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VERTEBRATE PESTS UNIT
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The breeding performance of Barn Owl populations in five regions of the United Kingdom – 2015 Data Set.

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1. Introduction

1.1 General

The barn owl (*Tyto alba*) is a charismatic and iconic species of Britain's agricultural landscape that typically hunts across open farmland, meadows, rough grassland and woodland-edge habitat, where there are high densities of their small mammal prey (Toms, 2014). The most frequently taken prey items in the UK are field vole (*Microtus agrestis*), bank vole (*Myodes glareolus*), wood mouse (*Apodemus sylvaticus*), common shrew (*Sorex araneus*) and pygmy shrew (*Sorex minutus*), although both UK commensal species, Norway rat (*Rattus norvegicus*) and house mouse (*Mus musculus*), are occasionally taken (Love et al., 2000; Martin, 2008).

1.2 A Fluctuating UK Barn Owl population

In the 18th century, barn owls were regarded as the most common species of owl over much of the country; where traditional low intensity agricultural practice, together with high reliance on livestock, provided a habitat rich in their prey items (Shawyer, 1987).

According to a review by Toms (2014):

- A decline in numbers was evident by the early 1900's following advances in agricultural practice, and this prompted Blaker to conduct the first nation survey; producing a barn owl estimate of 12,000 pairs for England and Wales.
- The next survey was for the British Trust for Ornithology's (BTO) first breeding bird atlas (Sharrock, 1976), which produced an estimate of between 4,500 and 9,000 pairs in Britain and Ireland
- In 1982, the Barn Owl Survey of Britain and Ireland by The Hawk Trust produced an estimate of 3,778 pairs in England and Wales with a further 640 pairs in Scotland and 33 pairs in the Channel Islands.
- Although the BTO's second breeding bird atlas, covering the years 1988 to 1991 (Gibbons et al., 1993), did not estimate the number of barn owl pairs in the UK, it did suggest a decline of 43% in the number of occupied 10 km squares, when compared with the BTO's first breeding atlas; although differences in survey techniques made comparison of these results questionable.
- Between 1995 and 1997, a more comprehensive national survey, Project Barn Owl, was carried out by the BTO and Hawk and Owl Trust using a standardised methodology, producing a new national estimate of approximately 4,000 breeding pairs (Toms, Crick and Shawyer, 2001).
- Like the previous BTO atlas, the most recent, 2007-2011 BTO Bird Atlas of Breeding and Wintering Birds in Britain and Ireland offered no estimate of absolute UK barn owl population size. However, considerable range increases were recorded, with 67% more 10 km squares occupied by breeding barn owls in Britain than in the previous 1988-91 census (Balmer et al., 2013).

By 2009, the barn owl population in the UK is believed to have increased to over 6,000 pairs, the most significant increases having occurred in those areas where concerted efforts have been made by the Barn Owl Conservation Network (BOCN) to conserve this bird (Shawyer, 2009), although the unusually severe winters of 2009/10 and 2010/11 would have likely reduced their numbers. Subsequently, 2011 was a relatively good year for barn owls, with Shawyer (2015[a]) conservatively estimating a UK breeding population of up to 9,000 pairs. The winter of 2012/13 was less severe than the preceding years, but the month of March 2013 was the coldest reported since 1962 and, during that month, numbers of dead barn owl reported to the BTO's ringing scheme were about three times above normal. With nest occupancy estimated to be below 72% of the 'all-years' average, 2013 was considered to be one of the worst barn owl breeding seasons since1958 (Shawyer; 2015[b]).

With the mild winter of 2013-14 followed by an early spring and one of the warmest summers on record, 2014 became a peak year for small mammals, and a very productive year for barn owls in many areas (Shawyer, 2015[a]; Barn Owl Trust, 2016); with an estimated 9,000 pairs attempting to breed in that year, providing the most reliable and up-to-date population estimate for the UK (Shawyer, 2014). Overall 2015 was a poor breeding season for barn owls in the UK, although not as bad as that of 2013, and with marked geographical variations (Shawyer, 2015[b]).

