# Changes in the British badger population, 1988 to 1997

Gavin Wilson, Stephen Harris
and Graeme McLaren

School of Biological Sciences,
University of Bristol,
Woodland Road, Bristol, BS8 1UG

PEOPLE'S TRUST
FOR ENDANGERED SPECIES

LONDON

ISBN 1 85580 018 7

British Library Cataloguing-in-publication data.

A catalogue record for this book is available from the British Library.

Printed and bound in Great Britain by Lindsay Ross International Ltd.

# Contents


**Foreword** ..... 5

**Executive summary** ..... 7

1. **Introduction** ..... 11
   - 1.1 The history of badgers in Britain ..... 11
   - 1.2 The 1980s badger survey ..... 13
   - 1.3 Other national badger surveys ..... 14
   - 1.4 Developments since the 1980s badger survey ..... 14
     - 1.4.1 Changes to the land classification scheme ..... 14
     - 1.4.2 Improved understanding of the sett classification scheme ..... 16
   - 1.5 Monitoring badger population changes ..... 20
     - 1.5.1 Changes in the number of badger social groups ..... 21
     - 1.5.2 Changes in the number of badgers ..... 21
   - 1.6 Aims of the 1990s badger survey ..... 21
2. **Methods** ..... 23
   - 2.1 The survey area ..... 23
   - 2.2 Survey protocol ..... 23
   - 2.3 Survey coverage ..... 24
   - 2.4 Data checking ..... 24
     - 2.4.1 Ensuring comparability between the two surveys ..... 24
     - 2.4.2 Preliminary data sorting ..... 27
   - 2.5 Criteria used for interpreting sett changes ..... 29
     - 2.5.1 Changes to main setts ..... 29
     - 2.5.2 Changes to annexe setts ..... 30
     - 2.5.3 Changes to subsidiary and outlying setts ..... 31
     - 2.5.4 Changes in sett status ..... 31
     - 2.5.5 Setts that had disappeared ..... 31
   - 2.6 Extracting the data from the field sheets ..... 31
   - 2.7 Were there any differences between resurveyed and new 1-km squares? ..... 32
   - 2.8 Statistical procedures ..... 33
   - 2.9 Presentation and interpretation of the results ..... 34
3. **Badger population changes, 1988 to 1997: sett changes** ..... 37
   - 3.1 Introduction ..... 37
   - 3.2 Changes in main sett numbers ..... 37
   - 3.3 Losses of main setts ..... 39
   - 3.4 Changes in the number of other types of sett ..... 42

3.5 Changes in the status of setts ... 44
3.6 Changes in the distribution of badger setts ... 45
3.7 Changes in the size of setts ... 47
3.8 The number of badger social groups in Britain ... 48
3.9 Discussion ... 49
**4. Badger population changes, 1988 to 1997: changes in badger numbers ... 51**
4.1 Introduction ... 51
4.2 Monitoring field signs ... 52
4.3 The relationship between field signs and badger numbers ... 52
4.4 Estimating changes in the number of badgers ... 55
4.5 The relationship between the change in the number of badgers and the change in the number of social groups ... 59
4.6 Discussion ... 60
**5. Changes in levels of badger persecution, 1988 to 1997 ... 61**
5.1 Introduction ... 61
5.2 Badger digging ... 62
5.3 Sett blocking ... 63
5.4 Snaring at setts ... 65
5.5 Discussion ... 65
**6. Changes in habitat selection by badgers, 1988 to 1997 ... 69**
6.1 Introduction ... 69
6.2 Changes in habitat availability ... 70
6.3 Habitats favoured as sites for main setts ... 74
6.4 Discriminant analyses to predict the presence of main setts ... 75
6.5 The influence of changes in habitat quality and persecution levels on badger numbers ... 79
6.6 Discussion ... 81
**7. Understanding the changes in the British badger population ... 85**
7.1 Introduction ... 85
7.2 Modelling the growth of the badger population ... 85
7.2.1 Background to the model ... 85
7.2.2 Parameters used in the analyses ... 85
7.2.3 Output from the model ... 86
7.2.4 Conclusions from the modelling study ... 87
7.3 The colonisation of new areas ... 88
7.4 When did the badger population changes occur? ... 89
7.5 Have changes to the law really benefited badgers? ... 90
7.6 Future badger population changes ... 90

**8. Acknowledgements** .......... **93**

**9. References** .......... **95**

**10. Appendices** .......... **101**

10.1 Instruction sheet describing how to record the badger data .......... 101

10.2 Badger data recording sheet .......... 103

10.3 Instruction sheet describing how to record the habitat data .......... 104

10.4 Instruction sheet describing how to record changes to the badger setts .......... 106

10.5 Data sheet for recording badger sett changes .......... 107

10.6 What is the best survey design? .......... 108

10.6.1 The underlying badger distribution - random or clustered? .......... 110

10.6.2 Detecting changes in the density of badger main setts in the land class groups .......... 111

10.6.3 Designing a repeat survey that maximises the chance of detecting change .......... 112

10.6.4 Determining the significance of the observed change .......... 113

10.7 Changes in the number of annexe, subsidiary, outlying and disused main setts, 1988-1997 .......... 114

10.8 Changes in the size of setts, 1988-1997 .......... 118

10.9 Changes to the badger protection laws .......... 126

10.10 Changes in the levels of persecution at annexe, subsidiary, outlying and disused main setts, 1988-1997 .......... 127

10.11 Summary of the views of the local Badger Groups that responded to a questionnaire circulated in spring 1997 .......... 133

# Foreword

Several years ago the People's Trust for Endangered Species was becoming increasingly aware of all the controversy surrounding the conservation of badgers, and in particular whether they were becoming too numerous. At the same time the PTES were concerned that there appeared to be no research currently underway to provide a sound scientific basis on which to attempt to resolve these difficulties. PTES therefore commissioned this national badger survey from Professor Stephen Harris at the University of Bristol, in the hope that its results would enable future decisions concerning the conservation of badgers to be made in the light of solid evidence.

Badgers have locally been heavily persecuted in Britain. There is a need, therefore, to protect both them and their setts from persecution of all kinds. Since the PTES was founded it has provided funding for local Badger Groups, especially in those areas where persecution levels are high, to help them protect the badgers in their own areas.

Under the Rio Convention, the British Government has an obligation to maintain and enhance biodiversity in Britain. To ensure that biodiversity is not lost we need to set up monitoring programmes so that we understand what changes are occurring and why. The badger study is an excellent example of the sort of monitoring work that could and should be done for mammals. Not only has it quantified changes, but it has also shown why changes are occurring, and highlighted regional differences in the pattern of change. The quality of these analyses are also a great tribute to the army of volunteers who worked hard to collect the field data. It is an example of how people with no expert training can collect high-quality data that can be used for monitoring changes in the status of British mammals. The data are of the quality that can be subjected to very detailed analysis. PTES hopes to undertake more such monitoring exercises in the future.

The results are totally unexpected - something all the referees have said. The results highlighted the value of exercises such as this - we have learnt a great deal about the biology of badgers that was previously unexpected because scientific studies are usually undertaken in high-density areas where the species is highly protected. So the results reflect what is going on in the wider countryside, and hence are of particular importance.

The results show that, contrary to general expectation, there has been a very high level of badger persecution in Britain, and that until the recent past badgers have been suffering the effects of that persecution. In the last few years changes to the law have allowed the species to start to recover. However, the report shows that badger main setts are still only found in a quarter of the lowland 1-km squares that were surveyed, so there are a lot of suitable areas for them still to colonise.

Also, the decline in the availability of suitable habitats in just nine years shows that there have been dramatic changes in the countryside that may, in the long term, be worrying both for badgers and other species of mammal.

It must be remembered that in Britain we have about 17% of the entire badger population of western Europe, and so from the European perspective we have a particular obligation to conserve the badgers within our shores.

There are, of course, many complicated problems that remain unsolved and the report has identified a number of issues that still need to be answered. The PTES will remain in the forefront of trying to resolve them.

Finally, PTES would like to thank all those referees whose comments were greatly appreciated and have contributed to the published report.

Professor John Beddington
Chairman of the Trustees
People's Trust for Endangered Species

*This report has gone to a number of scientific referees and has been revised in the light of their comments, but the conclusions remain those of the authors.*

# Executive Summary

1 This report presents the results of a badger survey undertaken between October 1994 and January 1997. A similar survey had been undertaken between November 1985 and early 1988, when 2455 1-km squares throughout Britain had been surveyed for badger setts and signs of badger activity. The aim of the project was to resurvey all of these 1-km squares to detect changes in the badger population.

2 There have been a number of developments since the 1980s survey. These include changes to the land classification scheme, an improved understanding of the functions of the different categories of badger sett, and changes to the badger protection laws. Their potential impact on the resurvey are discussed.

3 For comparability, the survey protocol was the same as for the 1980s survey. However, the surveyors were sent additional instruction sheets and recording forms to record details of any sett changes that had occurred since the 1980s survey.

4 Badger main setts are not randomly distributed, and so resurveying the same 1-km squares, rather than surveying a new random sample of 1-km squares, is best suited for detecting change in data where there are large 95% confidence limits about the population means. Repeatedly surveying the same 1-km squares has the further advantage that the fate of individual setts can be monitored, and the factors leading to sett losses and gains quantified.

5 Of the original 2455 1-km squares, 2271 (93%) were resurveyed. In addition, a further 307 new 1-km squares were surveyed to: (i) enlarge the database for future resurveys; and (ii) provide a quality check for the 1-km squares that had been resurveyed.

6 The data were first checked for biases associated with differences in recorder effort, and for potential biases due to increased data quality as a result of resurveying the same 1-km squares. No such biases were detected.

7 The data on change are presented by seven land class groups and by 14 regions. We show that the former facilitates analyses of the impact of habitat changes on the badger population, whereas regional data facilitate analyses of local patterns of change, and in particular local variations in the impact of anthropogenic factors on the badger population.

8 Since the 1980s survey, the increase in the number of badger social groups in Britain, based on the number of main setts, was 24%. It was estimated that there were 50,241±4327 (±95% confidence limits) badger social groups in Britain. This change was not uniformly distributed throughout the country, being least in two of the three arable landscapes. Regionally there was also great variation; whilst in some regions there had been little change or even small declines in the number of badger social groups, in the West Midlands there had been an 86% increase.

9 There had generally been large increases in the number of other types of sett; nationally, annexe setts had increased by 87%, subsidiary setts by 54% and outlying setts by 55%, whereas the number of disused main setts had declined by 41%. These increases occurred in most regions, including those that showed little or no change in the number of badger social groups. The total number of all types of sett had increased by 43%, to 247,885±22,836.

10 In the period since the 1980s survey, 29% of all recorded main setts were lost. Of these, 13% were still in use by badgers but were no longer main setts, 8% had completely disappeared and were assumed to have been destroyed, and 7% had been lost due to factors such as land use changes. This high rate of main sett loss was in large part due to persecution.

11 Of the 241 new main setts recorded in the 1990s, 71 (29%) had originated by the expansion of an existing sett of a lower status. The most frequent category of sett "upgraded" to a main sett was subsidiary setts (28 cases). Most main setts that were first recorded in the 1990s were established from new.

12 In addition to the changes in the number of setts, there was a significant increase in the size of main setts, a small increase in the size of subsidiary setts, but no change in the size of annexe and outlying setts. For main, annexe and subsidiary setts, there was an increase in the number of well-used holes.

13 There has been a slow expansion of badgers into new areas of Britain. In the 1980s, only 17% of rural 1-km squares in Britain contained main setts, and 30% contained setts of any type. When looking at just the five lowland land class groups, these figures were 22% and 35% respectively. In the 1990s, main setts were found in an additional 4% of rural 1-km squares, and any setts in an additional 3%; when looking just at the five lowland land class groups, these figures had also increased by 4% and 3% respectively.

14 Activity scores, based either on a variety of field signs or just on dung pits, were used to examine the changes in the total number of badgers in Britain. The value of these field signs is discussed, and it is shown that field signs are a reliable measure of badger numbers across a wide range of population densities.

15 Signs of badger activity were recorded in 31% of 1-km squares in the 1980s and 38% in the 1990s; for just the five lowland land class groups, these figures were 38% and 45% respectively. Thus, despite the expansion of badgers into new areas, the majority of lowland 1-km squares in Britain still showed no signs of badger activity.

16 Based on changes in activity levels, we estimated that the number of badgers in Britain had increased by 77%. Of this, 47% was due to an increase in the size of social groups, 30% was due to the establishment of new social groups.

17 There were regional differences in the amount of change; whilst some areas had undergone no increase in the total number of social groups, they still showed increases in mean social group size. This was because there had to be a minimum group size before dispersal led to the establishment of new social groups. Despite increases in numbers, badger populations in some areas were still below this critical mean group size.

18 Badger digging had declined to less than half that recorded in the 1980s, and snaring at setts continued to be very infrequent. However, sett blocking, predominantly by foxhunts, was at comparable levels to that recorded in the 1980s. The number of setts blocked in a region was dependent on the intensity of fox hunting, and this relationship remained the same for both surveys. Of the main setts blocked in the 1990s, 20% had been blocked illegally.

19 There was a relationship between the level of badger digging in a region and the rate of population growth, in terms of the number of social groups. This relationship is discussed. It is unlikely that changes in levels of digging alone could account for this relationship, but it is probable that digging was just the most visible indication of a number of forms of persecution. We argue that reductions in digging were evidence of an overall decline in all types of badger persecution, which led to the regional differences in badger population increases. We also argue that reductions in the levels of persecution in recent years have allowed the badger population to recover.

20 There have been no habitat changes between the two surveys that could have led to the observed increases in badger numbers. Based on the habitats preferred by badgers, the number of "good" 1-km squares declined by 19%. We defined "specific" and "general" habitats for badgers. There had been small declines in their availability, but there was no simple relationship between the abundance of these habitat types and badger densities.

21 Habitat richness in a 1-km square was the best indicator of the presence of badgers, and 1-km squares which gained main setts between the two surveys had a mean habitat richness score above 5.0, those which lost main setts had a mean habitat richness score of less than 5.0. This reinforces an earlier analysis that highlighted the importance of habitat richness rather than abundance for predicting the distribution of badger setts.

22 Since most lowland 1-km squares still contain no badger setts of any type, there is substantial scope for further badger population expansions. However, in areas with established badger populations, it is unlikely that there will be further significant population increases.

23 Computer modelling was used to determine the demographic process that could have led to these badger population increases. It is shown that badger populations can respond rapidly to reductions in adult mortality, and that small but consistent increases in adult survivorship of 18% per annum led to a 75% population increase in just six years. This is equivalent to just one extra adult per social group surviving each year.

24 We analyse data from a long-term study in Gloucestershire, and show that an increase in adult survival of 14% per annum would lead to the population increases recorded there. This reinforces our argument that it was reductions in the levels of persecution, leading to an increase in adult survival, which led to the badger population increases recorded in this survey.

25 Using questionnaire data from local Badger Groups, it is shown that in some areas attitudes to badgers have changed, and that farmers and landowners are becoming less tolerant of the badgers on their land. This in turn appears to be leading to a rise in persecution levels.

26 We conclude by discussing past and future trends in the badger population. We then compare the pattern of changes seen in otter populations in Britain, and discuss the need to continue to protect badgers.

# 1. Introduction

## 1.1 The history of badgers in Britain

The history of badgers in Britain over the last 150 years is discussed by Cresswell, Harris & Jefferies (1990). Badgers were generally perceived to be rare and in danger of at least local extinctions in the latter half of the 19th century, and at the turn of the century local naturalists reported that badgers were rare or uncommon in many parts of England and that they were sparsely distributed in Scotland. The status of badgers at that time is summarised in the Victoria County Histories (see Cresswell, Harris & Jefferies, 1990) and by Brown (1882), Harting (1888), Pease (1898), Millais (1905) and Ritchie (1920). The rarity of badgers was almost certainly the result of persecution and, in particular, widespread predator control by gamekeepers. In 1911, there were 22,000 gamekeepers in Britain (Potts, 1980), and badger control was part of their duties. However, after the 1914-1918 war, the intensity of predator control declined, and many species of carnivore started to recover (Langley & Yalden, 1977).

Badgers certainly appeared to be more common in the 1930s and 1940s than they had been earlier in the century (e.g. Thompson, 1931; Graham, 1946; Neal, 1948). Whether this represented a real population recovery, or an over-estimation of the impact of earlier levels of persecution, is less clear. A number of reports in the early decades of this century appeared to challenge the views summarised in the Victoria County Histories. These suggested that badgers, whilst not common, were not as rare as previously reported e.g. Thorburn (1920). Other authors e.g. Batten (n.d.) and Pitt (n.d.) reported that badgers had been rare due to persecution, but that numbers had increased substantially after the First World War as a result of a reduction in gamekeeping pressure.

Both views were equally prevalent. Since badgers did not undergo the extensive range reduction shown by other persecuted carnivores (Langley & Yalden, 1977), it is difficult to resolve these conflicting assessments of the impact of persecution on badger numbers in the years preceding the First World War. Cresswell, Harris & Jefferies (1990) concluded that the impact of gamekeepers on badger numbers was less dramatic than for other carnivores, and considered it unlikely that badger numbers had really increased dramatically following the First World War.

Their assessment was based in large part on the view of badger behaviour prevailing at the time, which was derived from a number of studies. Kruuk & Macdonald (1985) described badgers as "contractionists"; one feature of such species was that they would not expand their territories to encompass nearby suitable habitat but would maintain a constant territory size irrespective of changes in neighbouring social groups. This view was in part based on a long-term field study at Woodchester Park, Gloucestershire, where it took nine to ten years for a high-density badger population to recover to their former density following the culling of a small number of social groups (five in 1978, six in 1979) (Cheeseman *et al.*, 1993). These data suggest that badgers were slow to expand and colonise vacant territories. It was such arguments that led Cresswell, Harris & Jefferies (1990) to conclude that any badger population changes following a reduction in pressure from gamekeepers and other forms of persecution could only led to a slow recovery and expansion into new areas.

This view has been reinforced by more recent studies by Roper (1993), who concluded that setts, and particularly main setts, are a valuable resource that cannot easily be replaced. He argued, therefore, that offspring stand to gain more from remaining in their natal group and inheriting the parental sett than from leaving and trying to construct new setts of their own. This argument has been supported by Doncaster & Woodroffe (1993), who examined the distribution of territorial boundaries of adjacent social groups in relation to the position of main setts. They argued that territorial behaviour in badgers is an adaptation to maximizing long-term reproductive success by defending the main sett, which is a critical resource.

East Anglia is the only part of Britain where the impact of badger persecution, especially by gamekeepers, has remained conspicuous. In the 1800s, badgers had been common in parts of Norfolk (Southwell, 1901; Patterson, 1908) and of Suffolk

(Rope, 1911). However, with the increased interest in game shooting in the latter part of the 19th century (Tapper, 1992), the number of gamekeepers increased. One gamekeeper can effectively manage about four square kilometres of land and, in the years leading up to the First World War, this was the density of gamekeepers across virtually all of Norfolk and Suffolk (Tapper, 1992). This intensity of gamekeeping pressure in East Anglia led to a dramatic decline in many species, including badgers. In Norfolk, only 23 badger setts were occupied in 1971 (Vine, 1970); in the next decade the number of occupied setts fluctuated between 25 and 35 and, in most of west Norfolk, badgers would have become extinct if it had not been for reintroductions in the 1970s (Anon., 1981).

During the 1980s the population expanded, and in Norfolk 65 setts were active in 1992 (Vine, 1993). In Suffolk, badgers were more common but largely confined to the south of the county; in the early 1990s there were approximately 270 recorded setts, of which 88 were thought to be main setts (Harris, 1993). Thus, in the early 1990s, there were no more than 150 badger social groups in Norfolk and Suffolk; even if these counties contained badgers at the modest densities recorded in comparable habitat types in neighbouring counties, there could have been around 1450 social groups (Harris, 1993; Reason, Harris & Cresswell, 1993). If the badger populations in these neighbouring counties were also below carrying capacity for the environment, e.g. because they had also been reduced following persecution, then the potential number of badger social groups in Norfolk and Suffolk might be higher than 1450.

From 1963, The Mammal Society instigated a national system for recording badger setts, and this led to a plethora of mammal reports describing the status of badgers on a county or local basis. The national results are summarised by Neal (1972; 1977; 1986) and Clements, Neal & Yalden (1988). This database provided an invaluable source of information that led to the improvement of badger legislation, and was used extensively in the parliamentary debates that led to the introduction of the Badgers Act 1973 (Hardy, 1975). Subsequently, these records were used to document the impact of badger digging on the badger population in Yorkshire, especially in West Yorkshire, where the proportion of active setts declined from 91% in the period 1970 to 1976, to only 34% in the period 1977 to 1978 (Paget & Patchett, 1978). Paul Patchett estimated that the badger population had dropped from an estimated 312 in 1970 to 112 in 1978, a decline of 64%, and this estimate was almost certainly on the low side (Paul Patchett, unpubished data). The decline in the number of active setts in West Yorkshire was so well documented that it provided the evidence for the Home Secretary to establish an Area of Special Protection for badgers (under section 6 of the Badgers Act 1973) in the metropolitan county of West Yorkshire in 1979. This Area of Special Protection remained in force until 1981, when badger protection was further enhanced under the Wildlife and Countryside Act 1981 (Appendix 10.9). The National Federation of Badger Groups also monitored levels of persecution at known setts, and their report subsequently provided strong evidence in support of the need to protect badger setts (Anon., 1990), thereby helping ensure the passage of the Badgers Act 1991.

The database provided by The Mammal Society's recording scheme has also been used to monitor local threats to established badger setts in several parts of Britain. In Essex, Skinner, Skinner & Harris (1991a) found that in the twenty-year period up to the mid-1980s, 36% of the 574 badger setts recorded by Cowlin (1972) had disappeared, with agricultural activities being the main identifiable cause of sett losses. Furthermore, of the remaining setts, there was a 14% reduction in the number occupied by badgers, and modal sett size was reduced from six holes to three. All this suggested a significant reduction in the badger population.

However, the situation in Essex may have been extreme; during the twenty-year period between the two surveys there had been a heavy demand for land to meet housing needs, intensive arable farming was widespread in the remaining rural areas, and there was an ever-increasing expansion of the road network. Furthermore, being low-lying, Essex had few natural sites for badgers to construct their setts, and 30% were dug in man-made slopes (Skinner, Skinner & Harris, 1991b). This heavy reliance on man-made embankments to build their setts may have exacerbated the vulnerability of the badgers in Essex to anthropogenic changes.

The only comparable survey was that undertaken in Surrey by "Clem" Clements (*pers. comm.*). Like Essex, Surrey is close to London and has undergone many recent changes, especially in the north and east of the county. These include extensive housing developments and the construction of three motorways. Clements resurveyed all the known badger setts in the part of Surrey west of the A23 and outside the Greater London area.

Within this area, 346 setts of all types had been recorded up to 1976, and a further 220 by the end of 1984. All the setts were resurveyed between November 1991 and May 1993; these constituted around half the known setts in the county. Occupancy levels were lower than in many parts of southern Britain; only 23% of main setts were occupied in the early 1970s, 36% in the early 1980s and 31% in the early 1990s. A similar pattern of increase in occupancy levels to the early 1980s, with a small decline thereafter, was also observed for other sett types. However, despite these relatively low occupancy levels, the number of destroyed main setts had only risen from three in the early 1970s to five in the early 1990s.

Although monitoring the fate of known setts can provide valuable clues as to the main sources of persecution, it cannot be used to quantify population changes, since there is no measure of the rate at which new setts are established. Thus in Essex, Skinner, Skinner & Harris (1991a) recorded 216 setts not included in Cowlin's (1972) database, but there was no way of determining how many of these were new setts dug in the period between the two surveys, and how many had not been recorded in the earlier survey.

Whilst clearly very valuable, an improved understanding of badger biology had highlighted a number of limitations with The Mammal Society's database for monitoring future changes in badger populations. Perhaps most importantly, recorded setts were not classified into different types and there were no data from areas where setts where absent, so the rate of appearance of new setts could not be quantified (Cresswell, Harris & Jefferies, 1990). Also, the quality and quantity of the data from each county are determined by the enthusiasm of the local recorder. So, to improve upon the database that was available for monitoring badger population changes, the Nature Conservancy Council funded a new badger survey in the 1980s; the field work for this was scheduled to last from November 1985 to December 1987, although a few 1-km squares already started were completed in early 1988 (Cresswell, Harris & Jefferies, 1990).

## 1.2 The 1980s badger survey

To aims of the 1980s badger survey were:-

a. To provide a baseline against which any future changes in badger numbers could be assessed.
b. To quantify the habitat requirements and sett site characteristics for badgers in different parts of Britain.
c. To undertake a stratified survey so that the results could be extrapolated to estimate badger distribution and density throughout Britain.
d. To compare the potential and actual badger populations in Britain, and to calculate the effects of land-use changes, persecution and control operations on badger numbers.

To achieve these goals, 2455 1-km squares randomly selected from within 32 land classes (Bunce, Barr & Whittaker, 1981a; 1981b) were surveyed for badger setts and signs of badger activity. Badger densities were presented for each of the 32 land classes, and the number of badger social groups was estimated to be 42,891±3851 (±95% confidence limits) (Cresswell, Harris & Jefferies, 1990). Assuming a mean of 5.9 adult badgers per social group, this was estimated to equate to approximately 250,000 adult badgers, with 105,000 cubs born each year. This badger population was not evenly distributed throughout Britain; 24.9% were in south-west England and 21.9% in south-east England, whereas only 14.0% were found in Wales and 9.9% in Scotland (Cresswell *et al.*, 1989).

After the publication of the results of the 1980s badger survey, the data were reanalysed following changes to the land classification scheme which led to a number of the 1-km squares included in the original survey being reallocated to a new land class (see section 1.4.1). The new land classes were used to recalculate the badger population size; the estimate of the number of badger social groups in Britain was little affected, this changing from 42,891±3851 to 41,894±4404 (Reason, Harris & Cresswell, 1993). The fact that the reclassification made no significant difference to the badger population estimates is a reflection of the robustness of the land classification scheme; the increase in the size of the 95% confidence limits of the population estimate was due to a reduction in the number of 1-km squares surveyed for badgers in some of the smaller land classes following their allocation to a nearby land class.

Also, new data on badger reproductive biology (Cresswell *et al.*, 1992) allowed for an improved estimate of the number of badger cubs born each year; this was revised upwards to 172,000 per annum (Harris *et al.*, 1992). These authors also provided a resumé of the main causes of badger mortality. Adult mortality was estimated to be 61,000 per annum, cub mortality 64,500 pre-emergence and 41,500 post-emergence. The major identified cause of mortality was road traffic accidents; these killed a minimum of 50,000 adults and cubs per annum. The next most important single cause of mortality was badger digging, with an estimated 10,000 badgers killed each year.

## 1.3 Other national badger surveys

Following the publication of the results of the British survey, the same approach has been used to determine the number of badger social groups in Northern Ireland (Feore, Smal & Montgomery, 1993; Feore, 1994) and in the Irish Republic (Smal, 1993; 1995). Data collection was exactly as developed in Britain, except that unlike the British survey large numbers of volunteers were not used. Also, there was no national land class system available in Ireland, and so instead the 1-km square in the extreme south-west of each 10-km square was surveyed. This gave approximately a one percent coverage, as in the British survey, but the lack of stratification meant that extrapolating the results was potentially more problematic. In Northern Ireland, a land classification scheme was completed during the course of the badger survey, and in retrospect it turned out that the Northern Ireland badger survey had adequately sampled each land class (Feore, 1994).

Both the Irish surveys were undertaken in habitats similar to those in Britain where there were comparable badger densities. The same approach is now being used in Lithuania, where badger densities are much lower, and habitats somewhat different. However, progress to date suggests that the approach will be equally successful (Edvardas Mickevicius, *pers. comm.).*

In addition to detailed badger surveys along the lines developed by Cresswell, Harris & Jefferies (1990), the overall status of badgers in western Europe has been reviewed by Griffiths & Thomas (1993) and Griffiths, Griffiths & Thomas (1993). They showed that badgers appeared to be particularly abundant in Britain, Ireland and Sweden, and that badger populations were either stable or increasing throughout much of Europe. Only the populations in Albania and parts of the former Yugoslavia appeared to be decreasing. They assumed that the badger population in Britain was stable. In reviewing the status of all mammals in Britain, Harris *et al.* (1995) reinforced the view that the badger population in Britain was of high importance from a European perspective, and as such worthy of particular protection. Thus, it is important to monitor any badger population changes in Britain carefully.

## 1.4 Developments since the 1980s badger survey

Since the survey in the 1980s, the land classification system has been developed and expanded to cover all of Britain, and further research has added to our understanding of badger behaviour and the sett classification system. In this section we consider these developments and their potential impact on the survey design.

### *1.4.1 Changes to the land classification scheme*

In the 1980s survey, a land classification scheme developed by the Institute of Terrestrial Ecology was used to ensure that the selected survey squares adequately sampled all landscape types in Britain. The development of the land classification scheme is summarised by Bunce *et al.* (1996). The initial classification in 1977, that was used for the 1980s badger survey, was based on 281 attributes describing the climate, topography, human geography, solid geology and drift, in each 1-km square. Indicator Species Analysis (Hill, Bunce & Shaw, 1975) was used to classify a sample of 1212 1-km squares from across Britain into 32 groups, which were called land classes. To improve the estimates of the relative size of each land class in Britain, a further 4800 1-km squares were assigned to land classes using 76 key indicator attributes. The original 1212 1-km squares were distributed on a 15 by 15 kilometre grid; these additional 1-km squares were four kilometres to the north-west, north-east, south-west and south-east of the original 1-km squares. Thus, approximately 6000 1-km squares were allocated to a land class, and the 2455 1-km squares surveyed during the original badger survey were randomly selected from this grid. Selecting 1-km squares from this grid had the added advantage that there was a minimum distance of four kilometres between survey squares, thereby avoiding clumping in areas where there were a large number of volunteers.

Subsequent to the original badger survey, the Institute of Terrestrial Ecology assigned every 1-km square in Britain to a land class. This would not have been practical using all 76 of the key indicator attributes. So a smaller number of map-derived

**Table 1.1.** Details of the seven land class groups used to analyse the badger population changes.

| Land class group | Land classes in land class group | Number of 1-km squares in land class group | Distribution |
|---|---|---|---|
| Arable I | 2 | 14,460 | Southern and south-east England |
| Arable II | 3, 4, 9, 11, 12 | 48,385 | East Midlands, eastern and south-east England |
| Arable III | 14, 25, 26 | 18,339 | North-east England, southern and eastern Scotland |
| Pastoral IV | 1, 5, 6, 7, 8 | 34,730 | South-west England, the Severn valley and south Wales |
| Pastoral V | 10, 13, 15, 16, 27 | 35,383 | North-west and north-east England, into southern Scotland |
| Marginal upland VI | 17, 18, 19, 20, 28, 31 | 35,438 | Wales, Peak District, Lake District, north-east England and north-east Scotland |
| Upland VII | 21, 22, 23, 24, 29, 30, 32 | 45,150 | North Pennines, southern Scotland and Scottish highlands |
| **Total** | | **231,885** | |

variables, containing information on coastal features, altitude, climate, geology, drift, and other features (Bunce *et al.*, 1997), were used to allocate 1-km squares to land classes by means of logistic regression and linear discriminant functions. This new procedure meant that 62% of the original 1212 1-km squares were allocated to their original land classes, with the majority of the remainder allocated to "nearby" and, hence, relatively similar land classes (Bunce *et al.*, 1996). Besides allowing better estimates of the area and distribution of the different land classes, this new classification procedure also reduced the number of geographical outliers.

The other development since the original badger survey is that the new land classes have been grouped into four strata for interpretative purposes (Barr *et al.*, 1993). For the original badger survey, Cresswell, Harris & Jefferies (1990) grouped the land classes for some analyses, particularly those on habitat relationships. However, these groupings were somewhat arbitrary, and were based in part on badger densities in the constituent land classes (Cresswell, Harris & Jefferies, 1990). The land class groupings developed by Barr *et al.* (1993) reflect the ecological characteristics and the most widely used relationships between the classes, with the overall ranking determined by the first axis of the principal component analyses of the land cover data recorded in a sample of eight 1-km squares from each of the 32 land classes surveyed in 1978 (Bunce *et al.*, 1996).

At the broadest level, the 32 land classes are aggregated into four basic groups based on the dominant land cover; these are the "arable", "pastoral", "marginal upland" and "upland" land class groups (Barr *et al.*, 1993; Bunce *et al.*, 1996). The basic characteristics of these four major land class groups are summarised by Bunce *et al.* (1996). The arable land class group at the next level is further divided into three groups, the pastoral land class group into two groups. Recent surveys on brown hares (Hutchings & Harris, 1996) and on bats and habitats (Walsh, Harris & Hutson, 1995; Walsh & Harris, 1996a; 1996b) used these seven land class groups to analyse their data (see Table 1.1). This approach proved to be highly successful because the seven groups reflected differences in patterns of land use that were of greatest relevance to predominantly lowland species of mammal; their distributions are shown in Figure 1.1.

These seven land class groups are also used in this report to analyse any badger population changes between the two surveys. This approach is particularly useful in highlighting changes in different landscape types. It also facilitates analyses of the patterns of habitat use by badgers within the different landscape types. However, within each land class group, there may be local differences in

**Table 1.2.** The regions used to analyse the badger population changes.

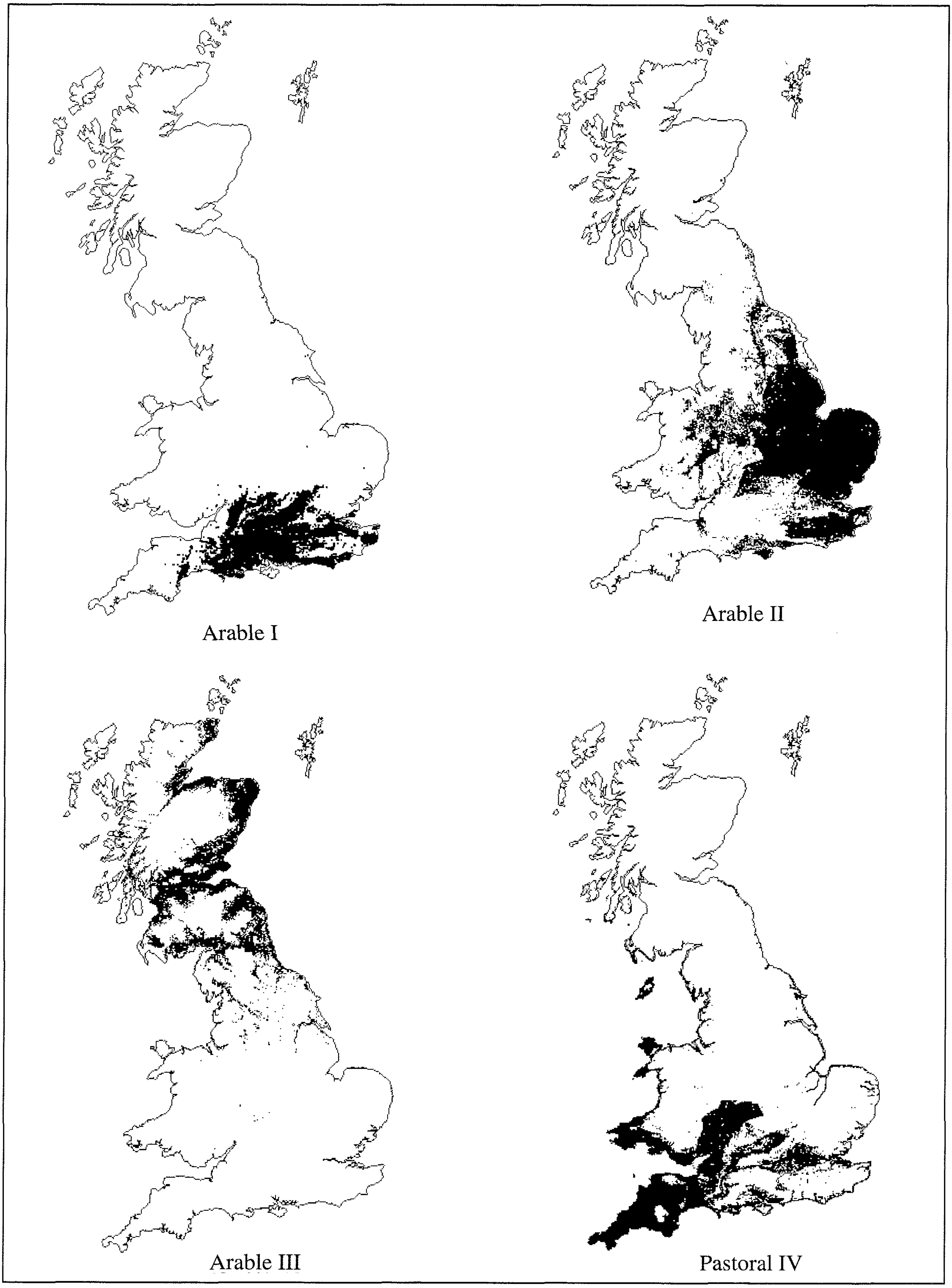
| Region | Number of 1-km squares in region | Counties |
|---|---|---|
| North England | 15,815 | Cleveland, Cumbria, Durham, Northumberland, Tyne & Wear |
| North-west England | 7505 | Cheshire, Greater Manchester, Lancashire, Merseyside |
| North-east England | 15,620 | Humberside, North Yorkshire, South Yorkshire, West Yorkshire |
| West Midlands | 15,685 | Gloucestershire, Hereford & Worcester, Shropshire, Staffordshire, Warwickshire, West Midlands |
| East Midlands | 13,351 | Derbyshire, Leicestershire, Lincolnshire, Nottinghamshire |
| Central England | 11,337 | Bedfordshire, Buckinghamshire, Hertfordshire, Greater London, Oxfordshire, Northamptonshire |
| East Anglia | 16,641 | Cambridgeshire, Essex, Norfolk, Suffolk |
| South-west England | 18,494 | Avon, Cornwall, Devon, Dorset, Somerset |
| Southern England | 9063 | Berkshire, Hampshire, Isle of Wight, Wiltshire |
| South-east England | 9487 | Kent, Surrey, East Sussex, West Sussex |
| North Scotland | 48,738 | Central, Fife, Grampian, Highland, Tayside |
| South Scotland | 28,568 | Arran, Borders, Dumfries & Galloway, Lothian, Strathclyde |
| Mid and north Wales | 11,734 | Anglesey, Clwyd, Gwynedd, Powys |
| South Wales | 9847 | Dyfed, Mid Glamorgan, South Glamorgan, West Glamorgan, Gwent |
| **Total** | **231,885** | |

the patterns of change in the badger population as a result of a variety of anthropogenic factors. These may, for instance, be associated with different human population densities, proximity to urban areas, and historical factors, since badger digging and other forms of badger persecution are higher in some areas than others (Reason, Harris & Cresswell, 1993). Thus, changes in the badger population are also presented regionally; the fourteen regions used for these analyses are described in Table 1.2. In defining these regions, wherever possible counties with generally similar land use, human population density, and/or past patterns of badger persecution, were grouped together.

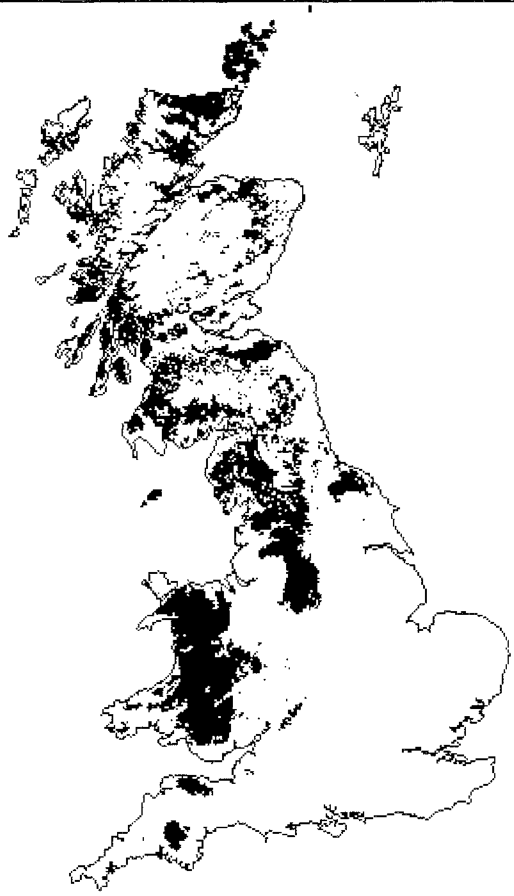
### *1.4.2 Improved understanding of the sett classification scheme*

The sett classification scheme used in the 1980s badger survey was based on an increasing awareness that there are a number of different types of sett within badger territories, and of these the most important is the main sett (Kruuk, 1978; 1989; Cheeseman *et al.*, 1981; Harris, 1984). Thornton (1988) produced a formal framework for classifying badger setts into four different types. These sett types were defined by size, their position within a badger territory, and constancy of usage. The 1980s survey showed that each badger social group had, on average, 4.10 setts i.e. one main, 0.43 annexe, 0.86 subsidiary, 1.57 outlying and 0.24 disused main setts. This remained roughly constant irrespective of badger population density. In the Republic of Ireland, the pattern of sett distribution per social group was remarkably similar, with 4.09 setts per social group, these comprising one main, 0.50 annexe, 1.32 subsidiary, 1.08 outlying and 0.19 disused main setts (Smal, 1995). The relative abundance of the different sett types per social group was also similar in Northern Ireland, but there were slightly more setts (5.49) per group i.e. one main, 0.72 annexe, 2.04 subsidiary, 1.60 outlying and 0.13 disused main setts (Feore, 1994).

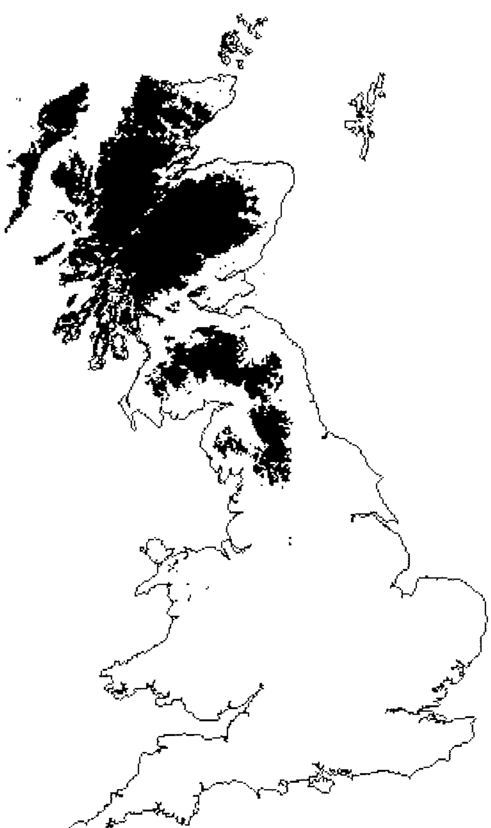
The remarkable consistency of the results between these three surveys may be an artefact, because size was a key characteristic used to define


Arable I
Arable II
Arable III
Pastoral IV

Pastoral V



Marginal upland VI



Upland VII

*Figure 1.1. Distribution of the seven land class groups used to analyse the badger population changes. Redrawn from Barr* et al. *(1993)*

sett status. However, this is unlikely to be the case, because main setts in Ireland were smaller than those in mainland Britain, possibly because more main setts were dug in habitats such as hedgerows, which restricted their size. The alternative explanation for the consistency of the results is that these definitions were biologically meaningful, and that different sett types played specific roles in the social life of badgers. This argument has been reinforced by improvements in our understanding of badger biology since the 1980s survey.

Roper (1992) showed that setts of different size and status are built according to the same basic architectural principles, but that main setts are larger in terms of area and volume, and contain more chambers, nests and latrines. Since suitable sites to construct main setts may be in short supply, and sett construction can take a considerable amount of time and energy, it has been argued that they are an important resource for badger social groups, and that main sett availability is an ultimate reason for the evolution of sociality and territoriality in badgers (Doncaster & Woodroffe, 1993; Roper, 1993). Their studies reinforce the definition of a main sett used in the 1980s survey i.e. that it is of key importance to the badger social group, is in constant use, and is the breeding sett.

Whilst main setts are generally large, they can be small, especially in areas of low population density, and under exceptional circumstances a main sett may have only a single hole e.g. one in suburban Bristol had a single hole but contained eleven badgers (adults and cubs) (Stephen Harris, unpublished data). In lowland habitats, in the 1980s main setts were generally easily recognised as such, irrespective of their size and the habitat in which they were found, due to their position within the territory and the level of badger activity in the vicinity of the sett. Greater difficulty occurred in upland areas where the main sett was in a rock face or natural cleft in the rock. In such situations, digging was limited, group size was generally small, and so signs of activity were fewer than in lowland areas. However, despite the potential difficulties, overall surveyors reported few problems with identifying main setts. This was important because correct classification of active main setts was critical to the success of the survey.

Having contended that main setts are generally in constant use, it is also true that they may be abandoned, as shown by the number of disused main setts recorded in the 1980s badger survey, with the proportion of disused to active main setts increasing with declining density of social groups (Cresswell, Harris & Jefferies, 1990). A number of authors have also shown that entire badger social groups may move, perhaps several kilometres, and take up residence in a new main sett, often after living in the original main sett for some months or even years (Skinner, 1987; Kruuk, 1989; Sleeman, 1992; Sleeman & Mulcahy, 1993). Why such long distance movements occur is less clear. However, whilst the pattern of use of main setts may be less permanent in areas of low badger population density, this was not a problem for the survey protocol, since in the 1980s survey volunteers reliably distinguished between main setts that were and were not in use.

The role of other sett types was less clear when the original survey was undertaken, and Neal & Cheeseman (1996) stated that they were least happy about the distinction between annexe and subsidiary setts. Their concern stemmed from the apparent lack of difference in the function of these two types of sett, arguing that both were used for alternative accommodation and for some sows in the social group to rear cubs. This argument fails to take account of a number of important differences in the two types of sett. Annexe setts by definition are close to main setts and hence in the centre of the territory, whereas subsidiary setts are more widely distributed within the territory. Annexe setts are also larger (Cresswell, Harris & Jefferies, 1990). In addition, the proportion of sows that breed rises with the increased availability of annexe setts, and this increased reproductive output by the social group is a function of the number of younger sows whose blastocysts implant, rather than an increased proportion of sows carrying blastocysts (Cresswell *et al.*, 1992). Since the presence of annexe setts correlates with increased productivity by younger sows, Cresswell *et al.* (1992) argued that annexe setts enabled younger sows and their cubs to avoid the aggression of older, more dominant sows. Aggression levels between sows appear to be high, and neo-natal losses due to infanticide were estimated to be 35% by Cresswell *et al.* (1992) and 42% by Page, Ross & Langton (1994). In contrast, there is little evidence for subsidiary setts being used for breeding on a regular basis. Since the main sett, the prime breeding site, is a key resource that is usually near the centre of the territory, annexe setts by definition must also be placed centrally. It seems unlikely that subsidiary setts, which by definition tend to be further from the main sett (see Appendix 10.1), would be preferred breeding sites even for younger sows.

Further evidence for the difference between these two types of sett is to be found in this report (section 3.4); as population density rises, there is a disproportionate rise in the number of annexe as opposed to subsidiary setts, reinforcing the idea that the former are more important as an alternative source of accommodation and as secondary breeding sites. Thus we argue that annexe and subsidiary setts do have distinct functions.

The difference between subsidiary and outlying setts is less clear, and it is unlikely that these two sett types have specific individual functions. Both are probably used mainly as temporary refuges during the night, either for rest between foraging bouts or when disturbed. Butler & Roper (1994) argued that low levels of disturbance cause badgers to return to the main sett, whereas with higher levels of disturbance they will always take refuge in the nearest sett. In their paper they use the term "outlier" sett, but it would appear that they grouped all setts other than main setts as "outliers".

Subsidiary and outlying setts are also sometimes used as diurnal refuges. Kruuk (1978) reported that whilst adult boars were always found in the main sett, a younger male and several adult females spent many days in the small "outliers" (he also did not distinguish between subsidiary and outlying setts), and one of these females was lactating. Roper & Christian (1992) monitored the behaviour of a single group of badgers over an eight-month period (September to April). They found that two females rarely slept away from the main sett, whereas a third female and the two males used "outliers" (again, they did not distinguish between subsidiary and outlying setts) most frequently in the spring and autumn. Of their five animals, no individual slept in "outliers" on more than 50% of the days for which data were available, and the overall frequency of "outlier" use, averaged over the whole period across all five animals, was 26% of days. The main sett was the only sett that ever contained all the members of the social group at the same time, and was the primary sett used for overwintering.

Whilst some other authors have failed to distinguish between subsidiary and outlying setts, when we examined the pattern of change between sett types (section 3.5), we found that subsidiary setts were the category of sett most likely to be expanded into main setts. Thus, it appears that subsidiary setts may have either a distinct function, or are built at specific sites, and so for our analyses we retained the distinction between subsidiary and outlying setts.

This different pattern of use of the various sett types is reflected in the permanency of occupancy of setts. Over two consecutive years, O'Corry-Crowe, Eves & Hayden (1993) found that there was an increasing tendency to occupy the same setts in successive years, in the order outlier setts> (88.2% change) >subsidiary>annexe>main setts (9.1% change). All studies therefore support the assertion that main setts, and often annexe setts as well, are in continuous use, whilst subsidiary and outlying setts are used intermittently. This is reflected by the levels of activity shown at the different sett types: in the 1980s survey, 48% of holes at main setts were classified as well used, 34% of holes at annexe setts, and only 24% of holes for both subsidiary and outlying setts (Cresswell, Harris & Jefferies, 1990).

Thus, further developments in our understanding of badger biology have reinforced the validity of the sett classification scheme used in the 1980s survey, and so no modifications were needed for the repeat survey.

## 1.5 Monitoring badger population changes

Badger population changes can occur in two ways: there can be an increase (or decrease) in the number of social groups, and/or there can be an increase (or decrease) in the number of badgers within social groups. These may occur in parallel or independently. For instance, at Woodchester Park, whilst the number of social groups remained constant (at 21), there was a steady increase in mean group size, which more than doubled in about a decade (Neal & Cheeseman, 1996).

Changes in the number of social groups and the size of social groups have different implications. The general perception is that the number of social groups only increases slowly, particularly in areas of high population density (Neal & Cheeseman, 1996), and that even when social groups are removed from such areas, recolonisation is a protracted process, taking up to a decade (Cheeseman *et al.*, 1993). Whilst such changes may be slow, an increase in the number of social groups is likely to reflect a long-term and more permanent increase in badger population size.

