



BTO Research Report No. 557

**The BTO Barn Owl
Monitoring Programme:
2000-2008**

Authors

D.I. Leech, C.J. Barimore, C.R. Shawyer & S.E. Newson

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D.I. Leech, C.J. Barimore, C.R. Shawyer & S.E. Newson

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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 being 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 of:

Monitoring 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 across five regions of England. In 2002, a network of volunteer ornithologists began gathering additional information at 'BOMP Network' sites over a wider geographical area.
- 1.3 This report reviews data collected over the first nine years of the survey period (2000-2008). Rates of occupancy are investigated, along with breeding statistics, in relation to year, geographical location, main habitat type and weather conditions.
- 1.4 In 2007, 190 sites were monitored by WCP and a further 475 were visited by BOMP Network volunteers, while in 2008, WCP monitored 191 sites and the BOMP Network monitored 572. 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 widely distributed within the UK, including sites 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 nine years of the study, as has the proportion of occupied sites at which Barn Owls bred. This may indicate a decline in Barn Owl populations over this period, but appears more likely to be an artefact of biased selection towards occupied sites at the beginning of the BOMP Network establishment or of increasing nest site availability over time.
- 1.6 Weather conditions have previously been reported to affect both Barn Owl abundance and the proportion of pairs that are in sufficient condition to breed, with cold, wet weather during the winter reducing the availability of small mammal prey and the ability of Barn Owl to hunt successfully. Analyses using national temperature (Central England Temperature) and rainfall (England & Wales Precipitation) datasets suggest that the proportion of sites at which owls were present was reduced following cold, wet winters and that the proportion of occupied sites at which the birds attempted to breed was also lower. These results suggest that a reduction in body condition during inclement winters, results in the suspension of breeding during the following breeding season and possibly to an increased mortality rate.
- 1.7 Weather conditions also had a significant effect on Barn Owl productivity, with females laying earlier and producing larger clutches and broods after warmer winters. Such a relationship is expected if inclement weather increases thermoregulatory costs, reduces hunting efficiency or opportunity or reduces the abundance of prey species, thereby negatively influencing body condition. This may be supported by the finding that female weights at WCP sites were lower following colder winters. Adults in poorer condition may reduce their investment in reproduction during the following season. Alternatively, harsh

winters may reduce the size of prey populations the following spring, reducing food availability during the breeding season.

- 1.8 Site occupancy rates were significantly higher and clutch and brood sizes were significantly larger at BOMP sites in areas of natural grassland, relative to sites in arable and pastoral areas. These results are likely to reflect inter-habitat variation in the density of prey species, particularly Field Vole (*Microtus agrestis*).
- 1.9 Occupancy rates were also influenced by geographic location. Sites towards the north of the UK were more likely to record Barn Owls. This may either be a response to lower densities of nest sites in these regions (Toms *et al.* 2000), although climate and habitat quality may also vary with longitude, thus influencing population sizes.
- 1.10 The proportion of sites occupied by breeding pairs of Stock Dove fell at WCP sites over the period 2000-2008. It is uncertain whether this trend is representative of actual changes in abundance at surveyed sites or is a result of an increase in nest site availability in the wider countryside.
- 1.11 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 2008* (Eaton *et al.* 2009a) that reports the current status and trends of bird populations in the UK.

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, because it is largely nocturnal, is not vocal and occurs at low densities. To overcome these problems, BOMP methodology asks participants to visit known nest sites on an annual basis to determine whether Barn Owls are breeding and to collect information on breeding success. These data are collated at the BTO each year and analysed, with the aim of producing annual trends in occupancy rates and 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.* 2009a). This report presents an analysis of the first nine years of BOMP data (2000-2008).

2.1 History of Barn Owl population surveys in the UK

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

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

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

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

not identical, it was not clear whether or not a further decline had occurred between these two surveys. It is important to note that these two surveys were specifically designed to be carried out over a 3-4 year period: the difficulty of assessing trends between annual surveys having been emphasised by the finding that, in southwest Scotland, numbers of Barn Owl pairs which breed can more than double across a single three- to four-year cycle of vole abundance (Taylor *et al.* 1988).

2.2 Conservation status of the Barn Owl

Although the UK Barn Owl population may have declined slightly or remained essentially stable in recent decades, there is 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, BirdLife International 2004). 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 is included in Schedule 1 of the Wildlife and Countryside Act 1981, affording it protection by special penalties at all times. In 2002 it was included on the Amber List of Birds of Conservation Concern (Eaton *et al.* 2009b) 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 over 40 local Biodiversity Action Plans under Local Agenda 21 of the International Convention on Biodiversity.

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

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

The lack of an ongoing, annual monitoring scheme for Barn Owl has hampered the assessment of national population trends and, consequently, of the success or otherwise of local conservation measures. Annual monitoring of this species is particularly important given its inclusion on the UK Government’s Farmland Bird Index of Sustainable Development and the Government’s Publics Service Agreement target to reverse the decline in the index by 2020. Furthermore, concerns about

the use of newer types of rodenticide as well as other pesticides require the ability to detect, at the earliest opportunity, any widespread detrimental impact of poisoning through annual monitoring of Barn Owl populations, their breeding performance and survival. In addition, a carefully designed monitoring programme can help identify whether any changes in abundance are driven by changes in breeding performance or survival, and link these demographic processes to likely causal factors in the environment, such as habitat or climatic change.

2.3 Potential impacts of weather conditions and climate change

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

The latest scientific evidence suggests that there are a range of possible climate outcomes for given emissions trajectories (Murphy *et al.* 2009). These ranges are wide and may change in future as the science develops further. The latest UK Climate Projections (UKCP09) make this explicit by providing a range of projections of the future climate with associated probabilities, based on the strength of evidence provided by current knowledge, climate modelling capability and using expert judgement. These projections suggest that the UK is likely to experience an increase in seasonal temperatures, more so in summer than in winter. For example, the projections give a range of summer average temperature increases for the south-east of England of between 2 and 6.4°C by the 2080s (2070-2099) under a medium emissions scenario. In contrast, increases in winter mean temperature are given as +3 (1.6-4.7) °C (Murphy *et al.* 2009). As well as rising temperatures, climate change is likely to lead to changes in the number of extreme events: specifically, increases in hot days (nationwide and particularly in south east England) and decreases in frost days (greatest where frost days are currently more frequent).

Such changes in weather conditions may have important consequences for the UK Barn Owl population. One of the first steps in attempting to predict the impact of such climatic changes is to investigate the current relationships between weather parameters and population processes. The BOMP dataset provides an excellent opportunity to explore such associations and the results of analyses of both BOMP and Nest Record Scheme (NRS) data with respect to weather conditions are contained within this report.

2.4 Aims and work plan of the Barn Owl Monitoring Programme

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

To monitor Barn Owl populations – through standardised recording of nesting rates, breeding performance and survival at a set of Barn Owl nest sites that 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 can be monitored on an annually basis.*
- *To assess change in the number of breeding attempts, using site occupancy rates.*

- *To monitor breeding productivity of Barn Owls, using standardised nest recording methods.*
- *To monitor survival rates and dispersal of Barn Owls, through the ringing of chicks and adults.*
- *To examine breeding performance and site occupancy in relation to environmental variables, in particular broad-scale 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 up 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.

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 work closely 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.

This report presents an update of results from the first nine seasons of BOMP (2000-2008).

3. METHODS

3.1 Overall strategy of BOMP

Barn Owl biology and behaviour means that this species is most easily surveyed by monitoring 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 also allow measures of productivity to be recorded and for adult and young Barn Owls to be ringed, 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 The Wildlife Conservation Partnership (WCP). Additional studies carried out at WCP sites have contributed to the methodological development of the scheme.

