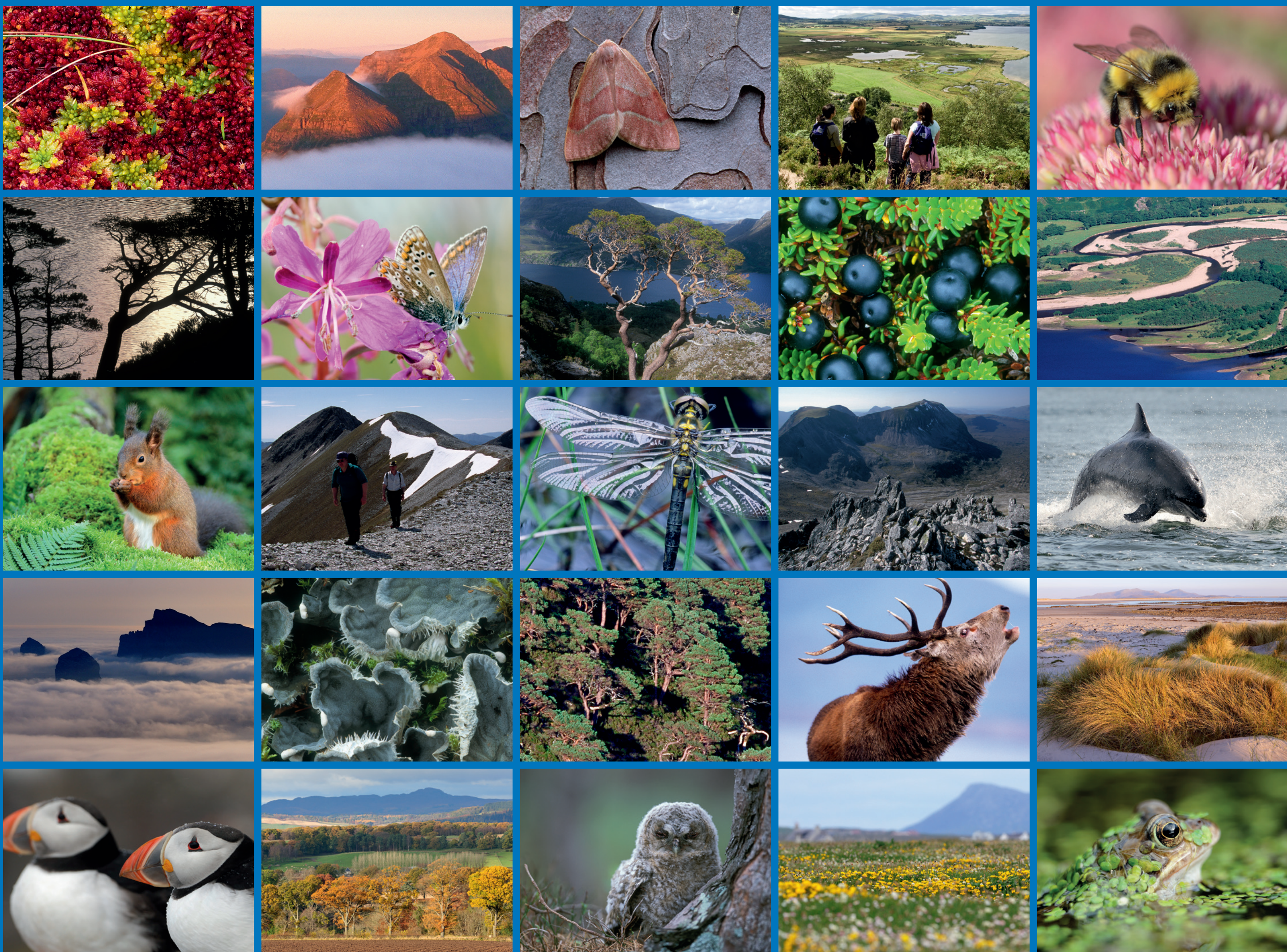
Research Report No. 1205

Badger impacts on biodiversity and agriculture in Scotland: a literature review



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RESEARCH REPORT

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Badger impacts on biodiversity and agriculture in Scotland: a literature review

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RESEARCH REPORT

Summary

Badger impacts on biodiversity and agriculture in Scotland: a literature review

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Keywords

badger; population; predation; wildlife; agriculture

Background

This literature review details work published to date on badger predation and feeding activity in Scotland. It was commissioned by NatureScot in 2019. It is not a NatureScot position statement.

Using literature from Europe this study identifies:

- How badger predation and feeding activity could impact wildlife in Scotland.
- How badger predation and feeding activity could impact agriculture in Scotland.
- How these impacts (on wildlife and agriculture) relate to changes in badger abundance/ distribution.
- The extent of any control measures being applied to address impacts and an assessment of the effectiveness of such measures.

Main findings

- The badger is widely distributed in Scotland, with the highest density of sets in the (pre-1996) Borders and Lothian regions and low densities in the Central and Highland regions.
- Overall, the density of main setts, a proxy for populations, was much lower than in England, with the highest density in Scotland less than half that in England and the average density about one quarter of that in England.
- Badger numbers are certainly increasing in England, but it is currently not possible to say with certainty whether numbers are increasing in Scotland, though there is some indication of an increase.
- Impacts on biodiversity in Scotland appear to be low. There are some situations where badgers predate ground-nesting birds, but they appear to be much less significant predators than foxes.
- Badgers have a significant negative impact on hedgehogs in parts of England, but there is little evidence for such an impact in Scotland, particularly as data on changes in numbers

of both species is lacking. The lower density of both badgers and hedgehogs suggest that this negative interaction may not occur in Scotland, though further studies are needed.

- No significant impacts on invertebrates or plants of conservation significance were evident from the literature, though there is some suggestion that badgers might affect bumblebee populations by predating nests.
- Damage by badgers to growing crops, infrastructure and livestock was reported by farmers. In most cases, reported economic losses were small, but there were some situations where they were significant, resulting, for example, in the issue of a licence to take action. In general, levels of concern are significantly lower than in England, probably because badgers are less common in Scotland and concerns about disease transmission are much lower. Badgers were considered responsible for some losses of livestock (lambs), though evidence was generally circumstantial.

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1. INTRODUCTION

This literature review was commissioned by NatureScot in 2019 to consider:

- How badger predation and feeding activity could impact wildlife in Scotland
- How badger predation and feeding activity could impact agriculture in Scotland
- How these impacts relate to changes in badger abundance or distribution
- The extent of any control measures being applied to address impacts and an assessment of the effectiveness of such measures.

1.1 Methodology

The main search engine used to locate pertinent literature was Google Scholar. This indexes publications of all types (journal and conference papers, theses and dissertations, academic books, pre-prints, abstracts, technical reports and other scholarly literature from all broad areas of research). A wide variety of search terms was used, appropriate to the section of report. Both the terms ‘badger’ and ‘*Meles*’ were used to list as wide a range of publications as possible. These terms were combined with action terms such as ‘diet, predation, foraging, damage’ and object terms, such as ‘mammals, hedgehogs, birds, waders, gulls, invertebrates, reptiles, amphibians’ to give a broad coverage. Returns from searches were then examined for literature that appeared pertinent to the review, so that irrelevant results, such as those from outside Europe, were ignored. When combined with an examination of the bibliography of recent journal articles, this gave excellent coverage of the subject. Many journal articles were downloaded from the internet, using links from Google Scholar. Where these were not available, copies were requested from the authors, for recent publications, or from the NatureScot library, for older publications. In addition, the author owns copies of most of the books quoted in the bibliography.

To identify any further topics of interest, particularly for the section on impacts on biodiversity, a range of experienced specialists known to the author was also consulted directly and any suggestions followed up with further literature searches. Individuals consulted in this way are listed in the acknowledgements and noted in the text where appropriate.

