Development of methods for surveying and estimating population size of short-eared owls (*Asio flammeus*)

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SUMMARY

BACKGROUND

The short-eared owl is listed on Annex 1 of the EU Wild Birds Directive and is a qualifying species for some classified Special Protection Areas. However, estimates of the breeding population of this species in the United Kingdom are considered to be unreliable and trends largely unknown. This report reviews available information (published literature and original data sources) required to make recommendations for developing and refining survey techniques for counting breeding short-eared owls.

MAIN FINDINGS

- Habitats used by breeding short-eared owls include heather moorland, white grass moorland (where not too heavily grazed), young conifer plantations (where coup size > 50 ha) and some other rough grassland and marsh (particularly coastal areas). The distribution is extensive in the 'uplands' but very localised in 'lowlands'. Any national survey to estimate population size could sample the contiguous upland areas that are occupied but in the lowlands, specific targeting of sites would be appropriate.

- Timing of breeding can vary, probably in relation to vole abundance, and in some years birds may not breed even if holding a territory. Fieldwork for intensive censuses (for example of SPAs) will need to include the earliest potential period of territory occupancy (early March) and pilot work should investigate the proportion of territories that may only be detected once young have hatched.

- Population densities can vary between years and probably spatially, perhaps in relation to local vole abundance and also with conditions influencing immigration from Scandinavia. The British breeding population is not necessarily closed but the degree of integration with populations in mainland Europe is not clear and requires further study.

- Evidence from some local surveys and the national Breeding Bird Survey suggests a degree of synchronicity in population variations across Britain. This is counter to what might be expected if populations were solely driven by vole abundance, which in turn is at least partly determined by local land management practices. Study of the relationships between vole and short-eared owl abundances across Britain could identify the relative importance of local, national and international determinants of owl abundance within Britain.

- Further analyses of data held by individuals and other sources (e.g. the Nest Record Scheme) could provide further information on timing of breeding and population fluctuations.

- Short-eared owl data collected during the national Hen Harrier survey in 2004 probably underestimates absolute population size with estimates ranging from 423-658 apparently occupied territories in Scotland, 78-117 in Wales and 1-2 in Northern Ireland. Data were not available from England.

- A pilot study is essential to refine survey techniques in advance of any national survey or intensive census of, for example, designated sites. A pilot survey should sample the range of densities of short-eared owls that any site or sites are likely to host. It needs to include intensive fieldwork at a number of sites plus the trialling of extensive but low-intensity monitoring. The latter should aim to develop resource-efficient methods of monitoring population trends and, if successful, would allow local intensive fieldwork at a smaller number of sites (e.g. sampled areas as part of a national survey or designated sites) to be placed in the context of the likely stage in any population cycle.

1 INTRODUCTION

1.1 Background

This report reviews available information with the aim of developing recommendations for survey techniques for estimating the population size of breeding short-eared owls ***Asio flammeus*** in the United Kingdom. The short-eared owl is listed on Annex 1 of the EU Wild Birds Directive as a species considered vulnerable in Europe and is a qualifying species for a small number of classified Special Protection Areas (SPA) in the United Kingdom (Stroud ***et al.*** 2001). Recent estimates of the breeding population for Britain (1,000 – 3,500 breeding pairs in 1988-91; Gibbons ***et al.*** 1993) and for Scotland (780 – 2,700 breeding pairs in 1988-91; Greenwood ***et al.*** 2003) are considered to be unreliable with trends largely unknown (e.g. Greenwood ***et al.*** 2003).

Specific objectives of this review are:

1. To make recommendations for developing and refining current survey techniques for breeding short-eared owls with the ultimate aim of determining accurate and precise population estimates for designated Special Protection Areas (SPAs) and for national surveys of the Scottish, and other UK populations.

2. To investigate annual variation in breeding numbers and density and to identify any implications for estimating population sizes in a given area, for example, the possible requirement for repeat surveys over a number of years to produce robust estimates.

3. To consider the requirements for collection of data on prey (small mammals) abundance in conjunction with survey fieldwork.

1.2 Structure of report

This report presents a review of scientific literature and other available information on breeding short-eared owls where this is relevant to the refinement of survey techniques. The information is presented in sections on habitats and distribution, behaviour and the timing of breeding and population densities. The scientific literature was identified using the ISI Web of Science search facility (http://portalt.wok.mimas.ac.uk), and along with other ornithological publications (e.g. national and regional distribution atlases and standard handbooks), were reviewed for information relevant to the assessment and development of methods for quantifying population sizes of short-eared owls. In addition, searches were made on the wider internet for relevant 'grey' literature and other information. In addition, original data on the distribution and abundance of breeding short-eared owls was sourced from:

1. The BTO atlases of breeding bird distribution covering the two periods 1968-72 and 1988-91 (Sharrock 1976, Gibbons ***et al.*** 1993).

2. The Breeding Bird Survey (e.g. Raven ***et al.*** 2004)

3. Observations of short-eared owls recorded during fieldwork for a national survey of breeding Hen Harriers in 2004 organised by the Royal Society for the Protection of Birds (RSPB).

Analyses and interpretation of these data is described within the section on population densities (Section 4). Additional information, for example local counts, was also sought from individuals known to have worked, or be working on short-eared owls in Scotland.

Following a review of the available information, the implications of each aspect (habitats, distribution, behaviour and population densities) for designing and undertaking surveys and censuses are discussed. A further section of the report considers the implications of prey abundance, and its variability, on surveys of short-eared owls, and how it could influence interpretation of survey data. A final section reviews some additional information on surveys of short-eared owls from overseas and further expands the overall review to give recommendations for further work needed to develop and refine survey techniques for the species in Britain.

