The Influence of the 2001 Foot and Mouth Disease Outbreak on Barn Owl Productivity in the UK

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1. EXECUTIVE SUMMARY

1. The Barn Owl is a scarce breeding species that underwent substantial decline in the UK during the 20th century. It is currently on the Birds of Conservation Concern Amber listing due in part to the fact that the species has declined in abundance by greater than 25% over the last 25 years, and it is subject both to a conservation action plan and to a number of local Biodiversity Action Plans.

2. In 2001, the UK was seriously affected by an outbreak of Foot and Mouth Disease (FMD), resulting in the slaughter of a significant proportion of the national herd. Large parts of the countryside were placed under access restrictions and rodenticide use increased.

3. Increased levels of activity around farms during the breeding season may have resulted in increased disturbance and reduced Barn Owl breeding performance. Increased rodenticide use could also have negatively impacted on survival rates of adults and offspring. Conversely, these potentially detrimental impacts might have been offset by reductions in disturbance following the imposition of access restrictions and the potential impact of reduced grazing pressure leading to improved grass swards and hence to larger prey populations.

4. Data concerning the location of Barn Owl breeding attempts, occupancy rates and breeding performance were collected by participants in the BTO Barn Owl Monitoring Program (BOMP), funded by The Sheepdrove Trust, from 2000 onwards. A significant amount of Barn Owl productivity data (currently 600+ records p.a.) is also collected annually by participants in the BTO Nest Record Scheme, funded by the BTO/JNCC partnership.

5. Data concerning the location of land to which access was restricted, premises at which livestock were slaughtered and premises at which FMD infection was confirmed were obtained from the Central Science Laboratory (CSL) FMD database. Data concerning rodenticide use at premises in a restricted set of counties, predominantly in the north of England, was obtained from a database held at the Rural Development Service

6. BOMP data, NRS data and the FMD datasets were mapped using the ArcView GIS mapping program. The program was then used to calculate the minimum distance between each individual Barn Owl record and the location of a farm at which access had been restricted, a farm where livestock had been slaughtered, a farm where FMD infection had been identified and a farm where rodenticides had been used.

7. The Barn Owl data were then split into two categories – records that were within 5km of farms at which FMD-related measures had taken place, and those that were greater than 5km from any such premises. The influence of FMD-related measures on occupancy and breeding performance were then analysed separately for pre-outbreak (1998-2000) and post-outbreak (2001-2003) datasets using a repeated measures GENMOD procedure in SAS, controlling for northings, eastings, year and habitat type.

8. In general the results suggested that any impacts of FMD-related measures on Barn Owl occupancy rates and breeding performance were likely to have been marginal. Although occupancy rates at the set of Core BOMP monitoring sites was lower near land with access restrictions after the FMD outbreak compared with sites further away a similar result was not found among the larger sample of BOMP Network Sites monitored by volunteers. Similarly occupancy rates were lower at BOMP Core sites near farms where slaughter had occurred than at those which were more distant, but the sample size was very small for the former category and the result was not repeated for BOMP Network Sites.

9. Interestingly, both occupancy at BOMP Network sites and clutch size at all sites was greater post-outbreak, but not pre-outbreak, near infected premises than at sites that were more

distant. It is possible that slaughter and/or disinfection took place more rapidly at these sites, reducing disturbance. In addition, clutch size was larger near sites where rodenticides were used, than at sites more distant, perhaps suggesting that rodent populations were higher at these farms, hence the need for increased control. However, it should be noted that for these analyses the sample sizes of some of the categories were relatively small.

10. Overall, on the basis of these analyses there is relatively little evidence to suggest that the FMD operations had major impacts on the Barn Owl populations using the affected farms. The results tend to be contradictory and only relatively weakly significant between different aspects of the types of FMD treatment, suggesting that other confounding factors might be affecting the results. Care should be taken when interpreting some results, significant proportion of the Barn Owl records that are within 5km of infected farms and those at which slaughter occurred originate from a relatively limited geographical area.

2. INTRODUCTION

2.1 Status of the UK Barn Owl population

The Barn Owl *Tyto alba* is one of the most widely distributed terrestrial bird species, occurring on all the continents except Antarctica (Taylor 1994). Although the Barn Owl was once considered a common species of farmland areas in Britain, the size of the population has decreased significantly over the last 150 years. An early national survey carried out by Blaker (1933) estimated the size of the population in England and Wales to be approximately 12,000 breeding pairs, and suggested that numbers had fallen over the previous 30-40 years, possibly due to increased persecution.