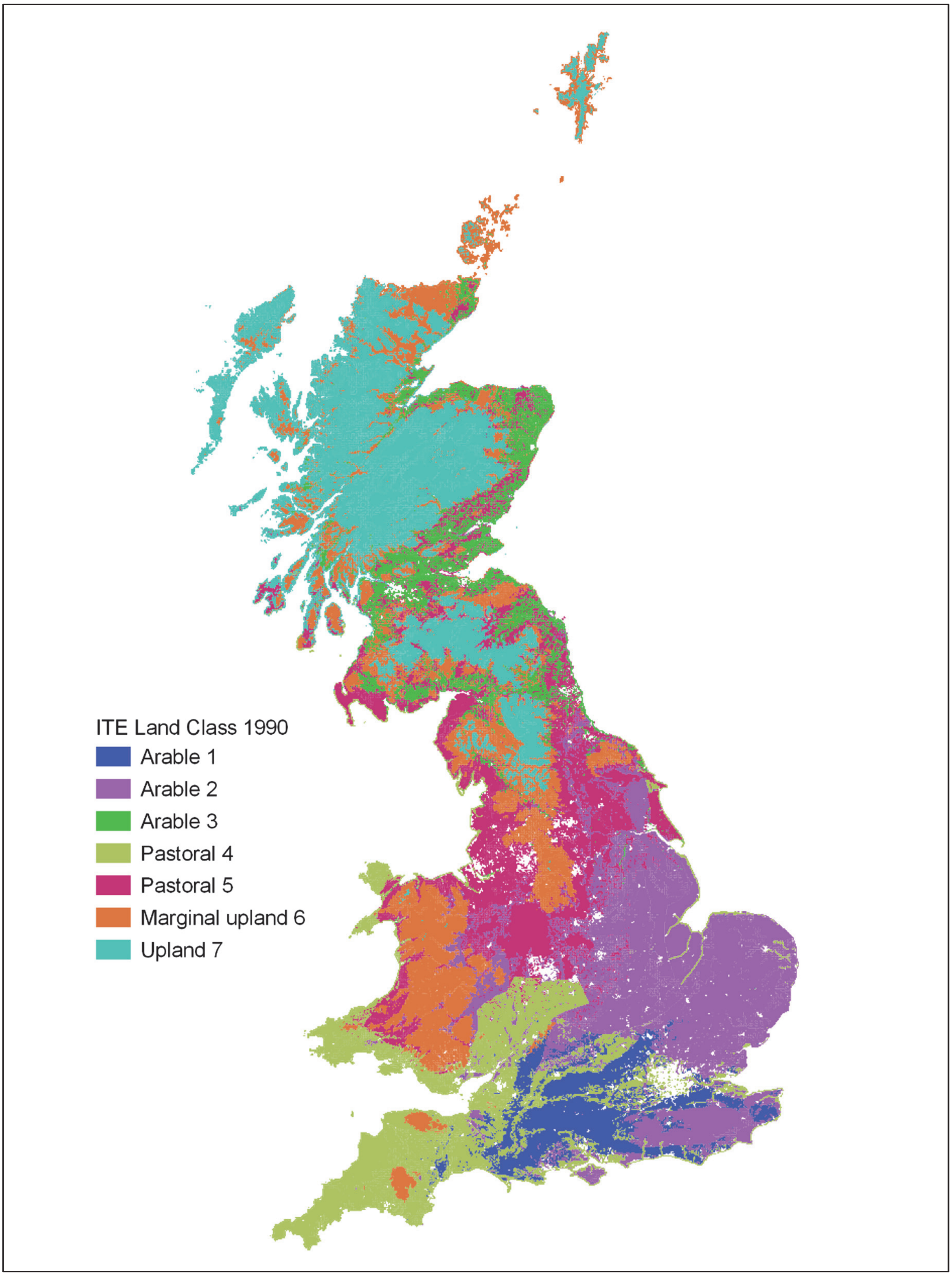

Figure 1. The 7 ITE land class groups used for badger surveys of Great Britain in 1985/8 and 1994/7 and England and Wales in 2011-13. Land class groups Arable 1 and Pastoral 4 have the highest densities of main setts; land class group Upland 7 has the lowest. Land class groups are aggregations of the 32 land classes described by Bunce et al. (1996). © Crown copyright [and database rights] 2020 OS 100017908.

2. OCCURRENCE OF THE BADGER IN BRITAIN AND SCOTLAND

2.1 Distribution and density

The badger (*Meles meles)* is widely distributed in Great Britain and Ireland. In Scotland, the species has been recorded throughout the mainland, except for some areas above 500m asl. It is absent from all Scottish islands except Arran and Skye (Delahay *et al*., 2008; Rainey *et al*., 2009).

Within this wide distribution, the density of badger social groups, as measured by the density of main setts (see below), varies widely. In Britain, the highest density of main setts is found within the south-west region of England, where a density of close to 0.7 main setts per square kilometre was recorded during a survey in 1994-1997 (Wilson *et al*., 1997). By contrast, the same survey recorded much lower densities in Scotland (North Scotland: 0.03 main setts km^{-2}, South Scotland 0.07 main setts km^{-2}). The surveys of Great Britain in 1985-8 and 1994-7 and the survey of England and Wales in 2011-13 stratified their sampling according to seven land class groups aggregated from the 32 land classes described by Bunce *et al*. (1996). These divided the country into 7 broad landscape types (Figure 1): three arable landscapes, two pastoral ones, marginal upland and upland. In most cases, results were presented according to these strata, with results for geographic regions being derived from these.

All badger surveys to date have been based on searching for badger setts within a sample area and assuming that one main sett is present in each social group's territory. The resulting density of main setts thus equates to the density of social groups. However, converting this figure to the number of individuals is difficult, as the characteristics of the sett are a poor predictor of the number of individuals associated with it (Wilson *et al*., 2003; Lara-Romero, Virgós and Revilla, 2012). A subsequent study based on the results of the 2011-2014 survey of England and Wales (Judge *et al*., 2014) and using a method based on genotyping hair samples and using capture-recapture statistics at a sample of 120 main setts gave an estimate of the total badger population in England and Wales in 2011–14 of 485,000 (95% confidence interval 391,000–581,000), and an overall density of 3.29 badgers km^{-2} (95% CI 2.64–3.94) (Judge *et al*., 2017). This study also gave estimates of mean badger group size in six of the seven land class groups, as no setts were found in the small sample of upland squares (Table 1).

Table 1 Estimates of the mean number of badgers per social group in each land class group and the total number of social groups sampled that group. Land class group 7 (Upland) was not included because no main setts were recorded in any of the surveyed squares in this group during the 2011–13 sett survey (from Judge et al., 2017).

Land Class Group	Number of social groups	Estimated mean number of badgers/ social group	Standard error of estimate
1. Arable, open, varied agriculture	13	6.54	1.38
2. Flat, arable and intensive agriculture	15	6.27	1.74
3. Arable, lowlands with variable land use	3	2.67	0.27
4. Pastoral, undulating, mainly fertile pasture	38	7.92	0.86
5. Pastoral, heterogeneous land use	8	7.50	1.72
6. Marginal upland	12	4.17	0.57

Few data on social group sizes are available for Scotland. At a site NE of Aviemore, the number of badgers per social group declined from 5.3 to 3.7 between 1978 and 1982 (Kruuk and Parish, 1987) and at 7 setts across 3 sites (Ardnish, New Deer, Speyside) the mean number of badgers per social group was 5.4 (range 2-11) (Kruuk and Parish, 1982). These figures are within the range reported by Judge *et al*. (2017).

