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The BTO Barn Owl Monitoring Programme: 2000-2007

Authors

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1. EXECUTIVE SUMMARY

1.1 The 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 the 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.*

1.2 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 '*core*' sites, distributed throughout five regions of England. In 2002, a network of volunteer ornithologists began gathering additional information at '*BOMP Network*' sites over a wider geographical area.

1.3 This report reviews data collected over the first eight years of the survey period (2000-2007). Rates of occupancy are investigated, along with breeding statistics, in relation to year, geographical location, main habitat type and weather conditions.

1.4 In 2006, 197 sites were monitored by WCP and a further 453 were visited by BOMP Network volunteers, while in 2007, WCP monitored 190 sites and the BOMP Network monitored 475. WCP sites are located across the whole of England, although as a consequence of sampling methodology they tend to be concentrated in the southern, eastern and northern regions. BOMP Network sites are more broadly scattered across the UK, including several locations in Scotland and Wales.

1.5 The proportion of sites at which Barn Owls were recorded as present (whether breeding or not) has declined over the eight years of the study, as has the proportion of occupied sites at which owls bred. This may indicate a decline in Barn Owl populations over this period, but is more likely to be an artefact of biased selection towards occupied sites at the beginning of the BOMP Network establishment or of increasing nest site availability over time.

1.6 Weather conditions have previously been reported to affect 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. Analyses using national temperature (Central England Temperature) and rainfall (England & Wales Precipitation) datasets indicated that the proportion of sites at which owls were present was reduced following cold, wet winters and that the proportion of occupied sites at which the birds attempted to breed was also lower. These results suggest that a reduction in body condition during inclement winters results in the suspension of breeding during the following breeding season and possibly even to an increased mortality rate.

1.7 Weather conditions also had a significant effect on Barn Owl productivity, with females laying earlier and producing larger clutches and broods after warmer winters. The strong correlation between winter and spring temperatures makes it difficult to ascertain the relative contribution of weather conditions in these two periods, but when both factors are included in the statistical models, only variation in winter temperatures is consistently identified as significant. Such a relationship is as predicted if inclement weather increases thermoregulatory costs, reduces hunting efficiency or opportunity or reduces the abundance of prey species, thereby negatively influencing body condition. This may be supported by the finding that female weights at WCP sites were lower following colder winters. Adults in poorer condition may reduce their investment in reproduction during the following season. Alternatively, harsh winters may reduce the size of prey populations the following spring, reducing food availability during the breeding season.

1.8 Site occupancy rates were significantly higher and clutch and brood sizes were significantly larger at BOMP sites in areas of natural grassland, relative to sites in arable and pastoral areas. The same relationship between habitat and clutch and brood sizes was also apparent in the longer-running NRS dataset. These results are likely to reflect inter-habitat variation in the density of prey species, particularly Field Vole (*Microtus agrestris*).

1.9 Occupancy rates were also influenced by geographic location. Sites towards the west of the UK were significantly more likely to contain breeding Barn Owls. This may either be a response to lower densities of nest sites in these regions (Toms *et al.* 2000) limiting the size of the population, although climate and habitat quality may also vary with longitude, thus influencing population sizes.

1.10 The proportion of sites occupied by breeding pairs of Stock Dove and Jackdaw fell at WCP sites over the period 2000-2007. Breeding Bird Survey results suggest that this trend is not representative of actual changes in abundance and it is therefore possible that an increase in nest site availability is responsible for this observation.

1.11 Rates of nest site loss calculated over the period 2000-2008 were similar for trees, buildings and pole-boxes. Rates were approximately 50% of those recorded between the Hawk & Owl Trust Barn Owl survey (1982-85) and Project Barn Owl (1995-97). This may reflect a real decrease in site destruction due to increased awareness of the need to protect traditional breeding sites, but we cannot exclude the possibility that differences in the methodologies used in collecting the site loss data are responsible for the observed differences.

1.12 The increasing value of BOMP to conservationists is shown by the inclusion of its results in the annual and widely disseminated *The State of the UK's Birds 2004* (Eaton *et al*. 2005) 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).

2. 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 BTO surveys, such as the Breeding Bird Survey, as it is an elusive bird being 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 them 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. The value of BOMP is shown by the inclusion of its results in the annual publication *The State of the UK's Birds* (e.g. Eaton *et al*. 2004) and in the reports of the Rare Breeding Birds Panel (e.g. Ogilvie & RBBP 2003). This report presents an analysis of the first eight years of BOMP data (2000-2007).

2.1 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). Its pale plumage, partly diurnal or crepuscular hunting behaviour, and habit of nesting in buildings and more recently in nestboxes, make it more noticeable than some other owls and many local 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 in an area (as distinct from actual breeding place) is often 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 twelve years earlier. 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 these two surveys were specifically designed to be carried out over a 3-4 year period: the difficulty of assessing trends between annual surveys having been emphasised by the finding that, in southwest Scotland, numbers of Barn Owl pairs which breed can more than double across a single three- to four-year cycle of vole abundance (Taylor *et al.* 1988).

2.2 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 40+ 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 Conservation Network, 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 feeding habitat, increasing the availability of prey, providing habitat corridors to promote dispersal and provide connectivity of habitat, coupled with the provision of nest boxes on these habitat corridors and elsewhere in areas where a shortage of nest and roost sites was considered to be a limiting factor. 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 1987, 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. Annual monitoring of this species is particularly important given its 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 as well as other pesticides 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 or climatic change.

2.3 Potential impacts of weather conditions and climate change

The effects of weather, in particular climatic extremes, on Barn Owl survival and productivity have been reported previously (Shawyer 1987). The duration of winter snow cover, strong winds and heavy rain can impede hunting directly, by reducing visibility, auditory capabilities and manoeuvrability, and indirectly, by reducing the activity levels of rodent prey. Such inclement conditions, when persistent, can also lead to increased thermoregulatory costs and declines in prey abundance. The increased costs associated with such conditions may either result in lower rates of adult or chick survival or lead to a reduction in adult body condition causing a reduced investment in reproduction or, in some cases, the suspension of breeding. Conditions, particularly cold winter or spring weather can reduce vegetation growth that may, in turn, have implications for the abundance and/or the availability 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 analyses of both BOMP and Nest Record Scheme (NRS) data with respect to weather conditions are contained within this report.

2.4 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 and vulnerable 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 annual monitoring, piloted recording methods and gathered preliminary data at 159 sites.

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, although data were still collected by WCP at 170 sites. 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 568 sites were monitored in 2002, 203 by WCP and 365 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 600 sites were monitored in 2003, 205 by WCP and 395 by BOMP Network participants. Occupancy rates and productivity were analysed in relation to year, Northing, Easting, habitat type, temperature and rainfall. The report also included an analysis of the impact of the 2001 Foot and Mouth Disease outbreak on the UK Barn Owl population.

2004 breeding season: A total of 542 sites were monitored in 2004, 204 by WCP and 338 by BOMP Network participants. Occupancy rates and productivity were analysed in relation to year, Northing, Easting, habitat type, temperature and rainfall. The report also included an analysis of the influence of temperature and rainfall on NRS data collected between 1980 and 2002.

2005 breeding season: A total of 570 sites were monitored in 2005, 202 by WCP and 368 by BOMP Network participants. Occupancy rates and productivity were analysed in relation to year, Northing, Easting, habitat type, temperature and rainfall. The report also included an analysis of the influence of temperature and rainfall on NRS data collected between 1980 and 2005. The analysis of occupancy rates of other species nesting in BOMP sites was also refined to include more information about the type of nest site and weather variables.

2006 breeding season: A total of 650 sites were monitored in 2006, 197 by WCP and 453 by BOMP Network participants. Analyses were as 2005.

2005 breeding season: A total of 665 sites were monitored in 2007, 190 by WCP and 475 by BOMP Network participants. The report also includes an analysis of rates of nest site loss over the period 2000-2007 and compares these figures to those recorded using a questionnaire sent out as part of Project Barn Owl (1995-1997).

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. BTO staff liaise with the Barn Owl Conservation Network (*www.bocn.org*), producing articles for the BOCN Newsletter and speaking at BOCN symposia. The Barn Owl Bulletin, the annual newsletter produced by the BTO for BOMP participants, also includes features about other relevant organisations, including BOCN and The Barn Owl Trust.

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), 2002 (Leech *et al*. 2003), 2003 (Leech *et al*. 2005a), 2004 (Leech *et al.* 2005b) and 2005 (Leech *et al*. 2006) are also available.

3. METHODS

3.1 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, Shawyer *et al*. 1987, 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. Many 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.

It should be noted that nest site occupancy provides 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. However, given the species' high degree of nest site faithfulness (Taylor 1991), except in occasional years when prey is especially scarce (Shawyer 2006), it is reasonable to assume that significant changes in site occupancy provide useful information about the species' status and population trends.

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, BOMP 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 Barn Owl 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 25 years of WCP field experience. The guidelines appeared as an Appendix in a previous annual report (Leech *et al.* 2005b).

3.2 Study sites

Each BOMP study site is an actual or potential nest site for a single pair of Barn Owls. Where two or more 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. Barn Owl nest boxes are often positioned in pairs, and in some instances paired boxes are occupied simultaneously by the same pair of owls, either roosting apart or with one containing old young from the first brood and the other eggs from a second brood.

As there is a relatively high turnover of 'natural' sites, due for example to the felling of hollow trees for reasons of human safety, to barn conversions, to the shifting location of bale-stacks and waterlogging of natural sites, and because accurate recording of eggs and young is often difficult at natural sites where nests are located within deep cavities, observers are encouraged to target nest-box sites. As a result of this and the fact that natural sites are becoming increasingly uncommon in the UK, almost all of the sites that have been registered for BOMP are nestboxes. The widespread distribution of nestboxes 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 Shawyer (2008) now estimates that about 75% of Barn Owls in the UK now breed in nestboxes. Their occupation indicates the benefit that conservation measures targeted at restoring foraging habitat, coupled with the provision of artificial nest sites, have had for the species. Many individuals who install nestboxes generally inspect them too. BOMP provides a framework for collating such observations, ensuring that the data are recorded to a recognised standard thereby 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 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 ('pole-box' or 'A-frame' in trees, Dewar & Shawyer 1996), 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 the characteristics of pole-boxes but mounted on trees. WCP also monitors a further 75 supplementary ('extra') sites that have been ~~are~~ included in the programme since 2002.

