BTO Research Report 411

The BTO Barn Owl Monitoring Programme: fourth year 2003

Authors

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CONTENTS

Page No.

List of Tables and Figures 3

EXECUTIVE SUMMARY 5

1. INTRODUCTION 7
1.1. History of Barn Owl population surveys in the UK 7
1.2. Conservation status of the Barn Owl 8
1.3. Potential impacts of weather conditions and climate change 9
1.4. The 2001 Foot & Mouth Disease outbreak 9
1.5. Aims and work plan of the Barn Owl Monitoring Programme 10

2. METHODS 13
2.1. Overall strategy of BOMP 13
2.2. Study sites 14
2.3. Fieldwork methods 15
2.4. Data collation 17
2.5. Calculating breeding parameters 17
2.5.1. Site occupancy 17
2.5.2. Laying date 18
2.5.3. Clutch and brood size 18
2.5.4. Nesting success 18
2.6. Assigning habitat categories 18
2.7. Weather data 19
2.8. Statistical models 20

3. RESULTS 21
3.1. Survey coverage 21
3.2. Occupancy rates 22
3.3. Productivity 24
3.4. Influence of weather conditions 25
3.5. Occupancy rates of other species 26

4. DISCUSSION 29
4.1. Occupancy rates 29
4.2. Productivity 30
4.3. Recommendations for future analyses 31

Acknowledgements 33

References 35

Appendix 39

LIST OF TABLES AND FIGURES

Page No.

TABLES

Table 2.3. Visiting schedule adopted as standard for the BOMP Network sites, designed to document the key events in the Barn Owl's breeding cycle 16

Table 2.6. Broad habitat categories used in the analyses of BOMP data 19

Table 3.1. Total number of BOMP sites surveyed annually 2000-2003 21

Table 3.2.1. Influence of location, year and habitat on the presence of Barn Owl, whether breeding or non-breeding 22

Table 3.2.2. Influence of location, year and habitat on the presence of breeding Barn Owl 23

Table 3.3. Influence of location, year and habitat on laying date, clutch size and brood size 24

Table 3.4.1. Influence of weather conditions on box occupancy (N=1321). Temperature comes from the Central England Temperature record and precipitation from the England & Wales Precipitation record 25

Table 3.4.2. Influence of weather conditions on productivity. Temperature comes from the Central England Temperature record and precipitation from the England & Wales Precipitation record 26

Table 3.5.1. The number and proportion of sites occupied by breeding Stock Dove, Jackdaw and Kestrel. 26

Table 3.5.2. Influence of location, year and habitat on the presence of breeding Stock Dove, Jackdaw and Kestrel. 27

FIGURES

Figure 3.1. Distribution of registered BOMP sites 2000-2003. 21

Figure 3.2. Annual variation in percentage of sites at which Barn Owls present (thin line) and in which Barn Owls breeding (thick line) 23

EXECUTIVE SUMMARY

1. Barn Owl is a scarce breeding species that has undergone a substantial population decline in the UK during the 20th century. It is listed as of Amber conservation concern in the UK but has been poorly covered by the national, long-running population monitoring schemes operated by BTO. The BTO Barn Owl Monitoring Programme (BOMP) was set up in 2000 with the aim:

   To monitor Barn Owl populations through standardised recording of nest occupancy rates, breeding performance and survival at a set of Barn Owl nest sites broadly representative of the distribution of the Barn Owl in Britain.

2. Fieldwork involves repeat visits to registered sites, particularly to paired nest boxes, over the Barn Owl nesting season between April and October, to assess occupancy, gather breeding statistics, and ring adults and chicks. The Wildlife Conservation Partnership (WCP) has undertaken the development of BOMP methodology and has carried out fieldwork since 2000 at a set of '*BOMP* C*ore*' sites, distributed throughout five regions of England and matched for nest box design. In 2002, a network of volunteer ornithologists began gathering additional information at '*BOMP Network'* sites over a wider geographical area.

3. This is the fourth report of BOMP, covering the four seasons 2000–03. Rates of occupancy are investigated, along with breeding statistics, in relation to year, geographical location, main habitat type and weather conditions.

4. WCP visited 158 sites in 2000 and, despite Foot and Mouth Disease access restrictions, 171 in 2001. In 2002, 586 sites were visited in total, of which WCP covered 196 and BOMP Network volunteers 390. In 2003, 198 sites were monitored by WCP and a further 415 were visited by BOMP Network volunteers. WCP sites are located across the whole of England, although as a consequence of sampling methodology they tend to be concentrated in the southern and eastern regions and north-eastern. BOMP network sites are more broadly scattered across the UK, including several locations in Scotland and Wales.

5. The proportion of sites at which Barn Owls were recorded as present (whether breeding or not) has declined over the four years of the study, as has the proportion where breeding Barn Owls have been recorded. This may indicate a decline in Barn Owl populations over this period, but may also be an artefact of site selection of the BOMP Network sites, which may have originally been biased towards sites that were already known to have been occupied in previous years.

6. While the decline in presence is linear, that in breeding occupancy fluctuates between years, peaking in 2000 and 2002. Regular fluctuations in Short-tailed Vole numbers which peak and trough over a three to four year cycle are known to influence breeding success. Weather conditions may have an effect on both Barn Owl abundance and the proportion of pairs that are in sufficient condition to breed, with cold, wet weather during the winter reducing the availability of small mammal prey and the ability of Barn Owl to hunt successfully.

7. Analyses using national temperature (Central England Temperature) and rainfall (England & Wales Precipitation) datasets indicated that breeding occupancy, but not overall presence, was significantly lower following cold wet winters. This result suggests that, while inclement winter conditions may not have influenced survival rates, they may have resulted in a loss of body condition leading to suspension of breeding during the following season. Unfortunately the weather datasets are too highly correlated to permit us to distinguish the effects of temperature and rainfall.

8. Occupancy rates were also influenced by geographic location. Sites to the west of the UK were significantly more likely to contain breeding Barn Owls, suggesting that either abundance is higher or that a greater proportion of the population are in sufficient condition to breed, possibly due to the milder winters experienced in the west of the UK. Breeding occupancy was also higher in the north of the UK, possibly due to a general increase in the availability of natural grassland, and therefore increased rodent abundance, and/or nesting sites in less intensively farmed areas.

9. Habitat also influenced occupancy rates, with a higher proportion of sites overall occupied by breeding Barn Owl in natural grassland areas and fewer in arable and pastoral areas, possibly due to differences in prey availability. The apparent suitability of habitats did differ between WCP and BOMP Network sites, but this might simply reflect the geographical distributions of the two sets of sites.

10. Occupancy rates of three other species – Stock Dove, Jackdaw and Kestrel – were also analysed with respect to year, geographical location and habitat. Many of the significant relationships identified were in the opposite direction to those identified for Barn Owl, suggesting that there may be a degree of competitive exclusion occurring.

11. Sufficient data were collected over the four years of the study to permit analysis of laying dates, clutch sizes and brood sizes. None of the productivity parameters displayed any significant trends over the period 2000-2003, nor were they related to weather conditions. This suggests that individuals in poor condition suspend breeding rather than producing small clutches or reducing investment in incubation or provisioning. No significant relationships were identified between any measure of productivity and Northing, Easting or habitat type.

12. Additional funding from English Nature was secured to investigate the response of the UK Barn Owl population to the 2001 Foot & Mouth Disease (FMD) outbreak and the measures taken to prevent transmission of the disease using both BOMP and Nest Record Scheme data. Information about the location of infected premises, access restrictions and slaughtered livestock throughout the UK were obtained from the Central Science Laboratory and data concerning the use of rodenticides in the north of England was provided by the Rural Development Service. Neither FMD infection *per se* nor any of the procedures put in place to prevent disease transmission were found to have any major impacts on Barn Owl occupancy rates or productivity. However, it should be noted that these results should be interpreted with caution as it is possible that uncontrolled confounding factors may have affected the analyses.

13. BOMP's increasing value to conservationists is shown by the inclusion of its results in the annual and widely disseminated *The State of the UK's Birds* 2003 (Eaton *et al*. 2004) that reports the current status and trends of bird populations in the UK, as well as in the annual report of the Rare Breeding Birds Panel, published in the journal *British Birds* (Ogilvie & RBBP 2003).

1. INTRODUCTION

The Barn Owl Monitoring Programme (BOMP) was set up in 2000 as a means of monitoring Barn Owl populations in the UK. This species is poorly monitored by other national surveys, such as the BTO/JNCC/RSPB Breeding Bird Survey, as it is mostly active at night, is largely non-vocal and occurs at low densities. To overcome these problems, BOMP methodology involves participants visiting known nest sites annually to ascertain whether Barn Owls are using the site each year and to collect data about the productivity of any breeding attempts observed. Each year the data are collated at the BTO and analysed, with the aim of producing annual trends in occupancy rates and a range of breeding parameters. This report presents an analysis of the first four years of BOMP data (2000-2003).

1.1. History of Barn Owl population surveys in the UK

The Barn Owl *Tyto alba* is one of the world's most widely distributed land birds, being found on all continents except Antarctica. It is a moderately widespread bird throughout the UK, found especially on farmland, although generally absent from upland and heavily urbanised areas and from the far north and northwest of Scotland, including Shetland, Orkney and the Hebrides (Gibbons *et al.* 1993, Shawyer 1987). Its pale plumage, partly diurnal or crepuscular hunting behaviour, and habit of nesting in buildings make it more noticeable than other owls and many people know of it as a characteristic part of the countryside. Where small mammals are perceived as pests, Barn Owls that feed on them may typically be viewed as actively beneficial to man. Where Barn Owls occur, therefore, their presence is relatively widely known and appreciated.

Throughout the 18th and early 19th centuries, it was regarded as our most common species of owl (Latham 1781, Rivière 1830, Macgillivray 1840, Holloway 1996). Since about the middle of the 19th century, however, factors such as increasing persecution and collection of specimens for taxidermy are said to have contributed to a population decline. This perceived decline prompted one of the earliest national surveys of the breeding population of any wild bird (Blaker 1933, 1934). Blaker's evidence, collected through a request for information he circulated throughout England & Wales, supported a population estimate of about 12,000 breeding pairs in these countries in 1932, and indicated that a substantial decline had indeed occurred over the previous 30–40 years. The decline appears to have continued through the 1950s and 1960s (Prestt 1965, Parslow 1973) and was suggested to have stemmed from the increased use of toxic chemicals (especially organochlorine seed dressings), loss of hunting habitat, increased disturbance and the hard winters of 1946/47 and 1962/63 (Dobinson & Richards 1964). During 1968–72, the population was estimated to number between 4,500 and 9,000 pairs (Sharrock 1976), but these figures are based on only partly quantified observations.

During 1982–85, the Hawk and Owl Trust (known then as the Hawk Trust) undertook a four-year census of Barn Owls in Britain, Ireland and the Channel Islands. They estimated the size of the breeding population at 3,778 pairs in England & Wales, 640 pairs in Scotland, and 4,400 pairs in Britain as a whole (Shawyer 1987). These figures represented a decline of about 70% in England & Wales since Blaker's 1932 survey, although differences in methods between the surveys mean that the precision of this figure is unknown (Toms *et al.* 2001).

The most recent nationwide survey was *Project Barn Owl*, undertaken jointly by BTO and Hawk and Owl Trust in the UK, Isle of Man and Channel Islands during 1995–97 (Toms 1997, Toms *et al.* 2000, 2001). This project established a random sample of survey sites, which were 2x2-km tetrads of the national grid, and devised new survey methods that could be repeated at intervals in the future to produce directly comparable results. This survey produced a population estimate of about 4,000 pairs for the whole area of study (Toms *et al.* 2001), a slightly lower figure than produced by the Hawk Trust survey for Britain alone. Because the confidence interval around the Project Barn Owl figure included the previous Hawk Trust estimate and as the methodologies were not identical, it was not clear whether any further decline had occurred between these two surveys. It is important to note that such surveys need to be carried out over a 3-4 year period: the difficulty of assessing trends between annual surveys has been emphasised by the finding that, in southwest Scotland, numbers of breeding pairs of Barn Owls can more than double across a single three- to four-year cycle of vole abundance (Taylor *et al.* 1988).

