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The BTO Barn Owl Monitoring Programme: sixth year 2005

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 is the sixth report of BOMP, covering the seasons 2000–05. Rates of occupancy are investigated, along with breeding statistics, in relation to year, geographical location, main habitat type and weather conditions.

1.4 In 2005, 197 sites were monitored by WCP and a further 353 were visited by BOMP Network volunteers. WCP sites are located across the whole of England, although as a consequence of sampling methodology they tend to be concentrated in the southern, 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 six 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 site selection of the BOMP Network sites, which may originally have been biased towards sites that were known to have been occupied in previous years.

1.6 The proportion of WCP sites occupied annually by breeding Barn Owl is lower than that at BOMP Network sites. This probably reflects the original sampling method used by WCP which were stratified for sites where Barn Owls had bred previously, roosted previously or where they had never been used before. The two types of site have also been monitored over different lengths of time. Assuming original occupancy rates were inflated, WCP sites have been monitored for six years whereas monitoring only began at BOMP Network sites four years ago and there has been less time for a more natural level of occupancy to be attained.

1.7 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 wet winters. The proportion of occupied sites at which owls attempted to breed was also lower during breeding seasons preceded by cold, wet winters. These results suggest that birds lose body condition during inclement winter conditions, leading to suspension of breeding during the following breeding season and possibly even to increasing rates of mortality.

1.8 Occupancy rates were also influenced by geographic location. Sites to the west of the UK were significantly more likely to contain breeding Barn Owls, than to the south and east. Possible causes behind these patterns are discussed, including the potential influence of climate, habitat and nest site availability. No significant effect of habitat type on occupancy rates was identified.

1.9 Sufficient data were collected over the five years of the study to permit analysis of laying dates, clutch sizes and brood sizes, although sample sizes for clutch size were relatively small. Evidence for temporal trends in productivity was weak but habitat type did have a significant effect on clutch and brood sizes, which were higher in rough grassland areas where small mammal, particularly Field Vole, population densities are likely to be greater.

1.10 Weather conditions during the winter months also had a significant effect on Barn Owl productivity, with females laying later after cold, wet winters and producing larger broods after drier winters. These relationships are 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. Adults in poorer condition may reduce their investment in reproduction during the following season.

1.11 Conversely, there was little evidence to suggest that weather conditions during the breeding season significantly influenced productivity, with significant relationships limited to a counter-intuitive negative correlation between clutch size and temperature.

1.14 NRS data for Barn Owl over the period 1980-2005 were also used to calculate laying date, clutch size and brood size at individual nests. The results of subsequent analyses supported the findings of the BOMP productivity analysis, demonstrating that brood sizes were larger in rough grassland habitats and during those breeding seasons preceded by drier winters.

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

1.16 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 six years of BOMP data (2000-2005).

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

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

The most recent nationwide survey was *Project Barn Owl*, undertaken jointly by BTO and Hawk and Owl Trust in the UK, Isle of Man and Channel Islands during 1995–97 (Toms 1997, Toms *et al.* 2000, 2001). This project established a random sample of survey sites, which were 2x2-km tetrads of the national grid, and devised new survey methods that could be repeated at intervals in the future to produce directly comparable results. This survey produced a population estimate of about 4,000 pairs for the whole area of study (Toms *et al.* 2001), a slightly lower figure than produced by the Hawk

Trust survey for Britain alone. Because the confidence interval around the Project Barn Owl figure included the previous Hawk Trust estimate and as the methodologies were not identical, it was not clear whether any further decline had occurred between these two surveys. It is important to note that these two surveys were 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 Trust and other specialist groups in fostering more widespread recognition of the species’ conservation importance. Attention has been directed towards the creation and management of areas of suitable hunting habitat, increasing the availability of prey, providing habitat corridors to promote dispersal, coupled with the provision of nest boxes in areas where a shortage of nest and roost sites could be a limiting factor. 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. This is particularly important given the species’ inclusion on the UK Government’s Farmland Bird Index of Sustainable Development and the Government’s Publics Service Agreement target to reverse the decline in the index by 2020. Furthermore, concerns about the use of newer types of rodenticide 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). 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 can also lead to increased thermoregulatory costs and declines in prey species abundance. The increased costs associated with such conditions may either result in lower rates of adult survival or 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 visibility of small mammal species.

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

Such changes in weather conditions may have important consequences for the UK Barn Owl population. One of the first steps in attempting to predict the impact of such climatic changes is to investigate the current relationships between weather parameters and population processes. The BOMP dataset provides an excellent opportunity to explore such associations and the results of 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 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 561 sites were monitored in 2002, 198 by WCP and 363 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 586 sites were monitored in 2003, 200 by WCP and 386 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 527 sites were monitored in 2004, 200 by WCP and 327 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 550 sites were monitored in 2005, 197 by WCP and 353 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.

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) and 2004 (Leech *et al.* 2005b) 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 the field experience of WCP. 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 barn conversions, the shifting location of bale-stacks and waterlogging of natural sites, and because accurate recording of eggs and young is often difficult 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 throughout the UK, almost all of the sites that have been registered are nest boxes. The widespread distribution of boxes clearly highlights the extent of the public's interest in Barn Owls (Project Barn Owl estimated that there were some 25,000 boxes in the UK; Toms *et al.* (2000) and Shawyer (*pers comm.*) now estimates that 75% of Barn Owls in the UK now breed in nestboxes. Their occupation indicates the benefit that conservation measures have had for the species. Although some individuals who erect nestboxes generally inspect them too, BOMP provides a framework for collating such observations, ensuring that the data are recorded to a recognised standard and maximising the benefit derived.

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

Prior to the 2000 pilot survey, 125 sites were 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 supplementary ('extra') sites that are included in the programme in most years.

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), potentially reducing parasite loads in the box. However, to counter these positive effects, nest boxes may be more obvious to competing species or predators and may provide less shelter from the elements in some circumstances.