2 BREEDING SHORT-EARED OWLS – HABITATS AND DISTRIBUTION

2.1 Review of habitats and distribution

Knowledge of the distribution of, and habitats used by, breeding short-eared owls is required in order to identify areas to be targeted for specific surveys. Fieldwork for national and local ornithological atlases show breeding short-eared owls to be widely distributed through the uplands of Scotland, England and Wales but also that they are found in lesser numbers in some lowland areas (e.g. Gibbons ***et al.*** 1993). Fieldwork for the 1988-91 breeding bird atlas found them in 426 10-km squares in Scotland, 209 in England, 39 in Wales, five in the Isle of Man and six in Northern Ireland (Figure 1, Gibbons ***et al***. 1993). In the uplands, habitats in which they have been found breeding are heather moorland, rough grassland and newly planted forestry (e.g. Goddard 1935, Roberts & Bowman 1986, Shaw 1995). In lowland parts of Britain, breeding short-eared owls have been found on salt marshes, dune systems and other areas of rough grassland, mostly, though not exclusively, in coastal areas (e.g. Taylor ***et al.*** 1981, Buckland ***et al.*** 1990, Grainger 2003, Figure 1). Elsewhere in Europe, short-eared owls can breed in agricultural areas including cereal crops, meadows and in rye grass fields (Korpimäki & Norrdahl 1991 (Finland), Michelat 1997, Arroyo & Bretagnolle 1999 (France)). A different suite of small mammal species, as potential prey, on mainland Europe may make it possible for short-eared owls to breed within relatively intensive agricultural areas; the distribution of breeding short-eared owls in France in 1993 appeared to be associated with areas where common voles (***Microtus arvalis***) were abundant (Michelat 1997), a prey species that is absent from mainland Britain. Although breeding in the more intensive agricultural habitats is not reported from Britain, the possibility of nesting in such sites in Britain should not be excluded

In southern Scotland and northern England, the highest densities of breeding short-eared owls in 'open habitats' are reported from rough grassland adjacent to heather moors (marginal hill ground or 'white moor') (McGarry 1998, Raw 2000, Stott 2002), but the more heavily grazed areas, at least in the eastern Cheviots, were avoided (McGarry 1998). Similar habitat preferences are not specifically reported elsewhere, but are likely.

Although widely reported as nesting within young plantations, the only published information on the age of trees and coup sizes occupied was from a one-year study in 1991 in Glentrool Forest, Dumfries and Galloway (Shaw 1995). Both first and second rotation plantations were occupied, with first rotation plantings supporting breeding short-eared owls for up to 12 years after planting. The highest densities were found amongst 3 – 7 year old plantings. The smallest occupied coup for second rotation planting was 62 hectares. Little relationship was found with size of first rotation plantings, but these tended to be considerably larger. The location of nests did not suggest avoidance of woodland edges, with some being within 75 m of standing trees, implying that the area requirement (coup size) could be a function of hunting area required rather than expanse of area in which to nest. The study could not determine whether a group of small but nearby restocked coups could cumulatively provide sufficient habitat for breeding short-eared owls. The Glentrool study was undertaken during a year of high vole abundance (see Section 5) and it was considered that occupation of the smaller restock areas may not be typical during years of average or low vole abundance (Shaw 1995).

Although fluctuations in breeding density and distribution of short-eared owls are reported (Section 5), there was a 15% decline in the number of 10-km squares in Britain in which short-eared owls were recorded between the two national atlas periods, 1968-72 and 1988-92, with losses seemingly spread throughout their range (Gibbons ***et al.*** 1993). In Scotland, the contraction in range over that 20-year period was 18% measured at the same scale. Some local atlases (north-east Scotland and Fife) report that most declines have been in lowland, coastal areas (Buckland ***et al.*** 1990, Grainger 2003). The 4-5 year period over which field data for the atlases were collected should have tended to smooth out any fluctuations potentially due to 3-4 year cycles of their small mammal prey (Section 5), and so it is possible that a real decline has occurred.

2.2 **Habitats and distribution - implications for surveys**

A national survey of breeding short-eared owls in Britain should sample their recent distribution from both national breeding atlases supplemented by local atlases and other local information where available. In the uplands, occupied habitats tend to be more contiguous than those in the lowlands and could therefore justify different sampling strategies. Sampling of, for example 10-km squares, in the uplands would be appropriate provided an adequate proportion of the range of the species is included. In the lowlands, the more localised distribution of the species and restricted availability of suitable breeding habitat would allow more specific targeting of known or likely breeding sites.

Occupancy of conifer plantations is dependent on age (size) of trees and area within the suitable age class. Plantings greater than 15 years old (of any rotation) need not be included, unless particularly stunted due to specific unfavourable environmental conditions. Coup sizes of suitable age class trees of less than 50 hectares might also be excluded, but if these are close to other potential hunting areas (other young plantations, moorland or rough grassland), these should be included as potential nesting areas. The possibility of nesting within arable, or other intensively farmed areas should not be excluded, but as the number and frequency in such areas are likely to be very small, it may be worth relying on supplementary reports for their recording, rather than specific survey effort.

3. BEHAVIOUR AND TIMING OF BREEDING

3.1 **Review of behaviour and timing of breeding**

Information on the timing of breeding and diurnal variation in the behaviour of breeding short-eared owls is required to identify times of year, and of day, in which to concentrate fieldwork for censuses and surveys. In Britain, short-eared owls are reported as laying as early as mid-March (e.g. Goddard 1935), but peak laying periods are typically in April and early May with variations likely to be related to vole abundance and weather (Mikola 1983, Cramp 1985, Roberts & Bowman 1986, NRS data). Clutch sizes can vary substantially (between 2 and 9, median 5: NRS data (n=56 clutches), with larger clutches in years with abundant voles. When prey is scarce, however, short-eared owls may even abstain from breeding (Cramp 1985).

