.1	3.26, 0.07	3.47, 0.06 (179)
Reeves' Muntjac	0.546, <0.8	0.02, 0.89	0.06, 0.81 (68)

Table III.A.1.3 Results of a simulation-based study of the power of a simple GLM to detect a range of gradual, long-term declines in presence/absence data. Each set of simulations consisted of 100 replicates, each based, as shown, on a sample size of 2000 BBS survey squares with declines in the "true" probability of detection of the model animal over a given period of years. The line of the table referring to a 25% decline over 25 years is shown in bold: this magnitude and rate of population change has been used as a key level for bird monitoring, and we suggest elsewhere that it could be extended to mammals.

Number of Years	Average proportion of squares where presence is detected		Overall Decline	Percentage of replicates where a decline significant at a=0.05 was detected (likelihood-ratio test)
	Start of Decline	End of Decline		
10	0.3	0.27	10%	90%
10	0.1	0.09	10%	38%
10	0.03	0.027	10%	13%
10	0.03	0.025	25%	65%
25	**0.03**	**0.025**	**25%**	**87%**

Table III.A.1.4 Mammals recorded on more than 1% of WBBS random stretches during the 1998 trial survey. Data on mammals were received from 93 of the 103 stretches surveyed. (Adapted from Marchant & Gregory 1999, Table 5).

Species	Total animals counted	Number of occupied stretches	% Stretches occupied
Counted in BBS			
Hedgehog	1	13	14
Mole	10	37	40
Shrew spp.*	13	18	19
Rabbit	1547	60	65
Brown Hare	102	30	32
Mountain Hare	42	8	9
Red Squirrel	3	4	4
Grey Squirrel	107	34	37
Brown Rat	3	11	12
Red Fox	13	36	39
Stoat	1	13	14
Weasel	1	11	12
Badger	1	17	18
Red Deer	299	12	13
Fallow Deer	2	4	4
Roe Deer	23	22	24
Reeves' Muntjac	1	5	5
Not counted specifically in BBS			
Water Vole	3	8	9
American Mink	3	7	8
Otter	8	14	15

*Shrew species were not separated on the survey form.

Table VII.1.1 Summary of the potential contributions of the proposed monitoring schemes to the monitoring of each mammal species in the UK. "M" (for Main) indicates that a multi-species scheme is considered potentially to provide data central to the future monitoring of the species in question; "C" (for Combination) indicates that a combination of schemes will provide complementary and equally important information without any scheme necessarily being dominant; "A" (for Ancillary) indicates that a scheme will contribute supplementary information. Question marks indicate that a particular scheme may not be useful for the species shown, depending on species-specific factors such as the precise timing of survey visits (see species accounts). Multi-species schemes are referred to as follows: Breeding Bird Survey (BBS); National Game Bag Census (NGBC); Winter (visual) Transect Survey (WTS); Sign Transect Survey (STS); Mammals on Roads (MOR); Mammals on Nature Reserves (MONR); Garden Mammal Watch (GMW); Owl Pellets Scheme (OP).

Species	Multi-species schemes								Single species scheme	
	BBS	NGBC	WTS	STS	MOR	MONR	GMW	OP	Role	Suggested Approach
Hedgehog	C			C?	C	C	C			
Mole	C		C	C	A	C	C			
Lesser White-toothed Shrew									M	Monitoring techniques need development: live-trapping or faecal signs.
Common Shrew								A	M	Live-trapping/capture-mark-recapture with other small mammals, but needs development and piloting.
Pygmy Shrew								A	M	Live-trapping/capture-mark-recapture with other small mammals, but needs development and piloting.
Water Shrew								A	M	Live-trapping/capture-mark-recapture with other small mammals, but needs development and piloting. Faecal counts a possibility.
Rabbit	A		A	M	A		A			
Brown Hare	A/M	A	M		A					
Mountain Hare	A	A	M		A					
Red Squirrel	A		A	A	A	A	A		M	Existing intensive monitoring of Red/Grey interactions with central data collation.
Grey Squirrel	C		C	C	C	C	C			
Bank Vole								A	M	Live-trapping/capture-mark-recapture with other small mammals, but needs development and piloting.