It should be noted that nest site occupancy provides a minimum estimate of Barn Owl abundance in a specified area, because 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 a useful indicator of Barn Owl status and population trends.

BOMP's collection of detailed breeding performance and survival information complements 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). 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 that were only visited during late chick stage and those that received multiple visits. Taylor also noted that site fidelity was high, with only 0.9% of males and 5.6% of females changing nest sites between consecutive breeding seasons. We are confident, therefore, that nest site inspections will not compromise the welfare of Barn Owls, nor the integrity of the data gathered, provided that they are carried out following the protocols described in BOMP's Barn Owl Fieldwork Guidance Notes. These guidelines, which have been given to all BOMP participants, build upon those in the *Nest Record Scheme Handbook*, which themselves have been followed successfully for many years by nest recorders (Crick *et al.* 1999), and also draw upon 25 years of WCP field experience. The guidelines appeared as an Appendix in a previous annual report (Leech *et al.* 2005b).

3.2 Study sites

Each BOMP study site is an actual or potential nest site for a single pair of Barn Owls. Where two or more sites are in close proximity, and likely to be used by the same pair of owls, they are registered

separately but their linkage, or pairing, is also recorded. Barn Owl nest boxes are often positioned in pairs, and in some instances paired boxes are occupied simultaneously by the same pair of owls, either roosting apart or with one containing old young from the first brood and the other eggs from a second brood.

As there is a relatively high turnover of 'natural' sites, due for example to the felling of hollow trees for reasons of human safety, to barn conversions, to the shifting location of bale-stacks and waterlogging of natural sites, and because accurate recording of eggs and young is often difficult at natural sites where nests are located within deep cavities, observers are encouraged to target nest-box sites. As a result of this and the fact that natural sites are becoming increasingly uncommon in the UK, almost all of the sites that have been registered for BOMP are nestboxes. The widespread distribution of nestboxes clearly highlights the extent of the public's interest in Barn Owls (Project Barn Owl estimated that there were some 25,000 boxes in the UK; Toms *et al.* (2000) and Shawyer (2008) now estimates that about 75% of Barn Owls in the UK now breed in nestboxes. Their occupation indicates the benefit that conservation measures targeted at restoring foraging habitat, coupled with the provision of artificial nest sites, have had for the species. Many individuals who install nestboxes generally inspect them too. BOMP provides a framework for collating such observations, ensuring that the data are recorded according to a recognised standard thereby maximising the benefit derived.

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

Prior to the 2000 pilot survey, 125 sites were selected by WCP to be visited 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, being similar to pole-boxes but mounted in trees. WCP also monitors a further 75 supplementary ('extra') sites that have been included in the programme since 2002.

Because of the regional nature of WCP activities, and because most BTO volunteers have registered several sites within their home areas, there is substantial geographical clumping of sites. Although BOMP is intended to be a national programme within the UK, no sites have yet been registered in Northern Ireland, probably a consequence of the Barn Owls scarcity there (Scott *pers. com.*).

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

3.3 Fieldwork methods

Monitoring at BOMP Network sites is carried out at two possible 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 of surrounding area:* The habitat surrounding the site is recorded using the standard BTO habitat codes (Crick 1992), which incorporates 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 regarding 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).

- *Ringling 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 7th 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 been developed using the length of the relaxed wing chord (Shawyer *pers comm.*).
- *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 being assessed.
- *Measurement of dead chicks (length of 7th primary)*: primary feathers are generally very resilient and therefore can be useful in estimating the age at which any dead chicks died.
- *Ringling 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 |
|---------------------------------|---|
| <i>Late April to mid May</i> | Site occupancy Count eggs and any chicks just hatched Catch and ring adults Identify moulted feathers |
| <i>Mid July to early August</i> | Count chicks at 6-8 weeks old Ring chicks Identify whether second broods begun Collect / identify moulted feathers |
| <i>October</i> | 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, which also includes 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).
- 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 *pers comm.*)

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.

3.4 Data collation

WCP data were recorded on standard paper forms developed during the first year of BOMP (Leech *et al.* 2005b, Appendix 2). BOMP Network data have been 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).

3.4.1 Incorporation of BOMP sites into the NRS

Whilst the data collected by BOMP participants and NRS volunteers is largely the same, the format is not identical and as a consequence have been loaded into two distinct databases. To ensure that BOMP and NRS productivity data for Barn Owl could be pooled easily each year, it was decided in 2007 that BOMP nest contents data should be submitted on Nest Record Cards or ideally electronically via software designed for this purpose, known as Integrated Population Monitoring Reporter (IPMR). These data are then 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). For this each BOMP participant was 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 noted for each record together with a letter indicating the number of the brood (A = first brood, B = second brood, etc.). By doing this, it 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 approach is that it allows BOMP records to be checked easily for inconsistencies using standard data checking programs that 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).

3.5 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.

From the 2004 season onwards, BOMP Network participants were able to record the identity of registered sites that were located within 500m of each other. If these sites were not occupied simultaneously by breeding Barn Owls at any point during the study period, these were treated as paired sites for the purpose of 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 these analyses the midpoints between earliest and latest possible FEDs were used to provide a measure of laying date uncertainty 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

For determining clutch size, it is important to know whether egg-laying has finished or not. Thus records were omitted from these analyses if nests were only visited once, if they 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 eggs (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 imprecisely estimated as ‘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 BOMP.

3.5.4 Data for repeat broods

Because second broods are likely to be unrecorded by BOMP and that 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.

| 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. The records were then allocated to broad habitat categories as indicated in Table 3.6.1.

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 comparable with the distribution of BOMP sites. Mean monthly values for these variables were obtained from the Hadley Centre for Climate Prediction and Research (<http://hadobs.metoffice.com/hadcet/data/download.html>) for the years 2000-2008 (BOMP data).

For the analyses of occupancy rates here, mean annual values of CET and EWP over the period November-March were included in the models to investigate the influence of winter weather nest box occupancy 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 1990-2008 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 nest box 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. As the dataset included information from the same nest sites in several different years, a repeated measures GENMOD procedure was used, with a site identifier as the repeated variable and specifying an autoregressive correlation function. Barn Owls are a relatively long-lived species (mean life-expectancy = 3 years, maximum = 13 years, Robinson 2005), and using a repeated-measures approach therefore allows us to control for the fact that the same pair might be breeding at a specific site in successive years. In all models of occupancy rates, a binomial error distribution was assumed and a logit link function was specified.

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

3.8.2 Barn Owl laying date and productivity – BOMP dataset

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

- For all analyses of laying date information, a normal distribution was assumed and an identity link function was specified, and for all analyses of clutch and brood size data, a Poisson error distribution was assumed and a log link function was specified.
- Temperature and rainfall terms were included as separate independent variables in the same model as there was no significant correlation between the two parameters either during winter ($R^2 < 0.01$, $P = 0.917$) or during the breeding season ($R^2 < 0.01$, $P = 0.994$). Temperatures during the breeding season were strongly and significantly correlated with those during the winter ($R^2 = 0.42$, $P = 0.030$), although the same was not true of the rainfall parameters ($R^2 = 0.12$, $P = 0.426$). All initial models therefore contained winter weather parameters only.

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.