Analysis of BTO Nest Record Scheme (NRS) data suggests that 5% of clutches were started (first egg laid) by the 5th April, 15% by 11th April, 25% by 23rd April, 37% by 30th April and 68% by 15th May, however this was based on a sample of just 19 nest records. A greater sample of laying dates has been estimated from ringing data of young birds in nests (Moss ***et al.*** 2005). The analysis assumed that birds were ringed at the mid-point of the nestling period and back calculation from the dates of ringing was used to estimate the dates of laying first eggs, based on published data on incubation period (e.g. Harrison 1975). Data based on the ringing dates of nestlings (n = 124 nests) suggested an earlier laying period with 5% of clutches started by 27th March, 15% by 2nd April, 25% by 9th April, 57% by 30th April and 81% by 15th May (Figure 2). No latitudinal or altitudinal trends in laying dates were apparent (Moss ***et al.*** 2005). The analyses reported by Moss ***et al.*** (2005) included only nest records and ringing data for which altitude details were available, and for nest records where there was an estimable date for laying of the first egg.

In a study on moorland in Wales, females tended to sit tight during incubation, whilst being fed by the males (Roberts & Bowman 1986). Males usually brought the first food to incubating females at about 'nightfall'. When in the vicinity of the nest, males were generally sensitive to the presence of human observers, making themselves visible, though not necessarily mobbing humans approaching nests with incubating females (Roberts & Bowman 1986). Once young have hatched (incubation period 24 – 29 days, for each egg but starts with the first egg; Mikola 1983), both adults can become more vocal and aggressive with distraction and mobbing displays, and from about one week old, the young may be fed during daylight hours, but mostly after 17:00 or before 08:00 (Roberts & Bowman 1986). The timing of hunting activities of a single radio-tagged short-eared owl (monitored on Orkney during May and June 1990 during its late incubation and chick-rearing period), with supplementary information gathered by visual monitoring of four additional neighbouring territories, suggested close synchrony with periods of activity of the main prey, Orkney voles ***Microtus arvalis orcadensis*** (Reynolds & Gorman 1999). Daytime activity was for short periods only, and, based on the published graphs, peaked between 05:30 and 07:30 and again between 18:30 to 20:30. Interestingly, despite a peak in vole activity during the afternoons, hunting owls tended to be inactive at that time. Hunting short-eared owls can range widely, with few birds seen actively hunting within 500 m of nests in the Welsh study (Roberts and Bowman 1986). In contrast, in young coniferous plantations in Dumfries and Galloway, observations of hunting birds suggested that most, although not always, remained within the coup used for nesting (Shaw 1995). Published information on the behaviour of non-breeding territorial birds, and how this may differ from those with nests, appears to be lacking.

3.2 **Behaviour - implications for surveys and censuses**

The number of occupied territories within any count or survey area should be assessed, during the period between which it can be reliably assumed that birds will have returned to their breeding areas, but also before the onset of incubation. During the incubation period, females can prove elusive because they are solely responsible for covering the eggs (Mikola 1983). Males may be present frequently in the nesting area during that time however, particularly as they have to feed the female (Mikolan1983). Also, birds that fail during incubation, or indeed forego a breeding attempt in any year, may go undetected if fieldwork starts after the onset of the main incubation period. The period between occupancy of a territory and before onset of incubation is likely to be variable in timing and also duration, so that a pragmatic approach to surveys will be necessary. Extensive surveys that aim to assess short-eared owl abundance, should aim for initial visit(s) between early March and mid-April. Where the aim is to accurately census a restricted area, for example an SPA, more intensive fieldwork is desirable during March (also with repeated visits in April) to maximise the likelihood of recording any occupied territories. Further work is required to determine search effort required for both ‘extensive’ and ‘intensive’ fieldwork (Section 6).

For either broad survey or intensive census work in Britain, a series of visits that can reasonably be expected to detect territorial short-eared owls would involve fieldwork in the following periods:

Period 1 (early March – mid April)	To check for occupancy
Period 2 (mid April – late May)	To check for occupancy in event of a late season and to check for males attending incubating females.
Period 3 (June)	To check for adults feeding young (if required)
Period 4 (late June – late July)	To check for late/replacement broods (if required)

It is not clear from current information what proportion of additional territories might be detected during Periods 3 and 4, nor the search effort required per unit area within each period. These are key areas requiring further research (Section 6).

At all stages of the breeding cycle, activity during daylight hours peaks in early morning and evening (Section 3.1). In Orkney at least, where activity during chick rearing appears associated with that of the Orkney vole ***Microtus arvalis orcadensis***, peak activity in a small number of individuals did not start until 05:30 (at least an hour after dawn) and had finished by 20:30 (at least an hour before dusk). Orkney, or common voles are not available on mainland Britain, thus the activity patterns of short-eared Owls on the mainland may differ from those on Orkney. Indeed, there are likely to be regional and temporal differences in periods of activity by breeding short-eared owls, dependent on prey type, abundance and behaviour. Mornings and evenings appear to be the most likely common periods of peak activity (assuming surveying is not possible after dark) and therefore fieldwork should be carried out within those hours. Further work should quantify this more rigorously, however there is sufficient information to suggest that survey effort is best concentrated in the morning and evening periods. Fieldwork for investigative studies into optimum timing for surveying should cover the periods of 4 hours after dawn and 5 hours before dusk. This would also permit some examination of bird activities outside the expected peak periods, and for the early part of the season would effectively cover most daylight hours.