1.2. Conservation status of the Barn Owl

Although the UK Barn Owl population may have declined slightly or remained essentially stable in recent decades, there is ample evidence that a substantial decline took place during the 20th century as a whole. Less comprehensive data from other parts of the world range suggest that similar declines have been widespread across Europe and elsewhere (Colvin 1985, Shawyer 1987, Tucker & Heath 1994). The Barn Owl has qualified under international criteria, through its 'moderate decline' in Europe as a whole, as a species of European conservation concern (SPEC category 3; Tucker & Heath 1994).

In the UK, Barn Owl was included in Schedule 1 of the Wildlife and Countryside Act 1981, affording it protection by special penalties at all times. More recently, it has been included on the Amber List of Birds of Conservation Concern (Gregory *et al*. 2002) due both to its decline in breeding range of between 25-49% and because it is listed as a species with unfavourable conservation status in Europe. A UK conservation action plan for the species has been developed (RSPB Species Action Plan 0735), as well as a number of local Biodiversity Action Plans under Local Agenda 21 of the International Convention on Biodiversity.

Much conservation work has focused on the Barn Owl in recent years, stimulated in many cases by the work of the Hawk and Owl Trust, Barn Owl Trust and other specialist groups in fostering more widespread recognition of the species' conservation importance. Attention has been directed towards the creation and management of areas of suitable hunting habitat, increasing the availability of prey, providing habitat corridors to promote dispersal, coupled with the provision of nest boxes in areas where a shortage of nest and roost sites could be a limiting factor (Shawyer 1987). Over the same period, attention has also been focused on other factors that may have played a part in the Barn Owl's decline, in particular 'second-generation' rodenticides (Shawyer 1985) and mortality due to collisions with road traffic (Bourquin 1983, Massemin & Zorn 1998, Shawyer & Dixon 1999). The second-generation rodenticides difenacoum, bromadiolone, brodifacoum and flocoumafen are used to control Brown Rats *Rattus norvegicus* in and around agricultural premises, particularly in areas where resistance to warfarin is high (Shawyer 1985, Harrison 1990). Barn Owls are potentially vulnerable to secondary poisoning from ingesting poisoned rodents. Chemical residue monitoring by the Centre for Ecology and Hydrology has found that a small proportion of Barn Owl corpses contain potentially lethal doses of rodenticide (Newton *et al.* 1991; Newton & Wyllie 1992).

Attempts to increase the population have, in the past, included large-scale programmes for releasing captive-bred birds (e.g. Ramsden & Ramsden 1989, Warburton 1992). Concerns that some releases may have been against the birds' and the species' best interests led in 1992 to Barn Owl being added to the list, in Schedule 9 of the Wildlife and Countryside Act, of species of animals that may not be released or allowed to escape into the wild without a licence, and to the Government setting up the 'Captive Barn Owl Release Scheme', to prevent indiscriminate releases by inappropriate methods. This scheme, which had prompted a very low take-up rate and was felt by the Government to have shown limited benefits, was discontinued in 2002.

The lack of an ongoing, annual monitoring scheme for Barn Owl has hampered the assessment of national population trends and, consequently, of the success or otherwise of local conservation measures. This is particularly important given the species' inclusion on the UK Government's Farmland Bird Index of Sustainable Development and the Government's Publics Service Agreement target to reverse the decline in the index by 2020. Furthermore, concerns about the use of newer types of rodenticide require the ability to detect, at the earliest opportunity, any widespread detrimental impact of poisoning through annual monitoring of Barn Owl populations, their breeding performance and survival. In addition, a carefully designed monitoring programme can help identify whether any changes in abundance are driven by changes in breeding performance or survival, and link these demographic processes to likely causal factors in the environment, such as habitat change.

1.3. Potential impacts of weather conditions and climate change

As aerial hunters, Barn Owls may be particularly susceptible to the influence of weather conditions on both survival rates and productivity. Strong winds, heavy rain and snow may impede hunting directly by reducing visibility and manoeuvrability and indirectly, by reducing the abundance and activity levels (availability) of rodent prey. Such inclement conditions can also lead to increased thermoregulatory costs and declines in prey species abundance. The increased costs associated with such conditions may either result in lower rates of adult survival or may lead to a reduction in adult body condition causing a reduced investment in reproduction or, in extreme cases, the suspension of breeding. Weather conditions may also influence vegetation growth that may, in turn, have implications for the abundance and/or the visibility of small mammal species.

The UKCIP02 report (Hulme *et al*., 2002) predicts that temperatures in the UK will rise by an average of 2.0-3.5°C by 2080, with temperatures in summer and autumn likely to increase more than those in winter and spring. Very hot spells in summer are likely to become more frequent and very cold winters less so. Mean annual rainfall is predicted to decrease by up to 15% by 2080, although there may be large regional differences, with the southeast becoming generally drier than the northwest. Rainfall is likely to decrease during the summer months, but increase during the winter, with intense periods of winter rain becoming more frequent. Under a High Emissions scenario, rainfall in the southeast is predicted to fall by up to 50% in the summer, but increase by up to 30% in the winter. Winter snowfall will become a rare event, possibly decreasing by up to 90% by 2080.

Such changes in weather conditions may have important consequences for the UK Barn Owl population. One of the first steps in attempting to predict the impact of such climatic changes is to investigate the current relationships between weather parameters and population processes. The BOMP dataset provides an excellent opportunity to explore such associations and the results of the preliminary analysis are contained within this report.

1.4. The 2001 Foot & Mouth Disease outbreak

In 2001, the UK was seriously affected by an outbreak of Foot and Mouth Disease (FMD), resulting in the slaughter of a significant proportion of the national herd. Large parts of the countryside were placed under access restrictions and rodenticide usage increased. Increased levels of activity around farms during the breeding season may have resulted in increased disturbance and reduced Barn Owl breeding performance. Increased rodenticide use could also have been detrimental to the survival rates of adults and offspring. Conversely, such impacts may have been offset by reductions in disturbance following the imposition of access restrictions as well as the potential benefits of reduced grazing pressure leading to improved grass swards and hence to larger prey populations.

Funding to investigate the impact of such activities was obtained from English Nature in 2003. Data concerning the location of land to which access was restricted, premises at which livestock were slaughtered and premises at which FMD infection was confirmed were obtained from the Central Science Laboratory database. Data concerning rodenticide use at premises in a restricted set of counties, predominantly in the north of England, was obtained from a database held at the Rural Development Service. These datasets were then used in conjunction with Barn Owl data collected by participants in both BOMP and the Nest Record Scheme to compare breeding parameters before and after the outbreak at both affected and unaffected sites. The results of this analysis are included in Appendix 1 of this report.

1.5. Aims and work plan of the Barn Owl Monitoring Programme

The Barn Owl Monitoring Programme (BOMP) was set up in 2000 to address the needs of conservationists to be better informed about this important species. BOMP's overall aim and strategy are:

> *To monitor Barn Owl populations – through standardised recording of nesting rates, breeding performance and survival at a set of Barn Owl nest sites broadly representative of the distribution of the Barn Owl in Britain.*

The key activities of BOMP are as follows:

- *To establish a set of Barn Owl sites, which provide a broadly representative coverage of the British Barn Owl population, for annual monitoring.*
- *To assess changes in numbers attempting to breed, using the rates of site occupancy.*
- *To monitor breeding productivity of Barn Owls, using standardised nest recording.*
- *To monitor survival rates and dispersal of Barn Owls, through the ringing of both young birds and adults.*
- *To examine breeding performance and site occupancy in relation to environmental variables, in particular the type of habitat surrounding each site.*
- *To provide an annual report of each year's results and to provide analyses and interpretation to assist conservation action and research.*

Fieldwork is undertaken by a combination of professionals and volunteers. The Wildlife Conservation Partnership (WCP) undertakes fieldwork to monitor a set of '*core sites*' in England and undertakes methodological development. BOMP coverage was greatly swelled in 2002 by opening the scheme to volunteers and developing "BOMP Network" sites. Even if unable to contribute formally to BOMP, fieldworkers have been encouraged to submit extra records to the national Barn Owl databases held by BTO's Nest Record and Ringing Schemes.

The programme for BOMP has developed steadily since it started in 2000 and can be summarised as follows:

- *2000 breeding season*: Funding for the programme was confirmed in June, when fieldwork by WCP began. At this time, most nests already contained small young. This reduced the opportunities to catch adult birds (especially males) for ringing, which is best undertaken during the period of egg laying and incubation. WCP defined a core set of sites for future annual monitoring, piloted recording methods at these sites and gathered preliminary data.
- *2001 breeding season*: A letter outlining the objectives of the Barn Owl Monitoring Programme was sent to more than 200 active Barn Owl ringers and nest recorders in early March 2001. Development of the BOMP network continued, and a few volunteers piloted recording methods. Foot and Mouth Disease (FMD) caused a major problem from late February onwards. Volunteers were unable to gain full access to many sites, and 20% of the WCP core sites could not be visited. Since access restrictions in some areas persisted until the end of the year, plans for recording late broods in October could not be implemented.
- *2002 breeding season*: A total of 586 sites were monitored in 2002, 196 by WCP and 390 by BOMP Network participants. Occupancy rates and productivity were analysed in relation to year, Government Office Region, and habitat type. Factors governing the amount of food stored in prey larders and the occupancy rates of other species were also investigated.

- *2003 breeding season*: A total of 613 sites were monitored in 2003, 198 by WCP and 415 by BOMP Network participants. Occupancy rates and productivity were analysed in relation to year, Northing, Easting, habitat type, temperature and rainfall. This report also includes an analysis of the impact of the 2001 Foot and Mouth Disease outbreak on the UK Barn Owl population.

Throughout the project, opportunities have been taken to publicise BOMP, to recruit more volunteers, to provide feedback, and to raise public awareness about the population status of the Barn Owl. We produce an annual newsletter that acts as a forum for the exchange of ideas and information between volunteers, in addition to providing feedback. The BTO works with other organisations concerned with the conservation of Barn Owls, thereby ensuring that the monitoring results provide effective guidance for conservation action.

This report presents a summary of results obtained during the first four seasons of BOMP. Annual reports for 2000 (Crick *et al*. 2001), 2001 (Beaven *et al.* 2002) and 2002 (Leech *et al*. 2003) are also available

2. METHODS

2.1. Overall strategy of BOMP

Barn Owl biology and behaviour means that the species is most easily surveyed by the monitoring of potential nest sites during the breeding season (Bunn *et al*. 1982, Bibby *et al*. 1992). Absolute numbers of Barn Owls are difficult to assess (Toms *et* al. 2001) and so the rates of site occupancy are a useful guide to overall population levels of breeding Barn Owls. Nest visits allow the recording of information concerning productivity and also provide good opportunities to trap and ring adult and young birds, thereby enabling the study of survival rates and dispersal.

A key feature of BOMP has therefore been the establishment of a set of nesting sites at which occupancy and breeding parameters are monitored every year. Most of the sites have been selected and surveyed by BTO volunteers, some of whom are ringers and are licensed to handle and ring young and adult Barn Owls at the nest. Volunteers were asked to guarantee to monitor at least one Barn Owl nest site for a minimum of three consecutive years. A further substantial sample of sites in five English regions is monitored by WCP. Additional studies carried out at WCP sites aid the methodological development of the overall scheme. Many BOMP sites are within central strongholds of the Barn Owl's range, and therefore in the areas that are most important to the species' viability, while others are in more peripheral areas, where the amplitude of population changes is likely to be greater.