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 overall 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), maintaining sufficient space for successful nesting and potentially reducing parasite loads in the box. However, to counter these positive effects, nest boxes may be more obvious to competing species or predators.

3.3 Fieldwork methods

Monitoring at BOMP Network sites 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 (Leech *et al.* 2005b, Appendix 1).

At the first level, key information can be gathered with minimal disturbance to Barn Owls. Option 1 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 3.3.1).

Requirements for Option 1:

- *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, demanding greater experience and commitment, 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.

Requirements for Option 2:

- *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, sometimes 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 usually 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 3.3.1).

- *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 from 12 days to fledging can be estimated by taking the length of the unfurled section of the 7^{th} primary feather, and prior to this, by the total length of pin, and by consulting one of two separate (pin and feather) growth curves (Shawyer 1998). A further growth curve for the 11 days following hatching has also recently been developed using the length of the relaxed wing chord (Shawyer *in prep.*).
- *Sexing of young*: The degree of speckling on the underside of the body and wings can be used to estimate a nestling's sex after the fourth week of age (Shawyer 1998). Chick weight may provide a useful measure of condition and sex; the value of this technique is also being assessed.
- *Measurement of dead chicks (length of 7^{th} primary)*: primary feathers are generally very resilient and therefore can be useful in estimating 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, weight, 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 3.3.1 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.
- Variation in the presence of moulted wing feathers from the female at the first breeding attempt, usually between late April and early June, is being investigated to assess whether it can be used as positive indicator that a second brood will not be attempted.
- The length of moulted primary and secondary wing feathers found at the nest during the early stages of breeding provide a means of aging the adults up to their fifth calendar year. A calibration curve has been produced that enables individual feathers to be identified, inferring moult pattern and therefore permitting age to be determined (Shawyer *in prep*.)

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.

3.4 Data collation

WCP data are recorded on standard paper forms developed during the first year of BOMP (Leech *et al.* 2005b, Appendix 2). During the 2002 and 2003 breeding seasons, BOMP Network data were recorded on an equivalent form on which all the information for Option 1 and Option 2 could be entered (Leech *et al.* 2005b, Appendix 3). Prior to the 2004 breeding season, a number of changes were made to the BOMP Network recording system (for new form design see Leech *et al.* 2005b, Appendix 4):

3.4.1 Incorporation of BOMP sites into the NRS

Whilst the nature of the data collected by BOMP participants and volunteers recording Barn Owls for the NRS is almost identical, the information was being submitted in two slightly different formats and loaded into two distinct databases. Furthermore, some recorders were submitting the same data to both schemes, making any attempt to combine the datasets time consuming and increasing the potential for replication of data.

To ensure that BOMP and NRS productivity data for Barn Owl could be pooled easily each year, it was decided that BOMP data relating to nest contents should be submitted on Nest Record Cards or electronically via Integrated Population Monitoring Reporter (IPMR) and loaded into the NRS Oracle database each year along with any standard nest records submitted (see Leech *et al.* 2005b, Appendix 5 for example of a Nest Record Card and a NRS Coding Card). Each BOMP participant was therefore registered as a nest recorder and supplied with a NRS Starter Pack (see www.bto.org/survey/nest_records/index.htm for more details). The BOMP Site Code was recorded on each record together with a letter indicating the number of the brood (A = first brood, B = second brood, etc.). This allows the records to be linked with information on the BOMP forms that are not submitted on standard nest records, e.g. details of prey items, specific habitat features and other species present.

A further advantage of this technique is that it allows BOMP records to be checked easily for inconsistencies using the standard programs used to check nest record data. Laying dates, clutch sizes, brood sizes and failure rates can also be calculated using standard NRS programs (Crick *et al.* 2003).

3.4.2 Changes to the BOMP Network recording form

While the habitat recording, habitat features, site details, prey items, pellet and feather moult sections remained unchanged on the redesigned BOMP Network forms, a number of changes were made to the other sections:

- Removal of habitat maps. The habitat map on the front of the form significantly increased the production time when sites were registered initially and was becoming the limiting factor controlling the number of new sites that could be registered each season. Extracting information from the map is also a very time-consuming and expensive procedure. As much of the information (habitat, adjacent sites) that could be culled from these maps was already recorded elsewhere on the form, the decision was made not to add them to forms for newly registered sites in future.
- Site use tick box. The original form design did not allow participants to record the occupancy status of the site specifically and relied on handwritten notes that could be both difficult to interpret and time consuming to input. A tick box was therefore added to the form which enables observers to differentiate between sites at which Barn Owls were roosting and those in which they were breeding, sites that were not used, sites that were usable but not occupied, sites that were unusable because of damage to boxes or to the presence of other species and sites that were not visited.

- Number of nesting attempts. A tick box was added to allow observers to record explicitly (if known) the number of breeding attempts that had occurred at each site.
- Proximity of other potential nest sites. Space was provided in which to record the number of alternative nesting sites within 500m (thereby summarising information that was previously given on the site map) and to record the number of these that were checked for Barn Owl occupancy. This change was intended to allow differentiation between sites at which Barn Owls had truly vacated and those at which they had simply moved to a nearby site to breed but had continued to occupy the territory. Analysis of these data led to some sites previously registered separately being treated as 'paired' sites in future analyses.
- Other species present. Tick boxes were provided to allow observers to record explicitly the presence of other species at the nest site and to differentiate between breeding and roosting birds. Previously, any information about additional species was obtained from handwritten notes in the section of the form designed to record Barn Owl nest contents, which could be very difficult to interpret.
- Nest contents. The section of the form relating to nest contents was removed as all the information is now submitted through IPMR or via Nest Record Cards. The submission method used is also recorded on the form.

As in previous years, the data were input into two separate MS Access databases, one containing WCP data and the other containing BOMP Network data.

3.5 Calculating breeding parameters

3.5.1 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'. Sites that were not visited and those at which Barn Owls were prevented from nesting, e.g. by the presence of other species, were excluded from all analyses.

Barn Owls may start to lay a repeat clutch before 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 is the potential for simultaneous breeding.

During the 2004 season, for the first time, BOMP Network participants were able to record the identity of registered sites that were located within 500m of each other. If these sites have not been occupied simultaneously by breeding Barn Owls at any point over the study period then they are treated as paired sites for the purpose of all analyses.

3.5.2 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. This methodology was used to determine laying dates for both BOMP and NRS data.

Unfortunately, visits to sites during the laying and incubation periods are relatively infrequent and the range of possible FEDs for the majority of nesting attempts is greater than the 10-day cut-off point, resulting in greatly reduced sample sizes for the analyses. However, additional measurements of chicks at WCP sites permit egg-laying dates to be estimated to +- 1 day using standard growth curves relating the length of the wing or the seventh primary to the age of the chick (Crick *et al*. 2001). The hatching date of the oldest chick was therefore back calculated and the FED was estimated by assuming a mean incubation period of 32 days.

3.5.3 Clutch and brood size

The key factor to ascertain in determining clutch size is whether egg laying has finished or not. Thus records were omitted from these analyses if nests were only visited once, if they were 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. This methodology was used to calculate clutch and brood sizes for both the BOMP and the NRS datasets.

3.5.4 Nesting success

The simplest measure of nesting success is to calculate the proportion of monitored nests that 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). This methodology was used to calculate failure rates for both BOMP and NRS data.

3.5.5 Data for repeat broods

As productivity may vary between first and second broods, any breeding attempts identified as repeats by observers were removed from the BOMP dataset prior to analysis of laying date, clutch size, brood size or failure rate. As NRS participants do not necessarily distinguish between first broods and repeat attempts, all nests at which the estimated FED occurred after 4th July were removed from the dataset prior to analysis. This cut-off date was selected because Joys & Crick (2004) identified it as the upper 95% quartile in their analysis of first egg dates in the NRS dataset.

3.6 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 3.6.1. Records from the NRS dataset were also assigned to the habitat categories listed in Table 3.6.1 on the basis of the primary habitat code noted by the recorder.

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

Table 3.6.1 Broad habitat categories used in the analyses of BOMP data.

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 3.6.1.

For the purposes of the current analysis, sites recorded as Mixed Farmland (E3) were included in the 'Arable' category rather than being assigned to a separate 'Mixed' category, as had previously been the case (Leech *et al.* 2005b). As BOMP Network sites are classified on the basis of the dominant habitat type, they cannot easily be classed as 'Mixed' - this change was therefore made to enable WCP and BOMP Network data to be analysed together in the same models.

3.7 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 (BOMP data) and for the years 1980-2002 (NRS data).

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.

3.8 Nest site loss

One of the factors postulated to be responsible for the decline in Barn Owl populations during the 20th Century was the loss of nest sites due to the removal of mature trees and demolition or conversion of old agricultural buildings (Shawyer 1987). BOMP participants are asked to record whether unoccupied sites are potentially usable by Barn Owls in the current or future seasons, and these data enable us to investigate rates of site loss in an unbiased manner. A site was considered destroyed if there was no possibility of use by Barn Owls in the future, with the exception of a) sites at which the monitored nest box had fallen down but where the original natural structure to which they were attached remained and b) sites that had been occupied by other species. Figures for the period 1982/85–1995/97 relate to unpublished data collected during Project Barn Owl (Toms 1997, Toms *et al.* 2000, 2001) using a questionnaire sent to surveyors who had taken part in the HOT Barn Owl Survey (Shawyer 1987). Questionnaire coverage extended to 72% of the sites surveyed under the HOT survey, and the response rate was approximately 25%, although this varied across the UK (Toms *et al*. 2000).

3.9 Statistical models

3.9.1 Barn Owl occupancy

Factors influencing both the proportion of sites at which Barn Owls were present, whether breeding or non-breeding, and the proportion of occupied sites at which Barn Owls were actually breeding were investigated in the current analysis. As the dataset 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. Barn Owls are a relatively long-lived species (mean life-expectancy = 3 years, maximum = 13 years, Robinson 2005), and using a repeated-measures approach therefore allows us to control for the fact that the same pair might be breeding at a specific site in successive years. In all models of occupancy rates, a binomial error distribution was assumed and a logit link function was specified.

WCP and BOMP Network data were analysed together, with the categorical variable ‘Site type’ (either ‘WCP’ or ‘BOMP Network’) included as an independent variable. Northing, Easting, year, primary habitat type, winter temperature and winter precipitation were also included as independent variables in all models.