By the time of publication of the first Breeding Bird Atlas (Sharrock, 1976), the UK population size had decreased to between 4,500 and 9,000 pairs. Potential explanations for this continuing decline included poisoning by organochlorine pesticides present in the food chain and loss of hunting habitat.

The results of a four-year Hawk and Owl Trust survey carried out between 1982 and 1985 indicated that the size of the Barn Owl population in England, Wales and Scotland had fallen still further to c. 4,400 pairs, a decrease in abundance of 69% since Blaker's survey 50 years earlier (Shawyer, 1987). Poisoning by "second generation" rodenticides, a lack of suitable roosting and nesting sites, increased probability of collision with road traffic and severe winter weather were all potential factors implicated in this decline. Data collected between 1994 and 1997 for Project Barn Owl, a survey organised jointly by the BTO and the Hawk and Owl Trust, suggested that, by this period, the population had stabilised at approximately 4,000 breeding pairs (Toms *et al*., 2001).

The Barn Owl is currently on the Birds of Conservation Concern Amber listing (Gibbons *et al*., 1996), both due to the poor conservation status of the species in Europe (Tucker & Heath 1994), and to the fact that the species has declined in abundance by greater than 25% over the last 25 years. Within Europe its decline prompted its placement in SPEC (Species of European Concern) Category 3. In the UK, the species is subject to a conservation action plan (RSPB Species Action Plan 0735) and a number of local Biodiversity Action Plans. Data from the Nest Record Scheme indicate that nest failure rates at both the egg and nestling stages have decreased over the last 30 years. However, the latest NRS trends published in the Wider Countryside Report 2004 (Baillie *et al*. 2005) indicate that brood sizes have displayed a significant linear decline over the last 15 years.

One of the recommendations of Project Barn Owl was that there was an urgent need for the development of a monitoring scheme specifically for Barn Owls in the UK, as current range of schemes were not suitable for the species (Toms *et al.* 2000). In 2000, the BTO initiated the Barn Owl Monitoring Programme specifically to assess nest occupancy, breeding performance and survival rates at a representative set of nests in England, Scotland and Wales on an annual basis.

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

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

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

2.2 Foot and Mouth Disease

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

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

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

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

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

2.3.1 Disturbance

- Increased levels of disturbance around nesting sites, during either the disinfection of buildings or the destruction of livestock may have led to an increase in the incidence of nest desertion.

- On infected farms and on those uninfected farms where restrictions were in place, a reduction in both public access and farming activity may have resulted in decreased levels of disturbance around the nest site or hunting grounds.

- Reduced traffic in areas where access is restricted may lower the incidence of collisions with vehicles, a major cause of mortality for this species (Newton *et al.*, 1991).

2.3.2 Prey availability

- The removal of livestock and foodstuffs from buildings on infected properties, and the subsequent disinfection of the buildings involved, may have reduced the availability of food to rodent populations. A decrease in rodent numbers may have resulted in a reduction in food availability for barn owls.

- The number of rodents in farm buildings may have been reduced directly by the increased application of rodenticides in order to decrease the possibility of disease transmission between farms. While commensal rodents such as House Mice and Brown Rats, the species most likely to be affected by the above measures, seldom constitute a significant proportion of the Barn Owl's diet during the breeding season, they may constitute important prey species during the winter months (Shawyer, 1987).

- Slaughter of livestock (cattle and sheep) and the confinement of surviving animals to farm buildings or small areas of pasture led to unprecedented increases in the extent of uncropped/ungrazed grassland both on infected farms and on those properties where restrictions were in place. Such grassland may have provided better habitat for small mammals, increasing the availability of prey species for Barn Owls and thus positively influencing occupancy rates and the productivity of breeding events.

2.3.3 Poisoning

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

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

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

3. METHODS

3.1 Barn Owl datasets

3.1.1 Nest Record Scheme (NRS)

The Nest Record Scheme (NRS), funded by the BTO/JNCC Partnership, has been collecting information about the breeding attempts of UK bird species since 1939. Over 1.25 million records for 232 species are currently help by the NRS, of which over 450,000 are currently computerised.

A network of 550-600 volunteer nest recorders and recording groups across the UK submit a total of *c.* 30,000 records to the NRS each year. Each NRC details the history of a single breeding attempt at an individual nest. Observers record species, county, year, their name (or personal code), place name, 6-figure grid reference, altitude, dates of each visit, numbers of eggs or young, standardised codes to describe the development of nests, eggs, young, activity of the parents and the outcome of the nest (giving cause of any failure if known). Recorders are encouraged to visit each nest site on at least 2 occasions during the breeding period so that various breeding parameters, particularly nest failure rates (see Section 3.3.3), may be calculated. In addition, observers record specific details of the nest site and the habitat surrounding it using a set of standard habitat codes. The habitat-coding scheme (Crick 1992) is a simple-to-use hierarchical system based on vegetation structure but includes aspects of land management and human activity. The height of the nest above ground, the floristic and structural details of the nest site itself and the degree of nest exposure are also noted.