As with the BOMP dataset, temperature and precipitation showed no significant correlation over the period 1980-2008, either during winter ($R^2 < 0.01$, $P = 0.801$) or during the breeding season ($R^2 = 0.05$, $P = 0.099$), 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 ($R^2 = 0.28$, $P < 0.001$), and the same was true of winter and spring precipitation parameters, although the relationship was weak ($R^2 = 0.075$, $P = 0.028$). All initial models therefore contained winter weather parameters only, although the effects of including spring weather parameters were investigated in some cases, with appropriate caveats concerning interpretation included in the text.

3.8.4 Female weight

Factors influencing the weight of female Barn Owls were investigated using repeated measures GENMOD models similar to those described in Section 3.9.1, 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'.

3.8.5 Nest occupancy by other species

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

As with analysis of Barn Owl occupancy rates, year, Northings, Eastings and primary habitat type were included as independent variables in all models. Winter temperature and precipitation were also included, again separately due to the significant correlation between the two variables (see Section 3.9.1). 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.

4. RESULTS

4.1 BOMP coverage

The 2008 season was the ninth year of data collection at WCP sites and the seventh year of data collection at BOMP Network sites. The number of both core and supplementary sites monitored by WCP has remained approximately constant since the 2002 breeding season, while the number of sites covered by BOMP Network participants has been more variable (**Table 4.1.1**).

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---------------------|------|------|------|------|------|------|------|------|------|
| WCP | 159 | 170 | 203 | 205 | 204 | 202 | 197 | 190 | 191 |
| BOMP Network | - | - | 365 | 395 | 338 | 368 | 453 | 475 | 572 |
| TOTAL | 159 | 170 | 568 | 600 | 542 | 570 | 650 | 665 | 763 |

Table 4.1.1 Total number of BOMP sites surveyed annually 2000-2008

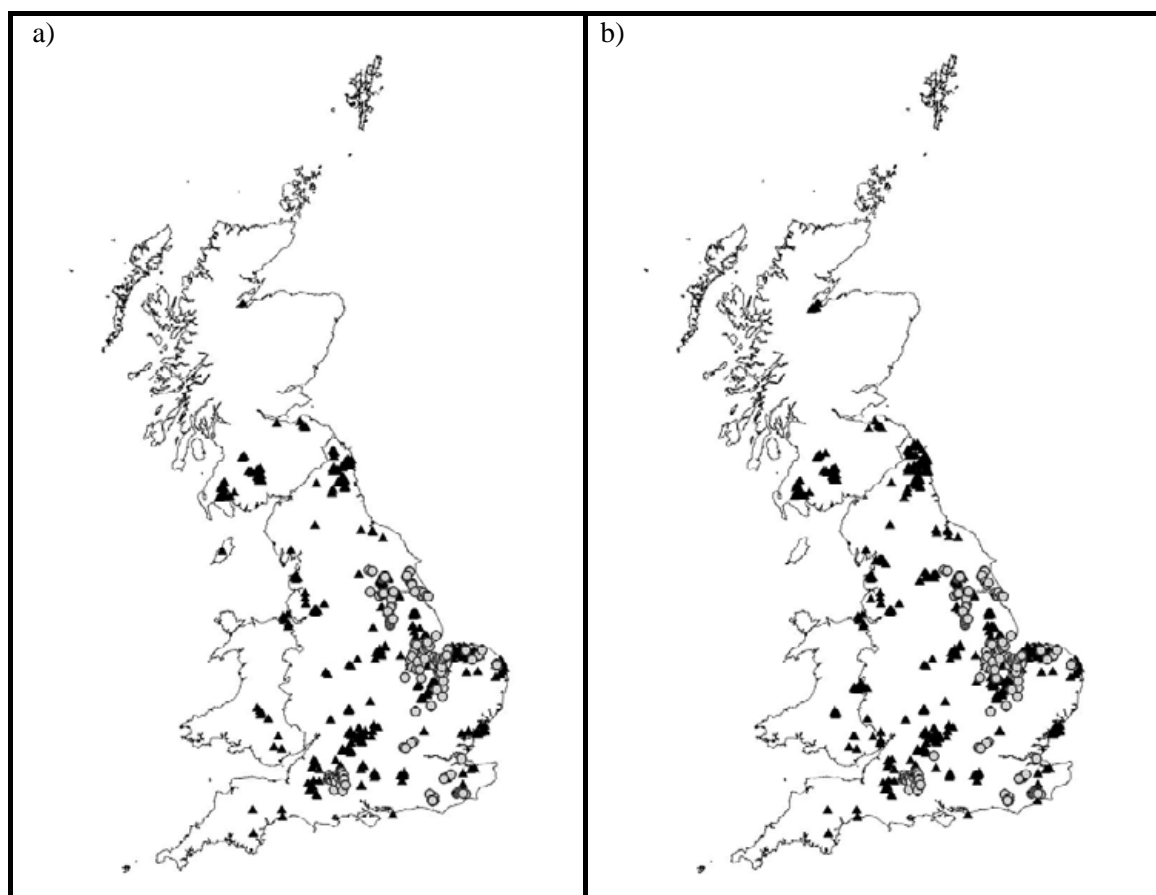


Figure 4.1.1 Distribution of WCP (grey circle) and BOMP Network (black triangle) sites monitored in a) 2007 and b) 2008.

It is encouraging to note that the number of sites monitored in 2008 was the highest in any year of the survey, thanks to both the recruitment of new volunteers and to existing volunteers expanding their coverage. **Figure 4.1.1** shows the distribution of all BOMP sites monitored in 2008. 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 2009 were located in these areas, reflecting the targeted promotional effort. Coverage in Wales remained poor even though Barn Owls breed throughout much of the country (Gibbons *et al.*, 1993).

4.2 Barn Owl occupancy rates

Factors influencing Barn Owl occupancy rates were investigated using a pooled dataset containing information from both WCP and BOMP Network sites. In total, over the nine study years, Barn Owls were present in 3309 of the 4633 sites visited (71.3%) and were found to be breeding at 2608 (56.3%) sites.

a)

| | DF | X ² | P | Direction |
|--------------------------------------|----|----------------|--------|------------|
| Site occupancy (N =4633) | | | | |
| Year | 1 | 69.34 | <0.001 | - |
| Northing | 1 | 4.02 | 0.043 | + |
| Easting | 1 | 2.54 | 0.111 | |
| Primary habitat | 2 | 8.81 | 0.012 | G > A > P |
| Site type | 1 | 0.21 | 0.649 | |
| Number of boxes at site | 1 | 0.23 | 0.635 | |
| Over-winter temperature | 1 | 95.49 | <0.001 | + |
| Over-winter precipitation | 1 | 26.08 | <0.001 | - |
| Proportion breeding (N =3309) | | | | |
| Year | 1 | 15.25 | <0.001 | - |
| Northing | 1 | 1.01 | 0.316 | |
| Easting | 1 | 0.56 | 0.453 | |
| Primary habitat | 2 | 0.30 | 0.862 | |
| Site type | 1 | 14.96 | <0.001 | BOMP > WCP |
| Number of boxes at site | 1 | 0.58 | 0.446 | |
| Over-winter temperature | 1 | 66.48 | <0.001 | + |
| Over-winter precipitation | 1 | 10.62 | 0.001 | - |

Table 4.2.1 Factors influencing site occupancy and the proportion of pairs breeding a) over the period 2000-2008 and b) over the period 2002-2008. In the 'Primary Habitat' row, 'G' indicates rough grassland, 'A' indicates arable land and 'P' indicates pastoral land.