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 had not been occupied simultaneously by breeding Barn Owls at any point over the three study years (2002-2004) then they were 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 Statistical models

3.8.1 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 and primary habitat type were also included as independent variables in all models. The influence of temperature and precipitation over the winter period on BOMP site occupancy rates were investigated using two separate models due to the relatively high degree of correlation between these two weather variables over the six study years (R^2=0.69, P=0.040).

3.8.2 Barn Owl productivity – BOMP dataset

Models used to investigate factors influencing the various measures of productivity were identical to those described in Section 3.8.1 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.

- Weather variables for the winter and breeding season periods were included as separate independent variables in the same model as there was no significant correlation between winter and breeding season temperatures (R^2=0.35, P=0.212) or precipitation (R^2<0.01, P=0.898). However, the influence of temperature and rainfall were still investigated separately due to the significant relationship of the two weather variables during the winter (see Section 3.8.1).

3.8.3 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.

Temperature and precipitation showed no significant correlation over the period 1980-2005, either during winter (R^2<0.01, P=0.811) or during the breeding season (R^2=0.01, P=0.697), 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=0.48, P<0.001), although the same was not true of precipitation (R^2<0.01, P=0.912). The influence of winter weather conditions and those during the breeding season were therefore analysed in separate models.

3.8.4 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.

3.8.5 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. In addition, BOMP Network participants do not record the design of the Nestbox at the same level of detail as is recorded at WCP sites. The two datasets were therefore analysed separately.

As with analysis of Barn Owl occupancy rates, year, Northings, Eastings and primary habitat type were included as independent variables in all models of WCP data. 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.

Models used to analyse other species occupancy at BOMP Network sites were similar, but did not contain the term for ‘Box type’. Terms for weather variables were also removed from the models as only two years of data are available and thus effects of precipitation and temperature could not be distinguished from those of the term ‘year’.

4. RESULTS

4.1 BOMP coverage

The 2005 season was the sixth year of data collection at WCP sites and the fourth 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 (mean = 199), while the number of sites covered by BOMP Network participants (mean = 355) is more variable (Table 4.1.1).

	2000	2001	2002	2003	2004	2005
WCP sites	159	170	198	200	200	197
BOMP Network sites	-	1	363	386	327	353
TOTAL	159	171	561	586	527	550

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

Figure 4.1.1 Distribution of WCP (black triangle) and BOMP Network (grey circle) sites monitored in a) 2004 and b) 2005.

The encouraging increase in coverage at BOMP Network sites in 2005, following a significant reduction in coverage (c. 10%) in 2004, was due 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 2005. 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 2005 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

a)

	DF	X^2	P	Direction
Site occupancy (N = 2183)				
Year	1	15.54	<0.001	-
Northing	1	1.56	0.212	
Easting	1	11.68	<0.001	-
Primary habitat	2	2.29	0.319	
Site type	1	2.22	0.136	
Over-winter temperature	1	2.10	0.147	
Proportion breeding (N = 1724)				
Year	1	9.23	0.002	-
Northing	1	0.46	0.498	
Easting	1	0.76	0.384	
Primary habitat	2	1.70	0.428	
Site type	1	22.42	<0.001	N > W
Over-winter temperature	1	18.49	<0.001	+

b)

	DF	X^2	P	Direction
Site occupancy (N = 2183)				
Year	1	27.21	<0.001	-
Northing	1	1.79	0.181	
Easting	1	11.24	<0.001	-
Primary habitat	2	2.36	0.308	
Site type	1	2.29	0.130	
Over-winter precipitation	1	17.20	<0.001	-
Proportion breeding (N = 1724)				
Year	1	21.95	<0.001	-
Northing	1	0.38	0.539	
Easting	1	0.85	0.356	
Primary habitat	2	1.71	0.426	
Site type	1	24.67	<0.001	N > W
Over-winter precipitation	1	31.21	<0.001	-

Table 4.2.1 Factors influencing site occupancy and the proportion of pairs breeding 2000-2005 a) with over-winter temperature included in the model and b) with over-winter precipitation included in the model. It was not possible to combine these models due to the significance of the correlation between temperature and precipitation during the winter period. Directions of significant linear relationships are given in the right-hand column. In the 'Site Type' row, 'W' indicates WCP sites and 'N' indicates BOMP Network sites.

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 six study years, Barn Owls were present in 1980 of the 2554 sites visited (77.5%) and were found to be breeding in 1596 (62.4%).

The results of the occupancy rate analyses (Table 4.2.1) indicate that, although occupancy rates did not differ significantly between BOMP Network and WCP sites, a higher proportion of birds present at BOMP Network sites elected to breed. Both the proportion of sites at which Barn Owls were present and the proportion of birds breeding, decreased significantly over the six-year monitoring period (Figure 4.2.1). 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.