The number of nest records held for Barn Owl over the period 1998-2003 is presented in Table 3.1.1. With the exception of Wales and northern Scotland, both areas that were relatively unaffected by the FMD outbreak, national coverage is good (Figure 3.1), particularly in the FMD 'hotspots' of southern Scotland and south-western England.

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

Table 3.1.1 Total number of sites monitored by BOMP (Core only 2000/1, Core and Network 2002/3) and NRS.

Figure 3.1.1 Distribution of records received by the Nest Record Scheme 1998-2003.

3.1.2 Barn Owl Monitoring Programme (BOMP)

The Barn Owl Monitoring Programme (BOMP) was set up by the BTO in 2000 and is funded by The Sheepdrove Trust.

BOMP participants are asked to register individual Barn Owl nest sites and to visit them each year. Repeat visits throughout the breeding season (typically April-October) are encouraged as this permits the calculation of nest failure rates using Mayfield estimates (Section 3.2.3). Information about dates of each visit, numbers of eggs or young, the development of nests, eggs, young, activity of the parents and the outcome of the nest are recorded in the same format as for NRS records. In addition, as sites are visited annually whether Barn Owls attempt to breed or not (not necessarily true of NRS sites), the occupancy status (birds breeding, roosting or absent) can be also be recorded. Habitat recording at Network sites differs slightly from that of the NRS, with observers 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.

In the initial two years of the project (2000-2001), a set of Core Sites were monitored by the Wildlife Conservation Partnership (WCP) who had also erected the nestboxes initially and helped to develop the BOMP methodology. From 2002 onwards, these Core Sites were supplemented by additional Network Sites registered and surveyed by volunteer fieldworkers (Table 3.1.1). As indicated by Figure 3.1.2, by January 2004 BOMP sites had been established over much of England, Wales and lowland Scotland. The number of Network Sites continues to increase, with over 900 Network Sites currently registered for BOMP.

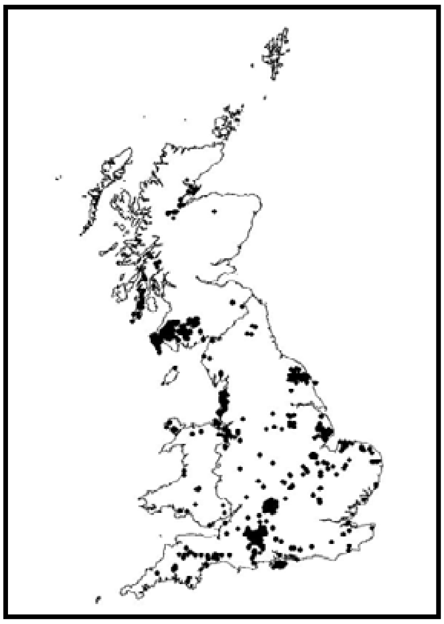

Figure 3.1.2 Distribution of Core and Network sites monitored for the Barn Owl Monitoring Programme 2000-2003.

3.2 Foot and Mouth Disease (FMD) datasets

3.2.1 Access restrictions

The central grid references of 14,715 sites at which access was prevented in 2001, defined as the serving of FMD Access Restriction Form A, were obtained from the Central Science Laboratory (CSL) FMD database (Figure 3.2.1).

Figure 3.2.1 Location of sites at which access was prevented in 2001 in response to the FMD outbreak.

3.2.2 Slaughtered livestock and infected properties.

The location of 2026 infected premises, defined as those premises for which FMD Numbers had been allocated, were obtained from the CSL database (Figure 3.2.2a). The location of all premises at which there was evidence from the dataset that livestock had been slaughtered was also obtained from the CSL database (Figure 3.2.2b). This included not only infected premises, but also those where animals had been slaughtered on suspicion of infection (N=240) and those where livestock had had dangerous contact with animals from infected premises (N=9083).