b)

| | DF | X ² | P | Direction |
|--------------------------------------|----|----------------|--------|------------|
| Site occupancy (N =4319) | | | | |
| Year | 1 | 27.75 | <0.001 | - |
| Northing | 1 | 3.24 | 0.072 | |
| Easting | 1 | 5.88 | 0.015 | - |
| Primary habitat | 2 | 14.90 | 0.006 | G > A > P |
| Site type | 1 | 11.94 | 0.001 | WCP > BOMP |
| Number of boxes at site | 1 | 0.01 | 0.912 | |
| Over-winter temperature | 1 | 34.53 | <0.001 | + |
| Over-winter precipitation | 1 | 24.74 | <0.001 | - |
| Proportion breeding (N =3030) | | | | |
| Year | 1 | 2.95 | 0.861 | |
| Northing | 1 | 1.85 | 0.1739 | |
| Easting | 1 | 1.88 | 0.1703 | |
| Primary habitat | 2 | 0.13 | 0.937 | |
| Site type | 1 | 19.04 | <0.001 | BOMP > WCP |
| Number of boxes at site | 1 | 0.11 | 0.738 | |
| Over-winter temperature | 1 | 60.94 | <0.001 | + |
| Over-winter precipitation | 1 | 13.19 | 0.003 | - |

Table 4.2.1 (continued)

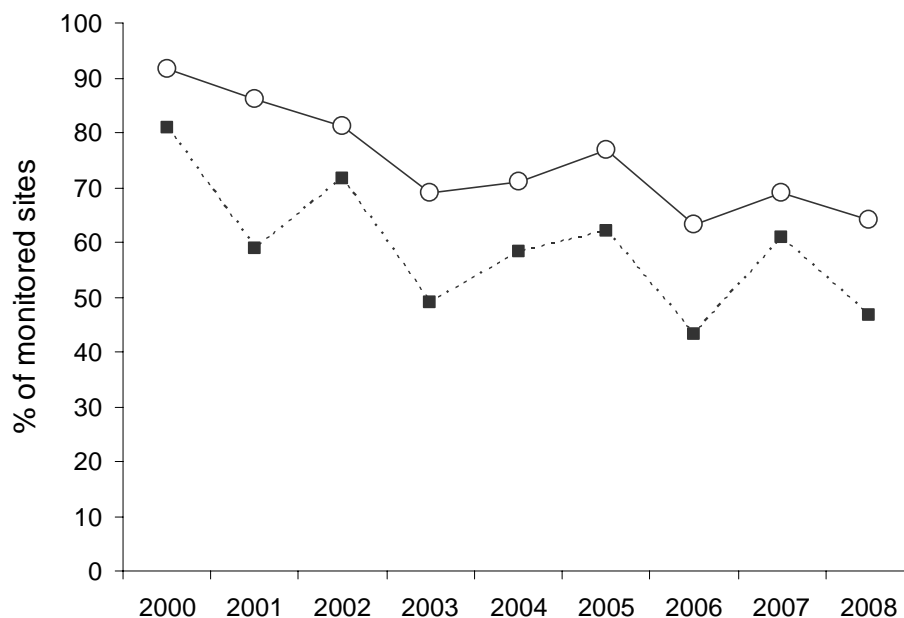
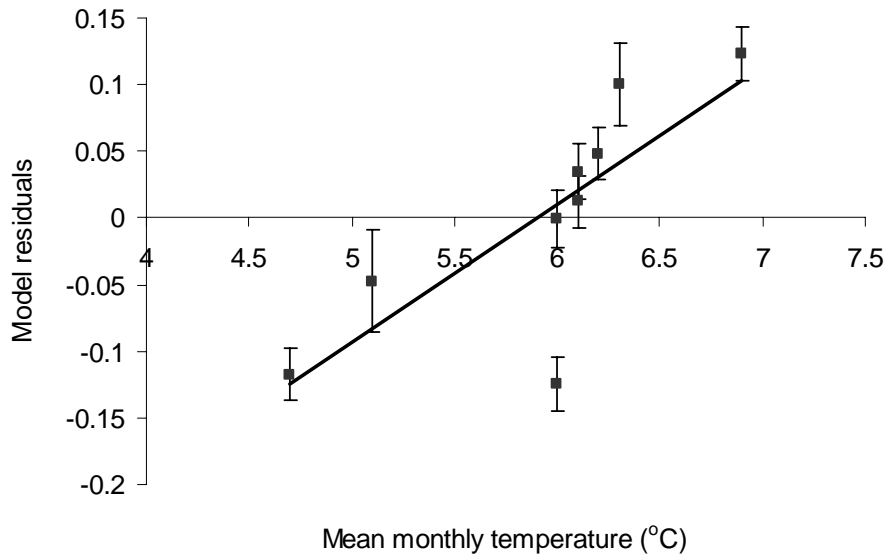


Figure 4.2.1 Annual variation in the proportion of BOMP sites at which Barn Owls were recorded as present (solid line) and the proportion of sites at which owls were recorded as breeding (dashed line).

The results presented in **Table 4.2.1** indicate that the occupancy rate of boxes has declined over the nine study years (**Figure 4.2.1**) and that this relationship holds even if the first two years of data, when information was collected at WCP sites only, are omitted from the analysis. A negative trend in the proportion of Barn Owls observed that went on to breed was also detectable when the full dataset is analysed, but disappeared when the first two years were dropped (**Table 4.2.1b**). Whilst there is some evidence to suggest that occupancy rates at WCP sites were higher than those at BOMP Network sites, the proportion of recorded pairs that elected to breed was significantly higher at the latter. The number of additional boxes at each BOMP site had no effect on the likelihood of occupancy or of breeding initiation.

a)



b)

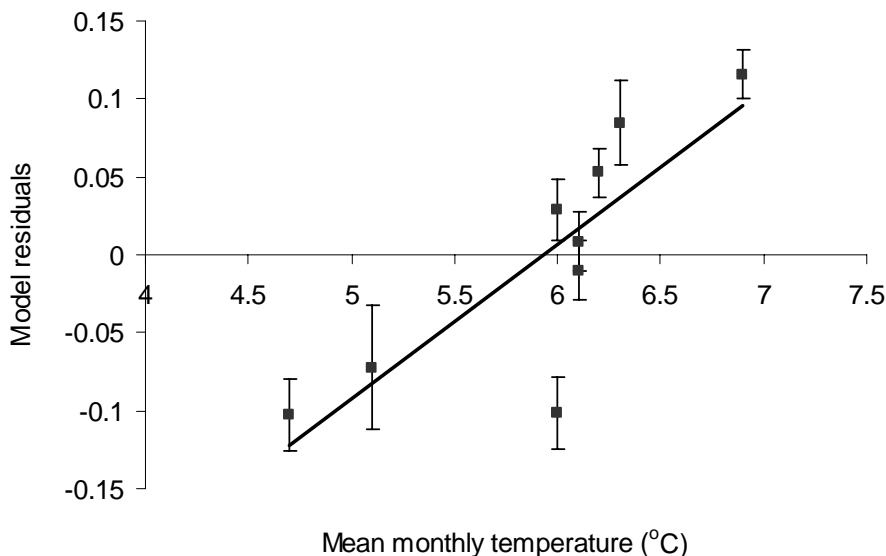


Figure 4.2.2 Relationship between mean winter (Nov-Mar) temperatures and the proportion of sites occupied by Barn Owls and b) the proportion of Barn Owls occupying BOMP sites that attempted to breed. The residuals here were generated using the GENMOD procedure, with all terms included in the model except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

There was weak evidence that site occupancy varied geographically, with birds present at a higher proportion of sites towards the north of the UK, but the proportion of birds breeding did not appear to be influenced by longitude or latitude. Habitat type significantly influenced the probability of Barn Owls being present at a site, with occupancy rates highest in rough grassland, intermediate on arable land and lowest in pastoral areas, but no significant relationship between habitat and the proportion of pairs breeding was identified. Temperature over the winter period (Nov-Mar) significantly influenced occupancy rates, with Barn Owls present at a higher proportion of boxes and a higher proportion of those individuals present electing to breed following warmer winters (**Figure 4.2.2**). Precipitation over the winter period had a significant negative effect on occupancy, with the proportion of occupied sites decreasing and the proportion of observed pairs electing to breed reduced following wetter winters (**Figure 4.2.3**).