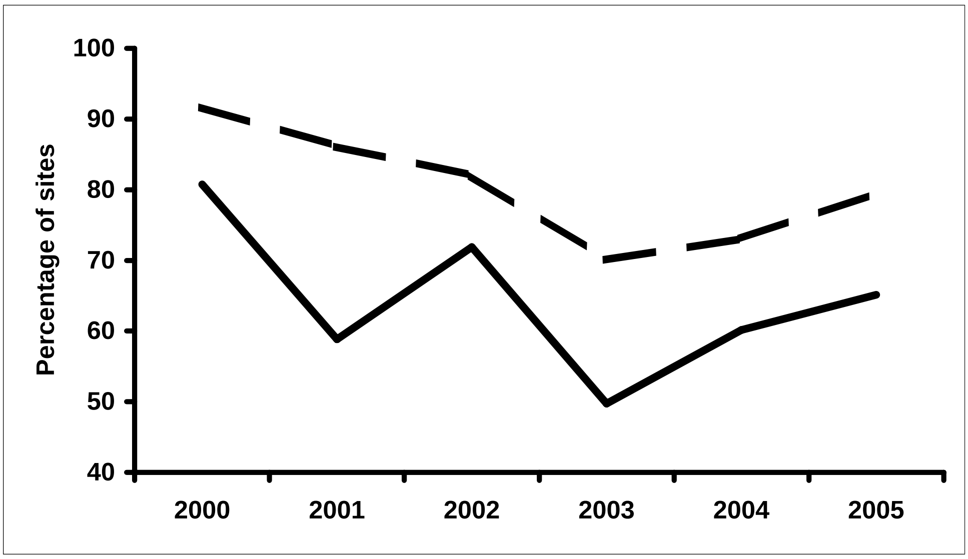
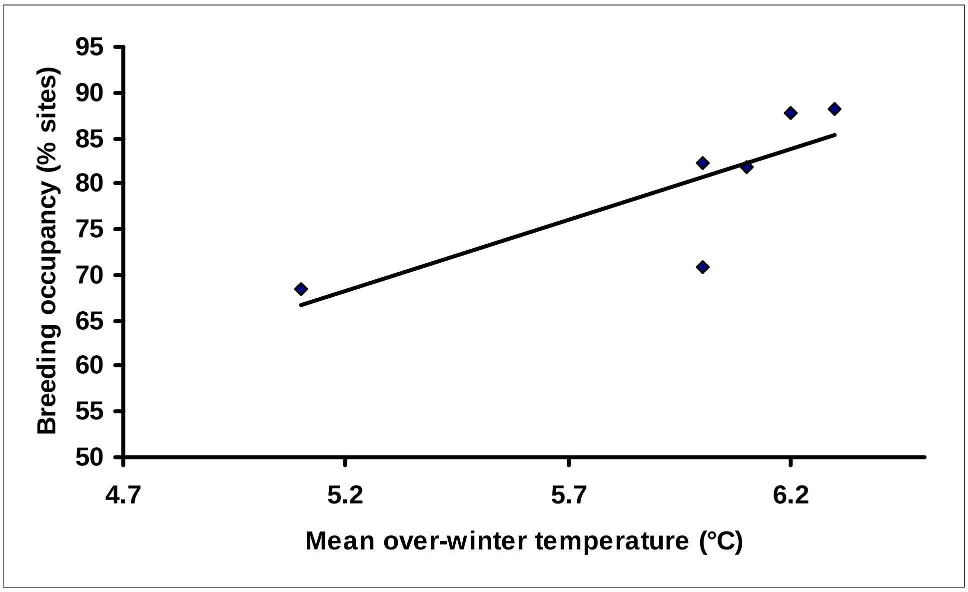


Figure 4.2.1 Annual variation in the proportion of BOMP sites at which Barn Owls were recorded as present (dashed line) and the proportion of sites at which owls were recorded as breeding (solid line).

Rainfall, but not average temperatures, over the winter period had a significant effect on the proportion of sites at which birds were observed, with fewer sites occupied following wetter winters. Both rainfall and temperature significantly influenced the proportion of birds breeding, however, with a higher proportion of birds breeding when weather conditions during the preceding winter were warm and dry (Figure 4.2.2). Unfortunately, as rainfall and temperature during the winter are significantly negatively correlated (see Section 3.8.1), it is difficult to determine the degree to which each factor is responsible for mediating the proportion of birds breeding.

Box design was not included in these models as the level of information available differs between WCP and BOMP Network sites. If the analysis was limited purely to WCP sites, where the most detailed information is available, it was clear that box design did have a significant effect both on the presence of Barn Owls ($N = 1044$, $P < 0.006$ all models) and on the proportion of observed pairs electing to breed ($N = 841$, $P < 0.001$ all models), with A-frame boxes containing fewer pairs of which a reduced proportion bred. However, the inclusion of box type in the model did not alter the relationships between occupancy rates and weather conditions observed in the full dataset.

a)



b)

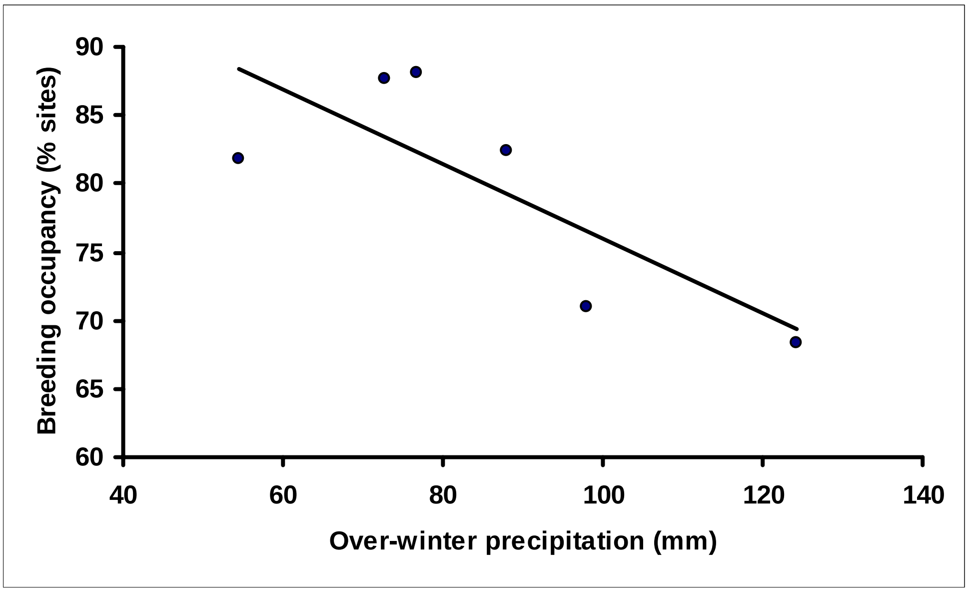


Figure 4.2.2 Relationship between a) winter temperatures and b) winter precipitation on the proportion of Barn Owls occupying BOMP sites that attempted to breed. For the purposes of this analysis, the winter period was defined as November-March.

4.3 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 both the breeding season and the preceding winter (Tables 4.3.1 and 4.3.2). Again, it was necessary to analyse the influence of temperature and precipitation separately due to the significant correlation between these variables during the winter. However, as winter temperatures were not significantly correlated with those experienced during the breeding season, both variables could be included in the same model, as was the case for precipitation (see Section 3.8.3). Mayfield failure rates could not be modelled as complete clutch and brood failures were too infrequent.