Examination of the breeding range of the barn owl shows that, in the UK, the species is at the northernmost limit of its geographical distribution (Hagemeijer and Blair, 1997). Indeed, even within the UK, differences have been reported in their abundance from the lowland south to the highlands of the north (Balmer et al., 2013). It is therefore unsurprising that, together with prey abundance, and probably historical persecution, weather conditions, in particular climatic extremes, can exert a significant effect on the breeding performance of barn owls in the UK (Shawyer, 1987; Toms, 2014).

1.3 The Barn Owl as a sentinel species

Like many other species of vertebrate wildlife in the UK, the barn owl is exposed to second-generation anticoagulant rodenticides (SGARs) (Shore et al. 2014). The barn owl has been identified by the Health and Safety Executive as a sentinel species for other species that are generalist predators of small mammals in rural areas and are also exposed to SGARs (HSE, 2017). The barn owl is an ideal species for monitoring breeding performance, being one of the most frequently monitored species by the British Trust for Ornithology's Nest Record Scheme. In 2014, 2,766 barn owl nest records were submitted to the BTO, a number only exceeded by blue tit and great tit; while in 2015, 1,803 barn owl nest records were submitted to the BTO, a number only exceeded by blue tit, great tit, swallow and tree sparrow. Since the mid 1990's and following major improvements in habitat quality, barn owl nest site availability would appear to have become an important limiting factor for the species and their willingness to occupy man made nest-boxes has increased the number of birds monitored by the Nest Record Scheme. In addition, these artificial nest sites appear to be having a positive effect on the national population and by 2006 were believed to contribute more than 70% of all known breeding sites for this species in the UK (Shawyer 2006).

1.4 Objectives of the study

One of the important CRRU monitoring projects for rodenticide stewardship conducted by the Centre for Ecology & Hydrology (CEH) is the monitoring of SGAR residues in the livers of 100 barn owls each year, in an attempt to quantify exposure in free-living birds. However, reports of these data provide no contextual information on the status and breeding success of the UK barn owl population that carries them. Therefore, it is the purpose of the CRRU Barn Owl Monitoring Study (BOMS) to bridge this gap by monitoring various breeding parameters in a representative sample of barn owl populations across the UK. To this end, a CRRU contract is now in place with Colin Shawyer of the Wildlife Conservation Partnership (WCP) to conduct this work. The output from the WCP will be an "Annual Data Set", giving barn owl nest monitoring data for the preceding season.

The BOMS will provide annual data on key breeding parameters for selected barn owl populations that will be used alongside liver residue monitoring to assess the environmental impact of the UK Rodenticide Stewardship Regime. CRRU received the annual data set for 2015, together with similar available data from the same nest sites, from 2011 to 2014. This report comprises an analysis of the 2015 breeding data and a comparison with equivalent data from four previous breeding seasons.

2. Methodology Overview

The main aim of the BOMS is to examine a substantial core sample of barn owl nests and broods across five regions of the UK, in order to investigate various breeding performance parameters year on year. The same set of core sites will be monitored annually throughout the course of this project, which is initially of three years duration. The examination of breeding adults, eggs and developing chicks undertaken during nest monitoring, will also allow the concerns that are occasionally made about the unknown effects of the low-level SGAR liver residue levels on barn owl breeding productivity to be investigated (e.g. see Toms, 2014; pg 236).

Data collection at each nest site was based largely on that successfully developed and validated for the BTO's 10-year Barn Owl Monitoring Programme (Crick et al., 2001). The field research for the BTO project involved inspection of nests by Wildlife Conservation Partnership (WCP), BTO and Barn Owl Conservation Network (BOCN) nest recorders, under Natural England Disturbance Licences, primarily to determine nest occupancy levels, clutch size and brood size. For the purpose of the BTO project and that of the BOMS, brood size at ringing is considered synonymous to fledging success.

For the BOMS, brood size was recorded at successful nests and where nests were not visited at the egg stage, clutch size was estimated from the number of chicks and the age intervals between them. Chick ages were determined by wing development, either by wing cord for chicks under 13 days of age or the length of the developing 7th primary feather for older chicks (Shawyer 1998). The hatch date was derived from the age of the oldest chick and the first successful egg date determined by adding the 30 day incubation period.