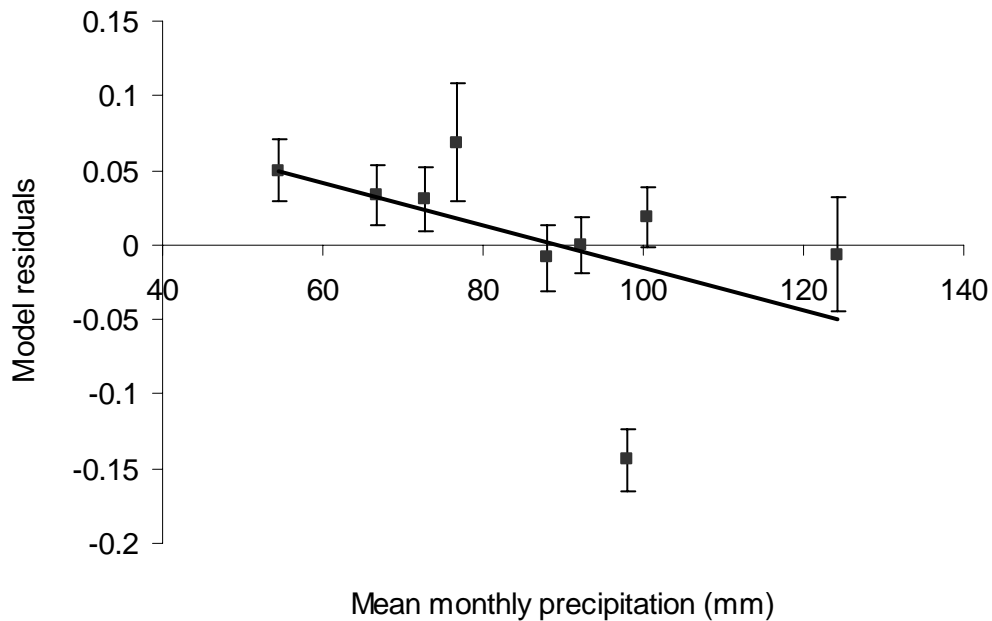


Figure 4.2.3 Relationship between mean winter (Nov-Mar) precipitation and the proportion of sites occupied by Barn Owls. The residuals were generated using here GENMOD procedure, with all terms included in the model except precipitation. Error bars signify ± 1 S.E.

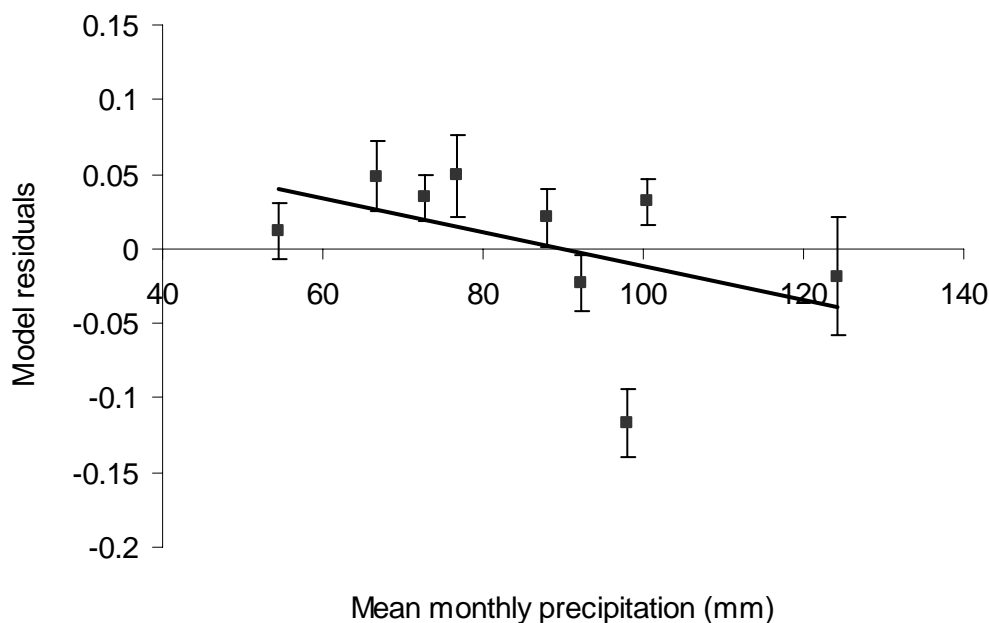


Figure 4.2.4 Relationship between mean winter (Nov-Mar) precipitation and the proportion of Barn Owls occupying BOMP sites that attempted to breed. The residuals were generated using here GENMOD procedure, with all terms included in the model except precipitation. Error bars signify ± 1 S.E.

4.3 Female weight at laying

Over the period 2001-2008, 648 females were weighed at 158 different nest sites. The results in **Table 4.3.1** show that mean weights increased with latitude and declined through the nesting cycle (with mean weights of non-breeders lower than those for breeders at any stage of egg or chick development). Weather conditions also had a significant influence of female weight, with females significantly lighter after colder, wetter winters (**Figure 4.3.1**).

| | DF | X ² | P | Direction |
|---------------------------|----|----------------|--------|---------------|
| Year | 1 | 4.56 | 0.033 | - |
| Northing | 1 | 5.49 | 0.019 | + |
| Easting | 1 | 5.01 | 0.025 | |
| Primary habitat | 2 | 3.29 | 0.193 | |
| Nest stage | 1 | 64.18 | <0.001 | E > M > C > R |
| Over-winter temperature | 1 | 11.62 | <0.001 | + |
| Over-winter precipitation | 1 | 4.32 | 0.038 | - |

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

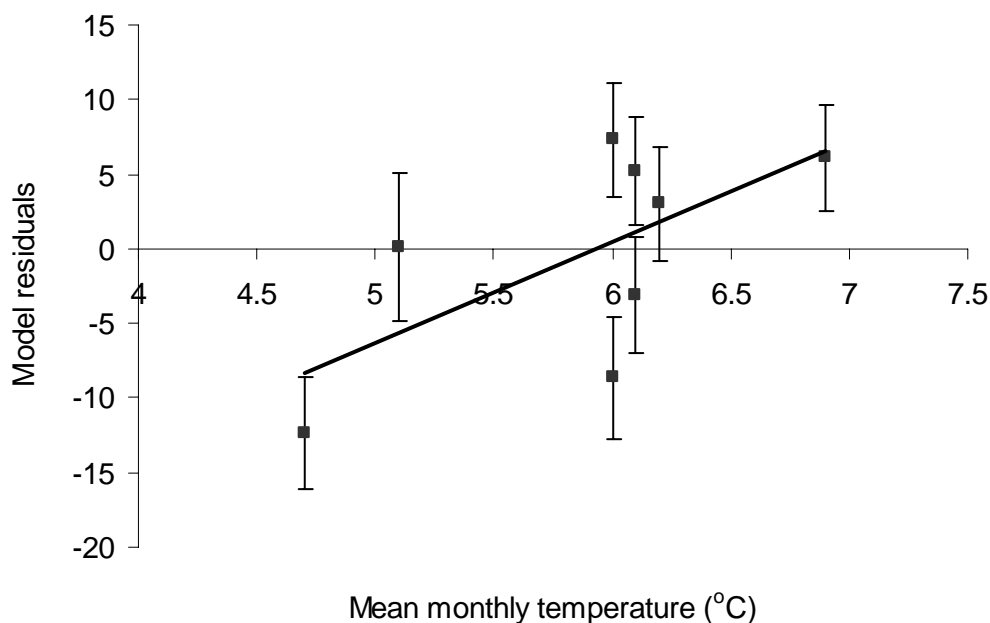


Figure 4.3.1 Relationship between mean winter (Nov-Mar) temperature and female body mass. The residuals were generated using here GENMOD procedure, with all terms listed in Table 4.3.1 included in the model except temperature. Error bars signify ± 1 S.E.