3.9.2 Barn Owl productivity – BOMP dataset

Models used to investigate factors influencing the various measures of productivity were identical to those described in Section 3.9.1 above, except:

- For all analyses of laying date information, a normal distribution was assumed and an identity link function was specified, and for all analyses of clutch and brood size data, a Poisson error distribution was assumed and a log link function was specified.
- Temperature and rainfall terms were included as separate independent variables in the same model as there was no significant correlation between the two parameters either during winter (R^2<0.01, P=0.904) or during the breeding season (R^2<0.01, P=0.977). Temperatures during the breeding season were strongly and significantly correlated with those during the winter (R^2=0.63, P=0.019), although the same was not true of the rainfall parameters

(R^2=0.14, P=0.353). All initial models therefore contained winter weather parameters only, although the effects of including spring weather parameters were investigated in some cases, with appropriate caveats concerning interpretation included in the text.

3.9.3 Barn Owl productivity – NRS dataset

Whilst the NRS dataset does undoubtedly contain data for the same sites in different years, such replication is more difficult to detect than it is in the BOMP dataset, as sites are not identified by unique codes. While observers usually provide grid references, this is not always the case and the reference given may vary slightly between years, making the automated identification of repeated sites impossible. In addition, due to the much longer span of NRS data, it is much more likely that there may be some turnover of pairs at individual sites. NRS data were therefore analysed using standard GENMOD procedures and not by using repeated-measures GENMOD.

As with the BOMP dataset, temperature and precipitation showed no significant correlation over the period 1980-2005, either during winter (R^2<0.01, P=0.775) or during the breeding season (R^2=0.04, P=0.094), and both weather variables could therefore be included as independent variables in the same model. Temperatures during the breeding season were significantly correlated with those during the winter (R^2=0.26, P<0.001), and the same was true of winter and spring precipitation parameters, although the relationship was weak (R^2=0.067, P=0.023). All initial models therefore contained winter weather parameters only, although the effects of including spring weather parameters were investigated in some cases, with appropriate caveats concerning interpretation included in the text.

3.9.4 Female biometrics

Factors influencing the weight of female Barn Owls were investigated using repeated measures GENMOD models similar to those described in Section 3.8.1, with a normal distribution assumed and an identity link function specified, and Northing, Easting, year and primary habitat type included as independent variables in all models. As female weight may vary at different stages of the reproductive cycle, an additional categorical term specifying the stage of the cycle was also included in the models. This term had four different categories, representing ‘Roosting’, ‘Clutch’, ‘Mixed’ (eggs and chicks) and ‘Brood’. Again, the influence of winter temperatures and winter precipitation had to be investigated separately due to the high degree of correlation between the two variables.

3.9.5 Other species occupancy

Factors influencing the proportion of BOMP sites at which other species were recorded as breeding were also investigated using species-specific models similar to those used for Barn Owl occupancy. Prior to 2004, the recording of other species at BOMP Network sites was not standardised and may not have been consistent between observers. Analysis was therefore restricted to WCP sites.

As with analysis of Barn Owl occupancy rates, year, Northings, Eastings and primary habitat type were included as independent variables in all models. Winter temperature and precipitation were also included, again separately due to the significant correlation between the two variables (see Section 3.8.1). The models contained two additional variables:

- Box type – the number of potential breeding cavities, and therefore the probability of occupancy, varies between the three Barn Owl nestbox designs (Polebox, A-frame and Square).
- Paired box – again, the presence of a paired nestbox provides additional cavities in which other species could potentially nest.

3.9.6 Nest site loss

The analysis was carried out using techniques mirroring the Mayfield method for estimating nest success (Mayfield 1961, 1975). The total number of sites recorded as having been destroyed was divided by the sum of the total number of years over which observations were made across all sites, giving an estimate of the annual rate of disappearance of sites. Significant differences in rate of loss between the three main site types (trees, buildings and pole-boxes) were tested for using the GENMOD procedure with a logit link and binomial errors.

4. RESULTS

4.1 BOMP coverage

The 2007 season was the eighth year of data collection at WCP sites and the sixth year of data collection at BOMP Network sites. The number of both core and supplementary sites monitored by WCP has remained approximately constant since the 2002 breeding season, while the number of sites covered by BOMP Network participants is more variable (**Table 4.1.1**).

	2000	2001	2002	2003	2004	2005	2006	2007
WCP	159	170	203	205	204	202	197	190
BOMP Network	-	-	365	395	338	368	453	475
TOTAL	159	170	568	600	542	570	650	665

Table 4.1.1 Total number of BOMP sites surveyed annually 2000-2005

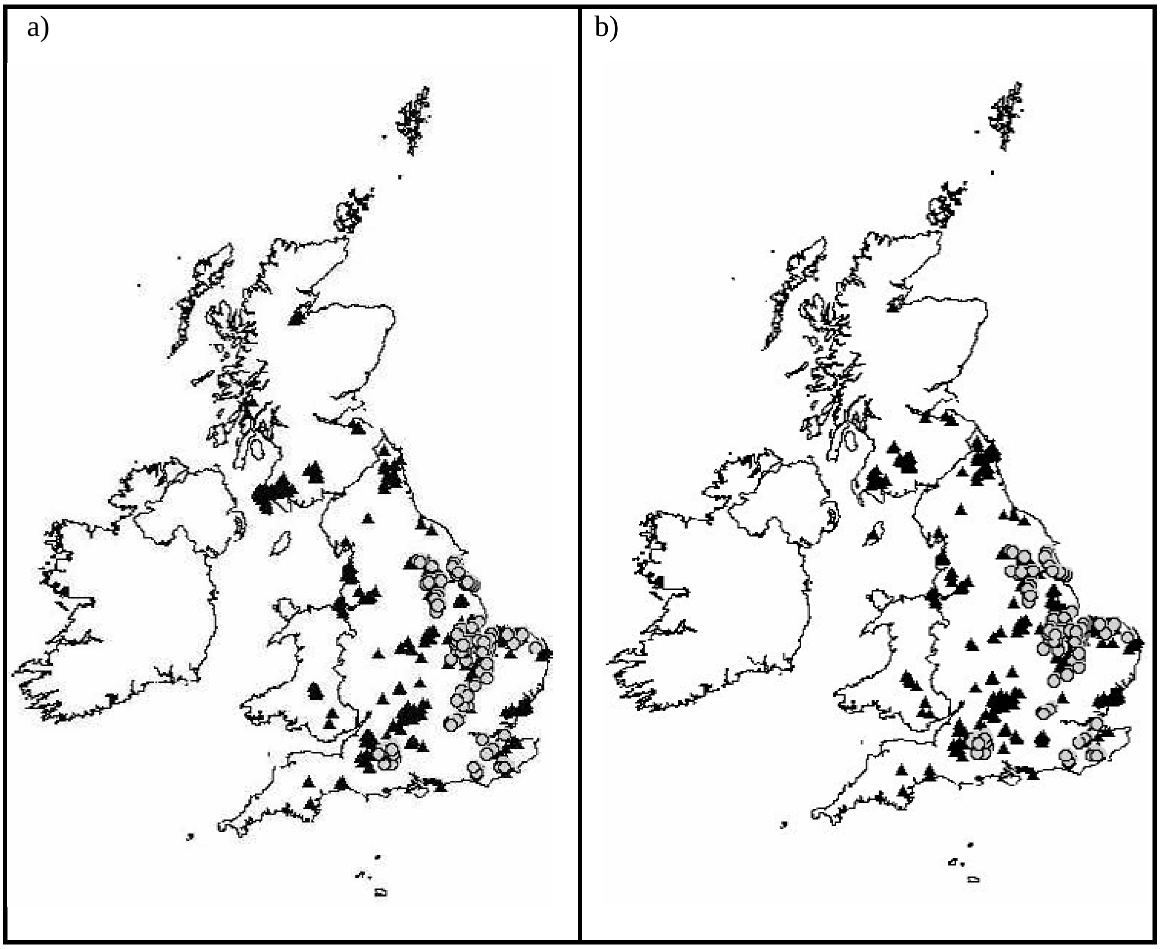


Figure 4.1.1 Distribution of WCP (grey circle) and BOMP Network (black triangle) sites monitored in a) 2006 and b) 2007.

It is encouraging to note that the number of sites monitored in 2007 was the highest in any year of the survey, thanks to both the recruitment of new volunteers and to existing volunteers expanding their coverage. **Figure 4.1.1** shows the distribution of all BOMP sites monitored in 2007. As in previous years, coverage was generally good in the South, East and North of England. Although coverage is still poorer in western England and the majority of Scotland, many of the sites new to the project in 2007 were located in these areas, reflecting the targeted promotional effort. Coverage in Wales remained poor even though Barn Owls breed throughout much of the country (Gibbons *et al*., 1993).

4.2 Barn Owl occupancy rates

Factors influencing Barn Owl occupancy rates were investigated using a pooled dataset containing information from both WCP and BOMP Network sites. In total, over the eight study years, Barn Owls were present in 2855 of the 3924 sites visited (72.8%) and were found to be breeding in 2279 (58.1%).

a)

	DF	**X^2**	**P**	**Direction**
Site occupancy (N =3630)				
Year	1	54.27	<0.001	-
Northing	1	1.39	0.238	
Easting	1	8.57	0.003	-
Primary habitat	2	12.06	0.002	G > A > P
Site type	1	6.17	0.013	W > N
Number of boxes at site	1	<0.01	0.961	
Over-winter temperature	1	28.73	<0.001	+
Over-winter precipitation	1	10.59	0.001	-
Proportion breeding (N =2674)				
Year	1	4.96	0.026	-
Northing	1	0.13	0.723	
Easting	1	0.33	0.566	
Primary habitat	2	0.04	0.980	
Site type	1	18.96	<0.001	N > W
Number of boxes at site	1	0.30	0.584	
Over-winter temperature	1	63.44	<0.001	+
Over-winter precipitation	1	6.63	0.010	-

Table 4.2.1 Factors influencing site occupancy and the proportion of pairs breeding a) over the period 2000-2007 and b) over the period 2002-2007. In the ‘Site Type’ row, ‘W’ indicates WCP sites and ‘N’ indicates BOMP Network sites. In the ‘Primary Habitat’ row, ‘G’ indicates rough grassland, ‘A’ indicates arable land and ‘P’ indicates pastoral land.

b)