The biometric measurements of young birds caught at the nest included sexing, measurement of wing development (to age and determine first egg date) and body weight, to establish body condition and growth patterns. Adult birds were treated in a similar way but were aged from their wing moult pattern, or from the length of moulted primary and secondary wing feathers found at nests (Shawyer 1998), or for those owls which were already ringed, the year in which ringing had occurred. Both young and adult birds were ringed and whole prey items found at nests were identified, weighed and sexed.

All birds handled and eggs found in the nest were screened for any unusual growth characteristics and physiological deformities, although it is acknowledged that these are rarely observed. In order to increase the sample size beyond that of the BOMS, BOCN nest recorders throughout the UK have been requested to report any unusual physiological characteristics they may find to WCP.

Each nest under observation was visited on at least one occasion, and in order to collect the necessary nest data for BOMS, the visit was optimally timed to occur when chicks were between 3 and 9 weeks of age. In this study no attempt was made to record second broods which can occur in a small number of barn owls and normally only in those years when field vole abundance is particularly high.

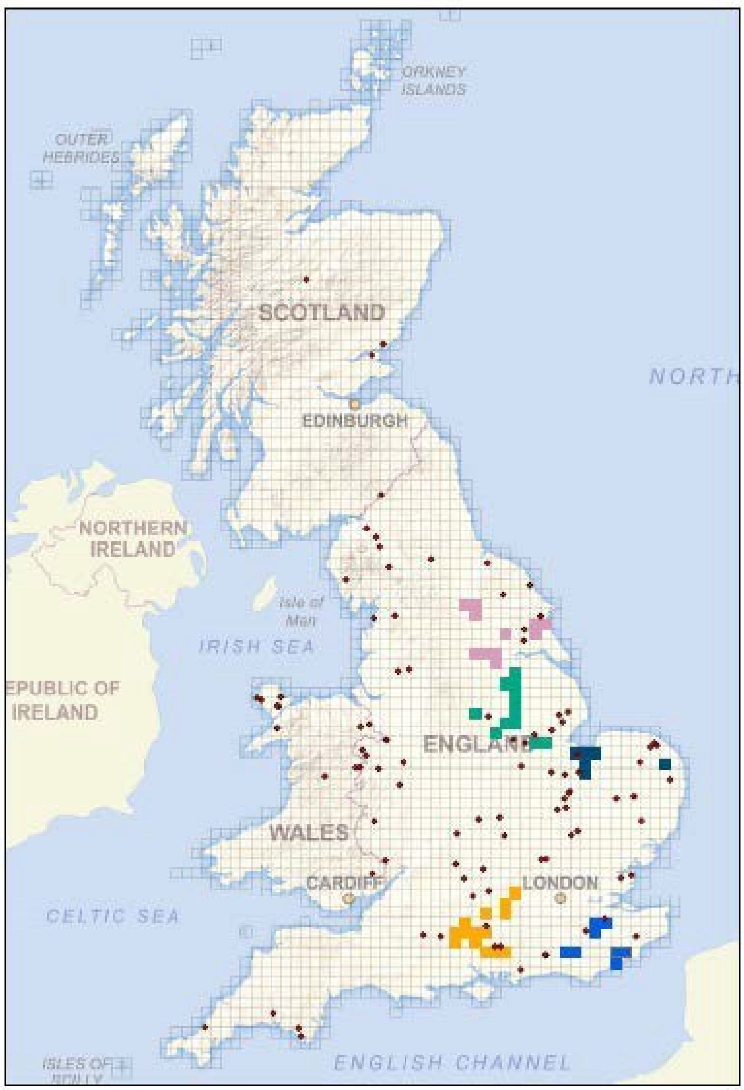
Key Performance Indicators for each of the proposed survey areas of the BOMS are:

- Nest occupancy data
- Nest Productivity (mean number of chicks fledged) for successful nests in each region
- Individual records of any chicks or eggs which show abnormal development

The proposed survey area for the BOMS focused on the following five areas, surveying a total of 130 nests (Figure 1):

Region 1 – (N) SE Yorkshire, Mid/West Yorkshire and SW Yorkshire (25 nests)
Region 2 – (E) East and West Norfolk (25 nests)
Region 3 – (C) Berkshire, South Hampshire, North Hampshire, South Wiltshire and North Wiltshire (25 nests)
Region 4 – (SE) Kent (25 nests)
Region 5 – (Midlands) Nottinghamshire, South Lincolnshire and Cambridgeshire (30 nests).