4.4 Barn Owl productivity

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

Mean laying dates demonstrated a negative relationship with study year, although a test of the relationship was not significant. Weather conditions during winter also appeared to influence the timing of laying, with laying delayed following colder, wetter winters (**Figure 4.4.1 a & b**). As winter and spring temperatures were significantly positively correlated ($R^2 = 1.012$, $P = 0.035$) it is difficult to determine which period is most important for determining timing of laying, but it is interesting to note that when terms for spring temperature and rainfall are included in the model, neither is significantly correlated with laying date while both winter weather variables remain so.

| | DF | X ² | P | Direction |
|---------------------------------|----|----------------|--------|-----------|
| First egg date (N = 620) | | | | |
| Year | 1 | 3.52 | 0.061 | |
| Northing | 1 | 0.02 | 0.897 | |
| Easting | 1 | 1.95 | 0.162 | |
| Primary habitat | 2 | 0.18 | 0.916 | |
| Over-winter temperature | 1 | 42.37 | <0.001 | - |
| Over-winter precipitation | 1 | 24.80 | <0.001 | + |
| Clutch size (N = 203) | | | | |
| Year | 1 | 0.37 | 0.542 | |
| Northing | 1 | 1.62 | 0.203 | |
| Easting | 1 | 0.11 | 0.737 | |
| Primary habitat | 2 | 4.73 | 0.089 | |
| Site type | 1 | 1.10 | 0.294 | |
| Over-winter temperature | 1 | 4.10 | 0.043 | + |
| Over-winter precipitation | 1 | 9.38 | 0.002 | - |
| Brood size (N = 1335) | | | | |
| Year | 1 | 0.72 | 0.395 | |
| Northing | 1 | 0.02 | 0.892 | |
| Easting | 1 | 0.45 | 0.503 | |
| Primary habitat | 2 | 5.64 | 0.060 | |
| Site type | 1 | 1.51 | 0.219 | |
| Over-winter temperature | 1 | 19.89 | <0.001 | + |
| Over-winter precipitation | 1 | 5.02 | 0.025 | - |

Table 4.4.1 Factors influencing productivity of Barn Owls breeding at BOMP sites 2000-2008. Directions of significant linear relationships are given in the right-hand column. In the 'Primary habitat' row, P = Pastoral, A = Arable and G = Grassland (natural).

Winter weather conditions also had a significant influence on productivity, with both clutch and brood sizes observed to be larger following warmer winters (**Figure 4.4.1 c & d**).

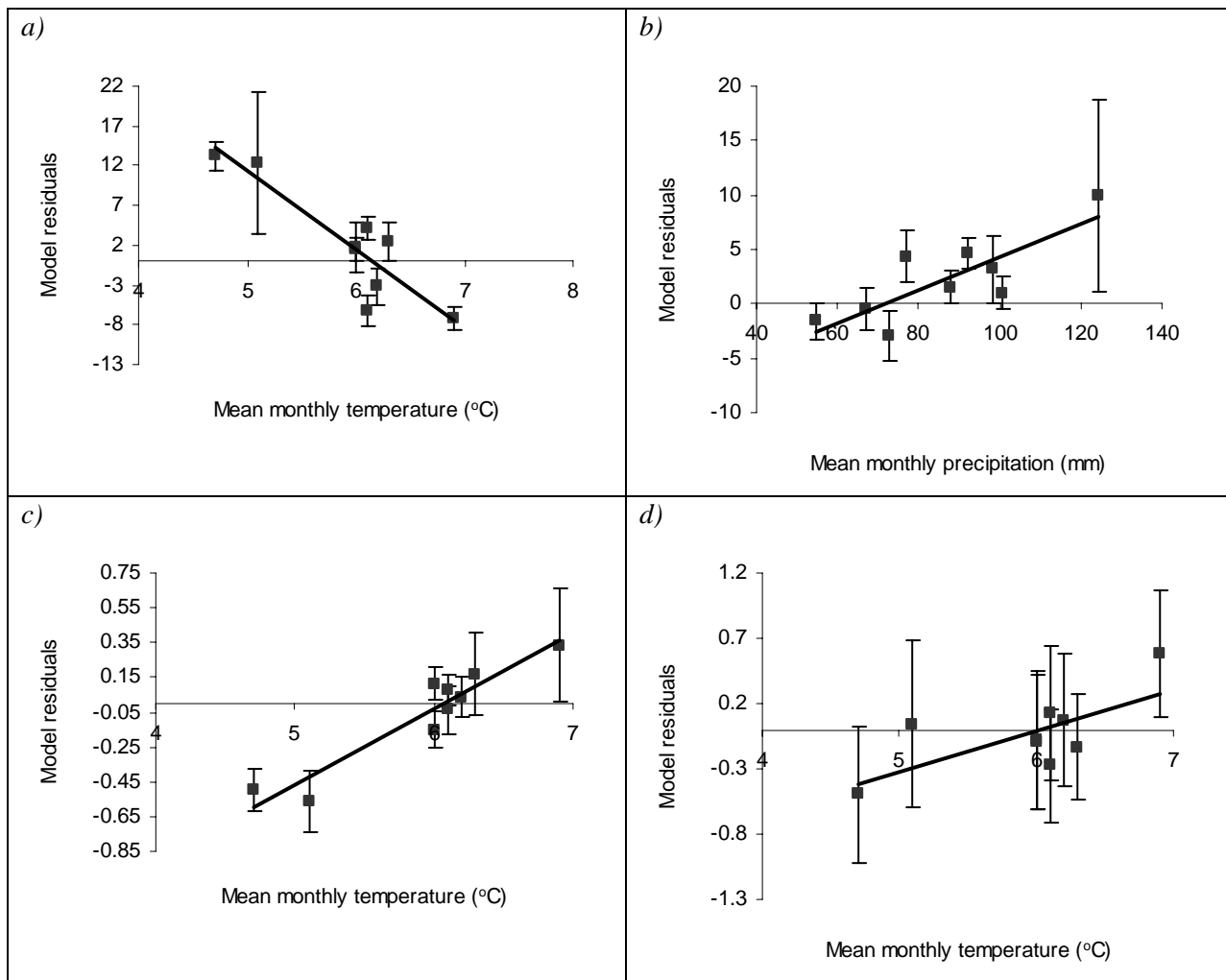


Figure 4.4.1 Relationship between a) laying date and winter temperature, b) laying date and winter rainfall, c) clutch size and winter temperature and d) brood size and winter temperature. The residuals were generated using here GENMOD procedure, with all terms listed in Table 4.4.1 included in the model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