There was some suggestion that laying dates had advanced progressively over the past five years and although this relationships was significant only in the model containing temperature data (Table 4.3.1), as was the positive correlation between year and brood size. No significant regional variation in any of the breeding parameters was identified, but habitat type did appear to have a significant effect on productivity, with owls in rough grassland tending to lay earlier and to produce larger clutches and broods. Mean first egg dates also differed between WCP and BOMP Network sites, with birds at the former sites laying significantly earlier than those at the latter (Tables 4.3.1 and 4.3.2).

	DF	X^2	P	Direction
First egg date (N = 440)				
Year	1	6.20	0.013	-
Northing	1	0.12	0.729	
Easting	1	3.24	0.072	
Primary habitat	2	1.21	0.545	
Site type	2	15.91	<0.001	N > C
Breeding season temperature	1	<0.01	0.988	
Over-winter temperature	1	8.08	0.005	-
Clutch size (N = 144)				
Year	1	3.65	0.056	
Northing	1	2.61	0.106	
Easting	1	0.53	0.467	
Primary habitat	2	8.37	0.015	G > A > P
Site type	2	1.93	0.165	
Breeding season temperature	1	2.13	0.144	
Over-winter temperature	1	3.55	0.059	
Brood size (N = 1030)				
Year	1	4.30	0.038	+
Northing	1	0.00	0.957	
Easting	1	0.61	0.435	
Primary habitat	2	9.15	0.010	G > P > A
Site type	1	0.32	0.569	
Breeding season temperature	1	6.36	0.012	-
Over-winter temperature	1	0.27	0.603	

Table 4.3.1 Factors influencing productivity of Barn Owls breeding at BOMP sites 2000-2005 with over-winter and breeding season temperature included in the model. It was not possible to combine these models due to the significance of the correlation between temperature and precipitation during the winter period. 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). In the 'Site Type' row, 'W' indicates WCP sites and 'N' indicates BOMP Network sites.

	DF	X^2	P	Direction
First egg date (N = 440)				
Year	1	3.10	0.078	
Northing	1	0.07	0.786	
Easting	1	3.03	0.082	
Primary habitat	2	1.20	0.549	
Site type	2	16.07	<0.001	N > C
Breeding season precipitation	1	0.94	0.330	
Over-winter precipitation	1	17.29	<0.001	+
Clutch size (N = 144)				
Year	1	0.90	0.342	
Northing	1	2.61	0.106	
Easting	1	0.53	0.467	
Primary habitat	2	8.37	0.015	G > A > P
Site type	2	1.93	0.165	
Breeding season precipitation	1	2.34	0.126	
Over-winter precipitation	1	3.13	0.077	-
Brood size (N = 1030)				
Year	1	0.00	0.996	
Northing	1	0.00	0.954	
Easting	1	0.69	0.405	
Primary habitat	2	9.07	0.011	G > P > A
Site type	1	0.46	0.497	
Breeding season precipitation	1	0.05	0.829	
Over-winter precipitation	1	10.42	0.001	-

Table 4.3.2 Factors influencing productivity of Barn Owls breeding at BOMP sites 2000-2005 with over-winter and breeding season precipitation included in the model. It was not possible to combine these models due to the significance of the correlation between temperature and precipitation during the winter period. 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). In the ‘Site Type’ row, ‘W’ indicates WCP sites and ‘N’ indicates BOMP Network sites.

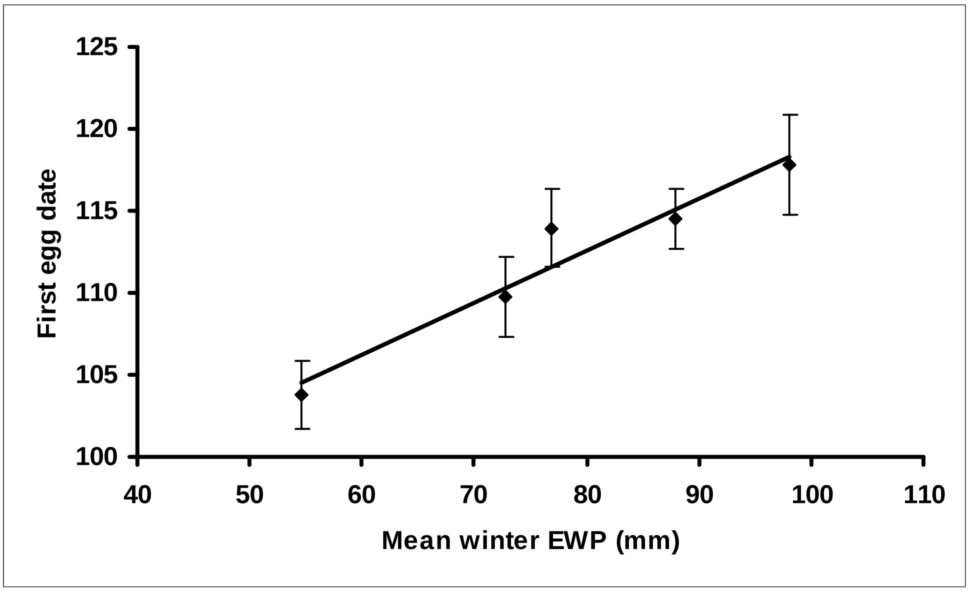


Figure 4.3.1 Relationship between laying dates and mean winter EWP.