Even in areas where badgers are not persecuted, adult mortality is around 30% per annum (Harris, Cresswell & Cheeseman, 1992), and cub mortality, including pre-emergence losses, is much higher

(Cheeseman *et al.*, 1987; Harris & Cresswell, 1987). Factors that affect either adult or cub mortality rates would lead to changes in social group size; these could be either long or short term. For instance, reduced levels of persecution, thereby reducing adult mortality rates, could lead to a long term growth in social group size. In contrast, adverse weather patterns, particularly if they only last one or two years, may lead to a short term decline in group size. Hot dry summers, for instance, can lead to high levels of cub mortality due to starvation (Neal & Cheeseman, 1996). In fact, following particularly unfavourable summers, entire cohorts can disappear from the badger population (Cheeseman *et al.*, 1987). Longer term changes in weather patterns could, however, lead to more significant population changes. The weather in Britain is variable, but there is evidence for cycles (Burroughs, 1992), and the current scenario for climate change is for mean temperatures to rise, for extremely warm seasons and years to occur more frequently, and for summer precipitation to decrease in southern Britain (Anon., 1996). Thus the trend is towards exactly the sort of weather conditions that are least favourable for the survival of badger cubs (Neal & Cheeseman, 1996). A succession of hot, dry summers could, therefore, lead to a succession of years with poor cub recruitment, and this would lead to a slow reduction in mean group, and hence population, size.

### *1.5.1 Changes in the number of badger social groups*

In this report, we used changes in the number of active main setts, which provide a measure of the number of badger social groups, to estimate long-term trends in the badger population (Cresswell, Harris & Jefferies, 1990). Wherever we refer to main setts, this specifically means active main setts only.

### *1.5.2 Changes in the number of badgers*

Badger social group size can be very variable (Cheeseman *et al.*, 1987), and so monitoring trends in badger numbers is more difficult than monitoring the number of social groups. In the 1980s survey, Cresswell, Harris & Jefferies (1990) assumed a mean of 5.9 adults per social group. This was based on a small number of studies, and at the time provided the best estimate available of mean social group size. Whilst it may have been a reasonable assumption for most areas of Britain, Cresswell, Harris & Jefferies (1990) accepted that social group size was likely to be smaller in low density areas.

In this report, because there are likely to be local variations in mean social group size, rather than try to estimate social group size, we have used field signs to estimate the percent change in the number of badgers. For both surveys, the presence or absence of badger footprints, paths or runs, and dung pits, were recorded in each of nine sub-squares within each 1-km square. We used these activity data to explore the relationship between badger numbers and the levels of activity recorded during the two surveys, and also the relationship between badger numbers and both the number of setts per social group and the levels of use of the setts within a social group. These relationships are then used to calculate the percentage change in the number of badgers in Britain between the two surveys. Of necessity, this is a provisional estimate. Further work will enable us to quantify the exact relationship between field signs and badger numbers, and this can then be used to estimate the number of badgers in Britain during the two surveys.

## 1.6 Aims of the 1990s badger survey

Since the publication of the results of the 1980s survey, there have been changes to the badger protection laws that were specifically designed to safeguard setts for the first time (Appendix 10.9). Following the introduction of the Badgers Act 1991, a number of reports suggested that badger numbers were increasing, and this culminated in a report from the National Farmers' Union arguing that there were too many badgers in some areas, and that they were in need of population control (Anon., 1995a). In view of the widespread perception that there had been a dramatic increase in the number of badgers in at least some areas of Britain, the aims of the repeat survey were:-

a. To determine whether there had been any changes in the number of badger social groups in Britain and to identify any regional and landscape differences in the pattern of change.
b. To determine whether there had been any changes in the number of badgers in Britain and to identify any regional and landscape differences in the pattern of change.
c. To determine whether there had been any changes in the levels of badger persecution and,

in particular, sett disturbance in Britain, and any regional and landscape differences in the pattern of change.

d. To determine any changes in the habitat preferences of badgers in Britain in response to any changes in habitat availability.

e. To determine how changes in persecution levels and habitat availability could have led to any badger population changes.

# 2. Methods

In this Chapter, we discuss the methods used for the survey, and in particular the statistical basis for the approach we adopted.

## 2.1 The survey area

The 1980s survey covered mainland England, Scotland and Wales, plus Anglesey, Arran, Canvey Island, the Isle of Grain, the Isle of Sheppey and the Isle of Wight. This included all of the islands believed at that time to have established badger populations, but excluded those islands for which there were only occasional badger records; see Cresswell, Harris & Jefferies (1990) for a discussion as to why other islands were not included in the survey. Since the 1980s survey, there have been small changes in the recorded status of badgers on some of these islands. Foulness, for instance, was excluded because badger sightings were few, and records of setts were even fewer (Laver, 1898; Cresswell, Harris & Jefferies, 1990). More recently, at least three main setts, and a number of smaller setts, have been identified, most of which are in artificial banks, since the area is reclaimed marshland (Don Hunford, *pers. comm.*). However, the number of social groups on the island is likely to remain low.

Badgers have also been recorded on the island of Skye since the 1980s survey (Roger Cottis, *pers. comm.*). To date around fifty disused setts have been identified on the island; these are mainly associated with ancient deciduous woodland. Some of these have become disused in the last few decades, whereas others may not have been used this century. A number of factors may have contributed to this slow pattern of population decline. These include: the development of crofting communities last century; the activities of gamekeepers, who were active up to 1945 on the sporting estates on the island; the hunting of badgers for their valuable pelts; and, more recently, indiscriminate rabbit control. However, despite this widespread persecution, it appears that a remnant population has survived on the island. Roger Cottis (*pers. comm.*) has collected evidence of five reliable sightings in the last 25 years, and in April 1997 a badger was run over on the island and its body recovered. Thus, it would appear that badgers have persisted on Skye, although their numbers remain very low.

The results from Skye also suggest that badgers can persist at very low levels for extended periods; therefore, it may be that badgers have also survived on other islands or areas where they are currently believed to be absent. Whilst the recovery of such relict populations is important and should be carefully monitored, the number of active setts will be very low, and so omitting islands such as Foulness and Skye from this and future surveys will have no significant effect on the overall results.

## 2.2 Survey protocol

The survey started in October 1994 and was completed by January 1997. As in the 1980s survey, field work was largely confined to the autumn, winter and spring, when the vegetation was at its lowest, although some upland areas were surveyed in early or late summer.

The primary aim was to survey the same 2455 1-km squares included in the 1980s survey. In addition, new 1-km squares were surveyed when there were no repeat 1-km squares left within easy travel distance for the surveyor. Additional 1-km squares were surveyed partly to increase the sample size for future surveys, and partly because the data from these new 1-km squares were required as a quality check for the data collected from the resurveyed 1-km squares (see section 2.6). However, all analyses of change and the badger population estimates are based only on the data from the resurveyed 1-km squares.

For both resurveyed and new 1-km squares, each surveyor was sent the same instruction and recording sheets used in the original survey. The first instruction sheet described how to record the badger data (Appendix 10.1), and asked the surveyor to classify all the setts that he/she found into one of four types (main, annexe, subsidiary or outlying); the definitions of these sett types are given in Appendix 10.1. In addition, a further category of disused main sett was recognised for some of the analyses. This was because in the 1980s survey, it became apparent that setts which clearly had been main setts could be abandoned (Cresswell, Harris & Jefferies, 1990). For each sett, the number of well-used, partially used and disused holes were recorded; the definitions of these are also given in Appendix 10.1. These details were recorded onto the form shown in Appendix 10.2. In addition there were two maps; these were copies of the 1:25,000 Pathfinder series, enlarged to a scale of approximately 1:6250. One map was used to mark the position of each badger sett. On this map, the survey 1-km square was divided into nine sub-squares, and surveyors were asked to record the presence or absence of badger footprints, badger paths or runs, and dung pits in each of the nine sub-squares on the recording form (Appendix 10.2). This provided a measure of badger activity in each 1-km square.

The other instruction sheet described how to record the habitat data (Appendix 10.3). The surveyor was asked to use the second map to shade in all habitat areas within the 1-km square that were greater than 50 metres in length or 500 square metres in area, using the 40 different habitat types described on the instruction sheet.

One extra instruction sheet and one extra recording form were included for 1-km squares that were also surveyed in the 1980s. The instruction sheet explained how to record any changes to the badger setts within the 1-km square since the 1980s survey (Appendix 10.4), and there was a recording sheet on which to record these changes (Appendix 10.5). It was essential to ensure that any changes were recorded accurately; each surveyor, therefore, was sent a copy of the badger data from the 1980s survey. Whilst it is possible that having the original data sheets could have biased the results by focussing the search effort to setts that had already been recorded, thereby missing any new setts, surveyors were given strict instructions to survey the whole 1-km square thoroughly. In addition, the whole 1-km square had to be surveyed to record the habitat data, and recorders were not sent a copy of the original habitat data. Having a copy of the original badger data was essential, since it enabled the surveyor to check the quality of the data recorded in the 1980s survey, to document any errors in the original data, and to determine whether a sett had fallen into disuse or disappeared since the survey in the 1980s. Had the surveyors not known the positions, size and status of setts recorded in the original survey, they would not have been able to check the quality of the original data or to document the factors leading to sett losses. Whether this approach biased the data collection is discussed further in section 2.6.

## 2.3 Survey coverage

Of the 2455 1-km squares surveyed in the 1980s, 2271 (93%) were resurveyed. The distribution of the resurveyed squares is shown in Figure 2.1, those not resurveyed in Figure 2.2. In addition, 307 new 1-km squares were surveyed; their distribution is shown in Figure 2.3. The proportion of 1-km squares resurveyed and number of new 1-km squares in each county, land class and land class group are shown in Tables 2.1, 2.2 and 2.3 respectively. The proportion of 1-km squares resurveyed was similar by county, land class and land class group, and there was no bias introduced by under-surveying particular areas or habitat types. Failure to resurvey 1-km squares was generally because of a lack of volunteers in the region, although 14 (0.6% of the original 2455) were not resurveyed because access was refused to all (nine) or part (five) of the 1-km square. In theory it is possible that access was refused because any setts on the land had been damaged or destroyed, or there had been some other form of illegal activity that the landowner did not want recorded. However, this was not considered to be a significant potential source of bias because badger setts were only recorded in the 1980s in five of the 14 1-km squares (36%) to which we were refused access. Of the total sample of 2455 1-km squares surveyed in the 1980s, 699 (28%) contained badger setts. Since access was refused to so few 1-km squares, and because this sub-sample was not skewed towards 1-km squares that held setts, there is no evidence that being refused access biased the survey results. Generally, there were few problems with obtaining permission to survey private land.

## 2.4 Data checking

### *2.4.1 Ensuring comparability between the two surveys*

For a repeat survey such as this, it is important to ensure that the data were treated in exactly the same way during both surveys to ensure comparability. This was essential to ensure that we were measuring real change rather than differences in interpretation between the two surveys. First, one of us (Stephen Harris) was involved in both surveys, and this helped ensure comparability. To further check that there were no differences between the two surveys, Penny Cresswell Lewns, who had been the full-time surveyor on the 1980s survey, met with Gavin Wilson to compare and discuss the interpretation of the field data provided by volunteers. A trial sample of 1-km squares for which Gavin Wilson had corrected the surveyors sett classifications were shown to

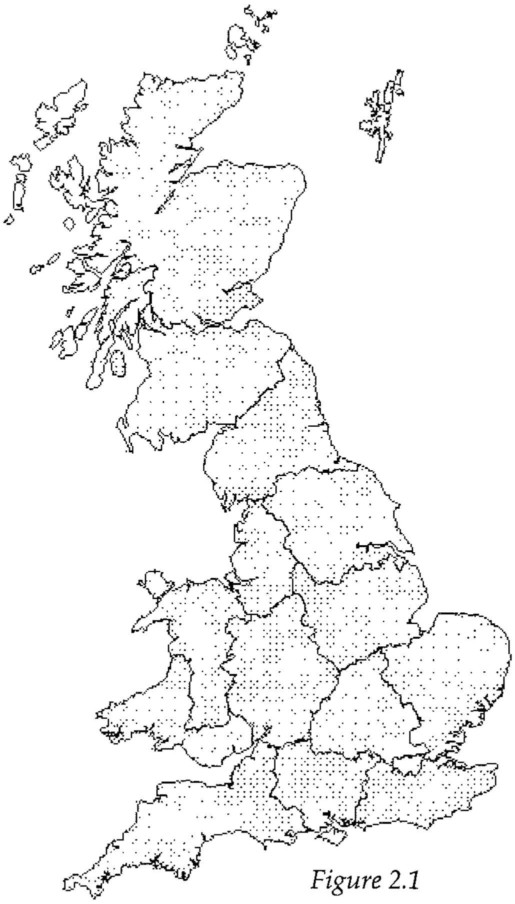


*Figure 2.1*

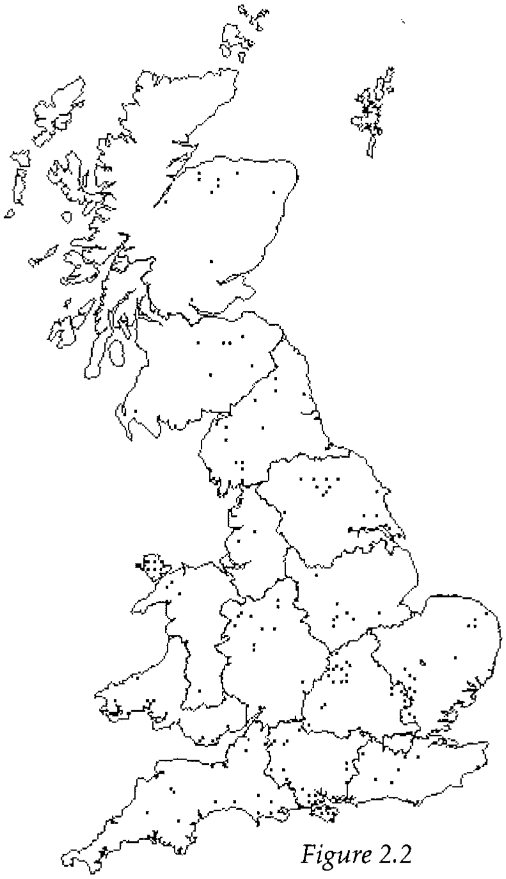


*Figure 2.2*

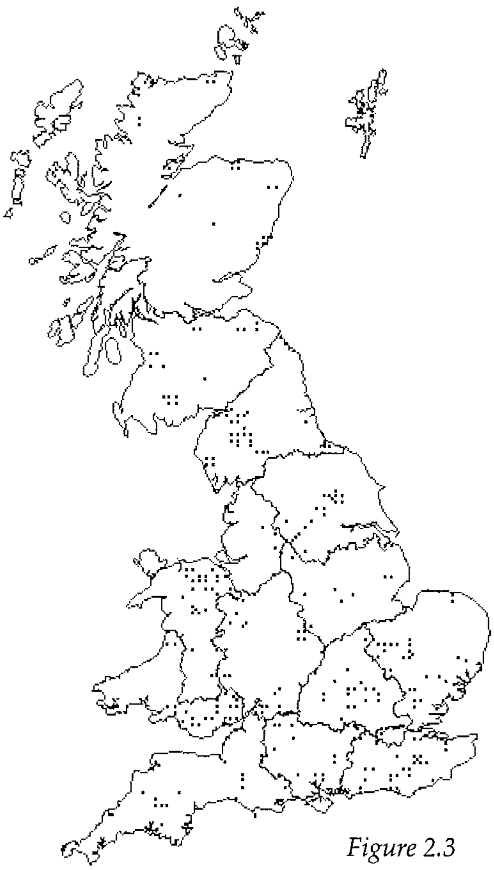


*Figure 2.3*

*Figure 2.1. The distribution of the 2271 1-km squares resurveyed in the 1990s. The lines indicate the boundaries of the regions used in this report*

*Figure 2.2. The distribution of the 184 1-km squares surveyed in the 1980s but which were not resurveyed in the 1990s. The lines indicate the boundaries of the regions used in this report*

*Figure 2.3. The distribution of the 307 new 1-km squares surveyed for the first time in the 1990s. The lines indicate the boundaries of the regions used in this report*

**Table 2.1.** The number of 1-km squares in each county or region included in the two badger surveys.

| County/region | Number of squares surveyed in the 1980s | Percent of county/ region surveyed | Number of squares re-surveyed in the 1990s | Percent resurveyed | Number of new squares surveyed in the 1990s |
|---|---|---|---|---|---|
| **England** | | | | | |
| Avon | 22 | 1.6 | 19 | 86 | 3 |
| Bedfordshire | 13 | 0.7 | 13 | 100 | 1 |
| Berkshire | 15 | 1.2 | 15 | 100 | 2 |
| Buckinghamshire | 14 | 1.1 | 14 | 100 | 4 |
| Cambridgeshire | 39 | 1.1 | 36 | 92 | 8 |
| Cheshire | 33 | 1.4 | 33 | 100 | 13 |
| Cleveland | 7 | 1.1 | 7 | - | 4 |
| Cornwall | 41 | 1.1 | 39 | 95 | 3 |
| Cumbria | 75 | 1.1 | 63 | 83 | 26 |
| Derbyshire | 49 | 1.9 | 47 | 96 | 3 |
| Devon | 56 | 0.8 | 53 | 95 | 10 |
| Dorset | 46 | 1.6 | 41 | 89 | 3 |
| Durham | 19 | 0.8 | 19 | 100 | 1 |
| Essex | 49 | 1.3 | 45 | 92 | 7 |
| Gloucestershire | 17 | 0.6 | 17 | 100 | 9 |
| Greater Manchester | 6 | 0.5 | 6 | - | 1 |
| Hampshire | 60 | 1.5 | 52 | 87 | 8 |
| Hereford & Worcester | 51 | 1.3 | 51 | 100 | 4 |
| Hertfordshire | 17 | 1.0 | 11 | 65 | 5 |
| Humberside | 35 | 1.0 | 25 | 71 | 1 |
| Kent | 73 | 1.9 | 70 | 96 | 10 |
| Lancashire | 32 | 1.0 | 30 | 94 | 1 |
| Leicestershire | 36 | 1.4 | 31 | 86 | 1 |
| Lincolnshire | 56 | 0.9 | 54 | 96 | 4 |
| Greater London | 4 | 0.2 | 4 | - | 1 |
| Merseyside | 3 | 0.4 | 3 | - | 0 |
| Norfolk | 36 | 0.7 | 32 | 89 | 2 |
| Northamptonshire | 28 | 1.0 | 18 | 64 | 2 |
| Northumberland | 80 | 1.6 | 76 | 95 | 1 |
| Nottinghamshire | 22 | 1.0 | 21 | 95 | 3 |
| Oxfordshire | 34 | 1.3 | 31 | 91 | 2 |
| Shropshire | 44 | 1.3 | 39 | 89 | 6 |
| Somerset | 55 | 1.6 | 53 | 96 | 7 |
| Staffordshire | 43 | 1.6 | 40 | 93 | 0 |
| Suffolk | 50 | 1.3 | 48 | 96 | 4 |
| Surrey | 33 | 2.0 | 31 | 94 | 1 |
| East Sussex | 24 | 1.3 | 22 | 92 | 10 |
| West Sussex | 39 | 1.9 | 36 | 92 | 7 |
| Tyne & Wear | 5 | 0.9 | 5 | - | 0 |
| Warwickshire | 28 | 1.4 | 28 | 100 | 5 |
| West Midlands | 2 | 0.2 | 2 | - | 0 |
| Isle of Wight | 19 | 4.3 | 10 | 53 | 0 |
| Wiltshire | 63 | 1.8 | 54 | 86 | 8 |
| North Yorkshire | 69 | 0.8 | 62 | 90 | 9 |
| South Yorkshire | 20 | 1.3 | 20 | 100 | 2 |
| West Yorkshire | 14 | 0.7 | 14 | 100 | 8 |
| **Totals** | **1576** | **1.2** | **1440** | **91** | **210** |

**Table 2.1** continued.

| County/region | Number of squares surveyed in the 1980s | Percent of county/ region surveyed | Number of squares re-surveyed in the 1990s | Percent resurveyed | Number of new squares surveyed in the 1990s |
|---|---|---|---|---|---|
| **Scotland** | | | | | |
| Arran | 16 | 3.2 | 16 | 100 | 0 |
| Borders | 30 | 0.6 | 27 | 90 | 0 |
| Central | 26 | 1.0 | 26 | 100 | 1 |
| Dumfries & Galloway | 56 | 0.8 | 55 | 98 | 5 |
| Fife | 28 | 1.9 | 28 | 100 | 0 |
| Grampian | 79 | 0.9 | 73 | 92 | 14 |
| Highland | 173 | 0.6 | 167 | 97 | 11 |
| Lothian | 30 | 1.7 | 30 | 100 | 6 |
| Strathclyde | 83 | 0.5 | 80 | 96 | 4 |
| Tayside | 72 | 0.9 | 72 | 100 | 1 |
| **Totals** | **593** | **0.8** | **574** | **97** | **42** |
| **Wales** | | | | | |
| Anglesey | 22 | 2.7 | 9 | 41 | 0 |
| Clwyd | 34 | 1.4 | 34 | 100 | 19 |
| Dyfed | 89 | 1.5 | 82 | 92 | 4 |
| Gwent | 8 | 0.6 | 8 | - | 12 |
| Gwynedd | 49 | 1.2 | 47 | 96 | 1 |
| Mid Glamorgan | 8 | 0.8 | 8 | - | 5 |
| South Glamorgan | 8 | 1.8 | 3 | - | 0 |
| West Glamorgan | 13 | 1.5 | 13 | 100 | 7 |
| Powys | 55 | 1.1 | 53 | 96 | 7 |
| **Totals** | **286** | **1.3** | **257** | **90** | **55** |

Penny Cresswell Lewns. She agreed with all the changes that were made, and confirmed that there was close comparability in the way the data were handled between the two surveys.

*2.4.2 Preliminary data sorting*

On receipt, the completed forms and maps for each 1-km square were carefully checked by Gavin Wilson to ensure uniformity of approach for the survey work, and that all the data had been entered correctly. Those 1-km squares that were not clear, or for which some data were missing, were returned to the surveyor for completion. The sett classifications were then carefully checked against the other field data, and care was taken to ensure that the sett classifications were consistent between the 1980s and 1990s surveys. Where there was doubt as to whether a sett had been correctly classified, this was either corrected or queried with the recorder. As for the original survey, fewest problems were encountered with identifying main setts, and most problems were encountered by surveyors who had confused annexe and subsidiary setts.

The habitat data were then checked to ensure that no improbable categories had been recorded; any queries were referred to the surveyor for clarification. Finally, the quality of the overall data collection was classified to one of the three following groups: a rating of "1" denoted clear field data with well-labelled maps and no queries; "2" denoted field data and/or maps that needed some care to interpret because there was ambiguity in the badger data that needed clarification, or the habitat data had not been fully completed, or the shading of the habitat types was such that the boundaries were not clearly defined; and "3" denoted data sheets and/or maps that were incomplete. In addition, there was a fourth category that denoted 1-km squares surveyed by Gavin Wilson. Sample sizes in each cate-

**Table 2.2.** The number of 1-km squares in each land class included in the two badger surveys.

| Land class | Number of squares surveyed in the 1980s | Percent of land class surveyed | Number of squares re-surveyed in the 1990s | Percent resurveyed | Number of new squares surveyed in the 1990s |
|---|---|---|---|---|---|
| 1 | 159 | 1.1 | 157 | 99 | 28 |
| 2 | 233 | 1.6 | 208 | 89 | 30 |
| 3 | 158 | 1.0 | 143 | 91 | 30 |
| 4 | 118 | 1.3 | 104 | 88 | 16 |
| 5 | 48 | 1.3 | 37 | 77 | 6 |
| 6 | 97 | 1.0 | 83 | 86 | 10 |
| 7 | 90 | 3.9 | 84 | 93 | 4 |
| 8 | 76 | 1.9 | 67 | 88 | 7 |
| 9 | 126 | 1.1 | 115 | 91 | 13 |
| 10 | 138 | 1.0 | 129 | 93 | 29 |
| 11 | 110 | 1.2 | 97 | 88 | 12 |
| 12 | 36 | 1.0 | 34 | 94 | 5 |
| 13 | 70 | 1.0 | 66 | 94 | 9 |
| 14 | 15 | 1.7 | 13 | 87 | 2 |
| 15 | 53 | 1.3 | 50 | 94 | 3 |
| 16 | 35 | 1.1 | 31 | 89 | 1 |
| 17 | 150 | 1.2 | 142 | 95 | 31 |
| 18 | 46 | 0.9 | 44 | 96 | 9 |
| 19 | 43 | 0.8 | 43 | 100 | 7 |
| 20 | 28 | 1.1 | 26 | 93 | 3 |
| 21 | 66 | 0.7 | 66 | 100 | 4 |
| 22 | 107 | 0.9 | 98 | 94 | 2 |
| 23 | 34 | 0.5 | 32 | 94 | 1 |
| 24 | 43 | 0.6 | 40 | 93 | 0 |
| 25 | 122 | 1.2 | 116 | 95 | 13 |
| 26 | 61 | 0.9 | 59 | 97 | 7 |
| 27 | 60 | 0.9 | 57 | 95 | 7 |
| 28 | 70 | 1.0 | 68 | 97 | 14 |
| 29 | 37 | 1.4 | 36 | 97 | 0 |
| 30 | 9 | 1.0 | 9 | - | 0 |
| 31 | 12 | 1.5 | 12 | 100 | 1 |
| 32 | 5 | 0.4 | 5 | - | 3 |
| **Totals** | **2455** | **1.1** | **2271** | **93** | **307** |

gory were as follows: category 1 - 1067 (47%); category 2 - 357 (16%); category 3 - 110 (5%); and category 4 - 737 (32%). Thus overall only 21% of the resurveyed 1-km squares had queries that required clarification, and the quality of data collection was high. All the new 1-km squares were surveyed by volunteers; the quality ratings for these were as follows: category 1 - 209 (68%); category 2 - 79 (26%); and category 3 - 19 (6%).

The following tests were undertaken to determine whether there were differences in the quality of data between these four quality categories and, in particular, whether the volunteer surveyors were collecting data comparable with those collected by Gavin Wilson. First, the mean main sett density for each of these four data quality categories were compared within each of the six land class groups for which sample sizes were adequate (i.e. excluding Upland VII), using Kruskal-Wallis tests; for five there was no difference in recorded main sett densities (Arable I, $X^2$=6.24, n.s.; Arable II, $X^2$=5.77, n.s.; Arable III, $X^2$=6.65, n.s.; Pastoral IV, $X^2$=3.66, n.s.; Pastoral V, $X^2$=4.17, n.s.). For Marginal upland VI, there was a significance difference ($X^2$=21.10, $p$<0.0001) because badger density was low, and most main setts occurred in the 1-km squares rated "1". Applying the same tests to all other sett types showed that there were no significant differences in three land class groups (Arable II, $X^2$=4.50, n.s.; Pastoral IV, $X^2$=7.36, n.s.; Pastoral V, $X^2$=7.38, n.s.). For

**Table 2.3.** The number of 1-km squares in each land class group included in the two badger surveys.

| Land class group | Number of squares surveyed in the 1980s | Percent of land class group surveyed | Number of squares re-surveyed in the 1990s | Percent resurveyed | Number of new squares surveyed in the 1990s |
|---|---|---|---|---|---|
| Arable I | 233 | 1.6 | 208 | 89 | 30 |
| Arable II | 548 | 1.1 | 493 | 90 | 76 |
| Arable III | 198 | 1.1 | 188 | 95 | 22 |
| Pastoral IV | 470 | 1.3 | 428 | 91 | 55 |
| Pastoral V | 356 | 1.0 | 333 | 94 | 49 |
| Marginal upland VI | 349 | 1.0 | 335 | 96 | 65 |
| Upland VII | 301 | 0.7 | 286 | 95 | 10 |
| **Totals** | **2455** | **1.1** | **2271** | **93** | **307** |

the other three, there were differences. In Arable I ($X^2$=9.52, $p$<0.05) this was due to fewer setts in the 1-km squares surveyed by Gavin Wilson, who had surveyed a significant number of squares from the Kent marshes and similar habitats where fewer setts would be expected. In Arable III ($X^2$=15.88, $p$<0.005), this was because the small number of 1-km squares rated "3" actually held a high number of setts. In Marginal upland VI ($X^2$=28.41, $p$<0.0001) this occurred because Gavin Wilson concentrated on surveying the more remote upland 1-km squares, which contained fewer setts. Thus, there were no consistent patterns to suggest that there were differences in the quality of the data within any of the four sub-samples of the data. Therefore, they were pooled for all further analyses.

## 2.5 Criteria used for interpreting sett changes

It was important that any sett changes between the two surveys were correctly identified, and so the surveyor carefully checked the original field data to ensure that they had been recorded correctly. It was possible, for instance, that setts were missed or the position of a sett was wrongly recorded. It was emphasized to volunteers to take as much care as possible when making these judgments, especially if they felt that a sett had been missed or if they felt that its status had been wrongly assessed. When making these judgments, they were asked where possible to consult with the relevant landowner, farmer, gamekeeper, shooting tenant or any other person who may know the local badger setts and who would be able to comment on the situation in the 1980s. Where surveyors felt that the original data had been recorded incorrectly, they were then asked to document fully on the recording form their reasons for coming to this decision, providing as much information as possible so that the rationale behind their conclusions could be checked later. These sheets were then carefully evaluated prior to accepting or rejecting the decision of the new surveyor. The following criteria were used in making these assessments:-

### *2.5.1 Changes to main setts*

On thirty occasions, surveyors considered that a main sett had been missed in the 1980s survey. They usually based this assessment on one or more of the following criteria:-

a. Their personal knowledge of the area extended back to 1980s.
b. The landowner, farmer or gamekeeper knew that the sett was present in the 1980s and from his/her description it appeared to have been a main sett at that time.
c. Evidence of the age of sett, such as a large number of holes, the size of the spoil heaps or the presence of old elder trees at the sett.
d. The difficulty/complexity of the habitat to survey. This occurred when a main sett was found in the 1990s survey in an inaccessible area, such as on a cliff face, or in impenetrable scrub, such that it may have been missed in the 1980s. One main sett had been missed in the 1980s survey because, at the time of the survey, the whole area was flooded, and the surveyor had assumed that there would be no sett under water.

Being sure that a main sett had been missed in the 1980s survey is never easy, and many of the above criteria are not an infallible guide. For instance, whilst a local farmer may know when a sett appeared, it does not mean that it has always been a main sett, and reports of setts from landowners and farmers often proved on inspection to be fox earths. So a fox earth could have been present and subsequently taken over by badgers between the two surveys. Since surveyors in the 1980s were not asked to record all fox or rabbit holes, it is not possible to know if the holes in question had been inspected on the 1980s survey but not been occupied by badgers. Also, studies on released badgers have shown that setts can be dug quickly, and within a few years they can appear to be large, active and of great age (Stephen Harris, unpublished data). Finally, finding a sett in an area of impenetrable scrub does not mean that the area was not surveyed in the 1980s and, in any case, surveyors would have recorded tracks and trails into the scrub, had it contained an active sett.

Thus, it has to be accepted that we cannot always be sure that a sett was missed. However, based on careful scrutiny of the data, we accepted that it was likely that thirty main setts had been missed in the 1980s survey. These were evenly distributed across the four quality ratings used in the 1980s survey. Of the 2271 1-km squares resurveyed, main setts were thought to have been missed in 11/767 (1.4%), 9/682 (1.3%), 4/202 (2.0%) and 6/620 (1.0%) 1-km squares for quality ratings 1, 2, 3 and 4 respectively. Hence, the setts that were judged likely to have been missed were evenly distributed across all the quality ratings.

For a further 12 cases (nine from quality rating 2, three from quality rating 4), surveyors thought it likely that a main sett had been missed in the 1980s survey, but could find no one locally who could confirm or refute this assessment, which was usually based on criteria (c) and (d). However, it was considered possible that these twelve setts had also been missed. Therefore, the original database was corrected to allow for these 42 main setts for which there was strong evidence, or for which it appeared likely, that they were missed during the 1980s survey, and all subsequent changes were measured against these corrected data.

In a very few cases where surveyors considered main setts to have been missed last time, this assessment was not accepted when the previous surveyor was known to be reliable and/or the sett was in an obvious position in terrain that was easy to survey. For these cases, the sett was classified as having been dug between the two surveys.

Where surveyors considered that a main sett had appeared since the 1980s survey, this was accepted by default. Many of these 1-km squares with new main setts were accompanied by reports of a perceived increase in local badger activity, particularly in the last four to five years, as well as substantiating field evidence such as increased levels of badger activity (footprints, paths or runs, or dung pits) and other types of sett in the same 1-km square.

### *2.5.2 Changes to annexe setts*

Where main setts were found in the original survey, it was unlikely that an associated annexe sett would be missed because, by definition, they are close to main setts and usually connected by a clear path. Therefore, where a main sett was recorded in the 1980s survey, any annexe setts that were not recorded then were assumed to have appeared in the intervening years. An annexe setts was considered to have been missed in the 1980s survey when:-

a. It was in association with a main sett which was thought to have been missed in the 1980s survey (n=3).
b. The landowner or some other person confirmed that the annexe sett was definitely present at the time of the 1980s survey. In practice, apart from those annexe setts which were associated with previously missed main setts, this only occurred near to the edge of 1-km squares when there was a main sett outside the 1-km square being surveyed (n=21).

Annexe setts were considered to be new when:-

a. The previous surveyor was known to be reliable and/or the sett was in an obvious position in terrain that was easy to survey. These were generally in association with new main setts; this occurred only rarely.
b. The annexe sett was found near a main sett recorded on the 1980s survey and for which there was no reason to suspect that the annexe sett had been missed.
c. The annexe sett was found in association with a new main sett which was either inside or just outside the 1-km square.

### *2.5.3 Changes to subsidiary and outlying setts*

Subsidiary setts usually consist of only a few holes; mean size in the 1980s was 4.3±0.1 holes, and outlying setts usually consist of only one or two holes; mean size in the 1980s was 1.8±0.1 holes (Cresswell, Harris & Jefferies, 1990). Furthermore, neither type of sett is in continuous use, and so deciding whether such setts had been missed in the 1980s survey was not easy. Therefore, only 20 subsidiary setts and 36 outlying setts were classed as missed when a landowner or some other person confirmed that a sett had been present since before the time of the last survey. All other subsidiary and outlying setts recorded for the first time in the second survey were considered to be new. As these smaller types of sett can be overlooked more easily, especially if they were not in use at the time of the 1980s survey, there is a potential but unavoidable bias that a few were wrongly classified as new in the second survey. However, the number will be small and it will have no effect on the overall conclusions.

### *2.5.4 Changes in sett status*

Surveyors were asked to determine whether there had been a change in the status of a sett between the two surveys. This assessment was based on a significant increase or decrease in activity, and whether the sett now appeared to be in one of the other sett categories. The surveyors were asked to provide as much information as possible to enable us to assess the validity of their conclusions. In practise, most of the changes were clear-cut, with setts showing a marked decrease or increase in size and/or activity, leading to a straightforward re-categorisation. In those cases where surveyors noted a slight difference in size and/or activity of a sett but were unsure if it should be placed in a new category, the sett was entered into the database with no change in category.

### *2.5.5 Setts that had disappeared*

Whilst surveyors were asked to determine why setts disappeared between the two surveys, in practise this proved to be difficult to ascertain except where there had been an obvious change in land use e.g. a hedgerow had been removed, or the land developed. Often, however, the factors leading to the loss of a sett could not be determined with certainly; these setts were, therefore, simply classified as "lost".

## 2.6 Extracting the data from the field sheets

After the data had been checked and verified, the location of each sett was assigned to one of the following habitat types from the land-use map: hedgerows, treelines, semi-natural broadleaved woodland, broadleaved plantations, semi-natural coniferous woodland, coniferous plantations, semi-natural mixed woodland, mixed plantations, young plantations, parkland, tall scrub, low scrub, bracken, coastal sand-dunes, lowland heaths, heather moorlands, upland unimproved grassland, semi-improved grassland, improved grassland, arable, amenity grassland, unquarried inland cliffs, quarries and open-cast mines, and built land. In addition to these categories, which correspond to the habitat categories marked on the land-use map, the following habitat types were also recognised for sett locations: woodland edge, river banks, railway embankments, roadside verges, dry ditches and man-made embankments, and others.

Badger activity data were extracted as follows. For each of footprints, paths or runs, and dung pits, the number of the nine sub-squares within each 1-km square that were positive was recorded separately, thus giving a scale of 0 to 9 for each of the three activity measures. Hole blocking, snaring and digging were each scored on a scale of 0 to 3. For hole blocking, "1" denoted only one or two holes blocked, "2" denoted several holes loosely blocked or fewer severely blocked with items such as logs that the badgers would have difficulty in removing, and "3" denoted many holes blocked, often with immovable objects. Snaring was rarely recorded, and then only on the first point of the scale, to indicate some evidence of snaring around the sett; more extensive snaring around setts was not observed, and surveyors were not asked to record snaring away from the sett area. For digging, "1" denoted some evidence of a past attempt at digging into the sett, "2" was a more recent relatively small dig at the sett or a more serious attempt some time ago, and "3" denoted a serious attempt in which several holes had been dug, usually recently. These classifications were based on the field notes supplied by the surveyor (see Appendices 10.1 and 10.2). If the information supplied was not clear, the surveyor was contacted to ensure that his/her field notes had been interpreted correctly. In practice, the number of setts suffering direct interference, other than hole blocking, proved to be low, and so for digging and

**Table 2.4.** Comparison by land class group of the number of main setts in the 1990s in resurveyed and new 1-km squares. The figures are means ±s.e.

| Land class group | Number of squares resurveyed | Number of new squares | Mean number of main setts in resurveyed squares | Mean number of main setts in new squares | Signif-icance |
|---|---|---|---|---|---|
| Arable I | 208 | 30 | 0.45±0.12 | 0.73±0.14 | $p<0.05$ |
| Arable II | 493 | 76 | 0.24±0.06 | 0.18±0.05 | n.s. |
| Arable III | 188 | 22 | 0.10±0.07 | 0.18±0.11 | n.s. |
| Pastoral IV | 428 | 55 | 0.49±0.10 | 0.51±0.11 | n.s. |
| Pastoral V | 333 | 49 | 0.25±0.08 | 0.22±0.07 | n.s. |
| Marginal upland VI | 335 | 65 | 0.14±0.05 | 0.19±0.05 | n.s. |
| Upland VII | 286 | 10 | 0.02±0.04 | 0.50±0.31 | - |
| **Totals** | **2271** | **307** | **0.25±0.03** | **0.31±0.03** | **n.s.** |

snaring these classifications were not subsequently used in the analyses, which were based just on the presence or absence of each type of interference.

The habitat data were measured to the nearest 0.5 hectares, or the nearest 50 metres for linear features, using a pen tracer and bit pad. In addition to the 40 habitat types listed on the field sheet (Appendix 10.3), two additional habitat types were measured, as had been done in the 1980s surveys. Habitat 41 was sea, which was the area of each 1-km square below the mean low water mark, and habitat 42 was canals, which were separated from canalised ditches (habitat 28) and were recorded as an area and not a linear measure.

Finally, for each 1-km square, the square number, the Ordnance Survey national grid coordinates, the county code and the land class code from the Institute of Terrestrial Ecology's land classification system were recorded, and all the data for each 1-km square were entered in fixed format onto the University of Bristol mainframe computer; 249 columns of data were entered for each 1-km square. The data were then checked manually and by a variety of data checking programmes. In addition, the badger sett changes were entered into a *Microsoft Excel* spreadsheet for each of the 2271 1-km squares.

## 2.7 Were there any differences between resurveyed and new 1-km squares?

One potential problem with re-surveying the same 1-km squares at regular intervals is that with each survey the quality of the data improve. If this is a problem, it would be reflected in improved reliability of the sett classifications and/or an increase in the number of setts recorded, especially the smaller more-easily missed types of sett. Improved data quality could be a particular problem for subsidiary and outlying setts, which may be disused for long periods. Small disused setts may be missed in a one-off survey, but if their locality had been recorded in an earlier survey, particular effort will be made to relocate the sett in subsequent surveys. Thus, in theory at least, an increase in the quality of the data could lead to an increase in the number of setts recorded in a 1-km square even though there had been no real change. This would then bias the results of any analyses of change.

An additional potential problem with monitoring programmes is that repeated visits to the same 1-km square might lead the farmer or landowner to behave in a way other than might otherwise have been the case, since he/she was aware that his/her activities were being recorded. If this occurred, it would lead to a different trend in the monitored 1-km squares when compared to the rest of Britain.

To check whether either of these problems had occurred, Mann-Whitney tests were used to compare mean numbers of both main setts, and all other sett types combined, in the 1990s by land class group for the 2271 resurveyed 1-km squares with those in the 307 new 1-km squares (Tables 2.4 and 2.5). Nationally, there were no differences in either the densities of main or other setts. Main sett densities were higher in both Arable I and Upland VII for new as opposed to resurveyed 1-km squares, but this was almost certainly an artifact of the small number of new 1-km squares in each of

**Table 2.5.** Comparison by land class group of the number of other setts (i.e. annexe, subsidiary, outlying and disused main setts combined) in the 1990s in resurveyed and new 1-km squares. The figures are means ±s.e.

| Land class group | Number of squares resurveyed | Number of new squares | Mean number of other setts in resurveyed squares | Mean number of other setts in new squares | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 30 | 2.21±0.77 | 2.60±0.86 | n.s. |
| Arable II | 493 | 76 | 0.74±0.22 | 0.28±0.08 | $p<0.05$ |
| Arable III | 188 | 22 | 0.22±0.21 | 0.90±0.66 | n.s. |
| Pastoral IV | 428 | 55 | 1.94±0.54 | 1.93±0.45 | n.s. |
| Pastoral V | 333 | 49 | 0.88±0.31 | 0.63±0.18 | n.s. |
| Marginal upland VI | 335 | 65 | 0.62±0.23 | 0.63±0.18 | n.s. |
| Upland VII | 286 | 10 | 0.10±0.24 | 1.30±0.94 | - |
| **Totals** | **2271** | **307** | **0.98±0.15** | **1.01±0.14** | **n.s.** |

these land class groups. For other sett types, densities were significantly lower in new 1-km squares in Arable II. Whereas the reverse pattern was seen in Upland VII, the number of setts was too small for statistical analysis; there were no significant differences for any of the other land class groups. Since there was no evidence that sett densities were higher in 1-km squares surveyed twice compared to those only surveyed once, we concuded that the original data were reliable. Hence, the changes recorded during this survey were real rather than artifacts of poor quality data collection during the original survey. This result also confirms that the results were not biased by sending surveyors a copy of the original badger data.

## 2.8 Statistical procedures

The majority of the data used in these analyses were collected by volunteers with no scientific training, and so this report is designed to be read by non-specialists. This section therefore is designed to help them understand the statistics presented in this report.

There were bound to be some differences between the two badger surveys. Some changes in our sample of squares may have occurred by chance, or be too small to indicate a real change overall. It is important, therefore, to know which of the changes we observed were large enough to be statistically significant and thus indicate real change in the British badger population. Hence the use of statistics.

The rationale behind statistics is simple; they never say that something definitely has, or has not, occurred, but they do give a probability that something is a real change. When we are less than 95% confident that there has been real change, we treat the result as one that has probably occurred by chance, and such differences are indicated in the report as not being significant (n.s.). This occurs when the changes are very small, or when larger changes occur but with small sample sizes. For the badger survey, the latter was a particular problem in low density areas such as East Anglia. When a change is statistically significant, probability values are given as $p<0.05$, $p<0.01$, $p<0.001$ or $p<0.0001$. This means, respectively, that we are at least 95%, 99%, 99.9% or 99.99% confident that the changes observed represent real change.

As well as a probability value, where appropriate we have also given the value of the statistical test that was used. Several different statistical tests are used in this report, depending on the type of analysis and the nature of the data. Where data were heavily biased toward zero, as was the case for most of the data on badger setts, we used non-parametric statistical methods. For example, the *Wilcoxon matched pairs test* was used to analyse the changes in badger sett numbers between the 1980s and 1990s. These changes are also given as percents when the number of setts recorded in both surveys exceeded ten, or when the number of setts in one survey was large and there had been a substantial change. The *Mann-Whitney test* is similar to the Wilcoxon matched pairs test, but is used to examine differences between samples that are not paired.

We used this test when looking for differences between new and re-surveyed 1-km squares. *T-tests* are used to determine if two samples are statistically different from one aother. This test can only be used on data that are not heavily skewed towards zero but which are evenly spread around the mean.

The *Kruskal-Wallis* test is used to compare three or more groups of samples. For instance, we used it to see if there were any differences in the numbers of setts recorded in squares assigned different quality ratings. *Correlations* and *rank correlations* are used to measure association between two variables. If two variables are positively correlated, then as one rises or falls, so does the other. If they are negatively correlated, as one rises or falls the other does the opposite. The test statistic is given as "$r$", and the closer this is to 1, the stronger the correlation. For example, we used rank correlations to examine the relationship between changes in the number of active main setts and disused main setts between the two surveys. *Regressions* were used to look for a causal relationship between two variables. Unlike correlations, this test determines if a change in one variable directly causes change in another. The test statistic is "$R^2$", and the closer this is to 1, the more that the change in one variable depends on the other. For example, this test was used to examine the relationships between hunting intensity and the levels of hole blocking. Finally, *discriminant function analysis* is explained in detail in Chapter 6, where it was used to analyse patterns of habitat selection by badgers.

In addition to the statistical tests, a number of other terms are used. The *sample size*, given as "n=", is generally the number of 1-km squares used in the analysis. In this survey, 2271 1-km squares were surveyed. We want to know how representative the data collected in this sample are of the whole of Britain; to do this we need to know how much the real badger population could differ in size from the population estimate calculated from our sample. So we have calculated the *95% confidence intervals.* These are shown as the estimate ± the confidence interval. For example, in the 1980s Cresswell, Harris & Jefferies (1990) estimated that there were 42,891±3851 badger social groups in Britain. This means that whilst they estimated that there were 42,891 social groups, they were 95% certain that the true figure lay between 39,040 and 46,742. The *standard error*, given as±s.e., is a measure of the accuracy of a sample mean (the average) in relation to the population mean. The smaller the standard error, the more accurate is the mean, and the standard error declines as the sample size gets larger. Thus, we give the mean sett densities and their standard errors for each of the land class groups or regions. The *standard deviation*, given as ±s.d., is a measure of the variability of the sample, and the greater the variability, the higher the standard deviation. We use standard deviations in the modelling study in Chapter 7 to show the normal range within which the results will fall.

All the statistical analyses were done on *SPSS* (release 4.0), running on Bristol University's Unix mainframe computer.

## 2.9 Presentation and interpretation of the results

Whilst there have been a number of changes to the land classification system and an improved understanding of badger biology, there have been no changes that call into question the basic survey approach or necessitated any changes to the survey protocol. We, therefore, used the same approach as for the 1980s survey, thereby facilitating a direct comparison of the badger population in the two surveys. The statistical rationale behind a monitoring exercise such as this is discussed in Appendix 10.6.

When presenting the results, the percentage change is shown for each land class group or region, and the overall percentage change for the sample of 1-km squares that were surveyed. However, it must be remembered that this latter figure is not the actual percentage change for Britain as a whole, since slightly different proportions of each land class group or region have been surveyed. Thus, where necessary, the percent change nationally is also given. This takes account of the area of each land class, and hence its relative contribution to the overall change.

The aim of the survey was to monitor national, rather than local, changes in badger numbers. Very local patterns of change in the number of badger social groups could not be monitored accurately with a national scheme such as this, and so it is essential that local Badger Groups and others continue to monitor the badger setts within their area to quantify local patterns of change. However, it is important that a national survey such as this can detect badger population changes equally reliably in areas of both high and low population density. Monitoring changes in high density areas which hold a large proportion of the national badger population may be of particular importance, since this is where changes will have the biggest overall impact on the national badger population. Yet monitoring the badger population recovery in areas such as East Anglia, where badgers were largely exterminated by the activities of gamekeepers last century (Harris, 1993), is of greater significance from a biodiversity perspective Of the four objectives for conserving biodiversity listed in the report of the UK Biodiversity Steering Group, the first highlighted the need to conserve and enhance the natural ranges of native species (Anon., 1995b).

Thus, it is important that this monitoring scheme is able to detect changes at all population densities. However, because the distribution of badger setts is clumped, with most 1-km squares containing no main setts, population changes within each land class group or each region, in terms of the number of social groups, need to be substantial in areas of very low population density before they can be statistically significant (see Appendix 10.6). As we will show later in this report, the changes that have occurred in the number of main setts nationally, and in some land class groups and regions, are large enough to be statistically significant. These changes are discussed in Chapter 3. For those land class groups and regions where the change is not statistically significant because of the variability within the data, the survey results still demonstrate real changes in a random sample of the 1-km squares within that land class group or region. Whilst it is likely that the data indicate that there has been a real change overall in that land class group or region, they must be interpreted with caution, particularly where badger densities are low and relatively few 1-km squares contain a main sett.

Because of the problems with interpreting changes in low density areas, we have used a variety of other measures of change to help interpret the data on the number of social groups. These include changes in the number of annexe, subsidiary, outlying and disused main setts (section 3.4), the size of setts (the number of holes) and activity at setts (the number of active holes) (section 3.7), and the levels of badger activity (various field signs) away from setts (Chapter 4). We then compare these different measures of badger activity; where they all indicate changes in the same direction and of the same order of magnitude, these measures are used to reinforce the argument that the changes in the number of social groups in low density areas which are not statistically significant, are still likely to represent real change overall.

The two surveys were undertaken over very similar time periods; the first ran from November 1985 until early 1988, the second from October 1994 to January 1997. Thus, for each the majority of the field data were collected in the first two winters, with any gaps in the coverage filled in the early part of the third winter. Whilst this is a short period of time for an extensive survey such as this, it is not an instantaneous measure of the status of the British badger population. However, completing a large-scale survey in a shorter period of time is, from a practical perspective, impossible. Nor, for logistical reasons, was it possible to ensure that all the squares were resurveyed after exactly the same time period, and so for the great majority of 1-km squares the time between the two surveys was between seven and eleven years. Since the timing of the two visits to any one square were completely independent of any other variable, the time between the two surveys will not cause any bias in the analyses. For ease of presentation in the report, we treat these samples as if they were exactly nine years apart, and the results are presented as a measure of change for the nine-year period between the ends of the two surveys, i.e. 1988 to 1997.

For clarity, only the key results are presented in the text. All the additional tables documenting changes in the number of setts other than main setts are presented in Appendix 10.7, changes in the size of all setts in Appendix 10.8, and changes in persecution levels at setts other than main setts in Appendix 10.9.

# 3. Badger population changes, 1988 to 1997: sett changes

## 3.1 Introduction

In this Chapter we look at the pattern of sett changes in the British badger population. In particular, we examine the changes in the number and distribution of main setts, use this as a measure of the change in the total number of badger social groups, and examine factors leading to the loss of main setts. We then discuss the changes in the number and distribution of other sett types, the pattern of change between different categories of sett and, finally, changes in sett size. For these analyses, we use the data from the 2271 1-km squares surveyed in the 1980s and the 1990s to compare change, and we measure change against the corrected data for the 1980s i.e. we have allowed for the setts that we considered had been missed in the 1980s survey (see section 2.4).