In Scotland, the most recent badger survey in 2007-9 (Rainey *et al*., 2009) sampled 877 1km^2 squares, stratified by (pre-1996) region and broad habitat type (based on the Land Cover Map 2000 (Fuller *et al*., 1999)), searching for badger setts and signs of badgers (paths, dung pits and latrines, hairs and footprints). Of the squares surveyed, 585 were found to have no setts and no signs of badgers. Four squares recorded only a disused main sett, leaving 288 squares with evidence of badgers. Of these, 224 contained an active badger sett whilst 64 showed only signs of badgers. A total of 170 main setts was found by the survey, with a maximum of 4 main setts in a single square.

These data were then used to generate an estimate of the number of badger main setts in Scotland and the percentage of squares containing badger activity. Depending on statistical assumptions made, the results indicated that there are likely to be between 7300 and 11200 badger main setts in Scotland. In addition, it was estimated that between 12.7 and 17.2% of squares contain at least one active sett and between 17.2 and 23.2% of squares show some indicators of badger activity. Overall, the density of badger main setts in Scotland lay between 0.107 and 0.112 km^{-2}, with a 95% confidence interval of 0.087 – 0.134 km^{-2} (using both estimates given by Rainey *et al*. (2009)).

The distribution of badger setts was heterogenous in both types of stratification (region and habitat type), though the size of the standard errors indicates that there is a high degree of uncertainty in these estimates. By Dominant Habitat Type (DHT) (Table 2), the highest densities were found in squares dominated by arable, intensive grassland or deciduous woodland and the lowest densities in squares dominated by heather and bog.

Table 2 Estimated density of main setts for each dominant habitat type. Recalculated from Rainey et al. (2009) by taking the mean of two non-significantly different estimates of density which were calculated by different methods.

Dominant Habitat Type	**Estimated number of main setts**	**Mean number of main setts per km^2**
Acid grassland	400	0.043
Arable	2750	0.295
Coniferous	858	0.094
Deciduous	280	0.313
Heather & bog	685	0.019
Intensive grassland	3616	0.272
Natural grassland	213	0.038
Urban	200	0.148

By (pre-1996) region, the highest estimated density of setts and signs of occupation were found in the Borders and Lothian regions and the lowest in Central, Highland and Tayside (Table 3).

Table 3 Estimated density of main setts for each region, based on stratifying by dominant habitat type. Recalculated from Rainey et al. (2009) by taking the mean of two non-significantly different estimates of density which were calculated by different methods.

Region (pre-1996)	Estimated number of main setts	Mean number of main setts per km^2
Borders	1845	0.380
Central	89	0.033
Dumfries & Galloway	1613	0.241
Fife	305	0.210
Grampian	1927	0.215
Highland	950	0.034
Lothian	665	0.370
Strathclyde	1394	0.091
Tayside	372	0.048

Although the methodologies and stratification differ, overall, the density of main badger setts in Scotland was much lower than the density found in south-west England in the surveys of 1994-1997 (0.697 main setts km^{-2}) (Wilson *et al*., 1997) and 2011-13 (using Land Class 4 as a proxy, 0.755 main setts km^{-2}) (Judge *et al*., 2014).

2.2 Changes in badger numbers

An estimate of badger population size was given by Harris *et al*., 1995, who used the sett data from the 1985-88 survey (Cresswell, Harris and Jefferies, 1990) and an estimate of 6 as the mean social group size to conclude that the number of badgers in Britain was about 250,000 adults ((95% CI, 224,940 – 277,788). Assuming 10% of these are in Scotland (Cresswell *et al*., 1989), that gave a national population estimate for Scotland of 25,000 (95% CI: 22,494 – 27,788) in 1985-88.

Wilson *et al*. (1997) compared the results of surveys of Britain in 1985-1988 and 1994-1997 and concluded that there had been an increase in the number of main setts (and hence social groups) of 24% between the two surveys. However, this increase was not uniformly distributed by land class group (and hence region). The greatest increase (86%) was observed in the West Midlands region of England, with a small, though statistically insignificant, decline in North-West England. For the two Scottish regions (North and South), the number of social groups appeared unchanged, within the detection limits of the sampling system employed. No data were available on any changes to the size of social groups, so it was not possible to say whether the total number of badgers had changed.

Since that time, a further survey in England and Wales in 2011-2013 (Judge *et al*., 2014) concluded that the number of badger social groups in England has increased by 103% (95% confidence interval: 83-123%) since the 1985-1988 survey whilst in Wales there has been little change (-25 to +49%). Overall, this gives an annual rate of increase of 2.6% (2.2 -2.9%). The wide variation in the number of badgers per social group (Judge *et al*., 2017) means that this increase in the number of social groups cannot be extrapolated to estimate the increase in the number of badgers, though it seems reasonable to conclude that this has also increased.

In Scotland, the differing methodology of the 2007-9 survey from the earlier surveys means that a direct comparison is not possible, as the methods used to stratify the sample area and select squares for survey were different. In particular, the recent Scottish survey selected squares so as to over-sample areas where sett density, and perhaps mean social group size, was expected to be high and under-sample areas where sett density was expected to be low. This contrasts with the methodology of the previous surveys, where squares to be surveyed were randomly selected from within 7 land class groups and the same squares were visited in the two surveys. Revisiting sampling points used in previous surveys is recognised as a good way of improving the ability of a survey to detect change (Toms, Siriwardena and Greenwood, 1999).

Because of uncertainties over badger social group sizes, Rainey *et al*. (2009) did not give an estimate of population size. However, they did present a table comparing raw sett data from the 3 surveys stratified into Northern and Southern Scotland. These data (Table 4) are consistent with the hypothesis that there has been an increase in the number of main setts between the 1990s and 2007-9, but for the reasons given above it is not possible to be confident that this is the case.

Table 4. Raw data on the number of main setts counted in the three surveys of Scotland. For reasons given in the text, any changes must be interpreted with caution because of the differing methodologies between the 2007/8 survey and the earlier ones. From Rainey et al. (2009).

	Number of surveyed squares	Number of main setts	Number of 1km squares with main setts	Number of 1km squares with any setts
1980s (Wilson *et al*., 1997)				
Southern Scotland	208	15 (7.2%)	15 (7.2%)	31 (14.9%)
Northern Scotland	366	8 (2.2%)	6 (1.6%)	24 (6.6%)
1990s (Wilson *et al*., 1997)				
Southern Scotland	208	15 (7.2%)	14 (6.7%)	25 (12.0%)
Northern Scotland	366	12 (3.3%)	10 (2.7%)	20 (5.5%)
2007/9 (Rainey *et al*, 2009)				
Southern Scotland	399	105 (26.3%)	84 (21.1%)	140 (35.1%)
Northern Scotland	478	64 (13.4%)	52 (10.9%)	84 (17.6%)

The sett data provided by Rainey *et al*. (2009) were subsequently used by Mathews *et al*., (2018) to provide an estimate of the badger population of Scotland. Using a mean group size of 4.14, which they derived from the literature, they concluded that there were between 30,000 and 45,000 badgers in Scotland. This figure suggests an increase in population size from the estimate provided by Harris *et al*., 1995, despite using a lower figure for mean group size, but suffers from the same uncertainties about the number of setts, as discussed above. Even if the number of main setts has increased, the lack of associated data on changes in mean social group size makes it difficult to translate sett numbers into badger numbers.

Mathews *et al*., (2018) also used estimates of badger density in different habitats from the literature to provide a further estimate of population size. For Scotland, they estimated a population of 156,000 (95% CI: 115,000-267,000) if broadleaved woodland was included or 115,000 (95% CI: 85,000 – 198,000) if it was excluded. The uncertainty about broadleaved woodland derives from uncertainty as to whether earlier authors included this category within the broad grassland category. These estimates are both considerably higher than the estimate derived from sett data and Mathews *et al*., (2018) commented that this method may have overestimated badger density because lower densities of badgers than the national median would be expected at high altitudes and on acid soils.