The presence of a hunting short-eared owl during the breeding season does not necessarily indicate that a nest is nearby. The ranging behaviour of hunting birds is also likely to vary spatially and temporally and be influenced by prey type and abundance.

Polygyny has been recorded amongst short-eared owls (e.g. Roberts & Bowman 1986) and so one male on territory does not necessarily imply a single nesting attempt.

4. POPULATION DENSITIES

4.1 Review of population densities

Knowledge of actual population densities or home range size would permit some assessment of data collected in the field. For example, how far apart do short-eared owls seen at different times (or on different dates) have to be to confidently assign them to different territories? The breeding density of short-eared owls is widely reported to vary temporally with high densities (home ranges as small as 18 ha are reported) associated with years of high vole abundance (Mikola 1983, Cramp 1985, Korpimäki & Norrdahl 1991, Arroyo & Bretagnolle 1999, Poulin ***et al***. 2001). With observed fluctuations in breeding densities, low tenacity to some breeding sites and their migratory behaviour, it is generally accepted that short-eared owls can range widely (including, of course, crossing international boundaries) to find breeding sites with high numbers of voles (Korpimäki & Norrdahl 1991, Korpimäki 1994). Ringing recoveries of young reared in Scotland or northern England have come from Scandinavia, and also Spain in subsequent summers (Glue 2002), suggesting that there is at least natal dispersal between Britain and mainland Europe. There are insufficient recoveries of short-eared owls ringed as adults to quantify adult dispersal across Europe (e.g. Saurola 1997), and therefore to assess how the breeding populations in Britain mix with those elsewhere in Europe.

Published densities or territory sizes of breeding short-eared owls in Britain range from 1 apparently occupied territory (AOT) per 40 hectares to 1 AOT per 875 hectares (Table 1). The estimates listed in Table 1 largely refer to densities or territory sizes within areas of suitable habitat or within arbitrarily defined study areas. Based on timed counts during fieldwork for the 1988-91 breeding bird atlas and other studies, breeding densities were estimated to have varied between 1.5 – 5 pairs per occupied 10-km square (Gibbons ***et al.*** 1993). Fieldwork for the atlas of breeding birds in Cumbria suggested an average density of 2.4 birds per occupied 10-km square (Stott 2002). It should be noted that these estimates would also include areas of unsuitable habitat.

Few studies have quantified rigorously annual variations of breeding densities of short-eared owls in Britain. In Eskdalemuir (Dumfries and Galloway), during three years of a study (1976 –1978) in young plantations, the numbers of summer territories recorded were 21, 14 and 16 (Village 1987). Within 620 km^2 of Kielder Forest in northern England, the number short-eared owl AOTs was usually between zero and two during 1975-97, however three peaks occurred with over 15 AOTs during that period (Petty ***et al.*** 2000). In south-east Scotland, the number of apparent territories reported annually to the ***Borders Bird Report*** ranged from 10 – 61 (mean 28) between 1986 and 1995 (McGarry 1998, Figure 3). Although these reports are not from systematic surveys, they are likely to reflect peaks and troughs, with 57 and 61 AOTs in 1990 and 1991 respectively as a marked peak and 15 and 10 in 1986 and 1995 respectively as lows. On the Rinns of Islay, the number of short-eared owl territories reported within approximately 7000 hectares of heather moorland and forestry ranged from 0 – 20 (Malcolm Ogilvie ***pers comm.***, Figure 3). On 35 km^2 of moorland in Wales, four breeding 'sites' were reported as being probably occupied annually or at least regularly during a study period from 1971 to 1984 (Roberts & Bowman 1986) suggesting an apparently stable population. Only one site in the Welsh study was actually monitored for the duration of that study and assumptions for continuous occupancy are based on anecdote (n = 2) or not clear (n = 1), therefore evidence of a 'stable' population there might be considered weak. For the published studies from Eskdalemuir and Kielder, data on short-eared owl abundance was collected secondarily to other principal study species (Kestrel and Merlin respectively) and thus some concern must be expressed over thoroughness and consistency between years in each study. Data collected from the Borders and Islay are also likely to be subject to inconsistencies between years. Thus although identification of major peaks and troughs are probably valid, caution needs to be exercised if looking at more subtle fluctuations in these studied populations.

Table 1 ***Some published densities or territory sizes for breeding short-eared owls***

Year	Location	Habitat	Area per AOT (ha)	Study area (Km^2)	Reference
Scotland					
1934	Roxburgh	Young plantation	230 – 300	15	Goddard 1935
1954	Stirlingshire	Young plantation	40	14	Lockie 1955
1976-78	Dumfries	Young plantation	62 – 112	100	Village 1987
1991	Galloway	Young plantation	60 +	200	Shaw 1995
1985-2004	Islay	Moorland & plantation	350 +	70	M. Ogilvie ***pers comm..***
Elsewhere in UK					
1971-84	Wales	Moorland	875*	35	Roberts & Bowman 1986
Overseas					
1977-87	Finland	Farmland	96 +	17	Korpimäki & Nordahl1991
1991-94	Idaho	Shrubsteppe	4600 +	1604	Lehman ***et al.*** 1998

* Nearest neighbour distances, 2.25, 1.10 and 2.60 km (n = 4 'sites')
Note that the size of an AOT (or home range) given above may, to some degree, be an artefact of study area size.