Species	Multi-species schemes								Single species scheme	
	BBS	NGBC	WTS	STS	MOR	MONR	GMW	OP	Role	Suggested Approach
Field Vole								A	M	Live-trapping/capture-mark-recapture with other small mammals, but needs development and piloting.
Orkney Vole									M	Live-trapping/capture-mark-recapture.
Water Vole						A			M	Transect field sign searches within the grid used in previous surveys.
Wood Mouse								A	M	Live-trapping/capture-mark-recapture with other small mammals, but needs development and piloting.
Yellow-necked Mouse									M	Live-trapping/capture-mark-recapture in woods; techniques for other habitats need development.
Harvest Mouse						A			M	Standardised hair-tube surveys and nest searches.
House Mouse								A	M	Improvement of pest control records.
Brown Rat					C	C	C	C	C	Improvement of pest control records.
Ship Rat									M	Methods for island populations need development, use questionnaires for mainland populations.
Common Dormouse						A			M	National Dormouse Monitoring Scheme, perhaps expanded.
Fat Dormouse									M	Extension of present annual monitoring, formalised, to more sites; use of DETR licence returns.
Red Fox	A		A	M	A		M		A	Possible questionnaire surveys for urban foxes.
Pine Marten					A	A	A		M	Field sign transects in suitable habitat; genetic monitoring.
Stoat	A	M	A		A	A				
Weasel	A	M	A		A	A				
Polecat					A	A			M	Live-trapping/capture-mark-recapture in core range and areas of expansion, genetic monitoring.
Feral Ferret	C	C	C		C	C			A	Collate distribution data from other schemes as they are

Species	Multi-species schemes								Single species scheme	
	BBS	NGBC	WTS	STS	MOR	MONR	GMW	OP	Role	Suggested Approach
										reported.
American Mink					A	A			M	Collect abundance and distribution data through Otter and Water Vole monitoring.
Badger	A			A	A		A		M	Repeats of the National Badger Survey.
Otter					A	A			M	Repeats of previous Otter surveys, extending monitoring to coastal populations.
Wildcat					A	A			M	Questionnaire surveys and roadkill collection, periodical scat surveys, genetic monitoring.
Wild Swine									?	Need for monitoring uncertain.
Red Deer	A		C	C	A	A	A		C	Ongoing monitoring in certain habitats/regions, possibly new direct count surveys elsewhere.
Sika Deer	A		C	C	A	A			C	Ongoing monitoring in Scotland.
Fallow Deer	A		C	C	A	A	A		C	Ongoing monitoring in certain habitats/regions, possibly new pellet count/transect surveys elsewhere.
Roe Deer	A		C	C	A	A	A		C	Ongoing monitoring in certain habitats/regions, possibly new direct/pellet count/transect surveys elsewhere.
Reeves' Muntjac	A		C	C	A	A	A		C	Ongoing monitoring in certain habitats/regions, possibly new direct/pellet count/transect surveys elsewhere.
Chinese Water Deer	A		C	C	A	A				
Feral Goat									M	Maintain and formalise current monitoring.
Feral Sheep									M	Collate existing count data.
Red-necked Wallaby									M	Monitor areas of possible expansion.
Unestablished Aliens	A		A		A	A	A		M	Unestablished aliens scheme.

Figure I.1.1 How monitoring supports management by helping to answer key questions