2.3 Conclusions

Although there are many difficulties in counting badger setts and extrapolating from numbers of setts to numbers of badgers, the evidence that the number of badger main setts, and almost certainly badger numbers, have increased in England and Wales during the period 1985-2013 is compelling. Almost all this increase can be attributed to changes in England, while numbers in Wales appear to have changed little (Judge *et al*., 2014). For Scotland, the change in sampling strategy between the earlier and most recent surveys has complicated the picture. There appeared to be little change in the number of main setts between the two earlier surveys, which used the same methodology. However, the apparent increase in number of main setts between the earlier and latest survey could conceivably be the result of the change in sampling strategy and all one can say is that the results are consistent with the hypothesis that the number of main setts has increased. In addition, there are few large-scale studies in Scotland on the mean size of badger social groups in particular habitat types, so any estimate of badger numbers must rely on social group size data measured in very different landscapes.

3. FOOD, FORAGING BEHAVIOUR AND HABITAT ASSOCIATIONS

3.1 Badger diets

Badgers are omnivorous, eating a wide range of plant and animal foods ((Delahay *et al.*, 2008). The diet of badgers has been widely studied across their Palearctic range. Badgers occur in a wide range of environments ranging from xeric Mediterranean habitats to subarctic habitats in Russia and Scandinavia and cool wet Atlantic habitats in Britain and Ireland. As might be expected, this wide geographic range is reflected in their diet.

In southern Europe, studies have shown that the main components of the diet are rabbits, fruits, such as olives and figs, and arthropods (Barea-Azcón *et al.*, 2010; Del Bove and Isotti, 2001). A similar combination of plant and animal items was reported in a review of studies in the former Soviet Union (Roper and Mickevicius, 1995). In Scandinavia, badgers' summer diet contained large proportions of eggs, frogs and earthworms (Kauhala, Laukkanen and von Rége, 1998). In the Carpathians, badgers ate mainly fruit and earthworms (Mysłajek *et al.*, 2016). In all cases, a wide range of plant and animal food items was consumed, though often with a few items predominating.

In Britain, as well as western Europe, numerous studies have emphasized the importance of earthworms as a major dietary item throughout the year (Brown, 1983; Hofer, 1988; Kruuk and Parish, 1981; Roper and Lüps, 1995). This major item may be supplemented seasonally by a wide range of plant and animal foods, depending on their availability, so the badger may be characterised as an opportunistic generalist, using the most profitable foods, supplemented by other items whenever they are available or encountered (Neal, 1948; Roper, 1994). The range of items reported in badger diets is extensive, covering both vegetal (fruit, cereals, roots) and animal (invertebrates and vertebrates) items; a partial list is included in Delahay *et al.* (2008).

3.2 Habitat associations

The strong dependence of badgers on earthworms as a staple prey item in Britain is reflected in their distribution at both the landscape and local level. Data from national badger surveys shows the strong association between land classes or landcover types containing habitats with a high biomass of earthworms (see Table 8) with high densities of badger social groups. At a more local level, several studies have found a strong link between badger social group territories and the presence of earthworm-rich habitats, such as grazed pasture and deciduous woodland.

3.3 Foraging behaviour

Badgers are generally nocturnal, emerging at dusk to forage, though in northern summers, they can be active well before dusk (Neal, 1948). Although they are group-living carnivores, badgers generally forage individually, often following well-worn paths radiating out from the sett. When hunting for earthworms or other invertebrates on pasture or in woodland, badgers follow a meandering track, pausing to catch worms which have come to the surface to feed as well as other invertebrates they encounter (Kruuk, 1978).

4. IMPACT OF BADGERS ON BIODIVERSITY IN SCOTLAND

4.1 General considerations

Although the most important single food item of badgers in Britain is earthworms, they will also take a very wide range of vegetal and animal items when encountered. As they travel a considerable distance during their nightly foraging (e.g. in Białowieża Primeval Forest badgers travelled a mean nightly distance of 7km (Kowalczyk, Zalewski & Jędrzejewska, 2006); even if they travel at random badgers are likely to encounter suitable food items by chance.

4.2 Mammals

In some parts of their range, mammals, particularly young rabbits, may form an important, or occasionally principal (Martin, Rodriguez and Delibes, 1995) component of badger diets. Such a dependence on mammalian prey has not been recorded in those parts of their range where earthworms are a principal part of the diet, but small mammals (mice and voles) and carrion (deer and livestock) have frequently been recorded as a minor item (Kruuk and Parish, 1985; Kauhala, Laukkanen and von Rége, 1998), with the assumption that they are taken opportunistically. One exception to this was reported from an area of Switzerland, where badgers responded to an outbreak of the fossorial form of the water vole *Arvicola amphibius* by switching their major prey item from earthworms to water voles (Weber and Aubry, 1994). A review of multiple studies of the causes of neonatal mortality in ungulates reported few instances of badger predation (Linnell, Aanes and Andersen, 1995) and there is no evidence that ungulates, except for carrion, are a part of badger diets.

Apart from the case of the hedgehog (*Erinaceus europaeus*), no other impacts of conservation concern on other mammals in Scotland were identified by specialists.

4.2.1 Hedgehogs

Badgers are predators of hedgehogs and the two species occur in the same habitats and have a considerable overlap in diet (Doncaster, 1992).There is increasing evidence that hedgehog populations are declining across Britain (summarised in Roos, Johnston and Noble, 2012; Wilson and Wembridge, 2018) and there is concern that badgers are implicated in this decline. Studies in areas of high badger density have shown that hedgehogs are rare in pasture, which is an important foraging habitat for badgers, and more common in urban and suburban areas, where badgers are less common (Young *et al*., 2006). A recent study in England and Wales (Williams *et al*., 2018) showed that hedgehog occupancy of a stratified random sample of 1km OS grid squares was low (22% nationally) and was significantly negatively related to badger sett density and significantly positively related to the presence of urban and suburban areas. In addition, hedgehogs were absent from 71% of sites that had no badger setts, indicating that large areas of the rural landscape do not support hedgehog or badger populations.

The study of Williams *et al*. (2018) was conducted across England and Wales and included many areas where badger sett densities are high. The predicted sett density at which the probability of hedgehogs being present fell to zero was 3.29 main setts km^{-2} (95% CI:2.17 – 4.40). This is far greater than an earlier estimate (Micol, Doncaster and Mackinlay, 1994), based on work in Oxfordshire, which concluded that above sett densities of 0.227 setts km^{-2} hedgehogs would be limited to isolated pockets in a site. In fact, the national badger surveys of England and Wales indicate that this density of setts (not just main setts) is currently exceeded in all land-classes except the uplands. The most recent survey of Scotland used a different habitat classification system, but this shows that badger setts are below this density in several land-use types (see Table 2).

The absence of hedgehogs and badgers, both of which depend largely on invertebrate food, from large areas of England and Wales lends support to the proposition that hedgehog declines are driven by declines in invertebrate biomass, perhaps as the result of agricultural intensification or climate change.

In Scotland, the highest estimate of badger main sett densities in the most recent survey (Rainey *et al*., 2009) was 0.33 main setts km^{-2} (in areas dominated by deciduous woodland). Although the data from Williams *et al*. (2018, figure 4) suggest that at this sett density badgers and hedgehogs should be able to coexist, further work is needed, particularly as sample sizes from current hedgehog surveys are inadequate to determine whether the hedgehog is declining in Scotland (D Wembridge, People’s Trust for Endangered Species, personal communication, 2020).