Results from the analysis of a longer-term Barn Owl productivity dataset collected by Nest Record Scheme participants between 1980 and 2008 were largely consistent with those from the BOMP analysis, identifying a significant relationship between winter temperatures and both clutch and brood sizes (**Table 4.4.2**). Habitat type and latitude were also found to influence productivity, with Barn Owls nesting in areas of rough grassland producing on average larger clutches and broods than those on agricultural lands. No latitudinal, habitat- or weather-related variation in productivity is identifiable if the data run is restricted to the pre-BOMP period (1980-1999), suggesting that these results are driven primarily by the relationships observed during the BOMP period, when sample sizes are on average 4-7 times greater per annum.

| | DF | X ² | P | Direction |
|---------------------------------|----|----------------|--------|-----------|
| First egg date (N = 231) | | | | |
| Year | 1 | 1.04 | 0.308 | |
| Northing | 1 | 0.78 | 0.378 | |
| Easting | 1 | 1.26 | 0.262 | |
| Primary habitat | 2 | 1.33 | 0.515 | |
| Over-winter temperature | 1 | 5.05 | 0.025 | - |
| Over-winter precipitation | 1 | 0.04 | 0.842 | |
| Clutch size (N = 548) | | | | |
| Year | 1 | 0.03 | 0.871 | |
| Northing | 1 | 1.10 | 0.295 | |
| Easting | 1 | 0.00 | 0.949 | |
| Primary habitat | 2 | 0.44 | 0.506 | |
| Over-winter temperature | 1 | 5.97 | 0.015 | + |
| Over-winter precipitation | 1 | 0.44 | 0.506 | |
| Brood size (N = 3807) | | | | |
| Year | 1 | 20.45 | <0.001 | - |
| Northing | 1 | 1.25 | 0.263 | |
| Easting | 1 | 0.40 | 0.526 | |
| Primary habitat | 2 | 8.29 | 0.016 | G > P > A |
| Over-winter temperature | 1 | 53.89 | <0.001 | + |
| Over-winter precipitation | 1 | 3.55 | 0.060 | |

Table 4.4.2 Factors influencing productivity of Barn Owls as recorded by Nest Record Scheme (NRS) participants 1980-2008. Directions of significant linear relationships are given in the right-hand column.

4.5 Occupancy rates of other species

Data from BOMP sites can also be used to investigate variation in the occupancy rates of three additional species that frequently utilise Barn Owl nest sites – Stock Dove (*Columba oenas*), Jackdaw (*Corvus monedula*) and Kestrel (*Falco tinnunculus*). However, the results must be interpreted with care as there is some evidence to suggest that the effort invested in recording species other than Barn Owl varies between recorders. In addition, the probability of other species occupying the box may depend on whether the design provides additional cavities. For these reasons, a conservative analysis of occupancy rates for species other than Barn Owl, using data from a subset of Core sites at which either Pole-box or A-frame boxes are present over the period 2002-08 (**Table 4.5.1**).

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|--------------------|------|------|------|------|------|------|------|
| Stock Dove | 19% | 23% | 15% | 14% | 17% | 13% | 14% |
| Jackdaw | 24% | 26% | 21% | 20% | 23% | 17% | 27% |
| Kestrel | 17% | 12% | 14% | 14% | 13% | 13% | 17% |
| Barn Owl | 49% | 30% | 43% | 43% | 34% | 49% | 44% |
| Unoccupied | 12% | 18% | 15% | 14% | 15% | 15% | 11% |
| TOTAL BOXES | 198 | 203 | 203 | 207 | 207 | 197 | 195 |

Table 4.5.1 Frequency of use of Core sites containing either Pole-box or A-frame boxes by different species. Note that the percentage in any one year may exceed 100% because more than one species may occupy a box in a single season.

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

| | DF | X ² | P | Direction |
|---------------------------|----|----------------|--------|-----------|
| Stock Dove | | | | |
| Year | 1 | 5.45 | 0.020 | - |
| Northing | 1 | 3.52 | 0.061 | |
| Easting | 1 | 0.30 | 0.587 | |
| Primary habitat | 2 | 0.48 | 0.786 | |
| Box type | 1 | 0.44 | 0.508 | |
| Number of boxes at site | 1 | 0.19 | 0.665 | |
| Presence of Barn Owl | 1 | 0.00 | 0.958 | |
| Over-winter temperature | 1 | 2.20 | 0.137 | |
| Over-winter precipitation | 1 | 2.19 | 0.138 | |
| Jackdaw | | | | |
| Year | 1 | 1.04 | 0.308 | |
| Northing | 1 | 9.39 | 0.002 | + |
| Easting | 1 | 0.51 | 0.474 | |
| Primary habitat | 2 | 0.53 | 0.768 | |
| Box type | 1 | 15.91 | <0.001 | P > A |
| Number of boxes at site | 1 | 15.69 | <0.001 | + |
| Presence of Barn Owl | 1 | 22.11 | <0.001 | - |
| Over-winter temperature | 1 | 0.31 | 0.580 | |
| Over-winter precipitation | 1 | 3.90 | 0.048 | - |
| Kestrel | | | | |
| Year | 1 | 0.01 | 0.907 | |
| Northing | 1 | 9.30 | 0.002 | - |
| Easting | 1 | 2.53 | 0.112 | |
| Primary habitat | 2 | 1.59 | 0.452 | |
| Box type | 1 | 38.84 | <0.001 | P > A |
| Number of boxes at site | 1 | 0.16 | 0.692 | |
| Presence of Barn Owl | 1 | 0.01 | 0.920 | |
| Over-winter temperature | 1 | 0.48 | 0.489 | |
| Over-winter precipitation | 1 | 0.02 | 0.887 | |

Table 4.5.2 Factors influencing proportion of WCP sites occupied by breeding Stock Dove, Jackdaw and Kestrel 2002-2008. Directions of significant linear relationships are given in the right-hand column. In the 'Box type' row, 'P' = Polebox design and 'A' = A-frame box design.

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 2008* (Eaton *et al.* 2009a) that reports the current status and trends of bird populations in the UK. 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.* 15% of the national population of Barn Owl and with a good geographical spread, gives the results added importance. Although BOMP concentrates on nestbox sites, these are increasingly used by the species in the UK: 38% of nesting attempts recorded under Project Barn Owl in the mid-1990s were in boxes (Toms *et al.* 2000) and Shawyer (2008) has estimated that this has now increased considerably to about 75%. While the non-random nature of the sample may influence the resulting trends to some degree, we are able to control for factors such as geographical location and habitat. We therefore consider that there is every reason to expect that BOMP would detect a major real change in population and will provide information about the demographic mechanisms and environmental factors underlying any change, thus providing valuable pointers to direct effective conservation efforts.

5.1 Influence of weather conditions on occupancy and productivity

Barn Owls were present at a significantly greater proportion of BOMP sites following warmer, drier winters. Temperature and snow cover have both been observed to influence Barn Owl survival rates, particularly those of juvenile birds in Britain (Shawyer 1987), and on the Continent (Altwegg *et al.* 2003, 2006). This relationship may be the result of increased energetic costs at lower ambient temperatures, a decline in the abundance of small mammal prey, the survival of which may also be positively related to temperature (Berry *et al.* 1969, Hornfeldt 1994), the decreased accessibility of prey species due to changes in their activity patterns and the increased protection provided by the snow layer (Shawyer 1987, Pucek *et al.* 1993), or to a combination of these factors.