Figure 1. A map of England showing the locations of the 10 kilometre squares in each of the five Regions containing the barn owl nest sites surveyed in 2015. The location of the barn owls obtained by CEH for the CRRU liver residue analysis survey in the same year are also presented (red diamonds).



(Region1 = pink; Region 2 = purple; Region 3 = yellow; Region 4 = blue; Region 5 = green).

3. Results

3.1 The 2015 Data Set

Of the 130 barn owl nests monitored in 2015, a total of 103 young birds fledged from 41 nests. In addition there was evidence of 14 barn owl pairs which failed, mainly on eggs, 23 pairs where breeding had not been attempted and a further 33 nests where adult singletons were present. The overall mean productivity for the successful nests was 2.51 fledged birds (Table 1), with mean productivities for the five Regions ranging between 2.38 and 2.60.

Table 1 Barn owl nest occupancy in 2015, indicating the number of nests monitored and the number of young birds that fledged.

2015	**Region 1 (N)**	**Region 2 (E)**	**Region 3 (C)**	**Region 4 (SE)**	**Region 5 Midlands)**	**Total**
Total number of nests monitored	25	25	25	25	30	130
Nest site occupancy by adult pairs	11	9	15	20	25	78
Nests that produced fledgling birds	5	4	13	12	7	41
Total number of birds fledged	13	10	31	31	18	103
Mean productivity per successful nest	**2.60**	**2.50**	**2.38**	**2.58**	**2.57**	**2.51**

Region 3 (N) and Region 4 (SE) produced the largest number of fledglings, with each producing 31 fledged chicks from 13 and 12 nest sites respectively (Table 1).

3.2 Comparison of the 2015 data with available data from 2011 to 2014

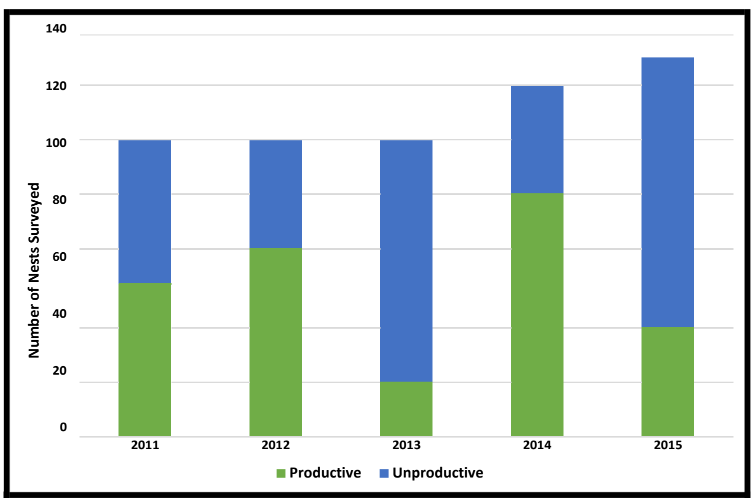
Of the 130 barn owl nest sites surveyed in 2015, between 98 and 121 of these sites had been monitored by WCP each year between 2011 and 2014 (Table 2; Figure 2). The proportion of nests that were productive and produced fledged young was highest in 2014 (where 64.5% of nests produced a total of 336 fledged birds) and lowest in 2013 (where 23.2% of nests produced a total of 83 fledged birds), which corresponds well with the barn owl productivity assessments of the BOCN (Shawyer, 2015[a]; Shawyer, 2015[b]). The average date for the first successful egg to be laid across the five regions was between the 10th and 23rd April in 2011, 2012 and 2014, and was on the 18th May and the 12th May in 2013 and 2015 respectively.

Table 2 Barn owl nest productivity between 2011 and 2015; indicating total numbers of nests monitored, average date of first egg laid, numbers of nests that produced fledged birds, numbers of fledged birds produced, and the mean productivity per successful nest.