In Finland, national monitoring of a series of 10-km squares recorded between about 50 and 280 AOTs in each year between 1982 and 1996 (Saurola 1997). Ringers, whose main motivation is likely to be to find nests and ring young, undertook most of the fieldwork for the Finnish monitoring programme and may, therefore, miss territories where breeding did not occur or which failed early in the nesting cycle and so some of the apparent fluctuations in population size may potentially be an artefact of both search effort and non-breeding by territory holding birds. Within a more intensive study of 47 km^2 of farmland in the west of the Finland, the number of nesting short-eared owls ranged from zero to 49 pairs during 1977-87 (Korpimäki & Norrdahl 1991). A study in Idaho found between 11 and 35 AOTs during 1991-94 within 160,541 hectares of shrubsteppe, but different search methods were prioritised in different years and thus the observed variation may have, at least in part, been a function of those different methods (Lehman ***et al.*** 1998).

4.2 Analyses of atlas and survey data

4.2.1 ***Timed counts from BTO atlas data***

4.2.1.1 Methods

Two atlases of the distribution of breeding birds covering the whole of Britain and Ireland have been completed. The first was undertaken during 1968-72 (Sharrock 1976) and the second over the period 1988-91 (Gibbons ***et al.*** 1993). Both mapped the distribution of all breeding species based on 10-km by 10-km squares of the Ordnance Survey's national grid. The earlier atlas gives only categories of evidence for breeding within each 10-km square. The second repeats this but also introduces quantitative measures of relative abundance based on timed counts in sample tetrads within each 10-km square. Comparison of the two atlases permits an assessment of broad changes in distribution (though not abundance) during the 20-year interval between the periods covered.

Short-eared owls were recorded in 685 10-km squares during fieldwork for the 1988-91 atlas (Figure 1) and only data from these squares were included in subsequent analyses of abundance. Abundance data for the 1988-91 atlas were based on the number of individuals encountered by fieldworkers during visits of known duration to sampled tetrads within sampled 10-km squares. These timed counts within sample tetrads within those occupied 10-km squares were examined for evidence of variation in abundance between the four years in which field work was undertaken. This was investigated at two levels: (i) the proportion of tetrads surveyed in a given year from which owls were recorded during timed counts (the number of qualifying tetrads - that is any tetrad from a 10-km square in which short-eared owl was recorded - surveyed ranged from 24 to 241 in each year); and (ii) the number of individuals seen per tetrad surveyed per year within each occupied 10-km square. At the first level, it should be noted that the results will inevitably confound owl abundance with the proportion of surveyed tetrads in any one year that contain suitable habitat. Analysis of variance (ANOVA) was used to assess annual variation with either the proportion of surveyed tetrads recording short-eared owls or the average number seen per survey tetrad as the dependent variable and year (n=4) as a categorical independent variable. The proportion of tetrads in which owls were seen was log-transformed to normalise the data. For the average number of owls seen per survey tetrad, a poisson error term and log link function were assumed.

4.2.1.2 Results

No significant differences in either the proportion of surveyed tetrads in which short-eared owls were seen (F_3 = 1.18, ***P*** = 0.32) or the average number of short-eared owls seen per tetrad (F_3 = 0.87, ***P*** = 0.46) were detected (Table 2 & Table 3). Note that only tetrads within 10-km squares that were recorded as occupied by short-eared owls were included in this analysis.

Table 2 ***The proportion of surveyed tetrads in which short-eared owls were recorded during fieldwork for the 1988-91 breeding bird atlas. Only tetrads within 10-km squares recorded as occupied are included.***

Year	No. tetrads surveyed	Proportion where short-eared owls recorded	
		Mean	SE
1988	241	0.131	0.008
1989	189	0.134	0.012
1990	98	0.123	0.012
1991	24	0.184	0.033

Table 3 ***The average number of short-eared owls recorded per surveyed tetrad within each occupied 10-km square.***

Year	No. tetrads surveyed	Number of short-eared owls seen per surveyed tetrad	
		Mean	SE
1988	241	0.185	0.015
1989	189	0.183	0.021
1990	98	0.155	0.020
1991	24	0.229	0.041

Although there was no evidence for gross changes in abundance or distribution in the four years of the 1988-91 atlas from the timed counts, this does not eliminate the possibility that abundance could have varied locally or regionally and could simply not be detected at the national level. Only 31 of the 10-km squares in the above analyses included tetrads that were surveyed in two or more years and these included only 6 tetrads in which short-eared owls were seen. Therefore, it was not realistic to look for evidence for regional or local variations in abundance within the data collected for the atlas.

4.2.2 ***Breeding Bird Survey data***

4.2.2.1 Methods

The Breeding Bird Survey (BBS) monitors changes in abundance of widespread species of bird within the UK. It assesses changes in the number of registrations for species encountered along fixed transect routes within randomly selected 1-km squares across the UK. During the first eleven years of the BBS (1994-2004), short-eared owls were recorded in 83 1-km squares (Figure 4). Squares were surveyed twice during the period April – June, but not all squares were surveyed in each year of the period considered. Observers are asked, where possible, to start the survey (which generally takes 1-1.5 hours) between 06:00 and 07:00 hours. Therefore, much of the BBS data can be expected to have collected at a time of day when short-eared owls might be expected to be most active, although at least one visit would likely occur during the incubation period, when detection rates of females might be expected to be low (Section 3.1). The maximum number of registrations during either of two visits was taken as the count for each year. Analysis of variance (ANOVA), with the count as the dependent variable was used to examine the effects of square (n=95) and year (n=11) both as categorical variables, and to look for evidence of temporal variation in abundance across the whole country. The analysis assumed a poisson error distribution and log-link function.