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

Studies of Barn Owl populations in England (Shawyer 1987), Scotland (Taylor 1992), Utah (Marti 1994) and Switzerland (Altwegg *et al.* 2006) have identified significant relationships between the number of breeding pairs of Barn Owl and the severity of weather conditions during the previous winter, although the Swiss study focussed solely on extreme winter events. While snow cover (number of days of lying snow) was the significant weather parameter identified in the majority of studies, this is likely to correlate strongly with mean air temperatures and the causal mechanisms remain unclear. A further study by de Bruijn (1994) in Holland found no effect of snow cover, nor any correlation between the number of breeding pairs and an index of winter severity.

Whilst improvements to the analyses of weather data here, to make use of spatio-temporal data are recommended in the long-term (see section 5.6), weather undoubtedly appears to influence Barn Owl

occupancy and breeding performance. In particular analysis of the BOMP dataset indicated that Barn Owls laid earlier following warmer, drier winters (Table 4.4.1), suggesting that females may take longer to reach breeding condition following harsher winters. Clutch and brood sizes were significantly positively correlated with over-winter temperatures at BOMP sites, suggesting that a reduction in condition may also lead to reduced investment in the brood, although another possible explanation might be that prey populations may be suppressed following harsher winters (Altwegg *et al.* 2006). In the absence of vole population monitoring at a national scale, it is difficult to determine which of these two mechanisms is responsible for the observed patterns of productivity.

The UKCIP09 report (Murphy *et al.* 2009) presents a series of potential climate change scenarios over a series of time scales (2020, 2050 and 2080), based on the level of emissions of greenhouse gases over this period. Under medium emissions scenarios, temperatures in the UK will rise by an average of 1.6-4.7 °C by 2080, with temperatures in summer and autumn likely to increase by more than those in winter and spring. Based on the results of these analyses, warmer winters are likely to positively impact on Barn Owls, leading to an increase in both the number of birds breeding and the mean reproductive output per pair. However, it is possible that any benefit may be offset by increasing precipitation during the winter months, with intense periods of rainfall becoming more frequent.

5.2 Spatial variation in occupancy and productivity

Barn Owl was present at a slightly higher proportion of sites in the north of Britain than in the south. 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.

Clutch and brood sizes were significantly larger at BOMP sites in areas of natural grassland, relative to sites in arable and pastoral areas. The same relationship between habitat and clutch and brood sizes was also apparent in the longer-running NRS dataset. These results are likely to reflect differences in the availability of small mammal prey, particularly Field Vole (*Microtus agrestis*), between habitats, as densities are likely to be higher in areas of rough grassland, the species' favoured habitat (Harris & Yalden 2008) than in agricultural land, where harvesting and grazing by livestock reduces those primary components of grassland, such as tussock structure, litter layer and length of sward, which are all necessary to provide Field Vole habitat (Shawyer 1998). Previous studies have shown that Field Vole population densities display a negative relationship with grazing intensity in meadows (Schmidt *et al.* 2005) and in agricultural areas, the species' distribution is generally limited to areas of set-aside or field margins, although the management practices of in these areas are not always optimised to favour voles (Harris & Yalden 2008).

5.3 Temporal trends in occupancy and phenology

Both the proportion of sites at which Barn Owls were recorded as present and the proportion of occupied sites at which Barn Owls were recorded as breeding have declined since the Programme began in 2000. While the population size of Barn Owls in the UK has not been estimated since Project Barn Owl finished in 1997, a study which takes account of the conservation work undertaken in the eastern half of England, primarily to provide foraging habitat, artificial nest sites and re-create habitat connectivity, suggests that the population has doubled in this part of Britain since 2000 (Shawyer 2008). The observed declines in occupancy since the initiation of BOMP may therefore be an artefact of the non-random selection of monitoring sites or more probably, if BOMP Network participants were more likely to select sites at which Barn Owls were known to be present or breeding in previous years, then initial occupancy rates may have been artificially inflated and a subsequent decrease might be predicted until a more 'natural' level is reached. Alternatively this may be a consequence of the increased number of nest boxes which are believed to have been installed in the vicinity of the core and network sites, since the project began. This has provided Barn Owls with alternative nest site choice and because most of these are not monitored for BOMP, may account for the apparent decline in occupancy that has been observed at the BOMP monitored sites.

BOMP data indicate that laying dates have advanced significantly over the laying period. A similar trends have been observed for many other bird species in response to a rise in early spring temperatures driven by anthropogenic climatic change (Crick *et al.* 1997, Crick & Sparks 1999).

5.4 Proportion of pairs breeding at WCP and BOMP Network sites

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

5.5 Occupancy rates of other species

The proportion of sites occupied by breeding pairs of Stock Dove fell at WCP sites over the period 2000-2008. As with Barn Owls, it may be possible that occupancy rates are declining due to the increased availability of artificial nest sites, the provision of which is increasing at a faster rate than the population is growing.

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

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

5.6 Recommendations for future analyses and data collection

Second broods. An important parameter influencing overall Barn Owl productivity may be the number and outcome of second broods. This is currently one of the biggest gaps in our knowledge. During the last ten years WCP, through the use of a sub-set of 80 sites, has been investigating the frequency of double-brooding and the relationship between female moult and first egg dates. Early laying dates and the suspension of wing moult have, in combination, been shown to provide valuable indicators of double brooding in Barn Owls. These indicators can alert fieldworkers to those sites which are worth re-visiting later in the season, specifically in July to record second clutches and October/November to record brood size and fledging success. An additional practical recommendation would be to try and encourage BOMP network contributors further to continue to monitor Barn Owl boxes late into the season, and to record whether or not they do so.

Nest survival and partial clutch / brood losses. In past analyses, an estimate of nest survival i.e. the probability of fledging one or more young has been estimated using the Mayfield method (Mayfield 1961, 1975). However, complete nest failure in the Barn Owl is rare, and it would be more useful to consider this question in terms of partial clutch and brood losses. These analyses are not straightforward, because of the need to account for non-independence of individual eggs / chicks

within nests. Some work would be needed to evaluate the options for such an analysis in relation to nest record / BOMP data.

Use of weather data. Previous analyses of BOMP data has made use of monthly Central England Temperature (CET) and England and Wales Precipitation (EWP) index data. These data have a temporal, but not a spatial component, so it is assumed that the weather is the same at all sites. More ideal would be use spatially explicit weather data, such as UKCIP09 which provides weather data at a 5-km square resolution, where appropriate weather values are matched at the individual site level. However, development to make use of these data is not trivial and currently a limitation of UKCIP09 as a data source is that these data are only publically available up to 2006.

Recording of other species. Prior to 2004, the recording of other species nesting in Barn Owl boxes was not standardised at BOMP network sites. For this reason, the analyses of other species have been restricted to WCP sites. Ideally time would be spent examining the implications of nesting by other species on the current analyses, and perhaps to consider more thorough analyses that consider all species in the same analyses.

Standardisation and extraction of Barn Owl data. Currently the various Barn owl datasets are recorded in different formats, habitat recording is not directly comparable across BOMP network volunteers, WCP and NRS. Some data are also received each year in paper form and parts from different datasets need to be appended each year to produce a dataset ready for analyses. At present the time needed each prepare data for analyses is not efficient. Further investment into BOMP would be needed to improve this, but it would save costs for this in the longer-term.

Estimates of annual survival. 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. 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.

Repeat census of UK Barn Owl population. 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.

Use of Barn Owl boxes by other species. 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. This work which is currently being trialled in England by WCP, currently involves (in 2010) 75 occupied Kestrel and 75 occupied Little Owl sites. In future years it would be worth considering whether a similar monitoring scheme to BOMP could be undertaken to cover these amber-listed species.

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