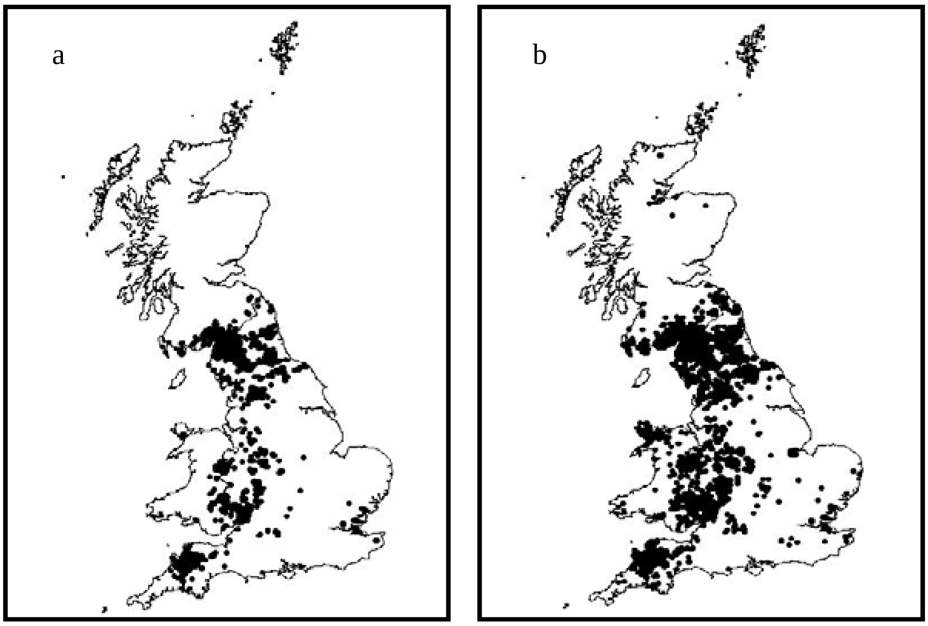

Figure 3.2.2 a) Location of farms at which FMD infection was confirmed and b) Location of farms at which livestock were slaughtered due to FMD infection, suspicion of infection or due to dangerous contact with diseased animals.

3.2.3 Rodenticide application

Detailed rodenticide data was obtained from the Rural Development Service (RDS) database for 2,283 premises in 12 counties/regions: Borders (N=2), Cheshire (1), Cleveland (16), Durham (231), Cumbria (1,309), Essex (9), Lancashire (89), North Yorkshire (411), Northamptonshire (4), Northumberland (188), South Yorkshire (1), Tyne & Wear (12), West Yorkshire (10) (Figure 3.2.3). Data had been input for all sites within these regions at which rodenticides had been applied in response to the FMD outbreak – information for other counties/regions had not been input at the time of the request. In addition to the location of properties, information concerning the timing and extent of baiting and the types of compound used were available for the majority of sites.

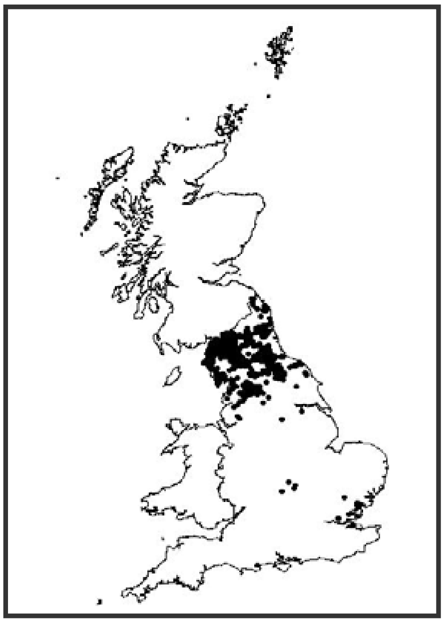

Figure 3.2.3 Location of premises at which rodenticide data were held in the RDS database.

3.2.4 Disinfection and disposal data

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

3.3 Analytical methods

3.3.1 Calculation of laying dates

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 nests (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.

3.3.2 Calculation of clutch and brood sizes

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

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

3.3.3 Calculation of nesting success

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

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

3.3.4 Matching of Barn Owl and FMD datasets

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

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

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

3.4 Statistical methods

3.4.1 FMD proximity categories

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

3.4.2 Habitat categories

A primary habitat code is associated with all BOMP Core Site and NRS records. Each record was assigned to a broad habitat category on the basis of the first two levels of the primary habitat code (Crick 1992) as indicated in Table 2.4. 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 3.4.

3.4.3 Statistical models

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

BTO Habitat Code	Description	Habitat Category
A1-A6	Woodland	WOOD
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	Farmland	MIXED
E4	Farmland	ARABLE
F1-F3	Human sites	OTHER
G1-G10	Water bodies (freshwater)	OTHER
H1-H4	Coastal	OTHER
I1-I7	Inland rock	OTHER
J	Miscellaneous	OTHER

Table 3.4 Broad habitat categories used in the FMD analysis.