4.2.2.2 Results

There was a significant effect of year but not of survey square on the number of registrations of short-eared owls recorded in spring for the BBS during 1994-2004 (Table 4) suggesting there were annual variations in bird abundance at a national level in the UK. Not including data from 2001, when access restrictions limited survey effort, the greatest indices of abundance were over twice those of the lowest, with apparent peaks in 1996-97 and also in 2002-03 (Figure 5).

Table 4 ***Results of ANOVA examining the influence of year and survey square on the number of registrations of short-eared owls recorded during BBS fieldwork, 1994-2003.***

Source of variation	Degrees of freedom	F-value	***P***
Model	105	3.13	0.02
Survey square	95	1.03	0.33
Year	10	6.90	<0.01
Error	849		

The absence of variation between survey squares is likely to simply reflect the low number of registrations per square during such low intensity fieldwork; on only 14 occasions were more than two registrations recorded (the maximum of the two visits) in any square in any year. It should be noted that the random approach to site selection and constancy of survey effort across sites and years should make interpretation of BBS data robust despite the small sample sizes per surveyed square.

4.2.3 ***2004 Hen Harrier Survey data***

4.2.3.1 Methods

The 2004 Hen Harrier Survey was organised by the RSPB. In Scotland, Wales and Northern Ireland, the survey was based on 10-km squares. A proportion of these were self-selected by Raptor Study Groups and these were supplemented by squares selected by SNH, which were mainly to ensure coverage of relevant designated SPAs. The remaining surveyed squares were randomly selected from the recorded distribution of breeding hen harriers during the two BTO breeding atlases. The latter squares were selected from two strata based principally on the relative abundance of harriers recorded during fieldwork for the 1988-91 breeding bird atlas. A higher sampling intensity targeted 46% of squares in the higher abundance category and 13% of squares of those with lower abundance indices. In England, the survey assumed at least near-comprehensive knowledge of the distribution of the small population of breeding hen harriers; no specific volunteer fieldwork was therefore carried out in England and no recording of short-eared owls was thus possible.

Although the survey was principally aimed at determining a population estimate for breeding hen harriers in the UK, fieldworkers were also asked to record sightings of short-eared owls. Specific forms were distributed amongst surveyors on which the location (six figure grid reference), date and time of all sightings of short-eared owls could be recorded (Appendix 1). The forms permitted each sighting to be assigned with activity codes (mobbing, alarming, wing clapping, carrying prey, hunting or 'other') and habitat codes (heather dominated moorland, grass dominated moorland, young plantation, rough grazing, marsh or 'other'). In addition, signs of owl presence (pellets or moulted feathers) and nesting evidence (eggs, young, fledged juveniles) could be recorded.

Reports of short-eared owls were returned, in time for inclusion for this review, from a total of 141 10-km squares (Figure 6). None were returned from England reflecting the different survey strategy for that country. Forty percent of the returns for short-eared owls did not include an activity code and a further 33% were of birds just seen or hunting, the lowest category for identifying territorial short-eared owls defined by Shaw (1995; see Section 6). The remaining 27% were evenly divided into Shaw's categories 'b' to 'e' of ascending evidence for breeding (see Section 6). As the priority of the surveyors was to accurately count Hen Harriers, for analytical purposes we have assumed that, in cases for which specific activity codes that gave evidence of breeding were absent, a single record of a short-eared owl represented an apparently occupied territory (AOT). Two birds seen together at one site were considered as one AOT unless territorial conflict behaviour was reported. In deriving population estimates from the Hen Harrier survey, we have assumed that the survey also representatively sampled the breeding distribution of short-eared owls and that the survey protocol would have reliably detected territorial birds. There are several reasons why these assumptions might be expected to be incorrect and these are discussed in Section 4.2.3.2. Three separate mean densities (AOTs per 10-km square) were then calculated based on different spatial separations of short-eared owl sightings; (i) birds recorded more than 500 m apart relate to different AOTs, (ii) birds recorded more than 1000 m apart to different AOTs, and (iii) birds recorded more than 2000 m apart relate to different AOTs. These are based on the range of territory sizes and population densities in published sources (Section 4.1). For each distance scenario, subsequent sightings with lesser separation distances were considered to be birds from the same AOT, unless any behavioural observations or confirmation of breeding suggested otherwise.

4.2.3.2 Results

Details of short-eared owls seen during fieldwork for the 2004 hen harrier survey were returned from 132 surveyed 10-km squares in Scotland, 5 in Wales and 4 in Northern Ireland (Figure 6). Of these, 45 (32%) were nil-returns, while no information was returned from 138 squares that were targeted for the survey of hen harriers (Figure 6). In the survey squares for which data on short-eared owls was returned, a total of 220 AOTs was estimated assuming birds recorded more than 500 m apart relate to different AOTs. With greater defining separation distances of 1000 m and 2000 m, the total number of AOTs was 179 and 142 respectively. Assuming that densities reported within the squares selected for the hen harrier survey are representative of those within the whole distribution of short-eared owls, and assuming that 426 10-km squares are occupied in Scotland, 39 in Wales and 6 in Northern Ireland (after Gibbons ***et al.*** 1993), a range of national population estimates have been derived (Table 5).