	DF	X^2	P	Direction
Site occupancy (N =3316)				
Year	1	21.50	<0.001	-
Northing	1	1.07	0.301	
Easting	1	6.60	0.010	-
Primary habitat	2	10.58	0.005	G > A > P
Site type	1	2.69	0.101	
Number of boxes at site	1	0.07	0.791	
Over-winter temperature	1	37.53	<0.001	+
Over-winter precipitation	1	24.83	<0.001	-
Proportion breeding (N =2389)				
Year	1	0.05	0.828	
Northing	1	0.62	0.432	
Easting	1	1.57	0.210	
Primary habitat	2	0.36	0.836	
Site type	1	25.27	<0.001	N > W
Number of boxes at site	1	<0.01	0.944	
Over-winter temperature	1	58.22	<0.001	+
Over-winter precipitation	1	9.98	0.002	-

Table 4.2.1 (continued)

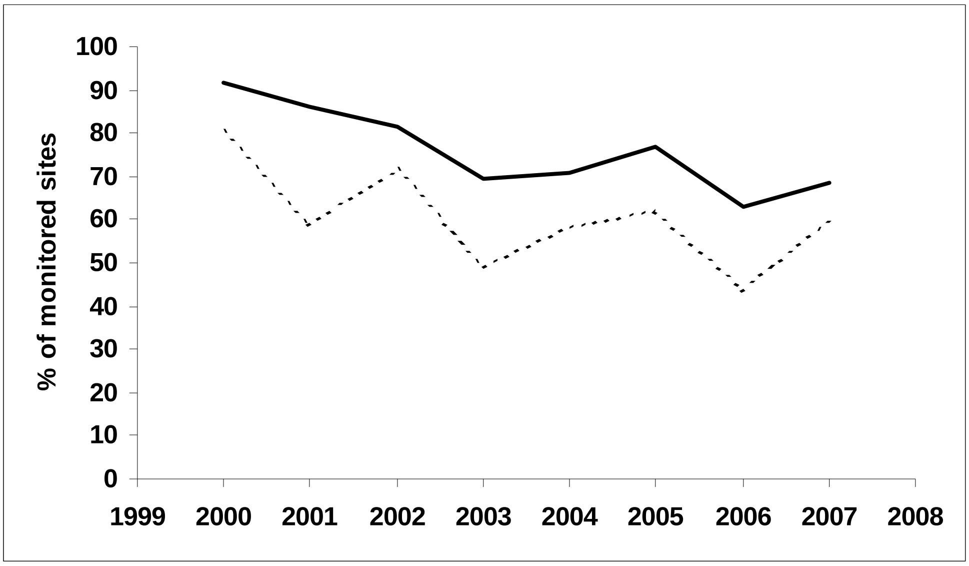
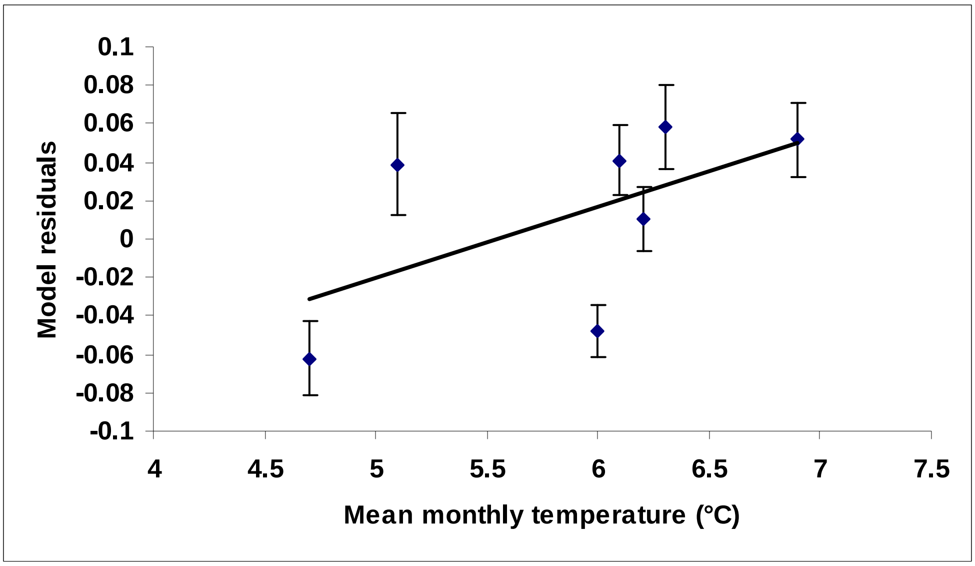


Figure 4.2.1 Annual variation in the proportion of BOMP sites at which Barn Owls were recorded as present (solid line) and the proportion of sites at which owls were recorded as breeding (dashed line).

The results presented in **Table 4.2.1** indicate that the occupancy rate of boxes has declined significantly over the eight study years (**Figure 4.2.1**) and that this relationship holds even if the first two years of data, when information was collected at WCP sites only, are omitted from the analysis.

A weaker negative trend in the proportion of Barn Owls observed that went on to breed is also detectable when the full dataset is analysed, but disappears when the first two years are dropped (**Table 4.2.1b**). Occupancy rates at WCP sites were higher than those at BOMP Network sites overall, although this difference as only weakly significant, but the proportion of recorded pairs that elected to breed was significantly higher at the latter. The number of additional boxes at each BOMP site had no effect on the likelihood of occupancy or of breeding initiation.

a)



b)

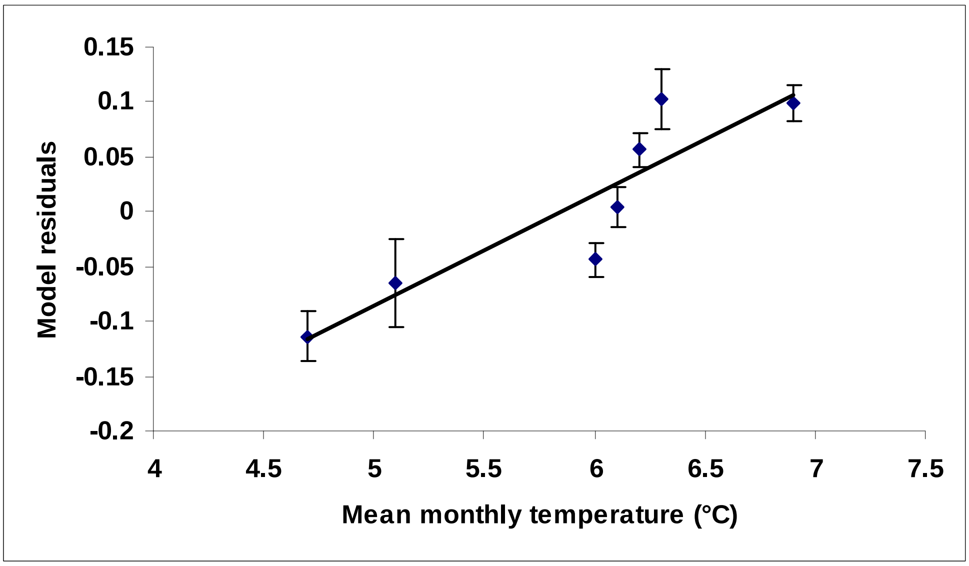


Figure 4.2.2 Relationship between mean winter (Nov-Mar) temperatures and the proportion of sites occupied by Barn Owls and b) the proportion of Barn Owls occupying BOMP sites that attempted to breed. The residuals were generated using here GENMOD procedure, with all terms included in the model except temperature. Error bars signify ± 1 S.E.

Site occupancy varied geographically, with birds present at a higher proportion of sites towards the west of the UK, but the proportion of birds breeding was influenced neither by longitude nor by latitude. Habitat type significantly influenced the probability of Barn Owls being present at a site, with occupancy rates highest in rough grassland, intermediate on arable land and lowest in pastoral areas, but no significant relationship between habitat and the proportion of pairs breeding was identified. Temperature over the winter period (Nov-Mar) significantly influenced occupancy rates, with Barn Owls present at a higher proportion of boxes and a higher proportion of those individual present electing to breed following warmer winters (**Figure 4.2.2**). Precipitation over the winter period had a significant negative effect on occupancy, with the proportion of occupied sites decreasing and the proportion of observed pairs electing to breed reduced following wetter winters (**Figure 4.2.3**).

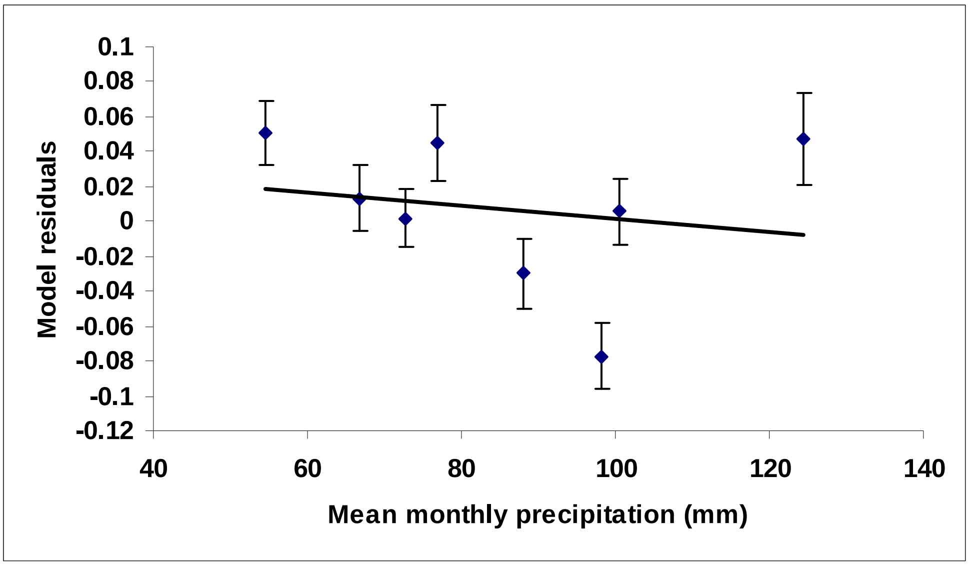


Figure 4.2.3 Relationship between mean winter (Nov-Mar) precipitation and a) the proportion of sites occupied by Barn Owls. The residuals were generated using here GENMOD procedure, with all terms included in the model except precipitation. Error bars signify ± 1 S.E.