4.3 Birds

A review of birds in the diet of badgers (Hounsome and Delahay, 2005) examined 110 published studies of badger diet from across the species’ range. Remains of 45 bird species from 11 orders were detected. In general, the frequency of occurrence was low (5.55% for all studies, 7.97% for UK studies), though the authors noted that frequency increased significantly with latitude. This relationship is illustrated, for example, by the low frequency of occurrence of bird remains reported from studies of badger diet in Mediterranean (6.7%) (Barea-Azcón *et al*., 2010) and the relatively high frequency of occurrence in southern Finland (~20%) (Kauhala, Laukkanen and von Rége, 1998).

In Scotland, Kruuk (1989) recorded a low frequency of occurrence of birds in a sample of 2159 badger faeces (Table 5) from 6 areas in central Scotland. Leitch and Kruuk (1986) estimated that birds constituted 1.4% of the total annual biomass taken each year by badgers at a site NE of Aviemore and concluded that this consumption of 32-70kg of avifauna (including scavenged items) by the 30 badgers in the area would have an insignificant impact on bird populations. However, this study did not cover many of the parts of Scotland with the densest badger populations and assumes that the consumption of birds is the result of opportunistic predation over a large area and wide range of species, which may not always be the case.

Table 5. Occurrence and volume of bird remains in a sample of 2159 badger faeces from 6 areas of Scotland (New Deer, Speyside, Monymusk, Ardnish, Glen Feshie, Stonehaven) (Kruuk, 1989).

Species	Percent occurrence	Percent by volume (estimated)
Woodpigeon	2.1	0.8
Passerines	0.2	0.08
Others or unidentified	6.6	1.5

In a major review of the importance of predation as a driver of bird population changes in Scotland, Ainsworth *et al*. (2016) listed species implicated in predation events for a number of species and species groups, covering literature from both Britain and Europe (Table 6). Listing did not necessarily indicate that a species was a key driver of population change but did indicate that it had been identified in one or more studies as a predator of adults or at nests. The fox (*Vulpes vulpes*) was by far the most commonly listed mammalian predator, followed by ‘small Mustelids’, with the badger listed only for the grey partridge, which has a limited distribution in Scotland.

Table 6. The importance of different predators to species or species groups. Listing does not necessarily indicate that a particular predator is significant in affecting the dynamics of the species concerned. 'Small Mustelids', though not defined, is assumed to include Stoat and Weasel. Data extracted from the review by Ainsworth et al. (2016).

Species/group	**Species listed in 'Importance of different predator species'**	**Badger mentioned?**
Black grouse	Fox, Mustelids (stoat), Corvids (carrion crow)	No
Grey partridge	Fox, Mustelids (stoat, badger), Corvids, rats	Yes
Lapwing	Fox, small Mustelids (stoat), Corvids, heron, buzzard, common gull	No
Golden plover	Fox, carrion crow	No
Oystercatcher	Hedgehog, raven, gulls	No
Curlew	Fox, small Mustelids, large gulls	No
Capercaillie	Fox, crow, pine marten, goshawk	No
Red grouse	Corvids, fox, small Mustelids, hen harrier	No
Upland waders	Fox, Mustelids, Corvids	No
Other upland birds	Hen harrier, American mink	No
Lowland gamebirds and wildfowl	Fox, Corvids	No
Lowland waders	Fox, hooded crow, raven, jackdaw, gulls	No
Other lowland birds	Jay, cat, pine marten (Europe)	No
Raptors and Corvids	'ground predators'	No

Although it seems clear that badgers are not significant drivers of bird population declines in Scotland, there may be some particular cases where bird aggregations of conservation significance are affected by badger predation. Apart from the cases described below, the specialists consulted were unaware of any other significant impacts of badgers on birds of conservation concern.

4.3.1 Colonial ground-nesting birds

Colonial ground-nesting species, such as several species of terns and gulls, can be very vulnerable to both avian and mammalian predators. Where these species are of conservation concern, action may be taken to reduce predation losses by constructing predator-proof fences to exclude mammalian predators. (Yates, 2010; White and Hirons, 2019). In most cases, the fox is considered to be the main ground predator to be excluded, but badgers have also been mentioned in some cases. In no case, has the relative importance of foxes and badgers been assessed.

The majority of the Scottish population of the sandwich tern (*Sterna sandvicensis*) nests at the Sands of Forvie NNR (Aberdeenshire). A decline between 1987 and 1998 was attributed to several years of predation by foxes (Short, 2014). The main nesting area is now protected by an electric fence, which has reduced fox activity to about 16% of what it would otherwise have been (Patterson, 1977). There is no suggestion that badgers have been implicated in these predation events, but this provides an example of action that can be taken to defend small areas used by colonial nesting birds where ground predators are considered to be a conservation problem.

4.3.2 Ground-nesting waders

Although habitat changes and agricultural intensification may be the most important factors implicated in the decline of many ground-nesting waders, predation may also be an important driver of change.

Only rarely have predators been identified to species, with most studies only distinguishing between avian and mammalian predators. However, the use of nest cameras, which can identify the predator involved with a high degree of certainty, has the potential to change this. In a review of predation on wader nests in Europe, Macdonald and Bolton (2008) listed 216 nest predation events identified using nest cameras, predominantly in wet grassland. 132 were by foxes, 21 by stoats, 15 by crows, 12 by badgers, eight by hedgehogs (all on South Uist), small numbers by other predators, and in 16 cases the predator could not be determined.

At Loch Leven, a mixed assemblage of waders nesting on wet grassland is protected by an electric fence to deter ground predators. A badger sett is located close by, but badgers are not considered to be a significant threat, though they will certainly take eggs opportunistically (G White, RSPB, personal communication, 2020).

At this and other fenced sites (RSPB sites at Otmoor, Minsmere, the Dee Estuary and Lough Earne (NI)), the main ground predator of concern is the fox; badgers are not considered to be a significant factor affecting wader breeding success, though individual predation events occur from time to time. (G White, RSPB, personal communication, 2020).

The predominance of the fox, a generalist predator of rodents and birds, as the principal nest predator of waders in lowland grassland led Ausden *et al*. (2009, p 37) to conclude that *"At virtually all sites Foxes are the only predators that, on their own, have the potential to cause the decline of a breeding Lapwing population through nest predation on lowland wet grassland in Britain."*

In a more upland situation (Table 7), monitoring of 183 nests of seven species of waders in the Cairngorms by either camera (59 nests) or datalogger (124 nests) was able to identify two avian and three mammalian predators, including one predation event by a badger (Jarrett *et al*., 2019). Interestingly, no predation event by foxes was observed by camera, though this species is widely considered the most important mammalian predator of wader nests (Ainsworth *et al*., 2016) and was probably responsible for the majority of nocturnal nest failures.

Table 7. Causes of failure for 54 wader nests (common sandpiper, curlew, golden plover, lapwing, oystercatcher, redshank, snipe) in East Cairngorm monitored with cameras or dataloggers in 2018 and 2019 (Jarrett et al., 2019). Diurnal failures are more likely to involve avian predators, nocturnal ones, mammalian predators.