Nesting rates provide a minimum estimate of Barn Owl abundance in a specified area, as they only include those individuals attempting to breed in monitored sites and do not record the presence of unpaired individuals, pairs not attempting to breed, or any pairs breeding in unmonitored nest sites.

BOMP's collection of detailed information concerning breeding performance and survival can be complemented by that gathered nationally by the BTO Nest Record and Ringing Schemes. These schemes, unlike BOMP, do not impose any requirement on volunteers for consistent recording; thus the potential exists for changes in recording effort and methods to influence results, as the set of sites monitored by volunteers changes over time. By using a set of sites that are monitored every year, the information gathered more precisely indicates the effects of changes in the environment surrounding Barn Owl sites.

All BOMP participants, and other BTO volunteers collecting similar data, need a valid Schedule 1 Licence before approaching any nest site. It is important to note that Barn Owls tend not to be easily disturbed by careful fieldwork (Percival 1990, Taylor 1991). Several long-term studies of the breeding biology of Barn Owls indicate that monitoring active nest sites is unlikely to bring about desertion (Lenton 1984, Wilson *et al.* 1987, de Bruijn 1994, Taylor 1994). Percival (1990) found from Nest Record Scheme data that nests visited only during the late chick stage did not fledge significantly more chicks than others that had also been visited earlier in the breeding period. Taylor (1991) examined the effect of nest inspections and radio tagging on breeding success of Barn Owls in southwest Scotland. He found that the various measures of productivity did not differ significantly between those nests only visited at the late chick stage and those that received multiple visits. Taylor also noted that site fidelity was high, with only 0.9% of males and 5.6% of females changing nest sites between consecutive breeding seasons. We are confident, therefore, that nest site inspections will not compromise the welfare of Barn Owls, nor the integrity of the data gathered, provided that they are carried out following the protocols described in BOMP's Barn Owl Fieldwork Guidance Notes. These guidelines, which have been given to all BOMP participants, build upon those in the *Nest Record Scheme Handbook*, which themselves have been followed successfully for many years by nest recorders (Crick *et al*. 1999), and also draw upon the field experience of WCP. The guidelines appeared as an Appendix in last year's annual report (Beaven *et al.* 2002).

2.2. Study sites

Each BOMP study site is an actual or potential nest site for a single pair of Barn Owls. Where two or more potential nest sites are in close proximity, and likely to be used by the same pair of owls, they are registered separately but their linkage, or pairing, is also recorded and they may be treated as a single site if appropriate. Barn Owl nest boxes are often positioned in pairs, and in some instances paired boxes are occupied simultaneously by the same pair of owls, with one containing old young from the first brood and the other eggs from a second brood.

There is a relatively high turnover of 'natural' sites, due for example to the increasing loss of barns and hollow trees, including barn conversions, the shifting location of bale-stacks and waterlogging of tree cavities. In addition the accurate recording of eggs and young is often difficult where nests are located within deep cavities. As a result, observers are encouraged to target nest-box sites. This is likely to become increasingly relevant for long-term monitoring because although Toms *et al.* (2000) found that *c*. 40% of Barn owls were breeding in nestboxes in the mid 1990s, Shawyer (pers. comm.) estimates that this will have increased substantially by the end of this decade. As a result, almost all of the sites that have been registered are nest boxes. The widespread distribution of boxes clearly highlights the extent of the public's interest in Barn Owls (Project Barn Owl estimated that there were some 25,000 boxes in the UK; Toms *et al*. 2000), and their occupation indicates the benefit that conservation measures have had for the species. Although some individuals who erect nestboxes generally inspect them too, BOMP provides a framework for collating such observations, ensuring that the data are recorded to a recognised standard and maximising the benefit derived.

Observers register their sites by sending details of their location to BTO HQ. For nest boxes, information is recorded on floor area, the positioning of the entrance hole (at top or bottom of box), and how the box is sited (for example mounted on a pole, in a barn, or in a tree). Grid references are held in confidence by the BTO in the light of the species' protection under Schedule 1 of the Wildlife and Countryside Act 1981.

Prior to the 2000 pilot survey, 125 sites were randomly selected by WCP to be visited by them every year. These 'core' sites were chosen on the criteria outlined in the 2000 BOMP Report (Crick *et al.* 2001). WCP sites comprise two nest-box designs, the proportions of which are identical in four of the five study regions. Boxes in the fifth region, the southwest, are a hybrid of the two designs, with design characteristics similar to pole-boxes but which are mounted on trees. WCP also monitors additional 'extra' sites that are to be included in the programme in as many years as possible.

Because of the regional nature of WCP activities, and because most BTO volunteers have registered several sites within their home areas, there is substantial geographical clumping of sites. Although BOMP is intended to be a national programme within the UK, no sites have yet been registered in Northern Ireland.

BOMP's concentration of effort into nest-box sites should not affect the analysis of differences between years, regions or habitats, although breeding performance may be somewhat enhanced compared to natural sites. Nesting in boxes may improve Barn Owl breeding success, as the nesting environment has been specially designed for this purpose. Nest recorders may remove old nest debris from boxes at the end of the breeding season (legally this is permitted only between 1 August and 31 January of the following year, but for Barn Owls considerably later than 1 August is usually more appropriate), potentially reducing parasite loads in the box. However, to counter these positive effects, nest boxes may be more obvious to predators and may provide less shelter from the elements in some circumstances.

2.3. Fieldwork methods

The volunteer-based component of the Barn Owl Monitoring Programme is carried out at two levels of commitment, described to potential contributors as Option 1 and Option 2. Full details of these are given in the Guidance Notes (Appendix 1 of Beaven *et al.* 2002).

At the first level, key information can be gathered with minimal disturbance to Barn Owls. Option 1 requires a licence to disturb a Barn Owl from the relevant statutory conservation agency and involves checking the registered nest sites at least twice, and preferably more regularly, for signs of occupancy, assessing fledging success, and checking for signs of re-nesting and second broods (see Table 2.3).

- *Site occupancy*: A visit to the site in late April or early May usually reveals whether the site is occupied by Barn Owls (or has been during the current calendar year). A series of brief monthly visits from April to October is ideal. Evidence of usage, including pellet remains, moulted feathers and prey items is recorded, as is the identity and reproductive status of any other species occupying the box.
- *Second broods*: These are important in determining the overall productivity of a pair. Instances of double brooding can be identified more reliably where nest boxes are placed in closely adjacent pairs, as second clutches are often laid at different sites to the first.
- *Habitat/land-use surrounding site*: The habitat surrounding the site is recorded using the standard BTO habitat codes (Crick 1992), which incorporate information concerning broad habitat types as well as more detailed information concerning crop types and livestock. 'Micro-habitat' features near the nest (for example ditch banks within a landscape of large arable fields) are potentially the most important factors in terms of attracting Barn Owls to breed at many sites, and are also recorded. Staff at BTO HQ have access to additional information concerning land-use at a wider scale, such as the Centre for Ecology & Hydrology's satellite-derived Land Cover data (Haines-Young *et al*. 2000).

The second level of monitoring also requires a licence from the relevant statutory conservation agency and demands greater experience and commitment: it involves visiting nests to record additional information about the nest contents. Nest recorders choosing Option 2 are invited to record clutch size, brood size, age of young, losses of young, the presence of other species nesting at the site, and details of species, number and weight of any prey animals stored there. The following are to be recorded where possible:

- *Clutch size*: the number of eggs present – recorded during a visit in late April or early May. For the most part, second broods are detected on the visits made in July or August, when the female is sitting on eggs in an adjacent (paired) nest box while the male is still feeding young from the first brood (as well as his mate).
- *Hatching success*: counts of unhatched eggs or eggshells.
- *Brood size*: the number of young present, preferably at early and late nestling stages.
- *Age of young*: as judged from the development of down, or estimated from feather length and wing length.
- *Losses of young*: any dead or missing young are noted.
- *Prey stored at nest*: presence, species composition, number (and, if possible, weight) of prey stored at nests, to provide an indication of food availability.
- *Dates of laying, hatching and fledging*: these are recorded when visits coincide with these events, but hatching, and hence laying dates, can also be deduced from the age of the nestlings.

- *Fledging success*: The number of young fledged from a site. This must include zeros (total failures) to give an accurate indication of the breeding performance of Barn Owls each year. In practice, this is likely to be measured as the number of young in the nest at 5-8 weeks old, at ringing age, because most chick losses have occurred by this time. A late visit to the nest site is useful to record the presence of any remains or rings of chicks that died prior to fledging. The fledging success of any second broods is assessed through a final site visit in October.

Under Option 2, suitably licensed ringers are encouraged to ring the adults and young, record chick measurements and, for adults, note their age, sex, and state of brood patch and moult (Table 2.3).

- *Ringing young*: this is important for measuring survival rates and dispersal, when breeding adults are recaptured in subsequent years and when dead birds are found and reported under the BTO Ringing Scheme; 10-15% of ringed Barn Owls are subsequently reported to the BTO's Ringing Office.
- *Measurements of young*: on each visit, ringers are asked to measure wing length (maximum chord) and weight of chicks. Nestling age can be estimated by taking the length of the unfurled section of the 7th primary feather, or its pin, and consulting one of two separate (pin and feather) growth curves (Shawyer 1998). In addition, the degree of speckling on the underside of the body and wings can be used to estimate a nestling's sex. Chick weight may provide a useful measure of condition; the value of this technique is being assessed.
- *Measurement of dead chicks (length of 7th primary)*: this can help estimate the age at which any dead chicks died.
- *Ringing adults*: only ringers who have experience of catching birds at a nest site are permitted to ring adults and take biometric measurements. Guidelines have been provided as part of the fieldwork Guidance Notes and we encourage the sharing of information between ringers. Ringing of adult birds is necessary for the robust estimation of survival rates, and allows assessments of dispersal and movements by breeding individuals. Typically fewer than 100 adults are ringed each year, and the ratio of chicks ringed to adults ringed is approximately 12:1. Ringers are therefore urged to catch more adults.
- *Measurements of adults*: the age, sex, moult and brood patch condition of adult birds is recorded using standard techniques.

Visit period	**Information sought, ringing activity**
Late April to mid May	Site occupancy Count eggs and any chicks just hatched Catch and ring adults Identify moulted feathers
Mid July to early August	Count chicks at 6-8 weeks old Ring chicks Identify whether second broods begun Collect/identify moulted feathers
October	Count second broods at 6-8 weeks old Ring chicks

Table 2.3. Visiting schedule adopted as standard for the BOMP Network sites, designed to document the key events in the Barn Owl's breeding cycle.

Work by WCP has been carried out at the full Option 2 level and also involves the development and testing of new methods.

- When combined with egg weight, measurements of length and breadth of eggs can be used to assess egg density, which declines predictably through incubation due to respiration by the developing embryo (Rahn & Ar 1974). A portable electronic pan balance is needed for accurate weighing. Egg measurements may prove useful for determining a relatively precise laying date and can also be used by ringers to assess when to revisit the nest in order to optimise data gathering and to ring the chicks. The period between egg measurement and hatching can be estimated by referring to a standard curve (Percival 1990, Shawyer 1998 and pers. comm.).
- A method of estimating post-ringing chick mortality is being investigated by WCP. This involves visiting a sample of sites six to eight weeks after ringing, and making thorough searches of pellet debris at boxes where young have been ringed for a number of years.
- WCP is assessing whether the presence of shredded pellets and of incubating females in July or August are effective indicators of second breeding attempts.
- The presence of moulted wing feathers from the female between late April and mid July may be an effective indicator that a second brood will not be attempted; this, too, is being investigated.