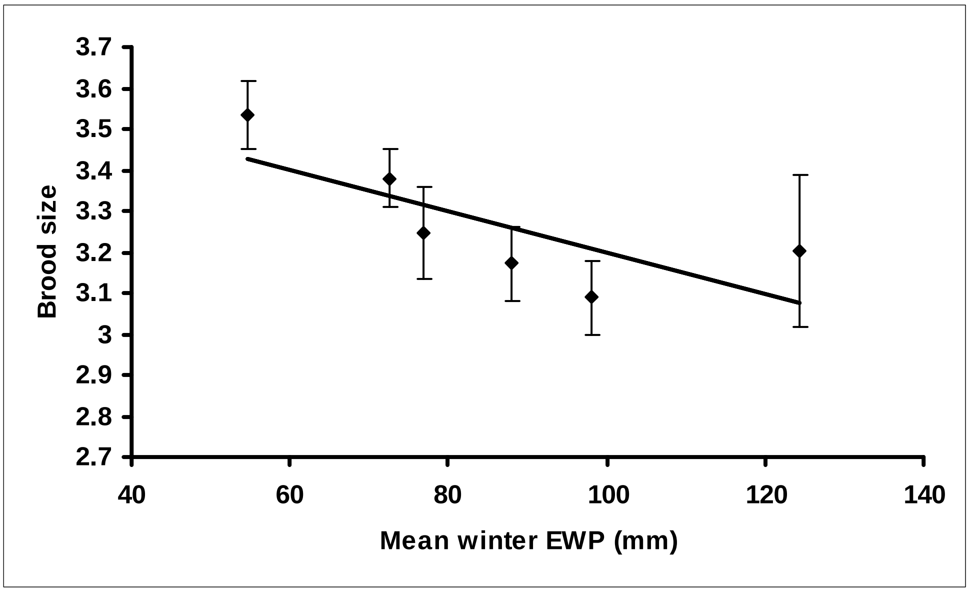


Figure 4.3.2 Relationship between brood size and mean winter EWP.

Weather conditions during the winter period significantly influenced productivity. Laying was delayed following cold, wet winters, by one day for each 0.02°C drop in mean winter CET or each 3.4mm increase in mean winter EWP (Figure 4.3.1). Winter rainfall was also inversely correlated with brood size, the mean number of chicks falling by 0.07 with each 10mm increase in mean winter EWP (Figure 4.3.2). In contrast, levels of precipitation during the breeding season itself had no measurable effect on any of the reproductive parameters recorded. While breeding season temperatures did significantly influence brood size, the relationship was a negative one, with mean brood sizes falling by 0.3 chicks for every 1°C rise in temperature (Figure 4.3.3).

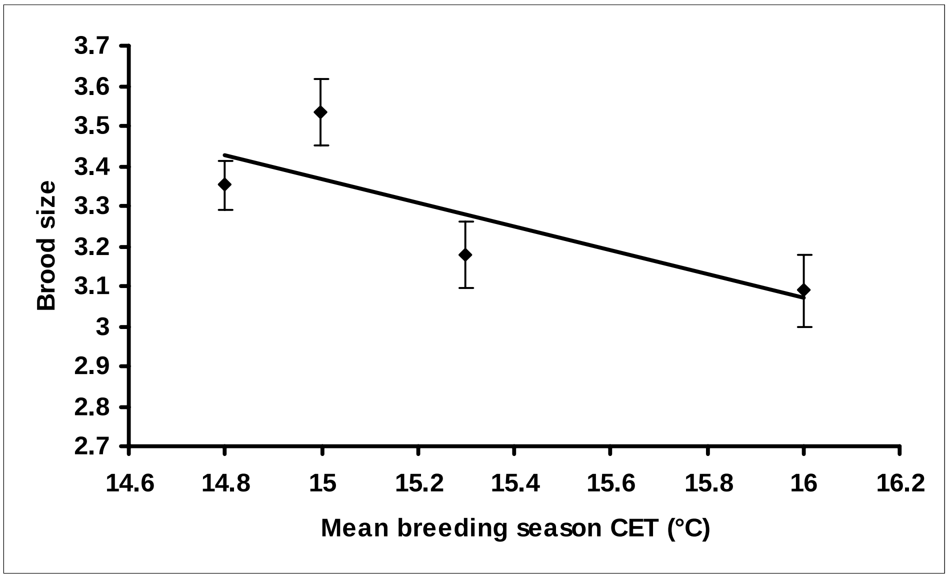


Figure 4.3.3 Relationship between brood size at BOMP sites and mean winter CET.

a)

	DF	X^2	P	Direction
First egg date (N = 161)				
Year	1	0.27	0.600	
Northing	1	0.24	0.621	
Easting	1	1.87	0.172	
Primary habitat	4	2.17	0.704	
Breeding season temperature	1	3.20	0.074	
Breeding season precipitation	1	2.96	0.085	
Clutch size (N = 444)				
Year	1	1.55	0.213	
Northing	1	2.17	0.141	
Easting	1	0.47	0.491	
Primary habitat	4	3.28	0.512	
Breeding season temperature	1	0.27	0.601	
Breeding season precipitation	1	0.06	0.814	
Brood size (N = 2757)				
Year	1	0.02	0.879	
Northing	1	1.37	0.241	
Easting	1	4.22	0.040	+
Primary habitat	4	15.57	0.004	G>P>M>A>W
Breeding season temperature	1	1.23	0.268	
Breeding season precipitation	1	0.51	0.476	

Table 4.3.3 Factors influencing productivity of Barn Owls as recorded by the NRS a) with breeding season weather parameters included in the model and b) with over-winter weather parameters included in the model. It was not possible to combine these models due to the significance of the correlation between temperatures during the winter period and those during the breeding season. Directions of significant linear relationships are given in the right-hand column. In the 'Primary habitat' row, P = Pastoral, A = Arable, M = Mixed farmland, G = Grassland (natural) and W = Wood.

b)

	DF	X^2	P	Direction
First egg date (N = 161)				
Year	1	0.10	0.752	
Northing	1	0.55	0.458	
Easting	1	2.67	0.102	
Primary habitat	4	2.09	0.719	
Over-winter temperature	1	1.03	0.311	
Over-winter precipitation	1	0.03	0.859	
Clutch size (N = 444)				
Year	1	1.36	0.243	
Northing	1	2.44	0.118	
Easting	1	0.46	0.496	
Primary habitat	4	3.34	0.502	
Over-winter temperature	1	0.02	0.878	
Over-winter precipitation	1	0.05	0.820	
Brood size (N = 2757)				
Year	1	0.55	0.458	
Northing	1	1.08	0.299	
Easting	1	3.53	0.060	
Primary habitat	4	15.07	0.005	G>P>M>A>W
Over-winter temperature	1	1.30	0.254	
Over-winter precipitation	1	9.19	0.002	-

Table 4.3.3 (continued)

A similar analysis was carried out using Barn Owl data collected by Nest Record Scheme (NRS) volunteers over the period 1980-2005 (Table 4.3.3). While no significant relationship was identified between temperature and precipitation either within the winter period or within the breeding season, winter temperatures and breeding season temperatures were significantly correlated (see Section 3.8.3). Data for the two periods were therefore analysed separately.