Table 5 ***Population estimates for short-eared owls extrapolated from data collected during the 2004 survey of hen harriers to their distribution recorded during the 1988-91 BTO atlas.***

Country	Defining separation distance for AOTs		
	500m	1000m	2000m
Scotland	658	536	423
Wales	117	94	78
Northern Ireland	1-2	1-2	1-2

In Scotland, the densities were 1.5, 1.3 and 1.0 AOTs per 10-km^2 for separation distances of 500m, 1000m and 2000m respectively. In Wales, they were 3.0, 2.4 and 2.0 AOTs per 10-km^2. Population estimates generated from BTO atlas data assumed densities of 1.5 to 5 pairs per 10-km^2, in part estimated from published studies (as in Table 1). For Scotland at least, densities of short-eared owls derived from the hen harrier survey appear to be at lowest end of the range (for a defining separation distance of 500m) or below it. Comparison of Figures 1 and 6 (the 88-91 BTO atlas distribution and the distribution of short-eared owl returns from the 2004 hen harrier survey) indicates that the 2004 survey might reasonably expect to have effectively sampled the distribution of short-eared owls, except for those in lowland areas along the east coast; 42% of all 10-km squares reported as occupied by short-eared owls in Scotland during 1988-91 were included in the 2004 survey. The priority of fieldwork was, understandably, to accurately count hen harriers (RSPB unpublished) and as such field protocols may not have been best suited for detecting short-eared owls:

- Field season – late March to end of July with at least two survey visits between late March and early June. This is potentially compatible for surveying short-eared owls, though field work in early March may have detected further territories (Section 4.2). The timing of visits to all squares was not available for this review, for those squares visited for which visit dates were available, only 28% were surveyed in March or April, and so in practice it is probable that a number of early breeding attempts by short-eared owls could have gone undetected.
- Timing of visits – from 08:00 to 20:00 – although the extremes do overlap with periods of high activity for short-eared owls, 72% of the returns with time of day included were between 09:00 and 19:00 hours, times when owls were likely to be less active (Section 3.2) and therefore potentially go undetected.
- Areas to visit – Heather dominated moorland, upland young forest (<10-15 years old) and mature spruce forest but excluding ground above 600 m, built-up areas and those within 500 m of occupied dwellings, interior of unbroken thicket and post-thicket stage plantations, upland areas dominated by bracken or without any heather cover and major rock features – Although this will include much common ground that could potentially be occupied by short-eared owls, a major exclusion is that of 'white' or marginal hill ground that does not include heather cover. Several authors report such areas as important where grazing intensity is not too great (Section 2.1). The assumptions of avoidance of areas within 500 m of occupied dwellings and bracken-dominated areas are not reported for short-eared owls. No guidance is given on second rotation forestry plantings. It is possible that some coups of sufficient size to accommodate short-eared owls (Section 3.1) would have been considered unsuitable for hen harriers and thus excluded from the survey.

Considering the above field protocols, it is reasonable to assume that the population densities for short-eared owls derived from the 2004 hen harrier survey could be underestimates, although to an unknown degree.

4.3 **Population densities – Implications for surveys**

Densities of breeding short-eared owls can vary temporally and potentially spatially; therefore it is unlikely that rigid guidelines could be developed for defining minimum distances between observations in order to reasonably expect them to refer to different territories. Different assumptions as to minimum defining distances can lead to different population estimates. Surveys that aim to derive population estimates (rather than simply trends) and censuses should aim to maximise the likelihood of recording behaviour that confirms occupancy of breeding territories and also the likelihood of simultaneous recording of birds in neighbouring territories. As eggs are not laid in all years (Section 3.1), surveys should not rely simply on finding nests or recording nesting attempts to confirm occupancy of a territory.

5. IMPLICATIONS OF PREY ABUNDANCE FOR SHORT-EARED OWL SURVEYS

In Britain, the principal diet of short-eared owls is the field vole ***Microtis agrestis***, although alternatives (notably birds, wood mouse ***Apodemus sylvaticus***, brown rat ***Rattus norvegicus*** and pygmy shrew ***Sorex araneus***) are readily taken where available and also in the absence of field voles, for example on some islands (Glue 1977). Vole abundance can influence the abundance and breeding behaviour of short-eared owls (Sections 3.1 & 4.1) and vole abundance is also known to vary temporally: a 3-year cycle of abundance has been reported in Glentrool Forest (Shaw 1995) and a 3-4 year cycle in Kielder Forest (Petty ***et al.*** 2000). Short-eared owls are widely reported to respond to variations in vole abundance in Britain, but with the exception of the Kielder Forest study (Petty ***et al.*** 2000), few empirical data are published to support this. Although there is some evidence that avian predators (including short-eared owls) can generate cycles of ***Microtus*** voles in northern European grasslands (Korpimäki ***et al.*** 2002), in conifer plantations in northern England, it was considered that other factors, such as forestry management practices, were of greater significance (Petty ***et al.*** 2000). If land management practices are a major determinant of prey abundance in Britain, it is perhaps quite likely that annual fluctuations in numbers of breeding short-eared owls are asynchronous across regions.

Monitoring in western Finland and in the Canadian prairies suggests that short-eared owls can rapidly show numerical responses associated with changes in vole density (Korpimäki & Norrdahl 1991, Korpimäki 1994, Poulin ***et al.*** 2001). In Finland, the breeding densities of short-eared owls were dependent on vole densities in the current spring and also in the preceding autumn, but not in the preceding spring (Korpimäki 1994). In Britain, a combination of anecdotal evidence and some empirical data suggest similar responses (e.g. Village 1987, Petty ***et al.*** 2000).