## 3.2 Changes in main sett numbers

The changes in the number of main setts recorded in our sample squares are shown in Tables 3.1 and 3.2. Whilst overall there has been an increase of 22%, the pattern of change has been very variable (see Figures 3.1 to 3.3). A Wilcoxon matched pairs test showed that of the seven land class groups, the mean number of main setts $km^{-2}$ (i.e. population density in terms of social groups) did not change significantly for Arable I, Arable III, Marginal upland VI and Upland VII ($z=-0.34$, n.s.; $z=-0.24$, n.s.; $z=-1.83$, n.s.; $z=-1.60$, n.s.; respectively), whereas Arable II, Pastoral IV and Pastoral V all showed significant increases ($z=-2.89$, $p<0.01$; $z=-3.11$, $p<0.05$; $z=-2.92$, $p<0.01$). Six regions (North England, North-west England, East Midlands, Southern England, South Scotland and South Wales) have shown only small changes that were not significant. The greatest increase has been in the West Midlands, where there was a 86% increase in the number of badger social groups, and there was an above-average increase in South-west England (23%). There have also been large but non-significant rises in the number of badger social groups in North-east England (24%) and Mid and north Wales (35%), and in East Anglia, where there was a rise from 9 to 14 main setts in the 161 1-km squares surveyed. Whilst sample sizes were too small for statistical analysis, this rise is in close agreement with that recorded in Norfolk by Vine (1993) and in Suffolk by Margaret Grimwade (*pers. comm.*). Thus, this monitoring exercise has detected population changes even in very low density areas; we discuss the ability of a survey such as this to monitor small badger population changes in more detail in Appendix 10.6.

The changes in badger density, in terms of

**Table 3.1.** The change in the number of badger social groups, 1988-1997, by land class group.

| Land class group | Number of squares | Number of main setts in the 1980s | Number of main setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 95 | 94 | -1 | n.s. |
| Arable II | 493 | 93 | 119 | 28 | $p<0.01$ |
| Arable III | 188 | 18 | 17 | -6 | n.s. |
| Pastoral IV | 428 | 173 | 211 | 22 | $p<0.01$ |
| Pastoral V | 333 | 58 | 84 | 45 | $p<0.01$ |
| Marginal upland VI | 335 | 32 | 46 | 44 | n.s. |
| Upland VII | 286 | 2 | 5 | - | n.s. |
| **Totals** | **2271** | **471** | **576** | **22** | $\mathbf{p<0.0001}$ |

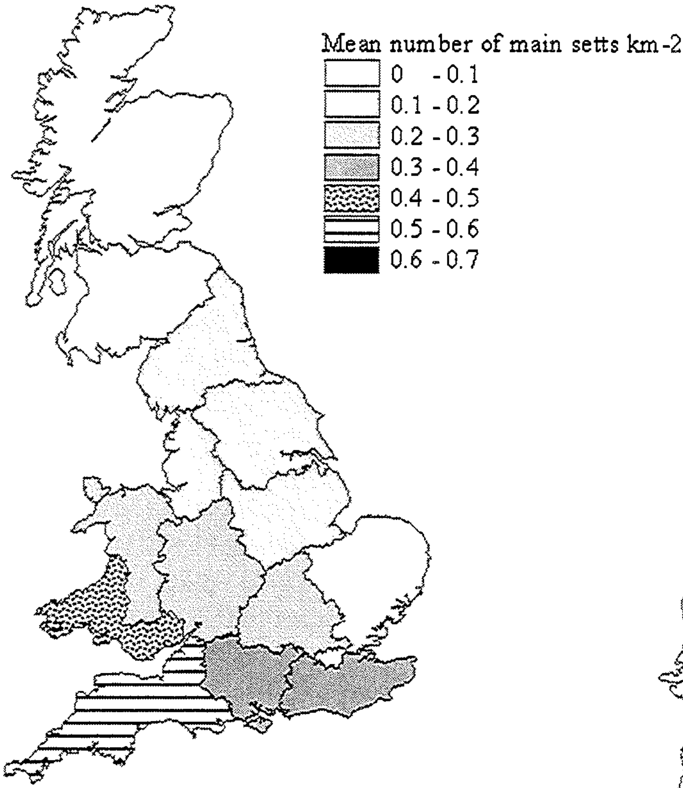



***Figure 3.1.*** *Regional variation in the mean number of main setts km$^{-2}$ in the surveyed squares in the 1980s*

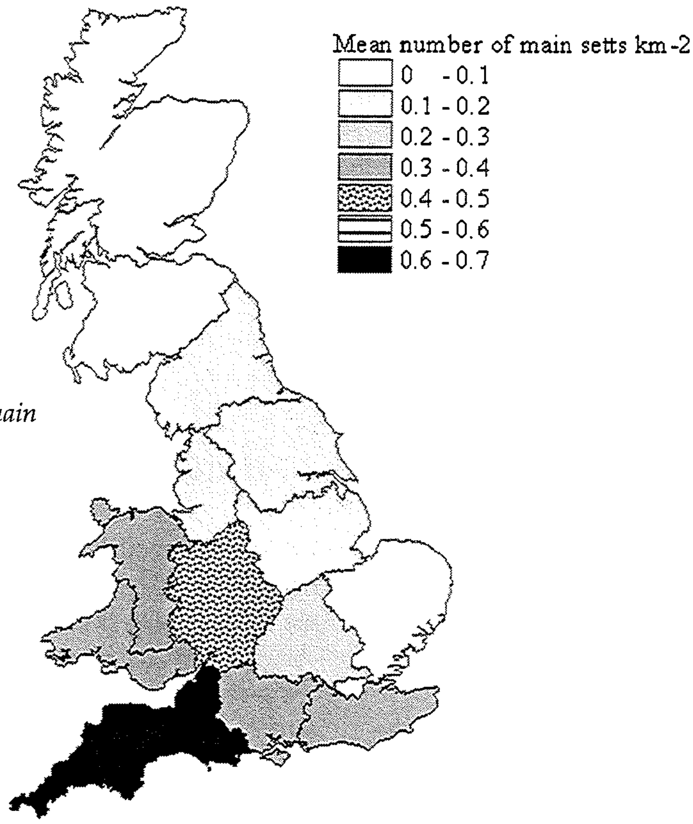



***Figure 3.2.*** *Regional variation in the mean number of main setts km$^{-2}$ in the surveyed squares in the 1990s*

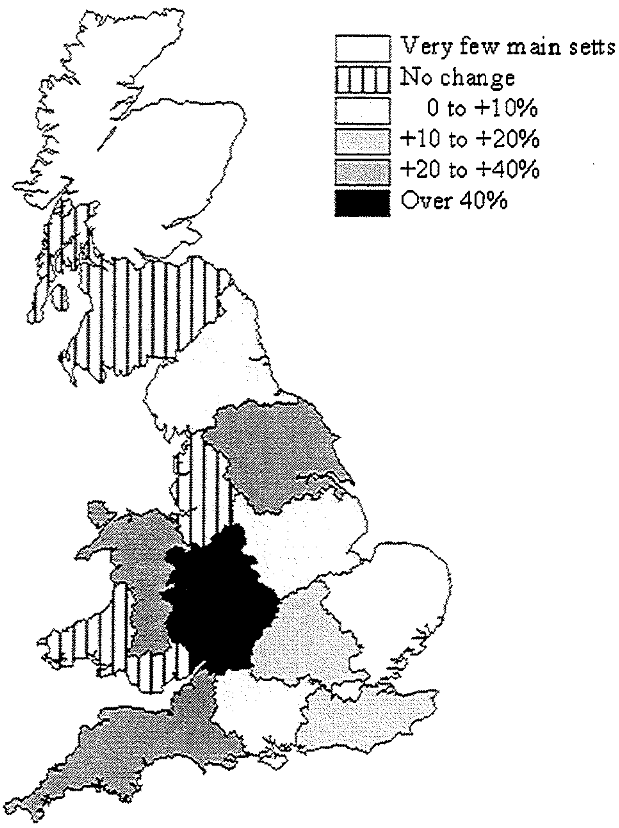



***Figure 3.3.*** *Pattern of change in the mean number of main setts km$^{-2}$ in the surveyed squares between the two surveys. No pattern of change has been ascribed to regions with very*

**Table 3.2.** Regional differences in the change in the number of badger social groups, 1988-1997.

| Region | Number of squares | Number of main setts in the 1980s | Number of main setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| North England | 170 | 18 | 19 | 6 | n.s. |
| North-west England | 72 | 13 | 12 | -8 | n.s. |
| North-east England | 121 | 17 | 21 | 24 | n.s. |
| West Midlands | 177 | 44 | 82 | 86 | $p<0.001$ |
| East Midlands | 153 | 28 | 29 | 4 | n.s. |
| Central England | 91 | 22 | 26 | 18 | n.s. |
| East Anglia | 161 | 9 | 14 | - | - |
| South-west England | 205 | 116 | 143 | 23 | $p<0.01$ |
| Southern England | 131 | 46 | 49 | 7 | n.s. |
| South-east England | 159 | 54 | 62 | 15 | n.s. |
| North Scotland | 366 | 8 | 12 | - | - |
| South Scotland | 208 | 15 | 15 | 0 | n.s. |
| Mid and north Wales | 143 | 34 | 46 | 35 | n.s. |
| South Wales | 114 | 47 | 46 | -2 | n.s. |
| **Totals** | **2271** | **471** | **576** | **22** | $\mathbf{p<0.0001}$ |

social groups km$^{-2}$, are shown in Figure 3.4. There were significant differences in the badger densities across all land class groups (Kruskal-Wallis tests; for the 1980s, $X^2$=78.5, $p<0.0001$; for the 1990s, $X^2$= 103.2, $p<0.0001$). Using the mean number of main setts km$^{-2}$, there have also been changes in the rank order of the land class groups, but those land class groups that had similar population densities in the 1980s have remained unchanged (Figure 3.5). Using Spearman rank correlations to examine the pattern of change by land class groups, there was no relationship between main sett density in the 1980s and the percentage change in the number of main setts

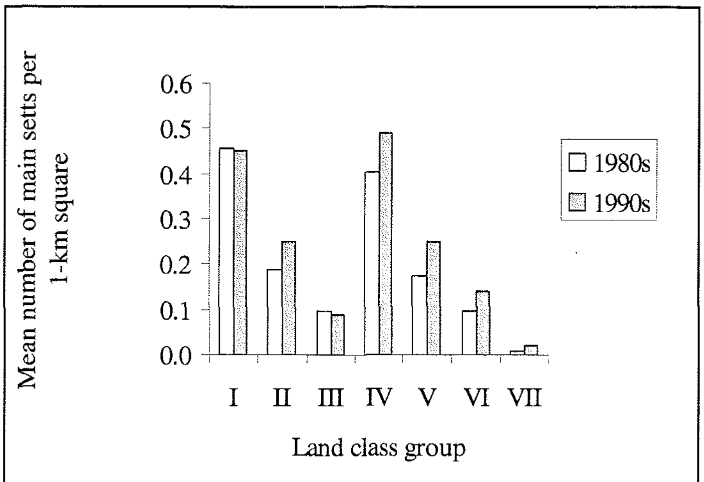



*Figure 3.4. Changes in the mean number of main setts km$^{-2}$ by land class groups between the two surveys*

($r_s$=0.23, n.s.), the difference in the number of active and disused main setts in the two surveys ($r_s$=0.77, n.s.), the difference in main sett numbers in the two surveys and the total activity score (see section 4.2) in the 1980s ($r_s$=-0.26, n.s.), the difference in main sett numbers in the two surveys and the total activity score in the 1990s ($r_s$=-0.03, n.s.), or the difference in main sett numbers in the two surveys and the difference in the total activity score in the two surveys ($r_s$=0.96, n.s.). Thus, the increases in the number of social groups were not related to the density of badger social groups present in the 1980s nor the total number of badgers (based on the measures of activity). Nor were the changes simply because disused main setts had been reoccupied.

## 3.3 Losses of main setts

Whilst there has overall been an increase in the number of main setts, there have also been substantial losses. Of the 471 main setts recorded in the 1980s, 136 (29%) had been "lost". The overall increase occurred because 241 new main setts had been established (Table 3.3). The losses of main setts since the 1980s occurred across all land classes, with all showing a quarter to a third of all main setts lost (Table 3.4). For 40 of these (8%), the sett had completely disappeared, and no sign was left to indicate that a main sett had been present on the site. A further 63 (13%) had changed status; 22 had

**1980s**

| Land class group | Kruskal-Wallis mean rank | Significance |
|---|---|---|
| Arable I | 1351 | n.s. |
| Pastoral IV | 1290 | |
| | | $p<0.0001$ |
| Arable II | 1132 | n.s. |
| Pastoral V | 1118 | |
| | | $p<0.05$ |
| Arable III | 1047 | n.s. |
| Marginal upland VI | 1037 | |
| | | $p<0.0001$ |
| Upland VII | 951 | |

**1990s**

| Land class group | Kruskal-Wallis mean rank | Significance |
|---|---|---|
| Pastoral IV | 1331 | n.s. |
| Arable I | 1319 | |
| | | $p<0.0001$ |
| Pastoral V | 1145 | n.s. |
| Arable II | 1135 | |
| | | $p<0.0001$ |
| Marginal upland VI | 1022 | n.s. |
| Arable III | 992 | |
| | | $p<0.0001$ |
| Upland VII | 921 | |

***Figure 3.5.*** *Comparison of the rank order of the land class groups, based on mean number of main setts km$^{-2}$. The breaks denote those land class groups where the badger population densities are significantly different*

become disused main setts, 11 annexe setts, 23 subsidiary setts, and seven only had one or two active holes and appeared to be serving as outlying setts. The remaining 33 main setts had gone, but for these the factor leading to their loss could be determined; the main causes were land use changes (Table 3.5).

The loss of 29% of all main setts in nine years was particularly surprising, especially when it has been argued that main setts are a valuable resource that are not easily replaced (Doncaster & Woodroffe, 1993; Roper, 1993). It is probable that many of these losses were the result of interference or persecution. Of the main setts recorded in the 1980s, 25 (5%) had been lost as a consequence of land use changes. How many of these were destroyed illegally, and how many legally i.e. a licence had been issued under the Protection of Badgers Act 1992, was not known. In some cases the loss of the main sett may have been accidental e.g. some main setts were covered by fallen trees in the gale of 16 October 1987, and subsequently destroyed by the heavy machinery that cleared the fallen trees (Stephen Harris, unpublished data). This may have contributed to the loss of the seven main setts where the causal factor was identified as being woodland loss (Table 3.5). For the 8% of main

**Table 3.3.** Losses and gains in the number of main setts, 1988-1997, within each land class group.

| Land class group | Number of main setts in the 1980s | Number of main setts "lost" | Number of main setts in the 1990s | Number of new main setts | Percent change overall | Significance |
|---|---|---|---|---|---|---|
| Arable I | 95 | 35 | 94 | 33 | -1 | n.s. |
| Arable II | 93 | 22 | 119 | 48 | 28 | $p<0.01$ |
| Arable III | 18 | 5 | 17 | 5 | -6 | n.s. |
| Pastoral IV | 173 | 45 | 211 | 83 | 22 | $p<0.01$ |
| Pastoral V | 58 | 17 | 84 | 43 | 45 | $p<0.01$ |
| Marginal upland VI | 32 | 12 | 46 | 26 | 44 | n.s. |
| Upland VII | 2 | 0 | 5 | 3 | - | n.s. |
| **Totals** | **471** | **136** | **576** | **241** | **22** | $\mathbf{p<0.0001}$ |

**Table 3.4.** Factors leading to the disappearance of main setts recorded in the 1980s, by land class groups.

| Land class group | Number of main setts in the 1980s | Number (percent) not found | Number (percent) reduced in status | Number (percent) lost for known reason | **Total number (percent) of main setts "lost"** |
|---|---|---|---|---|---|
| Arable I | 95 | 7 (7) | 17 (18) | 11 (12) | **35 (37)** |
| Arable II | 93 | 7 (8) | 10 (11) | 5 (5) | **22 (24)** |
| Arable III | 18 | 2 (11) | 2 (11) | 1 (6) | **5 (28)** |
| Pastoral IV | 173 | 14 (8) | 20 (12) | 11 (6) | **45 (26)** |
| Pastoral V | 58 | 9 (16) | 5 (9) | 3 (5) | **17 (29)** |
| Marginal upland VI | 32 | 1 (3) | 9 (28) | 2 (6) | **12 (37)** |
| Upland VII | 2 | 0 | 0 | 0 | **0** |
| **Totals** | **471** | **40 (8)** | **63 (13)** | **33 (7)** | **136 (29)** |

setts which could no longer be found, there was no obvious reason for the sett to have gone because there was no change in land use between the two surveys. Also, since there was no sign to indicate that a main sett had been present on the site, these main setts must have been destroyed rather than just fallen into disuse. From our sample, we estimated that, in Britain as a whole, between the two surveys 3468 active main setts had disappeared in this way. Finally, for the 13% of main setts that were reduced in status, a number had fallen into disuse, or showed very low levels of badger activity. This could also be an indication of interference or disturbance (Aaris-Sørensen, 1987), especially when a new main sett had been established nearby in the same 1-km square. Thus, we argue that the majority of the 29% of main setts losses were due to persecution or interference.

To determine if there was anything unusual about the main setts that were lost, 1-km squares with a single main sett were examined. We confined the analyses to squares with only one main sett to eliminate any confounding influences from the presence of other main setts nearby. The sample was divided into three groups: those that contained a single main sett in the 1980s but which had no main sett in the 1990s; those with a single main sett in both the 1980s and the 1990s; and those with a single main sett in the 1990s but no main sett in the 1980s (Table 3.6). For these three categories, the size of the main sett (all holes combined), the level of badger activity in the 1-km square, measured as the total activity score (see section 4.2), and the number of annexe setts per main sett, were compared. These measures were chosen because field signs provide a measure of badger numbers (see Chapter

**Table 3.5.** Known reasons for the loss of main setts in each land class group.

| Land class group | Building, development and/or road construction | Digging and/or disturbance | Loss of hedgerow and/or treeline | Loss of woodland | Loss of pasture | **Totals** |
|---|---|---|---|---|---|---|
| Arable I | 1 | 1 | 3 | 4 | 2 | **11** |
| Arable II | 3 | 1 | - | - | 1 | **5** |
| Arable III | - | 1 | - | - | - | **1** |
| Pastoral IV | - | 5 | 2 | 2 | 2 | **11** |
| Pastoral V | 3 | - | - | - | - | **3** |
| Marginal upland VI | - | - | - | 1 | 1 | **2** |
| Upland VII | - | - | - | - | - | **0** |
| **Totals** | 7 | **8** | 5 | 7 | 6 | **33** |

**Table 3.6.** Comparison of the main setts that persisted between the two surveys (no change), those that were only present in the 1980s (lost), and main setts that were first recorded in the 1990s (new). For the main setts present in both surveys, data are given for the 1980s and the 1990s. The analysis is confined to those 1-km squares that contained a single main sett. The figures are means ±s.e.

| | Number of 1-km squares | Number of holes per main sett | Total activity score | Number of annexe setts per main sett |
|---|---|---|---|---|
| Lost main setts | 67 | 9.4±0.7 | 5.7±0.6 | 0.30±0.1 |
| No change - in the 1980s | 181 | 13.2±0.8 | 5.9±0.4 | 0.34±0.1 |
| No change - in the 1990s | 181 | 15.4±0.8 | 8.3±0.4 | 0.68±0.1 |
| New main setts | 158 | 12.0±0.6 | 8.5±0.4 | 0.46±0.1 |

4), and the number of annexe setts is a measure of productivity (Cresswell *et al.*, 1992).

We then compared main setts which had persisted from the 1980s to the 1990s with new main setts first recorded in the 1990s. The new setts were significantly smaller ($z$=-3.31, $p$=0.001), they had significantly fewer annexe setts ($z$=-2.17, $p$<0.05), but there was no difference in total activity scores ($z$=-0.49, n.s.). Thus, even though there are comparable levels of badger activity as recorded by field signs, new main setts are smaller. When comparing the main setts recorded in the 1980s that had gone by the 1990s, with those present in both surveys, there was no significant difference in the total activity scores ($z$=-0.002, n.s.) or the number of annexe setts ($z$=-0.30, n.s.), but the main setts that were lost were significantly smaller ($z$=-2.60, $p$<0.01). Thus, it would appear that badger numbers were comparable in both samples, but that the setts that were lost, being smaller, were newer setts. Hence, it would appear that main setts losses were predominantly from areas where the badgers were recent colonists.

At Woodchester Park and Wytham Woods, Oxfordshire, the badgers have been studied continuously for over two decades. At both sites the badgers are also well protected. In neither locality has there been a high rate of replacement of main setts, which also suggests that the high rate of main sett loss reported in this study is not a natural process. Of the possible anthropogenic factors, the loss of so many setts across all land class groups suggests that the pattern of loss is not attributable to development pressure or farming activities, since the intensity of these pressures would vary with landscape type.

It would appear, therefore, that a high rate of main sett loss occurs in areas where the badgers are not well protected and monitored and where they are recent arrivals. Furthermore, there is no obvious cause for the loss of most of these setts. The most likely explanation for this pattern of events is that this is a feature of persecution in areas where the badgers are not allowed to become well-established. The main factors leading to the loss of so many main setts are deliberate or accidental sett destruction, or the loss of the badgers, such as by accidental or deliberate snaring or shooting at night. If the latter, the setts that could not be relocated must have then been destroyed. Persecution pressure on badgers is discussed further in Chapter 5.

## 3.4 Changes in the number of other types of sett

The pattern of change in other types of sett is summarised in Appendix 10.7 and Figure 3.6. The most substantial increase was for annexe setts, which in the surveyed squares increased by 82%; subsidiary and outlying setts increased by 53% and 51% respectively. The number of disused main setts declined by 42%. In the 1980s, the average number of setts per social group was 4.10 (one main, 0.24 disused main, 0.43 annexe, 0.86 subsidiary and 1.57 outlying setts). By the 1990s, this had risen to 4.96 (one main, 0.11 disused main, 0.69 annexe, 1.14 subsidiary and 2.02 outlying setts).

The increase in the number of annexe setts was of particular importance. Cresswell *et al.* (1992) showed that annexe setts serve as additional breed-

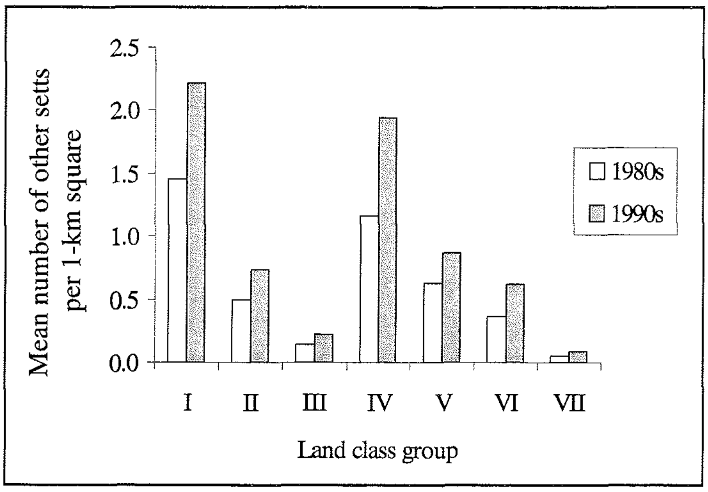



*Figure 3.6. Changes in the density of annexe, subsidiary and outlying setts combined by land class groups between the two surveys; the figures are the mean number of main setts km$^{-2}$. The pattern of change should be compared with that for main setts (Figure 3.4)*

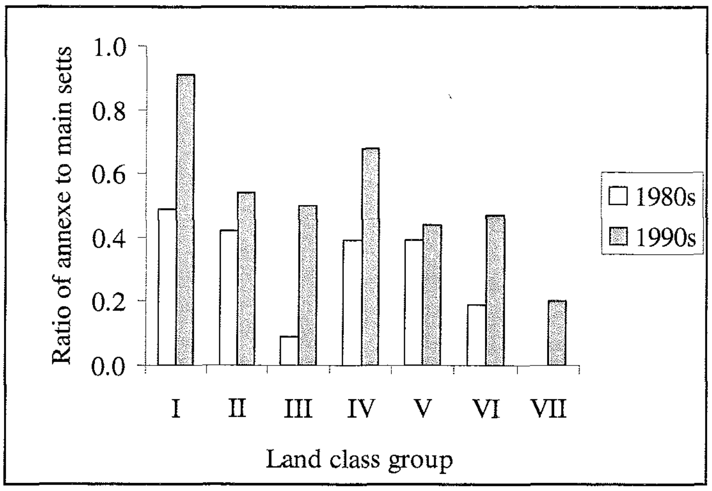



*Figure 3.7. Changes in the ratio of annexe to main setts by land class group*

ing sites, thereby increasing productivity within social groups, so that land classes with higher numbers of annexe setts had a greater overall productivity. Thus, growth in the number of other types of sett, and particularly annexe setts, is a measure of growth within badger social groups. The disproportionately large increase in the number of annexe setts between the two surveys is shown by plotting the ratio of the number of annexe to main setts both by land class group and regionally (Figures 3.7 and 3.8). The overall growth of the number of setts within established social groups is shown by plotting the ratio of the number of annexe, subsidiary and outlying setts combined to main setts both by land class and regionally (Figures 3.9 and 3.10).

The pattern of growth within established social groups is different from the expansion of social groups into new areas. A Wilcoxon matched pairs test showed that of the seven land class groups, the mean number of annexe, subsidiary and outlying setts combined km$^{-2}$, did not change significantly for Arable III and Upland VII (z=-0.68, n.s.; z=-1.36, n.s.; respectively), whereas Arable I, Arable II, Pas-

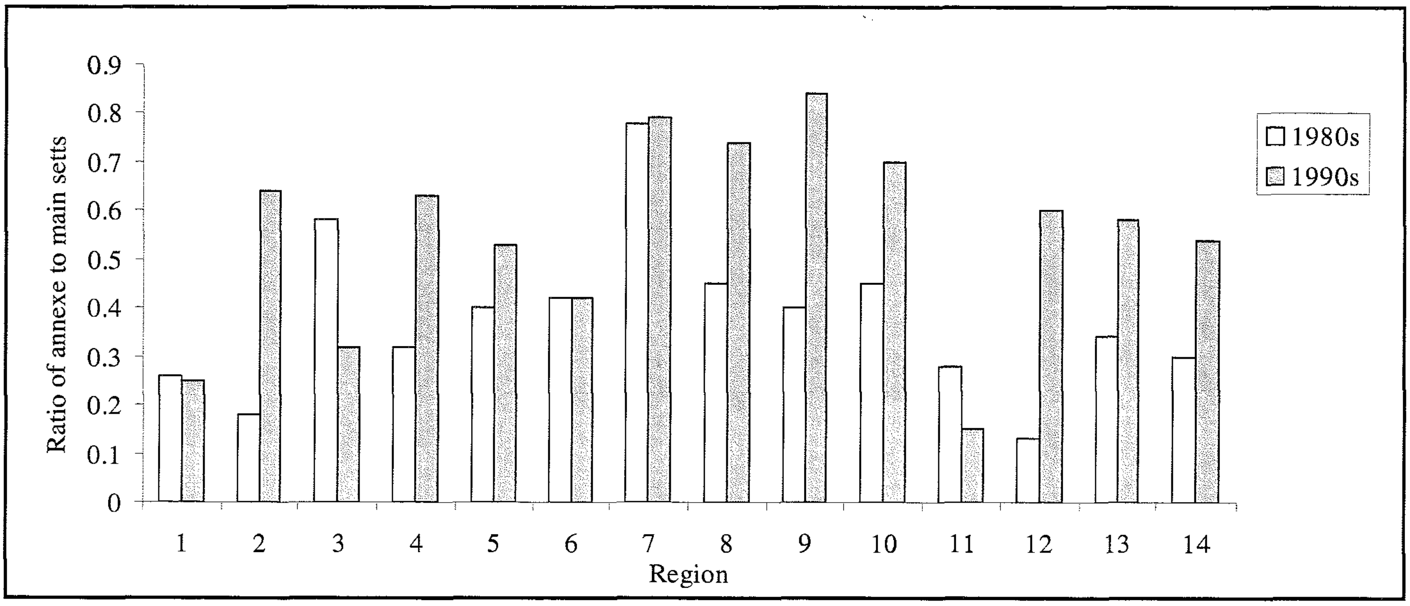



*Figure 3.8. Regional pattern of change in the ratio of annexe to main setts. The numbers denote the regions, as follows: 1=North England, 2=North-west England, 3=North-east England, 4=West Midlands, 5=East Midlands, 6=Central England, 7=East Anglia, 8=South-west England, 9=Southern England, 10=South-east England, 11=North Scotland, 12=South Scotland, 13=Mid and north Wales, 14=South Wales*

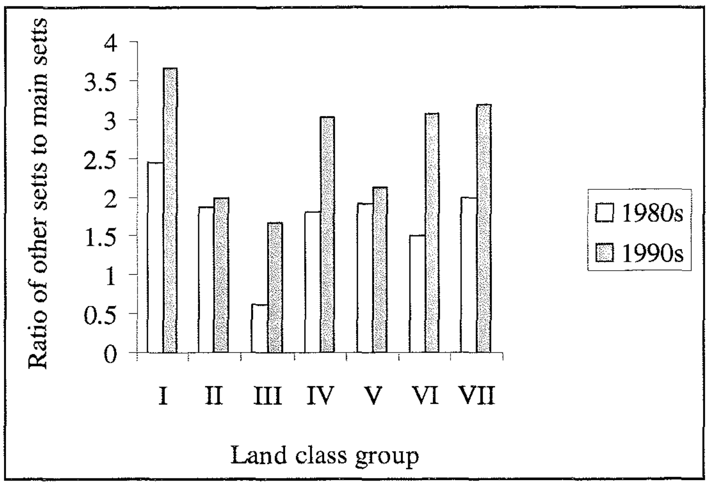



***Figure 3.9.*** *Changes in the ratio of annexe, subsidiary and outlying setts combined to main setts by land class group*

toral IV, Pastoral V and Marginal upland VI all showed significant increases ($z$=-4.19, $p$<0.0001; $z$=-3.79, $p$<0.001; $z$=-6.51, $p$<0.0001; $z$=-2.98, $p$<0.01; $z$=-3.26, $p$<0.001; respectively). Some regions (e.g. North-west England, Southern England and South Scotland) that showed little or no growth in the number of social groups still showed substantial growth in the number of annexe and other sett types within established social groups. Other regions that showed little growth in the number of social groups (e.g. North England and East Midlands) also showed little increase in the number of annexe setts within established social groups. Conversely, land class groups (e.g. Arable II) and regions (e.g. North-east England and East Anglia) that showed a substantial growth in the number of social groups showed little increase in the number of annexe or other sett types within social groups. Not surprisingly, comparing the percent change in the number of main setts and annexe setts by land class group revealed no relationship ($R^2$=0.03, n.s.).

These data suggest that the pattern of changes in the badger population are complex; increases in the number of social groups are not necessarily matched by growth within social groups, but there can be growth within social groups without population expansion into new areas. These relationships are explored in greater detail in section 4.5.

## 3.5 Changes in the status of setts

For the smaller sett types that disappeared or fell into disuse, it was hard to determine the exact reasons for their disappearance because so few field signs remained. However, some smaller sett types increased in status, and became main setts; these changes are summarised in Table 3.7. Losses of disused main setts are shown in Table 3.8; of the 64 disused main setts recorded in the 1990s, 22 (34%) had been active main setts in the 1980s.

Although there has been a substantial increase in the number of main setts, relatively few, only 71/241 (29%), originated by expansion of an estab-

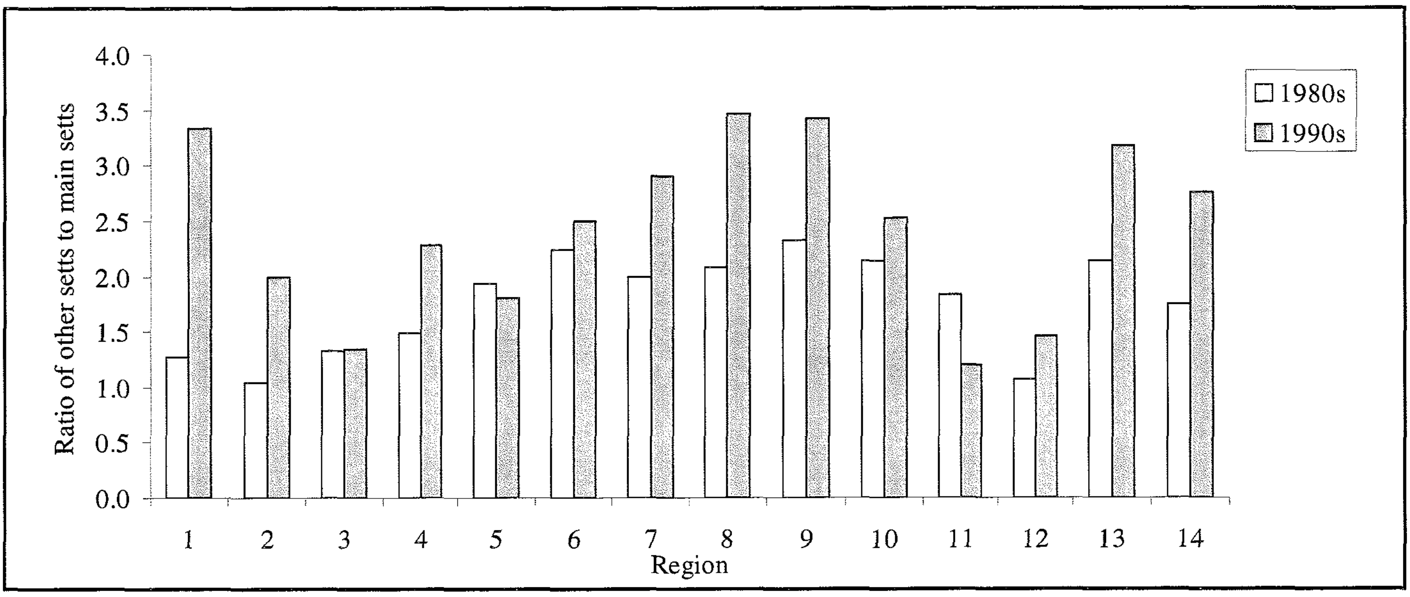



*Figure 3.10. Regional pattern of change in the ratio of annexe, subsidiary and outlying setts combined to main setts. The numbers denote the regions, as follows: 1=North England, 2=North-west England, 3=North-east England, 4=West Midlands, 5=East Midlands, 6=Central England, 7=East Anglia, 8=South-west England, 9=Southern England, 10=South-east England, 11=North Scotland, 12=South Scotland, 13=Mid and north Wales, 14=South Wales*

**Table 3.7.** Summary of the types of sett that changed in status between the two surveys to become active main setts.

| Land class group | Annexe setts | Subsidiary setts | Outlying setts | Disused main setts |
|---|---|---|---|---|
| Arable I | 0 | 6 | 0 | 0 |
| Arable II | 4 | 3 | 4 | 2 |
| Arable III | 0 | 0 | 0 | 2 |
| Pastoral IV | 6 | 10 | 7 | 6 |
| Pastoral V | 0 | 6 | 4 | 4 |
| Marginal upland VI | 0 | 3 | 2 | 2 |
| Upland VII | 0 | 0 | 0 | 0 |
| **Totals** | **10** | **28** | **17** | **16** |

lished, lower status sett. The main category of sett expanded into main setts were subsidiary setts; 28 (7%) of these had become main setts between the two surveys. Of the 14 annexe setts that became main setts, in five cases there was a simple exchange of status with the nearby main sett. Most new main setts were dug from new, reinforcing the assertion that the different sett types have specific functions and are established in different types of locality. Thus, a site that may be suitable for an outlying sett, for instance, may not be suitable for a main sett.

## 3.6 Changes in the distribution of badger setts

Besides a significant increase in the number of main setts, there has also been an increase in the distribution of badgers. In the 1980s, the maximum number of main setts recorded in a 1-km square was six (Cresswell, Harris & Jefferies, 1990); this agreed with the theoretical maximum calculated by Thornton (1987), based on Kruuk's (1978) minimum nearest neighbour distance for main setts of 300 metres. Since most 1-km squares with main setts in the 1980s still only had one main sett, the recent increase in the number of badger main setts could all have occurred within 1-km squares that were already occupied. In fact, this was not the case, and most changes have been from 1-km squares with no main setts to 1-km squares having one main sett.

However, even though badgers have clearly expanded into new areas, the majority of 1-km squares surveyed still did not contain a badger sett. The distribution of 1-km squares with main setts in the two surveys is shown by land class groups and regions in Tables 3.9 and 3.10, and all types of sett by land class groups and regions in Tables 3.11 and 3.12. In the 1980s, only 378/2271 1-km squares (17%) contained main setts, and 676/2271 1-km squares (30%) contained setts of any type. When

**Table 3.8.** Changes in the status of disused main setts recorded in the 1980s.

| Land class group | Sett was still a disused main sett | Sett could not be found | Sett had become a rabbit warren | Sett had become an active main sett | Sett had become an annexe sett | Sett had become a subsidiary sett | Sett had become an outlying sett | **Totals** |
|---|---|---|---|---|---|---|---|---|
| Arable I | 10 | 6 | 1 | 0 | 0 | 4 | 0 | **21** |
| Arable II | 8 | 6 | 1 | 2 | 1 | 2 | 1 | **21** |
| Arable III | 0 | 1 | 1 | 2 | 0 | 0 | 0 | **4** |
| Pastoral IV | 6 | 7 | 2 | 6 | 1 | 1 | 0 | **23** |
| Pastoral V | 8 | 10 | 4 | 4 | 0 | 3 | 3 | **32** |
| Marginal upland VI | 3 | 3 | 0 | 2 | 0 | 0 | 0 | **8** |
| Upland VII | 0 | 2 | 0 | 0 | 0 | 0 | 0 | **2** |
| **Totals** | **35** | **35** | **9** | **16** | **2** | **10** | **4** | **111** |

**Table 3.9.** Changes in the number of 1-km squares in each land class group containing main setts 1988-1997.

| Land class group | Number of squares | Number (percent) of 1-km squares with main setts in the 1980s | | Number (percent) of 1-km squares with main setts in the 1990s | | Percent change | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 208 | 74 | (36) | 76 | (37) | 3 | n.s. |
| Arable II | 493 | 81 | (16) | 102 | (21) | 26 | n.s. |
| Arable III | 188 | 17 | (9) | 15 | (8) | -12 | n.s. |
| Pastoral IV | 428 | 126 | (29) | 160 | (37) | 27 | $p<0.01$ |
| Pastoral V | 333 | 51 | (15) | 72 | (22) | 41 | n.s. |
| Marginal upland VI | 335 | 27 | (8) | 37 | (11) | 37 | n.s. |
| Upland VII | 286 | 2 | (1) | 5 | (2) | - | - |
| **Totals** | **2271** | **378** | **(17)** | **467** | **(21)** | **24** | $p<0.0001$ |

looking at just the five lowland land class groups, only 21% contained main setts in the 1980s, and 33% setts of any type. The absence of any type of badger sett from the majority of lowland rural Britain suggests either that substantial areas of rural Britain were unsuitable for badgers, or else anthropogenic factors had led to the loss of badgers from much of rural Britain. Equally, their recent spread into new areas suggests that the factors limiting their distribution hitherto have changed. Main setts are now found in an additional 4%, and any setts in an additional 3%, of all rural 1-km squares, and for just the five lowland land class groups, these figures are also 4% and 3% respectively. To try to understand why these changes have occurred, we examine the impact of changing levels of persecution on badger numbers in Chapter 5,

**Table 3.10.** Regional changes in the number of 1-km squares with main setts, 1988-1997.

| Region | Number of squares | Number (percent) of 1-km squares with main setts in the 1980s | | Number (percent) of 1-km squares with main setts in the 1990s | | Percent change | Significance |
|---|---|---|---|---|---|---|---|
| North England | 170 | 17 | (10) | 18 | (11) | 6 | n.s. |
| North-west England | 72 | 11 | (15) | 11 | (15) | 0 | n.s. |
| North-east England | 121 | 12 | (10) | 17 | (14) | 42 | n.s. |
| West Midlands | 177 | 42 | (24) | 68 | (38) | 59 | $p=0.0001$ |
| East Midlands | 153 | 26 | (17) | 27 | (18) | 4 | n.s. |
| Central England | 91 | 19 | (21) | 24 | (26) | 26 | n.s. |
| East Anglia | 161 | 9 | (6) | 14 | (9) | 56 | n.s. |
| South-west England | 205 | 78 | (38) | 105 | (51) | 35 | $p<0.001$ |
| Southern England | 131 | 36 | (27) | 42 | (32) | 17 | n.s. |
| South-east England | 159 | 46 | (29) | 46 | (29) | 0 | n.s. |
| North Scotland | 366 | 6 | (2) | 10 | (3) | 67 | n.s. |
| South Scotland | 208 | 15 | (7) | 14 | (7) | -7 | n.s. |
| Mid and north Wales | 143 | 28 | (20) | 34 | (24) | 21 | n.s. |
| South Wales | 114 | 33 | (29) | 37 | (32) | 12 | n.s. |
| **Totals** | **2271** | **378** | **(17)** | **467** | **(21)** | **24** | $p<0.0001$ |

**Table 3.11.** Changes in the number of 1-km squares in each land class group containing any setts (i.e. all types combined), 1988-1997.

| Land class group | Number of squares | Number (percent) of 1-km squares with setts in the 1980s | | Number (percent) of 1-km squares with setts in the 1990s | | Percent change | Signif-icance |
|---|---|---|---|---|---|---|---|
| Arable I | 208 | 115 | (55) | 117 | (56) | 2 | n.s. |
| Arable II | 493 | 140 | (28) | 160 | (32) | 14 | $p$=0.01 |
| Arable III | 188 | 31 | (16) | 28 | (15) | -10 | n.s. |
| Pastoral IV | 428 | 209 | (49) | 229 | (54) | 10 | $p$<0.05 |
| Pastoral V | 333 | 111 | (33) | 125 | (38) | 13 | $p$=0.01 |
| Marginal upland VI | 335 | 60 | (18) | 74 | (22) | 23 | n.s. |
| Upland VII | 286 | 10 | (3) | 13 | (5) | 30 | n.s. |
| **Totals** | **2271** | **676** | **(30)** | **746** | **(33)** | **10** | **$p$<0.0001** |

and of habitat changes in Chapter 6.

## 3.7 Changes in the size of setts

Changes in the size of main, annexe, subsidiary and outlying setts are summarised by land class group and regions in Appendix 10.8. Overall, there have been significant increases in the size of main setts since the 1980s, a small increase in the size of subsidiary setts, but no change in the size of annexe and outlying setts. For main setts, the majority of the increase in size occurred because there was an increase in the number of well-used holes; there was a small decrease in the number of disused holes. For annexe setts, whilst there was no overall change in size, there was a decrease in the number of disused holes and an increase in the number of

**Table 3.12.** Regional changes in the number of 1-km squares with setts (i.e. all types combined), 1988-1997.

| Region | Number of squares | Number (percent) of 1-km squares with setts in the 1980s | | Number (percent) of 1-km squares with setts in the 1990s | | Percent change | Signif-icance |
|---|---|---|---|---|---|---|---|
| North England | 170 | 44 | (26) | 41 | (24) | -7 | n.s. |
| North-west England | 72 | 22 | (31) | 25 | (35) | 14 | n.s. |
| North-east England | 121 | 24 | (20) | 23 | (19) | -4 | n.s. |
| West Midlands | 177 | 84 | (47) | 115 | (65) | 37 | $p$<0.0001 |
| East Midlands | 153 | 42 | (27) | 50 | (33) | 19 | n.s. |
| Central England | 91 | 35 | (38) | 35 | (38) | 0 | n.s. |
| East Anglia | 161 | 18 | (11) | 27 | (17) | 50 | $p$=0.05 |
| South-west England | 205 | 130 | (63) | 145 | (71) | 12 | $p$<0.05 |
| Southern England | 131 | 58 | (44) | 64 | (49) | 10 | n.s. |
| South-east England | 159 | 68 | (43) | 68 | (43) | 0 | n.s. |
| North Scotland | 366 | 24 | (7) | 20 | (5) | -17 | n.s. |
| South Scotland | 208 | 31 | (15) | 25 | (12) | -19 | n.s. |
| Mid and north Wales | 143 | 45 | (31) | 55 | (38) | 22 | n.s. |
| South Wales | 114 | 51 | (45) | 53 | (46) | 4 | n.s. |
| **Totals** | **2271** | **676** | **(30)** | **746** | **(33)** | **10** | **$p$<0.0001** |

**Table 3.13.** The number of badger social groups in Britain in the 1990s. How these figures were derived is explained in the text.

| Land class group | Number of 1-km squares in land class group | Area of rural land ($km^2$) in land class group | Mean main sett density in the 1980s | Mean main sett density in the 1990s | Total number of main setts in land class group in the 1990s |
|---|---|---|---|---|---|
| Arable I | 14,460 | 14,069 | 0.457 | 0.452 | 6366 |
| Arable II | 48,385 | 46,387 | 0.189 | 0.241 | 11,381 |
| Arable III | 18,339 | 17,391 | 0.096 | 0.090 | 1600 |
| Pastoral IV | 34,730 | 30,949 | 0.404 | 0.493 | 16,743 |
| Pastoral V | 35,383 | 33,974 | 0.174 | 0.252 | 8586 |
| Marginal upland VI | 35,438 | 34,793 | 0.096 | 0.137 | 4816 |
| Upland VII | 45,150 | 42,069 | 0.007 | 0.017 | 749 |
| **Totals** | **231,885** | **219,633** | **0.207** | **0.254** | **50,241** |

well-used holes. For subsidiary setts, the increase in size was the result of an increase in the number of well-used holes, whereas for outlying setts there was no change. Thus, except for outlying setts, all sett types showed an increase in the number of well-used holes, and for main and subsidiary setts this was accompanied by an overall increase in sett size.

The regional patterns of change are more complex; regions such as North England and North-west England, which showed little or no increase in the number of social groups, showed substantial growths in the sizes of main setts, whereas regions such as North-east England and the West Midlands, which showed significant increases in the number of badger social groups, showed little growth in the size of main setts. The pattern of change for the smaller types of sett was even more variable.

## 3.8 The number of badger social groups in Britain

To estimate the total number of badger social groups in Britain, we used the mean main sett densities for each land class group shown in Table 3.13. These density estimates are based on the number of 1-km squares that were surveyed, minus the area of sea. Only 1-km squares that were predominantly rural were included in the survey. Thus, to estimate the number of badger social groups in Britain, we obtained the number of urban squares in each land class from the *Countryside Information System* (version 5.40) (Institute of Terrestrial Ecology, Monks Wood, Abbots Ripton, Huntingdon, PE17 2LS). For this, urban 1-km squares were defined as being more than 75% built up. The densities for each land class group were then multiplied by the number of rural 1-km squares to give the number of badger social groups; the 95% confidence intervals were calculated as explained in Appendix 10.6. By this means we estimated the number of badger social groups in Britain as 50,241±4327.

In the 1980s, only a small sample of 1-km squares in Britain had been classified to a land class (see section 1.4.1), and estimates of both the area of Britain, the area of each land class, and the area of any particular habitat type, were less precise than those available today. Thus, Cresswell, Harris & Jefferies (1990) used 207,501 $km^2$ as the estimate of the area of rural land in Britain when deriving their population estimate, whereas we have used an estimate of 219,633 $km^2$. Largely as a result of the improved estimate for the area of rural land in each land class, whilst we have estimated that the number of badger social groups in Britain has risen by 24%, the new estimate for the number of badger social groups in Britain is not exactly 24% higher than that given by Reason, Harris & Cresswell (1993).

As in the previous survey, this estimate does not include the number of badger social groups living in urban areas. In the 1980s, Cresswell, Harris & Jefferies (1990) estimated that there were no more than 200 active main setts in urban areas, and of these 37 were in Bristol, the city with the largest ur-

**Table 3.14.** The number of badger setts in Britain in the 1990s. How these figures were derived is explained in the text. The percent change is the change in the total number of setts in Britain between the two surveys.

| Land class group | Number of active main setts | Number of annexe setts | Number of subsidiary setts | Number of outlying setts | Number of disused main setts | **Totals** |
|---|---|---|---|---|---|---|
| Arable I | 6366 | 6197 | 10,422 | 14,647 | 986 | **38,618** |
| Arable II | 11,381 | 7084 | 9445 | 18,889 | 1417 | **48,216** |
| Arable III | 1600 | 711 | 1244 | 1777 | 178 | **5510** |
| Pastoral IV | 16,743 | 12,566 | 19,019 | 33,962 | 1698 | **83,988** |
| Pastoral V | 8586 | 4089 | 9199 | 16,354 | 681 | **38,909** |
| Marginal upland VI | 4816 | 3164 | 5273 | 13,711 | 703 | **27,667** |
| Upland VII | 749 | 132 | 1762 | 2202 | 132 | **4977** |
| **Totals (±s.e.)** | **50,241 ±4327** | **33,942 ±4629** | **56,364 ±7045** | **101,543 ±12,268** | **5795 ±1616** | **247,885 ±22,836** |
| Percent change since 1980s | 24 | 87 | 54 | 55 | -41 | 43 |

ban badger population (Harris & Cresswell, 1991). Since then, a number of local Badger Groups have reported an increase in the number of badgers seen in urban areas (see Appendix 10.11). However, many of these reports are of badgers coming into gardens on the edges of urban areas to forage, especially in hot dry summers (see Table 10.11.1). Whilst it is likely that there are now more main setts in urban areas, it is unlikely that the number of badger social groups living in urban areas exceeds 250.

We then used the same approach to estimate the number of setts of all types in each land class group and Britain as a whole (Table 3.14). The percentage change in the actual number of setts in Britain is also shown; we have estimated that there are now 247,885 setts of all types in Britain i.e. approximately 70,000 more than the estimate of Cresswell, Harris & Jefferies (1990). This table also shows the percent change in the number of each type of sett for Britain as a whole.

## 3.9 Discussion

In this Chapter, we have shown that there has been a 24% increase in the number of badger social groups, and that this pattern of increase is not evenly distributed across Britain. The greatest increases have been in some of the land class groups with the lowest overall population densities. Regionally, the increases have been complex, with some regions showing little or no increase in the number of badger social groups, whereas others have shown substantial increases. The picture is further complicated by the increase in setts other than main setts, and/or the increase in sett types, that occurred independently of the changes in the number of social groups. These other changes suggest that there have also been increases in the size of social groups, and we examine this further in Chapter 4.

The surprisingly high rate of loss of main setts between the two surveys (29%) also suggests that persecution of badgers was still widespread. This argument is reinforced by the analyses showing that "lost" main setts were generally smaller than those that survived between the two surveys. Since we have shown that newer main setts are smaller than those which have been present for some time, this suggests that setts are being destroyed before the badgers become well established. Persecution levels, and their impact on badger numbers, are explored further in Chapter 5.

# 4. Badger population changes, 1988 to 1997: changes in badger numbers

## 4.1 Introduction

Other than at very low population densities, badgers mark their territorial boundaries, and features within the territory, with latrines (Neal & Cheeseman, 1996). In addition, there are often conspicuous pathways connecting the boundary latrines, and well-used pathways within the territory connecting setts and leading to foraging areas. These are often particularly obvious where they pass through a hedge or under a fence. Finally, badgers leave characteristic foraging signs, as described by Neal & Cheeseman (1996). These field signs are easy to find and distinguish from those left by other species.