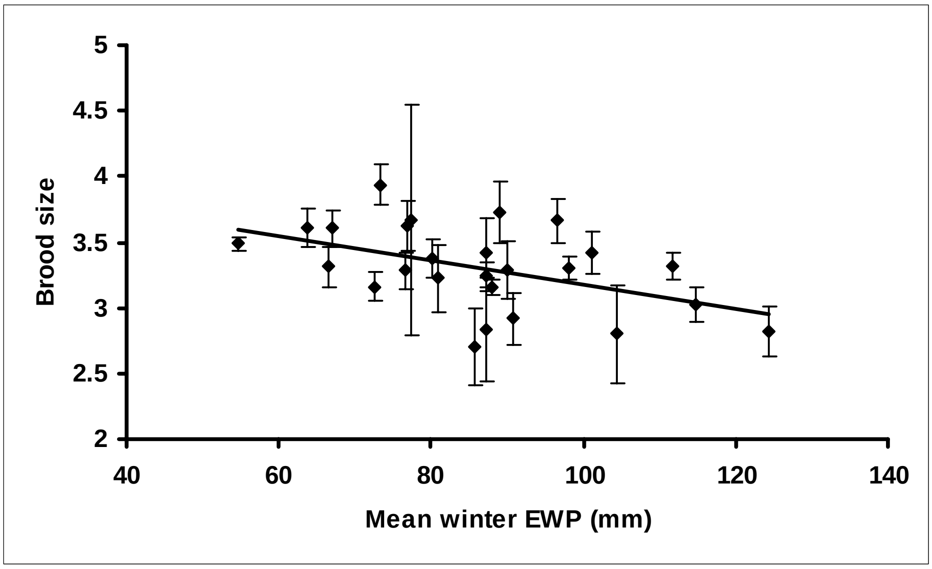


Figure 4.3.4 Relationship between brood size as calculated using the NRS dataset and mean winter EWP.

The NRS analysis failed to identify any significant annual or regional variation in productivity save for weak evidence of an increase in brood sizes towards the east of Britain (Table 4.3.3). Brood sizes did vary according to habitat type, however, with owls breeding in areas of natural grassland producing larger brood than those in agricultural or woodland areas. Brood sizes were also found to be significantly lower following wetter winters (Figure 4.3.4), decreasing by 0.06 chicks with every 10mm increase in mean EWP, but weather conditions during the breeding season were not observed to have any effect on productivity.

4.4 Female biometrics

During the period 2000-2006 the weights of female Barn Owls were recorded on at least once occasion at 137 WCP sites (a total of 377 measurements were collected). Analyses indicated that, while winter temperatures did not influence female weight ($X^2 = 1.05$, $P = 0.305$), birds were significantly lighter following wetter winters ($X^2 = 6.54$, $P = 0.011$).

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*) (Table 4.5.1).

a)

	2000 N=160	**2001** N=161	**2002** N=189	**2003** N=191	**2004** N = 193	**2005** N = 193
Stock Dove	5.00%	18.63%	21.16%	25.65%	16.58%	15.54%
Jackdaw	5.63%	9.32%	23.81%	26.70%	22.80%	22.80%
Kestrel	7.41%	10.13%	17.46%	12.57%	15.03%	16.58%

b)

	2004 N = 304	**2005** N = 326
Stock Dove	10.53%	7.67%
Jackdaw	9.87%	8.28%
Kestrel	6.91%	6.13%

Table 4.5.1 Proportion of sites occupied by breeding Stock Dove, Jackdaw and Kestrel at a) WCP sites (2000-2005) and b) BOMP Network sites.

The occupancy rates of Stock Dove, Jackdaw and Kestrel at BOMP Network sites appear to be less than half those at WCP sites. As we suspect that the degree to which other species are recorded may vary between site types, the datasets were analysed separately. While it was possible to construct models incorporating winter weather variables for the WCP dataset (Tables 4.5.2 and 4.5.3), this is not yet possible for BOMP Network sites due to the shorter run of data (Table 4.5.4).

	DF	X^2	P	Direction
Stock Dove (N = 1044)				
Year	1	7.12	0.008	+
Northing	1	4.32	0.038	+
Easting	1	2.98	0.084	
Primary habitat	2	0.59	0.745	
Box type	2	0.26	0.877	
Paired box	1	0.01	0.941	
Over-winter temperature	1	6.53	0.011	-
Jackdaw (N = 1044)				
Year	1	28.10	<0.001	+
Northing	1	9.34	0.002	+
Easting	1	0.18	0.673	
Primary habitat	2	4.45	0.108	
Box type	2	10.25	0.006	P > S > A
Paired box	1	11.39	<0.001	PD > UN
Over-winter temperature	1	0.68	0.409	
Kestrel (N = 895)				
Year	1	11.85	<0.001	+
Northing	1	12.29	<0.001	-
Easting	1	0.03	0.854	
Primary habitat	2	1.84	0.399	
Box type	1	33.78	<0.001	P > A
Paired box	1	3.32	0.068	
Over-winter temperature	1	0.04	0.846	

Table 4.5.2 Factors influencing proportion of WCP sites occupied by breeding Stock Dove, Jackdaw and Kestrel 2000-2005 with over-winter temperature included in the model. It was not possible to combine these models due to the significance of the correlation between temperature and precipitation during the winter period. Directions of significant linear relationships are given in the right-hand column. In the 'Box type' row, 'P' = Polebox design, 'S' = Square box design and 'A' = A-frame box design. In the 'Paired box' row, PD = paired and 'UN = unpaired boxes.