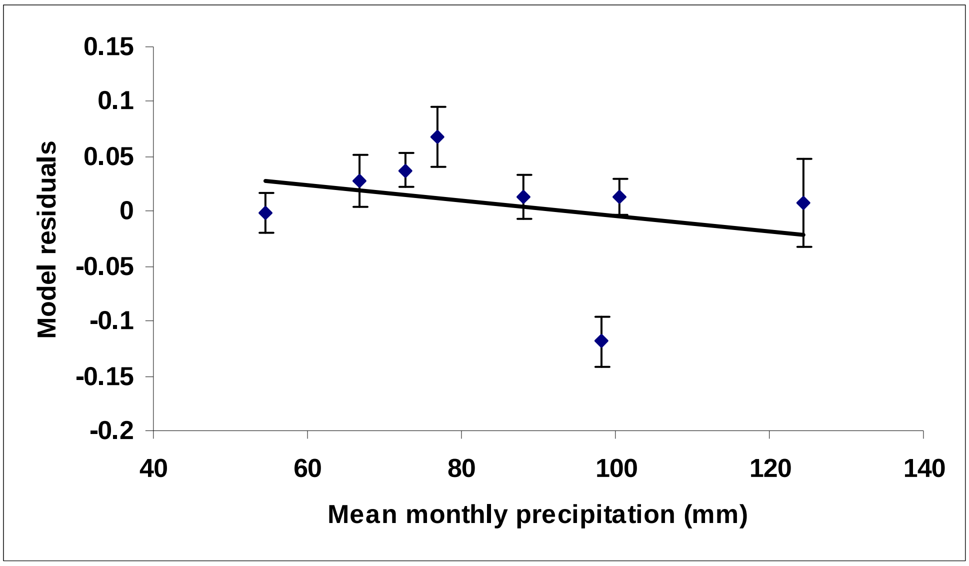


Figure 4.2.4 Relationship between mean winter (Nov-Mar) precipitation and the proportion of Barn Owls occupying BOMP sites that attempted to breed. The residuals were generated using here GENMOD procedure, with all terms included in the model except precipitation. Error bars signify ± 1 S.E.

4.3 Female weight at laying

Over the period 2001-2007, 565 females were weighed at 153 different nest sites. The results in **Table 4.3.1** show that mean weights increased with latitude and declined through the nesting cycle (with mean weights of non-breeders lower than those for breeders at any stage of egg or chick development). Weather conditions also had a significant influence of female weight, with females significantly lighter after colder, wetter winters (**Figure 4.3.1**).

	DF	X^2	P	Direction
Year	1	2.70	0.101	
Northing	1	7.31	0.007	+
Easting	1	3.68	0.055	
Primary habitat	2	3.37	0.186	
Nest stage	1	55.52	<0.001	E > M > C > R
Over-winter temperature	1	11.06	<0.001	+
Over-winter precipitation	1	4.12	0.042	-

Table 4.3.1 Factors influencing mass of females caught at the nest. In the 'Nest stage' row, 'E' signifies eggs, 'M' signifies a mixture of eggs and chicks, 'C' signifies chicks and 'R' signifies a bird that was roosting with no contents in the nest.

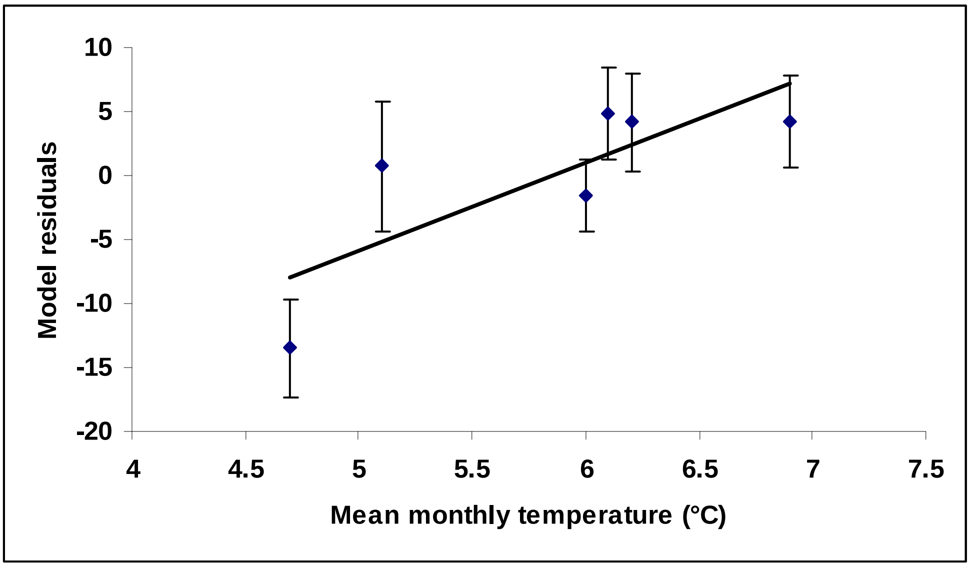


Figure 4.3.1 Relationship between mean winter (Nov-Mar) temperature and female body mass. The residuals were generated using here GENMOD procedure, with all terms listed in Table 4.3.1 included in the model except precipitation. Error bars signify ± 1 S.E.

4.4 Barn Owl productivity

Laying date of the first egg in the clutch, clutch size and brood size were all analysed with respect to year, region, longitude, latitude, habitat type and weather conditions during the preceding winter (Table 4.4.1). Mayfield failure rates could not be modelled as complete clutch and brood failures were too infrequent.

Mean laying dates demonstrated a significant negative relationship with study year, the average date of clutch initiation advancing by approximately half a day per year (parameter estimate = -0.439). This relationship persisted even when a term representing mean spring temperature was included in the model (X^2 = 4.01, P = 0.044). Weather conditions during winter also appeared to influence the timing of laying, with laying delayed following colder, wetter winters (**Figure 4.4.1 a & b**). As winter and spring temperatures were significantly positively correlated (R^2 = 0.626, P = 0.019) it is difficult to determine which period is most important in determining timing of laying, but it is interesting to note that when terms for spring temperature and rainfall are included in the model, neither is significantly correlated with laying date while both winter weather variables remain so.

	DF	X^2	P	Direction
First egg date (N = 547)				
Year	1	6.42	0.011	-
Northing	1	0.17	0.677	
Easting	1	3.00	0.083	
Primary habitat	2	0.44	0.803	
Over-winter temperature	1	39.48	<0.001	-
Over-winter precipitation	1	22.54	<0.001	+
Clutch size (N = 185)				
Year	1	0.06	0.805	
Northing	1	1.03	0.311	
Easting	1	<0.01	0.987	
Primary habitat	2	6.70	0.035	G > A > P
Site type	1	1.28	0.259	
Over-winter temperature	1	9.08	0.003	+
Over-winter precipitation	1	2.96	0.085	
Brood size (N = 1202)				
Year	1	2.01	0.156	
Northing	1	0.02	0.885	
Easting	1	0.94	0.333	
Primary habitat	2	7.50	0.024	G > P > A
Site type	1	0.53	0.468	
Over-winter temperature	1	19.08	<0.001	+
Over-winter precipitation	1	1.88	0.170	

Table 4.4.1 Factors influencing productivity of Barn Owls breeding at BOMP sites 2000-2007.Directions of significant linear relationships are given in the right-hand column. In the 'Primary habitat' row, P = Pastoral, A = Arable and G = Grassland (natural).

Winter weather conditions also had a significant influence on productivity, with both clutch and brood sizes observed to be larger following warmer winters (**Figure 4.4.1 c & d**). Again, models were re-run including additional terms for spring rainfall and temperatures, but in no case was the significance of the winter temperature term affected, nor did spring temperatures display any significant positive correlation with productivity.

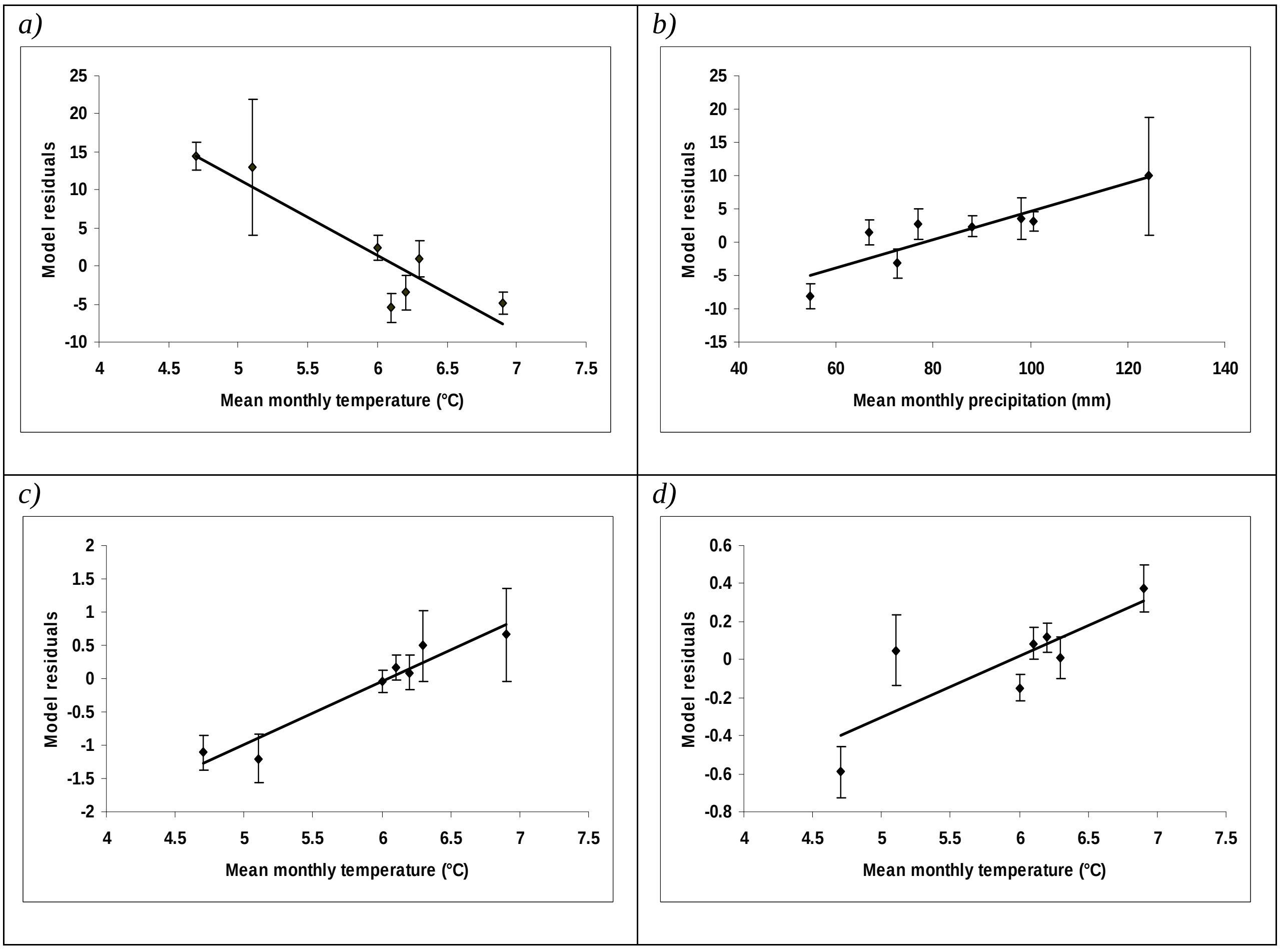


Figure 4.4.1 Relationship between a) laying date and winter temperature, b) laying date and winter rainfall, c) clutch size and winter temperature and d) brood size and winter temperature. The residuals were generated using here GENMOD procedure, with all terms listed in Table 4.4.1 included in the model except that plotted along the X axis. Error bars signify ± 1 S.E.