The standard equation used to derive egg density from egg measurements comes from a study by Hoyt (1979), and is drawn from information for 115 species. This equation is applicable to all species, except a few that have relatively pointed eggs. Percival (1990) used a slightly different equation that was based on a smaller number of species, as reported by Hoyt (1979) and Furness & Furness (1981), and created a curve that relates egg density to hatching date, based on Barn Owl egg measurements. Shawyer (see above) has adapted this further, but these curves need to be validated for use, as part of BOMP, to make sure that a curve specific to Barn Owls is available.

2.4. Data collation

Data are recorded using standardised forms (see Beaven *et al.* 2002 for examples) and the information collected was entered into one of two Microsoft Access databases, one for WCP Core data and the other for BOMP Network data. The former containing more detailed information on certain aspects.

2.5. Calculating breeding parameters

2.5.1. Site occupancy

A site was classed as ‘used for nesting’ if a breeding attempt had been made, as signified by the presence of one or more eggs or chicks on at least one visit made during the season. If a Barn Owl(s) was encountered or if fresh pellets were present, but no eggs or chicks were recorded during the season, the site was classed as ‘used for roosting’.

Barn Owls may start to lay a repeat clutch before or soon after the youngest in the first brood has fledged. At some sites paired boxes were erected with the intention of providing a potential site for repeat nesting attempts. These boxes are usually placed very close together and are thus very unlikely to be used simultaneously by two different pairs. For analytical purposes, the pair of boxes was therefore treated as a single site and if a breeding attempt was initiated in either box then the site was classed as ‘Used for nesting’. However, in a few cases two pairs did nest in paired boxes. If this occurred during any season, the paired boxes are treated as two separate sites in all years as there was the potential for simultaneous breeding.

2.5.2. Laying date

Very few nests are found sufficiently early for the laying date of the first egg (FED) to be known with certainty. For the most part, back-calculation is required, based on information on clutch size and the age or stage of the nest contents on each visit. Given the visit date and the stage of development of the contents, as recorded by the observer, and information about the typical length of the egg-laying interval, incubation and nestling periods and whether or not the eggs hatch synchronously, it is possible to calculate the earliest and latest possible first egg dates for each nest (Crick *et al.* 2003).

An acceptable level of uncertainty used in the analysis of laying dates will vary according to species and study, but for the purpose of this analysis the midpoints between earliest and latest possible FEDs were used provided they were known to within ± 5 days. If the range of possible FEDs exceeded 10 days, the record was excluded from the analysis.

2.5.3. Clutch and brood size

The key factor to ascertain in determining clutch sizes, is whether egg-laying has finished or not. Thus records were omitted from these analyses if nests were only visited once (unless incubation had begun, as signified by warm eggs), only visited when the eggs were cold (suggesting the nest had failed before the first visit), if laying may still have been in progress on the last visit or if the maximum recorded brood size exceeded the maximum number of recorded young (Crick *et al.* 2003). Clutch sizes of a single egg were also excluded from the analysis as this sample is likely to include clutch sizes estimated at '1+' where eggs were present but no count was made.

Records were excluded from the analysis of brood size if no visit was made while any of the young were alive. Broods apparently consisting of a single chick were excluded from the analysis, as this sample is likely to include brood sizes estimated at '1+' where chicks were present but no count was made.

2.5.4. Nesting success

The simplest measure of nesting success is to calculate the proportion of monitored nests which successfully fledged at least one offspring. However, such estimates of nest success are subject to biases caused by early egg losses (Snow 1955) and the problems of categorising nests not followed to fledging (Mayfield 1961, see Crick *et al.* 2003 for summary).

To overcome these problems, Mayfield (1961, 1975) suggested a method for estimating nest success that was based on the calculation of the daily survival or failure rates of nests. The method allows the inclusion of all nests, so long as they have been visited at least twice. Nest survival rates are based on the "nest-day" as the unit of exposure of nests to mortality factors. Ten nest-days can represent one nest observed twice, 10 days apart, or 10 nests observed twice each, on two successive days. To calculate a daily nest failure rate, the number of nests that fail during the period of observation are summed and divided by the total number of nest-days over which observations were made. Further details of the methodology and a summary of the assumptions can be found in Crick *et al.* (2003).

2.6. Assigning habitat categories

A primary habitat code is associated with all WCP sites. Each record was assigned to a broad habitat category on the basis of the first two levels of the primary habitat code (Crick 1992) as indicated in Table 2.6. For BOMP Network sites, participants are asked to record the proportion of each of the major BTO habitat categories (Levels 1 and 2 – Crick 1992) within the 1km square in which the nest site is centred. For the purposes of this analysis, each site was allocated the habitat code of the most prevalent habitat type. Where one or more habitat types were equally prevalent (N=10), that which was most likely to influence Barn Owl breeding success was selected as the primary habitat. The records were then allocated to broad habitat categories as indicated in Table 2.6

BTO Habitat Code	Description	Habitat Category
B1-B7 C1-C9 D1-D6	Scrubland Semi-natural grassland and marsh Heathland and bogs	GRASS GRASS GRASS
E1, E2, E5, E6	Farmland	PAST
E3	Farmland	MIXED
E4	Farmland	ARABLE
A1-A6 F1-F3 G1-G10 H1-H4 I1-I7 J	Woodland Human sites Water bodies (freshwater) Coastal Inland rock Miscellaneous	Excluded from analyses due to small sample sizes

Table 2.6. Broad habitat categories used in the analyses of BOMP data

2.7. Weather data

The two climatic parameters used in these analyses were the Central England Temperature (CET) index (Manley 1974, Parker et al. 1992) and the England and Wales Precipitation (EWP) index (Wigley *et al*. 1984, Jones & Conway 1997). These data were used because the area of Britain from which they are collected is broadly representative of that from which the BOMP data are derived. Mean monthly values for these variables were obtained from the Hadley Centre for Climate Prediction and Research (www.metoffice.com/research/hadleycentre/obsdata/index.html) for the years 2000-2004.

For the analyses of occupancy rates, mean annual values of CET and EWP over the period November-March were included in the models to investigate the influence of winter weather on breeding behaviour during the following spring. For analyses of laying date and clutch size, mean annual values of CET and EWP included in the analyses were calculated over the period Mar-June. This range of months was selected because the central 80% of first egg dates for Barn Owl that can be calculated with an accuracy of ± 5 days from the NRS dataset 1990-2003 (N=190) fall between the beginning of April and the end of June, and the weather in the month immediately preceding the laying season may also influence characteristics of the clutch. For analyses of brood size, means of CET and EWP over the period May-Aug were included in the model as the average incubation period is approximately one month and chicks take approximately 50 days to fledge.

The influence of temperature and precipitation were analysed separately due to the high degree of correlation between these two weather variables over the four study years (Nov-Mar, R^2=0.917; Mar-Jun, R^2=0.465; May-Aug, R^2=0.679).

2.8. Statistical models

All analyses were performed in SAS v8.02. As the dataset used in the analyses of occupancy rates and brood sizes included information from the same nest sites in several different years, a repeated measures GENMOD procedure was used, with a site identifier as the repeated variable and specifying an autoregressive correlation function. Such models allow us to control for characteristics of specific sites that may influence occupancy or productivity in a similar manner each year. As Barn Owls are a relatively long-lived species (mean life-expectancy = 3 years, maximum = 13 years, Robinson 2005), repeated-measures analyses also allow us to control for the fact that the same pair might be breeding at a specific site in successive years.

Due to the relative paucity of data, repeat values for a small number of sites only were present in the laying date (N=1) and clutch size (N=9) datasets. These repeat values were removed from the datasets prior to analysis and a straightforward GENMOD procedure was then used.

For the analyses of occupancy rates and failure rates, a binomial error distribution was assumed and a logit link function was specified. For the analyses of laying date information, a normal distribution was assumed and an identity link function was specified. For the analyses of clutch and brood size data, a Poisson error distribution was assumed and a log link function was specified. In all models, Northing, Easting, year and primary habitat type were included as independent variables.

3. RESULTS

3.1. Survey coverage

The number of boxes registered for BOMP has increased with each successive year of the Programme, with 850 registered at the start of the 2003 field season, of which 255 (30%) were monitored by the Wildlife Conservation Partnership (WCP) and the rest by the BOMP Network of volunteer recorders. Although the Core Sites monitored by WCP are covered in all years the overall figure represents the maximum potential number of sites that could have been covered, as Network sites are not necessarily covered in all years. Table 3.1 presents a breakdown of survey coverage 2000-2003 by year and monitoring category.

	2000	2001	2002	2003
WCP Core sites	158	171	196	198
BOMP Network sites	-	-	390	415
TOTAL	158	171	586	613

Table 3.1. Total number of BOMP sites surveyed annually 2000-2003.

The distribution of these sites across the UK is mapped in Figure 3.1. Coverage is generally good in the South, East and North of England, but poorer in western England. Coverage in Scotland is good in the north-western lowlands, but poor elsewhere and there are very few BOMP sites in Wales even though Barn Owls breed throughout much of the country (Gibbons *et al*., 1993).

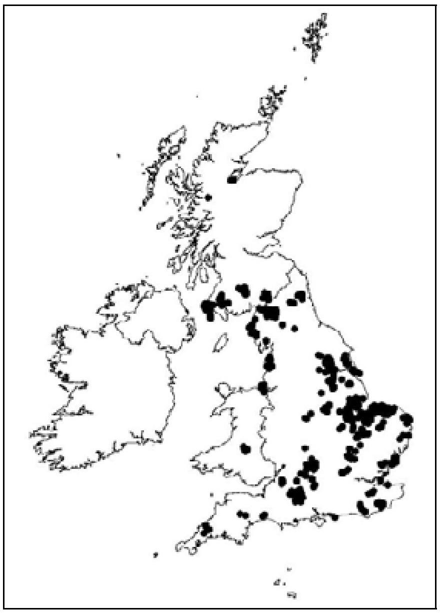

Figure 3.1. Distribution of registered BOMP sites 2000-2003.

3.2 Occupancy rates

Variation in occupancy rates, in terms of both the presence of birds and the presence of active nests, was investigated for the dataset as a whole and for WCP and BOMP Network sites separately. In total, over the four study years, Barn Owls were present in 1101 of the 1436 sites visited (76.7%) and were breeding in 870 (60.85%).

The proportion of sites at which Barn Owls were present varied significantly with location, year and habitat type (Table 3.2.1). The probability of a site containing a breeding pair or roosting individual was greater in sites that were further north and west. These relationships persisted when a subset of data containing only those sites monitored by WCP was analysed, but neither Northing nor Easting had a significant effect on the likelihood of Barn Owls being present when the analysis was restricted to those sites monitored by BOMP Network volunteers. Year had a highly significant negative influence on the probability of Barn Owls being present in all three datasets, indicating that the proportion of boxes containing either breeding or roosting Barn Owls was lower in later years of the survey.

	DF	X^2	P
All sites (N=1321)			
Northing	1	7.55	0.006
Easting	1	5.43	0.020
Year	1	60.26	<0.001
Primary habitat	3	10.15	0.017
WCP sites (N=674)			
Northing	1	7.10	0.008
Easting	1	7.50	0.006
Year	1	25.04	<0.001
Primary habitat	3	9.22	0.026
BOMP Network (N=647)			
Northing	1	2.02	0.155
Easting	1	0.89	0.346
Year	1	10.36	0.001
Primary habitat	2	6.85	0.033

Table 3.2.1. Influence of location, year and habitat on the presence of Barn Owl, whether breeding or non-breeding.