Field signs, and particularly faeces, are frequently used as a measure of animal abundance e.g. see reviews by Putman (1984), Staines & Ratcliffe (1987) and Sutherland (1996b). Factors such as the dunging behaviour of the particular species being studied, differential search ability of surveyors, differential findability in different habitat types, and differential decay rates, amongst others, can all in theory affect the reliability of dung counts for estimating the abundance of animals. However, Putman (1984) concluded that, when trying to use field signs to assess abundance, there is good evidence to conclude that many of the potential sources of error are insignificant in practice. This is likely to be particularly true with badgers: their faeces accumulate in latrines (Brown, 1993) which are easy to identify and persist for extended periods. Finding dung pits is also made easier because badgers generally place their latrines in conspicuous places (Kruuk, 1978). Also, surveyors were asked to record other field signs, such as paths and runs, which are obvious irrespective of weather conditions.

The idea that counts of dung pits or latrines, or other field signs, may provide a measure of the number of badgers in an area is supported by the work of Brown (1993) and Hutchings (1996). There are some problems because of the seasonality of badger behaviour. The activity of badgers declines substantially for a period of about six weeks early in the new year (Harris, 1982), and their scent marking behaviour shows marked seasonal trends. However, Brown (1993) showed that the number of faeces produced each night is constant each season, and so the number of faeces deposited in a territory in a particular time period can be used as a measure of social group size (Brown, 1993; Hutchings, 1996).

Whilst there is a relationship between the number of badgers and the number of faeces on a territory, faecal density is not easy to measure in the field. However, overall changes in badger activity, both in terms of the number of latrines and other field signs within a 1-km square, can be measured with a high degree of reliability, especially if the measures used are easily quantified in the field and can be recorded equally reliably across all habitat types. There will be variability in the results between individual 1-km squares, depending on the month when each square was surveyed, and so individual 1-km squares, or small sub-samples of 1-km squares, cannot be compared. However, both the 1980s and the 1990s surveys were undertaken across exactly the same months of the year, and so comparing the means across land class groups or regions will eliminate this problem, since all land class groups and regions were sampled across the entire survey period. Also, the problem will have been minimised, because the field work was confined to the autumn, winter and early spring, when vegetation is lowest and field signs are most visible. Finally, many of the field signs that were recorded (dung pits rather than actual faeces, paths and runs) remain visible for an extended period, irrespective of how recently they have been used. Thus, seasonal variability in the behaviour of badgers will be less important when monitoring a variety of field signs than if a single measure, such as faecal counts, was used.

In this Chapter we discuss the value of field signs for estimating changes in the number of badgers in Britain. We show that there is a significant linear relationship between the various field signs recorded during the survey and badger numbers across a wide range of population estimates, and then use the data to provide a provisional estimate of the percent change in the badger population in Britain. In particular, we use field signs to estimate

**Table 4.1.** Changes in the number of 1-km squares with field signs in the two surveys.

| | Number (percent) of 1-km squares with signs in the 1980s | Number (percent) of 1-km squares with signs in the 1990s |
|---|---|---|
| Footprints | 380 (17) | 601 (26) |
| Paths or runs | 666 (29) | 810 (36) |
| Dung pits | 397 (17) | 643 (28) |

how much of the change has been due to the growth in social group size and how much has been due to the spread of badgers and the establishment of new social groups. We then use this relationship to demonstrate that there is a minimum group size before badgers disperse and establish new social groups. This relationship may in part explain the differences in the pattern of population growth in the different land class groups and regions. Finally, we discuss the limitations of the data, and further work that needs to be done to improve upon these estimates.

## 4.2 Monitoring field signs

During both surveys, the presence of footprints, paths or runs, and dung pits were recorded in each of nine sub-squares within the 1-km square. The relative proportion of 1-km squares with the various field signs recorded remained the same between the two surveys (Table 4.1), indicating that these measures were robust and that one or other of them was not unduly influenced by any differences in weather conditions between the two surveys. Furthermore, paths or runs were the field signs recorded most frequently, and these were the field signs that were particularly obvious and were least likely to be influenced by weather conditions (section 4.1).

From these field data, measures of "total activity" were obtained by combining all these scores (score range 0 to 27), and measures of scent marking activity by combining the scores for "dung pits" (score range 0 to 9).

## 4.3 The relationship between field signs and badger numbers

The pattern of change between the two surveys for total activity scores is shown in Tables 4.2 and 4.3, for dung pits in Tables 4.4 and 4.5. Comparing across land class groups, in both the 1980s and the 1990s both mean total activity and mean dung pits scores were correlated with mean main sett density, but the correlation was slightly better with the former (total activity score for the 1980s, $R^2$=0.96, $p$<0.01; for the 1990s, $R^2$=0.99, $p$<0.01; total dung pit score for the 1980s, $R^2$=0.91, $p$<0.01; for the 1990s $R^2$=0.96, $p$<0.01). For both, however, the relationship was different between the two surveys, with higher total activity and dung pit scores recorded for the same mean main sett density in the 1990s than in the 1980s (Figures 4.1 and 4.2) ($t$-tests, total activity scores, $t$=3.26, $p$<0.01; dung pit scores,

**Table 4.2.** Changes in the total activity scores between the two surveys, by land class group.

| Land class group | Number of squares | Mean total activity score ±s.e. in the 1980s | Mean total activity score ±s.e. in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 3.86±0.37 | 4.66±0.37 | 21 | $p$<0.01 |
| Arable II | 493 | 1.57±0.16 | 2.94±0.16 | 87 | $p$<0.0001 |
| Arable III | 188 | 0.52±0.10 | 0.94±0.19 | 81 | $p$<0.05 |
| Pastoral IV | 428 | 3.07±0.22 | 5.34±0.32 | 74 | $p$<0.0001 |
| Pastoral V | 333 | 1.59±0.19 | 3.03±0.31 | 91 | $p$<0.0001 |
| Marginal upland VI | 335 | 0.79±0.12 | 1.71±0.24 | 117 | $p$<0.0001 |
| Upland VII | 286 | 0.25±0.09 | 0.26±0.11 | 4 | n.s. |
| **Totals** | **2271** | **1.70±0.08** | **2.88±0.11** | **69** | ***p*<0.0001** |

**Table 4.3.** Regional changes in the total activity scores between the two surveys.

| Region | Number of squares | Mean total activity score ±s.e. in the 1980s | Mean total activity score ±s.e. in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| North England | 170 | 1.01±0.18 | 1.87±0.30 | 85 | $p<0.01$ |
| North-west England | 72 | 1.78±0.49 | 2.97±0.64 | 67 | $p<0.05$ |
| North-east England | 121 | 0.99±0.26 | 1.46±0.33 | 47 | n.s. |
| West Midlands | 177 | 2.87±0.32 | 6.68±0.45 | 133 | $p<0.0001$ |
| East Midlands | 153 | 1.82±0.32 | 2.60±0.34 | 43 | $p<0.01$ |
| Central England | 91 | 1.92±0.41 | 4.10±0.69 | 114 | $p<0.01$ |
| East Anglia | 161 | 0.33±0.06 | 1.30±0.29 | 294 | $p<0.0001$ |
| South-west England | 205 | 4.98±0.39 | 7.30±0.47 | 47 | $p<0.0001$ |
| Southern England | 131 | 2.48±0.38 | 3.73±0.52 | 50 | $p<0.001$ |
| South-east England | 159 | 2.99±0.39 | 3.26±0.42 | 9 | n.s. |
| North Scotland | 366 | 0.27±0.07 | 0.28±0.08 | 4 | n.s. |
| South Scotland | 208 | 0.53±0.13 | 0.53±0.13 | 0 | n.s. |
| Mid and north Wales | 143 | 1.45±0.27 | 3.70±0.38 | 155 | $p<0.0001$ |
| South Wales | 114 | 1.70±0.22 | 3.70±0.40 | 118 | $p<0.0001$ |
| **Totals** | **2271** | **1.70±0.08** | **2.88±0.10** | **69** | $\boldsymbol{p<0.0001}$ |

$t$=7.70, $p<0.001$). Similarly, when considering the relationship between total activity score and the percent of 1-km squares occupied i.e. containing a badger sett of any type, there was a highly significant relationship in both the 1980s ($R^2$=0.86, $p<0.01$) and the 1990s ($R^2$=0.96, $p<0.01$). As for the relationship with main sett density, the slope of the line in the 1990s was significantly different from that for the 1980s ($t$-test; $t$=3.18, $p<0.05$) (Figure 4.3).

The change in the slope for the relationship in the 1990s, compared to the 1980s, suggests that there were higher levels of activity in the occupied 1-km squares in the 1990s than in the 1980s. To investigate this further, we selected those 1-km squares which had the same number of main setts (excluding those with none) in the 1980s as in the 1990s; thus we factored out any effects due to changes in the number of badger social groups. We then used a Wilcoxon matched pairs test to compare their mean activity scores; of the 232 1-km squares, 156 (67%) had higher activity scores in the 1990s ($z$=-6.85, $p<0.0001$). Thus, there had been a highly significant increase in mean activity scores, even in the absence of any changes in the number of badger social groups. This suggests that there has been an increase in badger numbers in addition

**Table 4.4.** Changes in the dung pit scores between the two surveys, by land class group.

| Land class group | Number of squares ±s.e. in the 1980s | Mean dung pit score ±s.e. in the 1990s | Mean dung pit score | Percent change | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 0.96±0.12 | 1.22±0.13 | 27 | $p<0.05$ |
| Arable II | 493 | 0.35±0.05 | 0.72±0.07 | 106 | $p<0.0001$ |
| Arable III | 188 | 0.12±0.03 | 0.27±0.07 | 132 | $p<0.05$ |
| Pastoral IV | 428 | 0.61±0.06 | 1.24±0.09 | 103 | $p<0.0001$ |
| Pastoral V | 333 | 0.33±0.05 | 0.77±0.08 | 133 | $p<0.0001$ |
| Marginal upland VI | 335 | 0.18±0.04 | 0.48±0.07 | 172 | $p<0.0001$ |
| Upland VII | 286 | 0.06±0.03 | 0.01±0.01 | -75 | n.s. |
| **Totals** | **2271** | **0.37±0.02** | **0.71±0.03** | **92** | $\boldsymbol{p<0.0001}$ |

**Table 4.5.** Regional changes in the dung pit scores between the two surveys.

| Region | Number of squares | Mean dung pit score ±s.e. in the 1980s | Mean dung pit score ±s.e. in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| North England | 170 | 0.20±0.12 | 0.51±0.10 | 155 | *p*<0.001 |
| North-west England | 72 | 0.42±0.14 | 0.61±0.16 | 46 | n.s. |
| North-east England | 121 | 0.26±0.08 | 0.39±0.09 | 50 | n.s. |
| West Midlands | 177 | 0.56±0.08 | 1.65±0.14 | 195 | *p*<0.0001 |
| East Midlands | 153 | 0.44±0.09 | 0.74±0.11 | 68 | *p*<0.01 |
| Central England | 91 | 0.41±0.12 | 0.97±0.19 | 137 | *p*<0.01 |
| East Anglia | 161 | 0.03±0.02 | 0.25±0.06 | 733 | *p*<0.001 |
| South-west England | 205 | 0.98±0.11 | 1.67±0.15 | 70 | *p*<0.0001 |
| Southern England | 131 | 0.60±0.12 | 1.00±0.14 | 67 | *p*<0.001 |
| South-east England | 159 | 0.79±0.13 | 0.81±0.13 | 2 | n.s. |
| North Scotland | 366 | 0.05±0.02 | 0.03±0.01 | -40 | n.s. |
| South Scotland | 208 | 0.08±0.02 | 0.14±0.04 | 75 | n.s. |
| Mid and north Wales | 143 | 0.36±0.08 | 0.98±0.14 | 172 | *p*<0.0001 |
| South Wales | 114 | 0.36±0.07 | 1.02±0.14 | 183 | *p*<0.0001 |
| **Totals** | **2271** | **0.37±0.02** | **0.71±0.03** | **92** | ***p*<0.0001** |

to the increases in the number of badger social groups documented in section 3.2.

That this is the case is also suggested by the relationship between the total activity scores and mean dung pit scores in each land class group and the numbers of setts; there has been a consistent pattern of change in both. Thus, for all sett types combined and mean activity score for the 1980s, $r$=0.99, $p$<0.001; for all sett types combined and mean activity score for the 1990s, $r$=0.96, $p$<0.001; for all sett types combined and mean dung pit score for the 1980s, $r$=0.98, $p$<0.001, for all sett types combined and mean dung pit score for the 1990s, $r$=0.97, $p$<0.001; for all setts combined other than main setts and mean activity score for the 1980s, $r$=0.99, $p$<0.001; for all setts combined other than main setts and mean activity score for the 1990s, $r$=0.95, $p$<0.001; for all sett types combined other than main setts and mean dung pit score for the 1980s, $r$=0.98, $p$<0.001; for all sett types combined other than main

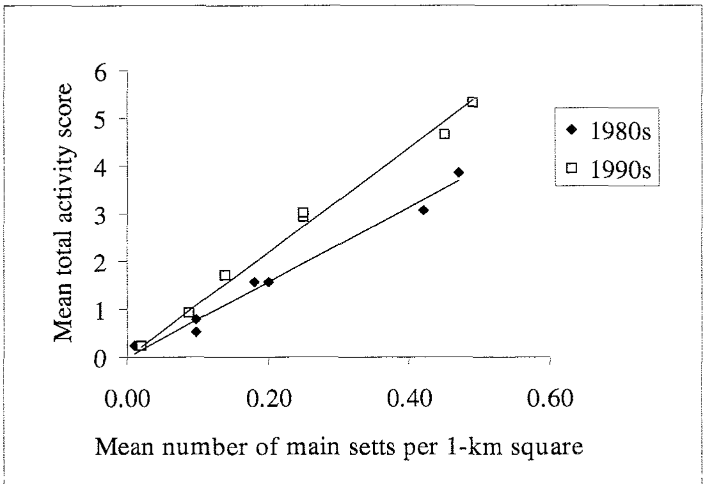



*Figure 4.1. Relationship between the mean number of main setts km*$^{-2}$ *and mean total activity scores in each land class group in the 1980s* ($y$=0.77$x$+0.02) *and 1990s* ($y$=10.55$x$+0.10)

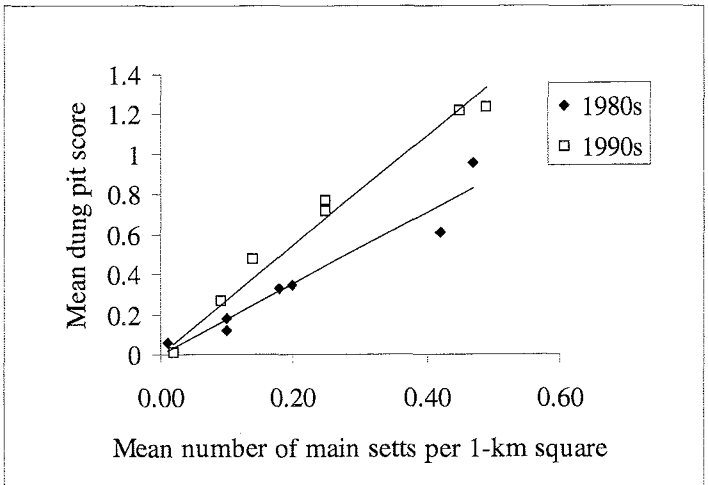



*Figure 4.2. Relationship between the mean number of main setts km*$^{-2}$ *and mean dung pit scores in each land class group in the 1980s* ($y$=0.53$x$+0.01) *and 1990s* ($y$=0.38$x$+0.01)

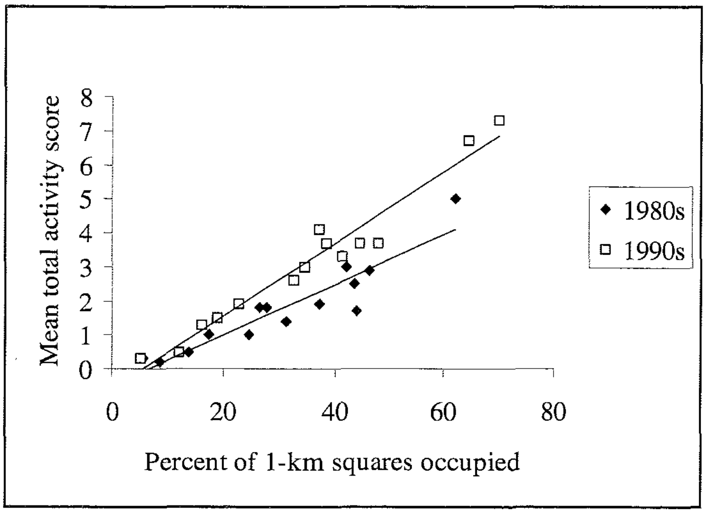



***Figure 4.3.*** *Relationship between the mean total activity scores and the percent of 1-km squares occupied (i.e. containing any type of sett) in each region in the 1980s* ($y$=0.074$x$-0.49) *and 1990s* ($y$=0.11$x$-0.61)

setts and mean dung pit score for the 1990s, $r$=0.97, $p$<0.001.

The mean total activity score was used to examine the pattern of change in badger activity in the various land class groups (Figure 4.4), and Wilcoxon matched pairs tests used to compare the activity scores in the 1980s and 1990s. There were significant increases between the 1980s and the 1990s for the total activity scores for Arable I ($z$=-2.60, $p$<0.01), Arable II ($z$=-5.80, $p$<0.0001), Arable III ($z$=-2.10, $p$<0.05), Pastoral IV ($z$=-8.80, $p$<0.0001) Pastoral V ($z$=-6.20, $p$<0.0001) and Marginal upland VI ($z$=-5.70, $p$<0.0001); only Upland VII showed no significant change ($z$=-2.60, n.s.).

For the sample squares, the overall increase in total activity scores was 69%, and 92% for dung pit scores. These figures are compared with land class and regional changes in the number of social groups and other sett types in Tables 4.6 and 4.7. When comparing the number of 1-km squares in the two surveys with any signs of activity, or just with dung pits, there was a significant increase in both measures (Tables 4.8 to 4.11). Signs of badger activity were recorded in 31% of 1-km squares in the 1980s and 38% in the 1990s; for just the five lowland land class groups, these figures were 38% and 45% respectively. Dung pits were recorded in 17% of 1-km squares in the 1980s and 28% in the 1990s. For just the five lowland land class groups, the figures were 22% and 35% respectively.

## 4.4 Estimating changes in the number of badgers

We have shown that badger density, in terms of the number of social groups, is correlated with field signs. However, to use this relationship to calculate the change in the actual number of badgers, we need to have some idea of the number of adult badgers per social group, and whether this varies according to landscape type and/or regionally. Unfortunately, data on typical social group sizes are limited. For the 1980s survey, Cresswell, Harris & Jefferies (1990) used a mean figure of 5.9 adult badgers per social group, this being derived from a limited number of studies in areas where badgers were reasonably common. Since the 1980s, further field studies from a greater range of habitats have suggested that this mean figure may be a little high. For instance, in Cumbria social groups typically have four or fewer adults (Jean Scott, *pers. comm.*), and in parts of north-west Essex mean group size is around three adults (Christine Skinner, *pers. comm.*). O'Corry-Crowe, Eves & Hayden (1993) found that mean social group size was four adults in East Offaly in the Republic of Ireland, and Feore (1994) showed significant variation in social group size in different habitat types in Northern Ireland. Yet despite these more recent studies, we still do not have enough information on which to quantify the variation in badger group size in different habitats or regions.

For the following calculations, we have, therefore, assumed a mean social group size of 5.9 adults in the 1980s, and also repeated the calculation with

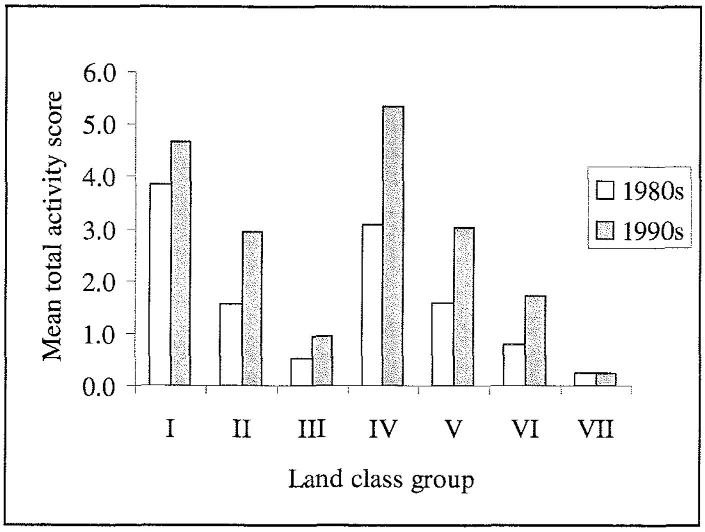



***Figure 4.4.*** *Changes in the mean total activity scores for each land class group between the 1980s and the 1990s*

**Table 4.6.** Comparison of the changes, 1988-1997, in the number of main setts, all other sett types combined, total activity scores and mean dung pit scores, by land class group.

| Land class group | Number of squares | Percent change in number of main setts | Percent change in number of all other setts | Percent change in mean total activity score | Percent change in mean dung pit score |
|---|---|---|---|---|---|
| Arable I | 208 | -1 | 53 | 21 | 27 |
| Arable II | 493 | 28 | 48 | 87 | 106 |
| Arable III | 188 | -6 | 52 | 81 | 132 |
| Pastoral IV | 428 | 22 | 67 | 74 | 103 |
| Pastoral V | 333 | 45 | 37 | 91 | 133 |
| Marginal upland VI | 335 | 44 | 72 | 117 | 172 |
| Upland VII | 286 | - | 86 | 4 | -75 |
| **Totals** | **2271** | **22** | **57** | **69** | **92** |

a mean of five adults per social group to determine how much effect this would have on the estimate for the change in badger numbers. For the calculations, we used the relationship between main sett density and total activity scores, since this was slightly better than for dung pits alone. The relationship was highly significant ($R^2$=0.98, $p$<0.001) (Figure 4.1). In addition, whilst the seven land class groups showed great differences in badger density in terms of the number of social groups, all the points were very close to the regression line. This was important, since it indicated that there was a strong linear relationship between badger numbers and field signs across a wide range of population densities. Thus the relationship between badger numbers and field signs recorded during the badger surveys is robust.

**Table 4.7.** Regional comparison of the changes, 1988-1997, in the number of main setts, all other sett types combined, total activity scores and mean dung pit scores.

| Region | Number of squares | Percent change in number of main setts | Percent change in number of other setts | Percent change in mean total activity score | Percent change in mean dung pit score |
|---|---|---|---|---|---|
| North England | 170 | 6 | 93 | 85 | 155 |
| North-west England | 72 | -8 | 54 | 67 | 46 |
| North-east England | 121 | 24 | 6 | 47 | 50 |
| West Midlands | 177 | 86 | 99 | 133 | 195 |
| East Midlands | 153 | 4 | 41 | 43 | 68 |
| Central England | 91 | 18 | 26 | 114 | 137 |
| East Anglia | 161 | - | 132 | 294 | 733 |
| South-west England | 205 | 23 | 76 | 47 | 70 |
| Southern England | 131 | 7 | 38 | 50 | 67 |
| South-east England | 159 | 15 | 46 | 9 | 2 |
| North Scotland | 366 | - | -24 | 4 | -40 |
| South Scotland | 208 | 0 | -3 | 0 | 75 |
| Mid and north Wales | 143 | 35 | 68 | 155 | 172 |
| South Wales | 114 | -2 | 27 | 118 | 183 |
| **Totals** | **2271** | **22** | **57** | **69** | **92** |

**Table 4.8.** Changes in the number of 1-km squares in each land class group with signs of badger activity in the two surveys.

| Land class group | Number of squares | Number (percent) of 1-km squares with signs of activity in the 1980s | | Number (percent) of 1-km squares with signs of activity in the 1990s | | Percent change | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 208 | 114 | (55) | 122 | (59) | 7 | n.s. |
| Arable II | 493 | 147 | (30) | 187 | (38) | 27 | $p<0.01$ |
| Arable III | 188 | 33 | (18) | 33 | (18) | 0 | n.s. |
| Pastoral IV | 428 | 227 | (53) | 263 | (61) | 16 | $p<0.01$ |
| Pastoral V | 333 | 114 | (34) | 138 | (41) | 21 | $p<0.05$ |
| Marginal upland VI | 335 | 67 | (20) | 95 | (28) | 42 | $p<0.01$ |
| Upland VII | 286 | 12 | (4) | 16 | (6) | 33 | n.s. |
| **Totals** | **2271** | **714** | **(31)** | **854** | **(38)** | **20** | $\boldsymbol{p<0.0001}$ |

First, assuming a mean of 5.9 adults per social group, we plotted the relationship between mean total activity score and adult badger densities per land class group in the 1980s; the equation for the regression line was y=1.37x i.e. a mean activity score of one was equivalent to 1.37 adult badgers. Obviously, this is a mean relationship across a large number of 1-km squares, and does not hold true for individual, or small samples, of squares. We then applied this relationship to the total activity scores for the 1990s, and calculated the change in the number of badgers. This showed that badger numbers had increased overall by 77%. Since we know from Chapter three that the number of social groups had increased by 24%, we estimated an increase in mean badger social group size of 47%. The

**Table 4.9.** Regional changes in the number of 1-km squares with signs of badger activity in the two surveys.

| Region | Number of squares | Number (percent) of 1-km squares with signs of activity in the 1980s | | Number (percent) of 1-km squares with signs of activity in the 1990s | | Percent change | Significance |
|---|---|---|---|---|---|---|---|
| North England | 170 | 47 | (28) | 55 | (32) | 17 | n.s. |
| North-west England | 72 | 24 | (33) | 26 | (36) | 8 | n.s. |
| North-east England | 121 | 22 | (18) | 28 | (23) | 27 | n.s. |
| West Midlands | 177 | 99 | (56) | 140 | (79) | 41 | $p<0.001$ |
| East Midlands | 153 | 47 | (31) | 61 | (40) | 30 | $p<0.05$ |
| Central England | 91 | 36 | (40) | 41 | (45) | 14 | n.s. |
| East Anglia | 161 | 16 | (10) | 28 | (17) | 75 | $p<0.05$ |
| South-west England | 205 | 144 | (70) | 156 | (76) | 8 | n.s. |
| Southern England | 131 | 52 | (40) | 67 | (51) | 29 | $p<0.05$ |
| South-east England | 159 | 76 | (48) | 70 | (44) | -8 | n.s. |
| North Scotland | 366 | 26 | (7) | 26 | (7) | 0 | n.s. |
| South Scotland | 208 | 33 | (16) | 23 | (11) | -30 | n.s. |
| Mid and north Wales | 143 | 42 | (29) | 72 | (50) | 71 | $p<0.0001$ |
| South Wales | 114 | 50 | (44) | 61 | (54) | 22 | n.s. |
| **Totals** | **2271** | **714** | **(31)** | **854** | **(38)** | **20** | $\boldsymbol{p<0.001}$ |

**Table 4.10.** Changes in the number of 1-km squares in each land class group with dung pits in the two surveys.

| Land class group | Number of squares | Number (percent) of 1-km squares with dung pits in the 1980s | | Number (percent) of 1-km squares with dung pits in the 1990s | | Percent change | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 208 | 77 | (37) | 96 | (46) | 25 | $p<0.0001$ |
| Arable II | 493 | 83 | (17) | 141 | (29) | 70 | $p<0.0001$ |
| Arable III | 188 | 17 | (9) | 23 | (12) | 35 | $p<0.01$ |
| Pastoral IV | 428 | 121 | (28) | 203 | (47) | 68 | $p<0.0001$ |
| Pastoral V | 333 | 61 | (18) | 108 | (32) | 77 | $p<0.0001$ |
| Marginal upland VI | 335 | 33 | (10) | 69 | (21) | 109 | $p<0.0001$ |
| Upland VII | 286 | 5 | (2) | 3 | (1) | -40 | n.s. |
| **Totals** | **2271** | **397** | **(17)** | **643** | **(28)** | **62** | $\boldsymbol{p<0.0001}$ |

remaining 30% of the increase in badger numbers was due to the establishment of new social groups.

For these calculations, it makes little difference whatever mean group size is assumed. Assuming a mean group size of five adult badgers, the slope of the line is $y=1.62x$, and so an activity score of one equals 1.62 badgers. Using the same calculation as before, we calculated that the number of badgers in Britain had increased by 76%, of which 42% was due to an increase in mean social group size, and 34% was due to the establishment of new social groups.

Thus, assuming a lower figure of five adult badgers per social group in the 1980s does not significantly influence the overall percentage change that we calculated. This is because we have used a good

**Table 4.11.** Regional changes in the number of 1-km squares with dung pits in the two surveys.

| Region | Number of squares | Number (percent) of 1-km squares with dung pits in the 1980s | | Number (percent) of 1-km squares with dung pits in the 1990s | | Percent change | Significance |
|---|---|---|---|---|---|---|---|
| North England | 170 | 23 | (14) | 36 | (21) | 57 | $p<0.001$ |
| North-west England | 72 | 14 | (19) | 19 | (26) | 36 | $p<0.01$ |
| North-east England | 121 | 14 | (12) | 22 | (18) | 57 | $p<0.01$ |
| West Midlands | 177 | 55 | (31) | 106 | (60) | 93 | $p<0.01$ |
| East Midlands | 153 | 32 | (21) | 48 | (31) | 50 | $p<0.01$ |
| Central England | 91 | 17 | (19) | 33 | (36) | 94 | $p<0.0001$ |
| East Anglia | 161 | 4 | (2) | 19 | (12) | 375 | $p<0.001$ |
| South-west England | 205 | 86 | (42) | 125 | (61) | 45 | $p<0.0001$ |
| Southern England | 131 | 31 | (24) | 55 | (42) | 77 | $p<0.0001$ |
| South-east England | 159 | 49 | (31) | 49 | (31) | 0 | $p<0.001$ |
| North Scotland | 366 | 9 | (2) | 9 | (2) | 0 | n.s. |
| South Scotland | 208 | 11 | (5) | 17 | (8) | 55 | $p<0.01$ |
| Mid and north Wales | 143 | 27 | (19) | 56 | (39) | 107 | $p<0.0001$ |
| South Wales | 114 | 25 | (22) | 49 | (43) | 96 | $p<0.0001$ |
| **Totals** | **2271** | **397** | **(17)** | **643** | **(28)** | **62** | $\boldsymbol{p<0.0001}$ |

straight line relationship as the basis for our calculations. Perhaps a more critical assumption for these calculations is that there was relatively little variation in badger social group size across all land class groups in the 1980s, the starting point for our calculations. Had this been an unrealistic assumption, the mean total activity scores across land class groups, when plotted against the mean number of main setts in a land class, would not fall on a straight line. For both of these calculations, for simplicity we did not include the very small intercept value, since clearly the regression line should pass through zero; had we included the intercept value in the calculations, the estimated population change would have been 1% higher for both calculations.

One possible problem with this assumption is that our activity scores were independent of the actual number of badgers; they could be dependent on the number of main setts rather than social group size. However, if this was the case, we would expect to see the same mean activity scores for any given mean number of main setts in both surveys. This was not the case: in both surveys, for an equivalent mean number of main setts, a higher activity score was recorded in the 1990s than in the 1980s.

Finally, we have assumed that the relationship between badger density and the total activity scores remains the same at all population densities. While this is presently an assumption, the good linear relationship shown in Figure 4.1 between main sett density and total activity scores, with all the points close to the line and no evidence of greater spread at high or low densities, indicates that this is a linear relationship, at least at the badger population densities recorded during the survey.

Thus we conclude that there has been an increase in both the number of main setts and the number of badgers, and that the activity scores are a realistic measure of this change. Whilst there is a strong relationship between badger numbers and the activity scores we measured in the field, at present it can only be used to produce an estimate of the rate of change. Before we can use this relationship to calculate the actual number of badgers in Britain, we need to determine a realistic mean social group size at different population densities, and also quantify landscape and regional effects on social group size. Until that work has been completed, we will not produce an estimate of the total number of badgers in Britain.

## 4.5 The relationship between the change in the number of badgers and the change in the number of social groups

When comparing the local patterns of change, even land class groups such as Arable I and Arable III, where there had been no significant change in the number of badger social groups, showed significant increases in the total activity scores, by 21% and 81% respectively (Figure 4.4). To understand why there appears to be different patterns of change in different land class groups, we then plotted the percent change in badger density, based on the mean total activity score for each land class group, against the percent change in the number of badger social groups. For this analysis, the Upland VII land class group was omitted because there were very few 1-km squares with either main setts or signs of badger activity.

The results are shown in Figure 4.5. Again, it is a good relationship, with all the points close to the regression line. The results suggest that increases in the number of badger social groups started to occur after mean social group size had increased by approximately 25% of that seen in the 1980s. This may also explain in part the differing pattern of results seen between land class groups; it would appear that some have only so far seen limited increases in

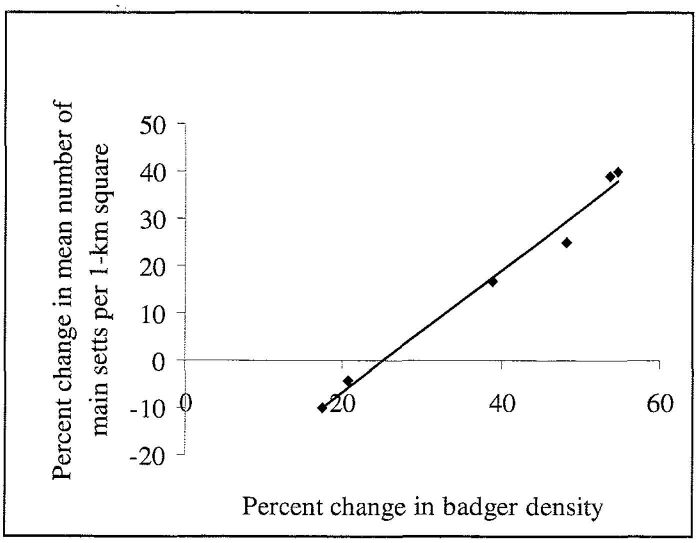



***Figure 4.5.*** *The relationship between the percent change in badger numbers, calculated from the total activity score for each land class group, and percent change in the mean number of badger social groups for each land class group. The Upland VII land class group has been excluded* ( y=*0.50*x-14.16, $R^2$=0.99)

social group size, and these changes have not yet reached the critical point at which new social groups are formed.

This observation of a critical mean social group size, below which the rate of establishment of new social groups is limited, may also explain the observations made by Cheeseman *et al.* (1993). They found that at Woodchester Park the rate of colonisation was low, and that it took approximately ten years for the badgers to recolonise a small number of cleared territories. However, these territories were cleared in 1978 and 1979, when mean social group size was less than three adults. A decade later, mean social group size had increased to around eight adults (Neal & Cheeseman, 1996). Our data suggest that, had the removals been undertaken later, when mean group size was much larger, recolonisation would occurred faster.

## 4.6 Discussion

In this Chapter we have shown that field signs can be used to estimate the change in the total number of badgers in Britain. At present, we do not have estimates for mean social group sizes in different land class groups, and so cannot yet use this relationship to estimate the badger population size in Britain. Whilst Cresswell, Harris & Jefferies (1990) provided a preliminary estimate, their mean social group size was based on a limited number of studies, and a number of these were from areas where the badgers had been studied intensively for some time. As we have shown for Woodchester Park, the indirect protection that accrues as a result of such studies can lead to an increase in social group size. Thus, the estimate used by Cresswell, Harris & Jefferies (1990) may err on the high side. So until we have more information on typical social group sizes from areas where the badgers are not being intensively studied, we will not estimate the number of badgers in Britain.

However, the value we used for the mean social group size for our calculations only had a small effect on the estimate for the percent change in the number of badgers in Britain. We have produced two provisional estimates of the rate of change, both of which are very close, and shown that the increase in the number of badgers in Britain has been about 77% in nine years. When more data are available on social group sizes, we will be able to refine this estimate, but the strength of the relationship we used as the basis for our calculations suggests that any changes to this estimate will be small. In the next two Chapters we will examine some of the factors that may have contributed to this rate of population growth.

# 5. Changes in levels of badger persecution, 1988 to 1997

## 5.1 Introduction

Since persecution by gamekeepers last century, and more recently by badger diggers, is believed to have had a significant impact on badger numbers, changes to the badger protection laws could have had a big impact on badger populations. Since the time of the sett survey initiated by The Mammal Society in 1963, there have been significant changes in the levels of protection afforded to badgers, and these are summarised in Appendix 10.9. In the 1980s survey, the levels of badger digging, hole blocking and snaring were documented. The results were an instantaneous survey of the levels of persecution during the winter months. Such a survey, therefore, cannot assess seasonal differences in persecution levels, and infrequent persecution, such as snaring at setts, would be recorded only rarely, even though such low levels of persecution could have a significant impact on the badger population. Similarly, persecution away from setts, such as hunting badgers with lurchers, shooting at night with the aid of powerful lamps ("lamping") or widespread snaring, could not be recorded because these activities leave few field signs. Thus, this sort of survey provides a minimum snap-shot estimate of the levels of selected types of persecution, and so it is difficult to assess the impact of the observed levels of persecution on badger populations. However, this approach does have the advantage that the field signs are easy to record and relatively unambiguous, and so they provide a quantified means of monitoring changes in the levels of some major forms of badger persecution.

In the 1980s, the levels of persecution at badger setts were high; Cresswell, Harris & Jefferies (1990) recorded digging at 10.5% of active main setts, with hole blocking at 15.7% and snaring at 1.0%. Digging and hole blocking were consistently higher at active main than at other types of sett, and these patterns of persecution declined generally in the order active main sett>disused main sett>annexe sett>subsidiary sett>outlying sett. These authors argued that this implied that the persecution was deliberately targeted at badgers, as opposed to being incidental persecution associated with killing foxes, since the incidence of persecution declined in parallel with the levels of badger use of each sett type (see section 1.4.2).

Following the 1980s survey, for the first time the Protection of Badgers Act 1992 offered protection to badger setts as well as their occupants. This resurvey, therefore, provides an opportunity to determine whether this legislation has led to a reduction in the interference with badger setts. When analysing the results, the number of affected setts

**Table 5.1.** Changes in the number of active main setts showing signs of digging in the two surveys by land class group, 1988-1997.

| Land class group | Number of setts dug in the 1980s | Total number of main setts | Percent main setts dug | Number of setts dug in the 1990s | Total number of main setts | Percent main setts dug | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 6 | 86 | 7 | 1 | 94 | 1 | - |
| Arable II | 10 | 84 | 12 | 7 | 119 | 6 | - |
| Arable III | 2 | 17 | 12 | 3 | 17 | 18 | - |
| Pastoral IV | 10 | 158 | 6 | 5 | 211 | 2 | - |
| Pastoral V | 8 | 52 | 15 | 4 | 84 | 5 | - |
| Marginal upland VI | 4 | 30 | 13 | 3 | 46 | 7 | - |
| Upland VII | 1 | 2 | - | 1 | 5 | - | - |
| **Totals** | **41** | **429** | **10** | **24** | **576** | **4** | $p<0.01$ |

**Table 5.2.** Regional differences in the number of active main setts showing signs of digging in the two surveys, 1988-1997.

| Region | Number of setts dug in the 1980s | Total number of main setts | Percent main setts dug | Number of setts dug in the 1990s | Total number of main setts | Percent main setts dug | Significance |
|---|---|---|---|---|---|---|---|
| North England | 6 | 16 | 38 | 5 | 19 | 26 | - |
| North-west England | 2 | 12 | 17 | 3 | 12 | 25 | - |
| North-east England | 3 | 15 | 20 | 0 | 21 | 0 | - |
| West Midlands | 5 | 41 | 12 | 1 | 82 | 1 | - |
| East Midlands | 5 | 27 | 19 | 2 | 29 | 7 | - |
| Central England | 1 | 18 | 6 | 0 | 26 | 0 | - |
| East Anglia | 1 | 8 | - | 2 | 14 | 14 | - |
| South-west England | 4 | 109 | 4 | 2 | 143 | 1 | - |
| Southern England | 3 | 43 | 7 | 3 | 49 | 6 | - |
| South-east England | 3 | 48 | 6 | 0 | 62 | 0 | - |
| North Scotland | 0 | 8 | - | 0 | 12 | 0 | - |
| South Scotland | 2 | 15 | 13 | 2 | 15 | 13 | - |
| Mid and north Wales | 3 | 27 | 11 | 3 | 46 | 7 | - |
| South Wales | 3 | 42 | 7 | 1 | 46 | 2 | - |
| **Totals** | **41** | **429** | **10** | **24** | **576** | **4** | ***p*<0.01** |

within a land class group or region were generally too small for statistical analysis, and so significance levels are only presented for the national changes. Also, since there was no information on persecution levels at setts missed in the 1980s survey, some of the sample sizes used in these analyses are slightly different from those in other Chapters.

## 5.2 Badger digging

Overall, the levels of badger digging at main setts had declined significantly, to just under half that recorded in the 1980s; only 4% of main setts showed evidence of having been dug in the 1990s (Table 5.1). Based on the 1-3 score, there were no significant differences in the severity of digging at main setts in each land class group between the two surveys (Kruskal-Wallis test; $X^2$=3.84, n.s.). Thus, while the extent of digging had declined, where it still occurred the damage to main setts that had been dug remained the same. As in the 1980s, lower levels of digging were recorded for annexe and subsidiary (2% each) and outlying setts (1%) (Tables 10.10.1 to 10.10.3). Also, there had been no change in the levels of digging at these types of sett. Thus, as in the 1980s, it appears that digging was deliberately targeted at badgers, since it increased in parallel with the frequency of occupation of each type of sett. However, unlike the 1980s, signs of digging were most common at disused main setts (6%) (Table 10.10.4). It is hard to know from a one-off survey such as this whether this was because digging led to some main setts being abandoned. Some local Badger Groups reported that this was a problem (Appendix 10.11), and these results also suggest that this may be occurring.

Whilst levels of digging have declined nationally, locally it can still be a significant problem (Tables 5.2 and 10.10.5). For all types of sett, but particularly main setts, digging levels were higher in North and North-west England than for any other regions; in these two regions, a quarter of all main setts showed signs of having been dug and, contrary to the national trend, these two regions showed little change in levels of badger digging since the 1980s, and the number of badger social groups showed no significant change. Overall, although there is no significant correlation between the percent of main setts dug and the percent change in the number of badger social groups in each region (Spearman rank correlation; $r_s$=-0.407, n.s.), the general pattern is for no increase or a small decline in the number of main setts in areas where levels of digging are highest (Table 5.3).

Whilst the overall pattern is clear, three regions (East Anglia, Mid and north Wales, and South Wales) do not conform to the general trend. In fact, for the rest of Britain there is a significant negative correlation between the percent main setts dug in a

**Table 5.3.** Regional comparison of the levels of digging at main setts in the 1990s and the change in the number of main setts; the regions are shown in descending order of the level of digging.

| Region | Percent main setts dug in the 1990s | Percent difference in number of main setts |
|---|---|---|
| North England | 26 | 6 |
| North-west England | 25 | -8 |
| East Anglia | 14 | 56 |
| South Scotland | 13 | 0 |
| East Midlands | 7 | 4 |
| Mid and north Wales | 7 | 35 |
| Southern England | 6 | 7 |
| South Wales | 2 | -2 |
| West Midlands | 1 | 86 |
| South-west England | 1 | 23 |
| North-east England | 0 | 24 |
| Central England | 0 | 18 |
| South-east England | 0 | 15 |
| North Scotland | 0 | 50 |

region and the percent change in the number of badger social groups (Spearman rank correlation; n=11 pairs, $r_s$=-0.754, $p$<0.01). Why these three regions do not conform to the overall trend is less clear. The situation in East Anglia is difficult to analyse, since the number of setts is of necessity small. Whilst there has been an increase in the number of main setts, a reintroduction programme in south and east Suffolk, where 16 social groups of badgers have been released in the last decade (Margaret Grimwade, *pers. comm.*), may have contributed to the increase. Thus, the observed increase in the region may not just be a reflection of natural population growth. The anomalous positions of Mid and north Wales and South Wales are less easy to understand. It may be that in both Mid and north Wales and South Wales, other forms of persecution are more common than elsewhere in Britain, and that is why there has been no significant change in the number of badger social groups in either region (Table 3.2). Their anomalous positions in the rankings, therefore, may simply reflect the complexity of the situation in these two regions. Whatever the reasons for the differences in these three regions, across most of Britain there is a correlation between levels of badger digging and rates of badger population recovery.

## 5.3 Sett blocking

The proportion of each type of sett that had some or all holes blocked had not changed significantly for any type of sett between the two surveys (Tables 5.4 and 10.10.6 to 10.10.9). However, the increase in the number of setts since the 1980s has meant that the total number of blocked setts has increased. There are, however, quite large regional differences in the proportion of setts that had been blocked (Tables 5.5 and 10.10.10).

The extent of sett blocking is not related to badger population density; there was no relationship between the percent of main setts blocked and mean main sett density across regions ($R^2$=0.03, n.s.). Thus, it is unlikely that the majority of sett blocking was undertaken by landowners or others in response to problems caused by badgers. Had this been a significant problem, the level of

**Table 5.4.** Changes in the number of main setts showing signs of hole blocking, 1988-1997, by land class group.

| Land class group | Number of setts blocked in the 1980s | Total number of main setts | Percent main setts blocked | Number of setts blocked in the 1990s | Total number of main setts | Percent main setts blocked | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 16 | 86 | 19 | 13 | 94 | 14 | - |
| Arable II | 19 | 84 | 23 | 22 | 119 | 18 | - |
| Arable III | 2 | 17 | 12 | 2 | 17 | 12 | - |
| Pastoral IV | 18 | 158 | 11 | 25 | 211 | 12 | - |
| Pastoral V | 8 | 52 | 15 | 9 | 84 | 11 | - |
| Marginal upland VI | 3 | 30 | 10 | 3 | 46 | 7 | - |
| Upland VII | 0 | 2 | - | 0 | 5 | - | - |
| **Totals** | **66** | **429** | **15** | **74** | **576** | **13** | **n.s.** |

**Table 5.5.** Regional changes in the number of main setts showing signs of hole blocking, 1988-1997.

| Region | Number of setts blocked in the 1980s | Total number of main setts | Percent main setts blocked | Number of setts blocked in the 1990s | Total number of main setts | Percent main setts blocked | Significance |
|---|---|---|---|---|---|---|---|
| North England | 4 | 16 | 25 | 3 | 19 | 16 | - |
| North-west England | 2 | 12 | 17 | 0 | 12 | 0 | - |
| North-east England | 2 | 15 | 13 | 2 | 21 | 10 | - |
| West Midlands | 13 | 41 | 32 | 17 | 82 | 21 | - |
| East Midlands | 9 | 27 | 33 | 8 | 29 | 28 | - |
| Central England | 5 | 18 | 28 | 5 | 26 | 19 | - |
| East Anglia | 2 | 8 | - | 2 | 14 | 14 | - |
| South-west England | 12 | 109 | 11 | 17 | 143 | 12 | - |
| Southern England | 9 | 43 | 21 | 8 | 49 | 16 | - |
| South-east England | 3 | 48 | 6 | 4 | 62 | 6 | - |
| North Scotland | 0 | 8 | - | 0 | 12 | 0 | - |
| South Scotland | 1 | 15 | 7 | 1 | 15 | 7 | - |
| Mid and north Wales | 3 | 27 | 11 | 5 | 46 | 11 | - |
| South Wales | 1 | 42 | 2 | 2 | 46 | 4 | - |
| **Totals** | **66** | **429** | **15** | **74** | **576** | **13** | **n.s.** |

sett interference would have increased in areas where badgers were more common. In any case, such activity would be illegal unless the relevant licence had been obtained (Harris *et al.*, 1994). However, under the Protection of Badgers Act 1992, it is legal for foxhunts to block badger setts, so long as they follow specific protocols (Appendix 10.9).

To determine whether the extent of sett blocking recorded in the 1980s and 1990s was related to the activity of foxhunts, we compared the extent of sett blocking with the intensity of foxhunting in each region. The number of days foxhunting per week in each region in the 1987-1988 and 1996-1997 hunting

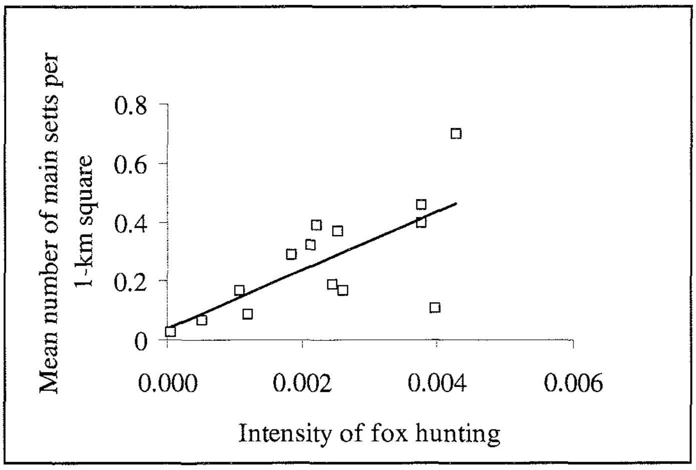



***Figure 5.1.*** *The relationship between mean number of main setts km$^{-2}$ in each region and hunting intensity (number of days hunting km$^{-2}$) in the 1990s (y=99.02x+0.04, $R^2$=0.49)*

seasons were extracted from the relevant edition of *Baily's Hunting Directory* (Anon., 1987; Alexander, 1996). The number of days hunting was then corrected for the area of each region (Table 1.2) to provide a measure of hunting intensity per unit area in the 1980s and the 1990s.

Analysing these data was confounded because, in both the 1980s and 1990s, hunting intensity was greatest in the regions with the highest badger population density, and this relationship did not change significantly between the two surveys. The relationship for the 1990s is illustrated in Figure 5.1 ($R^2$=0.49, $p$<0.01). When examining the data on sett blocking, it was clear that whilst the number of blocked setts in a region increased with hunting intensity, so did the total number of setts, and hence the proportion of setts blocked did not vary with hunting intensity ($R^2$=0.15, n.s.). So to examine the relationship between hunting intensity and sett blocking, we estimated the number of main setts in each region by multiplying the mean number of main setts km$^{-2}$ in the 1980s and the 1990s by the area of each region. We then used this figure, and the percent of blocked main setts in the 1980s and the 1990s (Table 5.5), to estimate the total number of blocked main setts in each region during both surveys. The hunting intensity in each region was then compared with the total number of blocked main setts. Hunting intensity was significantly correlated with the total number of blocked main setts in both surveys (for the 1980s, $R^2$=0.31, $p$<0.05; for

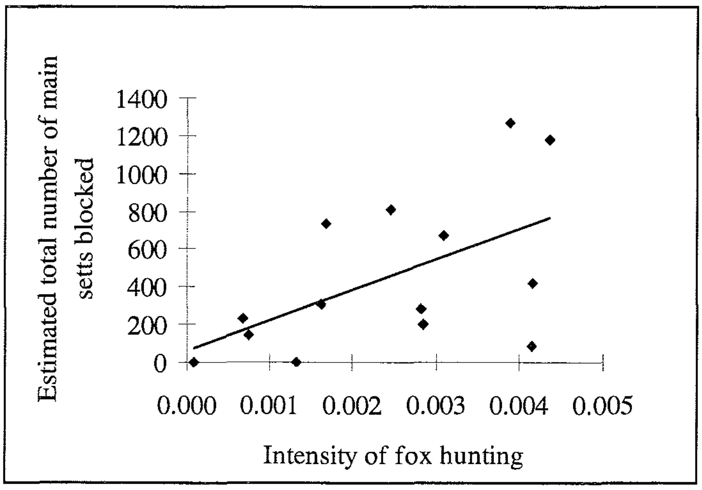



***Figure 5.2.*** *The relationship between the total number of main setts blocked in each region in the 1980s and the intensity of foxhunting (number of days hunting km$^{-2}$)* ($y$=16,116$x$+61.85, $R^2$=0.31)

the 1990s, $R^2$=0.40, $p$<0.05) (Figures 5.2 and 5.3). Thus, in the 1980s and the 1990s respectively, 31% and 40% of the regional variation in the number of setts blocked was explained by hunting intensity.