	2011	**2012**	**2013**	**2014**	**2015**
Total number of nests monitored	98	101	99	121	130
Average date of first egg (number of nests)	23/04/11 (46)	10/04/12 (53)	18/05/13 (22)	14/04/14 (64)	12/05/15 (43)
Nests that produced fledgling birds	56	63	23	78	41
Total number of birds fledged	**186**	**153**	**83**	**336**	**103**
Nest surveyed that were productive	**57.1%**	**62.4%**	**23.2%**	**64.5%**	**31.5%**
Mean productivity per successful nest	3.32	2.43	3.61	4.31	2.51
Total number of Barn Owl chicks ringed in Britain and Ireland*	***8534***	***7326***	***3042***	***14466***	***4934***

** Data from the BTO on number of Barn Owl chicks ringed in Britain and Ireland.*

Figure 2. Barn owl nests surveyed each year, indicating the proportion of productive nests that produced fledged young.

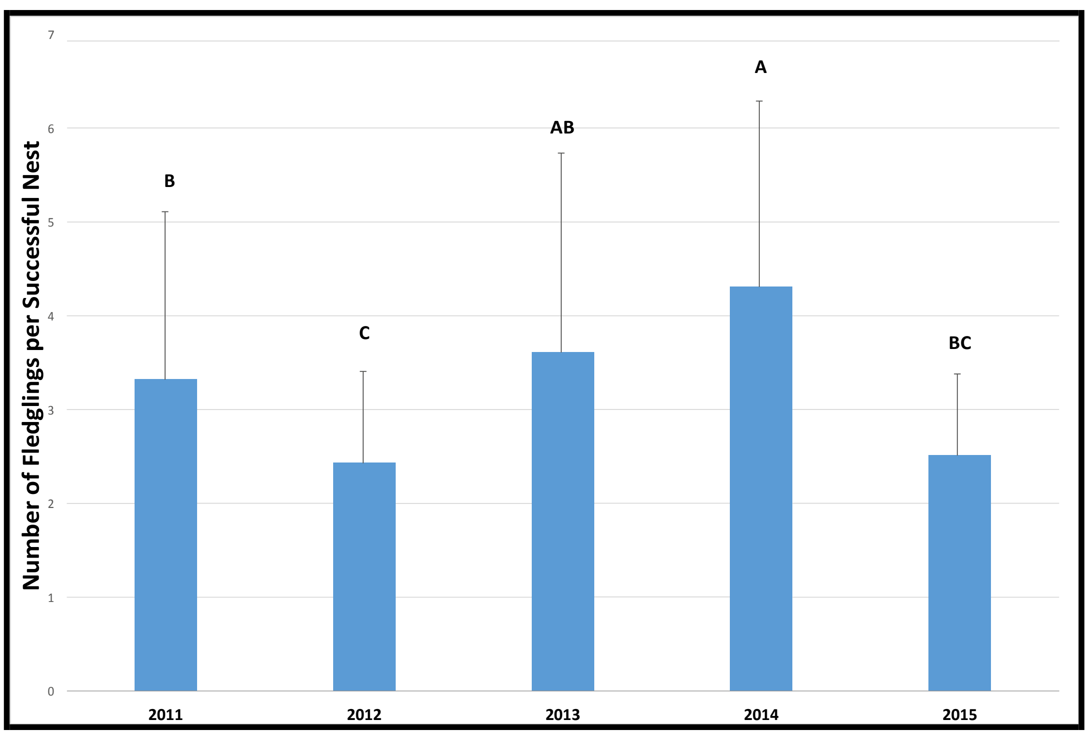


The number of birds fledged per successful nest site from each of the five regions between 2011 and 2015 (Table 3) were compared using a General Linear Model, and were found to differ significantly between years ($F = 15.16$; $p < 0.001$), but not to differ significantly between regions ($F = 1.92$; $p = 0.108$). GLM Tukey Pairwise Comparisons of the five years of barn owl productivity data indicate no significant difference between the 2014 and 2013 data, no significant difference between the 2013 and 2011 data and no significant difference between the 2013 and 2012 data (Figure 3).

Table 3. Mean barn owl nest productivity for each of the five Regions between 2011 and 2015 for the nests that successfully produced fledged birds (summary data derived from Table 4 and Table 1). Some nests were not visited in the "South-east" region in 2013, and those that were visited (16/25) produced no chicks.