Habitat also significantly influenced Barn Owl presence in all three datasets. When all sites were considered, birds were present in the greatest proportion of boxes in natural grassland and mixed farming habitats, with occupancy rates lower at sites in arable and pastoral areas. The hierarchy of habitat types stayed the same when only those sites monitored by WCP were included in the analysis. Interestingly, when BOMP Network sites were analysed in isolation, sites in natural grassland and pastoral areas displayed similar rates of occupancy, while those in arable areas were significantly less likely to be occupied.

	DF	X^2	P
All sites (N=1321)			
Northing	1	3.75	0.053
Easting	1	12.16	<0.001
Year	1	69.44	<0.001
Primary habitat	3	7.77	0.051
WCP sites (N=674)			
Northing	1	1.82	0.178
Easting	1	8.48	0.004
Year	1	48.28	<0.001
Primary habitat	3	14.01	0.003
BOMP Network (N=647)			
Northing	1	3.42	0.065
Easting	1	0.11	0.740
Year	1	26.22	<0.001
Primary habitat	2	6.37	0.041

Table 3.2.2. Influence of location, year and habitat on the presence of breeding Barn Owl.

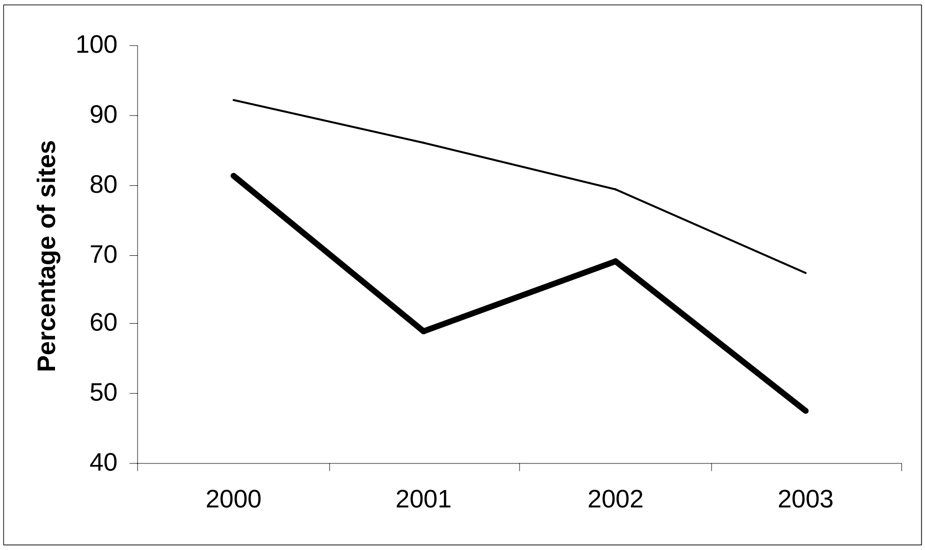

Figure 3.2. Annual variation in percentage of sites at which Barn Owls present (thin line) and in which Barn Owls breeding (thick line).

The probability of a site containing breeding pair was also significantly influenced by location, year and habitat (Table 3.2.2). Sites in the west of the UK were more likely to house breeding Barn Owls. The proportion of sites at which birds were breeding decreased in later years of the survey, as did the proportion of occupied sites. However, the pattern of decline differed, with occupancy rates exhibiting a steady decrease while the proportion of boxes containing breeding birds fluctuated, declining in 2001, increasing in 2002 and then declining again in 2003 (Figure 3.2). These differing relationships resulted in significant annual variation in the proportion of occupied boxes containing non-breeding birds (DF=1, X^2=17.94, P<0.001), which was highest in 2001 and 2003. The proportion of occupied sites containing non-breeding birds was also higher towards the east of the country (DF=1, X^2=8.96, P=0.003).

Habitat type also affected the probability of Barn Owls breeding at a particular site. In the analysis of the whole dataset and that of the subset of WCP sites, sites in areas of natural grassland were most likely to contain breeding Barn Owls, with relatively fewer observed in mixed farming areas, still fewer in arable habitats and the lowest proportion found in pastoral habitats. Again, the relative probabilities were different for the subset of BOMP Network sites, which identified pastoral areas as those most likely to contain breeding Barn Owls and arable areas as those least likely to.

3.3. Productivity

As nest sites are generally visited relatively infrequently (mean = 2.07 visits per site), and then often only post-hatching, first egg dates could only be calculated with a sufficient degree of accuracy for 28 sites using standard Nest Record Scheme methods (Crick *et al.* 2003). (Methods for estimating laying dates from chick measurements undertaken at Core Sites will be implemented in a future analysis). No significant relationship between Northing, Easting, year or habitat type and first egg date was identified for this small sample (Table 3.3). The paucity of data from the egg stage also meant that clutch size was difficult to determine accurately at the majority of sites. Analysis of data from the 62 sites for which clutch sizes could be calculated failed to identify any significant influence of Northing, Easting, year or habitat type (Table 3.3).

	DF	**X^2**	**P**
First egg date (N=28)			
Northing	1	0.08	0.777
Easting	1	0.01	0.926
Year	1	0.37	0.545
Primary habitat	3	1.48	0.688
Clutch size (N=62)			
Northing	1	0.07	0.795
Easting	1	0.12	0.732
Year	1	0.15	0.695
Primary habitat	3	1.61	0.658
Brood size (N=549)			
Northing	1	3.38	0.066
Easting	1	0.79	0.373
Year	1	0.52	0.469
Primary habitat	3	6.81	0.078

Table 3.3. Influence of location, year and habitat on laying date, clutch size and brood size.

Brood size could be determined at a much greater number of sites (N=549). Again no significant relationship with any of the factors in the model was identified, although the influence of Northing and habitat type did approach significance (Table 3.3), indicating that mean brood sizes may have been higher at sites in natural grassland and in more northern areas and lower in areas of mixed farmland. Such relationships may become more clearly defined with the addition of subsequent years of data to the BOMP dataset. As the outcomes of the vast majority of nests were either recorded as a success (15.06%) or as unknown (82.84%), there were too few definite failures recorded to permit analysis of the factors influencing Mayfield failure rates.

3.4. Influence of weather conditions

Controlling for location, year and habitat, weather conditions over the preceding winter significantly influenced both the overall proportion of boxes that were occupied by breeding Barn Owls and the proportion of occupied boxes in which birds attempted to breed (Table 3.4.1). Breeding occupancy was lower following colder, wetter winters, with a greater proportion of birds recorded as roosting but not breeding. Overall occupancy (breeders plus non-breeders) was unaffected by weather conditions. As temperature and rainfall are so closely correlated, it is not possible to distinguish which of these factors was responsible for the observed relationship.

	DF	X^2	P
Occupancy rate (N=1321)			
November-March Temperature	1	0.08	0.780
November-March Precipitation	1	0.02	0.875
Breeding occupancy (N=1321)			
November-March Temperature	1	16.43	<0.001
November-March Precipitation	1	20.60	<0.001
Proportion of non-breeders (N=1030)			
November-March Temperature	1	21.44	<0.001
November-March Precipitation	1	27.37	<0.001

Table 3.4.1. Influence of weather conditions on box occupancy (N=1321). Temperature comes from the Central England Temperature record and precipitation from the England & Wales Precipitation record (see text).

No significant relationship was identified between any measure of productivity and either mean temperature or mean precipitation over the preceding winter ($p > 0.100$ in all analyses). Furthermore, weather conditions immediately prior to and during the nesting cycle were not found to have a significant effect on laying dates, clutch size or brood size (Table 3.4.2), although the relationship between weather conditions and brood size (positive for precipitation, negative for temperature) did approach significance.

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	DF	X^2	P
First egg date (N=28)			
March-June Temperature	1	0.11	0.738
March-June Precipitation	1	0.04	0.842
Clutch size (N=62)			
March-June Temperature	1	0.01	0.931
March-June Precipitation	1	0.81	0.369
Brood size (N=549)			
May-August Temperature	1	3.56	0.059
May-August Precipitation	1	3.50	0.061

Table 3.4.2. Influence of weather conditions on productivity. Temperature comes from the Central England Temperature record and precipitation from the England & Wales Precipitation record (see text).

3.5. Occupancy rates of other species

Seven other bird species were recorded as breeding in Barn Owl boxes, including Stock Dove, Jackdaw, Kestrel, Tawny Owl, Little Owl, Mallard and Mandarin, although the occupancy rates of Stock Dove, Jackdaw and Kestrel only were sufficiently high to permit more detailed analysis (see Table 3.5.1).

	2000	2001	2002	2003
Stock Dove	7 (4.52%)	30 (18.99%)	70 (12.82%)	48 (8.32%)
Jackdaw	9 (5.81%)	15 (9.49%)	62 (11.36%)	48 (8.32%)
Kestrel	6 (7.41%)	16 (10.13%)	37 (6.78%)	22 (3.81%)

Table 3.5.1. The number and proportion of sites occupied by breeding Stock Dove, Jackdaw and Kestrel.

The probability of a BOMP site being occupied by breeding Stock Dove was significantly greater towards the east of Britain (Table 3.5.2). Sites in mixed farmland were also significantly more likely to support breeding Stock Dove (Table 3.5.2), with natural grassland displaying the lowest breeding occupancy rates for the species.

Breeding Jackdaws occupied a greater proportion of BOMP sites in the east of Britain and were also more prevalent at sites in the north (Table 3.5.2). Year also had a significant affect on the breeding occupancy rates of Jackdaw, with a greater proportion of sites occupied in the later years of the survey (Table 3.5.2). As with Stock Dove, breeding pairs of Jackdaw were significantly more likely to be found at sites in areas of mixed farmland, with the lowest breeding occupancy rates observed in areas of natural grassland (Table 3.5.2).

	DF	X^2	P
Stock Dove (N=1321)			
Northing	1	2.48	0.115
Easting	1	15.22	<0.001
Year	1	0.50	0.482
Primary habitat	3	11.63	0.009
Jackdaw (N=1321)			
Northing	1	11.0	0.001
Easting	1	21.31	<0.001
Year	1	4.97	0.026
Primary habitat	3	31.11	<0.001
Kestrel (N=1321)			
Northing	1	9.32	0.002
Easting	1	25.79	<0.001
Year	1	0.77	0.382

Table 3.5.2. Influence of location, year and habitat on the presence of breeding Stock Dove, Jackdaw and Kestrel.

Breeding occupancy rates of Kestrel were too low to allow analysis using the full model, but a restricted model containing Northing, Easting and year indicated that all but the latter significantly influenced the probability of a pair breeding at a BOMP site (Table 3.5.2). As with both Stock Dove and Jackdaw, breeding occupancy rates were highest in the east of Britain. However, Kestrel breeding occupancy rates also exhibited a significant negative relationship with Northing (Table 3.5.2), indicating that attempts were more prevalent at sites in the south of Britain.

4. DISCUSSION

It is clear that BOMP has successfully established a protocol for data collection that enables trends in population size and in breeding statistics to be calculated and is already providing valuable data for the conservation of the species. Fieldwork is inevitably concentrated in areas where Barn Owl are relatively abundant and, by monitoring such populations, BOMP is monitoring a key component of the Barn Owl's national population. Furthermore, the scale of the monitoring effort within BOMP, amounting to *c.* 14% of the national population of Barn Owl and with a good geographical spread, gives the results added importance. Although BOMP concentrates on nestbox sites, these are increasingly used by the species in the UK: 38% of nesting attempts recorded under Project Barn Owl in the mid-1990s were in boxes (Toms *et al.* 2000) and it is estimated that this will rise substantially by the end of the current decade (Shawyer pers. comm.). While the non-random nature of the sample may influence the resulting trends to some degree, there is every reason to expect that BOMP would detect a major real change in population and would provide information about the demographic mechanisms and environmental factors underlying that change, thus providing valuable pointers to direct effective conservation efforts. BOMP's value is shown by the inclusion of its results in the annual and widely disseminated document *The State of the UK's Birds* 2003 (Eaton *et al*. 2004) that reports the current status and trends of bird populations in the UK, as well as in the annual report of the Rare Breeding Birds Panel, published in the journal *British Birds* (Ogilvie & RBBP 2003).