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

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

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

4. RESULTS

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

4.1 Access restrictions

Occupancy rates at BOMP Core Sites within 5km of land where access restrictions had been put in place were significantly less likely to be occupied (N=119, Occupancy = 47.9%) than those that were more than 5km from restricted-access land (N=399, Occupancy = 58.7%) following the FMD outbreak (Table 4.1). The difference in occupancy rate between BOMP Core Sites within 5km of restricted-access land and those further than 5km from such land was not significant prior to the FMD outbreak (Table 4.1). However, it should be noted that the significance of this test was marginal and an equivalent comparison of occupancy rates at BOMP Network Sites did not identify a significant difference.

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

Table 4.1 Influence of the proximity of farms at which access restrictions were imposed on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

Sites greater than 5km from restricted-access land did not differ significantly from those within 5km of such land with respect to laying date, clutch size or brood size (Table 4.1). Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at either stage was too infrequent to permit analysis.

4.2 Slaughtered livestock

Occupancy rates at BOMP Core Sites within 5km of farms at which livestock had been slaughtered were much lower post-outbreak (N=14, Occupancy = 7.1%) than occupancy rates at BOMP Core Sites which were further away from such farms (N=504, Occupancy = 57.54%) (Table 4.2). The equivalent comparison prior to the FMD outbreak did not identify any such difference. However, care should be taken interpreting this result as the significance is marginal, the sample size of sites within 5km of farms at which livestock were slaughtered was very small and no significant difference was detected in the equivalent analysis of BOMP Network Site occupancy data post-outbreak (Table 4.2).

Again, neither laying date, clutch size or brood size varied significantly between sites close to farms at which livestock were slaughtered and those further away (Table 4.2). Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at wither stage was too infrequent to permit analysis.

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

Table 4.2 Influence of the proximity of farms at which livestock were slaughtered on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

4.3 Infected premises

Occupancy rates at BOMP Network Sites within 5km of farms where FMD infection was confirmed were significantly greater post-outbreak (N=96, Occupancy = 81.3%) than sites that were further than 5km from infected farms (N=630, Occupancy = 57.0%) (Table 4.3). Unfortunately, BOMP Network sites were not surveyed prior to 2002 and it is therefore not possible to repeat the analysis using pre-outbreak data. No such difference was detected between BOMP Core Sites less than 5km and those more than 5km from infected premises post-outbreak (Table 4.3), although it should be noted that the former category consisted of only 2 sites.

The results of the analyses also indicated that clutch sizes at sites within 5km of infected farms post-outbreak were significantly larger (N=20, Mean = 5.5) than those at sites greater than 5km from infected farms (N=152, Mean = 4.7) (Table 4.3). The equivalent test pre-outbreak did not identify any significant difference in clutch size between the two categories of site. Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at wither stage was too infrequent to permit analysis.

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

Table 4.3 Influence of the proximity of farms infected with FMD on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

4.4 Rodenticide application

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

Occupancy rates at BOMP Network sites post-outbreak were not significantly related to the proximity of premises at which rodenticides were used (Table 4.4). Clutch sizes at sites within 5km of rodenticide application were significantly larger (N=11, Mean = 6.0) than those at sites greater than 5km from such premises (N=18, Mean = 4.7), although sample sizes were small (Table 4.4). Variation in Mayfield failure rates at the egg and nestling stages could not be investigated, as the incidence of failure at wither stage was too infrequent to permit analysis.

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

Table 4.4 Influence of the proximity of farms at which rodenticides were applied on the occupancy rates and breeding success of Barn Owls. All analyses were performed using a repeated measures GENMOD procedure in SAS with site ID specified as the repeated measure, controlling for the effects of northings, eastings, year and primary habitat type, with the exception of clutch size (*) pre-outbreak where a simple GENMOD was used as the dataset contained no repeated measures.

5. DISCUSSION

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

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

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

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

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

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

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

Figure 5.1 Distribution of sites within 5km of a) premises at which livestock were slaughtered and b) premises infected with FMD.

However, due to the uneven distribution of Barn Owl recorders, it is possible that some of the Barn Owl data may not be representative of national trends. Figure 5.1 above indicates that the distribution of Barn Owl sites that were within 5km of premises at which animals were slaughtered (a), and particularly those within 5km of a FMD-infected farm (b), were primarily clustered in two relatively small areas of north-west England/south-west Scotland and south-west England, although the same was not true of sites within 5km of restricted-access land. The results presented with respect to slaughter of livestock and FMD infection should therefore be interpreted with caution, as it is possible that they may be subject to localised geographical or even to observer biases.

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