Region	**Year**					
	2011	**2012**	**2013**	**2014**	**2015**	**Mean**
North	3.00	2.33	3.00	3.33	2.60	**2.97**
East	2.33	3.00	3.50	4.52	2.50	**3.44**
Central	3.33	2.17	2.00	4.93	2.38	**3.23**
South-east	3.60	2.42	no breeding recorded	3.27	2.58	**2.93**
Midlands	4.00	2.21	4.00	5.06	2.57	**3.62**
Mean	**3.32**	**2.43**	**3.61**	**4.31**	**2.51**	

Figure 3. Mean number of fledgling barn owls produced per successful nests (with standard error) for all nests monitored between 2011 and 2015. Letters denote post hoc groups from a General Linear Model (using Tukey Pairwise Comparisons).



3.3 Unusual Growth Characteristics

Among the eggs and barn owls (both young and adult) studied during 2015, none was found to have any unusual growth characteristics or physical deformities, such as abnormal feather development and pattern of moult, that might suggest any sub-lethal effects of exposure to anticoagulant rodenticides.

3.4 Rodenticide Residues in UK Barn Owls

A long-term study has been conducted by CEH to investigate the exposure of UK barn owls to anticoagulants. The study shows that approximately 80-95% (values not adjusted for changes in the sensitivity of analytical methods) of UK barn owl individuals carry residues of one or more SGAR's (Shore et al., 2014). Generally, the residues levels found are low and are considered unlikely to have caused harm to the birds, their deaths having been caused by a range of other factors such as collisions with road traffic, starvation and disease (Shawyer, 1987; Toms, 2014; Smith and Shore, 2015). The barn owl liver residue results obtained for 2015, the year of collection of breeding data presented in this report, showed that 94% of 100 birds had been exposed to one or more SGAR. Among these, 84% contained residues lower than 100 ng/g wet wt. The geographical distribution of the birds sampled for liver residue analysis is shown in Figure 1. There is considerable concurrence in the locations of those birds and the locations of the nests studied in the present investigation of barn owl breeding performance. Therefore, this study serves as a monitoring procedure providing correlational evidence about barn owl breeding performance in the presence of the SGAR residues detected by the CEH investigation.

Table 4 Barn owl breeding data for 2011 to 2014.

Year	Parameter	Region 1 (N)	Region 2 (E)	Region 3 (C)	Region 4 (SE)	Region 5 (Midlands)	All Regions
2011	**Total number of nests**	16	20	16	22	24	98
	Nests that produced fledgling birds	6	12	12	10	16	56
	Total number of birds fledged	18	28	40	36	64	186
	Mean productivity per successful nest	**3.00**	**2.33**	**3.33**	**3.60**	**4.00**	**3.32**
2012	**Total number of nests**	16	19	17	21	28	101
	Nests that produced fledgling birds	6	14	12	12	19	63
	Total number of birds fledged	14	42	26	29	42	153
	Mean productivity per successful nest	**2.33**	**3.00**	**2.17**	**2.42**	**2.21**	**2.43**
2013	**Total number of nests**	14	20	18	17	30	99
	Nests that produced fledgling birds	2	10	1	0	10	23
	Total number of birds fledged	6	35	2	0	40	83
	Mean productivity per successful nest	**3.00**	**3.50**	**2.00**	**-**	**4.00**	**3.61**
2014	**Total number of nests**	25	25	22	21	28	121
	Nests that produced fledgling birds	15	21	14	11	17	78
	Total number of birds fledged	50	95	69	36	86	336
	Mean productivity per successful nest	**3.33**	**4.52**	**4.93**	**3.27**	**5.06**	**4.31**

4. Discussion

From 2011 to 2015 between 98 and 130 barn owl nest sites were surveyed each year across five regions of the UK, and during this time, between 23 and 78 of these nest sites were successful, producing between 83 and 336 fledgling birds each year. The five regions were geographically distributed from Yorkshire in the north to Kent and Central Southern England in the south (Figure 1).

The number of fledged birds produced from each successful nest was used as a measure of nest productivity, and was found not to differ significantly between the five Regions ($F = 1.92$; $p = 0.108$), but was found to differ significantly between years ($F = 15.16$; $p < 0.001$).