Occupancy rates of Stock Dove, Jackdaw and Kestrel have all increased significantly at WCP sites since monitoring started in 2000 (Tables 4.5.2 and 4.5.3). Box type significantly influenced Jackdaw and Kestrel occupancy, with both species exhibiting a preference for the multi-chambered pole-boxes over the A-frame design, and Jackdaw were more likely to be found at sites where pairs of boxes had been erected. Once these factors had been controlled for, it was possible to investigate the influence of region, habitat and winter weather on site occupancy. Occupancy rates of Jackdaw, Stock Dove and Kestrel exhibited latitudinal variation, with the former two species found more frequently at BOMP sites in the north of Britain and the latter more commonly observed at sites in the south. Habitat did not influence occupancy rates of any of the three species, but Stock Dove occupancy rates were significantly higher following cold, wet winters.

	DF	X^2	P	Direction
Stock Dove (N = 1044)				
Year	1	12.09	<0.001	+
Northing	1	4.35	0.037	+
Easting	1	3.01	0.083	
Primary habitat	2	0.51	0.777	
Box type	2	0.26	0.877	
Paired box	1	0.01	0.931	
Over-winter precipitation	1	10.32	0.001	+
Jackdaw (N = 1044)				
Year	1	28.64	<0.001	+
Northing	1	9.47	0.002	+
Easting	1	0.17	0.683	
Primary habitat	2	4.25	0.119	
Box type	2	10.34	0.006	P > S > A
Paired box	1	11.40	<0.001	PD > UP
Over-winter precipitation	1	0.51	0.474	
Kestrel (N = 895)				
Year	1	12.62	<0.001	+
Northing	1	12.30	<0.001	-
Easting	1	0.03	0.854	
Primary habitat	2	1.84	0.398	
Box type	1	33.75	<0.001	P > A
Paired box	1	3.32	0.068	
Over-winter precipitation	1	0.08	0.773	

Table 4.5.3 Factors influencing proportion of WCP sites occupied by breeding Stock Dove, Jackdaw and Kestrel 2000-2005 with over-winter precipitation included in the model. It was not possible to combine these models due to the significance of the correlation between temperature and precipitation during the winter period. Directions of significant linear relationships are given in the right-hand column. In the ‘Box type’ row, ‘P’ = Polebox design, ‘S’ = Square box design and ‘A’ = A-frame box design. In the ‘Paired box’ row, PD = paired and ‘UN = unpaired boxes.

No difference in occupancy rates between 2004 and 2005 or between habitats was observed for Stock Dove, Jackdaw or Kestrel (Table 4.5.4). Both Stock Dove and Kestrel exhibited a significant southerly bias in occupancy and Stock Doves were also found more frequently at boxes which did not contain breeding Barn Owls.

	DF	X^2	P	Direction
Stock Dove				
Year	1	3.21	0.073	
Northing	1	16.30	<0.001	-
Easting	1	1.56	0.212	
Primary habitat	2	1.36	0.508	
Paired box	1	4.65	0.031	PD > UN
Jackdaw				
Year	1	0.56	0.456	
Northing	1	2.57	0.109	
Easting	1	0.25	0.619	
Primary habitat	2	5.87	0.053	
Paired box	1	0.57	0.452	
Kestrel				
Year	1	1.35	0.245	
Northing	1	10.46	0.001	-
Easting	1	0.09	0.767	
Primary habitat	2	1.44	0.487	
Paired box	1	1.59	0.207	

Table 4.5.4 Factors influencing proportion of BOMP Network sites occupied by breeding Stock Dove, Jackdaw and Kestrel 2004-2005 (N = 513). Directions of significant linear relationships are given in the right-hand column. In the 'Paired box' row, PD = paired and 'UN = unpaired boxes.

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 (*pers. comm*.) estimates that this has now increased considerably. 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 Occupancy rates

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 (Figure 4.2.1). Such declines in occupancy over time could be an artefact of the non-random selection of monitoring sites. If BOMP 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. The proportion of occupied boxes containing breeding Barn Owls 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 the sampling method used by WCP at the outset of this project which adopted a stratified sampling method in the selection of sites to include those which had been used by breeding Barn Owls in the past, those used only for roosting and those which had never been used. In addition, WCP sites have been monitored for two additional years (2000 and 2001) – if occupancy levels were artificially inflated at the start of the project but then decrease over time until they reach a more 'natural level', those at WCP sites might be predicted to be lower.

The proportion of BOMP sites occupied by Barn Owls decreases as winter precipitation increases. Cold, wet weather may impose increased thermoregulatory costs on wintering birds while simultaneously reducing both the availability of small mammal prey (Hornfeldt 1994) and the ability of Barn Owl to hunt successfully. Measurements of precipitation during winter are also likely to correlate positively with snow cover, which may itself reduce hunting efficiency as rodents can forage unseen and Barn Owls are ill-equipped to plunge through the snow layer to catch prey, unlike some northern owls such as the Great Grey Owl (*Strix nebulosa*). The results of this analysis suggest that wet or snowy weather during winter leads to a reduction in mean body condition, such that fewer individuals either survive or are in sufficient condition to occupy and defend their nest sites during the following spring (Hardy *et al*. 1981, Shawyer 1987). The fact that female Barn Owls at WCP sites were lighter following wetter winters suggests that precipitation may indeed have a negative impact on energy reserves of adult birds at the beginning of the following breeding season. This could also explain the observed reduction in the proportion of occupied sites following cold, wet winters, as Shawyer (*in prep.*) has found that females below a threshold weight (approximately 345g) are unlikely to produce eggs even if they have occupied a nest site.

At least two other studies since those of Shawyer (1987), including one in Scotland (Taylor 1992) and one in Utah (Marti 1994) have identified a negative relationship between the number of breeding pairs of Barn Owl and the weather conditions over the previous winter. In both cases the weather parameter used was snow cover, although the mechanism proposed by Marti was actually increased adult mortality rather than suspension of breeding. However, 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.

Overall presence and breeding occupancy also vary geographically. 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 the body condition as discussed above.