Whilst this was a significant relationship, four regions (North England, West Midlands, Southwest England and South Wales) were outliers. For the three regions other than the West Midlands, this probably reflects local differences in hunting practices, and particularly the activities of gunpacks. These are packs of hounds used to drive foxes towards waiting guns, and are not recognised by the Masters of Foxhounds Association. Since gun packs are not listed in *Baily's Hunting Directory*, they were not included in the analysis, and so the measures of hunting intensity for areas with gunpacks are likely to be unrealistic. About a hundred gunpacks operate in Wales alone (Phelps, Allen & Harrop, 1997), and several in south-west England (John Bryant, *pers. comm.*). Hence the activities of gun packs and/or other local differences in hunting practices probably explain why these regions are outliers.

Thus, the widespread blocking of badger setts in both surveys, particularly in England, was largely due to the activities of foxhunts. Also, despite the changes in the law, the extent of sett blocking had not changed between the two surveys (Tables 5.4 and 5.5). Furthermore, there has been little change in the degree of sett blocking; 26/66 (39%) of main setts blocked in the 1980s were graded "2" or "3", whilst in the 1990s, 22/74 (30%) of blocked main setts were graded "2" or "3". Based on the 1-3 score, there were no significant differences in the severity of hole blocking at main setts between the two surveys (Kruskal-Wallis test; $X^2$=1.19, n.s.). Of the 74 active main setts with blocked holes in the 1990s, 15 (20%) were illegally blocked with rocks, oil drums, wire mesh and similar items. Whilst the remainder were blocked with soil, the surveyors were not asked to assess whether this had been undertaken in accordance with the provisions of the Protection of Badgers Act 1992. Thus, there is no evidence that nationally the new legislation has led to a significant improvement in the way that badger setts are blocked by foxhunts.

## 5.4 Snaring at setts

Snaring in the immediate vicinity of badger setts was not widespread in either the 1980s or the 1990s (Tables 5.6 and 10.10.11), and there was no significant change in this form of persecution.

## 5.5 Discussion

Badger persecution used to be widespread, and took many forms. The extent and variety of badger persecution in earlier centuries is illustrated by Howes' (1988) review of the history of badger persecution in Yorkshire. In the early part of this century, Blakeborough & Pease (1914) noted that, whilst badgers were rigourously preserved on a few estates, these were the exception, and that on 90% of estates badgers were systematically ha-

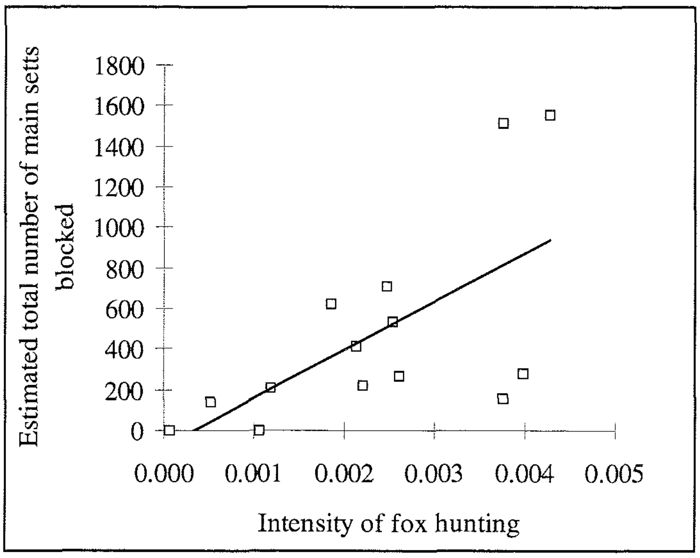



***Figure 5.3.*** *The relationship between the total number of main setts blocked in each region in the 1990s and the intensity of foxhunting (number of days hunting km$^{-2}$)* ($y$=239,173$x$-80.95,

rassed, dug-out, baited, shot or killed in other ways. If this is a reasonable assessment of the levels of badger persecution nationally, it is hardly surprising that at that time many local mammal recorders considered badgers to be very rare or on the verge of extinction (Cresswell, Harris & Jefferies, 1990).

Some forms of badger persecution have now ceased. Last century, badgers were hunted at night with hounds, and Blakeborough & Pease (1914) considered that this "sport" may have led to the preservation of badgers in some areas. There is little information on badger hunting, or when it finally died out. However, during the earlier part of this century, many badgers were also killed by traditional foxhunts. For instance, for the 1926-27 hunting season, of the 107 foxhunts in England and Wales that reported their kill for the season, 14 (13%) mentioned that they had also killed a total of 50 badgers (Anon., 1927). Of these, all but five were specifically recorded as having been killed by hounds. Badgers were killed by hounds when they were found above ground; this occurred because foxhunts "stopped out" badger setts (and fox earths) at night to ensure that the foxes were above ground the next day to hunt. When setts were "hard" blocked, so that it was not easy for the badgers to dig back in, they were also forced to spend the day above ground in cover. In such circumstances, they were at risk of being found and killed by the hounds. The Badgers Act 1991 made it illegal for foxhunts to block setts other than in a number of specified ways. When the methods stipulated in the Act are used, sett stopping should no longer be such a problem. However, in the 1990s survey, 20% of blocked main setts were blocked illegally with rocks, oil drums, wire mesh and similar items designed to prevent the badgers re-opening the hole. There was no evidence that the Badgers Act 1991 has reduced the problem of sett stopping nationally, although some local Badger Groups reported improvements in sett-stopping by their local foxhunts (see Appendix 10.11).

Other forms of badger persecution continue, and the most emotive of these is badger digging, and much of the legislation to protect badgers was designed to eliminate this "sport" (Harris *et al.*, 1994). Badger digging used to be widespread, both in its own right and as an incidental activity when foxes were being dug out of badger setts. In Staffordshire, for instance, Maurice Waterhouse recorded just over 300 setts in 1973; of these, 218 had been dug in the preceding three years. Examples like this led Peter Hardy, the Labour MP responsible for the passage of the Badgers Act 1973 through the House of Commons, to conclude that the badger population in Britain was still declining in the early 1970s, and that badger digging and other forms of persecution were significant contributory factors (Hardy, 1975).

Yet the Badgers Act 1973 still allowed badger digging to continue, so long as it was undertaken with the permission of the owner or occupier, or someone acting with their permission. As a consequence, the impact on the badger population was still significant in areas such as West Yorkshire, which in 1979 became an Area of Special Protection (see Appendix 10.9). Badger digging was finally made illegal in 1981, and by the time of the 1980s survey, levels of badger digging had declined, so that, of 35 local badger groups expressing a view on the extent of badger digging in their area, only 16 (46%) thought that it was or could still be a problem (Cresswell, Harris & Jefferies, 1990).

Since the 1980s survey, the protection afforded to badgers has been further reinforced, so that from 1991 onwards it has been illegal to interfere with a badger sett. In addition, there has been an increase in the number of local badger groups in Britain, from 19 in 1986 to 83 in 1997. This increased protection is reflected in the reduced number of main setts which had been dug in the 1990s survey; this had declined to less than half that seen a decade earlier.

Cresswell, Harris & Jefferies (1990) estimated that 9000 badger setts were dug each year in the mid-1980s. They assumed that one badger was killed per dig. This assumption has been supported by Griffiths (1994), who analysed the hunting diary of a badger digger. He found that over a seven year period, most successful hunting days resulted in the capture of a single badger, with a maximum of five. Cresswell, Harris & Jefferies' (1990) estimate of 9000 badgers killed by diggers each year also compared well with that produced by John Bryant (*pers. comm.*) of 10,000 badgers killed by diggers each year.

Whilst digging was widespread and common in the 1980s, remarkably few people were actually caught and prosecuted. Griffiths (1992) reviewed the number of police prosecutions for the eleven years 1979 to 1989; only 554 people were charged with badger digging, with the greatest proportion coming from Cheshire and Derbyshire, followed by Staffordshire and Wales. Whilst his analysis did not include prosecutions by the League Against Cruel

Sports and the Royal Society for the Prevention of Cruelty to Animals, at first sight a mean of 50 people charged per year is difficult to equate with a loss of 9000 badgers i.e. roughly 180 badgers killed for each person caught. Yet it would appear that this is a realistic estimate. The diary of a single badger digger revealed that in the seven years preceding his arrest, he had dug 152 badgers, of which 126 were captured (Griffiths, 1994). Hence, it would appear that the chances of any individual badger digger being caught are low, and that substantial numbers of badgers are killed for each individual charged. The apparent discrepancy between the estimates for the number of badgers killed by diggers, and the number of prosecutions, therefore, is not surprising.

It is also probable that only a subsection of offenders will be caught. Peachey (1992) produced a superficial analysis of a sample of 76 badger digging cases, involving 206 offenders, over the five year period February 1986 to January 1991. He argued that since 58% of the offenders who were apprehended lived in large conurbations, and a further 40% in large towns or boroughs, for the most part badger diggers are not rural residents. However, it is impossible to make any such generalisations from a small sub-sample of the few people who were caught. It would also represent a major change in the profile of badger diggers. Badger digging used to be a popular rural activity, and included all segments of society, from wealthy land owners to labourers, with whole villages turning out to dig badgers (Blakeborough & Pease, 1914). Local residents digging badgers are less likely to be reported than strangers, and this is especially true if the badger diggers have the permission of, or are known to, the land owner. Thus, it is hardly surprising that most of the badger diggers who are reported, and hence caught, are urban rather than local, rural residents.

It is extremely unlikely that such a well-established rural activity as badger digging would cease suddenly, especially when it was a widespread and serious problem in many areas prior to 1973. The little evidence that is available suggests that badger digging was undertaken by both rural and urban residents, that it has been on the decline since it was made illegal in 1981, and that this decline has continued into the 1990s.

Whilst badger digging has declined generally, it remains a significant problem in North and Northwest England, where a quarter of all main setts surveyed in the mid-1990s had been dug. There has also been no significant change in the number of main setts in these two regions of Britain, and badger population increases (in terms of the percent change in the number of social groups) have been least in those regions with the highest levels of digging (Table 5.3).

So has halving the level of badger digging in the last decade been a major factor in the recent increase in the badger population? By itself, this may at first sight seem unlikely. Yet in section 7.2 we show that an increase in survival of just one adult badger per social group per annum would lead to the observed population increases. With around 40,000 social groups in Britain in the 1980s (Reason, Harris & Cresswell, 1993), this would require that 40,000 fewer adult badgers were killed each year. Digging accounted for about 10,000 badgers per annum, and so any significant decline in the level of badger digging would make an important contribution to the population increase.

Also, digging is the most obvious, but by no means the only, form of badger persecution. Accidental snaring, killing with lurchers when the badgers are at out night foraging, or shooting badgers that are seen at night whilst people are out "lamping" for foxes, hares and rabbits, were all widespread in the 1980s (Stephen Harris, unpublished data). These activities leave few signs and are virtually unquantifiable. It is likely that digging, other forms of persecution and sett destruction occur in parallel (see section 5.5), since they all reflect a general intolerance to badgers, and that in combination they have a significant effect on badger population size. As reported by the local Badger Groups, since the 1980s survey there has been a general change in attitudes to badgers, coupled with an increased public awareness of the protection afforded to badgers (see Appendix 10.11). These changes are likely to have led to a widespread reduction in the levels of all forms of badger persecution, and hence a significant increase in adult survival.

The best evidence that widespread but low levels of persecution have an impact on badger populations comes from the long-term study at Woodchester Park. Following the onset of the Ministry of Agriculture Fisheries and Food's study on this site, the badgers were intensively monitored and, hence, protected. As a consequence, the badger population grew steadily over the next decade (Figure 7.3). Whilst there is no conclusive evidence that this population increase was the direct result of increased protection, it is highly likely that this was the major contributory factor (Neal & Cheeseman, 1996).

In section 7.2 we use simple computer models to examine the changes in levels of persecution that could lead to the increase in the badger population.

In the next Chapter we look at the changes in land use between the two surveys, to determine whether such changes could have contributed to the increase in badger numbers.

# 6. Changes in habitat selection by badgers, 1988 to 1997

## 6.1 Introduction

Reason, Harris & Cresswell (1993) examined the relationship between badger numbers and habitat structure. They showed that the most successful combination of habitat features for defining a "good" square for badgers included hedgerows, treelines, semi-natural broadleaved woodlands, semi-natural mixed woodlands, mixed plantations, parkland, tall scrub, low scrub, bracken, running natural water, lowland unimproved grassland, semi-improved grassland and improved grassland, such that "good" squares contained at least five of these habitat features, with the proviso that where the three grassland types were all present, they only counted as two habitat features, not three. They also showed that in the lowland areas, badger densities were significantly higher in 1-km squares with five or more of the favoured habitat features than those with four or fewer. These latter squares were classified as "poor" for badgers.

Finally, Reason, Harris & Cresswell (1993) showed that if all the lowland 1-km squares in Britain were managed to contain at least five of the favoured habitat features, the total number of badger social groups in Britain could be increased by 39%. This estimate assumed that badger populations in the 1-km squares with five or more habitat types were at carrying capacity; if this was not the case, then the potential for increasing the number of badger social groups would be even higher.

Since the 1980s badger survey, there have been substantial landscape changes in Britain, and these have been summarised by Barr *et al.* (1993). Some of the key changes are listed in Table 6.1; the definitions of the habitat types used by Barr *et al.* (1993) are broadly similar to those used in the badger survey. Most of the large changes were due to shifts between the major agricultural categories, principally tilled land and managed grass. The built-up category expanded at the expense of managed grass and tilled land, whereas broadleaved woodlands had come from managed grass. Conifer forests expanded in area, mainly at the expense of open shrub. As can be seen, in broad terms there were few changes, but within these categories changes were often more substantial. Within tilled land, for instance, there were increases in non-traditional crops, such as maize, which increased three-fold.

More substantial changes occurred in the linear features. Barr, Gillespie & Howard (1994) showed that in England and Wales, the length of hedgerows declined from 563,100 kilometres in 1984 to 431,800 kilometres in 1990 (77%), and that by 1993 this had declined further to 377,500 kilometres (67%), an annual loss of 20,600 kilometres of hedgerow. Thus, overall the increases in land cover between the two badger surveys (coniferous woodland, railways and roads, and built up) are all habitats not favoured by badgers. Whilst there has been a small increase in broadleaved/mixed woodland, most of this would still be young plantings, and as such unlikely to be favoured by badgers. All the losses (hedgerows, dense bracken and managed grass), however, were habitat features favoured by badgers. Hence the habitat changes between the two surveys should in theory have led to a decline in badger numbers.

In this Chapter, we investigate whether we could predict the presence of badger main setts in any 1-km square from our recorded habitat data and, in particular, consider whether the observed increases in badger numbers between the two surveys could be the consequence of particular habitat

**Table 6.1.** Summary of some of the main changes in land cover in Great Britain between 1984 and 1990. From Barr *et al.* (1992).

| Land cover type | Percent change |
|---|---|
| Broadleaved/mixed woodland | 1 |
| Coniferous woodland | 5 |
| Dense bracken | -11 |
| Rough grass/marshland | 45 |
| Managed grass | -2 |
| Tilled land | -4 |
| Railways and roads | 1 |
| Built up | 4 |

**Table 6.2.** Changes in the availability of "good" 1-km squares for badgers between the two surveys by land class groups. The definition of a "good" 1-km square is given in the text.

| Land class group | Number of squares | Number (percent) of "good" 1-km squares in the 1980s | | Number (percent) of "good" 1-km squares in the 1990s | | Percent change in the number of "good" squares | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 198 | 96 | (48) | 57 | (29) | -41 | *p*<0.0001 |
| Arable II | 467 | 189 | (40) | 155 | (33) | -18 | *p*<0.05 |
| Arable III | 185 | 67 | (36) | 46 | (25) | -31 | *p*<0.05 |
| Pastoral IV | 405 | 200 | (49) | 174 | (43) | -13 | *p*<0.05 |
| Pastoral V | 300 | 153 | (51) | 137 | (46) | -10 | n.s. |
| Marginal upland VI | 329 | 101 | (31) | 81 | (25) | -20 | *p*<0.05 |
| Upland VII | 285 | 16 | (6) | 12 | (4) | -25 | n.s. |
| **Totals** | **2169** | **822** | **(38)** | **662** | **(31)** | **-19** | ***p*<0.0001** |

changes. We examined changes in the availability of "good" 1-km squares for badgers between the two surveys, which habitats were favoured by badgers for building main setts, and then used discriminant analysis to determine which habitats or combination of habitats in a 1-km square were good predictors of the presence or absence of badger main setts. The analyses in this Chapter are confined to the 2169 1-km squares for which we had full habitat data for both surveys.

## 6.2 Changes in habitat availability

First, to determine whether there had been a change in availability of habitats preferred by badgers, we used the definitions of Reason, Harris & Cresswell (1993) to define "good" and "poor" squares. The availability of 1-km squares with five or more favoured habitat types declined by 19% in the nine years between the two surveys. However,

**Table 6.3.** Regional changes in the availability of "good" 1-km squares for badgers between the two surveys. The definition of a "good" 1-km square is given in the text.

| Region | Number of squares | Number (percent) of "good" 1-km squares in the 1980s | | Number (percent) of "good" 1-km squares in the 1990s | | Percent change in the number of "good" squares | Significance |
|---|---|---|---|---|---|---|---|
| North England | 162 | 55 | (34) | 47 | (29) | -15 | n.s. |
| North-west England | 69 | 37 | (54) | 31 | (45) | -16 | n.s. |
| North-east England | 116 | 36 | (31) | 23 | (20) | -36 | n.s. |
| West Midlands | 156 | 97 | (62) | 95 | (61) | -2 | n.s. |
| East Midlands | 143 | 54 | (38) | 34 | (24) | -37 | *p*<0.01 |
| Central England | 83 | 38 | (46) | 39 | (47) | 3 | n.s. |
| East Anglia | 158 | 43 | (27) | 38 | (24) | -12 | n.s. |
| South-west England | 200 | 111 | (56) | 88 | (44) | -21 | *p*<0.01 |
| Southern England | 123 | 65 | (53) | 35 | (28) | -46 | *p*=0.0001 |
| South-east England | 145 | 58 | (40) | 47 | (32) | -19 | n.s. |
| North Scotland | 364 | 60 | (16) | 37 | (10) | -38 | *p*<0.01 |
| South Scotland | 205 | 60 | (29) | 45 | (22) | -25 | n.s. |
| Mid and north Wales | 138 | 58 | (42) | 61 | (44) | 5 | n.s. |
| South Wales | 107 | 50 | (47) | 42 | (39) | -16 | n.s. |
| **Totals** | **2169** | **822** | **(38)** | **662** | **(31)** | **-19** | ***p*<0.0001** |

**Tables 6.4.** Changes in the number of main setts in "good" and "poor" 1-km squares for badgers between the two surveys by land class groups. The definitions of "good" and "poor" 1-km squares are given in the text.

| Land class group | Number of main setts in the 1980s | Number (percent) of main setts in "good" 1-km squares in the 1980s | | Number (percent) of main setts in "poor" 1-km squares in the 1980s | | Number of main setts in the 1990s | Number (percent) of main setts in "good" 1-km squares in the 1990s | | Number (percent) of main setts in "poor" 1-km squares in the 1990s | |
|---|---|---|---|---|---|---|---|---|---|---|
| Arable I | 90 | 48 | (53) | 42 | (47) | 93 | 45 | (48) | 48 | (52) |
| Arable II | 84 | 52 | (62) | 32 | (38) | 109 | 51 | (47) | 58 | (53) |
| Arable III | 18 | 9 | (50) | 9 | (50) | 17 | 9 | (53) | 8 | (47) |
| Pastoral IV | 168 | 103 | (61) | 65 | (39) | 207 | 119 | (57) | 88 | (43) |
| Pastoral V | 53 | 36 | (68) | 17 | (32) | 73 | 46 | (63) | 27 | (37) |
| Marginal upland VI | 32 | 19 | (59) | 13 | (41) | 45 | 28 | (62) | 17 | (38) |
| Upland VII | 2 | 1 | (50) | 1 | (50) | 5 | 1 | (20) | 4 | (80) |
| **Totals** | **447** | **268** | **(60)** | **179** | **(40)** | **549** | **299** | **(54)** | **250** | **(46)** |

**Tables 6.5.** Regional changes in the number of main setts in "good" and "poor" 1-km squares for badgers between the two surveys. The definitions of "good" and "poor" 1-km squares are given in the text.

| Region | Number of main setts in the 1980s | Number (percent) of main setts in "good" 1-km squares in the 1980s | Number (percent) of main setts in "poor" 1-km squares in the 1980s | Number of main setts in the 1990s | Percent change of main setts in "good" 1-km squares in the 1990s | Number (percent) of main setts in "poor" 1-km squares in the 1990s |
|---|---|---|---|---|---|---|
| North England | 18 | 8 (44) | 10 (56) | 19 | 8 (42) | 11 (58) |
| North-west England | 13 | 8 (62) | 5 (38) | 12 | 8 (67) | 4 (33) |
| North-east England | 17 | 9 (53) | 8 (47) | 19 | 8 (42) | 11 (58) |
| West Midlands | 37 | 30 (81) | 7 (19) | 70 | 54 (77) | 16 (23) |
| East Midlands | 25 | 15 (60) | 10 (40) | 28 | 11 (39) | 17 (61) |
| Central England | 20 | 9 (45) | 11 (55) | 24 | 13 (54) | 11 (46) |
| East Anglia | 9 | 6 (67) | 3 (33) | 13 | 3 (23) | 10 (77) |
| South-west England | 115 | 77 (67) | 38 (33) | 141 | 81 (57) | 60 (43) |
| Southern England | 42 | 26 (62) | 16 (38) | 49 | 20 (41) | 29 (59) |
| South-east England | 50 | 24 (48) | 26 (52) | 57 | 26 (46) | 31 (54) |
| North Scotland | 8 | 6 (75) | 2 (25) | 12 | 4 (33) | 8 (67) |
| South Scotland | 15 | 6 (40) | 9 (60) | 15 | 12 (80) | 3 (20) |
| Mid and north Wales | 34 | 25 (74) | 9 (26) | 45 | 31 (69) | 14 (31) |
| South Wales | 44 | 19 (43) | 25 (57) | 45 | 20 (44) | 25 (56) |
| **Totals** | **447** | **268 (60)** | **179 (40)** | **549** | **299 (54)** | **250 (46)** |

**Table 6.6.** The pattern of change between "good" and "poor" squares in the two surveys with and without main setts. The definitions of "good" and "poor" 1-km squares are given in the text.

| | Number (percent) of "good" 1-km squares in the 1980s | Number (percent) of "poor" 1-km squares in the 1980s | **Totals** | Number (percent) of "good" 1-km squares in the 1990s | Number (percent) of "poor" 1-km squares in the 1990s | **Totals** |
|---|---|---|---|---|---|---|
| Without a main sett | 611 (28) | 1199 (55) | **1810 (83)** | 433 (20) | 1292 (60) | **1725 (80)** |
| With a main sett | 211 (10) | 148 (7) | **359 (17)** | 229 (11) | 215 (10) | **444 (20)** |
| **Totals** | **822 (38)** | **1347 (62)** | **2169 (100)** | **662 (21)** | **1507 (69)** | **2169 (100)** |

whilst there has been a decline in all land class groups (Table 6.2), in some regions the changes were small, and there were even small increases in the availability of "good" squares (Table 6.3).

Whilst the number of main setts in "good" squares increased between the two surveys, there was a greater increase in the number of main setts in "poor" squares, and overall the proportion of main setts in "good" 1-km squares declined by 6% (Tables 6.4 and 6.5). Thus, most of the expansion has been into 1-km squares that were "poor" for badgers. The pattern of change between "good" and "poor" squares is summarised in Table 6.6; there was a net gain of 19 "good", and 67 "poor", 1-km squares with main setts. Yet in the 1990s, 65% of "good" 1-km squares still lacked a main sett, compared to 86% of "poor" 1-km squares. Thus, there was still a lot of 1-km squares with good badger habitat that lacked a main sett. The number of active main setts declined in 91 1-km squares. Of these, 51 were "good", and 40 were "poor", squares; a $X^2$ test showed that there was no significant difference ($X^2$=0.19, n.s.).

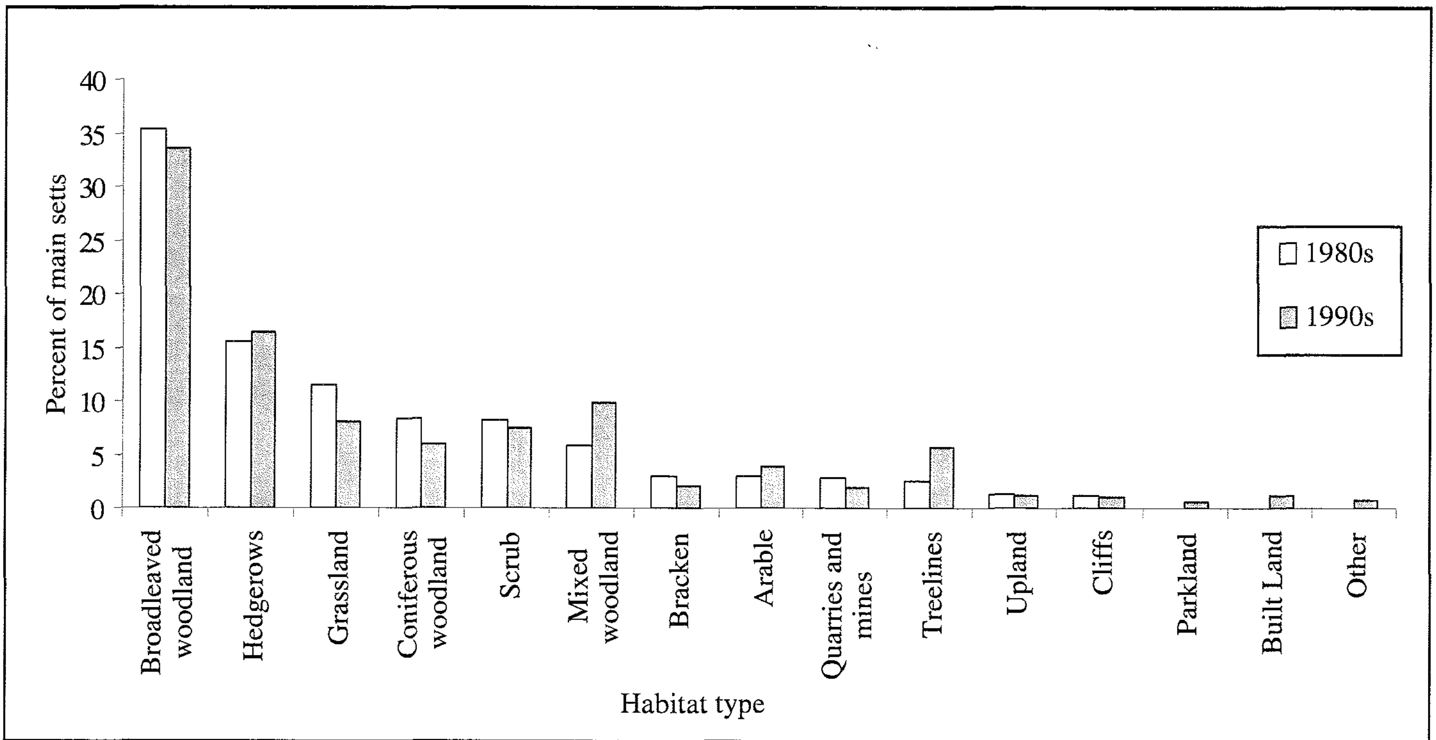



*Figure 6.1. The percent of main setts recorded in each habitat group across all land class groups in the 1980s and 1990s*

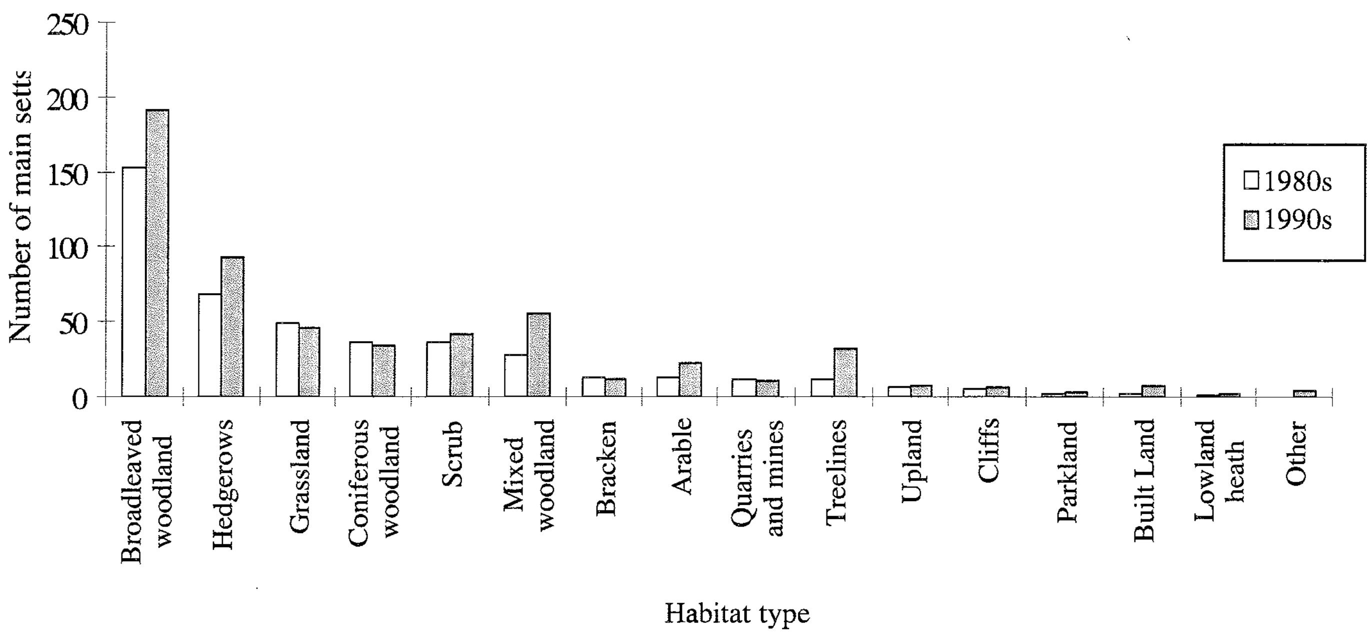



***Figure 6.2.*** *The number of main setts recorded in each habitat group across all land class groups in the 1980s and 1990s*

## 6.3 Habitats favoured as sites for main setts

Cresswell, Harris & Jefferies (1990) used the Bonferroni z-statistic to analyse habitat selection for main sett sites. Since there has been little overall change between the two surveys (Figure 6.1), that analysis has not been repeated here. Instead, we combined the habitats listed in Appendix 10.3 into functionally similar habitat groups as follows: *hedgerows* - hedgerows; *treelines* - treelines; *broadleaved woodland* - semi-natural broadleaved woodland, broadleaved plantations, young plantations; *coniferous woodland* - semi-natural coniferous woodland, coniferous plantations; *mixed woodland* - semi-natural mixed woodland, mixed plantations; *parkland* - parkland; *scrub* - tall scrub, low scrub; *bracken* - bracken; *lowland heath* - lowland heaths; *upland* - heather moorlands, blanket bog, upland unimproved grassland; *grassland* - lowland unimproved grassland, semi-improved grassland, improved grassland; *arable* - arable; *cliffs* - unquarried inland cliffs, vertical coastal cliffs, sloping coastal cliffs; *quarries and mines* - quarries and open-cast mines; *built land* - built land, amenity grassland; *other* - all the other habitat types listed in Appendix 10.3. We then looked at the number of main setts in each habitat group within each land class group. Across all land class groups except Arable III, broadleaved wood-

**Table 6.7.** The effects of habitat type on the size of main setts in the two surveys; only 1-km squares with a single main sett were included in the analysis. Sett size is defined as the number of holes of all types.

| Habitat type | Number of 1-km squares | Mean sett size ±s.e. in the 1980s | Number of 1-km squares | Mean sett size ±s.e. in the 1990s |
|---|---|---|---|---|
| Hedgerow | 41 | 13.7±1.2 | 63 | 17.2±1.2 |
| Broadleaved woodland | 71 | 12.3±1.0 | 127 | 15.0±0.9 |
| Scrub | 39 | 14.7±1.8 | 45 | 13.6±1.3 |
| Grassland | 32 | 11.0±1.6 | 37 | 11.4±1.6 |

land was the most important habitat for main sett sites, followed by hedgerows. In the Arable III land class group, coniferous woodland was more important. Since there were generally few differences between land class groups, these were combined to show the overall changes between the two surveys (Figure 6.1 and 6.2).

To look at the effect of habitat on the size of main setts, we compared the size of main setts in the four main habitat types. These were hedgerows; semi-natural broadleaved woodland; scrub (which included tall scrub, low scrub and bracken); and grassland (which included lowland unimproved, semi-improved and improved grassland). We confined the analysis to those 1-km squares that contained only one main sett to eliminate any influences of density on main sett size, and we grouped the samples across land class groups. The results are shown in Table 6.7. In the 1980s, there was no difference in main sett size in the different habitat types (Kruskal-Wallis test; $X^2$=3.11, n.s.), whereas in the 1990s there was (Kruskal-Wallis test; $X^2$=7.87, $p$<0.05). This was because the main setts in grassland were smaller; there was no significant difference in main sett size in the other three habitat types (Kruskal-Wallis test; $X^2$=2.91, n.s.). In Ireland it has been suggested that main setts are smaller than in Britain because they are mainly built in hedgerows, and this restricts their size (Smal, 1995). Yet in Britain setts built in hedgerows are no smaller than those in woodland.

## 6.4 Discriminant analyses to predict the presence of main setts

We then used discriminant analysis to classify 1-km squares as either having or not having badger main setts on the basis of the habitat variables recorded by the surveyors. This should show which habitats, or combination of habitats, are associated with the presence or absence of main setts. We carried out the analysis separately for each land class group, because the previous analysis showed that the habitats associated with main setts in one landscape type could be different from those associated with setts in other landscapes. Furthermore, if we based the discriminant model on the country as a whole, it would be biased to the high density areas of southern Britain, thereby masking habitats which may be locally important to badgers in other parts of the country.

For this approach, habitats were selected on the basis of how well they could discriminate between 1-km squares which did or did not contain main setts. First, the model determined the abundance of the various habitat types in 1-km squares with and without main setts, and then calculated a coefficient for each of these variables; these were then used to calculate a discriminant "score" for each 1-km square. Finally, these scores were used to predict whether a particular 1-km square contained a main sett. To determine how well habitat variables performed as predictors of the presence or absence of main setts, the predicted results were compared with the observed results; this is presented as a percentage of 1-km squares correctly classified.

To interpret the results of this analysis, the *prior*

**Table 6.8.** Results of the discriminant analysis using the habitat data from the 1980s to predict the presence or absence of main setts in a 1-km square.

| Land class group | Percent 1-km squares with main setts correctly predicted | Percent prior probability of main setts being present | Percent 1-km squares correctly classified overall |
|---|---|---|---|
| Arable I | 62 | 35 | 74 |
| Arable II | 57 | 16 | 70 |
| Arable III | 56 | 9 | 89 |
| Pastoral IV | 74 | 31 | 67 |
| Pastoral V | 62 | 15 | 77 |
| Marginal upland VI | 66 | 9 | 82 |
| Upland VII | 50 | 1 | 99 |

**Table 6.9.** Results of the discriminant analysis using the habitat data from the 1990s to predict the presence or absence of main setts in a 1-km square.

| Land class group | Percent 1-km squares with main setts correctly predicted | Percent prior probability of main setts being present | Percent 1-km squares correctly classified overall |
|---|---|---|---|
| Arable I | 64 | 34 | 75 |
| Arable II | 60 | 20 | 70 |
| Arable III | 60 | 8 | 95 |
| Pastoral IV | 72 | 39 | 67 |
| Pastoral V | 68 | 21 | 82 |
| Marginal upland VI | 53 | 11 | 80 |
| Upland VII | 40 | 2 | 98 |

*probability* needs to be known. This is the probability of predicting the presence of a main sett for a particular land class group by chance alone. For instance, if 70% of the 1-km squares in a given land class group did not contain main setts, there is a 70% probability that a particular 1-km square could be predicted not to have a main sett by chance alone. Thus, if a particular habitat type or combination of habitat types was important in predicting the presence or absence of a main sett, the percent of 1-km squares correctly classified using the discriminant function models must be greater than the percent correctly classified on the basis of prior probabilities alone.

Since we were primarily interested in investigating how well the habitat variables predict the presence of main setts, we present the results for the analyses for the 1980s and 1990s (Tables 6.8 and 6.9) as the percent of 1-km squares correctly predicted as having a main sett, and the prior probability. We have also included the overall results, which is the percent of 1-km squares correctly classified as having or not having a main sett. Unlike the habitat selection analysis, the habitats were not grouped because the discriminant model performs better with all the habitats included.

Although there have been changes in the percent of 1-km squares with main setts, as well as changes in the habitats selected for main sett sites, the results of the discriminant analyses are broadly similar between the two surveys. This was to be expected, given that the same 1-km squares were used for both analyses. Discriminant analysis was then used to isolate those variables which separate the 1-km squares with and without main setts. Stepwise selection produced several statistically significant habitat variables, which were then examined to see if they could explain the pattern of main sett changes between the 1980s and 1990s. Having selected the habitats which best predict the presence or absence of main setts, we used the results of the analysis of the habitats selected for sett sites (section 6.2) to group habitats into three categories for both the 1980s and the 1990s: "specific" habitats, "general" habitats, and "avoided" habitats (Tables 6.10 and 6.11). Specific habitats were those which predicted the presence of main setts and were also commonly used as main sett sites; general habitats were those variables which predicted the presence of main setts but which were not commonly used as sett sites - they were often foraging habitats; and avoided habitats were those which predicted the absence of main setts.

Whilst the pattern of discriminating variables remained broadly similar from the 1980s to the 1990s, there were some differences. To examine these further, we selected the 1-km squares which had no main setts in the 1980s and remained so in the 1990s, and those which had no main setts in the 1980s but which did in the 1990s. We then carried out the stepwise discriminant procedure on these two sub-groups of 1-km squares (Table 6.12). Not surprisingly, this showed that several of the habitats which best predict "appearance" of main setts are those which also predicted the "presence" of main setts. Thus, main setts are most likely to appear in 1-km squares with an abundance of "specific" or "general" habitats. However, these habitat types were already widely distributed in the 1980s (Reason, Harris & Cresswell, 1993), and an analysis of habitat change between the two surveys shows that there were no major changes in the

**Table 6.10.** Results of the stepwise analysis for those habitat variables which best predicted the presence and absence of main setts in each land class group in the 1980s. The definitions of "specific", "general" and "avoided" habitats are given in the text.

| Land class group | "Specific" habitats | "General" habitats | "Avoided" habitats |
|---|---|---|---|
| Arable I | broadleaved woodland<br>mixed woodland<br>coniferous plantations<br>tall scrub<br>bracken<br>quarries and open cast mines | improved grassland<br>semi-improved grassland<br>lowland unimproved grassland | built land |
| Arable II | broadleaved woodland<br>mixed plantation<br>coniferous plantation<br>hedgerows<br>tall scrub<br>quarries and open cast mines | improved grassland<br>semi-improved grassland | - |
| Arable III | coniferous plantations<br>treelines | running natural water<br>standing manmade water | - |
| Pastoral IV | broadleaved plantations<br>mixed plantation<br>tall scrub<br>bracken | improved grassland<br>running natural water | sea<br>arable<br>young plantation<br>built land |
| Pastoral V | broadleaved woodland<br>broadleaved plantations<br>low scrub | semi-improved grassland<br>amenity grassland | upland unimproved grassland<br>built land |
| Marginal upland VI | treelines<br>broadleaved woodland<br>broadleaved plantations<br>hedgerows<br>low scrub<br>bracken<br>quarries and open cast mines | running natural water | - |
| Upland VII | - | - | - |

availability of "specific" or "general" habitats (Table 6.13).

We then looked at the relationship between badger density, in terms of the number of social groups, and the availability of the "specific" and "general" habitats shown in Table 6.13; for the "specific" habitats, the linear features were treated separately. With either just the lowland land class groups or all land class groups, there was no relationship between badger density and the proportion of "specific" habitats per 1-km square ($r_s$=0.30 and $r_s$=-0.32 respectively, both n.s.) or the proportion of "general" habitats ($r_s$=0.50 and $r_s$=0.53 respectively, both n.s.). With the length of linear "specific" habitats, however, there was a relationship with both just the five lowland land class groups ($r_s$=0.90, $p$<0.05) and for all land class groups ($r_s$=0.93, $p$<0.01). Thus there is no simple relationship between badger density and the proportion of either "specific" or "general" habitats in a 1-

**Table 6.11.** Results of the stepwise analysis for those habitat variables which best predicted the presence and absence of main setts in each land class group in the 1990s. The definitions of "specific", "general" and "avoided" habitats are given in the text.

| Land class group | "Specific" habitats | "General" habitats | "Avoided" habitats |
|---|---|---|---|
| Arable I | broadleaved woodland<br>broadleaved plantations<br>mixed woodland<br>mixed plantation<br>tall scrub<br>bracken<br>quarries and open cast mines | improved grassland<br>semi-improved grassland | upland unimproved grassland |
| Arable II | broadleaved woodland<br>treelines<br>tall scrub<br>hedgerows<br>quarries and open cast mines | improved grassland<br>semi-improved grassland | arable |
| Arable III | broadleaved woodland<br>mixed plantation<br>coniferous plantations | semi-improved grassland<br>amenity grassland<br>running canalised water<br>standing manmade water | young plantation<br>blanket bog<br>coastal cliffs<br>upland unimproved grassland |
| Pastoral IV | broadleaved woodland<br>mixed woodland<br>mixed plantation<br>tall scrub<br>hedgerows<br>treelines | - | blanket bog<br>built land |
| Pastoral V | broadleaved woodland<br>treelines<br>hedgerows<br>quarries and open cast mines | - | lowland heaths<br>unquarried inland cliffs<br>blanket bog |
| Marginal upland VI | treelines<br>broadleaved woodland<br>broadleaved plantations<br>mixed plantation<br>coniferous plantations<br>hedgerows | semi-improved grassland | built land |
| Upland VII | - | - | - |

km square. This supports the conclusion of Reason, Harris & Cresswell (1993), who found that it was the presence of preferred habitats, rather than the amount of habitat, that influenced badger density. This is not to say that there is no relationship, but that the relationship cannot be identified with this broad-scale analysis.

**Table 6.12.** Results of the stepwise analysis for those habitat variables which best predicted the appearance of main setts between the two surveys.

| Land class group | Habitats predicting the appearance of main setts |
|---|---|
| Arable I | mixed plantation<br>tall scrub<br>improved grassland<br>arable |
| Arable II | coniferous plantation<br>hedgerows<br>improved grassland<br>semi-improved grassland |
| Arable III | coniferous plantation<br>low scrub<br>improved grassland<br>upland unimproved grassland |
| Pastoral IV | broadleaved woodland<br>broadleaved plantation<br>hedgerows |
| Pastoral V | broadleaved woodland<br>mixed woodland<br>hedgerows<br>tall scrub<br>built land |
| Marginal upland VI | broadleaved woodland<br>hedgerows<br>improved grassland<br>bracken |
| Upland VII | - |

## 6.5 The influence of changes in habitat quality and persecution levels on badger numbers

In this section we compare the impact of habitat changes and changes in persecution levels on the changes in the badger population. It was not possible to do a multiple regression analysis of these various factors on the regional changes in the number of main setts because the data were not normally distributed. So as an initial step we carried out a Spearman rank correlation; there was no significant correlation between regional changes in the number of main setts and the change in the number of "good" 1-km squares ($r_s$=-0.27, n.s.), changes in the level of badger digging ($r_s$=0.09, n.s.) or changes in the level of sett blocking ($r_s$=0.12, n.s.).

We then undertook a discriminant function analysis to compare the habitat richness, levels of digging and levels of sett blocking in the 1980s between those squares which subsequently gained and lost main setts between the two surveys (Table 6.14). Richness was defined as the number of the "favoured" habitats identified by Reason, Harris & Cresswell (1993) that were present in the 1-km square. This analysis only included those squares which had a main sett in the 1980s, because where there were no main setts in the 1980s, there could not have been any digging or blocking. This analysis showed that of the three factors, richness was the only significant discriminating variable between those squares which gained main setts and those which lost main setts between the two surveys ($p$<0.05). Overall, 62% of squares were correctly predicted to lose or gain a main sett based on richness alone. However, since the overall prior probability was 57%, this result was only slightly better than would have been predicted by chance. Furthermore, habitat richness by itself was only effective in predicting those 1-km squares which gained a main sett; 49% were correctly predicted (prior probability 31%). Of the 1-km squares that lost a main sett, 68% were correctly predicted, but the prior probability was 69%. Thus, whilst habitat richness influences the increase in the number of main setts, it does not explain the loss of main setts. Here other factors, particularly one or more forms of persecution, are likely to be important, but in this analysis changes in the levels of digging or blocking by themselves did not significantly influence the loss or gain of main setts. This result is likely to have been influenced by the relatively small number of main setts in the sample available for the analysis which had been dug or blocked.

The discriminant analysis also showed that those squares which gained additional main setts had a mean richness score greater than 5.0, which Reason, Harris & Cresswell (1993) had also identified as the critical number of favoured habitats, but that the squares which lost setts had a mean richness score of less than 5.0 (Table 6.14). Habitat richness in those squares that gained main setts was significantly greater than in those squares where the number of main setts stayed the same (Mann-Whitney test; $z$=-2.13, $p$<0.05). The habitat richness was not significantly different between 1-km squares which lost main setts and 1-km squares in

**Table 6.13.** Changes in the availability of "specific" and "general" habitats between the two surveys. All figures are means per 1-km square; hedgerows and treelines are given in metres, all other habitat types are hectares (which is the same as the percent of a 1-km square).

| | Arable I | | Arable II | | Arable III | | Pastoral IV | | Pastoral V | | Marginal upland VI | | Upland VII | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980s | 1990s | 1980s | 1990s | 1980s | 1990s | 1980s | 1990s | 1980s | 1990s | 1980s | 1990s | 1980s | 1990s |
| **Specific habitats** | | | | | | | | | | | | | | |
| Hedgerows | 3040 | 3680 | 3750 | 3260 | 1500 | 1190 | 4860 | 4530 | 4320 | 3980 | 980 | 910 | 17 | 12 |
| Treelines | 610 | 560 | 620 | 550 | 420 | 330 | 530 | 520 | 650 | 540 | 370 | 340 | 20 | 20 |
| **Totals** | **3650** | **4240** | **4370** | **3810** | **1920** | **1520** | **5390** | **5050** | **4970** | **4520** | **1350** | **1250** | **37** | **32** |
| Semi-natural broad-leaved woodland | 6.7 | 6.2 | 3.4 | 3.4 | 2.0 | 1.4 | 3.6 | 3.3 | 3.8 | 3.6 | 2.6 | 2.2 | 1.4 | 2.0 |
| Broadleaved plantations | 1.7 | 1.1 | 1.4 | 1.4 | 0.1 | 0.1 | 0.9 | 0.4 | 0.4 | 0.2 | 0.2 | 0.1 | 0.0 | 0.1 |
| Coniferous plantations | 2.5 | 1.8 | 1.0 | 0.8 | 6.6 | 6.5 | 1.4 | 1.0 | 3.9 | 4.0 | 8.6 | 8.7 | 11.9 | 11.3 |
| Semi-natural mixed woodland | | | | | | | | | | | | | | |
| Mixed plantations | 1.3 | 1.9 | 0.3 | 0.4 | 0.7 | 1.0 | 0.3 | 0.5 | 0.5 | 0.6 | 0.2 | 0.4 | 0.0 | 0.0 |
| Tall scrub | 0.6 | 0.5 | 0.2 | 0.3 | 0.2 | 0.2 | 0.4 | 0.5 | 0.3 | 0.3 | 0.1 | 0.2 | 0.0 | 0.0 |
| Low scrub | 0.6 | 0.5 | 0.4 | 0.3 | 0.7 | 0.7 | 1.2 | 1.4 | 0.7 | 0.6 | 0.4 | 0.6 | 0.2 | 0.2 |
| Bracken | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.2 | 0.7 | 0.7 | 0.4 | 0.5 | 3.3 | 3.0 | 1.4 | 1.1 |
| Quarries and open-cast mines | 0.4 | 0.2 | 0.4 | 0.4 | 0.4 | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.2 | 0.4 | 0.1 | 0.1 |
| **Totals** | **16.2** | **15.3** | **7.9** | **7.8** | **11.8** | **11.4** | **9.0** | **9.1** | **10.9** | **10.9** | **16.0** | **16.1** | **15.6** | **15.2** |
| **General habitats** | | | | | | | | | | | | | | |
| Lowland unimproved grassland | 3.8 | 3.8 | 1.4 | 1.8 | 1.4 | 1.3 | 2.4 | 2.6 | 1.5 | 3.1 | 0.6 | 1.8 | 0.5 | 1.2 |
| Semi-improved grass-land | 5.9 | 6.7 | 7.4 | 6.6 | 10.1 | 7.4 | 9.6 | 13.3 | 15.6 | 14.9 | 16.0 | 12.2 | 4.3 | 4.3 |
| Improved grassland | 10.6 | 9.0 | 9.5 | 8.5 | 12.6 | 16.8 | 21.7 | 18.5 | 22.0 | 21.5 | 10.4 | 16.0 | 2.5 | 3.0 |
| **Totals** | **20.3** | **19.5** | **18.3** | **16.9** | **24.1** | **25.5** | **33.7** | **34.4** | **39.1** | **39.5** | **27.0** | **30.0** | **7.3** | **8.5** |

**Table 6.14.** The habitat richness, severity of digging and severity of hole blocking for 1-km squares for different changes in the number of main setts. The analysis was confined to those 1-km squares which already had a main sett in the 1980s. The figures are means±s.e.

| Change in the number of main setts between the 1980s and the 1990s | Sample size | Mean habitat richness in the 1980s | Mean digging score in the 1980s | Mean hole blocking score in the 1980s |
|---|---|---|---|---|
| Contained fewer main setts in 1990s than in 1980s | 91 | 4.7±0.2 | 0.12±0.05 | 0.25±0.07 |
| Increased number of main setts from 1980s to 1990s | 41 | 5.4±0.2 | 0.14±0.01 | 0.24±0.01 |
| No change in number of main setts from 1980s to 1990s | 227 | 4.8±0.0 | 0.18±0.05 | 0.31±0.05 |
| Had no main setts in 1980s, did in 1990s | 150 | 5.0±0.1 | - | - |
| Contained no main setts in 1980s or 1990s | 1660 | 3.5±0.1 | - | - |
| **Total** | **2169** | | | |

which the number of main setts stayed the same (Mann-Whitney test; $z$=-0.39, n.s.). However, it was significantly lower in those 1-km squares in which there were no main setts in both surveys, and those in which there were no main setts in the 1980s but had main setts in the 1990s (Mann-Whitney test; $z$=-9.20, $p$<0.0001).