The number of fledged barn owls that have been recorded in this survey represents between 2.1% and 2.7% of the total number of barn owl chicks ringed by the BTO in Britain and Ireland each year (Table 2). Analysis of the five years of available data indicates a very high correlation between the two data sets (Pearson Correlation $R=0.993$; $p<0.001$). Assuming that numbers of barn owl chicks ringed across the UK each season is a reflection of the national productivity of the species, the BOMS survey would appear to provide a useful indication of barn owl productivity across the UK.

GLM Tukey Pairwise Comparisons of the five years of barn owl nest productivity data indicate that nest productivity was significantly higher in 2014 and 2013 than in 2012 and 2015 (Figure 3). For 2013, this is surprising when numbers of fledged birds produced each year are taken into consideration.

- In 2014 there was a mean nest productivity of 4.31 with 336 fledged birds produced from 78 nest sites
- In 2013 there was a mean nest productivity of 3.61 with 83 fledged birds produced from 23 nest sites
- In 2012 there was a mean nest productivity of 2.43 with 153 fledged birds produced from 63 nest sites
- In 2015 there was a mean nest productivity of 2.51 with 103 fledged birds produced from 41 nest sites

The year 2014 has been reported to be a very productive year for barn owls in many areas of the UK (Shawyer, 2015[a]; Barn Owl Trust, 2016), so the highest number of successful nests (with 78 successful nests out of 121 nest sites surveyed) and the high mean productivity per successful nest (4.36), is not surprising (Table 2).

However, 2013 had the lowest number of successful nests (with 23 successful nests out of 99 nest sites surveyed) producing 83 fledged birds, which is the lowest annual figure of the five year survey period. In addition, 2013 has been reported to be one of the worst barn owl breeding seasons since 1958 (Shawyer, 2015[a]), so the high mean productivity of 3.61 in successful nests was somewhat unexpected. This may have been due to the fact that in difficult years successful nests are those of the most experienced breeders, which are able to overcome adverse conditions to rear virtually normal broods.

The average date for the first egg laid in the nests monitored across the five regions was the 18th May and the 14th April in 2013 and 2014 respectively (Table 2), indicating that the few barn owls which were able to breed in 2013 had delayed their breeding activity on average by 34 days when compared with 2014. This, in combination with the high mean 2013 nest productivity would suggest that either environmental conditions or food availability were limiting factors for the barn owls at the onset of breeding, but not as the season progressed.

Indeed March was particularly cold and field vole numbers which were reported to be very low throughout the first quarter of 2013, appeared to begin a rapid recovery soon after, climaxing in 2014. This together with the mild winter of 2013-14, followed by an early spring and one of the warmest summers on record, enabled barn owls to have one of their most productive breeding seasons for decades in 2014 (Shawyer, 2015[a]; Barn Owl Trust, 2016).

In contrast, 2012 and 2015 produced higher numbers of fledged birds than 2013 (153 and 103 respectively), and had higher number of successful nests (63 out of 101 surveyed and 41 out of 130 surveyed respectively), so the lower mean nest productivity values when compared with 2013 was unexpected.

A possible explanation might be a higher proportion of inexperienced first year birds breeding in 2012 and 2015 when compared with 2013. Barn owls that are longer lived are reported to produce more eggs and fledglings in their lifetime (Marti, 1997), and Frey et al. (2011) noted that breeding success was higher for individuals that previously bred at a nest site when compared with owls that bred for the first time; suggesting that previous knowledge and experience enabled the birds to exploit the site more efficiently.

It is important to recognise that barn owl nest occupancy and breeding success can vary considerably from year to year for a very wide variety of reasons, including population numbers, prey availability and weather conditions (Toms, 2014). For this reason, both the 1982-1985 Barn Owl Survey of Britain and Ireland (Shawyer 1987) and the 1995-97 BTO/Hawk and Owl Trust barn owl survey (Toms et al., 2001) provided annual UK population estimates over their three or four year study periods, thus embracing a complete cycle of abundance for the field vole.