4.1. Occupancy rates

Occupancy rates of Barn Owl nest sites have declined significantly during the four years of the Programme, both in terms of the proportion at which owls were recorded as present and the proportion from which breeding pairs were reported. This relationship could be an artefact of the non-random selection of Network monitoring sites. If BOMP participants were more likely to select sites at which Barn Owl were known to be present or breeding in previous years, then initial occupancy rates may be have been artificially inflated and a subsequent decrease might be predicted until a more natural level is reached.

However, while overall presence has declined in a linear manner, breeding occupancy has fluctuated over the monitoring period, falling between 2000 and 2001, increasing in 2002 and decreasing again in 2003 (Figure 3.2), suggesting that additional factors are influencing inter-annual variation in whether the birds actually breed at a site, rather than merely occupying one. Cyclical changes in Short-tailed Vole numbers are known to be an important factor. Weather conditions may have an effect on both Barn Owl abundance and the proportion of pairs that are in sufficient condition to breed, with cold, wet weather during the winter reducing the availability of small mammal prey and the ability of Barn Owl to hunt successfully. Analysis of temperature and precipitation data for the UK indicated that this was indeed the case, with the proportion of BOMP sites occupied by breeding pairs significantly reduced following inclement winters. This decrease was not due to a decline in absolute presence of birds at nest sites, but rather to a reduction in the proportion of owls at occupied sites that were electing to breed. Low temperatures and high rainfall are therefore not necessarily leading to decreased survival, but instead may be causing an increased proportion of the population to suspend breeding due to poor body condition. The term for 'Year' remained significant in all models to which temperature and precipitation parameters were added, indicating that weather conditions were not solely responsible for the observed declines in occupancy rates between 2000 and 2003.

Both overall presence and breeding occupancy also vary geographically. Barn Owl were present at a higher proportion of sites in the west of the UK and were also breeding at a higher proportion of sites. This relationship may be a response to more clement winter weather, in particular higher temperatures, in the west of the country due to the proximity of the Gulf Stream, which may influence survival rates and/or body condition as discussed above. Analysis of BOMP data also indicated that owls were present at a higher proportion of northern sites, and the analysis of breeding occupancy approached significance in the same direction. This result suggests that Barn Owl may be more abundant in the north of the country, providing weaker evidence to support the fact that breeding conditions may also be better. The underlying causes of this relationship are not immediately obvious, but may relate to agricultural land use. Farming in the north of the UK is generally less intensive than that in the south and it is possible that the availability of both prey, due to more extensive areas of rough grassland, and natural nest sites, such as trees and farm buildings, may be greater as a result. Although BOMP participants are asked to record details of the habitat immediately surrounding the nest site in some detail, it is possible that this may not give an accurate representation of the area utilised by hunting birds, particularly if they tend to hunt further from the nest site. Further analyses of BOMP data using habitat information collected on a coarser scale, such as CS2000 Land Cover data (Haines-Young *et al.* 2000), may help to identify the cause of the observed relationship more precisely.

Habitat surrounding the nest site did explain some of the variance in occupancy rates, however, although the hierarchy of habitat types was different for the two types of BOMP site. WCP sites in areas of natural grassland were most likely to contain breeding Barn Owl, with relatively fewer observed in mixed farming areas, still fewer in arable habitats and the lowest proportion found in pastoral habitats. Conversely, BOMP network sites in pastoral areas were *most* likely to contain breeding Barn Owl, with fewest found in arable areas. These results may reflect differences in the relative distribution of BOMP Network and WCP sites nationally, the fact that data from the former are only available from 2002 onwards or the fact that the methodology of habitat data collection differs between the two types of site. Again, further analysis of the data using CS2000 Land Cover data may help to clarify the observed relationships.

The breeding occupancy rates of the three other species for which data were analysed – Stock Dove, Jackdaw and Kestrel – all displayed significant relationships with at least one of the parameters in the model in the opposite direction to that displayed by Barn Owl. Breeding attempts of all three species were more prevalent at sites in the east of the UK, were least frequently recorded in natural grassland sites for Jackdaw and Stock Dove, were more frequently recorded in later years for Jackdaw and were observed at a greater proportion of sites towards the south of the UK for Kestrel, although Jackdaw breeding occupancy did display a positive relationship with Northing similar to that of Barn Owl. Although anecdotal evidence suggests that Barn Owl and other bird species may breed simultaneously in the same site, particularly in nest boxes, these results suggest that some competitive exclusion may be taking place. Although it is not possible to ascertain the direction in which such exclusion may be taking place, it seems most likely that the presence of Barn Owl deters other species from breeding as it is difficult to see how any of these species, and Stock Dove in particular, could out-compete an owl, although Jackdaw nests may prevent entry to some sites. We plan to collect additional information about the effect of Jackdaw nests in future years of BOMP.

4.2. Productivity

None of the three measures of productivity – laying date, clutch size and brood size – collected by BOMP participants displayed any significant relationship with Northing, Easting, year or habitat type, although the sample sizes for the first two parameters were very small. In addition, none of the three variables displayed any significant relationship with weather conditions over the winter period. This lack of a relationship is perhaps as predicted if only those pairs that are above a certain threshold body condition attempt to breed and those that would produce smaller clutches/broods instead suspend breeding, as suggested by the analysis of occupancy rate data. This type of life history trade-off might be expected for a relatively large bird species that is likely to survive for a number of breeding seasons. Weather conditions immediately prior to and during the breeding season were not found to have any effect on breeding performance either. Further analysis of the data using temperature and precipitation figures summarised at a finer scale, available from individual weather stations, may help to identify any relationships that cannot be established using CET and EWP.

4.3. Recommendations for future analyses

As already mentioned, analyses of BOMP data in relation to the CS2000 Land Cover data may help to clarify the underlying causes of the geographical and habitat relationships with occupancy rates identified by this study. Analysis of productivity data in relation to regional figures for mean temperature and rainfall might also help to determine whether poor conditions during the breeding season reduce the productivity of individual nesting attempts.

One important parameter influencing overall Barn Owl productivity may be the number of broods produced per season. We are currently developing methods that may allow the estimation of multiple brooding by Barn Owl through observations of female moult and pellet shredding. These may provide valuable indicators of which sites should be followed up later in the season, as it is currently impractical to revisit all WCP core sites to assess the frequency of multiple brooding.

For year-round demographic modelling of the Barn Owl population, BOMP requires estimates of the annual survival rates of birds in their first and later years of life. As yet, it is too early to assess these parameters. The first annual report of BOMP presented the information available on Barn Owl movements and dispersal (Crick *et al.* 2001). The additional ringing activity generated by the introduction of BOMP will make more detailed analyses possible in the longer term.

It would be highly desirable within the next decade to conduct a repeat survey using Project Barn Owl methodology, to assess Barn Owl population trends using a randomised sample of study sites. This would help to validate the annual monitoring approach taken by BOMP and help to put the results in context.

With the exception of those in southern England, BOMP sites appear to have provided nesting sites for a wide variety of species other than Barn Owl. In future years it would be worth considering whether the scheme could be extended to cover these species, in particular the amber-listed Kestrel.

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APPENDIX 1: THE IMPACT OF THE 2001 FMD OUTBREAK ON THE UK BARN OWL POPULATION

INTRODUCTION

In 2001, the UK was seriously affected by an outbreak of Foot and Mouth Disease (FMD). A significant proportion of the national herd was slaughtered, large tracts of countryside were placed under access restrictions, preventing their use by members of the public, and rodenticide usage increased in certain areas to control the populations of rodents at farms and sites where slaughtered carcasses were stored at central disposal points.

Although the main concerns over these operations were on the impacts on farmers and rural communities, there were also concerns over the possible impacts of such widespread and invasive operations on the wider environment. One such issue was the possible impact of FMD operations on the populations of vulnerable Barn Owl populations in the areas affected. In particular, there were concerns that increased levels of activity around farms during the breeding season may have detrimentally affected a species that is normally highly protected from disturbance due to its position on Schedule 1 of the Wildlife & Countryside Act 1981. Furthermore, for a species already considered to be vulnerable to the impacts of rodenticide use, the increased use of these chemicals in and around farmland used by Barn Owls may have led to increased secondary poisoning, with impacts on site occupancy, breeding performance and survival. However, it was also possible that these potentially detrimental impacts might have been offset by reductions in disturbance following the imposition of access restrictions and the potential impact of reduced grazing pressure leading to improved grass swards and hence improved populations of their small mammal prey.

Thus, English Nature funded this project as a "contribution project" to the BTO's pre-existing Barn Owl Monitoring Programme. The broad aims were to support the development of the Programme to provide information that would help to investigate the potential impacts of FMD operations on Barn Owl Populations in the affected areas. In addition, the project would also use other existing datasets, such as data from the BTO's Nest Record Scheme, Ringing Scheme and the BTO and Hawk & Owl Trust's Project Barn Owl database to explore these impacts.

Foot and Mouth Disease

Between the 20th February and the 30th September 2001, livestock at 2030 individual properties throughout the UK were found to be infected with Foot and Mouth Disease (FMD). The incidence of the disease was greatest in Northern England, particularly in Cumbria and North Yorkshire, although Devon and Dumfries and Galloway both contained over 100 infected properties.

As FMD is a highly contagious disease, extreme measures were taken to prevent disease transmission to uninfected stock.

- Slaughter of infected and potentially infected stock – over 4,204,000 animals on 10,509 premises were slaughtered.
- Destruction of infected feedstuffs
- Disinfection of farm buildings and personnel/vehicles leaving the property
- Destruction of rodents, which might potentially have spread the disease, was advised

Potential influence of the FMD outbreak on the UK Barn Owl population

The control measures employed to eradicate the FMD outbreak had the potential to affect Barn Owls on farms due to changes in disturbance levels, declines in rodent prey and through the increased use of rodenticides. These potential effects are outlined below.

Disturbance

- Increased levels of disturbance around nesting sites, during either the disinfection of buildings or the destruction of livestock may have led to an increase in the incidence of nest desertion.
- On infected farms and on those uninfected farms where restrictions were in place, a reduction in both public access and farming activity may have resulted in decreased levels of disturbance around the nest site or hunting grounds.
- Reduced traffic in areas where access is restricted may lower the incidence of collisions with vehicles, a major cause of mortality for this species (Newton *et al*., 1991).

Prey availability

- The removal of livestock and foodstuffs from buildings on infected properties, and the subsequent disinfection of the buildings involved, may have reduced the availability of food to rodent populations. A decrease in rodent numbers may have resulted in a reduction in food availability for barn owls.
- The number of rodents in farm buildings may have been reduced directly by the increased application of rodenticides in order to decrease the possibility of disease transmission between farms. While commensal rodents such as House Mice and Brown Rats, the species most likely to be affected by the above measures, seldom constitute a significant proportion of the Barn Owl's diet during the breeding season, they may constitute important prey species during the winter months (Shawyer, 1987).
- Slaughter of livestock (cattle and sheep) and the confinement of surviving animals to farm buildings or small areas of pasture led to unprecedented increases in the extent of uncropped/ungrazed grassland both on infected farms and on those properties where restrictions were in place. Such grassland may have provided better habitat for small mammals, increasing the availability of prey species for Barn Owls and thus positively influencing occupancy rates and the productivity of breeding events.