Cause of nest failure	Number	Percent
Unattributed (diurnal)	23	42.6
Unattributed (nocturnal)	7	13.0
Abandoned/weather	8	14.8
Agricultural operations	4	7.4
Sheep (predated or trampled)	2	3.7
Badger	1	1.8
Stoat	3	5.6
Pine marten	3	5.6
Jackdaw	1	1.8
Common gull	2	3.7

4.4 Reptiles and amphibians

Reptiles and amphibians have been recorded in the diet of badgers, usually as minor components of the diet, though occasionally in larger quantities (e.g. Roper and Mickevicius (1995) for the former Soviet Union, Rosalino *et al*. (2005) for the Mediterranean). In Ireland, Cleary *et al*. (2009) found that frogs occurred in the diet throughout the year and were the most important animal component of diet in the summer (frequency of occurrence: 27%, ingested volume 22%). In six areas of Scotland, Kruuk (1989) recorded amphibians (frogs and toads) as occurring at a frequency of 5.5% in faeces, making up 1.7% of the diet by volume. Amphibia were eaten most often in areas with bogs and rough ground especially Ardnish (occurring in 11.4% of faeces), but correspondingly less in Monymusk and New Deer (3.6 and 2.8% of faeces), which are mostly agricultural or wooded (Kruuk and Parish, 1981). Both species of amphibians recorded as badger food items (frogs and toads) are common and widespread in Scotland, with no evidence of significant declines and no evidence that badgers threaten their populations (McInerny and Minting, 2016).

Reptiles form a small part of badger diets in Mediterranean areas (e.g. Martin, Rodriguez and Delibes (1995)), but there is no evidence for reptiles forming any part of badger diets in Britain. However, opportunistic consumption of rare reptiles could affect populations. One example comes from a reintroduction of Hungarian meadow vipers (*Vipera ursinii rakosiensis*) in Hungary, where 60% of the reintroduced individuals were predated. Of these, half were lost to avian predators and half to mammalian predators, with the fox and badger being named as the most likely predators, though no evidence was presented as to their relative importance (Sós *et al*., 2020). In Scotland, the most vulnerable reptile is likely to be the adder (*Vipera berus*), which occurs in habitats used by badgers and is widespread, if patchy in distribution, but may be contracting in range (Reading *et al*., 1996) and declining in numbers (Julian and Hodges, 2019). No other significant impacts on reptiles or amphibians were raised by the specialists consulted.

4.5 Invertebrates

Invertebrates, both annelids and arthropods form an important part of badger diets throughout Britain (see Section 3.1). Given the huge biomass of earthworms present in pasture and woodland, the badger's favoured foraging habitats, it seems unlikely that badgers would have a significant impact on this food resource. Brown (1983) used data on earthworm productivity (Table 8) to conclude that favoured habitats could support far more badgers than was actually the case, so the badgers were only taking a small proportion of earthworm productivity.

Table 8. Worm biomass in different habitats. Data recalculated from Brown (1983) for NE Scotland; Deciduous woodland data for Wytham Wood, Oxfordshire from Kruuk and Parish (1982).

Habitat	***Lumbricus terrestris* (kg/Ha)**	**Other earthworms (kg/Ha)**	**Total earthworm biomass (kg/Ha)**
Pasture	674	140	814
Arable	404	67	471
Coniferous woodland	0	3.5	3.5
Birch woodland	130	173	303
Deciduous woodland			714

Concerns have been raised about the impact of badgers on social Hymenoptera, specifically wasps and bumblebees (A. Tonhasca, NatureScot, personal communication, 2020). Although these have been recorded as minor dietary items in the British Isles (Cleary *et al*., 2009; Kruuk and Parish, 1981) and the badger is a known predator of bumblebee nests (Benton, 2006), there are few studies examining the level of badger predation or considering its impact on bumblebee populations. One exception is a recent study by Goulson, O'Connor and Park (2018). These authors collected data on the fate of 908 nests of several species of bumblebees, many from central Scotland. Of these, 100 nests showed evidence of partial or complete destruction and badgers were identified as the cause in 50% of cases. The authors (p7) concluded that "*it seems plausible that badgers have a significant negative impact on* *bumblebee populations*" and suggested that surveys in areas where badgers were being removed for disease control purposes could help to elucidate this.

4.6 Plants

Apart from cultivated crops, badgers eat a wide range of plant material (including fungi). Fruits, such as rowan berries and acorns, can form an important seasonal component of their diet, taken according to availability. Badgers will also dig for roots and the pignut *Conopodium majus* appears to be a favoured food, making up 5.3% by volume of badger diets in Scotland (Kruuk, 1989). I could find no expressions of concern about the impact of badgers on plants of conservation concern.

4.7 Conclusions

Although the number of specialists consulted was small, both their responses and the extensive literature review suggested that predation by badgers is generally opportunistic rather than targeted and generally considered a minor problem.

For birds, the fox is a predator of much greater concern and measures to protect breeding bird aggregations are generally driven by a desire to exclude foxes. The increasing use of nest cameras to collect information about which species of predator is responsible for individual predation events will help to elucidate better the relative importance of a range of avian and mammalian predators. Where bird aggregations are vulnerable to opportunistic badger predation, as well as foxes, there is good evidence that excluding predators from small areas with a well-designed fence can reduce losses to ground predators, though avian predators may remain significant (White and Hirons, 2019).

In England, the impact of badger predation on hedgehogs can be significant where badger populations are high, though the effects of intensive agriculture are probably much more significant, as evidenced by the disappearance of the hedgehog from large areas of the country where badgers are less common or absent (Williams *et al*., 2018). The density of badgers in Scotland is generally lower than in England, so predation of hedgehogs may be less likely to be a conservation concern, though further research is currently under way to investigate this relationship and it would be helpful to have a clearer picture of changes in badger and hedgehog populations in Scotland.

Some concerns were expressed by specialists on the possibility of badger predation on rare reptiles, though there is little literature on this subject from Europe and none at all from Britain. It would seem sensible to take this possibility into account in any conservation initiatives for the adder, in particular.

Apart from the case of bumblebees, for which one study was available, no concerns were raised by invertebrate specialists about the impact of badgers on invertebrate populations, even though this is the most important class of prey for badgers. Similarly, specialists raised no concerns about the impact of badgers on plants of conservation concern.

5. IMPACT OF BADGERS ON AGRICULTURE IN SCOTLAND

This section reviews the impact of badgers on agriculture. As Scotland achieved Officially Tuberculosis Free Status (OTF) in September 2009, any studies on the impact of this disease on both badgers and cattle are excluded. Also excluded are the impacts of badgers on the built environment (except farm buildings), gardens, public greenspace and recreational areas, such as golf courses.

5.1 Agricultural damage surveys

Badgers may impact on agriculture in a number of ways. In a survey of farmers in central England (Macdonald, 1984), which largely took place before attitudes were affected by the issue of bovine TB, badgers were rarely seen as a significant pest, with the most common causes of complaint being trampling and rolling of crops and tunnels collapsing under vehicles. Minor causes of complaint included spoil heaps blocking ditches, damaged fences and drains and chewing lambs' tails. In most cases, losses in time and money were considered inconsequential by respondents.

Symes (1989) reported an analysis of 2071 enquiries made to the agricultural advisory service (ADAS) for England and Wales in 1985-1987. In 1985-6, the period for which most data were available, 73% of enquiries came from the south of England, with 48% being from the South-west, where badger numbers are highest (Wilson *et al.*,1997). Enquiries came from both farmers (40%) and householders (43%). Symes also reported an NFU questionnaire survey of 500 farmers in Devon, where structural damage was the most frequent complaint (42% of respondents), closely followed by crop damage (39%) and then predation (14%). Only a quarter of farmers in Devon described badgers as welcome on their farm, compared with more than half in Macdonald's sample of farmers in the Midlands, reflecting, perhaps, the higher density of badgers in south-west England as well as concerns about bovine TB.

Wilson and Symes (1998) reported an update for the agricultural advisory service for England covering the period 1994-6. During this time, 1458 enquiries about badgers were received, with 49% coming from farmers. Agricultural crop damage reported included damage to pasture, where turf was pulled up to gain access to soil invertebrates, damage to cereal crops, including oats, wheat and maize, all of which are eaten by badgers, and, in a small number of cases, damage to commercial vineyards. Predation of lambs or poultry was reported in 2% of cases, and whilst the evidence was usually only circumstantial, in a small number of cases it was considered strong enough to warrant the issue of a licence to disturb or exclude badgers.