We then looked for differences in habitat richness between those squares which gained a main sett, regardless of whether one was present in the 1980s, and those which lost a main sett between the two surveys. Whilst this analysis showed a similar trend, in that those 1-km squares which gained main setts had a mean habitat richness greater than 5.0, and those which lost main setts had a mean habitat richness of less than 5.0 (Table 6.14), the difference was not significant (Mann-Whitney test; $z$=-1.80, n.s.). Using a discriminant function analysis, the change in habitat richness alone could not be used to discriminate between those 1-km squares which gained or lost main setts when either all the gains and losses were considered or when only those 1-km squares which had a sett in the 1980s were considered.

Finally, since habitat richness was an important factor in influencing whether a 1-km square did or did not have a main sett, we compared the changes in main sett density in "good" and "poor" 1-km squares in the 1980s and 1990s (Table 6.15). Mann-Whitney tests showed that "good" 1-km squares had significantly higher main sett densities in all land class groups except Arable I and Arable III in the 1980s, and all land class groups in the 1990s. Generally, main sett density increased in both "good" and "poor" 1-km squares between the two surveys; the increases were significant for Arable I "good" 1-km squares, Arable II "poor" 1-km squares, Pastoral IV "good" 1-km squares and Marginal upland VI "good" 1-km squares.

## 6.6 Discussion

In this Chapter we have shown that the pattern of habitat selection by badgers has not changed significantly between the two surveys, but that the availability of "good" 1-km squares for badgers have declined by 19% between the two surveys, and the proportion of badger main setts found in "good" squares has declined by 6%. However, there was no evidence that a shortage of suitable habitats was limiting badger numbers in the 1980s, and even though the availability of "good" 1-km squares declined between the two surveys, in the 1990s the majority of "good" 1-km squares still contained no main sett.

The analyses presented here have also reinforced the earlier conclusion of Reason, Harris & Cresswell (1993), who showed that habitat richness was an important factor influencing the distribution and density of badgers. Whilst we have shown that 1-km squares where main setts have survived or ap-

**Table 6.15.** Comparison of main sett densities in "good" and "poor" 1-km squares in the 1980s and 1990s, by land class group. The definitions of "good" and "poor" 1-km squares are given in the text. Land class group Upland VII has been excluded because there were so few 1-km squares with main setts. The figures are means±s.e.

| Type of 1-km square | Number of 1-km squares in the 1980s | Mean main sett density ±s.e. in the 1980s | Signif-icance of difference within land class group | Number of 1-km squares in the 1990s | Mean main sett density ±s.e. in the 1990s | Signif-icance of difference within land class group | Signif-icance of change between surveys |
|---|---|---|---|---|---|---|---|
| Arable I - good | 96 | 0.50±0.07 | n.s. | 57 | 0.79±0.10 | $p<0.0001$ | $p<0.05$ |
| Arable I - poor | 102 | 0.41±0.07 | | 141 | 0.34±0.05 | | n.s. |
| Arable II - good | 189 | 0.28±0.04 | $p<0.001$ | 155 | 0.33±0.05 | $p<0.01$ | n.s. |
| Arable II - poor | 278 | 0.11±0.02 | | 312 | 0.19±0.02 | | $p<0.05$ |
| Arable III - good | 67 | 0.13±0.04 | n.s. | 46 | 0.20±0.07 | $p<0.01$ | n.s. |
| Arable III - poor | 118 | 0.08±0.03 | | 139 | 0.06±0.02 | | n.s. |
| Pastoral IV - good | 200 | 0.51±0.06 | $p<0.01$ | 174 | 0.68±0.07 | $p<0.0001$ | $p=0.01$ |
| Pastoral IV - poor | 205 | 0.32±0.05 | | 231 | 0.38±0.04 | | n.s. |
| Pastoral V - good | 153 | 0.24±0.04 | $p<0.05$ | 137 | 0.34±0.06 | $p<0.01$ | n.s. |
| Pastoral V - poor | 147 | 0.12±0.03 | | 163 | 0.17±0.03 | | n.s. |
| Marginal upland VI - good | 101 | 0.19±0.05 | $p<0.005$ | 81 | 0.35±0.07 | $p<0.0001$ | $p<0.05$ |
| Marginal upland VI - poor | 228 | 0.06±0.02 | | 248 | 0.07±0.02 | | n.s. |
| **Totals - good** | **806** | **0.33±0.02** | $\mathbf{p<0.0001}$ | **650** | **0.42±0.02** | $\mathbf{p<0.0001}$ | $\mathbf{p=0.0001}$ |
| **Totals - poor** | **1078** | **0.16±0.01** | | **1234** | **0.19±0.01** | | $\mathbf{p=0.01}$ |

peared between the two surveys have higher mean habitat richness scores, other factors are also influencing the survival of badger main setts, and habitat richness in itself cannot be used to discriminate between squares where changes in the number of main setts have or have not occurred.

It is also unclear whether habitat richness is actually influencing the persistence of badger main setts, or whether habitat richness is an indication of more sensitive environmental management overall, and that part of this is a willingness of the landowner to tolerate the presence of badgers. As we showed in Chapter 3, roughly a third of all main setts were lost between the two surveys, and the main factor leading to these losses was probably persecution.

Whilst it would appear that in much of Britain suitable habitats for badgers are not limited in availability, there is no basis on which to decide when habitat availability could become a limiting factor. In the Netherlands, there was a substantial decline in badger numbers between 1960 and 1980, and landscape changes were thought to be an important contributory factor. Van der Zee *et al.* (1992), however, showed that the change in the number of small landscape elements, such as the clearance of hedgerows, old orchards and small woods, played a minor role in this decline, although the number of setts declined more in open landscapes than in woodland. The number of roads was more closely related to the decline in badger numbers.

In Britain an estimated 50,000 badgers were killed on the roads each year in the 1980s (Harris *et al.*, 1992). Whilst such a rate of mortality must have a significant impact on the badger population, so far there are no data on which to quantify the impact of these losses. In Essex, road type and distance to the nearest road have been shown to have an effect on badger distribution (Skinner, Skinner & Harris, 1991b), but traffic flow was not correlated with the seasonal distribution of badger road deaths (Skinner, Skinner & Harris, 1991a). Roads also fragment the landscape, and badgers are vulnerable to the effects of fragmentation (Bright, 1993). At present it is unknown how much additional landscape change, and particularly increases in the road network and/or traffic flow, have to occur before similar effects to those seen in the Netherlands are repeated in Britain.

Thus at present it is clear that the observed changes in main sett distribution and abundance, and the increase in badger numbers generally, are unlikely to have been caused by land use changes, since all the observed habitat changes should if anything have led to a reduction in badger numbers, not an increase.

# 7. Understanding the changes in the British badger population

## 7.1 Introduction

We have shown that in the nine years between the two surveys, the badger population in Britain underwent a significant increase, and we have attributed this to enhanced protection leading to the reduction in a variety of forms of badger persecution. As we explained in Chapter 1, hitherto it had always been assumed that any changes in the badger population would be slow, and so this sudden population recovery was an unexpected result. So in this Chapter, we analyse these badger population changes, and in particular consider the mechanisms by which they may have occurred. We then consider possible future changes in the badger population in Britain.

## 7.2 Modelling the growth of the badger population

In this section we use simple computer models to examine the relative importance of changes in fecundity and adult survivorship in driving badger population growth. The aim was simply to try to understand how the observed rates of population increase could have occurred, and whether this conforms to our hypothesis that the badger population has benefited from a decrease in persecution levels. Populations can grow by two mechanisms: there can be an increase in the number of young produced, and/or there can be a decrease in mortality rates. Since a reduction in persecution levels is more likely to lead to an reduction in mortality rates rather than an increase in fecundity, we particularly wanted to determine the impact of changes in adult survival on both population size and rates of population growth.

### *7.2.1 Background to the model*

The model we used for these analyses was *RAMAS* (Applied Biomathematics, Setauket, New York, 11733). This is a Leslie matrix model which incorporates data on age structure, fecundity and adult survivorship; both fecundity and survivorship can change with age (Ferson & Akçakaya, 1988). This type of model can, therefore, be used to analyse changes in both population size and age structure. A further advantage of a Leslie matrix model is that it can be used to estimate the rate of increase of a population (Usher, 1972). For this, *eigenvalues* ($\lambda$) are calculated; when $\lambda=1$, the population is stable, when $\lambda$ is greater than 1, the population is increasing, and when $\lambda$ is less than 1 the population is decreasing.

Density dependence can also be included in the model, in the form of the logistic equation:-

$$R=N\,[1+r\,((K-N)\,/\,K)]$$

where the annual recruitment to the first age class, R, is a density dependent function of N, the number of cubs produced each year. In *RAMAS*, K represents the level of recruitment that occurs at the equilibrium population density, and r is a parameter which determines the level of change in recruitment as density changes. At low densities, approximately 1+r multiplied by the potential number of offspring become recruits, and this amounts to an increase in fecundity at low densities (Ferson & Akçakaya, 1988). Random variation is introduced to the model by adding a coefficient of variation of 0.1 into the estimates of fecundity and adult survivorship.

### *7.2.2 Parameters used in the analyses*

In developing these models, we relied on data on badger population biology published by Anderson & Trewhella (1985), Cheeseman *et al.* (1987; 1988), Harris & Cresswell (1987), Cresswell *et al.* (1992), Harris, Cresswell & Cheeseman (1992), Page, Ross & Langton (1994) and White & Harris (1995). The information used in the *RAMAS* analyses are summarised in Table 7.1. The initial adult population size fluctuated around 60 adults, which produced 40 cubs. Values of r=0.5 and K=40 produced a stable model population ($\lambda=1$). During the simulations, the age structure will vary slightly because of

**Table 7.1.** The initial data used in the *RAMAS* model; the sources for the data are explained in the text.

| Age class | Number in age class | Fecundity | Survivorship |
|---|---|---|---|
| Cub | 40 | 0 | 0.60 |
| Second year | 20 | 0 | 0.70 |
| Third year | 14 | 0 | 0.70 |
| Fourth year | 10 | 2 | 0.70 |
| Fifth year | 7 | 2 | 0.70 |
| Sixth year | 5 | 2 | 0.70 |
| Seventh year | 3 | 2 | 0.70 |
| Eighth year and older | 1 | 2 | 0.70 |

the stochastic variation included within the model. The figures for fecundity are based on the figures given by Cresswell *et al.* (1992), and females did not breed until their fourth year. The 60 adult badgers were assumed to be spread across 10 social groups, each containing six adult badgers. The adult population was also biased towards females, such that 70% of adults were female. This reflects the situation seen in natural populations, where the sex ratio of cubs is roughly equal but the adult population is heavily skewed towards females. This reflects the higher mortality rate for adult males than females (Cheeseman *et al.*, 1987; Harris & Cresswell, 1987).

To make the predictions of the model as realistic as possible, we included density dependent effects on productivity. This occurs in real badger populations; Cresswell *et al.* (1992) found that at high densities, the overall fecundity of females is reduced, Woodroffe & Macdonald (1995) found that in larger groups a greater proportion of females lost their cubs, and Rogers, Cheeseman & Langton (1997) produced evidence for density dependent effects on adult body weight. In our model, as the adult population grew, the number of cubs produced did not rise in line with the number of adults, so that density dependence limited the number of cubs that were produced. If the population declined, the fecundity per female rose.

### *7.2.3 Output from the model*

With the stable population, fecundity and adult survivorship were increased by increments of 10% to examine their relative effects on population size. For each run of the model, 50 simulations were undertaken, with each one slightly different because stochasticity was applied to the fecundity and adult survivorship values. Each simulation lasted twenty years.

The model badger population was found to be highly sensitive to changes in adult survivorship, much more so than fecundity. The results are compared in Figures 7.1 and 7.2; for these, standard deviations rather than standard errors are shown, to illustrate the limits between which the population size is likely to vary. Several important points emerge from these graphs. Firstly, after changing

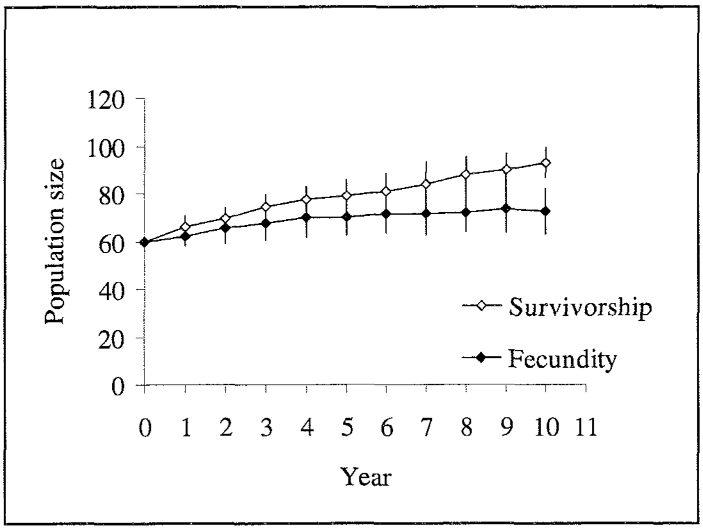



*Figure 7.1: The effect of increasing fecundity and survivorship by 10% per annum on the size of the model badger population. The figures are the means±s.d. for 50 runs of the model*

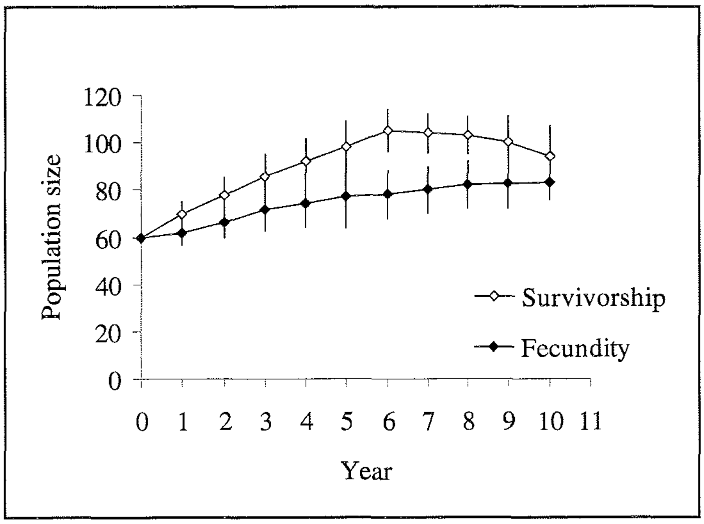



*Figure 7.2. The effect of increasing fecundity and survivorship by 18% per annum on the size of the model badger population. The figures are the means±s.d. for 50 runs of the model*

either fecundity or adult survivorship, the badger population responded rapidly, and appeared to be reaching a new equilibrium size within ten years. However, of the two parameters, a consistent increase in adult survivorship had the biggest impact; a 10% increase in adult survivorship led to a 55% increase in badger numbers in ten years. To obtain a 75% increase in the badger population, adult survivorship had to be increased by 18%. Then the badger population rose rapidly, increasing by 75% in six years. After this, the population declined because of a reduction in fecundity brought about by density dependence.

In reality, the badger population is unlikely to reach a stable end point. In Britain there are still large numbers of apparently suitable 1-km squares that are not yet occupied by badgers. It is likely, therefore, that dispersal, which was not included in the model population, would lead to the establishment of new social groups, thereby mitigating the effects of a density-dependent reduction in fertility. Thus, the decline seen in the model population would be unlikely to occur in reality. Our field data also suggest that dispersal would occur after the badger population had reached a critical density; in section 4.5 we showed that new social groups were established after a population increase of roughly 25% on the 1980s group size.

Changes in fecundity did not bring about such striking changes in population size. In fact, increased levels of fecundity could not bring about a 75% increase in population size. This is because density dependent effects reduced the likelihood of offspring surviving, and there is an upper limit on the number of cubs produced per social group. This is consistent with the observations of Cresswell *et al.* (1992), who found that there was no net reproductive gain from living in a large social group, and that there was a decline in productivity per adult with increasing group size. Thus, in the model, increasing fecundity from two to three offspring per female only led to a population increase of 30%, and further increases in fecundity did not lead to further increases in population size.

There are no data to show whether either fecundity or adult survivorship have changed in British badger populations. However, there is one long term series of data which provide the opportunity to compare real data with the results of our modelling study. At Woodchester Park, social group size has been monitored since 1978 (Chris Cheeseman, *pers. comm.*). As in our models, the badger population grew quickly (Figure 7.3), with the rate of growth slowing down after about ten years. The situation at Woodchester Park provides an interesting comparison, because as in our model population the number of social groups stayed the same, and there was little dispersal. At Woodchester, the initial mean group size was less than three adults. However, direct enumeration was used to estimate population size (Cheeseman *et al.*, 1987), and so in the early years the number of animals may have been under-estimated. Using the data for the years 1985 to 1994, which provide the most accurate measure of population size, mean group size at Woodchester increased from 5.3 to 8.8, an increase of 66%. Using our model, we calculated that this rate of growth would have been achieved by increasing adult survivorship by 14%. So there is some evidence to suggest that changes in the level of adult survivorship that we used in our models are realistic, and could be achieved in real badger populations. Also, the population growth at Woodchester Park was thought to have occurred following a reduction in persecution levels (Neal & Cheeseman, 1996).

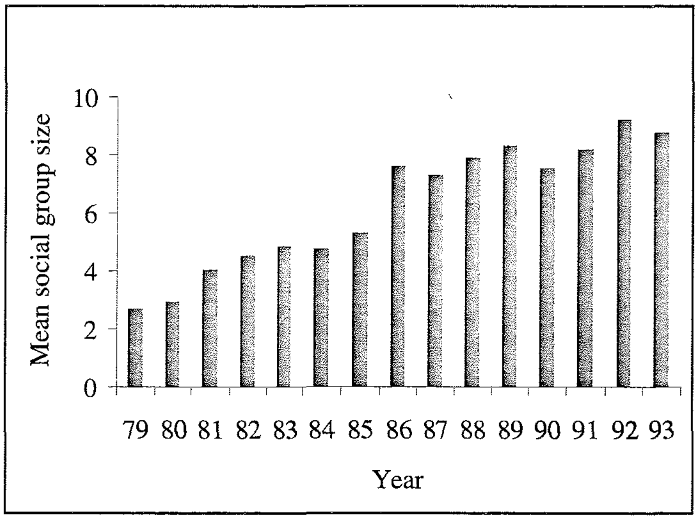



*Figure 7.3. Changes in the mean number of adult badgers per social group for the same 21 groups of badgers at Woodchester Park, Gloucestershire. Data supplied by Dr. Chris Cheeseman*

### *7.2.4 Conclusions from the modelling study*

Obviously, these simulations are entirely theoretical. Although they are useful in helping us to understand the effects of changes in fecundity and adult survivorship, the results need to be interpreted with care. The main aim was to determine whether increased fecundity, or adult survivorship, was most likely to lead to the observed increase in the badger population. The conclusion is clear: consistent, small changes in adult survivorship could have produced the observed population changes, and that badger populations respond quickly to changes in adult survivorship. Changes in fecundity could not have led to the estimated population changes. As the data from Woodchester Park show, the rates of population change we have calculated are entirely plausible.

In our analyses, the main effect of density dependence was to make the model populations grow more slowly as they approached carrying capacity. Because the initial social group size we used in the analyses was reasonably high, the populations in the model grew more slowly than would be the case if we had removed the density dependence. However, density dependence would not limit the growth of new social groups. Females in newly established, smaller groups would have a higher fecundity than those in well-established, and hence larger, social groups. It is likely, therefore, that the estimates of the rate of population increase presented here are conservative, because the growth of small social groups is likely to be faster than those of larger groups.

With a typical badger social group consisting of 5.9 adults, an increase in survivorship of 18% per annum means that one extra animal would survive into the following year. This increase, continued for just six years, would bring about the population increase that we estimated to have occurred in Britain. This increase in adult survival could occur in a number of ways: a reduction in levels of sett destruction, digging, snaring and/or lamping could all have contributed, and the relative importance of these various factors is likely to differ regionally.

There are other factors that could have contributed to a change in badger numbers. The two factors most frequently cited are changes in weather conditions and changes in cropping patterns, particularly an increase in novel crops such as maize. We have not tried to model the impact of these factors on badger numbers, since there are no quantified data on the impact of weather or agricultural changes on badger fecundity or survival. However, the main impact of adverse weather patterns is on cub, rather than adult, survival (Neal & Cheeseman, 1996). Since the *RAMAS* analyses have shown that changes in adult survival have the greatest effect on population size, adverse weather conditions are only likely to have a small effect on badger population size, unless of course they continue over a series of years. As for new cropping patterns, there are some data available on the impact of changes from pasture to cereals on badger populations (Kruuk & Parish, 1985), but not for other types of crop. However, the changes in badger numbers have been widespread, and there have been substantial increases in areas where little or no maize is grown. Thus, this particular land use change is unlikely to have played a major role in the overall badger population increase.

So the modelling work that we have undertaken supports our assessment that the increase in badger populations over the last few years is most likely to have been the result of reduced levels of persecution which have led to an increase in adult survival. These analyses also suggest that since the changes are rapid, most of the growth of social groups is likely to have occurred already, and that established badger populations are now probably reaching carrying capacity. This assessment is also supported by the work at Woodchester Park, where the rate of population growth has slowed in recent years (Figure 7.3), and mean maximum social group size is likely to be around ten adults (Chris Cheeseman, *pers. comm.*). However, there is still considerable scope for badgers to colonise areas of Britain that currently do not have established populations. If the reduction in persecution levels continues, this is likely to be the main pattern of change in the future. We discuss the colonisation of new areas in the next section.

## 7.3 The colonisation of new areas

In their analysis of the pattern of dispersal in two badger populations (Woodchester Park and suburban Bristol), Cheeseman *et al.* (1988) showed that dispersal movements generally were rare, that most occurred in sexually mature animals (i.e. those over two years of age), that more males than females moved, and that movements were less common in the higher density of the two populations they studied. In their analysis of the dispersal behaviour of badgers at Wytham Woods, da Silva, Macdonald & Evans (1994) also found low rates of adult dispersal, with no cubs dispersing, although at Wytham slightly more females dispersed.

Despite the increase in population density at Woodchester Park, a re-analysis of the dispersal data, to include the period when the badger population was approaching maximum group size, has shown very little change in the decade since the analysis of Cheeseman *et al.* (1988). Much as the earlier analysis showed, dispersal has remained an unusual event, with males more likely to move. Dispersal was not associated with particular age classes of individuals, and animals were more likely to move from larger to smaller groups (Chris Cheeseman, *pers. comm.*).

Woodroffe & Macdonald (1992) argued that during colonization of vacant areas, badger groups form demographically within the foraging ranges of "foundress" females, although data to support such a concept are sparse, and it seems hard to understand how this process could lead to the rapid establishment of new social groups revealed by this study. The recent analysis of the larger data base from Woodchester Park, however, showed that badgers would sometimes disperse in coalitions, and that these could be male, female or mixed-sex coalitions, and could include all ages (Chris Cheeseman, *pers. comm.*).

Most data come from studies of dispersal within established badger populations rather than dispersal into vacant habitats, so we do not know how this process occurs. However, the potential advantages of moving in coalitions are obvious, and they may also explain the threshold effect identified in section 4.5 of this report. We showed that dispersal into vacant areas only seems to occur once social groups have reached a critical size. Small social groups would no longer be viable if a coalition dispersed. Clearly, we need to know more about how badgers disperse into new areas, and how, contrary to expectations, they managed to establish so many new social groups in a relatively short period of time. Dispersal of coalitions of individuals from the same social group is a plausible mechanism facilitating the rapid establishment of new social groups.

## 7.4 When did the badger population changes occur?

With two independent samples such as we have here, collected nine years apart, it is impossible to determine whether or not the population changes occurred progressively over that time period. Equally, it is not possible to determine current trends; the badger population could, for instance, have reached a peak a couple of years before the onset of the second survey, and already be in decline again. So to help identify the current trends, and timing of any changes, in the spring of 1997 we sent a questionnaire to all 83 local Badger Groups in Britain. These are a valuable source of such information; their members have extensive local knowledge of the badgers in their area, and hence possible population changes; they are called to investigate possible offences against badgers, and so are familiar with local levels of persecution; and they spend a lot of time talking to local farmers and landowners, and so are aware of changing attitudes to badgers.

The questionnaire asked for information about local badger population changes, the nature and timing of these changes, the factors most likely to have led to the observed changes, local levels of persecution, the impact of the Protection of Badgers Act 1992 on the local badger population, the attitude of farmers and landowners to badgers, and the level of badger-related problems. Twenty-five Badger Groups responded to our request for information, and they provided a wide coverage of most of Britain. Their replies are summarised in Tables 10.11.1 and 10.11.2; in this section we will use their information to discuss the timing of the badger population changes.

The key piece of legislation enhancing the protection of badgers (Badgers Act 1991) did not become law until 25 October 1991, just four years before the onset of this survey. Our models suggest that even with an increased adult survival of 18%, it would take six years for the badger population to grow by 75%. So there has not been enough time since the change in the law for all of the population growth we have reported.

However, it is unlikely that attitudes to badgers changed the moment a new law was enacted. In fact, well before the new Act, a survey of midland farmers showed that half the farmers with badgers on their land welcomed them, and only 2% regarded them as a considerable nuisance (Macdonald, 1984). With this increasingly widespread tolerance of badgers, it seems probable that the population had started to recover from earlier levels of persecution prior to the Badgers Act 1991, although, as virtually all the local Badger Groups confirmed, this did greatly benefit the badgers in their area. This was generally by reducing levels of persecution, and also encouraging farmers and landowners to seek advice on how best to resolve any badger problems rather than take action themselves. This assessment is supported by the many farmers who reported increased signs of badger activity on their land within a year or two of the new Act. Thus, we suspect that badger populations had started to recover some time in the late 1980s.

However, the local Badger Groups also generally agreed that sett destruction had been, or remained, a problem, and that there were a minority of farmers that continued to resent the presence of badgers on their land. This reinforced the results of our own study; illegal sett destruction remains a problem, even if it only by a minority of landowners.

The other problem highlighted by a number of the Badger Groups was that whilst there were immediate benefits to badgers following the Protection of Badgers Act 1992, the attitudes of farmers and landowners had changed in the last two years, following the release of a report by the National Farmers' Union (Anon., 1995a). This report argued that there were "unnaturally high" populations of badgers in some areas, and that these posed a significant disease risk to farmers. This report was followed by a widespread campaign reinforcing this view. A number of Badger Groups reported that, thereafter, farmers were far less tolerant of the badgers on their land, and that there had been a rise in levels of interference with badger setts. These Badger Groups felt that badger numbers in their area were no longer improving and may even already be declining. Our modelling work has suggested that small increases in adult mortality rates will lead to an equally rapid population decline. Hence it is important to ensure that persecution levels are not allowed to rise, nor that there is any relaxation of the levels of protection afforded to badgers.

## 7.5 Have changes to the law really benefited badgers?

The impact of low levels of persecution on badger numbers has only recently become apparent, and this is remarkably similar to the situation seen with otters. Recent surveys in England (Strachan & Jefferies, 1996) and Scotland (Green & Green, 1997) have shown a continued population expansion. Whilst a number of factors contributed to the decline in otters, it was only after they became fully protected that the impact of persecution on otter numbers became apparent (Strachan & Jefferies, 1996). Previously, the impact of hunting and the activities of gamekeepers had been assumed to be minimal (Jefferies, 1989).

Similarly, for badgers it had been assumed that persecution was predominantly a welfare rather than a conservation problem (Harris *et al.*, 1994). This view was reinforced by the lack of any significant change in badger numbers during the 1970s, when they first became protected. However, in the years following the Badgers Act 1973, it was clear that many farmers and landowners continued to allow the badgers to be dug on their land. In West Yorkshire, for instance, groups of badger diggers went round the area offering to get rid of their badgers, an offer the farmer generally accepted (Paul Patchett, *pers. comm.*). Locally, populations continued to decline. It was only when both badgers and their setts were finally protected that the impact of persecution on badger numbers has become apparent. Persecution clearly was having a dramatic effect in preventing the growth of established populations or dispersal into new areas.

As the survey of local Badger Groups showed, attitudes to badgers have improved over recent years, and this has been a major factor in helping badger populations to recover. However, between the two surveys, there was still a high level of sett losses, and most of these had gone unreported. Thus the willingness of landowners and farmers to tolerate the badgers on their land is important. If attitudes change, small rises in the levels of illegal persecution could reverse the population increases seen so far.

## 7.6 Future badger population changes

In this Chapter we have shown that badger populations can respond quickly to changes in adult survivorship, and that our estimated changes in the badger population could have occurred in the nine years between the two surveys simply as the result of small reductions in the rate of adult mortality. This is consistent with our argument that the majority of the changes we have seen over the last few years have been the result of reductions in the level of illegal badger persecution.

This does not mean that the badger population will continue to grow indefinitely. There will be a limit on social group size, and this will be determined by the carrying capacity of the local environment. The modelling work, and the study at Woodchester Park, suggest that most changes will have occurred in a decade, and so in areas with established badger populations, growth in social group size is likely to be largely complete already.

However, there are substantial areas of lowland Britain where badgers are still absent, even though the habitat is suitable for them. Presumably, at some time in the past these areas were occupied by badgers, but they were exterminated before recording started last century. It would be expected, therefore, that if persecution levels do not rise again, these areas will eventually be recolonised, and that badgers will continue to expand their range within Britain for some time to come. If that is allowed to happen, we will be fulfilling one of the prime objectives for conserving our biodiversity (Anon., 1995b).

For recolonisation of areas with no badgers to continue, it is important that there should be no resumption of culling in areas with established badger populations, as argued by the National Farmers' Union (Anon., 1995a). This would be a return to the situation seen with the Badgers Act 1973, which clearly failed to conserve badgers adequately. Also, culling badgers in areas with established populations is likely to prevent any spread into new areas, as culling will maintain mean social group size below the threshold at which dispersal seems to occur.

Assuming that the current level of badger protection continues, therefore, the last question to consider is how long it will take badgers to recolonise all the suitable habitats available to them. That is virtually impossible to determine. Cheeseman *et al.* (1988) showed that dispersal movements were generally short, often only into the neighbouring group, and so it would seem probable that spread will occur by slow expansion from areas with established populations. This is particularly likely to be the case because the badger population is clumped in its distribution (see Appendix 10.6.1). Thus we could be looking at many decades before badger populations recover in East Anglia and parts of Scotland, where numbers have remained very low throughout this century following high levels of persecution during the period up to the First World War.

# 8. Acknowledgements

We are most grateful to the many hundreds of individuals, and the local Badger Groups, who responded to our pleas and helped collect the field data. Without all their considerable support, this survey would not have been possible. Often only one person signed each sheet, although several people worked together to survey the square, and so it is not possible to list all of the volunteers who took part in this exercise. However, we are greatly indebted to everyone who helped. We are also very grateful to all the land owners who allowed us access to their land.

Many people assisted with the onerous tasks of copying and distributing the recording forms and maps: we are particularly grateful to Mick Furlong, Martha Harris, Dr Charles Robertson, Suzanne Southern and Angela Stanford. We would also like to thank: Drs Bob Bunce and Dave Howard of the Institute of Terrestrial Ecology for responding so generously to our requests for information about the land classification scheme; Dr Piran White for his advice and use of his model to analyse the badger population changes; Dr Geoff Kirkwood for his statistical advice; Dr Elaine King for her help with organising the questionnaire survey of the local Badger Groups; the local Badger Group members who kindly answered our questionnaire; Penny Cresswell Lewns for her help in ensuring comparability between the two surveys; Helen Davies for preparing the maps for this report; Dr Mairi Cooper, Helen Davies, Dr Steve Gibson, Dr Don Jefferies, Kathie Claydon, Dr "E-J" Milner-Gulland, Dr Tony Mitchell-Jones, Professor Ian Montgomey, Dr Ruth Warren and Dr Derek Yalden for all their valuable comments on various drafts of this report; and the Joint Nature Conservation Committee for allowing us to use the data from the 1980s survey.

Finally, we are particularly grateful to the People's Trust for Endangered Species for funding this survey and for their patience whilst we struggled to get all the 1-km squares back so that we could complete the report. We are particularly grateful to Dr Valerie Keeble for all her help and encouragement, and for seeing the report through to publication.

# 9. References


Aaris-Sørensen, J. (1987) Past and present distribution of badgers *Meles meles* in the Copenhagen area. *Biological Conservation*, **41**, 159-165.

Alexander, K. (ed.) (1996) *Baily's hunting directory 1996-97*. Cambridge: Baily's.

Anderson, R.M. & Trewhella, W. (1985) Population dynamics of the badger (*Meles meles*) and the epidemiology of bovine tuberculosis (*Mycobacterium bovis*). *Philosophical Transactions of the Royal Society of London, series B*, **310**, 327-381.

Anon. (1927) *The hunting diary for 1927-28 - a guide and handbook for followers of hounds*. London: Walter Goldsmith & Co.

Anon. (1981) Norfolk badgers 1971-1981. *Transactions of the Norfolk and Norwich Naturalists Society*, **25**, 272-279.

Anon. (1987) *Baily's hunting directory 1987-88*. London: J.A. Allen & Co.

Anon. (1990) *The case for the protection of badger setts*. London: League Against Cruel Sports.

Anon. (1995a) *Badgers: their effect on agriculture and the countryside*. Unpublished report by the National Farmers' Union, London.

Anon. (1995b) *Biodiversity: the UK steering group report. Volume 1: meeting the Rio challenge*. London: HMSO.

Anon. (1996) *Review of the potential effects of climate change in the United Kingdom*. London: HMSO.

Barr, C., Gillespie, M. & Howard, D. (1994) *Hedgerow survey 1993 (stock and change estimates of hedgerow length in England and Wales, 1990-1993)*. Cumbria: Institute of Terrestrial Ecology.

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam, C.J., Hornung, M., Howard, D.C. & Ness, M.J. (1993) *Countryside survey 1990: main report*. London: Department of the Environment.

Batten, H.M. (n.d.) *British wild animals*. London: Odhams Press.

Blakeborough, J.F. & Pease, A.E. (1914) *The life and habits of the badger*. London: The Foxhound.

Bright, P.W. (1993) Habitat fragmentation - problems and predictions for British mammals. *Mammal Review*, **23**, 101-111.

Brown, J.A.H. (1882) The past and present distribution of some of the rarer animals of Scotland. IV. The badger. *Zoologist, series 3*, **6**, 1-9, 41-45.

Brown, J.A. (1993) *Transmission of bovine tuberculosis* (Mycobacterium bovis) *from badgers* (Meles meles) *to cattle*. Unpublished PhD thesis, University of Bristol.

Bunce, R.G.H., Barr, C.J. & Whittaker, H.A. (1981a) An integrated system of land classification. *Annual Report of the Institute of Terrestrial Ecology*, **1980**, 28-33.

Bunce, R.G.H., Barr, C.J. & Whittaker, H.A. (1981b) *Land classes in Great Britain: preliminary descriptions for users of the Merlewood method of land classification*. (Merlewood Research and Development Paper No. 86.) Grange-over-Sands, Cumbria: Institute of Terrestrial Ecology.

Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. & Lane, A.M.J. (1996) Land classification for strategic ecological survey. *Journal of Environmental Management*, **47**, 37-60.

Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. & Lane, A.M.J. (1997) ITE Merlewood land classification of Great Britain. *Journal of Biogeography*, in press.

Burroughs, W.J. (1992) *Weather cycles - real or imaginary*. Cambridge: Cambridge University Press.

Butler, J.M. & Roper, T.J. (1994) Escape tactics and alarm responses in badgers *Meles meles*: a field experiment. *Ethology*, **99**, 313-322.

Cheeseman, C.L., Jones, G.W., Gallagher, J. & Mallinson, P.J. (1981) The population structure, density and prevalence of tuberculosis (*Mycobacterium bovis*) in badgers (*Meles meles*) from four areas in southwest England. *Journal of Applied Ecology*, **18**, 795-804.

Cheeseman, C.L., Wilesmith, J.W., Ryan, J. & Mallinson, P.J. (1987) Badger population dynamics in a high-density area. *Symposia of the Zoological Society of London*, **58**, 279-294.

Cheeseman, C.L., Cresswell, W.J., Harris, S. & Mallinson, P.J. (1988) Comparison of dispersal and other movements in two badger (*Meles meles*) populations. *Mammal Review*, **18**, 51-59.

Cheeseman, C.L., Mallinson, P.J., Ryan, J. & Wilesmith, J.W. (1993) Recolonisation by badgers in Gloucestershire. In: *The badger* (ed. T.J. Hayden), pp. 78-93. Dublin: Royal Irish Academy.

Clements, E.D., Neal, E.G. & Yalden, D.W. (1988) The national badger sett survey. *Mammal Review*, **18**, 1-9.

Cochran, W.G. (1963) *Sampling techniques*. New York: John Wiley & Sons.

Cowlin, R.A.D. (1972) The distribution of the badger in Essex. *Essex Naturalist*, **33**, 1-8.

Cresswell, P., Harris, S., Bunce, R.G.H. & Jefferies, D.J. (1989) The badger (*Meles meles*) in Britain: present status and future population changes. *Biological Journal of the Linnean Society*, **38**, 91-101.

Cresswell, P., Harris, S. & Jefferies, D.J. (1990) *The history, distribution, status and habitat requirements of the badger in Britain*. Peterborough: Nature Conservancy Council.

Cresswell, W.J., Harris, S., Cheeseman, C.L. & Mallinson, P.J. (1992) To breed or not to breed: an analysis of the social and density-dependent constraints on the fecundity of female badgers (*Meles meles*). *Philosophical Transactions of the Royal Society of London Series B*, **338**, 393-407.

da Silva, J., Macdonald, D.W. & Evans, P.G.H. (1994) Net costs of group living in a solitary forager, the Eurasian badger (*Meles meles*). *Behavioral Ecology*, **5**, 151-158.

Doncaster, C.P. & Woodroffe, R. (1993) Den site can determine shape and size of badger territories: implications for group-living. *Oikos*, **66**, 88-93.

Feore, S.M. (1994) *The distribution and abundance of the badger* Meles meles L *in Northern Ireland*. Unpublished PhD thesis, Queen's University of Belfast.

Feore, S., Smal, C.M. & Montgomery, W.I. (1993) Survey of badger setts in Northern Ireland: progress report. In: *The badger* (ed. T.J. Hayden), pp. 23-25. Dublin: Royal Irish Academy.

Ferson, S. & Akçakaya, R.H. (1988) *Modelling fluctuations in age-structured populations*. New York: Applied Biomathematics.

Fletcher, M.R., Hunter, K. & Barnett, E.A. (1995) *Pesticide poisoning of animals 1994: investigations of suspected incidents in the United Kingdom*. London: Ministry of Agriculture, Fisheries and Food.

Graham, R. (1946) The badger in Cumberland. *Transactions of the Carlisle Natural History Society*, **7**, 88-89.

Green, R. & Green, J. (1997) *Otter survey of Scotland 1991-1994*. London: Vincent Wildlife Trust.

Greenwood, J.J.D. (1996) Basic techniques. In: *Ecological census techniques - a handbook* (ed. W.J. Sutherland), pp. 11-110. Cambridge: University Press.

Griffiths, H.I. (1992) Police prosecutions and badger persecution in England and Wales. *Animal Welfare*, **1**, 291-296.

Griffiths, H.I. (1994) The effects upon badgers (*Meles meles*) of the activities of a single, persistent poacher. *Animal Welfare*, **3**, 219-225.

Griffiths, H.I., Griffiths, C.A. & Thomas, D.H. (1993) *The badger* Meles meles *(L., 1758): an assessment of the population status, conservation needs and management requirements of the species in the Western Palaearctic. A report to the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats*. Strasbourg: Council of Europe.

Griffiths, H.I. & Thomas, D.H. (1993) The status of the badger *Meles meles* (L., 1758) (Carnivora, Mustelidae) in Europe. *Mammal Review*, **23**, 17-58.

Hardy, P. (1975) *A lifetime of badgers*. Newton Abbot: David & Charles.

Harris, S. (1982) Activity patterns and habitat utilisation of badgers (*Meles meles*) in suburban Bristol: a radio-tracking study. *Symposia of the Zoological Society of London*, **49**, 301-323.

Harris, S. (1984) Ecology of urban badgers *Meles meles*: distribution in Britain and habitat selection, persecution, food and damage in the city of Bristol. *Biological Conservation*, **28**, 349-375.

Harris, S. (1993) The status of the badger (*Meles meles*) in Britain, with particular reference to East Anglia. *Transactions of the Suffolk Naturalists' Society*, **29**, 104-112.

Harris, S. & Cresswell, W.J. (1987) Dynamics of a suburban badger (*Meles meles*) population. *Symposia of the Zoological Society of London*, **58**, 295-311.

Harris, S. & Cresswell, W.J. (1991) Bristol's badgers. *Proceedings of the Bristol Naturalists' Society*, **48**, 17-30.

Harris, S., Cresswell, W.J. & Cheeseman, C.L. (1992) Age determination of badgers (*Meles meles*) from tooth wear: the need for a pragmatic approach. *Journal of Zoology, London*, **228**, 679-684.

Harris, S., Cresswell, W., Reason, P. & Cresswell, P. (1992) An integrated approach to monitoring badger (*Meles meles*) population changes in Britain. In: *Wildlife 2001: populations* (eds D.R. McCullough & R.H. Barrett), pp. 945-953. London: Elsevier Applied Science.

Harris, S., Jefferies, D., Cheeseman, C. & Booty, C. (1994) *Problems with badgers?*, 3rd edition. Horsham: Royal Society for the Prevention of Cruelty to Animals.

Harris, S., Morris, P., Wray., S. & Yalden, D. (1995) *A review of British mammals: population estimates and conservation status of British mammals other than cetaceans*. Peterborough: Joint Nature Conservation Committee.

Harting, J.E. (1888) The badger, *Meles taxus*. *Zoologist, series 3*, **12**, 1-13.

Hill, M.O., Bunce, R.G.H. & Shaw, M.W. (1975) Indicator species analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland. *Journal of Ecology*, **63**, 597-613.

Howes, C.A. (1988) A review of badger persecution in Yorkshire. *Imprint, The Yorkshire Mammal Group Newsletter*, **10**, 5-12.

Hutchings, M.R. (1996) *The risk of transmission of bovine tuberculosis* (Mycobacterium bovis) *posed to cattle by badgers* (Meles meles). Unpublished PhD thesis, University of Bristol.

Hutchings, M.R. & Harris, S. (1996) *The current status of the brown hare* (Lepus europaeus) *in Britain*. Peterborough: Joint Nature Conservation Committee.

Jefferies, D.J. (1989) The changing otter population of Britain 1700-1989. *Biological Journal of the Linnean Society*, **38**, 61-69.

Krebs, C.J. (1989) *Ecological methodology*. New York: Harper & Row.

Kruuk, H. (1978) Spatial organization and territorial behaviour of the European badger *Meles meles*. *Journal of Zoology, London*, **184**, 1-19.

Kruuk, H. (1989) *The social badger: ecology and behaviour of a group-living carnivore* (Meles meles). Oxford: Oxford University Press.

Kruuk, H. & Macdonald, D. (1985) Group territories of carnivores: empires and enclaves. In: *Behavioural ecology - ecological consequences of adaptive behaviour* (eds. R.M. Sibley & R.H. Smith), pp. 521-536. Oxford: Blackwell Scientific Publications.

Kruuk, H. & Parish, T. (1985) Food, food availability and weight of badgers (*Meles meles*) in relation to agricultural changes. *Journal of Applied Ecology*, **22**, 705-715.

Langley, P.J.W. & Yalden, D.W. (1977) The decline of the rarer carnivores in Great Britain during the nineteenth century. *Mammal Review*, **7**, 95-116.

Laver, H. (1898) *The mammals, reptiles and fishes of Essex*. Buckhurst Hill: Essex Field Club.

Macdonald, D.W. (1984) A questionnaire survey of farmers' opinions and actions towards wildlife on farmlands. In: *Agriculture and the environment* (ed. D. Jenkins), pp. 171-177. Cambridge: Institute of Terrestrial Ecology.

Magurran, A.E. (1988) *Ecological diversity and its measurement*. London: Croom Helm.

Millais, J.G. (1905) *The mammals of Great Britain and Ireland*, vol. II. London: Longmans, Green & Co.

Neal, E. (1948) *The badger*. London: Collins.

Neal, E. (1972) The national badger survey. *Mammal Review*, **2**, 55-64.

Neal, E.G. (1977) *Badgers*. Poole: Blandford Press.

Neal, E. (1986) *The natural history of badgers*. Beckenham: Croom Helm.

Neal, E. & Cheeseman, C. (1996) *Badgers*. London: Poyser.

O'Corry-Crowe, G., Eves, J. & Hayden, T.J. (1993) Sett distribution, territory size and population density of badgers (*Meles meles* L.) in East Offaly. In: *The badger* (ed. T.J. Hayden), pp. 35-56. Dublin: Royal Irish Academy.

Page, R.J.C., Ross, J. & Langton, S.D. (1994) Seasonality of reproduction in the European badger *Meles meles* in south-west England. *Journal of Zoology, London*, **233**, 69-91.

Paget, R.J. & Patchett, P.N. (1978) National badger survey: report for south and west Yorkshire. *Naturalist, Leeds*, **946**, 103-104.

Patterson, A.H. (1908) The badger in Norfolk. *Zoologist, fourth series*, **12**, 426-427.

Peachey, B.F. (1992) *Hunting the badger: a study of the badger laws and the criminology of British badger offenders*. Yelverton, Devon: Shooting News.

Pease, A.E. (1898) *The badger*. London: Lawrence & Bullen.

Phelps, R.W., Allen, W.R. & Harrop, S.R. (1997) *Report of a review of hunting with hounds*. London: The Countryside Movement.

Pitt, F. (n.d.) *British animal life*. London: Allen & Unwin.

Potts, G.R. (1980) The effects of modern agriculture, nest predation and game management on the population ecology of partridges (*Perdix perdix* and *Alectoris rufa*). *Advances in Ecological Research*, **11**, 1-79.

Putman, R.J. (1984) Facts from faeces. *Mammal Review*, **14**, 79-97.

Reason, P., Harris, S. & Cresswell, P. (1993) Estimating the impact of past persecution and habitat changes on the numbers of badgers *Meles meles* in Britain. *Mammal Review*, **23**, 1-15.

Rogers, L.M., Cheeseman, C.L. & Langton, S. (1997) Body weight as an indication of density-dependent population regulation in badgers (*Meles meles*) at Woodchester Park, Gloucestershire. *Journal of Zoology, London*, **242**, 597-604.

Ritchie, J. (1920) *The influence of man on animal life in Scotland*. Cambridge: Cambridge University Press.

Rope, G.T. (1911) Mammals. In: *The Victoria history of the counties of England: Suffolk, vol. 1* (ed. W. Page), pp. 215-233. London: Archibald Constable & Co.

Roper, T.J. (1992) Badger *Meles meles* setts - architecture, internal environment and function. *Mammal Review*, **22**, 43-53.

Roper, T.J. (1993) Badger setts as a limiting resource. In: *The badger* (ed. T.J. Hayden), pp. 26-34. Dublin: Royal Irish Academy.

Roper, T.J. & Christian, S.F. (1992) Sett use in badgers (*Meles meles*). In: *Wildlife telemetry: remote monitoring and tracking of animals* (eds I.G. Priede & S.M. Swift), pp. 661-669. London: Ellis Harwood.

Skinner, C.A. (1987) *The ecology of the badger* (Meles meles) *in Essex*. Unpublished M.Phil. thesis, North East London Polytechnic.

Skinner, C., Skinner, P. & Harris, S. (1991a) The past history and recent decline of badgers *Meles meles* in Essex: an analysis of some of the contributory factors. *Mammal Review*, **21**, 67-80.

Skinner, C., Skinner, P. & Harris, S. (1991b) An analysis of some of the factors affecting the current distribution of badger *Meles meles* setts in Essex. *Mammal Review*, **21**, 51-65.

Skinner, P., Jefferies, D. & Harris, S. (1989) *Badger persecution and the law*. London: The Mammal Society.

Sleeman, D.P. (1992) Long-distance movements in an Irish badger population. In: *Wildlife telemetry: remote monitoring and tracking of animals* (eds I.G. Priede & S.M. Swift), pp. 670-676. London: Ellis Harwood.

Sleeman, D.P. & Mulcahy, M.F. (1993) Behaviour of Irish badgers in relation to bovine tuberculosis. In: *The badger* (ed. T.J. Hayden), pp. 154-165. Dublin: Royal Irish Academy.

Smal, C.M. (1993) The national badger survey: preliminary results for the Irish Republic. In: *The badger* (ed. T.J. Hayden), pp. 9-22. Dublin: Royal Irish Academy.

Smal, C. (1995) *The badger and habitat survey of Ireland*. Dublin: The Stationery Office.

Southwell, T. (1901) Mammals. In: *The Victoria history of the counties of England: Norfolk, vol. 1* (ed. H.A. Doubleday), pp. 246-251. London: Archibald Constable & Co.

Staines, B.W. & Ratcliffe, P.R. (1987) Estimating the abundance of red deer (*Cervus elaphus* L.) and roe deer (*Capreolus capreolus* L.) and their current status in Great Britain. *Symposia of the Zoological Society of London*, **58**, 131-152.

Strachan, R. & Jefferies, D.J. (1996) *Otter survey of England 1991-1994*. London: Vincent Wildlife Trust.

Sutherland, W.J. (1996a) The twenty commonest censusing sins. In: *Ecological census techniques - a handbook* (ed. W.J. Sutherland), pp. 317-318. Cambridge: University Press.

Sutherland, W.J. (1996b) *Ecological census techniques - a handbook.* Cambridge: University Press.

Tapper, S. (1992) *Game heritage: an ecological review from shooting and gamekeeping records.* Fordingbridge: The Game Conservancy.

Thompson, A.R. (1931) *Nature by night.* London: Ivor Nicholson & Watson.

Thorburn, A. (1920) *British mammals.* London: Longmans, Green & Co.

Thornton, P.S. (1987) *The density and distribution of badgers in south-west England.* Unpublished PhD thesis, University of Exeter.

Thornton, P.S. (1988) Density and distribution of badgers in southwest England - a predictive model. *Mammal Review,* **18**, 11-23.

Usher, M.B. (1972) Developments in the Leslie matrix model. In: *Mathematical models in ecology* (ed. J.N.R. Jeffers), pp. 29-60. Oxford: Blackwell Scientific Publications.

van der Zee, F.F., Wiertz, J., Ter Braak, C.J.F., van Apeldoorn, R.C. & Vink, J. (1992) Landscape change as a possible cause of the badger *Meles meles* L. decline in The Netherlands. *Biological Conservation,* **61**, 17-22.

Vine, A.E. (1970) Badgers in Norfolk. *Transactions of the Norfolk and Norwich Naturalists Society,* **22**, 191-200.

Vine, A.E. (1993) Norfolk badgers 1982-1992. *Transactions of the Norfolk and Norwich Naturalists Society,* **29**, 533-538.

Walsh, A.L. & Harris, S. (1996a) Foraging habitat preferences of vespertilionid bats in Britain. *Journal of Applied Ecology,* **33**, 508-518.