Poisoning

- Residues of second-generation rodenticides contained in their rodent prey may also prove toxic to Barn Owls. Newton *et al.* (1990) analysed the carcasses of 145 Barn Owls found dead in the UK and found that 10% contained residues of either or both of the rodenticides difenacoum and brodifacoum. Furthermore, they demonstrated that ingestion of three laboratory mice that died after ingesting brodifacoum was sufficient to cause mortality in four of the six Barn Owls to which they were fed, a similar result to that of Mendenhall and Pank (1980).

Increased disturbance and decreased food availability in areas infected with FMD may therefore decrease Barn Owl productivity and survival, potentially reducing the size of the population in subsequent breeding seasons. Increased rodenticide use may also increase the probability of mortality due to ingestion of poisoned prey.

Alternatively, reduced levels of disturbance due to access restrictions, together with the increased availability of small mammal prey resulting from increases in the extent of ungrazed grassland, may lead to increased Barn Owl occupancy rates and productivity in those areas infected by FMD and those uninfected areas subject to restrictions. Grasslands rich in prey may also draw Barn Owls away from farmyards and farm buildings, thus reducing their chances of coming into contact with rodents contaminated with rodenticides.

METHODS

Barn Owl datasets

The analysis uses two main sources of Barn Owl data – BOMP and the Nest Record Scheme (NRS). The NRS, funded by the BTO/JNCC Partnership, has been collecting information about the breeding attempts of UK bird species since 1939. Over 1.25 million records for 232 species are currently help by the NRS, of which over 450,000 are currently computerised.

A network of 550-600 volunteer nest recorders and recording groups across the UK submit a total of *c.* 30,000 records to the NRS each year. Each NRC details the history of a single breeding attempt at an individual nest. Observers record species, county, year, their name (or personal code), place name, 6-figure grid reference, altitude, dates of each visit, numbers of eggs or young, standardised codes to describe the development of nests, eggs, young, activity of the parents and the outcome of the nest (giving cause of any failure if known). Recorders are encouraged to visit each nest site on at least 2 occasions during the breeding period so that various breeding parameters, particularly nest failure rates (see Section 2.3.3), may be calculated. In addition, observers record specific details of the nest site and the habitat surrounding it using a set of standard habitat codes. The habitat-coding scheme (Crick 1992) is a simple-to-use hierarchical system based on vegetation structure but includes aspects of land management and human activity. The height of the nest above ground, the floristic and structural details of the nest site itself and the degree of nest exposure are also noted.

The number of nest records held for Barn Owl over the period 1998-2003 is presented in Table 1. With the exception of Wales and northern Scotland, both areas that were relatively unaffected by the FMD outbreak, national coverage is good, particularly in the FMD 'hotspots' of southern Scotland and south-western England.

	Year					
	1998	**1999**	**2000**	**2001**	**2002**	**2003**
BOMP	-	-	158	170	586	613
NRS	382	442	506	319	574	690

Table 1. Total number of sites monitored by BOMP and NRS.

Foot and Mouth Disease (FMD) datasets

Access restrictions

The central grid references of 14,715 sites at which access was prevented in 2001, defined as the serving of FMD Access Restriction Form A, were obtained from the Central Science Laboratory (CSL) FMD database (Figure 1).

Figure 1. Location of sites at which access was prevented in 2001 in response to the FMD outbreak.

Slaughtered livestock and infected properties.

The location of 2026 infected premises, defined as those premises for which FMD Numbers had been allocated, were obtained from the CSL database (Figure 2a). The location of all premises at which there was evidence from the dataset that livestock had been slaughtered was also obtained from the CSL database (Figure2b). This included not only infected premises, but also those where animals had been slaughtered on suspicion of infection (N=240) and those where livestock had had dangerous contact with animals from infected premises (N=9083).

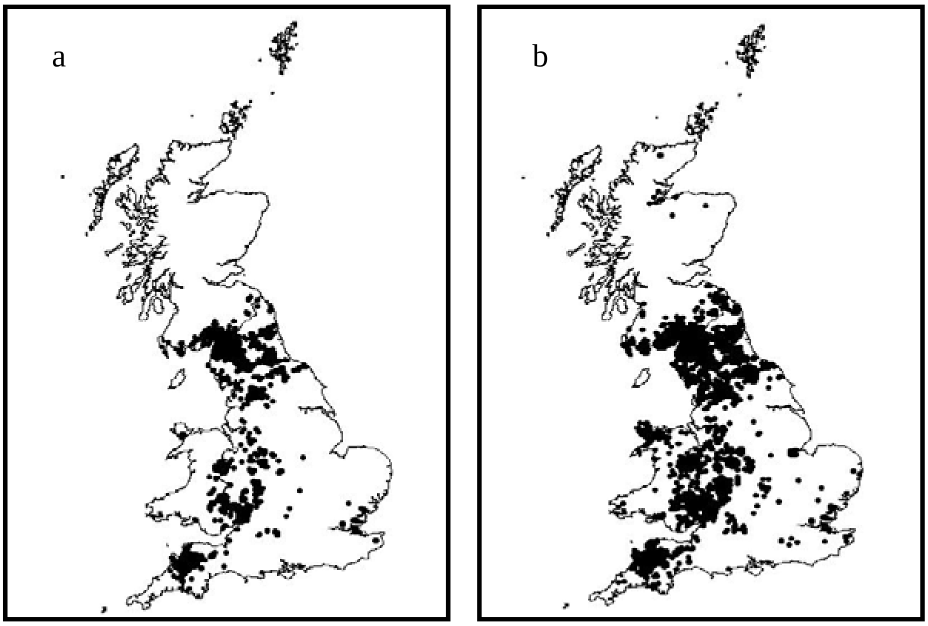

Figure 2 a. Location of farms at which FMD infection was confirmed and b. Location of farms at which livestock were slaughtered due to FMD infection, suspicion of infection or due to dangerous contact with diseased animals.

Rodenticide application

Detailed rodenticide data was obtained from the Rural Development Service (RDS) database for 2,283 premises in 12 counties/regions: Borders (N=2), Cheshire (1), Cleveland (16), Durham (231), Cumbria (1,309), Essex (9), Lancashire (89), North Yorkshire (411), Northamptonshire (4), Northumberland (188), South Yorkshire (1), Tyne & Wear (12), West Yorkshire (10). Data had been input for all sites within these regions at which rodenticides had been applied in response to the FMD outbreak – information for other counties/regions had not been input at the time of the request. In addition to the location of properties, information concerning the timing and extent of baiting and the types of compound used were available for the majority of sites.

Disinfection and disposal data

Unfortunately, the amount of information concerning the disinfection of premises recorded in the CSL database was very limited. No indication was given of the type, extent or timing of disinfection at any premises and data on whether any disinfection actually occurred at all was not available for many sites.

Analytical methods

The location of all data points in both the Barn Owl and the FMD datasets was plotted using ArcView GIS 3.3. For each Ban Owl data point, the location and distance of the nearest site contained in each FMD dataset (access restrictions, slaughtered livestock, infected premises and rodenticide application) were calculated using the Nearest Features v3.6d extension.

While the quality of the FMD information provided by CSL and RDS was generally high, a significant proportion of the records in both datasets (c. 1% of CSL data and c. 8% of RDS data) had no grid reference associated. In the majority of cases the only means of identifying the location of these sites was to manually search gazetteers for place names mentioned in the addresses, as few postcodes were available. Any sites for which a suitable match could not be found in the gazetteer were therefore excluded from the analysis.

In order to check for grid reference errors in the FMD datasets, a program was written in SAS v8.02 that compared the county specified in the address information with that specified by the grid reference according to an independent BTO dataset. The grid references of all mismatching sites were again checked manually using gazetteers and any sites for which no match could be found were excluded.

Statistical methods

FMD proximity categories

Nesting sites were grouped into two categories according to their proximity to premises identified by the individual FMD datasets, one containing sites within 5km of a FMD data point and one containing sites further than 5km from a FMD data point. A distance of 5km was chosen as the cut off point as this approximates to the mean diameter of a Barn Owl foraging territory while nesting (DEFRA 1988) and also allows a sufficient number of Barn Owl sites to be categorised as <5km to a FMD data point to permit analysis.

Habitat categories

A primary habitat code is associated with all BOMP Core Site and NRS records. Each record was assigned to a broad habitat category on the basis of the first two levels of the primary habitat code (Crick 1992) as indicated in Table 2.6 in the main report. For BOMP Network sites, participants are asked to record the proportion of each of the major BTO habitat categories (Levels 1 and 2 – Crick 1992) within the 1km square in which the nest site is centred. For the purposes of this analysis, each site was allocated the habitat code of the most prevalent habitat type. Where one or more habitat types were equally prevalent (N=10), that which was most likely to influence Barn Owl breeding success was selected as the primary habitat. The records were then allocated to broad habitat categories as indicated in Table 2.6 in the main report.

Statistical models

Breeding parameter data for BOMP and NRS sites for the three years prior to the FMD outbreak (1998-2000) were pooled as were those for the three post-outbreak years (2001-2003) and the two datasets were analysed separately. Occupancy rate data were analysed separately for BOMP Core and Network sites as the latter only contributed to the post-outbreak dataset (Network Sites were first monitored in 2002). Any differences identified between pre- and post-outbreak occupancy rates or breeding parameters might otherwise reflect a change in sampling strategy/site/observer identity, etc.

The FMD variables used in the analyses are known to be strongly correlated, as infected premises are a subset of slaughter sites, which are in turn a subset of sites at which access was restricted. All Barn Owl datasets were therefore analysed separately with respect to each of the four FMD variables (proximity of access restrictions, slaughtered livestock, infected premises and rodenticide application). The analyses of the influence of rodenticide application were performed on a reduced dataset of sites that feel within the boundaries of the 12 counties/regions for which rodenticide data were available.

All analyses were performed in SAS v8.02. As each of these datasets included information from the same nest sites in several different years, the data were analysed using a repeated measures GENMOD procedure, with a site identifier as the repeated variable. In the case of BOMP data, the side identifier used was the BOMP code, which is unique for each registered site. In the case of NRS data, where there is no site identifier per se, records from the same sites in different years were matched by a combination of observer identity and four-figure grid reference (six–figure grid references were not used as these are not always sufficiently consistent between years). In all models, northings, eastings, year and primary habitat type were included as independent variables in addition to the relevant FMD parameter.

For the analyses of occupancy rates and failure rates, a binomial error distribution was assumed and a logit link function was specified. For the analyses of laying date information, a normal distribution was assumed and an identity link function was specified. For the analyses of clutch and brood size data, a Poisson error distribution was assumed and a log link function was specified.

RESULTS

The breeding parameters used as dependent variables in all analyses are occupancy rates as measured by BOMP participants (figures for Core and Network Sites analysed separately – see methods), laying date (BOMP and NRS data pooled), clutch size (BOMP and NRS data) and brood size (BOMP and NRS data). Each parameter was analysed with to four FMD-related independent variables: proximity of restricted-access land, proximity of premises at which livestock were slaughtered, proximity of premises infected with FMD and proximity of farms at which rodenticides were applied (restricted dataset – see methods).

Access restrictions

Occupancy rates at BOMP Core Sites within 5km of land where access restrictions had been put in place were significantly less likely to be occupied (N=119, Occupancy = 47.9%) than those that were more than 5km from restricted-access land (N=399, Occupancy = 58.7%) following the FMD outbreak (Table 2). The difference in occupancy rate between BOMP Core Sites within 5km of restricted-access land and those further than 5km from such land was not significant prior to the FMD outbreak (Table 2). However, it should be noted that the significance of this test was marginal and an equivalent comparison of occupancy rates at BOMP Network Sites did not identify a significant difference.