Results from the analysis of a longer-term Barn Owl productivity dataset collected by Nest Record Scheme participants between 1980 and 2007 were consistent with those from the BOMP analysis, identifying a significant relationship between winter temperatures and both clutch and brood sizes (**Table 4.4.2**). Habitat type and latitude were also found to influence productivity, with Barn Owls nesting in areas of rough grassland producing on average larger clutches and broods than those on agricultural land, and pairs in the North raising smaller broods. No latitudinal, habitat- or weather-related variation in productivity is identifiable if the data run is restricted to the pre-BOMP period (1980-1999), suggesting that these results are driven primarily by the relationships observed during the BOMP period, when sample sizes are on average 4-7 times greater per annum.

	DF	X^2	P	Direction
First egg date (N = 231)				
Year	1	0.19	0.662	
Northing	1	0.22	0.640	
Easting	1	0.82	0.364	
Primary habitat	2	2.29	0.319	
Over-winter temperature	1	3.78	0.052	
Over-winter precipitation	1	0.02	0.895	
Clutch size (N = 548)				
Year	1	0.44	0.506	
Northing	1	2.08	0.149	
Easting	1	0.30	0.586	
Primary habitat	2	0.60	0.740	
Over-winter temperature	1	5.39	0.202	+
Over-winter precipitation	1	0.63	0.427	
Brood size (N = 3807)				
Year	1	0.01	0.934	
Northing	1	7.19	0.007	-
Easting	1	2.24	0.135	
Primary habitat	2	8.18	0.017	G > A > P
Over-winter temperature	1	31.08	<0.001	+
Over-winter precipitation	1	0.22	0.643	

Table 4.4.2 Factors influencing productivity of Barn Owls as recorded by Nest Record Scheme (NRS) participants 1980-2007. Directions of significant linear relationships are given in the right-hand column.

4.5 Occupancy rates of other species

Data from BOMP sites can also be used to investigate variation in the occupancy rates of three additional species that frequently utilise Barn Owl nest sites – Stock Dove (*Columba oenas*), Jackdaw (*Corvus monedula*) and Kestrel (*Falco tinnunculus*). However, the results must be interpreted with care as there is some evidence to suggest that the effort invested in recording species other than Barn Owl varies between recorders. In addition, the probability of other species occupying the box may depend on whether the design provides additional cavities. For these reasons, a conservative analysis of occupancy rates for species other than Barn Owl was performed, using data from a subset of Core sites at which either Pole-box or A-frame boxes are present over the period 2002-07 (**Table 4.5.1**).

	2002	2003	2004	2005	2006	2007
Stock Dove	22.8%	28.2%	18.7%	17.5%	20.5%	15.6%
Jackdaw	29.0%	32.5%	25.9%	25.3%	28.3%	20.0%
Kestrel	20.4%	15.3%	17.5%	17.5%	16.3%	16.3%
TOTAL BOXES	162	163	166	166	166	160

Table 4.5.1 Frequency of use of Core sites containing either Pole-box or A-frame boxes by species other than Barn Owl.

Analyses showed that occupancy rates of both Stock Dove and Jackdaw, but not those of Kestrel, have declined significantly since 2002 (**Table 4.5.2**). Latitude significantly influenced the occupancy rates of both Kestrel and Jackdaw, with northern sites housing relatively more of the latter and relatively fewer of the former, as did box design, with both species more prevalent in pole-boxes. Jackdaw was recorded more frequently at sites with higher numbers of boxes, and was more likely to be detected at sites at which Barn Owls were not present.

	DF	X^2	P	Direction
Stock Dove				
Year	1	5.26	0.022	-
Northing	1	2.97	0.085	
Easting	1	0.52	0.471	
Primary habitat	2	0.52	0.771	
Box type	1	0.42	0.519	
Number of boxes at site	1	0.02	0.880	
Presence of Barn Owl	1	0.16	0.685	
Over-winter temperature	1	2.26	0.133	
Over-winter precipitation	1	2.20	0.138	
Jackdaw				
Year	1	11.26	<0.001	-
Northing	1	10.48	0.001	+
Easting	1	0.47	0.493	
Primary habitat	2	0.96	0.619	
Box type	1	14.60	<0.001	P > A
Number of boxes at site	1	15.55	<0.001	+
Presence of Barn Owl	1	23.42	<0.001	-
Over-winter temperature	1	2.82	0.093	
Over-winter precipitation	1	0.13	0.724	
Kestrel				
Year	1	0.89	0.345	
Northing	1	9.24	0.002	-
Easting	1	1.90	0.168	
Primary habitat	2	1.61	0.447	
Box type	1	37.25	<0.001	P > A
Number of boxes at site	1	0.06	0.800	
Presence of Barn Owl	1	0.03	0.865	
Over-winter temperature	1	0.11	0.742	
Over-winter precipitation	1	0.84	0.359	

Table 4.5.2 Factors influencing proportion of WCP sites occupied by breeding Stock Dove, Jackdaw and Kestrel 2002-2007. Directions of significant linear relationships are given in the right-hand column. In the 'Box type' row, 'P' = Polebox design and 'A' = A-frame box design.

4.6 Site turnover

BOMP data were also used to calculate rates of site loss by habitat type (**Table 4.6.1**). A site was categorised as destroyed if it was rendered permanently unusable for Barn Owls, due either to natural causes or human activity. Rates did not differ significantly between the three categories included in the analysis: buildings, trees and pole boxes (GENMOD procedure, N = 600, X^2 =

	% p.a. BOMP 2000-2007	**% p.a. HOT-PBO 1982/85-1995/7**
Building	1.45	2.69
Tree	1.38	2.69
Pole	0.92	-

Table 4.6.1 Annual rates of BOMP site loss over the period 2000-2007 compared with average site loss rates between the 1982-1985 HOT survey and the 1996-1997 Project Barn Owl survey.

5. DISCUSSION

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. 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). Fieldwork is inevitably concentrated in areas where the Barn Owl is 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 Shawyer (2008) estimates that this has now increased considerably to about 75%. While the non-random nature of the sample may influence the resulting trends to some degree, we are able to control for factors such as geographical location and habitat. We therefore consider that there is every reason to expect that BOMP would detect a major real change in population and will provide information about the demographic mechanisms and environmental factors underlying any change, thus providing valuable pointers to direct effective conservation efforts.

5.1 Influence of weather conditions on occupancy and productivity

Barn Owls were present at a significantly greater proportion of BOMP sites following warmer, drier winters. Temperature and snow cover have both been observed to influence Barn Owl survival rates, particularly those of juvenile birds in Britain (Shawyer 1987), and on the Continent (Altwegg *et al*. 2003, 2005). This relationship may be the result of increased energetic costs at lower ambient temperatures, a decline in the abundance of small mammal prey, the survival of which may also be positively related to temperature (Berry *et al*. 1969, Hornfeldt 1994), the decreased accessibility of prey species due to changes in their activity patterns and the increased protection provided by the snow layer (Shawyer 1987, Pucek *et al*. 1993), or to a combination of these factors.

While increased mortality may contribute to the decline in box occupancy following harsher winter conditions in the UK population, surviving birds may be left with lower energy reserves at the start of the season. Individuals in poor condition may elect to suspend breeding if they are unable to occupy and defend nest sites or if the benefits in terms of increased survival probability and reproductive outputs in subsequent years outweigh the costs of failing to produce offspring during the current season (Hardy *et al*. 1981, Shawyer 1987). The proportion of observed pairs electing to breed was lower after colder, wetter winters (Table 4.2.1b, Figure 4.2.1), suggesting that this is indeed the case, and females at WCP sites were found to be lighter following colder, wetter winters (Table 4.3.1, Figure 4.3.1), providing further support for the hypothesis. Shawyer (*in prep.*) observed that females below a threshold weight (approximately 345g) are unlikely to produce eggs even if they have already occupied a nest site and that a minimum body weight of 360g is normally necessary before full clutches and successful hatching can be achieved.

Studies of populations in England (Shawyer 1987), Scotland (Taylor 1992), Utah (Marti 1994) and Switzerland (Altwegg *et al*. 2005) have identified significant relationships between the number of breeding pairs of Barn Owl and the severity of weather conditions during the previous winter, although the Swiss study focussed solely on extreme winter events. While snow cover (number of days of lying snow) was the significant weather parameter identified in the majority of studies, this is likely to correlate strongly with mean air temperatures and the causal mechanisms remain unclear. A further study by de Bruijn (1994) in Holland found no effect of snow cover, nor any correlation between the number of breeding pairs and an index of winter severity.

Analysis of the BOMP dataset indicated that owls laid earlier following warmer, drier winters (Table 4.4.1), suggesting that females may take longer to reach breeding condition following harsher winters. Clutch and brood sizes were significantly positively correlated with over-winter temperatures at BOMP sites, suggesting that a reduction in condition may also lead to reduced investment in the brood, although another possible explanation might be that prey populations may be suppressed following harsher winters (Altwegg *et al*. 2005). In the absence of vole population monitoring at a national scale, it is difficult to determine which of these two mechanisms is responsible for the observed patterns of productivity. It should also be noted that winter and spring temperatures are strongly positively correlated and that the latter factor may itself influence prey availability during the breeding season. However, when terms for both winter and breeding season temperatures were included in the productivity models, the significance of the former term was unaffected.