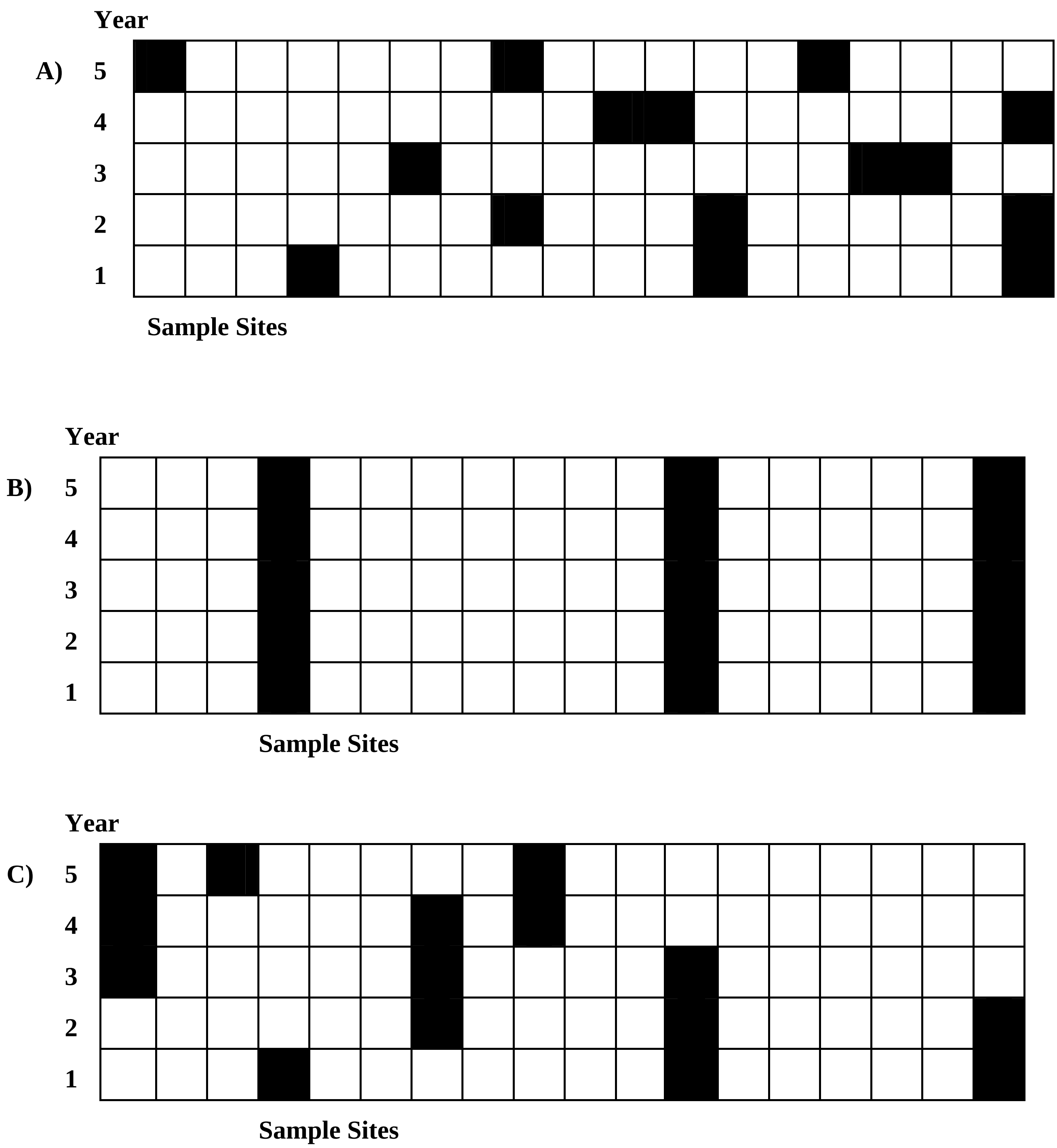

Figure II.3.2 **Various sampling designs**

The squares represent potential sample sites (horizontal axis) in different years (vertical axis); filled squares show sites sampled in each year.

A. Independent sampling in each year.
Some sites are sampled in more than one year, but only by chance.

B. Constant sampling sites.
The original random sample is maintained indefinitely.

C. Sampling with partial replacement.
In this particular case, one of the three sites drops out each year, being replaced with another site at random; each site stays in the sample for three years; it may re-enter the sample but only by chance.