Walsh, A.L. & Harris, S. (1996b) Factors determining the abundance of vespertilionid bats in Britain: geographical, land class and local habitat relationships. *Journal of Applied Ecology,* **33**, 519-529.

Walsh, A.L., Harris, S. & Hutson, A.M. (1995) Abundance and habitat selection of foraging vespertilionid bats in Britain: a landscape-scale approach. *Symposia of the Zoological Society of London,* **67**, 325-344.

White, P.C.L. & Harris, S. (1995) Bovine tuberculosis in badger (*Meles meles*) populations in southwest England: the use of a spatial stochastic simulation model to understand the dynamics of the disease. *Philosophical Transactions of the Royal Society of London, series B,* **349**, 391-413.

Woodroffe, R. & Macdonald, D.W. (1992) Badger clans: demographic groups in an antisocial species. *Journal of Zoology, London,* **227**, 696-698.

Woodroffe, R.W. & Macdonald, D.W. (1995) Female/female competition in European badgers *Meles meles*: effects on breeding success. *Journal of Animal Ecology,* **64**, 12-20.

Zar, J.H. (1984) *Biostatistical analysis,* 2nd edition. London: Prentice-Hall.

# 10. Appendices

## 10.1 Instruction sheet describing how to record the badger data

### GUIDELINES FOR RECORDING THE BADGER DATA

One of the maps has been divided into nine sub-squares. There is also a **Badger Data Sheet** on which is a sketch showing how each of these sub-squares is numbered one to nine, and underneath is a table on which you are asked to record whether you found: (a) footprints, (b) badger paths or runs and/or (c) dung pits in each of the nine sub-squares. All that is required is a simple yes or no.

Mark every sett you find on the same map, and denote each sett with a letter code that should be clearly shown on the map. If you find the same sett(s) as were present in the first survey, use the same letter code as for the first survey. Mark new setts with a new letter code to avoid any possible confusion. You should record every sett, even if it has been disused for a long time and is barely recognisable as an old badger sett. In such situations please also make some additional notes as to its state on the back of the **Badger Data Sheet**. A sett may be either a single hole or a series of a few or many holes. Sometimes two setts may be dug close together, when it may be difficult to decide whether you are looking at one sett or two. Basically, if you think all the holes are or could be interconnected underground, then it is one sett. There can be exceptions. For instance, setts dug in the banks on either side of a shallow ditch may have two separate series of holes on each side of the ditch with no underground connection. However, the entrance holes are only a few feet apart, and clearly form one sett complex. In contrast two separate series of holes on either side of a deep railway cutting would count as two separate setts. As a rough guide, two discrete series of holes separated by at least 15 metres, or closer if separated by a major obstacle such as a steep ditch or a road, would be classified as two separate setts.

Once you have marked the sett on the map, record the following information on the **Badger Data Sheet**:-

a. **The number of well-used holes:** these are clear of any debris or vegetation, are obviously in regular use, and may or may not have been excavated recently.

b. **The number of partially-used holes:** these are not in regular use and have debris such as leaves and twigs in the entrance, or have moss and/or other plants growing in or around the entrance. Partially-used holes could be in regular use after aminimal amount of clearance.

c. **The number of disused holes:** these have not been in use for some time, are partially or completely blocked, and could not be used without a considerable amount of clearance. If the hole has been disused for some time, all that may be visible is a depression in the ground where the hole used to be, and the remains of the spoil heap, which may be covered in moss or plants.

Please also record for each sett any signs of disturbance, in particular evidence of hole blocking by children or more serious attempts to block holes by e.g. landowners, sett stopping by hunts, etc., evidence of snaring around the sett, and any evidence of digging at the sett. A succinct precis of the extent and nature of any disturbance, and in particular your assessment as to the cause, will allow us to quantify the level of disturbance. It is particularly important that you differentiate between holes that have just been blocked and setts that have been dug by badger diggers. If you are in any doubt, a photograph will help us interpret your field notes, which in any case should be as comprehensive as possible.

# 10.1 continued

Finally, when the complete square has been surveyed, you should assign each sett to one of the following categories. This may be difficult, but is important, since by recognising and counting the number of main setts we can get an idea of the number of badger social groups in a particular type of habitat. As a guide to classifying each sett the following rules should be useful:-

a. **Main setts:** these usually have a large number of holes with large spoil heaps, and the sett gen erally looks well-used. There will be well-used paths to an from the sett and between sett ent rances. Although normally the breeding sett and in continuous use, it is possible to find a main sett that has become disused due to excessive digging or some other reason; it should be recorded as a disused main sett. In the first survey, the average size of an active main sett was twelve holes(including all categories of use).

b. **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. In the first survey the average size was fiveholes (including all categories of use).

c. **Subsidiary setts:** these often only have a few holes; four (including all categories of use) was the average number in the first survey. They are usually at least 50 metres from a main sett, and do not have an obvious path connecting with another sett. They are not continuously active.

d. **Outlying setts:** these usually have only one or two holes, often have little spoil outside the hole, have no obvious path connecting with another sett, and are only used sporadically. When not in use by badgers, they are often taken over by foxes or even rabbits. However, they can still be recognised as badger setts by the shape of the tunnel (not the actual entrance hole), which is usually at least 250 mm in diameter, and is rounded or a flattened oval shape. Fox and rabbit tunnels are smaller and often taller than broad.

These categories sound clear cut on paper, but in the field it may be difficult to place a sett in a particular category. In areas of low badger density main setts may be small, only a few holes, and in moorland and hill areas main setts may consist of only one or two entrances in a rocky cairn. Also do not expect to find an example of every type of sett; many badger social groups will not have an annexe sett, and many badger groups simply have a main sett and several outliers. In a poor badger habitat you may search a large area and still fail to find a main sett. So your decision on how to classify each sett may not be easy, and it is important that you have an overall view of all the setts in the area before you make a decision. So search the whole square before you start to classify the setts. If you find no setts or a large, very obvious main sett, then your decision is easy, and you need to do no more searching. However, if you are still in doubt, it may be necessary to extend your search for setts beyond the selected one kilometre square. However, it will rarely be necessary to go more than 500 metres into an adjacent square, and usually you will not need to go so far. It will be clear from your initial detailed search of the selected one kilometre square where most of the badger activity occurs, and so you only need search parts of those square(s) adjacent to the area of most badger activity. If you do have to move into nearby square(s) only search the minimum area needed for you to interpret your findings from the selected square. Indicate the additional areas you searched on the same map as you marked the setts. Do not record any habitat data from the additional area searched, but mark any additional setts on the map, and document the same information as with the badger setts within the square.

## 10.2 Badger data recording sheet

**BADGER DATA SHEET FOR SQUARE NO.**

Date of survey:-

Recorder(s):-

The nine squares on map 1 are numbered as shown below:-

| | | |
|---|---|---|
| 7 | 8 | 9 |
| 4 | 5 | 6 |
| 1 | 2 | 3 |

For each of these nine squares, please record the presence or absence of the following:-

| | Footprints | Paths or runs | Dung pits |
|---|---|---|---|
| Square 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |

For each sett, please record:-

| | No. of well-used holes | No. of partially-used holes | No. of disused holes | Evidence of hole blocking | Evidence of snaring | Evidence of digging | Category of sett |
|---|---|---|---|---|---|---|---|
| Sett A | | | | | | | |
| Sett B | | | | | | | |
| Sett C | | | | | | | |
| Sett D | | | | | | | |
| Sett E | | | | | | | |

If necessary, please continue on the reverse side of this sheet or on an additional sheet of paper. In particular make detailed notes on any digging, snaring, blocking or other form of disturbance at each sett on the back of this sheet, making it clear which sett is being referred to and the source of any disturbance.

# 10.3. Instruction sheet describing how to record the habitat data

**GUIDELINES FOR RECORDING THE HABITAT DATA**

Please record the habitat data on the map without the red squares drawn on it. This is a copy of the most up-to-date 1:25,000 map and has been enlarged several times. However, be aware that fields may have been merged, roads built, hedgerows removed and woods partially or completely felled since the revision. These changes will need to be marked on the map. All the habitat types have been numbered and described below; all you need to do in the field is first of all mark surviving hedgerows in one bright colour and treelines in another. Then use as many different colour pens as possible to mark the boundary of each field or habitat type. On the reverse of the map simply use the numbers from the list below to identify which colour has been used to code for which habitat type. Although there are many habitat types listed below, in most one kilometre squares you will use less than half a dozen of these categories, so the task should not be too complex. Also do not try to record every minute piece of, for example bracken. Only mark on the map habitats at least 50 metres in length or 500 square metres in area.

1. **Hedgerows**: less than 4 metres high and less than 5 metres wide. Classify them as continuous if the gaps are less than 10 metres wide.
2. **Treelines**: a line of single trees (minimum of three) greater than 4 metres high and less than two canopy widths apart. Hedgerows may be associated with treelines.
3. **Semi-natural broadleaved woodland**: predominantly broadleaved trees more than 5 metres high with a semi-natural or natural growth.
4. **Broadleaved plantations**: tree species not native to the site and of even age.
5. **Semi-natural coniferous woodland**: predominantly coniferous trees of any height with semi-natural or natural growth.
6. **Coniferous plantations**: predominantly coniferous trees which have been planted.
7. **Semi-natural mixed woodland**: at least 25% broadleaved and 25% coniferous trees with semi-natural or natural growth and trees over 5 metres high.
8. **Mixed plantations**: at least 25% broadleaved and 25% coniferous trees, planted.
9. **Young plantations**: young trees, up to 3 metres high, both coniferous and broadleaved,which have been planted.
10. **Recently felled woodland**: areas for which there is evidence that woodland has been felled recently.
11. **Parkland**: areas where the tree cover is less than 30%, the majority of the trees between 30 and 70 metres apart, and a minimum number of ten trees.
12. **Tall scrub**: between 3 and 5 metres high. N.B. stands of trees less than 5 metres high should be classified as woodland, not scrub.
13. **Low scrub**: bushy vegetation less than 3 metres high.
14. **Bracken**: land dominated by bracken with at least 75% cover.
15. **Coastal sand dunes**: include all stages of succession where the vegetation is grass-dominated or wet dune slacks.
16. **Coastal sand or mud flats**: should be fairly obvious.
17. **Coastal shingle or boulder beaches**: should be fairly obvious; include outcrops of bare rock on foreshores.
18. **Lowland heaths**: lowland areas with at least 25% dwarf shrubs.
19. **Heather moorlands**: as above but for upland sites.
20. **Blanket bog**: areas of peat with the vegetation dominated by heather.
21. **Raised bog**: at least half the peat area raised into a shallow dome.
22. **Marginal inundation**: swamps or fens but not coastal marshes.
23. **Coastal marsh**: predominantly salt marsh vegetation.

# 10.3 continued

24. **Wet ground**: areas of wet land found in association with other habitats e.g. wet areas in a grassland field or flushes in upland areas.
25. **Standing natural water**: ponds and lakes with no evidence of damming.
26. **Standing manmade water**: artificially created reservoirs and impoundments.
27. **Running natural water**: ditches, streams and rivers with no evidence of canalisation.
28. **Running canalised water**: a water course that has been confined to flow in a certain direction by man.
29. **Upland unimproved grassland**: in upland areas, and will include some areas used for rough grazing and poor quality grassland such as purple moor grass. They have not been improved by the application of fertilisers, herbicides or by drainage.
30. **Lowland unimproved grassland**: may be regularly grazed or mown, but may be totally neglected. Should not have been improved by the application of fertilisers or herbicides to significantly alter the composition of the sward. This includes herb-rich grasslands on downland, cliff tops, etc.
31. **Semi-improved grassland**: grassland which has been slightly modified by fertiliser or herbicide application, or by heavy grazing pressure and/or drainage.
32. **Improved grassland**: grassland that has had regular treatments of artificial fertilisers and herbicides. N.B. this should not include monoculture grassland i.e. grassland leys (see 33).
33. **Arable**: all classes of arable land, including grassland leys and horticulture. A grassland ley is defined as short-term grassland, and will usually have been re-seeded less than five years previously. It is characterised by evidence of ploughing, bare soil between the grass plants, a scarcity of broadleaf plants, and is usually dominated by a single grass species, often rye grass. There are usually less than 5-10 species per square metre. Category 32 consists of longer term grassland with a high density of grass and broadleaf species, usually in enclosed land.
34. **Amenity grassland**: this includes well maintained non-agricultural grass, such as playing fields, recreation grounds and golf courses.
35. **Unquarried inland cliffs**: unvegetated rock over 5 metres in height and at an angle of at least 60°. It includes scree.
36. **Vertical coastal cliffs**: as above but in coastal areas and mostly unvegetated.
37. **Sloping coastal cliffs**: at an angle of less than 60° and mostly vegetated.
38. **Quarries and open-cast mines**: any excavation (gravel pits, chalk pits, etc.), including unvegetated spoil heaps.
39. **Bare ground**: bare soil or ground not covered by vegetation and which does not fall into categories 35-38.
40. **Built land**: any urban areas including gardens and transport corridors. Will include road and motor way verges. For this category do not bother to mark built up areas, roads, etc. on the map unless there has been some change since the map was printed, when it should only be necessary to mark the changes.

## 10.4 Instruction sheet describing how to record changes to the badger setts

RECORDING CHANGES TO THE BADGER SETTS

The most difficult part of the survey is to accurately document any changes that may have occurred during the nine years between the two surveys. Yet this is clearly the most important part of the whole exercise, so please take a great deal of care in recording any changes that you think may have occurred. For most squares, it will be easy; during the first survey 71.5% of all the squares surveyed had no setts in them at all, and it is unlikely that there will have been any change in most of these. However, you must still survey these squares very carefully to check that no setts were missed the first time around, or that no new setts have been dug in the last few years. *So it is important that you check negative squares just as carefully as squares that contained a sett on the first survey.*

There are a number of reasons why things may be different between the two surveys:-

a. **The data were incorrectly recorded on the first survey**. This may be because a sett was missed or because its status was incorrectly assessed. However, before you jump to any conclusions, you must check all the available options. Was the sett really missed, or has it been dug in the intervening years? Large, well-established setts that may look very old can be quite new or may be a recently enlarged fox earth. So do not jump to a hasty conclusion; if in doubt the farmer, landowner, game keeper or shooting tenant may be able to help. If you think that a mistake was made on the first survey, fully document your reasons for making this assessment on the **Changes Data Sheet**.

b. **The status of a sett has changed**. A sett may still be present in the same position as before but it has significantly increased or decreased in activity, and as a consequence its status has changed. If you think that the status is different to that assessed on the original survey, but that the original assessment was correct, explain why you have come to this conclusion on the **Changes Data Sheet**.

c. **A sett has completely disappeared or ceased to be a badger sett**. It can often be difficult to be sure that a sett has disappeared, especially if its position was not mapped accurately during the first survey. Equally, it can be difficult if all you find are some rabbit or fox holes where you expected to find a badger sett. Are the rabbit or fox holes all that remains of the sett that was correctly documented last time or was an error made during the first survey? If it was a sett that has been abandoned, the spoil heaps should still be visible even after several years. If you think that the sett has been abandoned, try to determine why this might have occurred - e.g. a new sett may have been dug nearby, the sett may have been repeatedly disturbed and eventually abandoned, a change in the pattern of land use may have made the site less desirable, etc. Record your conclusions on the **Changes Data Sheet**. If a sett has completely disappeared, this may also have occurred for a number of reasons, such as land use changes (the removal of a piece of woodland or hedgerow), new road schemes, building developments (either residential or industrial), recreational schemes such as golf courses, or it may have been lost due to excessive digging. When a sett has disappeared, try to determine the factors that have led to the loss and give a detailed summary explaining why you have come to that conclusion. Also, document any remnants of the sett that you might be able to locate.

d. **A new sett has appeared**. This may be a sett that has been dug from scratch, or a rabbit warren or fox earth that has been enlarged and taken over by the badgers. To help you confirm that it is a new sett, the farmer, landowner, gamekeeper or shooting tenant may be able to advise you. Remember that size is not everything; large, well-established setts can be quite new. When you have decided that a sett has been established since the last survey, explain why you have come to this conclusion on the **Changes Data Sheet**.

It is obviously important that you sort out which of these reasons apply to any change(s) that you observe; to help us analyse the results, we need as full a report as possible. So please be as clear and as accurate in your assessment as possible. A **Changes Data Sheet** is supplied to document your observations, but please use additional sheets as necessary, and make it clear which sett is being referred to in each report. Finally, if you observe any changes, please add your telephone number to the **Changes Data Sheet**, so that we can telephone you if we need to clarify anything.

## 10.5 Data sheet for recording badger sett changes

**CHANGES DATA SHEET FOR SQUARE NO.**

Recorder(s):-

Did you record any changes to the status or presence of the badger setts documented in the first survey: Yes/No

If the answer is yes, please complete the rest of the information on this sheet.

Work telephone number: Home telephone number:

Details of the data you think were incorrectly recorded on the first survey:-

Details of the setts you think have changed in status:-

Details of the setts which have completely disappeared or ceased to be a badger sett:-

Details of the setts which have appeared since the last survey:-

Please give as much information as possible, and continue on the back of this sheet or on additional sheets as necessary.

## 10.6 What is the best survey design?

The first, and prime aim, of the 1980s survey was "to provide a baseline against which any future changes in badger numbers could be assessed" (Cresswell, Harris & Jefferies, 1990). Although changes in badger numbers could occur either through changes in the number of social groups or in the size of social groups, a change in the number of social groups is more likely to reflect long-term trends in the population. It is accordingly most important that we are able to monitor changes in the number of badger social groups accurately. In this section, therefore, we discuss the underlying rationale for the survey, and whether the survey design has provided an effective monitoring scheme.

The two key problems that need to be addressed by a national monitoring scheme are: *How do we sample representatively?* and *How many samples are needed?* These issues are discussed at length by Krebs (1989), who argues strongly for random sampling wherever possible. Sutherland (1996a) lists "not sampling randomly" as the first of twenty censusing sins, and the value of random sampling is also discussed by Cochran (1963), Magurran (1988) and Greenwood (1996), who also stress the value of stratified sampling. The 1980s badger survey used a stratified random approach. The 1-km squares were allocated to 32 strata reflecting similar patterns of land use, geology, climate, etc. using the Institute of Terrestrial Ecology's land classification scheme (section 1.4.1), and within these strata the 1-km squares to be surveyed were selected at random; just over 40% of the 6000 1-km squares actually assigned to a land class at that time were included in the 1980s survey. Stratified sampling allows a mean to be estimated with much greater precision. Using the data from the 1980s badger survey, Greenwood (1996) provided a worked example to demonstrate that the confidence limits for the population estimate are half those which would have been achieved without stratification. The value of using a stratified sample to reduce the confidence limits on the population estimate was also stressed by Cresswell, Harris & Jefferies (1990).

Stratification is of particular benefit for surveys of populations that are heterogeneously distributed, so long as the strata are relatively homogeneous. Under these circumstances, there is a substantial gain in the precision of the population estimate when compared with simple random sampling. In order to examine which stratification level is appropriate, we used the 1980s data to compare the size of the 95% confidence intervals with a random survey, with the sample divided into the seven land class groups, and the 32 land classes.

The 95% confidence intervals are calculated for a random survey as follows:-

$$t_{0.05}\, s/\sqrt{n}$$

where s is the standard deviation, n the number of 1-km squares and $t_{0.05}$ is the value of t at probability 0.05, for degrees of freedom of n-1.

For a stratified sample, the 95% confidence intervals are calculated as follows:-

$$t_{0.05} \sqrt{(W_h^2\, S_h^2 \,/\, n_h)}$$

where $n_h$ is the number of 1-km squares in stratum h, $W_h^2$ is the stratum weight i.e. the total number of 1-km squares surveyed in that land class group divided by the total number of 1-km squares in the land class group, and $S_h^2$ is the stratum variance.

When we applied these formulae to the 1990s data (see summary in Table 3.12), the population estimate and the 95% confidence intervals for the number of badger social groups in Britain were 55,787±5192 social groups without stratification, 50,241±4327 social groups with the sample stratified into the seven land class groups, and 50,850±4580 social groups with the sample stratified into 32 land classes.

The population estimate without stratification was obtained simply by multiplying the mean number of main setts per 1-km square in Britain by the area of rural land. This gave higher 95% confidence intervals than with a stratified sample. However, the 95% confidence interval is not much greater than when we stratified the sample. This is probably because although we used no stratification in the calculation, we had tried to survey 1% of each land class, and so all land classes contributed approximately equally to the population estimate. Had we selected the 2271 1-km squares to survey completely at random, the 95% confidence intervals undoubtedly would have been larger. The actual population estimate with this approach is also quite a bit larger because no allowance was made for the different areas of each land class, and the higher density areas of southern Britain were sampled more intensively than some of the lower density areas in the north (see Figure 2.1).

The estimates stratified using the seven land class groups and the 32 land classes are very similar, both in terms of the total population estimate and the 95% confidence intervals, with the seven land class groups producing a slightly lower 95% confidence interval. Whilst using a lower level of stratification should have produced the opposite result, this probably reflects the fact that very few squares were sampled in some of the smaller land classes, and they therefore had a large standard error. In contrast, the seven land class groups all have large sample sizes, and hence smaller standard errors, thereby producing a lower 95% confidence interval. This result is also probably in part a consequence of the Institute of Terrestrial Ecology grouping similar land classes together (see section 1.4.1), thereby reducing the variability in the badger data within each land class group. Hence this result is a reflection of the robustness of their land class groups. That is why we focussed our analyses on these land class groups.

Some potential variability within each stratum was also excluded by not surveying 1-km squares that are largely urban. There were two reasons for this. First, badgers are rare in urban habitats (Harris, 1984; Cresswell, Harris & Jefferies, 1990), and so monitoring changes in a small number of social groups would not be possible with a national survey such as this. Also, including large areas of urban land in the survey would further skew the data toward zeros because urban 1-km squares are very unlikely to contain badgers. An underlying assumption of the Poisson and negative binomial distributions is that each 1-km square included in the survey must at least have the potential to contain a badger sett. This is not true for many urban 1-km squares, and so including them in the survey would further complicate the statistical basis of the analyses.

Greenwood (1996) demonstrated that stratification can also be used to optimise sampling effort, and showed that optimal sampling would have meant that of the eight land class groupings used in the 1980s survey, 59% of the samples should have been taken in one relatively large land class group that had a high mean and variance. However, whilst this would be the preferred approach for a one-off sampling programme for which the prime aim was to obtain a population estimate, there were a number of conflicting aims for the badger monitoring programme. Whilst producing a reliable population estimate was important, it was equally important to provide a database to monitor changes well into the future. It is not possible to predict which strata will show the greatest badger population changes. Whilst some of the strata used in the sampling programme may have had badger populations at carrying capacity and, hence, the changes in these strata could be relatively low, in other strata the badger population may be well below carrying capacity, such that the largest future population changes will occur in these strata. Biasing the sampling away from some strata in the 1980s survey simply because they had few badgers, or a low mean and variance for the population estimate, would restrict the ability to monitor future population changes. Therefore, the approach adopted in the 1980s survey was to sample each stratum with equal intensity, since it was impossible to predict future needs.

Predicting the number of 1-km squares that should be monitored to reflect changes is less easy. Cresswell, Harris & Jefferies (1990) showed that a stable mean population estimate for all but the lowest density land classes was achieved with a sample of around 30 1-km squares, and so it was only necessary to survey around 1000 1-km squares to provide a reliable population estimate. Deciding on a database that can persist for an extended period, as is required for an effective monitoring system, is a lot harder, and there are no clear guidelines to help with this process. It is impossible, for instance, to predict the rate of attrition from the database due to refused access to land, the loss of 1-km squares due to urbanisation and other developments, and the future distribution of surveyors to repeat the exercise. Thus, in the 1980s survey, Cresswell, Harris & Jefferies (1990) aimed to achieve the largest coverage possible, whilst at the same time maintaining an even distribution of 1-km squares both regionaly and by habitat types.

This survey was designed as a monitoring exercise, and as such the aim was to measure real change in both the number of badger social groups and badger numbers in a random sample of 1-km squares stratified to represent each region and pattern of land use in Britain. The problems of monitoring population change are discussed in various papers in the volume edited by Sutherland (1996b). Here we use the 1980s data to determine which is the best survey design for a monitoring programme and, in particular, compare the benefits of surveying the original 1-km squares again or taking a new random sample of 1-km squares. For these analyses, the 1-km squares surveyed in the 1980s have been reallocated to the new land classes where necessary (see section 1.4.1), and the analyses were undertaken using the seven main land class groups.

The main questions we considered were:-

a. How big must any changes in the number of badger social groups be before we can detect them?
b. How good is our sampling regime?
c. Is a repeated design best for monitoring change in Britain's badger population?

We used four basic approaches to answer these questions:-

a. First we examined the distribution of main setts and the effect of this on the confidence intervals of our estimates.
b. We then examined the confidence intervals and the effect of sample size on the estimates.
c. The confidence intervals were then used to compare the effectiveness of resurveying the same 1-km squares as opposed to surveying a new random sample of 1-km squares for detecting change in the badger population.
d. We then describe the statistical analyses used to detect the changes observed between the surveys, based on surveying the same 1-km squares again.

*10.6.1 The underlying badger distribution - random or clustered?*

It is important to consider the underlying distribution of badger main setts because this could affect the confidence intervals for the estimates of the density of main setts in the land class groups. Smal (1995) examined these data from the 1980s in Britain and found that overall they followed a negative binomial distribution. This distribution is found when sampling a population which is aggregated. In the Republic of Ireland, however, Smal (1995) found that the distribution of main setts was random, and therefore fitted a Poisson distribution.

We examined the pattern of distribution of main setts in Britain by land class groups. The geographical distribution of plants or animals may be uniform, random, or aggregated, and the pattern of distribution determines the best survey design. Of the three patterns of distribution, badger main setts would have a uniform distribution when all habitats were equally suitable, and all territories were occupied. Thus there would be a constant, minimum, distance between main setts (see Kruuk, 1978). If this was the pattern of badger distribution, surveying would be easy, and a small sample of 1-km squares would provide an accurate population estimate with small confidence intervals. For a territorial species such as the badger, a random distribution would be unlikely to occur naturally unless patches of suitable habitat were both small and fragmented, so that generally only a single social group of badgers occupied each habitat patch. However, anthropogenic influences, such as persecution leading to the loss of social groups from areas with suitable habitat, could also lead to a random pattern of distribution.

An aggregated pattern of distribution occurs where badger setts, in this case, are clumped i.e. there is a greater probability of locating a second sett once one has been found. That undoubtedly will be the case for the smaller categories of sett, because they are only found within a territory and hence in the vicinity of each other and also a main sett. However, if it is the case that main setts are also aggregated, it means that there is a greater probability of finding main setts close to each other. This will occur if patches of suitable habitat are fragmented but large enough to hold several badger territories and/or if the natural pattern of distribution has been disrupted by persecution or other anthropogenic factors.

The best index to identify an aggregated distribution is the variance-to-mean ratio. If this value is greater than 1, the data show evidence of aggregation. The larger this value is above 1, the more clumped are the data. This index is especially useful for examining the main sett data because it is

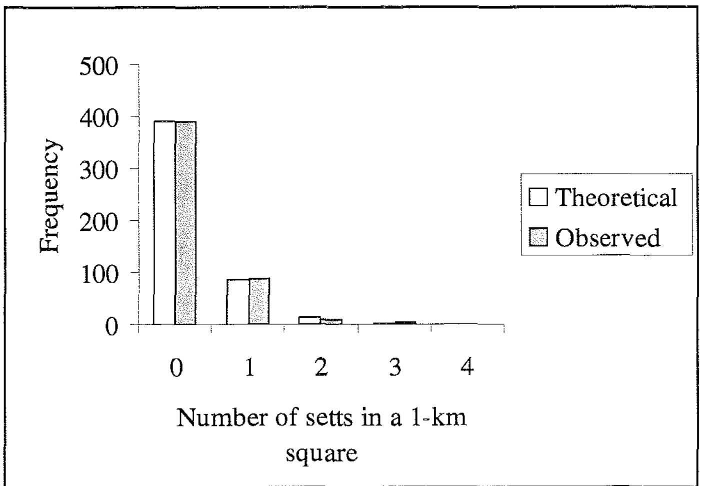



***Figure 10.6.1.*** *The distribution of main setts in the 1980s in the Arable II land class group compared to a negative binomial distribution*

only weakly affected by density (Krebs, 1989). We found that the main sett data for five land class groups (Arable I, Arable II, Pastoral IV, Pastoral V and Marginal upland VI) had a variance-to-mean ratio greater than 1, and a negative binomial distribution best described the distribution of main setts in these five land class groups; this is illustrated for the Arable II land class group in Figure 10.6.1. Whilst the distribution of main setts was aggregated in these five land class groups, this was most pronounced in Pastoral IV and Marginal upland VI, whereas Arable I was the least clumped. So whilst Arable I and Pastoral IV had similar mean main sett densities in the 1980s (0.47 and 0.42 main setts $km^{-2}$ respectively), their underlying distributions may be different.

For two land class groups (Arable III and Upland VII) the variance-to-mean ratio was equal to one, indicating that in these land class groups 1-km squares containing main setts are best described by a random distribution. This does not mean that environmental factors are not affecting their distribution, but is probably at least in part a reflection of the rarity of main setts in these land class groups (0.10 and 0.01 main setts $km^{-2}$ respectively). The rarity of setts is not in itself a complete explanation, since the density of main setts in Marginal upland VI was also only 0.10 $km^{-2}$, yet here the distribution was the most clumped of any of the land class groups.

*10.6.2 Detecting changes in the density of badger main setts in the land class groups*

First we examined the effects of sample size on the estimates of main sett density. For this, we calculated the mean number of main setts per 1-km square from a random sample of 25, 50, 100, 200, 300, 400 and all the 1-km squares from each of the seven land class groups (Figure 10.6.2). It can be seen that with a sample size of 50 or fewer 1-km squares, the mean density estimate is highly variable, and for most land class groups, a sample of 200 or more 1-km squares is needed before the mean main sett density remains constant. Thus, our samples within each land class group are adequate for estimating badger population densities.

Then we looked at how the 95% confidence intervals varied with increasing sample sizes, based on the standard errors of the means of the same sub-samples. From Figure 10.6.3, it can be seen that with a small sample size, the confidence intervals were extremely large but, as expected, they decline

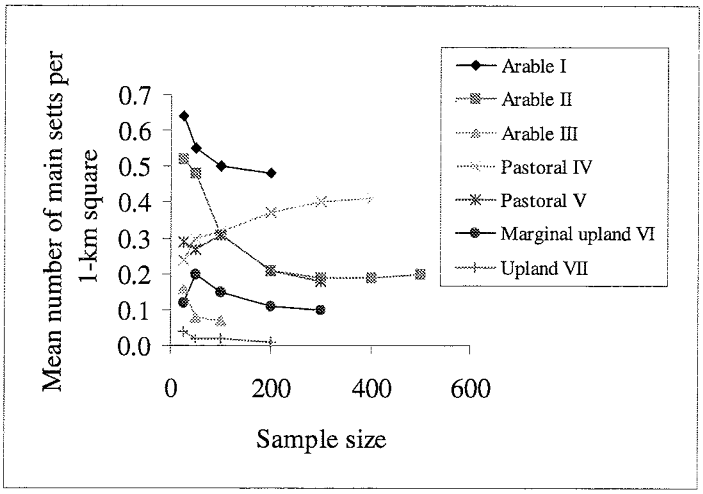



***Figure 10.6.2.*** *The effects of sample size on the estimated mean main sett density $km^{-2}$ in the 1980s for the seven land class groups*

in size rapidly as sample size increases, particularly for the land class groups with lower badger density. However, irrespective of badger density, increasing the sample size above 100 1-km squares per land class group has little impact on the size of the confidence intervals. For instance, for the land class group Pastoral V, the 95% confidence interval is ±23% with a sample size of 333 1-km squares; more than doubling the sample size to 700 1-km squares would only reduce the 95% confidence intervals to ±18%. Figure 10.6.3 also shows that with badger densities above about 0.15 main setts $km^{-2}$, as occurs in land class groups Arable I, Arable II, Pastoral IV and Pastoral V, increasing badger density does not affect the 95% confidence intervals for

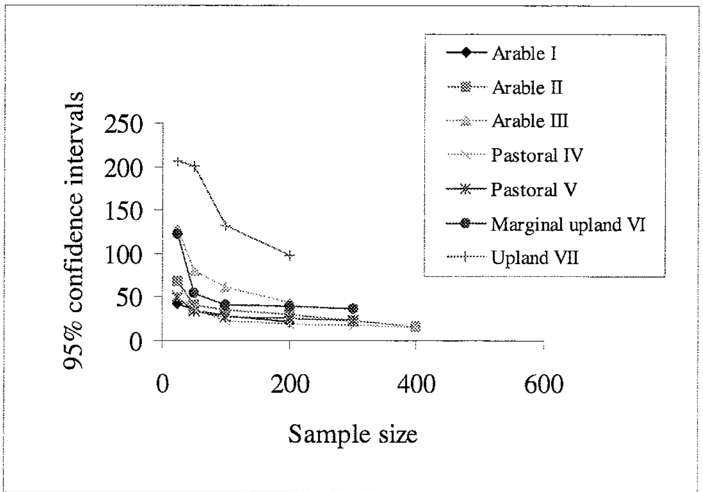



***Figure 10.6.3.*** *The effects of sample size and badger population density on the 95% confidence intervals of the mean population estimate, expressed as a percent of the mean*

any given sample size, and that the 95% confidence intervals for land class groups Arable III and Marginal upland VI, with mean densities of 0.10 main setts $km^{-2}$, are very similar. Only the land class group Upland VII, with a mean density of 0.01 main setts $km^{-2}$, had substantially higher 95% confidence intervals for any given sample size. Therefore, our sampling regime is robust and samples most badger densities equally effectively.

### *10.6.3 Designing a repeat survey that maximises the chance of detecting change*

Because the distribution of badger main setts is clumped in most land class groups, the 95% confidence intervals are quite large, even when both the mean density of main setts and the sample sizes are large. For example, in land class group Arable II, almost 500 1-km squares were surveyed but the 95% confidence interval is ±16% of the mean value. The 95% confidence interval for the number of social groups in the 1980s was ±9% (Cresswell, Harris & Jefferies, 1990) because of the large sample size and because stratified samples produce narrower population confidence intervals.

Because of the clumped distribution of badger main setts, and the effect this has on the 95% confidence intervals of the mean density estimates for each land class group, taking a new random sample of 1-km squares for the repeat survey would cause significant practical problems. Whilst the mean density estimates might vary between the two surveys, the large confidence intervals would require a population change of at least 25% in land class groups Arable I, Arable II, Pastoral IV and Pastoral V for this to be statistically significant, and any smaller population changes, or larger changes in lower density land class groups, would not be significant.

This problem is best overcome by taking a repeated sample from the same 1-km squares (Cochran, 1963); the two surveys are then highly correlated and small differences between the two samples, therefore, represent real change (Cochran, 1963). This is because the variance of the estimated change in main sett density for a repeated survey is equal to:-

$$S_1^2 + S_2^2 - 2rS_1S_2$$

where $S^2$ is the variance of samples 1 and 2, S is the standard deviation of samples 1 and 2 and r is the correlation coefficient between samples 1 and 2.

For two independent samples, however, the estimated change has a variance of:-

$$S_1^2 + S_2^2$$

This will be greater because, as r approaches 1, the variance of the estimate of change for the repeated sample declines (Cochran, 1963). This means that for almost all types of survey, the variance of the estimate of change will be less with a repeated design, and so a repeated design provides considerably greater analytical power given the nature of the data.

Hence we chose a repeated sample survey design because it gives the best chance of detecting change in Britain's badger population. This approach also has the considerable advantage that we can monitor the pattern of change as well as the magnitude of change i.e. the fate of individual setts can be followed and any changes in sett size and status quantified. It also enables subtle changes to be detected. For instance, setts may be lost but replaced by others; no overall numerical change would then mask significant local changes within the badger population. Such changes will only be detected by repeatedly surveying the same 1-km squares. Finally, where setts are lost, reasons for their disappearance can be determined and used to predict future patterns of population change.

However, whilst resurveying the same 1-km squares has significant advantages for a monitoring programme such as this, there are still practical problems with deciding what is real change, especially when relying just on changes in the number of main setts. The problems are in large part due to the aggregated nature of the data, and because most 1-km squares had no main setts, and very few had more than one. Thus, a large number of 1-km squares have to be surveyed within each land class group before real population changes can be detected reliably. The problem is illustrated in Figure 10.6.4, which shows the percentage change in mean main sett density that can be detected with different sample sizes at different badger population densities. With only 100 1-km squares sampled per land class group (which would have given reasonably good population estimates and 95% confidence intervals), only large changes in the number of social groups can be detected, even at the highest badger population densities. Even with 1000 1-km squares sampled, population changes of less than 20% could only be detected in the highest density land class groups. Surveying 1000 1-km squares in

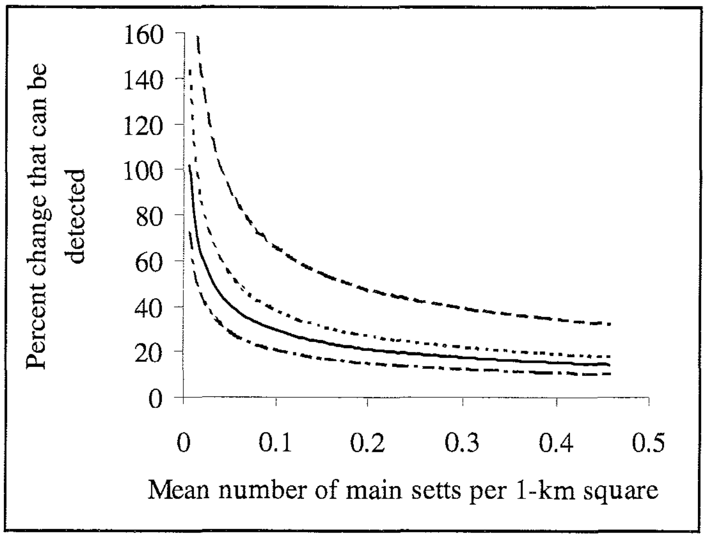



***Figure 10.6.4.*** *The percent change in the number of badger social groups that can be detected* (p<0.05) *at different population densities with various sample sizes. The lines indicate, from the top, samples of 100 1-km squares, the best fit line through the sample sizes for each land class group in this survey, 500 1-km squares, and 1000 1-km squares*

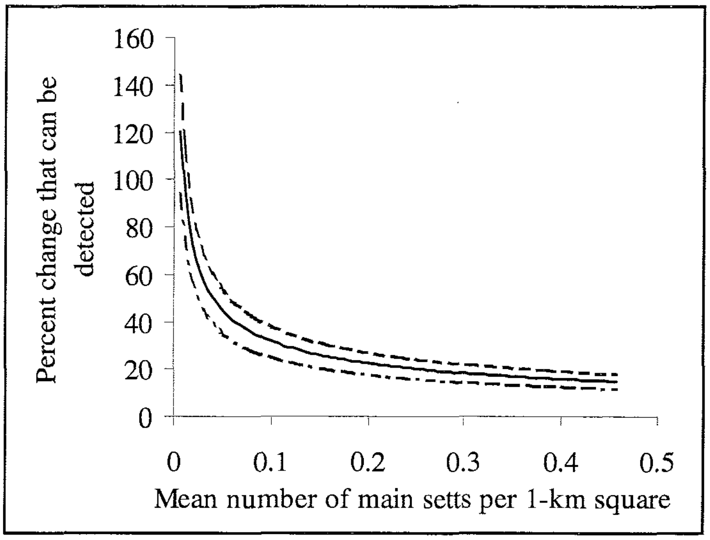



***Figure 10.6.5.*** *The percent change in the number of badger social groups that can be detected at different population densities at different levels of statistical significance. The lines are best fits through the sample sizes for each land class group in this survey. The lines indicate, from the top,* p<*0.01,* p<*0.05*

each land class group would not be logistically possible. However, the large increase in effort that would be required offered only a small increase in ability to detect change over the sample sizes we already have. So we have achieved a reasonable balance between what is feasible and the "ideal" sample size to detect population changes. In Figure 10.6.5 we illustrate the percent change in mean main sett densities that can be detected at different levels of significance with our data.

Both these graphs demonstrate that problems with sample sizes and our ability to detect change which is statistically significant remain roughly constant over a wide range of badger population densities, but that the limitations of any sampling protocol rise dramatically below densities of 0.1 main setts $km^{-2}$. At such low densities, it would be extremely difficult to detect even quite large population changes with any degree of statistical significance, however many 1-km squares were surveyed, if we relied solely on changes in the number of main setts. However, we have in part tried to overcome this problem by using a wide variety of measures of change (the total number of setts, changes in levels of activity at setts, the ratio of annexe to main setts and field signs). Where these different measures all provide evidence of a population change, even though it is not statistically significant, it is a measure of real change within our sample of 1-km squares and an indication of what is happening overall within that land class group.

### *10.6.4 Determining the significance of the observed change*

Having decided that a repeat survey is the best approach, the next problem is to decide how to determine the level of significance of any population changes. For the badger data, the mean and the variance of any population changes are not the best measures for determining the significance of any observed change because these data are not normally distributed, and because the confidence intervals are so high. However, the paired survey design enables us to use paired tests to determine the significance of any observed changes; in this report we use the Wilcoxon matched pairs test, which is a non-parametric analogue of the paired *t*-test, and 95% as powerful (Zar, 1984). For this, we use the data from the 1980s and the 1990s from just the 2271 1-km squares that were included in both surveys; the data presented in this report for the 1980s therefore differ slightly from those presented by Cresswell, Harris & Jefferies (1990).

## 10.7 Changes in the number of annexe, subsidiary, outlying and disused main setts, 1988-1997

**Table 10.7.1.** The change in the number of annexe setts, 1988-1997, by land class group.

| Land class group | Number of squares | Number of annexe setts in the 1980s | Number of annexe setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 53 | 92 | 74 | $p<0.001$ |
| Arable II | 493 | 45 | 72 | 60 | $p<0.05$ |
| Arable III | 188 | 2 | 8 | - | - |
| Pastoral IV | 428 | 82 | 157 | 91 | $p<0.0001$ |
| Pastoral V | 333 | 30 | 41 | 37 | n.s. |
| Marginal upland VI | 335 | 8 | 29 | - | - |
| Upland VII | 286 | 0 | 1 | - | - |
| **Totals** | **2271** | **220** | **400** | **82** | **$p<0.0001$** |

**Table 10.7.2.** Regional changes in the number of annexe setts, 1988-1997.

| Region | Number of squares | Number of annexe setts in the 1980s | Number of annexe setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| North England | 170 | 6 | 6 | - | - |
| North-west England | 72 | 5 | 8 | - | - |
| North-east England | 121 | 14 | 7 | -50 | n.s. |
| West Midlands | 177 | 19 | 70 | 268 | $p<0.0001$ |
| East Midlands | 153 | 12 | 17 | 42 | n.s. |
| Central England | 91 | 12 | 12 | 0 | n.s. |
| East Anglia | 161 | 7 | 11 | - | - |
| South-west England | 205 | 64 | 117 | 83 | $p=0.0001$ |
| Southern England | 131 | 21 | 43 | 105 | $p<0.01$ |
| South-east England | 159 | 24 | 41 | 71 | $p<0.05$ |
| North Scotland | 366 | 3 | 2 | - | - |
| South Scotland | 208 | 2 | 10 | - | - |
| Mid and north Wales | 143 | 12 | 28 | 133 | $p<0.01$ |
| South Wales | 114 | 19 | 28 | 47 | n.s. |
| **Totals** | **2271** | **220** | **400** | **82** | **$p<0.0001$** |

**Table 10.7.3.** The change in the number of subsidiary setts, 1988-1997, by land class group.

| Land class group | Number of squares | Number of subsidiary setts in the 1980s | Number of subsidiary setts in the 1990s | Percent change | Signif-icance |
|---|---|---|---|---|---|
| Arable I | 208 | 93 | 154 | 66 | $p<0.01$ |
| Arable II | 493 | 74 | 98 | 32 | $p<0.05$ |
| Arable III | 188 | 8 | 14 | - | - |
| Pastoral IV | 428 | 143 | 242 | 69 | $p<0.0001$ |
| Pastoral V | 333 | 67 | 89 | 33 | $p<0.05$ |
| Marginal upland VI | 335 | 38 | 49 | 29 | n.s. |
| Upland VII | 286 | 6 | 11 | - | - |
| **Totals** | **2271** | **429** | **657** | **53** | $\mathbf{p<0.0001}$ |

**Table 10.7.4.** Regional changes in the number of subsidiary setts, 1988-1997.

| Region | Number of squares | Number of subsidiary setts in the 1980s | Number of subsidiary setts in the 1990s | Percent change | Signif-icance |
|---|---|---|---|---|---|
| North England | 170 | 15 | 26 | 73 | n.s. |
| North-west England | 72 | 14 | 19 | 36 | n.s. |
| North-east England | 121 | 4 | 9 | - | - |
| West Midlands | 177 | 45 | 79 | 76 | $p<0.01$ |
| East Midlands | 153 | 21 | 24 | 14 | n.s. |
| Central England | 91 | 17 | 30 | 76 | n.s. |
| East Anglia | 161 | 8 | 18 | - | - |
| South-west England | 205 | 118 | 192 | 63 | $p<0.001$ |
| Southern England | 131 | 42 | 68 | 62 | $p<0.01$ |
| South-east England | 159 | 42 | 67 | 60 | n.s. |
| North Scotland | 366 | 12 | 11 | -8 | n.s. |
| South Scotland | 208 | 16 | 13 | -19 | n.s. |
| Mid and north Wales | 143 | 32 | 53 | 66 | $p<0.05$ |
| South Wales | 114 | 43 | 48 | 12 | n.s. |
| **Totals** | **2271** | **429** | **657** | **53** | $\mathbf{p<0.0001}$ |

**Table 10.7.5.** The change in the number of outlying setts, 1988-1997, by land class group.

| Land class group | Number of squares | Number of outlying setts in the 1980s | Number of outlying setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 155 | 216 | 39 | n.s. |
| Arable II | 493 | 127 | 194 | 53 | *p*<0.05 |
| Arable III | 188 | 17 | 19 | 12 | - |
| Pastoral IV | 428 | 273 | 431 | 58 | *p*<0.0001 |
| Pastoral V | 333 | 114 | 160 | 40 | n.s. |
| Marginal upland VI | 335 | 75 | 129 | 72 | *p*<0.01 |
| Upland VII | 286 | 8 | 14 | - | - |
| **Totals** | **2271** | **769** | **1163** | **51** | ***p*<0.0001** |

**Table 10.7.6.** Regional changes in the number of outlying setts, 1988-1997.

| Region | Number of squares | Number of outlying setts in the 1980s | Number of outlying setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| North England | 170 | 37 | 80 | 116 | n.s. |
| North-west England | 72 | 16 | 28 | 75 | n.s. |
| North-east England | 121 | 18 | 22 | 22 | n.s. |
| West Midlands | 177 | 96 | 170 | 77 | *p*<0.01 |
| East Midlands | 153 | 40 | 62 | 55 | n.s. |
| Central England | 91 | 37 | 41 | 11 | n.s. |
| East Anglia | 161 | 10 | 29 | 190 | *p*<0.01 |
| South-west England | 205 | 183 | 332 | 81 | *p*<0.0001 |
| Southern England | 131 | 86 | 94 | 9 | n.s. |
| South-east England | 159 | 73 | 96 | 32 | n.s. |
| North Scotland | 366 | 27 | 19 | -30 | n.s. |
| South Scotland | 208 | 19 | 13 | -32 | n.s. |
| Mid and north Wales | 143 | 60 | 89 | 48 | n.s. |
| South Wales | 114 | 67 | 88 | 31 | *p*<0.05 |
| **Totals** | **2271** | **769** | **1163** | **51** | ***p*<0.0001** |

**Table 10.7.7.** The change in the number of disused main setts, 1988-1997, by land class group.

| Land class group | Number of squares | Number of disused main setts in the 1980s | Number of disused main setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| Arable I | 208 | 21 | 14 | -33 | n.s. |
| Arable II | 493 | 21 | 12 | -43 | n.s. |
| Arable III | 188 | 4 | 2 | - | n.s. |
| Pastoral IV | 428 | 23 | 22 | -4 | n.s. |
| Pastoral V | 333 | 32 | 7 | - | $p<0.0001$ |
| Marginal upland VI | 335 | 8 | 6 | - | n.s. |
| Upland VII | 286 | 2 | 1 | - | n.s. |
| **Totals** | **2271** | **111** | **64** | **-42** | $\boldsymbol{p<0.001}$ |

**Table 10.7.8.** Regional changes in the number of disused main setts, 1988-1997.

| Region | Number of squares | Number of disused main setts in the 1980s | Number of disused main setts in the 1990s | Percent change | Significance |
|---|---|---|---|---|---|
| North England | 170 | 5 | 4 | - | n.s. |
| North-west England | 72 | 6 | 3 | - | n.s. |
| North-east England | 121 | 6 | 0 | - | n.s. |
| West Midlands | 177 | 16 | 9 | - | n.s. |
| East Midlands | 153 | 7 | 2 | - | n.s. |
| Central England | 91 | 5 | 2 | - | n.s. |
| East Anglia | 161 | 6 | 2 | - | n.s. |
| South-west England | 205 | 17 | 16 | - | n.s. |
| Southern England | 131 | 11 | 9 | - | n.s. |
| South-east England | 159 | 7 | 5 | - | n.s. |
| North Scotland | 366 | 6 | 1 | - | n.s. |
| South Scotland | 208 | 6 | 2 | - | n.s. |
| Mid and north Wales | 143 | 8 | 2 | - | n.s. |
| South Wales | 114 | 5 | 7 | - | n.s. |
| **Totals** | **2271** | **111** | **64** | **-42** | $\boldsymbol{p<0.001}$ |

# 10.8 Changes in the size of setts, 1988-1997

**Table 10.8.1.** The change in the size of main setts, 1988-1997, by land class group; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Land class group | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| Arable I | 6.1±0.4 | 8.4±0.7 | 3.0±0.3 | 4.5±0.6 | 3.1±0.5 | 3.7±0.5 | 12.5±0.8 | 16.6±1.5 | $p<0.001$ |
| Arable II | 5.8±0.5 | 8.7±0.7 | 3.4±0.4 | 3.4±0.4 | 4.1±0.7 | 3.2±0.4 | 13.5±1.0 | 15.2±1.1 | $p=0.0001$ |
| Arable III | 4.4±0.8 | 5.3±1.1 | 1.8±0.5 | 2.1±0.4 | 1.4±0.6 | 1.6±0.4 | 7.6±1.3 | 9.1±1.2 | n.s. |
| Pastoral IV | 6.5±0.5 | 8.4±0.5 | 3.5±0.4 | 3.9±0.3 | 3.2±0.4 | 3.2±0.3 | 13.3±1.0 | 15.5±0.8 | $p<0.0001$ |
| Pastoral V | 5.5±0.9 | 8.0±0.6 | 2.0±0.3 | 3.0±0.4 | 2.3±0.6 | 2.0±0.3 | 9.8±1.2 | 12.9±1.0 | $p<0.001$ |
| Marginal upland VI | 4.5±0.8 | 7.7±0.7 | 1.8±0.4 | 2.6±0.5 | 2.8±1.0 | 1.3±0.4 | 9.4±1.6 | 11.5±1.1 | n.s. |
| Upland VII | 3.5±0.5 | 5.0±0.6 | 1.9±1.0 | 3.4±1.6 | 2.5±2.5 | 1.0±0.6 | 7.0±1.0 | 9.4±2.1 | n.s. |
| **Totals** | **5.9±0.3** | **8.2±0.3** | **2.9±0.2** | **3.6±0.2** | **3.1±0.3** | **2.9±0.2** | **12.3±0.5** | **14.6±0.5** | $\boldsymbol{p<0.0001}$ |