Moore *et al.* (1999) carried out an extensive survey of 3600 farmers across England and Wales, stratified by region and farm type (including vineyards) in response to reported increases in both badger numbers and levels of damage. Of the 1982 respondents (return rate of 55.1%), almost 30% reported that badger damage had occurred in the previous year and 57% reported an increase in damage over the preceding 5 years. The incidence of damage depended on region and farm type, with the highest levels of damage being reported from the south-west (52% of respondents) and from dairy (52%) and mixed (50%) farms. The extent of crop damage varied greatly across farm types and regions. Cereal-growing farms had the highest proportion of respondents reporting badger damage, followed by fruit, grass and vegetables. The economic cost of crop damage was generally highest for fruit and vegetables, particularly in Wales, whilst the highest losses for cereals were in the south-west. The burrowing activities of badgers were reported as causing damage by 25% of respondents. Most burrowing damage, which occurred across all regions, was within fields or to fences, though there were some instances of damage to buildings. The majority of the reported livestock predation incidents involved sheep (60%), with 67% of incidents occurring in the south-west, north-west and Wales. An attempt was made to ground-truth a sample of these incidents by dividing them into four categories (accurate, likely, circumstantial and inaccurate) based on questioning the farmers about the evidence they had at the time. In 68% of cases there was only circumstantial evidence that badgers were responsible for predation events. Eleven farmers had reported attacks on sheep or lambs, but none had evidence that badgers were responsible.

In Scotland, a series of questionnaire surveys of farmers' attitudes to pests was carried out between 1998/99 and 2005/6 (Campbell and Hartley, 2007). These focussed mainly on arable farms (4 surveys), but with two surveys of fodder (grass) farms. Farms were selected on the basis of what crops they grew, so cannot be considered an entirely representative sample of all farm types. Farmers were asked which wildlife species they considered to be pests or serious pests, what sort of problems they caused and what action was taken. Badgers were never listed as a serious pest and on average were listed as a problem by 9.1% of respondents for arable farms and by 19% for fodder farms. On arable farms, data on the presence of badger setts was collected in 2004. This indicated that about 24% of arable and 33% of fodder farms had a badger sett. About 28% of arable farms with a badger sett considered they had a badger problem, compared with a mean of 9.1% for all arable farms. Similarly, 38% of fodder farms with a badger sett considered they had a badger problem, compared with a mean of 19%. A further analysis of these surveys between 1998 and 2012 (S Campbell, personal communication, 2020) suggested that about 3.6% of a sample of arable farmers (n=1680) and 3.2% of fodder farmers (n=370) reported problems with badgers damaging crops. Damage to grassland was recorded infrequently, with 0.8% of arable farmers and 2.2% of fodder farmers reporting damage. These figures are lower than those reported for England and Wales and Campbell concluded that in general badger damage to grass and crops was a minor issue. The same analysis suggested that about 9.7% of fodder farmers and 1.7% of arable farmers were concerned about livestock issues and 3.6% of arable farmers and up to 2.5% of fodder farmers were concerned about damage from badger digging.

5.2 Livestock and predation

Predation of livestock (predominantly sheep or poultry) has been referred to in a number of the surveys outlined above. The sporadic and transient nature of predation events can make it difficult to establish which predator was involved and often only circumstantial evidence is available (see Moore *et al*. (1999) for an example). In addition, badgers will certainly take carrion, (Hewson, 1984; Kruuk, 1989), which can complicate the picture. In general, foxes have been identified as more significant predators of lambs, though in the few studies available, percentage losses of lambs to foxes have been low (White *et al*., 2000). A study at a farm in SW Scotland illustrates the need for careful investigation before ascribing predation events to a particular predator (SASA, personal communication, 2020). Following persistent complaints that badgers were taking lambs, four CCTV cameras were set up to monitor parts of the lambing fields. Although no predation events were recorded, analysis showed both badgers and foxes present in the fields (10 recordings of badger, 7 of foxes), which were the best source of earthworms in the area. The ewes in the field showed no behavioural response to the presence of badgers but responded in an agitated way to the presence of foxes. On balance, it was concluded to be more likely that foxes rather than badgers were responsible for any losses of lambs to predation.

A recent questionnaire study of Scottish sheep farmers into the prevalence of attacks on sheep by dogs and wildlife (Murray, Warren and Lovatt, 2019) provides some data on their perceptions of the importance of particular predators. In total, 37% of sheep farmers (n= 1931) said that their sheep had been attacked, chased or preyed on by wildlife in the previous 12 months. When asked to identify the species responsible for the most recent attack, farmers most commonly identified the fox, though the badger was identified in 11% of cases (Table 9). This seems rather a high percentage and it is perhaps pertinent to note that in 65% of all cases farmers only witnessed the aftermath of the attack and in 58% of cases the attack was not witnessed by anyone, including the farmer.

Table 9. Wildlife species believed to be responsible for the most recent wildlife attack for farmers reporting wildlife attacks within the previous 12 months (37% of sheep farmers who responded). (Murray, Warren and Lovatt, 2019, fig 5.5).

Predator	Percent of respondents (n = 840)
Fox	25
Crow	21
Raven	19
Badger	11
White-tailed sea eagle	6
Black-backed gull	6
Skua	3
Golden eagle	1

The difficulty of identifying the causes of lamb mortality is well illustrated by a study on four crofts on Benbecula following persistent complaints that a high proportion of lambs were being taken by golden eagles (Campbell and Hartley, 2004). A careful examination of the sheep flocks involved, including such factors as ewe condition, lamb birth weights, livestock management practices and causes of individual lamb mortality, determined by searching for corpses, established that the level of lamb mortality was close to the average for the Western Isles and that losses due to eagle predation amounted to between 1 and 3% of the flock, in line with losses recorded elsewhere in Scotland. This conclusion is similar to that reached by Marquiss *et al*., (2005), who examined losses of lambs to white-tailed eagles on Mull and concluded that the number taken by eagles was small in comparison to losses from other causes, such as ewe condition and disease.

5.3 Pasture and crops

Grazed pasture is an important foraging habitat for badgers, which catch earthworms as well as a range of other invertebrates such as Tipulid larvae, beetles and caterpillars. On occasion, badgers will roll back turf to get at invertebrates beneath, but damage to pasture has rarely been reported as significant, though Milner (1967) gives an example of damage to upland pasture that amounted to a 10% loss of grass and Wilson and Symes (1998) illustrate a case of damage to pasture caused by badgers feeding on soil invertebrates in south-west England. Other studies of badgers feeding on pasture, such as Kruuk *et al*. (1979), make no mention of badgers causing significant damage.

The consumption of cereals by badgers has been widely reported from across western Europe (summarised by Roper *et al*. (1995)) and cereals can constitute a significant item of food during the summer. One study in southern England (Shepherdson, Roper and Lüps. P, 1990) found that wheat constituted more than 50% of badger diet by volume during the summer months and averaged at 30% over the year. In Scotland, Kruuk, (1989) recorded oats as making up 6.4% by volume of badger diets, though few of the sites he studied were in cereal-growing areas. Oats were clearly a favoured cereal and he commented "*if there was even a small field of oats, badgers fed on them a great deal*" (Kruuk and Parish, 1981, p782). The only other cereal available, barley, formed a minor component of badger diet and was taken in accordance with its availability.