The UKCIP02 report (Hulme *et al*. 2002) presents a series of potential climate change scenarios over a series of time scales (2020, 2050 and 2080), based on the level of emissions of greenhouse gases over this period. Under medium emissions scenarios, 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 by more than those in winter and spring. Based on the results of these analyses, warmer winters are likely to positively impact on Barn Owls, leading to an increase in both the number of birds breeding and the mean reproductive output per pair. However, it is possible that any benefit may be offset by increasing precipitation during the winter months, with intense periods of rainfall becoming more frequent.

5.2 Spatial variation in occupancy and productivity

Barn Owl was both present and bred at a higher proportion of sites in the west of Britain than in the east. These results may be the result of lower densities of nestboxes in these regions or the lower availability of other nest sites (Toms *et al.* 2000), or alternatively they may also be a reflection of differences in climate and habitat quality. The westerly-biased occupancy rates of this species may be a response to milder winter weather, in particular higher temperatures, in the west of the country due to the proximity of the Gulf Stream, which may in turn influence survival rates and/or the proportion of owls that are in sufficient condition to breed. There was no evidence to suggest that the productivity of those Barn Owls that did elect to breed was lower in the east of the country.

Site occupancy rates were significantly higher and clutch and brood sizes were significantly larger at BOMP sites in areas of natural grassland, relative to sites in arable and pastoral areas. The same relationship between habitat and clutch and brood sizes was also apparent in the longer-running NRS dataset. These results are likely to reflect differences in the availability of small mammal prey, particularly Field Vole (*Microtus agrestris*), between habitats, as densities are likely to be higher in areas of rough grassland, the species' favoured habitat (Harris & Yalden 2008) than in agricultural land, where harvesting and grazing by livestock reduces those primary components of grassland, such as tussock structure, litter layer and length of sward, which are all necessary to provide Field Vole habitat. Previous studies have shown that Field Vole population densities display a negative relationship with grazing intensity in meadows (Schmidt *et al*. 2005) and in agricultural areas, the species' distribution is generally limited to areas of set-aside or field margins, although the management practices of in these areas are not optimised to favour voles (Harris & Yalden 2008).

5.3 Temporal trends in occupancy and phenology

Both the proportion of sites at which Barn Owls were recorded as present and the proportion of occupied sites at which Barn Owls were recorded as breeding have declined since the Programme began in 2000. While Barn Owl abundance at a national scale has not been estimated since Project Barn Owl finished in 1997, a study which takes account of the of the conservation work undertaken in the eastern half of England, primarily to provide foraging habitat, artificial nest sites and re-create habitat connectivity, suggests that the population has doubled in this part of Britain since 2000 (Shawyer 2008). The declines in occupancy observed since the initiation of BOMP may therefore be an artefact of the non-random selection of monitoring sites. If BOMP Network participants were more likely to select sites at which Barn Owls were known to be present or breeding in previous years, then initial occupancy rates may have been artificially inflated and a subsequent decrease might be predicted until a more 'natural' level is reached. An alternative explanation might be that nest site availability is increasing at a faster rate than the population is growing, due to the plethora of Barn Owl study groups and projects that have been initiated since the turn of the century, and that the probability of any individual site being occupied is therefore decreasing.

BOMP data indicate that laying dates have advanced significantly over the laying period, and a non-significant trend towards advancement of laying was also observed when the NRS dataset was analysed. Similar trends have been observed for many other bird species in response to a rise in early spring temperatures driven by anthropogenic climatic change (Crick *et al*. 1997, Crick & Sparks 1999).

5.4 Occupancy rates at WCP and BOMP Network sites

The proportion of Barn Owl pairs recorded as attempting to breed was found to be significantly higher at BOMP Network sites in any given year. It is possible that this perceived difference in occupancy is due to an initial bias in the selection of BOMP Network sites towards boxes in which pairs were not only know to be present but at which they also regularly bred.

5.5 Occupancy rates of other species

The proportion of sites occupied by breeding pairs of Stock Dove and Jackdaw fell at WCP sites over the period 2000-2007. As Breeding Bird Survey data suggest that both species are currently increasing in abundance (Baillie *et al*. 2007), this is unlikely to reflect true population trends. As with Barn Owls, it may be possible that occupancy rates are declining due to the availability of artificial nest sites, the provision of which is increasing at a faster rate than that at which the population is growing.

All three species also displayed latitudinal variation in occupancy rates. Kestrel was recorded at a greater proportion of sites in southern Britain and Jackdaw recorded at a greater proportion of sites in the north. While BTO Bird Atlas data (Gibbons *et al*., 1993) suggest that these results might reflect actual variation in distribution of the former, this is not the case for Jackdaw. It is possible, however, that regional variation in the availability of alternative nest sites could result in the observed relationships.

Box type significantly influenced the probability of Kestrel and Jackdaw breeding at WCP sites, with both species exhibiting a preference for the polebox design that contains an additional nesting chamber. Similarly, Jackdaw bred more frequently at sites where an unoccupied paired box was available for nesting. Both these observations suggest that other species are more likely to breed at sites where they are able to avoid nesting in the same cavity as the owls. In addition, Jackdaw occupancy rates were negatively correlated with those of Barn Owls. It is possible that this is due to the latter out competing the former, but an alternative possibility is that Jackdaws exclude Barn Owls from boxes by blocking the entrances with their nests rather than vice versa. While sites at which this was thought to have happened were removed from the analysis (see Section 3.5.1), it may be difficult to ascertain in the field.

5.6 Rates of nest site loss

The rate of site loss over both periods studied was similar for both trees and buildings, suggesting that both are disappearing or becoming unsuitable for nesting at an approximately equal rate. The rates of loss between the HOT survey n the 1980s and Project Barn Owl in the 1990s were double those observed during the last decade, which may suggest that rates of site destruction are slowing, either due to increased awareness of the conservation issues or to the fact that those sites most prone to destruction of development had already been lost before BOMP was initiated. However, we cannot exclude the possibility that observed differences are the result of different methodologies. The BOMP figures are based on a restricted number of sites selected by volunteers, which may be those that are more likely to persist, biasing rates of site loss downwards. Conversely, responses to the questionnaire may have been more forthcoming from observers at sites that had been destroyed, biasing the calculations in the opposite direction.

5.7 Recommendations for future analyses

Our analyses of Barn Owl occupancy rates and breeding performance in relation to weather suggest that future climate change may actually be detrimental to the species. While it might have been considered that Barn Owl, being a generally southerly species, would benefit from warmer and drier summers, our analyses suggest that the wetter winters and drier springs expected with climate change may actually be detrimental to the species. It would be useful to take these analyses further and assess in a quantitative manner how Barn Owl breeding performance might change under different scenarios of climate change.

Several of the analyses above, suggest that examination 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.

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 and sufficient data may now have accumulated for a preliminary analysis of these data. Such an analysis, in relation to weather, would also be useful when considering how climate change might affect the population dynamics of the species.

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 and WCP has installed large numbers of nestboxes specifically designed for Kestrels but not Barn Owls, throughout the BOMP study areas. In future years it would be worth considering whether a similar monitoring scheme could be undertaken to cover these species, in particular the amber-listed Kestrel and the declining Little Owl.

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References

Altwegg, R., Roulin, A., Kestenholz, M. & Jenni, L. (2003) Variation and covariation in survival, dispersal, and population size in Barn Owls *Tyto alba*. *Journal of Animal Ecology* **72 (3),** 391-399.

Altwegg, R., Roulin, A., Kestenholz, M. & Jenni, L. (2006) Demographic effects of extreme winter weather in the Barn Owl. *Oecologia* **149 (1),** 44-51.

Baillie, S.R., Marchant, J.H., Crick, H.Q.P., Noble, D.G., Balmer, D.E., Barimore, C., Coombes, R.H., Downie, I.S., Freeman, S.N., Joys, A.C., Leech, D.I., Raven, M.J., Robinson, R.A. & Thewlis, R.M. (2007) *Breeding Birds in the Wider Countryside: their conservation status 2007.* BTO Research Report No. 487. BTO, Thetford. (http://www.bto.org/birdtrends).

Beaven, L.P., Leech, D.I., Shawyer, C.R., Balmer, D.E. & Crick, H.Q.P. (2002) *The BTO Barn Owl Monitoring Programme: 2nd report: second year 2001.* BTO Research Report No. 294. BTO, Thetford.

Berry, R.J., Jackobson, M.E. & Moore, R.E. (1969) Metabolic measurements on an island population of the house mouse during the period of winter mortality. *Journal of Physiology, London* **201**, 101–102.

Bibby, C.J., Burgess, N.D. & Hill, D.A. (1992) *Bird Census Techniques*. Academic Press.

Blaker, G.B. (1933) The Barn Owl in England: Results of the Census. I and II. *Bird Notes and News,* **15**, 169–172.

Blaker, G.B. (1934) *The Barn Owl in England and Wales*. RSPB, London.

Bourquin, J.D. (1983) Mortalité des rapaces le long de l'autoroute Genève–Lausanne. *Nos Oiseaux,* **37**, 149–169.

Bunn, D.S., Warburton, A.B. & Wilson, R.D.S. (1982) *The Barn Owl*. T. & A.D. Poyser, Calton.

Colvin, B.A. (1985) Common Barn Owl population decline in Ohio and the relationship to agricultural trends. *Journal of Field Ornithology,* **56**, 224–235.

Crick, H.Q.P. (1992) A bird-habitat coding system for use in Britain and Ireland incorporating aspects of land-management and human activity. *Bird Study,* **39**, 1–12.

Crick, H.Q.P., Baillie, S.R. & Leech, D.I. (2003) The UK Nest Record Scheme: its value for science and conservation. *Bird Study,* **50**, 254-270.

Crick, H.Q.P., Dudley, C. & Glue, D.E. (1999) *Nest Record Scheme Handbook.* British Trust for Ornithology, Thetford.

Crick, H.Q.P., Dudley, C., Glue, D.E. & Thomson, D.L. (1997) UK birds are laying eggs earlier. *Nature* **388**, 526.

Crick, H.Q.P., Shawyer, C.R., Siriwardena, G.M., Balmer, D.E. & Toms, M.P. (2001) *The BTO Barn Owl Monitoring Programme: 1st Report: Pilot Year 2000.* BTO Research Report No. 258. BTO, Thetford.

Crick, H.Q.P. & Sparks, T.H. (1999) Climate change related to egg-laying trends. *Nature* **399**, 423-424.

de Bruijn, O. (1994) Population ecology and conservation of the Barn Owl *Tyto alba* in farmland habitats in Liemers and Achterhoek (The Netherlands). *Ardea,* **82 (1),** 1-109.