For example, in years when vole numbers are particularly low, like 2013, most barn owls will remain at their winter roosts and make little attempt to occupy their breeding sites. This means that during years such as these, barn owls simply go unrecorded and if population estimates are based on these years alone, rather than peak years like 2014, they can prove widely inaccurate.

In the 2015 BOMS data set, of the 47 non-breeding females that were found occupying nest sites, all were under the threshold breeding body weight of 360g (Shawyer, 1994), and most weighed less than 340g. In comparison, the breeding females weighed between 380g and 430g.

It is likely that the poor breeding of 2015 was a result of low availability of small mammal prey, and the high occupancy of nest boxes by first year birds was a result of both the very good breeding season of 2014, and the more experienced birds (second year and older) remaining at their winter roosts, being in no condition to breed and therefore making little attempt to re-settle at their nest sites. This provided an opportunity for the young incomers to take up occupancy (Shawyer, 2015).

Across the five regions surveyed between 2011 and 2015, the overall mean nest productivity for the successful nests was 3.30 (n = 261), with annual mean productivities per region ranging between 2.00 and 5.06 (excluding Region 4 in 2013, where no fledgling birds were produced).

Shawyer (1987) estimated barn owl mean productivities of 3.35 (n=155) for England and Wales, and 2.84 (n=135) for Scotland, and presented annual productivity values for the British Isles between 1982 and 1986 ranging from 2.77 to 3.36, with a mean value of 3.00 (n=290).

In a BTO Research Report (Henderson et al., 1993), barn owl annual mean productivity was presented for six specified regions of England and Wales between 1988 and 1990, and ranged between 2.6 and 4.2 (n=246). Similarly an internal report to the Environment Agency (Shawyer 2010) reported an annual mean productivity between 2000 and 2009 ranging between 2.6 and 3.5 (n=581). These values are comparable with earlier data presented by Shawyer (1987) and with that presented in this report.

According to Shawyer 1987, the marked fluctuations in barn owl breeding productivity year on year is primarily a result of annual changes in small mammal abundance and extreme weather events at critical times during the barn owl's annual cycle (see Shawyer, 1987; Shawyer, 1998; Toms 2014).

Barn owl exposure to SGAR's in the UK would be expected to be greatest across agricultural areas, because of the close association between modern agricultural practice and Norway rat infestations, particularly around livestock and grain storage facilities. In addition, the high incidence of physiological resistance to anticoagulant rodenticides in Southern England might be expected to cause an increase in the use of anticoagulant rodenticides in this area, as the effectiveness of these rodenticides is reduced. Such areas would include Region 3 (Central Southern England), Region 4 (Kent) and Region 2 (Norfolk). Furthermore, the use of SGARs in these Regions would be expected to be relatively consistent from year to year, to address the consistent problem of resistant Norway rats in this area (Buckle and Prescott, 2012).

It is difficult to see how the annual fluctuations in barn owl productivity observed in the data of the BOMS between 2011 and 2015 can be associated with the approved use of rodenticides across the agricultural landscape, particularly in Southern England. If this were the case, the resulting decline in barn owl productivity would be expected to be relatively consistent year on year, to reflect the consistent use of these products, which clearly it is not. The BOMS observed peaks in barn owl productivity, particularly in the productive year of 2014, occurred primarily in Region 2, Region 5 and Region 3, which encompass the major agricultural areas of Southern England, where physiological resistance to the anticoagulant rodenticides in Norway rats is most extensive.

In conclusion, the number of breeding pairs of barn owl in any given year is determined by factors which include the level of overwintering mortality of breeding adults, the survival of first year birds and the successful recruitment of these birds into the breeding population. Data presented from various reported studies in Britain between 1988 and 2015 indicate that the productivity of barn owls has not changed markedly over this 28-year period. Breeding success is influenced by prey availability and survival, which in turn is shaped by numerous other factors such as climate, habitat quality and population density (Toms, 2014). Barn owls clearly are widely exposed to SGARs, but the impact of this on the productivity of the UK population is difficult to quantify directly.

The BOMS data obtained to date suggest that the magnitude of this impact, if any occurs, is low. The study will continue in the forthcoming years to assemble more information on this important aspect of the biology of UK barn owls, the chosen sentinel species for SGAR contamination.

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