	Pre-FMD (pre-2001)			**Post-FMD (post-2000)**		
	N	**X^2**	**P**	**N**	**X^2**	**P**
Occupancy (Core)	155	1.71	0.191	518	3.95	**0.047**
Occupancy (Network)	-	-	-	726	0.33	0.564
Clutch size*	123	2.14	0.144	172	0.04	0.835
Brood size	936	0.03	0.868	1462	0.06	0.800
Laying date	53	0.56	0.455	75	0.41	0.524

Table 2. Influence of the proximity of farms at which access restrictions were imposed on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

Sites greater than 5km from restricted-access land did not differ significantly from those within 5km of such land with respect to laying date, clutch size or brood size (Table 2). Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at either stage was too infrequent to permit analysis.

Slaughtered livestock

Occupancy rates at BOMP Core Sites within 5km of farms at which livestock had been slaughtered were much lower post-outbreak (N=14, Occupancy = 7.1%) than occupancy rates at BOMP Core Sites which were further away from such farms (N=504, Occupancy = 57.54%) (Table 3). The equivalent comparison prior to the FMD outbreak did not identify any such difference. However, care should be taken interpreting this result as the significance is marginal, the sample size of sites within 5km of farms at which livestock were slaughtered was very small and no significant difference was detected in the equivalent analysis of BOMP Network Site occupancy data post-outbreak (Table 3).

Again, neither laying date, clutch size or brood size varied significantly between sites close to farms at which livestock were slaughtered and those further away (Table 3). Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at wither stage was too infrequent to permit analysis.

	Pre-FMD (pre-2001)			**Post-FMD (post-2000)**		
	N	$\mathbf{X^2}$	**P**	**N**	$\mathbf{X^2}$	**P**
Occupancy (Core)	155	2.68	0.102	518	4.05	**0.044**
Occupancy (Network)	-	-	-	726	1.25	0.264
Clutch size*	123	0.05	0.815	172	0.60	0.438
Brood size	936	0.01	0.910	1462	0.00	0.966
Laying date	53	1.15	0.284	75	0.93	0.335

Table 3. Influence of the proximity of farms at which livestock were slaughtered on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

Infected premises

Occupancy rates at BOMP Network Sites within 5km of farms where FMD infection was confirmed were significantly greater post-outbreak (N=96, Occupancy = 81.3%) than sites that were further than 5km from infected farms (N=630, Occupancy = 57.0%) (Table 4). Unfortunately, BOMP Network sites were not surveyed prior to 2002 and it is therefore not possible to repeat the analysis using pre-outbreak data. No such difference was detected between BOMP Core Sites less than 5km and those more than 5km from infected premises post-outbreak (Table 4), although it should be noted that the former category consisted of only 2 sites.

The results of the analyses also indicated that clutch sizes at sites within 5km of infected farms post-outbreak were significantly larger (N=20, Mean = 5.5) than those at sites greater than 5km from infected farms (N=152, Mean = 4.7) (Table 3.3). The equivalent test pre-outbreak did not identify any significant difference in clutch size between the two categories of site. Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at wither stage was too infrequent to permit analysis.

	Pre-FMD (pre-2001)			**Post-FMD (post-2000)**		
	N	**X^2**	**P**	**N**	**X^2**	**P**
Occupancy (Core)	155	1.44	0.230	518	0.56	0.454
Occupancy (Network)	-	-	-	726	9.40	0.002
Clutch size*	123	0.09	0.759	172	5.75	0.017
Brood size	936	0.08	0.782	1462	0.06	0.812
Laying date	53	1.93	0.164	75	3.15	0.078

Table 4. Influence of the proximity of farms infected with FMD on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

Rodenticide application

Our ability to investigate the influence of rodenticide application on Barn Owl occupancy rates and the productivity of breeding attempts was limited by the fact that rodenticide data were only available for a restricted number of counties. Sample sizes were too small to allow comparison of occupancy rates at BOMP Core Sites or pre-outbreak laying dates between sites within 5km of rodenticide application and sites greater than 5km from rodenticide application.

Occupancy rates at BOMP Network sites post-outbreak were not significantly related to the proximity of premises at which rodenticides were used (Table 5). Clutch sizes at sites within 5km of rodenticide application were significantly larger (N=11, Mean = 6.0) than those at sites greater than 5km from such premises (N=18, Mean = 4.7), although sample sizes were small (Table 5). Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at wither stage was too infrequent to permit analysis.

	Pre-FMD (pre-2001)			Post-FMD (post-2000)		
	N	**X^2**	**P**	**N**	**X^2**	**P**
Occupancy (Core)	0	-	-	13	-	-
Occupancy (Network)	-	-	-	151	0.72	0.396
Clutch size*	12	0.03	0.868	29	9.06	**0.003**
Brood size	107	0.14	0.705	218	0.86	0.353
Laying date	2	-	-	12	1.76	0.184

Table 5. Influence of the proximity of farms at which rodenticides were applied on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

DISCUSSION

The outbreak of Foot-and Mouth Disease in Great Britain, which began with a confirmed case in an abattoir in Essex on 20 February 2001, became one of the biggest environmental and economic crises for the country in recent decades. Over 75% of land in England and Wales is farmed, and over half of this is through livestock farming (EA 2001). As a result of the epidemic, 8% of all livestock farms in Great Britain were directly affected and about one third of land in England and Wales was within Infected Areas at the height of the outbreak (EA 2001).

In a review of the environmental impact of the FMD outbreak, the Environment Agency listed a number of activities that caused pressure on the environment (EA 2001): carcass disposal, cleansing and disinfection, changes in livestock and farming practices and reduction in tourism. They concluded that there were minimal impacts on air quality, water quality (except for three incidents classified as serious) and soils. The EA also concluded that changes to grazing patterns in the short-term. Were unlikely to have much impact on biodiversity, but that the implications for biodiversity were complex. In general, however, there was very little systematic information on the impacts on biodiversity or potentially vulnerable species.

English Nature reviewed the potential effects of FMD on England's biodiversity (Robertson *et al.* 2001) and noted that the increased use of rodenticides around infected farm buildings to minimize the risk of spread of FMD by rats might potentially increase the risk of secondary poisoning of Barn Owls hunting around the buildings or using the buildings for roosting and breeding. Robertson *et al.* (2001) also noted that while decreases in livestock stocking rates in some areas might be beneficial in terms of helping to reverse the damaging effects of environmentally unsustainable livestock farming practices, in other parts of the country, losses of extensive grazing systems could be detrimental to some upland meadows and calcareous grasslands.

Both reviews noted the lack of factual information to permit objective assessment of the environmental impacts of the FMD outbreak. This project represents an attempt to use a pre-existing suite of monitoring schemes to assess the potential impacts of the FMD outbreak on a potentially vulnerable species of high conservation value. The Barn Owl is an iconic species within Britain of a healthy farmland landscape. Considerable monitoring effort is undertaken each year and the information gathered is both widespread and detailed.

Using data gathered as part of the BTO's Barn Owl Monitoring Programme and Nest Record Scheme we have been able to explore the potential impacts of various aspects of the operations associated with FMD at farms. In general the results suggested that any impacts were likely to have been marginal for the species. Thus although occupancy rates at the set of Core BOMP monitoring sites was lower near land with access restrictions after the FMD outbreak compared with sites further away (48% vs. 59%) a similar result was not found among the larger sample of BOMP Network Sites monitored by volunteers. Similarly occupancy was lower at sites near farms where slaughtering had occurred than those more distant (7% vs. 57%) but the sample size was very small for the former category among BOMP Core Sites and the result was not repeated for BOMP Network Sites.

Interestingly, both occupancy at BOMP Network sites and clutch size at all sites was greater post-outbreak near infected premises than at sites that were more distant (occupancy 81% vs. 57%; clutch size 5.5 eggs vs. 4.7 eggs). There were no differences in the pre-FMD years for clutch size. This result may suggest that FMD operations could have had some beneficial impact for Barn Owls around infected sites, although the precise reasons for this are unclear. It is possible that slaughter and/or disinfection took place more rapidly at the sites than at those where slaughtering took place at farms which were suspected to have FMD or which were in contact with an FMD-infected farm. If this was the case then the duration of any disturbance might have been minimised. In addition, clutch size was larger near sites where rodenticides were used, than at sites more distant (6.0 vs. 4.7 eggs). This perhaps suggests that rodent populations were higher at these farms, both requiring rodenticide applications and enhancing barn owl clutch size. However, it should be noted that for these analyses the sample sizes of some of the categories were relatively small and the results may be affected by other confounding factors.

Overall, on the basis of these analyses there is relatively little evidence to suggest that the FMD operations had major impacts on the Barn Owl populations using the affected farms. The results tend to be contradictory and only relatively weakly significant between different aspects of the types of FMD treatment, suggesting that other confounding factors might be affecting the results. Although we have not undertaken a power analysis, the sample sizes are generally sufficient to have had a reasonable chance of detecting a large impact on the monitored Barn Owl populations, so it would seem reasonable to conclude that the impacts, if any, have not been large.

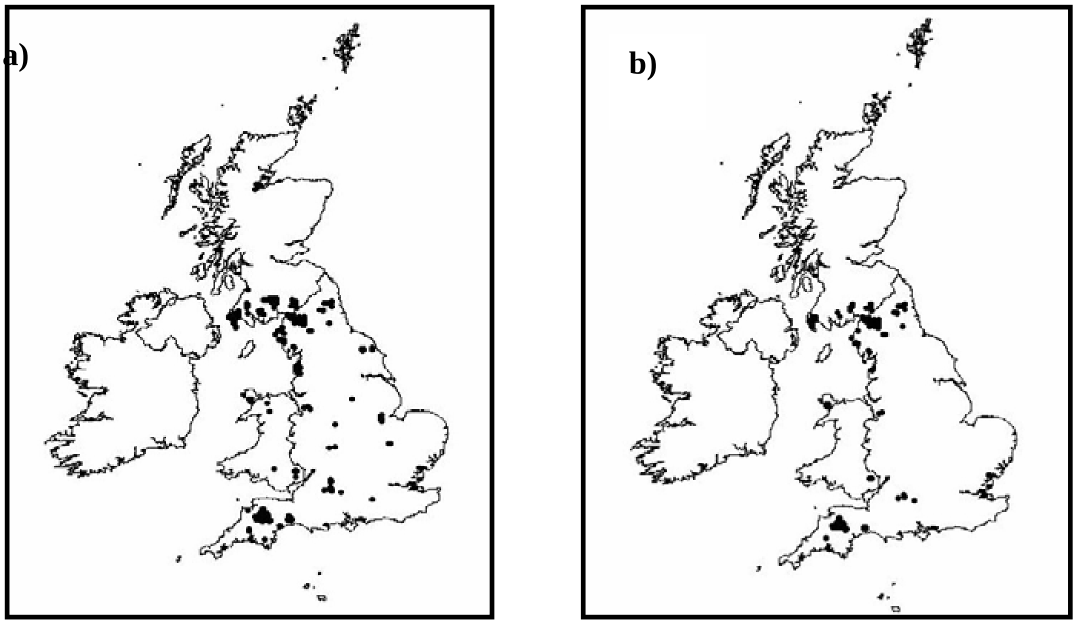

Figure 3. Distribution of sites within 5km of a) premises at which livestock were slaughtered and b) premises infected with FMD.

However, due to the uneven distribution of Barn Owl recorders, it is possible that some of the Barn Owl data may not be representative of national trends. Figure 3 above indicates that the distribution of Barn Owl sites that were within 5km of premises at which animals were slaughtered (a), and particularly those within 5km of a FMD-infected farm (b), were primarily clustered in two relatively small areas of north-west England/south-west Scotland and south-west England, although the same was not true of sites within 5km of restricted-access land. The results presented with respect to slaughter of livestock and FMD infection should therefore be interpreted with caution, as it is possible that they may be subject to localised geographical or even to observer biases.