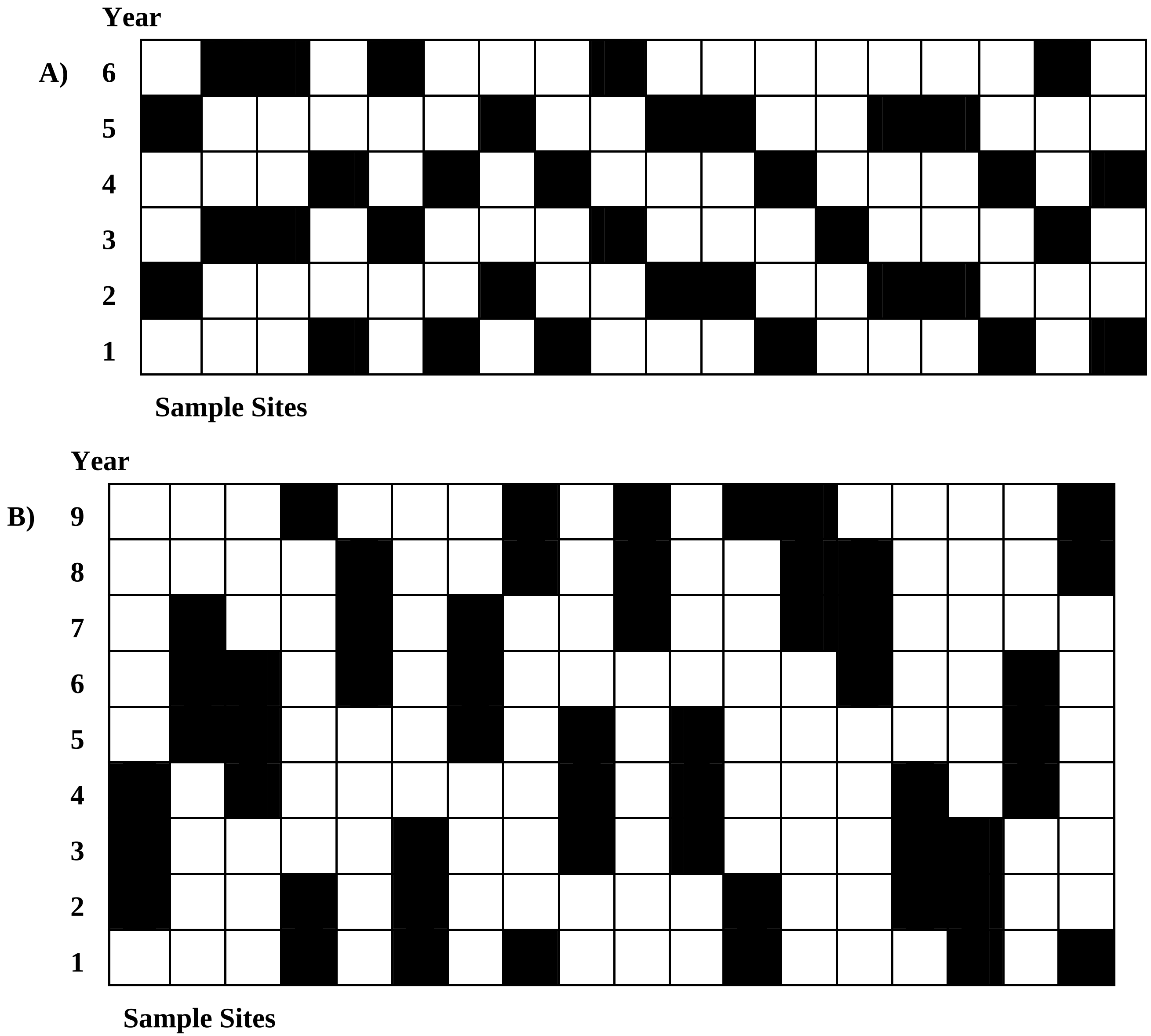

Figure II.3.3 Rotation Sampling

The squares represent potential sample sites (horizontal axis) in different years (vertical axis); filled squares show sites sampled in each year.

A. Simple rotation.
Each site remains in the sample for a single occasion. In this particular case, because one in three of the sites is sampled on each occasion, each site re-enters the sample after a gap of two occasions; each sampling cycle (during which every site is sampled once) is thus three occasions long.

B. More complex rotation.
East site remains in the sample for more than a single occasion. In this particular case, sites remain in the sample for three occasions but then drop out for six; each sampling cycle is nine occasions long.

Figure III.A.1.5 Sample sizes required for the detection of a 10% decline from a starting proportion p_1 at $\propto = 0.05$

Figure III.A.1.6 Sample sizes required for the detection of a 20% decline from a starting proportion p_1 at $\propto = 0.05$

Figure III.A.1.7 Sample sizes required for the detection of a 30% decline from a starting proportion p_1 at $\propto = 0.05$

APPENDICES

Appendix 1 Breeding Bird Survey Forms

Appendix 2 Garden BirdWatch Forms