5.2 Productivity

Although analysis of the BOMP productivity data did suggest that brood sizes have increased and that laying has become earlier over the six-year study period, the significance of these trends was dependent on which weather variables were included in the model and neither trend was supported by the analysis of NRS data over the period 1980-2005. Evidence for significant regional variation in productivity was similarly weak, with some suggestion that clutch sizes were greater in the south of Britain (BOMP data) and that brood sizes were larger towards the east (NRS data). The observation that laying dates were earlier at WCP sites than at BOMP Network sites is probably an artefact of differences in the timing of nest visits made by recorders. The accuracy of laying date estimation is greater for nests visited when the female is on eggs or young chicks – if nests are only visited when the chicks are at ringing age then the back-calculation of laying dates is unlikely to be accurate enough to allow the estimate to be retained in the model (i.e. within a range of 10 days – Section 3.5.2). As WCP sites tend to be visited earlier in the year, laying dates can be accurately estimated for a greater proportion of early nests and they therefore gain greater representation in the dataset.

The relationships identified between habitat type and productivity were more consistent between models. Clutch sizes at BOMP sites in areas of natural grassland were significantly greater than those in farmland areas, and brood sizes displayed a similar pattern in both the BOMP and the NRS datasets. These results may 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 than in agricultural areas where the distribution is generally limited to uncultivated or un-grazed field margins.

There was some evidence to suggest that weather conditions during the winter influenced the productivity of breeding attempts as well as the proportion of pairs breeding. Analysis of the BOMP dataset indicated that owls laid earlier following warmer, drier winters and analysis of both the BOMP and NRS datasets demonstrated that brood sizes were larger following drier winters. These relationships are as expected if adults are more energetically stressed during inclement weather, due either to the increased costs of thermoregulation, a decreased ability to hunt or a reduction in the food supply. Females may therefore take longer to reach breeding condition in the following spring, resulting in delayed laying. This hypothesis was supported by the unusually low weights of a large proportion of adult female Barn Owls captured by WCP at BOMP sites during April 2003 (Colin Shawyer, *pers. comm.*), all of which failed to breed during that particular season, and by the negative relationship between female weights and precipitation reported in this analysis.

Analysis of NRS data also supports the hypothesis that winter weather can impact on productivity during the following breeding season as mean brood sizes were found to be smaller following wetter winters. Adults in poorer condition may not only lay fewer eggs but may also be able to invest less energy in provisioning the offspring that they do produce, leading to brood reduction. Several other studies have identified correlation between winter weather conditions and productivity, including one previous analysis of NRS data (Percival 1990), which identified a negative influence of snow cover, temperature and rainfall on clutch size and nestling survival. However, neither de Bruijn (1994) nor Marti (1994) identified any relationship between snow cover and productivity within their study populations. Shawyer (1987) found that annual peaks in the duration of snow cover (a consequence of high winter precipitation and low temperature) between 1914 and 1985 were negatively correlated with the number of Barn Owls ringed (mainly pullus) during these years, suggesting that inclement weather acts to reduce occupancy and/or productivity.

Conversely, there was very little evidence that weather conditions during the breeding season had any significant influence on productivity, although increased chick mortality during short periods of extreme conditions in some years were reported (Shawyer *pers. comm.*). The only relationship identified was a counter-intuitive negative correlation between breeding season temperature and brood size. It is difficult to explain why brood sizes should be lower during warmer breeding seasons, but it may be possible that cloud cover is positively correlated with spring temperatures and that hunting success is higher during clear, moonlit nights. Alternatively, warmer temperatures may promote vegetation growth, making it more difficult for owls to catch their prey in long grass.

5.3 Barn Owl breeding success and climate change

The UK Climate Impacts Programme (UKCIP) was set up by DEFRA in 1997 to co-ordinate research into the repercussions of climate change at a national level. 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. Whilst the UKCIP02 report 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 by more than those in winter and spring, rainfall is likely to decrease during the summer months, but increase during the winter, with intense periods of winter rain becoming more frequent. The results of these analyses suggest that increasing winter precipitation may have a pronounced effect on Barn Owl productivity, with a reduction in the proportion of pairs breeding, delays in laying and a reduction in average clutch and brood sizes, which may in turn have a negative impact on the size of the Barn Owl population in the UK. If we are correct in our assumption that the size of small mammal populations is positively correlated to rainfall bat the start of the breeding season, the warmer, drier springs predicted may further reduce food availability and therefore productivity.

5.4 Occupancy rates of other species

The proportion of sites occupied by breeding pairs of Stock Dove, Jackdaw and Kestrel all increased at WCP sites over the period 2000-2006. This result could reflect the increasing population sizes of all three species over the last five years as detected by the Breeding Bird Survey (Baillie *et al*. 2005). Alternatively it may suggest that the declines in Barn Owl occupancy allowed the other species to utilise a greater proportion of sites. However, our results indicate that the presence of breeding Barn Owls displays a negative relationship with Jackdaw occupancy rates only, and it is possible that even this could be due to Jackdaws excluding Barn Owls from boxes by blocking the entrances with their nests rather than vice versa (although sites at which this is known to have happened were removed from the analysis – see Section 3.5.1).

All three species also displayed latitudinal variation in occupancy rates. Kestrel was recorded at a greater proportion of sites in southern Britain (WCP and BOMP Network sites) and Jackdaw recorded at a greater proportion of sites in the north (WCP sites). While atlas data (Gibbons *et al*., 1993) suggest that these results might reflect an actual bias in the 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. The results for Stock Dove are even less easily interpreted, as occupancy increased with latitude at WCP sites but decreased with latitude at BOMP Network sites, possibly reflecting differences in the geographic coverage of the two datasets.

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, both Stock Dove (BOMP Network) and Jackdaw (WCP) 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.

Winter weather conditions were found to influence the occupancy rates of Stock Dove at WCP sites, but not of Jackdaw or Kestrel. Contrary to predictions based on potential survival rates, occupancy rates were actually higher after cold, wet winters. As such conditions are unlikely to be directly beneficial to Stock Doves, these results may suggest that they benefit from reduced competition following harsher winters as fewer Barn Owls are occupying nest sites themselves.

5.5 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.

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