Although badger damage to growing cereal crops is perceived as a problem by farmers, particularly in England (Wilson and Symes, 1998), there have been few studies on the economic impact of this damage. Wilson (1993) recorded badger damage to fields of oats in southern England with badgers flattening between 1% and 9.6% of the field area in two separate years, making it unharvestable, but the economic cost of the damage was not estimated. Moore *et al*. (1999) estimated the economic losses of badger damage, based on questionnaire returns by farmers. The pattern of additional costs due to badgers was complex, but damage to fruit and vegetables resulted in a greater economic loss than damage to cereals or grass. Ground truthing of a sub-sample of 150 respondents showed that estimates of the area of damage and the economic costs were reasonably accurate. They noted that most reported damage was of little economic consequence to individual landowners, though approximately 5% estimated losses of over £1000.

In a fairly extensive study of wheat and barley fields in an area of southern England where badger density was moderately high (7.5 adults km^{-2}) (Roper *et al*., 1995), badgers clearly preferred wheat to barley. Overall, 0.25% of the crop area of wheat was damaged by badger trampling and feeding and 0.05% of the area of barley. Average loss of yield for wheat amounted to 7.21 kg ha^{-1}, which, assuming a typical yield for the area of 10^4 kg ha^{-1}, is a loss of less than 0.1%. Given the lower percentage of farmers in Scotland who expressed concerns about crop damage (Section 5.1), it seems unlikely that this will be an economically significant issue in Scotland unless badger populations increase markedly.

Where badgers are causing damage to growing crops, fencing, particularly electric fencing can be effective at excluding badgers (Wilson, 1993). However, this would only be cost-effective for very high-value crops, as fencing costs between £4.84 (strand electric fencing) and £15.20 (barrier fencing) per metre to erect (White and Hirons, 2019).

5.4 Infrastructure and buildings

The digging activities of badgers can cause damage to fields, roads and tracks. In the survey of England carried out by Moore *et al*. (1999) 25% of respondents reported burrowing damage within the last 12 months. Reports came from every region of England, with no obvious regional pattern. In cases of serious damage, a licence may be granted to allow the closure of setts involved in the damage and in England about 25% of successful licence applications involved this purpose. In the period 2002-2004, 2614 licence applications were made, of which about 88% were granted, so the number of licences issued was about 2090, of which about 520 were to remedy serious damage to agricultural land (data from Delahay *et al*. (2009).

Comparable data for Scotland illustrate the difference in the scale of badger-related problems between the two countries. For 2018, the most recent year available, NatureScot issued five licences to take action against badgers to prevent serious damage to land or other property and perhaps one or two for damage to growing crops (G Taylor, NatureScot, personal communication, 2020).

5.5 Remedial actions

Ways of preventing or reducing damage by badgers to crops or infrastructure are available, generally by excluding them with fences or gates (Poole *et al*., 2002; Tolhurst *et al*., 2008; Judge *et al*., 2011; White and Hirons, 2019). However, given the relatively low levels of damage that occur to crops or buildings in Scotland, it is doubtful if these would be considered cost-effective by farmers in many cases. Nevertheless, excluding badgers from access to stored cereals or cattle feed could be an important and good-practice biosecurity measure. In cases of serious damage, licences may be issued by NatureScot to allow the disturbance of setts or exclusion of badgers, where this is likely to reduce or solve a problem. However, the low number of licences issued for this purpose suggests that such situations are not common.

Concerns about badger damage to livestock, almost invariably lambs, has been expressed by a proportion of farmers. Instances of predation certainly occur, but the few cases available where further investigations have been made illustrate the importance of carefully assessing the reasons for lamb mortality. This may include actions such as reviewing husbandry practices, locating casualties and identifying causes of mortality, and monitoring the presence of predators. This will help to ensure that action taken in any particular case is appropriate, proportionate and cost-effective. It would be beneficial to have further examples of where such investigations have taken place.

5.6 Economic cost of badgers to agriculture

Few data are available on the economic cost of badger damage. For England and Wales, Moore *et al*. (1999) estimated the costs of damage to crops and infrastructure, using data from their questionnaire survey (see Section 5.1). Based on a sample of 1982 respondents to their questionnaire (3600 questionnaires distributed, return rate of 55.1%), and using estimates of the cost of damage supplied by respondents, they calculated the total cost of badger damage to be £41.5 million in 1997. This assumes that the responders were a representative and random sample of those who received the questionnaire, though this assumption was not tested. The burrowing activities of badgers resulted in the highest costs, followed by direct crop damage and then predation. The greatest economic losses due burrowing and direct crop damage occurred in south-west England, where badger density is greatest, and Wales suffered the highest costs from predation attributed to badgers. To put this cost in perspective, total income from farming (TIFF) for the UK in 1997 was £7631 million (Defra, 2019b); assuming that 78% of this comes from England and Wales (Defra, 2019b), TIFF for England and Wales was £5952.18 million, so the estimated cost of badger damage amounted to 0.697% of farm incomes.

Table 10. The estimated costs of badger damage in England and Wales in 1997, based on questionnaire returns from farmers (n= 1982). From Moore et al. (1999).

Type of damage	Cost (£ million)	95% C.I.
Burrowing	25.7	21.5-29.8
Direct crop damage	12.5	10.4-14.7
Predation	3.3	2.1-4.4
TOTAL	41.5	35.5-47.4

No cost data are available for Scotland, but some broad comparisons (Table 11) can be made between the levels of badger damage reported by Moore *et al*. (1999) and the unpublished analysis supplied by S. Campbell (personal communication, 2020) (see Section 5.1).

Table 11. Percent of farmers reporting types of damage by badgers in England, Scotland and Wales. Figures for England and Wales are reworked from Moore et al. (1999, Table 4); figures for Scotland are from S Campbell, SASA (personal communication, 2020), who provided figures for arable and fodder farmers separately.

Type of damage	Percent of respondents reporting damage by badgers			
	England	Wales	Scotland	
			Arable	Fodder (grass)
Burrowing	24.7	31.2	3.6	2.5
Crop damage	20.7	24.8	3.6	3.2
Livestock/predation	5.1	10.3	1.7	9.7

Although a direct comparison cannot be made, due to the different ways in which the data were collected, it is notable that in almost every category the levels of damage reported by Scottish farmers are well below those reported by farmers in England and Wales. It seems reasonable to suppose that this would translate into lower estimates of the cost of damage, but it would be unwise to extrapolate from the costs given for England and Wales, both because of the different way in which data were collected and because of the differences in farming systems.

5.7 Conclusions

Differences in the way data are collected on the impact of badgers on agriculture between Scotland and England and Wales make it difficult to draw any direct comparison between the two areas. However, the consistently lower proportion of farmers in Scotland expressing concerns about badger damage to crops, infrastructure or, for the most part, livestock is striking. There may be many reasons for this, but two stand out.

The first is the generally lower density of badgers in Scotland compared, in particular, with England. The highest density of badgers found in Scotland is less than half the highest density found in England and the mean density across Scotland is only about a quarter of that found in England. In addition, badger numbers, as measured by the number of social groups, are increasing significantly in England, with an estimated increase of 103% in the number of social groups between 1985-88 and 2011-13. Data on change in the number of social groups in Scotland are not available for this period because of the change in estimation methods referred to in Section 2.2, but there was no significant increase between the earlier surveys of 1985-88 and 1994-97 (Wilson *et al*., 1997, Table 4.7).

The second reason relates to farmer attitudes to badgers. In England and Wales, this is strongly coloured by concerns about the involvement of badgers in the transmission of bovine TB, which leads to serious economic losses, as well as having a significant social impact (Robinson, 2017). In the 12 months to September 2019, more than 45,000 cattle in England and Wales were slaughtered as TB reactors compared with 192 in Scotland, which retains its TB-free status (Defra, 2019a).

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