**Table 10.8.2.** Regional changes in the size of main setts, 1988-1997; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Region | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| North England | 4.1±1.1 | 6.7±1.1 | 1.4±0.4 | 2.1±0.6 | 1.9±0.4 | 1.7±0.4 | 7.3±1.7 | 10.5±1.6 | n.s. |
| North-west England | 4.0±0.6 | 7.4±1.3 | 0.9±0.4 | 2.0±0.7 | 1.7±0.8 | 2.5±1.0 | 6.6±0.8 | 11.9±2.6 | $p<0.05$ |
| North-east England | 4.9±1.1 | 6.3±1.0 | 3.5±0.9 | 2.2±0.4 | 1.3±0.5 | 1.0±0.3 | 9.8±1.9 | 9.5±1.7 | n.s. |
| West Midlands | 7.7±1.2 | 8.7±0.6 | 2.7±0.5 | 3.8±0.5 | 3.1±0.8 | 3.0±0.5 | 13.3±1.7 | 15.5±1.4 | $p<0.01$ |
| East Midlands | 5.3±0.8 | 6.5±0.8 | 2.8±0.8 | 3.4±0.9 | 4.6±1.8 | 2.8±0.6 | 12.7±2.0 | 12.7±1.8 | n.s. |
| Central England | 6.6±1.6 | 10.1±2.1 | 2.1±0.5 | 2.1±0.4 | 5.7±1.3 | 2.9±0.6 | 14.4±2.1 | 15.1±2.9 | n.s. |
| East Anglia | 3.9±1.3 | 6.6±0.9 | 4.6±1.3 | 2.7±1.1 | 5.3±2.7 | 3.1±1.5 | 13.4±3.0 | 12.5±3.3 | n.s. |
| South-west England | 7.1±0.6 | 9.0±0.7 | 4.2±0.5 | 4.3±0.4 | 3.2±0.4 | 3.2±0.4 | 14.4±1.2 | 16.6±1.3 | $p<0.001$ |
| Southern England | 7.0±0.7 | 10.3±1.7 | 2.7±0.5 | 5.0±1.1 | 5.2±1.2 | 4.1±0.7 | 14.8±1.6 | 19.4±3.2 | $p=0.05$ |
| South-east England | 6.1±0.5 | 6.5±0.7 | 3.7±0.5 | 4.7±0.7 | 2.7±0.5 | 3.2±0.6 | 12.5±0.9 | 14.5±1.3 | $p<0.05$ |
| North Scotland | 5.3±1.7 | 5.6±1.3 | 2.2±0.8 | 3.3±0.7 | 1.4±1.3 | 1.7±0.6 | 9.0±2.3 | 10.6±2.6 | n.s. |
| South Scotland | 4.1±0.7 | 5.3±0.8 | 1.6±0.4 | 2.1±0.5 | 1.9±0.5 | 1.2±0.4 | 7.6±1.2 | 8.6±1.0 | n.s. |
| Mid and north Wales | 4.8±0.7 | 9.7±1.0 | 2.2±0.4 | 2.8±0.6 | 3.6±1.2 | 2.3±0.6 | 10.6±1.7 | 14.8±1.8 | $p=0.01$ |
| South Wales | 6.0±0.7 | 7.5±0.7 | 2.4±0.5 | 2.2±0.5 | 2.1±0.7 | 2.6±0.9 | 11.0±1.3 | 12.8±1.7 | $p<0.001$ |
| **Totals** | **5.9±0.3** | **8.2±0.3** | **2.9±0.2** | **3.6±0.2** | **3.1±0.3** | **2.9±0.2** | **12.3±0.5** | **14.6±0.5** | $\mathbf{p<0.0001}$ |

**Table 10.8.3.** The change in the size of annexe setts, 1988-1997, by land class group; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Land class group | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| Arable I | 2.0±0.4 | 2.5±0.3 | 1.2±0.3 | 1.4±0.2 | 2.2±0.4 | 1.6±0.3 | 5.4±0.6 | 5.5±0.4 | n.s. |
| Arable II | 2.3±0.4 | 2.3±0.4 | 2.0±0.5 | 1.2±0.2 | 2.4±0.4 | 1.3±0.2 | 6.1±0.7 | 4.9±0.6 | n.s. |
| Arable III | 0.5±0.5 | 1.6±0.5 | 2.0±0.0 | 0.9±0.3 | 1.0±1.0 | 2.2±1.0 | 3.5±0.5 | 4.7±0.7 | - |
| Pastoral IV | 2.2±0.3 | 2.9±0.3 | 1.4±0.2 | 2.0±0.2 | 2.1±0.4 | 2.1±0.3 | 5.7±0.4 | 6.7±0.6 | $p<0.01$ |
| Pastoral V | 0.8±0.3 | 1.8±0.3 | 1.7±0.5 | 1.4±0.3 | 2.5±0.6 | 1.4±0.3 | 5.2±0.9 | 4.6±0.5 | n.s. |
| Marginal upland V1 | 1.1±0.5 | 1.8±0.2 | 0.3±0.2 | 1.7±0.5 | 1.3±0.7 | 0.4±0.2 | 2.7±1.1 | 3.9±0.6 | n.s. |
| Upland VII | - | - | - | - | - | - | - | - | - |
| **Totals** | **1.9±0.2** | **2.4±0.2** | **1.5±0.2** | **1.6±0.1** | **2.1±0.2** | **1.6±0.1** | **5.5±0.3** | **5.7±0.3** | **$p<0.01$** |

**Table 10.8.4.** Regional changes in the size of annexe setts, 1988-1997; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Region | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| North England | 1.7±0.8 | 2.4±1.3 | 1.9±1.1 | 2.7±2.1 | 1.1±0.7 | 2.0±2.0 | 4.7±1.2 | 7.1±1.8 | n.s. |
| North-west England | 0 | 0.7±0.6 | 0 | 1.3±0.8 | 3.3±1.1 | 2.3±0.8 | 3.3±1.2 | 4.2±1.3 | n.s. |
| North-east England | 1.9±0.5 | 3.1±1.1 | 2.1±0.7 | 1.1±0.5 | 2.6±0.7 | 1.4±0.6 | 6.5±0.5 | 5.6±1.8 | n.s. |
| West Midlands | 1.2±0.5 | 2.1±0.3 | 1.4±0.5 | 1.8±0.2 | 2.9±0.8 | 1.5±0.3 | 5.4±1.0 | 5.4±0.8 | n.s. |
| East Midlands | 1.5±0.6 | 1.8±0.4 | 0.8±0.7 | 0.6±0.3 | 1.0±0.5 | 1.0±0.4 | 3.4±0.6 | 3.4±0.7 | n.s. |
| Central England | 0.7±0.4 | 2.8±0.8 | 0.9±0.5 | 1.6±0.5 | 3.4±0.9 | 1.3±0.4 | 5.1±0.8 | 5.6±1.4 | n.s. |
| East Anglia | 2.0±0.0 | 2.1±1.0 | 0 | 1.5±0.9 | 0 | 0.7±0.5 | 2.0±0.0 | 4.3±1.5 | n.s. |
| South-west England | 2.0±0.3 | 2.9±0.3 | 1.5±0.3 | 1.9±0.3 | 2.1±0.5 | 1.8±0.3 | 5.7±0.4 | 6.6±0.8 | $p<0.05$ |
| Southern England | 3.0±1.0 | 2.1±0.4 | 1.4±0.5 | 1.5±0.3 | 2.4±0.8 | 2.7±0.7 | 6.7±1.5 | 6.3±1.1 | n.s. |
| South-east England | 2.6±0.4 | 2.1±0.3 | 1.7±0.5 | 1.6±0.3 | 1.8±0.5 | 1.3±0.3 | 6.1±0.7 | 5.0±0.8 | n.s. |
| North Scotland | 0.2±0.3 | 0 | 1.3±0.8 | 2.5±1.5 | 1.0±1.0 | 2.0±2.0 | 2.5±1.5 | 4.5±1.9 | - |
| South Scotland | 1.0±0.0 | 1.3±0.4 | 1.0±0.0 | 1.2±0.3 | 1.5±1.5 | 1.0±0.4 | 3.5±1.5 | 3.4±0.9 | - |
| Mid and north Wales | 1.1±0.4 | 2.2±0.3 | 2.3±0.8 | 1.3±0.5 | 2.2±0.8 | 0.9±0.4 | 5.5±1.6 | 4.4±0.9 | n.s. |
| South Wales | 3.0±0.9 | 4.2±1.1 | 0.8±0.2 | 1.7±0.7 | 1.8±0.9 | 2.8±0.6 | 5.7±0.7 | 7.8±1.4 | n.s. |
| **Totals** | **1.9±0.2** | **2.4±0.2** | **1.5±0.2** | **1.6±0.1** | **2.1±0.2** | **1.6±0.1** | **5.5±0.3** | **5.7±0.3** | **$p<0.01$** |

**Table 10.8.5.** The change in the size of subsidiary setts, 1988-1997, by land class group; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Land class group | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| Arable I | 1.0±0.2 | 1.5±0.2 | 1.4±0.2 | 1.2±0.1 | 2.2±0.3 | 2.1±0.2 | 4.6±0.3 | 4.8±0.2 | n.s. |
| Arable II | 1.0±0.2 | 2.0±0.2 | 1.1±0.2 | 1.4±0.2 | 1.9±0.3 | 1.6±0.3 | 4.1±0.2 | 5.0±0.3 | n.s. |
| Arable III | 0.3±0.3 | 1.2±0.3 | 2.0±0.7 | 1.5±0.3 | 1.9±0.7 | 1.4±0.6 | 4.1±0.6 | 4.0±0.4 | n.s. |
| Pastoral IV | 1.3±0.2 | 1.5±0.1 | 1.5±0.2 | 1.7±0.1 | 1.7±0.2 | 2.2±0.3 | 4.5±0.2 | 5.4±0.3 | $p<0.01$ |
| Pastoral V | 0.6±0.1 | 1.4±0.2 | 1.3±0.3 | 1.5±0.2 | 2.0±0.3 | 1.5±0.2 | 4.0±0.3 | 4.4±0.2 | n.s. |
| Marginal upland VI | 0.9±0.2 | 1.9±0.3 | 1.6±0.3 | 1.8±0.3 | 1.7±0.3 | 1.3±0.4 | 4.2±0.3 | 5.1±0.4 | n.s. |
| Upland VII | 0.5±0.5 | 1.0±0.4 | 1.5±0.5 | 1.5±0.3 | 1.6±0.6 | 1.5±0.4 | 3.6±0.6 | 4.0±0.3 | n.s. |
| **Totals** | **1.0±0.1** | **1.6±0.1** | **1.4±0.1** | **1.5±0.1** | **1.9±0.1** | **1.8±0.1** | **4.3±0.1** | **5.0±0.1** | $p$**=0.0001** |

**Table 10.8.6.** Regional changes in the size of subsidiary setts, 1988-1997; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Region | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| North England | 0.3±0.2 | 1.3±0.3 | 0.8±0.4 | 1.8±0.4 | 1.5±0.4 | 1.5±0.5 | 3.9±0.3 | 4.7±1.2 | n.s. |
| North-west England | 0.7±0.3 | 1.3±0.4 | 1.6±0.6 | 1.4±0.4 | 1.8±0.5 | 1.5±0.6 | 4.1±0.5 | 4.2±1.3 | n.s. |
| North-east England | 1.0±0.6 | 2.0±0.6 | 0.7±0.6 | 2.4±1.0 | 0.7±0.6 | 1.2±0.4 | 2.3±0.2 | 5.6±1.8 | - |
| West Midlands | 0.9±0.2 | 1.6±0.2 | 1.7±0.3 | 1.4±0.2 | 1.7±0.4 | 2.1±0.3 | 4.3±0.2 | 5.0±0.8 | n.s. |
| East Midlands | 1.0±0.3 | 2.2±0.4 | 0.7±0.3 | 0.9±0.2 | 1.8±0.5 | 0.9±0.4 | 3.6±0.2 | 4.0±0.8 | n.s. |
| Central England | 0.3±0.2 | 2.1±0.5 | 1.3±0.6 | 1.2±0.3 | 2.4±0.6 | 1.6±0.5 | 4.0±0.3 | 4.8±1.2 | n.s. |
| East Anglia | 0.5±0.5 | 1.7±0.4 | 1.0±1.0 | 1.4±0.4 | 2.0±2.0 | 1.4±0.7 | 3.5±0.3 | 4.5±1.6 | n.s. |
| South-west England | 1.1±0.3 | 1.8±0.2 | 1.5±0.2 | 1.6±0.2 | 1.8±0.3 | 2.1±0.3 | 4.7±0.2 | 5.6±0.7 | $p<0.01$ |
| Southern England | 0.8±0.3 | 1.2±0.2 | 1.5±0.3 | 1.8±0.3 | 2.3±0.5 | 2.3±0.3 | 5.0±0.4 | 5.3±0.9 | n.s. |
| South-east England | 1.3±0.2 | 1.6±0.3 | 1.1±0.2 | 1.2±0.2 | 1.9±0.4 | 2.1±0.3 | 4.3±0.2 | 5.0±0.8 | n.s. |
| North Scotland | 0.5±0.4 | 0.9±0.3 | 2.1±0.6 | 2.0±0.5 | 2.0±0.9 | 1.3±0.4 | 4.6±0.5 | 4.2±1.8 | n.s. |
| South Scotland | 0.5±0.2 | 0.7±0.2 | 1.3±0.3 | 1.2±0.3 | 1.3±0.5 | 2.3±0.5 | 3.2±0.3 | 4.2±1.1 | n.s. |
| Mid and north Wales | 0.8±0.2 | 2.1±0.3 | 1.5±0.4 | 1.4±0.2 | 1.6±0.3 | 1.1±0.4 | 3.8±0.3 | 4.6±1.0 | n.s. |
| South Wales | 0.9±0.3 | 1.1±0.3 | 1.6±0.5 | 1.7±0.3 | 2.4±0.5 | 1.6±0.4 | 4.9±0.3 | 4.3±0.8 | n.s. |
| **Totals** | **1.0±0.1** | **1.6±0.1** | **1.4±0.1** | **1.5±0.1** | **1.9±0.1** | **1.8±0.1** | **4.3±0.1** | **5.0±0.1** | $p<0.0001$ |

**Table 10.8.7.** The change in the size of outlying setts, 1988-1997, by land class group; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Land class group | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| Arable I | 0.5±0.1 | 0.6±0.1 | 0.6±0.1 | 0.6±0.1 | 0.8±0.1 | 0.5±0.1 | 1.8±0.1 | 1.7±0.1 | n.s. |
| Arable II | 0.4±0.1 | 0.7±0.1 | 0.4±0.1 | 0.5±0.1 | 0.8±0.1 | 0.5±0.1 | 1.6±0.1 | 1.7±0.1 | $p<0.05$ |
| Arable III | 0.8±0.3 | 0.5±0.2 | 0.3±0.1 | 0.6±0.2 | 1.3±0.4 | 0.5±0.2 | 2.4±0.4 | 1.6±0.2 | n.s. |
| Pastoral IV | 0.5±0.1 | 0.6±0.0 | 0.5±0.1 | 0.6±0.0 | 0.8±0.1 | 0.5±0.1 | 1.8±0.1 | 1.6±0.1 | n.s. |
| Pastoral V | 0.3±0.1 | 0.6±0.1 | 0.5±0.1 | 0.6±0.1 | 0.9±0.1 | 0.5±0.1 | 1.8±0.1 | 1.7±0.1 | n.s. |
| Marginal upland VI | 0.4±0.1 | 0.5±0.1 | 0.8±0.1 | 0.6±0.1 | 0.4±0.1 | 0.5±0.1 | 1.6±0.1 | 1.6±0.1 | n.s. |
| Upland VII | 0.3±0.2 | 0.3±0.2 | 0.6±0.5 | 0.7±0.2 | 0.8±0.4 | 0.3±0.3 | 1.7±0.2 | 1.3±0.2 | n.s. |
| **Totals** | **0.4±0.0** | **0.6±0.0** | **0.5±0.0** | **0.5±0.0** | **0.8±0.1** | **0.5±0.0** | **1.7±0.0** | **1.7±0.0** | **n.s.** |

**Table 10.8.8.** Regional changes in the size of outlying setts, 1988-1997; figures are means ±s.e. The statistical tests are for comparisons between the total number of holes in the 1980s and 1990s.

| Region | Number of well-used holes in the 1980s | Number of well-used holes in the 1990s | Number of partially-used holes in the 1980s | Number of partially-used holes in the 1990s | Number of disused holes in the 1980s | Number of disused holes in the 1990s | Total number of holes in the 1980s | Total number of holes in the 1990s | Significance |
|---|---|---|---|---|---|---|---|---|---|
| North England | 0.5±0.1 | 0.7±0.1 | 0.6±0.1 | 0.4±0.1 | 0.8±0.2 | 0.3±0.1 | 1.8±0.3 | 1.5±0.4 | n.s. |
| North-west England | 0.3±0.1 | 0.7±0.2 | 0.6±0.2 | 0.5±0.2 | 0.6±0.2 | 0.4±0.2 | 1.4±0.2 | 1.6±0.5 | n.s. |
| North-east England | 0.5±0.2 | 0.4±0.2 | 0.4±0.2 | 0.9±0.3 | 0.9±0.2 | 1.1±0.3 | 1.8±0.2 | 2.5±0.8 | n.s. |
| West Midlands | 0.5±0.1 | 0.6±0.1 | 0.5±0.1 | 0.7±0.1 | 0.9±0.2 | 0.3±0.1 | 1.8±0.2 | 1.6±0.2 | n.s. |
| East Midlands | 0.2±0.1 | 0.6±0.1 | 0.6±0.2 | 0.6±0.1 | 0.7±0.2 | 0.8±0.2 | 1.6±0.1 | 1.8±0.4 | n.s. |
| Central England | 0.3±0.1 | 0.9±0.2 | 0.4±0.1 | 0.5±0.1 | 0.6±0.1 | 0.4±0.1 | 1.4±0.1 | 1.7±0.4 | n.s. |
| East Anglia | 0.7±0.2 | 0.7±0.2 | 0.4±0.3 | 0.7±0.2 | 1.1±0.4 | 0.4±0.2 | 1.8±0.2 | 1.5±0.5 | n.s. |
| South-west England | 0.7±0.1 | 0.7±0.1 | 0.4±0.1 | 0.5±0.0 | 0.6±0.1 | 0.5±0.1 | 1.7±0.1 | 1.6±0.2 | n.s. |
| Southern England | 0.3±0.1 | 0.6±0.1 | 0.6±0.1 | 0.6±0.1 | 0.9±0.2 | 0.6±0.2 | 1.9±0.2 | 1.8±0.3 | n.s. |
| South-east England | 0.4±0.1 | 0.6±0.1 | 0.5±0.1 | 0.7±0.1 | 1.0±0.2 | 0.6±0.1 | 1.9±0.2 | 1.8±0.3 | n.s. |
| North Scotland | 0.2±0.2 | 0.3±0.1 | 0.9±0.3 | 0.5±0.2 | 0.8±0.4 | 0.4±0.2 | 1.9±0.4 | 1.3±0.5 | n.s. |
| South Scotland | 0.3±0.2 | 0.3±0.1 | 0.1±0.1 | 0.7±0.2 | 1.6±0.3 | 1.3±0.3 | 2.0±0.2 | 1.9±0.5 | n.s. |
| Mid and north Wales | 0.3±0.1 | 0.6±0.1 | 0.6±0.1 | 0.6±0.1 | 0.6±0.1 | 0.4±0.1 | 1.5±0.1 | 1.6±0.3 | n.s. |
| South Wales | 0.4±0.1 | 0.6±0.1 | 0.8±0.2 | 0.6±0.1 | 0.6±0.2 | 0.3±0.1 | 1.7±0.1 | 1.4±0.3 | n.s. |
| **Totals** | **0.4±0.0** | **0.6±0.0** | **0.5±0.0** | **0.5±0.0** | **0.8±0.1** | **0.5±0.0** | **1.7±0.0** | **1.7±0.0** | **n.s.** |

## 10.9 Changes to the badger protection laws

The early badger protection legislation was primarily designed to protect badgers from being dug out with the aid of dogs, and the level of protection was progressively strengthened when it was found that badger digging continued despite the changes to the law. Apart from badger baiting which, with bull baiting, was made illegal in 1835, badgers were first given legal protection by the Badgers Act 1973. Whilst providing a limited amount of protection to badgers, it still allowed landowners and authorised persons to take and kill badgers, and this included digging. There was provision in the Act for the Home Secretary to declare an Area of Special Protection if, after consultation with the Natural Environment Research Council, it appeared to be necessary for "the proper conservation of badgers". This made it illegal for anyone to kill badgers within the specified area unless "his action was necessary for the purpose of preventing serious damage to land, crops, poultry or any other form of property or for the purpose of preventing the spread of disease". The phrase "the proper conservation of badgers", used in the 1973 Act, is interesting; it presumably implies that those responsible for drafting the legislation were worried that allowing landowners to retain the right to kill badgers on their land would not provide adequate protection for the species, and that badger populations were at risk of further declines from control operations instigated by, or allowed by, landowners.

Badger digging was finally made illegal in 1981 by the amendments in Schedule 7 of the Wildlife and Countryside Act 1981. It is now no longer legal for anybody to carry out these activities without the necessary licences. However, a licence to dig for badgers has so far never been issued, nor is this likely to occur. There were further amendments in the Wildlife and Countryside (Amendment) Act 1985, which were designed to help obtain prosecutions for badger digging. Previously, defendants could claim that they were digging for foxes, and the prosecution would have to prove intent to take or kill badgers. This amendment put the onus on defendants to prove that they were after foxes, such that "he shall be presumed to have been digging for a badger unless the contrary is shown". A similar clause relates to attempting to kill, injure or take a badger (Skinner, Jefferies & Harris, 1989).

However, none of this legislation protected badger setts. This was changed by the Badgers Act 1991, which became law on 25 October 1991. This made it an offence intentionally or recklessly to damage, destroy or obstruct access to any part of a badger sett, to cause a dog to enter a sett or to disturb a badger whilst it is occupying a sett. A separate Act, The Badgers (Further Protection) Act 1991, which came into force on 25 September 1991, made provision for the removal, disposal or destruction of any dogs used illegally for badger digging. The new Act included a number of "exceptions" and licensable procedures to allow badgers and/or setts be destroyed, and there were provisions to facilitate activities such as fox hunting and gamekeeping, albeit with some restrictions. The various badger protection laws were consolidated on 16 July 1992 by the Protection of Badgers Act 1992; all the related older legislation was then repealed.

The definition of a "badger sett" within the meaning of the 1992 Act is given as "any structure or place which displays signs indicating current use by a badger"; thus, it includes main, annexe, subsidiary and outlying setts. Whilst the 1992 Act includes a general exemption to allow fox hunts to stop out foxes to prevent them going to ground whilst being hunted, the exception has many provisions. Thus the "stopper" cannot take any action other than obstructing the entrances, cannot dig into the tops and sides of entrances, cannot pack the soil hard into the entrances, and can only use materials specified under the Act i.e. (i) untainted straw or hay, leaf-litter, bracken, loose soil; (ii) bundles of sticks or faggots, or paper sacks that can be either empty or containing the items listed in (i) above. These materials can only be placed in the sett entrances on the day of the hunt, or after midday on the preceding day where items listed under (i) are used. If the items listed under (ii) are used, they can only be placed in the sett entrances on the day of the hunt and have to be removed the same day. These provisions were designed to minimise the damage to badger setts.

Legal restrictions regarding the use of chemicals have also increased in recent years, and these should have benefited badger populations. In particular, under the Control of Pesticides Regulations 1986, *Cymag* only has approval for use against rabbits and rats and no product is currently approved for gassing foxes. Thus, the risk of badger setts being accidentally gassed during fox control operations should have been removed, although the "accidental" gassing of setts during rabbit control operations remains a risk. However, the annual reports by MAFF show that the number of reported incidents each year is very low. For instance, of 56 cases of suspected pesticide poisoning of badgers reported in 1994, only one was due to the abuse of cyanide (and only three others were confirmed as having died from the effects of pesticides) (Fletcher,

## 10.10 Changes in the levels of persecution at annexe, subsidiary, outlying and disused main setts, 1988-1997

**Table 10.10.1.** Changes in the number of annexe setts showing signs of digging, 1988-1997, by land class group.

| Land class group | Number of setts dug in the 1980s | Total number of annexe setts | Percent annexe setts dug in the 1980s | Number of setts dug in the 1990s | Total number of annexe setts | Percent annexe setts dug in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 4 | 50 | 8 | 0 | 92 | 0 | - |
| Arable II | 3 | 35 | 9 | 1 | 72 | 1 | - |
| Arable III | 0 | 2 | - | 1 | 8 | - | - |
| Pastoral IV | 1 | 74 | 1 | 1 | 157 | 1 | - |
| Pastoral V | 4 | 27 | 15 | 3 | 41 | 7 | - |
| Marginal upland VI | 1 | 8 | - | 0 | 29 | 0 | - |
| Upland VII | 0 | 0 | - | 0 | 1 | - | - |
| **Totals** | **13** | **196** | **7** | **6** | **400** | **2** | **n.s.** |

**Table 10.10.2.** Changes in the number of subsidiary setts showing signs of digging, 1988-1997, by land class group.

| Land class group | Number of setts dug in the 1980s | Total number of subsidiary setts | Percent subsidiary setts dug in the 1980s | Number of setts dug in the 1990s | Total number of subsidiary setts | Percent subsidiary setts dug in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 2 | 90 | 2 | 1 | 154 | 1 | - |
| Arable II | 2 | 65 | 3 | 3 | 98 | 3 | - |
| Arable III | 1 | 8 | - | 0 | 14 | 0 | - |
| Pastoral IV | 4 | 138 | 3 | 2 | 242 | 1 | - |
| Pastoral V | 4 | 63 | 6 | 6 | 89 | 7 | - |
| Marginal upland VI | 0 | 38 | 0 | 1 | 49 | 2 | - |
| Upland VII | 0 | 5 | - | 0 | 11 | 0 | - |
| **Totals** | **13** | **407** | **3** | **13** | **657** | **2** | **n.s.** |

**Table 10.10.3.** Changes in the number of outlying setts showing signs of digging, 1988-1997, by land class group.

| Land class group | Number of setts dug in the 1980s | Total number of outlier setts | Percent outlier setts dug in the 1980s | Number of setts dug in the 1990s | Total number of outlier setts | Percent outlier setts dug in the 1990s | Signif-icance |
|---|---|---|---|---|---|---|---|
| Arable I | 3 | 146 | 2 | 1 | 216 | <1 | - |
| Arable II | 3 | 122 | 2 | 1 | 194 | 1 | - |
| Arable III | 1 | 15 | 7 | 0 | 19 | 0 | - |
| Pastoral IV | 1 | 261 | <1 | 2 | 431 | 0 | - |
| Pastoral V | 7 | 109 | 6 | 2 | 160 | 1 | - |
| Marginal upland VI | 0 | 72 | 0 | 1 | 129 | 1 | - |
| Upland VII | 0 | 8 | - | 1 | 14 | 7 | - |
| **Totals** | **15** | **733** | **2** | **8** | **1163** | **1** | **n.s.** |

**Table 10.10.4.** Changes in the number of disused main setts showing signs of digging, 1988-1997, by land class group.

| Land class group | Number of setts dug in the 1980s | Total number of setts | Percent disused main setts dug in the 1980s | Number of setts dug in the 1990s | Total number of setts | Percent disused main setts dug in the 1990s | Signif-icance |
|---|---|---|---|---|---|---|---|
| Arable I | 3 | 21 | 14 | 1 | 14 | 7 | - |
| Arable II | 1 | 21 | 5 | 0 | 12 | 0 | - |
| Arable III | 0 | 4 | - | 2 | 2 | - | - |
| Pastoral IV | 0 | 23 | 0 | 1 | 22 | 5 | - |
| Pastoral V | 2 | 32 | 6 | 0 | 7 | - | - |
| Marginal upland VI | 1 | 8 | - | 0 | 6 | - | - |
| Upland VII | 0 | 2 | - | 0 | 1 | - | - |
| **Totals** | **7** | **111** | **6** | **4** | **64** | **6** | **n.s.** |

**Table 10.10.5.** Regional changes in the number of setts other than active main setts (i.e. annexe, subsidiary, outlying and disused main setts combined) showing signs of digging, 1988-1997.

| Region | Number of setts dug in the 1980s | Total number of other setts | Percent other setts dug in the 1980s | Number of setts dug in the 1990s | Total number of other setts | Percent other setts dug in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| North England | 5 | 62 | 8 | 6 | 116 | 5 | - |
| North-west England | 4 | 37 | 11 | 4 | 58 | 7 | - |
| North-east England | 3 | 41 | 7 | 1 | 38 | 3 | - |
| West Midlands | 7 | 168 | 4 | 3 | 327 | 1 | - |
| East Midlands | 3 | 77 | 4 | 3 | 105 | 3 | - |
| Central England | 2 | 70 | 3 | 0 | 85 | 0 | - |
| East Anglia | 1 | 19 | 5 | 1 | 61 | 2 | - |
| South-west England | 3 | 355 | 1 | 3 | 657 | <1 | - |
| Southern England | 3 | 154 | 2 | 2 | 214 | 1 | - |
| South-east England | 6 | 140 | 4 | 1 | 209 | <1 | - |
| North Scotland | 0 | 45 | 0 | 0 | 33 | 0 | - |
| South Scotland | 2 | 42 | 5 | 1 | 38 | 3 | - |
| Mid and north Wales | 7 | 101 | 7 | 4 | 172 | 2 | - |
| South Wales | 2 | 132 | 2 | 3 | 171 | 2 | - |
| **Totals** | **48** | **1447** | **3** | **32** | **2284** | **1** | **n.s.** |

**Table 10.10.6.** Changes in the number of annexe setts showing signs of hole blocking, 1988-1997, by land class group.

| Land class group | Number of setts blocked in the 1980s | Total number of annexe setts | Percent annexe setts blocked in the 1980s | Number of setts blocked in the 1990s | Total number of annexe setts | Percent annexe setts blocked in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 7 | 50 | 14 | 8 | 92 | 9 | - |
| Arable II | 5 | 35 | 14 | 5 | 72 | 7 | - |
| Arable III | 0 | 2 | - | 0 | 8 | - | - |
| Pastoral IV | 2 | 74 | 3 | 12 | 157 | 8 | - |
| Pastoral V | 1 | 27 | 4 | 1 | 41 | 2 | - |
| Marginal upland VI | 0 | 8 | - | 2 | 29 | 7 | - |
| Upland VII | 0 | 0 | - | 0 | 1 | - | - |
| **Totals** | **15** | **196** | **8** | **28** | **400** | **7** | **n.s.** |

**Table 10.10.7.** Changes in the number of subsidiary setts showing signs of hole blocking, 1988-1997, by land class group.

| Land class group | Number of setts blocked in the 1980s | Total number of subsidiary setts | Percent subsidiary setts blocked in the 1980s | Number of setts blocked in the 1990s | Total number of subsidiary setts | Percent subsidiary setts blocked in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 8 | 90 | 9 | 11 | 154 | 7 | - |
| Arable II | 8 | 65 | 12 | 13 | 98 | 13 | - |
| Arable III | 0 | 8 | - | 1 | 14 | 7 | - |
| Pastoral IV | 9 | 138 | 7 | 8 | 242 | 3 | - |
| Pastoral V | 4 | 63 | 6 | 6 | 89 | 7 | - |
| Marginal upland VI | 0 | 38 | 0 | 2 | 49 | 4 | - |
| Upland VII | 1 | 5 | - | 0 | 11 | 0 | - |
| **Totals** | **30** | **407** | **7** | **41** | **657** | **6** | **n.s.** |

**Table 10.10.8.** Changes in the number of outlying setts showing signs of hole blocking, 1988-1997, by land class group.

| Land class group | Number of setts blocked in the 1980s | Total number of outlier setts | Percent outlier setts blocked in the 1980s | Number of setts blocked in the 1990s | Total number of outlier setts | Percent outlier setts blocked in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 4 | 146 | 3 | 3 | 216 | 1 | - |
| Arable II | 5 | 122 | 4 | 7 | 194 | 4 | - |
| Arable III | 1 | 15 | 7 | 2 | 19 | 11 | - |
| Pastoral IV | 11 | 261 | 4 | 10 | 431 | 2 | - |
| Pastoral V | 3 | 109 | 3 | 1 | 160 | 1 | - |
| Marginal upland VI | 3 | 72 | 4 | 1 | 129 | 1 | - |
| Upland VII | 0 | 8 | - | 0 | 14 | 0 | - |
| **Totals** | **27** | **733** | **4** | **24** | **1163** | **2** | **n.s.** |

**Table 10.10.9.** Changes in the number of disused main setts showing signs of hole blocking, 1988-1997, by land class group.

| Land class group | Number of setts blocked in the 1980s | Total number of disused main setts | Percent disused main setts blocked in the 1980s | Number of setts blocked in the 1990s | Total number of disused main setts | Percent disused main setts blocked in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 3 | 21 | 14 | 3 | 14 | 21 | - |
| Arable II | 7 | 21 | 33 | 1 | 12 | 8 | - |
| Arable III | 0 | 4 | - | 2 | 2 | - | - |
| Pastoral IV | 2 | 23 | 9 | 2 | 22 | 9 | - |
| Pastoral V | 5 | 32 | 16 | 0 | 7 | - | - |
| Marginal upland VI | 1 | 8 | - | 1 | 6 | - | - |
| Upland VII | 0 | 2 | - | 0 | 1 | - | - |
| **Totals** | **18** | **111** | **16** | **9** | **64** | **14** | **n.s.** |

**Table 10.10.10.** Regional changes in the number of setts other than active main setts (i.e. annexe, subsidiary, outlying and disused main setts combined) showing signs of hole blocking, 1988-1997.

| Region | Number of setts blocked in the 1980s | Total number of other setts | Percent other setts blocked in the 1980s | Number of setts blocked in the 1990s | Total number of other setts | Percent other setts blocked in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| North England | 4 | 62 | 6 | 5 | 116 | 4 | - |
| North-west England | 3 | 37 | 8 | 2 | 58 | 3 | - |
| North-east England | 1 | 41 | 2 | 2 | 38 | 5 | - |
| West Midlands | 21 | 168 | 13 | 21 | 327 | 6 | - |
| East Midlands | 6 | 78 | 8 | 11 | 105 | 10 | - |
| Central England | 5 | 70 | 7 | 6 | 85 | 7 | - |
| East Anglia | 3 | 19 | 16 | 1 | 61 | 2 | - |
| South-west England | 20 | 355 | 6 | 25 | 657 | 4 | - |
| Southern England | 12 | 157 | 8 | 6 | 214 | 3 | - |
| South-east England | 10 | 140 | 7 | 9 | 209 | 4 | - |
| North Scotland | 0 | 45 | 0 | 1 | 33 | 3 | - |
| South Scotland | 0 | 42 | 0 | 4 | 38 | 11 | - |
| Mid and north Wales | 4 | 101 | 4 | 3 | 172 | 2 | - |
| South Wales | 1 | 132 | 1 | 6 | 171 | 4 | - |
| **Totals** | **90** | **1447** | **6** | **102** | **2284** | **4** | **n.s.** |

**Table 10.10.11.** Changes in the number of setts other than active main setts (i.e. annexe, subsidiary, outlying and disused main setts combined) affected by snaring, 1988-1997, by land class group.

| Land class group | Number of setts snared in the 1980s | Total number of other setts | Percent other setts snared in the 1980s | Number of setts snared in the 1990s | Total number of other setts | Percent other setts snared in the 1990s | Significance |
|---|---|---|---|---|---|---|---|
| Arable I | 3 | 307 | 1 | 1 | 476 | <1 | - |
| Arable II | 1 | 243 | <1 | 1 | 376 | <1 | - |
| Arable III | 1 | 29 | 3 | 0 | 43 | 0 | - |
| Pastoral IV | 1 | 496 | <1 | 0 | 852 | 0 | - |
| Pastoral V | 3 | 231 | 1 | 0 | 297 | 0 | - |
| Marginal upland VI | 2 | 126 | 2 | 0 | 213 | 0 | - |
| Upland VII | 0 | 15 | 0 | 0 | 27 | 0 | - |
| **Totals** | **11** | **1447** | **1** | **2** | **2284** | **<1** | **n.s.** |

# 10.11 Summary of the views of the local Badger Groups that responded to a questionnaire circulated in spring 1997

**Table 10.11.1.** Summary of the responses from local Badger Groups to questions about changes in the status of the badgers in their area.

| Name of Badger Group | Have there been any local badger population changes? | Which factors have led to the local badger population changes? | Has the 1992 Badgers Act benefited badgers? | What is the attitude of local farmers and landowners to badgers? | Has there been any change in the problems caused by badgers? |
|---|---|---|---|---|---|
| Befordshire Badger Network | General impression is of an increase, with new setts appearing | Increased protection and awareness of landowners of need to guard against illegal activities on their land | Yes | Good; farmers are keen to protect badgers | Appear to be more problems in gardens |
| Buckinghamshire Badger Group | Overall, no change. In north of the county the population is more mobile | - | Some improvements; in the 1980s farmers had terriermen deal with the badgers on their land | Following the NFU campaign, farmers are much less tolerant of badgers even if they cause no problems | Current perceptions of badger problems grossly inflated; the number of problems has not changed |
| Cumbria Wildlife Trust Badger Co-ordinating Committee | Stable over most of county but sett losses on west coast | Sett losses due to deliberate destruction | Yes | Generally good | No real change; most problems relate to damage to gardens |
| Durham Badger Group | Generally stable; an increase in urban areas | Increases in urban areas due to habitat saturation and residents feeding the badgers | Yes | Generally good but a few would prefer not to have badgers on their land | Significant increase in problems urban areas |
| East Kent Badger Group | Overall, no change but some local increases and decreases | Decrease in persecution levels in some areas, but sett interference is still a problem locally | The 1992 Act has undoubtedly benefited badgers | The attitude of farmers remains the same, with the majority largely neutral | Local increases in badger problems, largely due to badly planned developments |

**Table 10.11.1** continued.

| Name of Badger Group | Have there been any local badger population changes? | Which factors have led to the local badger population changes? | Has the 1992 Badgers Act benefited badgers? | What is the attitude of local farmers and landowners to badgers? | Has there been any change in the problems caused by badgers? |
|---|---|---|---|---|---|
| East Yorkshire Badger Group | Population appears to have remained stable | - | Little real effect | A growing anti-badger attitude in response to TB issue, even though this is not a problem in Yorkshire | Farmers perceive an increase in problems, but there is very little evidence to support this |
| Eden Valley Badger Group | A slight increase | A decline in illegal persecution | Yes | Some farmers are very tolerant of badgers on their land; shooting estates are less so | Farmers regularly complain about badger numbers; this may simply be a consequence of the NFU campaign. Damage to gardens was worst in 1995 |
| Essex Badger Protection Group | No noticeable changes overall; some losses but increases in private gardens | - | Yes | More tolerance and understanding shown towards badgers | Yes; most problems are in residential areas |
| Faversham Badger Protection Group | Appears to be general increase | No information | Yes | Appears to be consistently good throughout area | Increased requests for assistance are probably due to better publicity rather than an increase in the number of problems |
| Glamorgan Badger Group | A slight increase in numbers | Heightened awareness of badger issues, a decline in digging and a sympathetic attitude to local farmers | Yes | Generally very good | No increase in badger problems over last decade |

**Table 10.11.1** continued.

| Name of Badger Group | Have there been any local badger population changes? | Which factors have led to the local badger population changes? | Has the 1992 Badgers Act benefited badgers? | What is the attitude of local farmers and landowners to badgers? | Has there been any change in the problems caused by badgers? |
|---|---|---|---|---|---|
| Grampian badger Survey | Probably stable overall; some new setts, but also some losses | Gains due to break up of large estates and more sympathetic keepering | Yes | Based on a sample of over 500 farmers and land-owners, 30% are sympathetic, 60% indifferent, and 10% hostile | Consistent level of complaints |
| Harrogate and District Badger Group | Probably stable | - | Yes | Farmers are very tolerant of badgers, in marked contrast to 30 years ago | Most farmers never encounter problems |
| Herefordshire Badger Group | New setts are being recorded, but unsure whether this indicates a population increase | - | Yes | Became more negative following increase in TB and new licensing requirements | Yes; especially due to TB, developments and greater encroachment into urban areas |
| Isle of Wight Badger Protection Group | Probably increasing | - | Very beneficial | The majority probably welcome them, but this is becoming less common following misinformation on TB, even though it has not been recorded in badgers on the island | No information |
| Kirklees Badger Protection Group | Probably a small increase | Protection of vulnerable setts has helped | Yes; more companies seek advice from the Group and terrier men are more cautious | There have never been problems with farmers | No; problems remain minimal |

**Table 10.11.1** continued.

| Name of Badger Group | Have there been any local badger population changes? | Which factors have led to the local badger population changes? | Has the 1992 Badgers Act benefited badgers? | What is the attitude of local farmers and landowners to badgers? | Has there been any change in the problems caused by badgers? |
|---|---|---|---|---|---|
| Lanarkshire Badger Group | Increased significantly | Legislation, education and an increase in public awareness | Yes | Yes; farmers now think there are too many badgers | Yes; in order of priority: gardens, developments, agricultural land |
| Lancashire Badger Group | An increase, with many new setts | Increased work by the Badger Group; heavy sentences have reduced the number of offences | Yes | Many are fairly tolerant to badgers, but others want to get rid of them | Yes, particularly in urban areas |
| Mid Derbyshire Badger Group | Possibly a slight increase | No information | It had some effect but illegal activities are on the increase | Yes; farmers think there are too many badgers following the NFU campaign and that in the farming press | Increased number of complaints from householders in hot dry summers |
| North Riding Badger Group | Appears to have been a decline, as shown by loss of main setts | Gamekeeping, lamping, digging and developments have all contributed to the decline | Yes | On the whole, attitudes of landowners are good, but this is changing, possibly because of the NFU report | The only real changes have been in hot, dry summers, when problems increase |
| North Tayside Badger Group | A significant decline since 1980 | Persecution - mainly gassing and snaring | No: a high level of ignorance about the 1992 Act, which was too late to save the badgers in some areas | Largely negative, due to scare-mongering on the TB issue, which is not a problem in Scotland | No change; few problems are caused by badgers |

**Table 10.11.1** continued.

| Name of Badger Group | Have there been any local badger population changes? | Which factors have led to the local badger population changes? | Has the 1992 Badgers Act benefited badgers? | What is the attitude of local farmers and landowners to badgers? | Has there been any change in the problems caused by badgers? |
|---|---|---|---|---|---|
| Radnorshire Badger Group | No information | No information | No | Attitudes to badgers have hardened, especially in the last 18 months | More problems due to land use changes |
| Shropshire Badger Group | Probably stable | - | Yes; has helped stop earlier widespread insidious persecution | Overall, an improvement in attitudes to badgers, but prejudices persist | Increased levels of crop damage, especially to maize |
| South Yorkshire Badger Group | Increased | A reduction in digging | Definitely | Most are keen to have badgers on their land but the recent NFU report has led to a change in attitudes | No |
| Warwickshire Badger Group | An increase in urban areas | Appearance of setts in new areas, and loss of established setts, may be a response to changes in land use | Appears to be little improvement; some farmers resent badgers simply because of the Act | Attitudes have always been very mixed; TB in neighbouring counties may have reduced tolerance of badgers | A rise in the number of problems in both urban and rural areas |
| West Surrey Badger Group | Overall, a decrease; both sett numbers and social group size seem to have declined | Developments leading to loss of setts and/or foraging areas, and road deaths | Yes | No change; attitudes are locally good | An increase in problems for householders |

**Table 10.11.2.** Summary of the responses from local badger groups to questions about changes in badger persecution levels in their area.

| Name of Badger Group | Have there been any changes in the level of badger digging? | Have there been any changes in other forms of badger persecution? | Have there been any changes in the levels of damage to setts by foxhunts? | Have there been any changes in the levels of damage to setts by farmers or landowners? | What do you think are the major threats to badgers in your area? |
|---|---|---|---|---|---|
| Bedfordshire Badger Network | No - it is a continuing but small problem | Lamping and shooting have probably increased | No change - a continuing but small problem | No change - a continuing but small problem | Development and increased traffic levels |
| Buckinghamshire Badger Group | No - digging was never a big problem | Difficult to determine; probably as widespread but illegal activities are now more secretive | Has diminished - there were severe problems in the past | Probably no change | Development and land use changes |
| Cumbria Wildlife Trust Badger Co-ordinating Committee | Low levels of digging, but not a serious problem | Snaring a problem; lamping widespread but the impact on badgers is hard to determine | Not a serious problem | Sett damage on the west coast is a lot lower than it used to be | Probably digging and illegal sett disturbance |
| Durham Badger Group | An increase in reported incidents, with setts dug out and destroyed | A significant increase in the use of snares | No; local hunts are closely monitored | No information | Digging, forestry and developments |
| East Kent Badger Group | Digging less apparent, perhaps due to success in prosecuting offenders | No change in snaring or shooting; lamping is still a minor problem | Levels of damage have declined dramatically since the 1992 Act | Whilst there have been localised incidents of widespread sett damage, generally the extent of the problem remains the same | |

**Table 10.11.2** continued.

| Name of Badger Group | Have there been any changes in the level of badger digging? | Have there been any changes in other forms of badger persecution? | Have there been any changes in the levels of damage to setts by foxhunts? | Have there been any changes in the levels of damage to setts by farmers or landowners? | What do you think are the major threats to badgers in your area? |
|---|---|---|---|---|---|
| East Yorkshire Badger Group | Probably a slight decline | Lamping has increased but the impact on badgers is not known | A decline in damage to setts from hard stopping | Little change | Local increase in antipathy of farmers to badgers |
| Eden Valley Badger Group | Levels of digging have always been low | Persistent reports of other forms of persecution are hard to confirm | Severity of sett blocking appears to be getting worse | Generally farmers have observed the law, with just a few exceptions | Sett disturbance |
| Essex Badger Protection Group | Yes; there has been no digging in the area for some time | Yes; there have been no signs of persecution for some time | No | No | Developments and disturbance |
| Faversham Badger Protection Group | The problem appears to be on the increase | Locally snaring is still a problem | No | No - this is rarely a problem | Digging and development |
| Glamorgan Badger Group | Far fewer incidents in the last two years following a successful prosecution | Low levels of snaring | The local hunt have never blocked setts | No. There are occasional problems with terriermen when they are killing foxes at lambing time | Developments and road traffic accidents |

Table 10.11.2 continued.

| Name of Badger Group | Have there been any changes in the level of badger digging? | Have there been any changes in other forms of badger persecution? | Have there been any changes in the levels of damage to setts by foxhunts? | Have there been any changes in the levels of damage to setts by farmers or landowners? | What do you think are the major threats to badgers in your area? |
|---|---|---|---|---|---|
| Grampian Badger Survey | No evidence of badger digging in the area | No change; a few reports of snaring, shooting and gassing each year | No fox hunts in the area | Less damage, particularly by forestry operations following introduction of new guidelines | In order: forest harvesting, land use changes and development |
| Harrogate and District Badger Group | Digging has declined | Other forms of badger persecution have also declined | Badger setts have never been damaged by foxhunts | This constitutes by far the biggest threat to setts in the area | Increased number of roads and traffic levels |
| Herefordshire Badger Group | An increasing problem | Snaring and lamping have increased | Sett damage by foxhunts has declined | Damage to setts is increasing | Developments, changes in land use and TB control operations |
| Isle of Wight Badger Protection Group | A small problem; 2.8% of recorded setts dug some time in the past | In 1996, 16.5% of setts affected by some form of persecution | A major improvement on earlier years, when many setts illegally blocked | Illegal sett interference appears to be increasing | Agricultural damage to setts and sett destruction |
| Kirklees Badger Protection Group | No; the frequency of digging remains at the same low level | Lamping is a serious problem but its impact on badgers is unkown | Not a problem | Not a problem now or in the past | Increased road traffic and development |

**Table 10.11.2** continued.

| Name of Badger Group | Have there been any changes in the level of badger digging? | Have there been any changes in other forms of badger persecution? | Have there been any changes in the levels of damage to setts by foxhunts? | Have there been any changes in the levels of damage to setts by farmers or landowners? | What do you think are the major threats to badgers in your area? |
|---|---|---|---|---|---|
| Lanarkshire Badger Group | Still goes on, but possibly declined in the last year | A few cases of snaring each year; no reports of shooting or lamping | No foxhunt in the area | Farmers and landowners are damaging more setts than in the past | Developments, forestry operations, digging and land use changes |
| Mid Derbyshire Badger Group | A decline following the 1992 Act, followed by an increase; present levels are the worst ever | Only isolated cases of snaring, shooting and lamping | The only foxhunt in the area does not stop setts | Damage and destruction of setts by landowners and farmers remains a problem | Digging |
| North Riding Badger Group | Badger digging was widespread before 1992; it then declined, but has increased again in the last 18 months | Lamping has increased by 60% since 1992; also an increase in snaring incidents | Problems from earth stoppers are continuing | Appears to have declined and farmers contact the Group for advice | In order of priority: development, hunting and shooting, removal of hedgerows and disturbance |
| North Tayside Badger Group | No information; digging is less common than nearby areas of Scotland | Snaring and shooting have always been a problem, and lamping is more common | No foxhunts in the area | Local landowners and farmers have eradicated setts recorded in 1980 | Land use changes, mainly farming and forestry |
| Radnorshire Badger Group | No information | No information | No information | No information | Land use changes, particularly forestry, agricultural changes, drainage and upland improvement |

**Table 10.11.2** continued.

| Name of Badger Group | Have there been any changes in the level of badger digging? | Have there been any changes in other forms of badger persecution? | Have there been any changes in the levels of damage to setts by foxhunts? | Have there been any changes in the levels of damage to setts by farmers or landowners? | What do you think are the major threats to badgers in your area? |
|---|---|---|---|---|---|
| Shropshire Badger Group | Digging levels were high but have declined in the last two or three years | An increase in lamping but its local impact on badgers is unclear | The number of problems has declined over the last five years | Work by the Group has led to an improvement in attitudes and a decline in sett damage | Changes in farming practices |
| South Yorkshire Badger Group | Digging has decreased year on year for the last decade | Absence of badgers from large areas of keepered land suggests that persecution is still a problem | Not a significant problem | Many farmers used to dig and shoot badgers but this has stopped with the change in the law | Development and land use changes |
| Warwickshire Badger Group | Badger digging appears to have increased this decade | No evidence of change in other forms of persecution | Great improvements in the last few years and most setts now stopped properly | Not possible to quantify since sett damage is mainly on private land | Development and land use change, with digging possibly a local concern |
| West Surrey Badger Group | No | No evidence of a change | No evidence of a change | A slight increase in levels of sett damage | Development |