Dewar, S.M. & Shawyer, C.R. (1996) *Boxes, Baskets and Platforms: Artificial nest sites for owls and other birds of prey*. HOT, London.

Dobinson, H.M. & Richards, A.J. (1964) The effects of the severe winter of 1962–1963 on birds in Britain. *British Birds,* **57**, 373–434.

Eaton, M.A., Noble, D.G., Cranswick, P.A., Carter, N., Wooton, S., Ratcliffe, N., Wilson, A., Hilton, G.M. & Gregory, R.D. (2004) *The State of the UK's Birds 2003.* BTO, the RSPB and WWT.

Furness, R.W. & Furness, B.L. (1981) A technique for estimating the hatching dates of eggs of unknown laying date. *Ibis*, **123**, 98–102.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (eds). (1993) *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.* T. & A.D. Poyser, London.

Glue, D.E. (1974) Food of the Barn Owl in Britain and Ireland. *Bird Study* **21**, 200-210.

Gregory, R.D., Wilkinson, N.I., Noble, D.G., Robinson, J.A., Brown, A.F., Hughes, J., Proctor, D.A., Gibbons, D.W. & Galbraith, C.A. (2002) The population status of birds in the United Kingdom, Channel Islands and Isle of Man: an analysis of conservation concern 2002-2007. *British Birds*, **95**, 410-450.

Hardy, A.R., Hirons, G.M. & Stanley, P.J. (1981) The relationship of body weight, fat deposit and moult to the reporductive cycles in wild Tawny Owls and Barn Owls. In *Recent Advances in the Study of Raptor Diseases*, pp.139-163.

Harris, S. & Yalden, D.W. (2008) *Mammals of the British Isles: Handbook, 4th Edition*. The Mammal Society, London.

Harrison, E. (1990) Rodenticides and Barn Owls: assessing the hazards. *Shell Agriculture*, **8**, 15–17.

Haines-Young, R.H., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. & Watkins, J.W. (2000) *Accounting for nature: assessing habitats in the UK countryside.* DETR, London

Holloway, S. (1996) *The Historical Atlas of Breeding Birds in Britain and Ireland 1875–1900*. T. & A.D. Poyser, London.

Hornfeldt, B. (1994) Delayed density-dependence as determinant of vole cycles. *Ecology,* **75 (3)**, 791-806.

Hoyt, D.F. (1979) Practical methods of estimating volume and fresh weight of bird eggs. *Auk,* **96**, 73–77.

Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R., Hill, S. (2002) *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.* Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK.

Jones, P.D. & Conway, D. (1997) Precipitation in the British Isles: an analysis of area-average data updated to 1995. *Int J Climatol*, **17**, 427-438.

Joys, A.C. & Crick, H.Q.P (2004) *Breeding periods for selected bird species in England*. BTO Research Report No. 352. BTO, Thetford.

Latham, J. (1781) *General Synopsis of Birds, Volume 1*. White, London.

Leech, D.I., Barimore, C.J., Crick, H.Q.P & Shawyer, C.R. (2006) *The BTO Barn Owl Monitoring Programme: sixth year*. BTO Research Report No. 454. BTO, Thetford.

Leech, D.I., Crick, H.Q.P & Shawyer, C.R. (2005a) *The BTO Barn Owl Monitoring Programme: fourth year 2003*. BTO Research Report No. 411. BTO, Thetford.

Leech, D.I., Crick, H.Q.P & Shawyer, C.R. (2005b) *The BTO Barn Owl Monitoring Programme: fifth year 2004*. BTO Research Report No. 424. BTO, Thetford.

Leech, D.I., Marchant, J.H., Beaven, L.P. & Crick, H.Q.P. (2003) *The BTO Barn Owl Monitoring Programme: third year 2002*. BTO Research Report No. 341. BTO, Thetford.

Lenton, G.M. (1984) Moult of Malayan Barn Owls, *Tyto alba*. *Ibis,* **126**, 188–197.

Macgillivray, W. (1840) *A History of British Birds. Volume 3*. Scott, Webster & Geary, London.

Manley, G. (1974) Central England Temperatures: monthly means 1659 to 1973. *Quart J Roy Meteorol. Soc.*, **100**, 389-405.

Marti, C.D. (1994) Barn Owl reproduction – patterns and variation near the limit of the species distribution. *Condor,* **96 (2)**, 468-484.

Massemin, S. & Zorn, T. (1998) Highway mortality of Barn Owls in north eastern France. *Journal of Raptor Research,* **32**, 229–232.

Mayfield, H. (1961) Nesting success calculated from exposure. *Wilson Bulletin,* **73**, 255–261.

Mayfield, H. (1975) Suggestions for calculating nest success. *Wilson Bulletin,* **87**, 456–466.

Newton, I. & Wyllie, I. (1992) Effects of new rodenticides on owls. In *The ecology and conservation of European Owls* (eds C.A. Galbraith, I.R. Taylor, S. Percival & S.M. Davies), pp 49–54. UK Nature Conservation series No. 5. JNCC, Peterborough.

Newton, I., Wyllie, I. & Asher, A. (1991) Mortality causes in British Barn Owls, *Tyto alba*, with a discussion of aldrin–dieldrin poisoning, *Ibis,* **133**, 162–169.

Ogilvie, M.A. & Rare Breeding Birds Panel. (2003) Rare Breeding Birds in the United Kingdom in 2001. *British Birds,* **96**, 476-519.

Parker, D.E., Legg, T.P. & Folland, C.K. (1992) A new daily Central England Temperature Series, 1772-1991. *Int J Climatol*, **12**, 317-342.

Parslow, J.L.F. (1973) *Breeding Birds of Britain and Ireland*. T. & A.D. Poyser, Berkhamsted.

Percival, S.M. (1990) *Population trends in British Barn and Tawny Owls in relation to environmental change*. BTO Research Report No. 57. BTO, Tring.

Prestt, I. (1965) An enquiry into the recent breeding status of some smaller birds of prey and crows in Britain. *Bird Study,* **12**, 196–221.

Pucek, Z., Jedrzejewski, W., Jedrzejewska, B. & Pucek, M. (1993) Rodent population-dynamics in a primeval deciduous forest (Bialowieza National Park) in relation to weather, seed crop and predation. *Acta Theriologica* **38**, 199–232.

Rahn, H. & Ar, A. (1974) The avian egg: incubation time and water loss. *Condor,* **76**, 147–152.

Ramsden, D. & Ramsden, F. (1989) Results of Barn Owl re-introduction carried out by the Barn Owl Trust in Devon. *Devon Birds,* **42**, 27–33.

Ramsden, D.J. (1998) Effect of barn conversions on loacl popualtions of Barn Owl *Tyto alba*. *Bird Study* **45(1)**: 68-76.

Rivière, B.B. (1830) *A history of the birds of Norfolk*. H.F. & G. Witherby, High Holborn, London.

Robinson, R.A. (2005) *BirdFacts* http://www.bto.org/birdfacts/

SAS Institute. (1990) *SAS/STAT User's Guide*. Version 6, fourth edition. SAS Institute, Cary, North Carolina.

Schmidt, N.M., Olsena, H., Bildsøeb, M., Sluydtsc, V. & Leirsb, H. (2005) Effects of grazing intensity on small mammal population ecology in wet meadows. *Basic & Applied Ecology* **6(1)**, 57-66.

Sharrock, J.T.R. (1976) *The Atlas of Breeding Birds in Britain and Ireland*. T. & A.D. Poyser, Berkhamsted.

Shawyer, C.R. (1985) *Rodenticides: a review and assessment of their potential hazard to non-target wildlife with special reference to the Barn Owl* Tyto alba. The Hawk Trust, London.

Shawyer, C.R. (1987) *The Barn Owl in the British Isles: its past, present and future*. The Hawk Trust, London.

Shawyer, C.R. (1998) *The Barn Owl*. Arlequin Press, Chelmsford.

Shawyer, C.R. (2006) *Adopt A Box News*, **28**, Hawk & Owl Trust.

Shawyer, C.R. (2008) Operation Riverside Link, a species recovery project - progress report 2007-2008. Environment Agency, Bristol.

Shawyer, C.R. & Dixon, N. (1999) *Impact of roads on Barn Owl* Tyto alba *populations*. Highways Agency, London.

Taylor, I.R. (1991) Effects of nest inspections and radiotagging on Barn Owl breeding success. *Journal of Wildlife Management,* **55**, 312–315.

Taylor, I.R. (1992) An assessment of the significance of annual variations in snow cover in determing short-term popualtion changes in field voles *Microtus agrestis* and Barn Owls *Tyto alba* in Britain. In *The ecology and conservation of European Owls* (eds C.A. Galbraith, I.R. Taylor, S. Percival & S.M. Davies), pp 32-38. UK Nature Conservation series No. 5. JNCC, Peterborough.

Taylor, I.R. (1994) *Barn Owls: predator–prey relationships and conservation*. Cambridge University Press, Cambridge.

Taylor, I.R., Dowell, A., Irving, T., Langford, I.K. & Shaw, G. (1988) The distribution and abundance of the Barn Owl in south-west Scotland. *Scottish Birds,* **15**, 40–43.

Toms, M.P. (1997) *Project Barn Owl – evaluation of an annual monitoring programme*. BTO No. Research Report 177. BTO, Thetford.

Toms, M.P., Crick, H.Q.P. & Shawyer, C.R. (2000) *Project Barn Owl Final Report*. BTO Research Report No. 197/HOT Research Report 98/1. BTO, Thetford.

Toms, M.P., Crick, H.Q.P. & Shawyer, C.R. (2001) The status of breeding Barn Owls *Tyto alba* in the United Kingdom 1995–97. *Bird Study,* **48**, 23–27.

Tucker, G.M. & Heath, M.F. (1994) *Birds in Europe: their conservation status.* Bird Life Conservation Series No. 3, Cambridge.

Warburton, T. (1992) *The release of captive-bred Barn Owls as an aid to the conservation of declining wild populations.* British Owl Breeding and Release Scheme, Ravenglass.

Wigley, T.M.L., Lough, J.M. & Jones, P.D. (1984) Spatial patterns of precipitation in England and Wales and a revised homogeneous England and Wales precipitation series*. J Climatol*, **4**, 1-25.

Wilson, R.T., Wilson, M.P. & Durkin, J.W. (1987) Growth of nesting Barn Owls *Tyto alba* in central Mali. *Ibis,* **129**, 305–318.