The relatively short run (10 years) of BBS data tentatively suggests two peaks of short-eared owl abundance across the whole of Britain, with a 4-5 year gap in between (Figure 5). Coincident minor peaks are also apparent from Islay (Figure 3), an area that did not contribute to the BBS indices during the period considered (Figure 5). Two peaks are apparent from the 15-year run of data in the Scottish Borders: the second is coincident with that on Islay and the early one apparent from the BBS data and there is 6 years between those peaks (Figure 3). Synchronous peaks of abundance across Britain would be unexpected if the principal determinant was locally variable vole abundance; regional changes in distribution and relative abundance would then be more likely. In north-east Scotland at least, high breeding densities are reported as often being preceded by influxes at the coast in the previous autumn (Buckland ***et al.*** 1990). Most short-eared owls seen on the east coast in autumn probably originate from Scandinavia (Glue 2002), and hence factors influencing population densities in, and emigration from, Scandinavia may drive some widespread peaks of abundance observed in Britain.

Indices of prey abundance could potentially aid interpretation of survey data. During periods of low prey density, fewer short-eared owls may breed (including some that occupy territories) and the species may range more widely while hunting. During periods of high prey density, a greater number of birds may breed in any one area and foraging ranges may not need to be as extensive. A reliable index of prey abundance could inform the expected territory size and therefore a realistic minimum separating distance between observations of owls to assign to different territories. Similarly, a reliable index could also potentially aid the interpretation of single-year surveys of particular sites. For example, a site could not be ruled out as being of some importance to the species if a low count in one year coincided with low prey abundance. Such interpretation needs a reliable index of prey abundance, knowledge of how that index varies and, importantly, a quantified relationship between prey and owl abundance and behaviour. Given that short-eared owl abundance may be influenced by factors outside of Britain, as well as by local prey abundance, such a model may prove to be complex. It could, however, inform the relative importance of local prey abundance variability and of conditions outside of Britain in influencing population densities of short-eared owls.

6. DEVELOPING AND REFINING SURVEY TECHNIQUES FOR SHORT-EARED OWLS

Monitoring of short-eared owls outside Britain has been attempted using a variety of methods. In Finland, they have been included within a monitoring programme for all raptors and owls that is based on fieldworkers attempting to find all nests within non-randomly selected 10-km squares (Saurola 1997). The maximum number of short-eared owl nests found during 15 years (1982-96) across all monitored squares was 132, and the maximum number of AOTs recorded was about 280 (Saurola 1997). Ringers, whose main motivation is likely to be to find nests and ring young, undertook most of the fieldwork for the Finnish monitoring programme and may, therefore, miss territories where breeding did not occur or which failed early in the nesting cycle. In Idaho, point counts, line transects and the searching of quadrats (6 and 9 km^2) were compared for monitoring all raptors, including short-eared owls in shrubsteppe (Lenham ***et al.*** 1998). The study reported that transect counts found more short-eared owl territories than did point counts, but there were differences in the methods employed, and also in the timing of fieldwork, in different years of the study (1991-1994), and therefore the comparison may not be valid. The authors did consider that their random sampling approach may have failed to detect an increase in short-eared owl territories between two years of their study, as indicated by non-random searching of 'known' sites. In Canada, timed roadside counts (the Canadian Breeding Bird Survey), suggest a decline in abundance over the period 1966-94 within two 'ecozones' (prairies and boreal plains), although the sample sizes were considered rather too small to be reliable (Kirk & Hyslop 1998); for the roadside counts, it was considered that a combined total of over 40 individuals on 14 or more survey routes per year was necessary to detect a reliable trend.

For a survey of breeding short-eared owls in Britain, sufficient information is available to identify areas to be targeted and the habitats in which to focus search effort (Section 2.2). Some information on diurnal and seasonal behaviour is also available to suggest suitable times of year and of day in which to undertake fieldwork (Section 3.2). In order to develop reliable survey and monitoring protocols a study needs to be designed to determine:

1. Which survey method, or combination of methods, should be employed, for example watches from vantage points (point counts), transects on foot or road point counts.
2. What search effort is required per unit area in order to identify occupied territories.
3. What survey effort is required to accurately separate neighbouring territories.
4. How many years a survey should cover in order to representatively sample the range of densities any site may host.
5. The efficacy of wide-scale (low intensity) monitoring of short-eared owl abundance in relation to a smaller number of more intensive surveys.
6. The value of prey abundance monitoring in facilitating the interpretation of owl monitoring.

Census work to count the number of short-eared owl territories in a given area, for example a sample square as part of a national survey or a designated SPA, should aim to identify separate territories as reliably as possible. Shaw (1995) defined six logical categories of ascending evidence for breeding by short-eared owls:

a) Birds seen using an area, usually for hunting, in the breeding season,
b) Birds mobbing corvids/raptors,
c) Courtship display,
d) Birds repeatedly carrying prey to an area [feeding incubating female or young],
e) Birds agitated by human presence,
f) Active nest located.

As birds do not necessarily breed in each year, all observations from (c) to (f) could be, or are certainly, indicative of territory occupancy, while birds seen simply using an area of suitable breeding habitat during the period March – June (a and b) could also be strongly indicative. Watches from a series of vantage points, at optimum times of day and year, are likely to be the best way to assess whether an area is occupied. Such observations should also maximise the chances of simultaneous observations of birds in neighbouring territories or observing behaviour that is likely to identify specific nesting areas. Simultaneous observations from more than one vantage point within the same count area would provide additional information on minimum separation distances for defining territories where observations are made on different dates. An assessment is needed of the maximum distances from which short-eared owls can be reliably detected in order to determine an optimum array of vantage points. Guidance also needs to be developed on the duration of observations from vantage points in order to give some measure of the likelihood of detecting all territories, or what a likely underestimate of occupancy may be.

Intensive survey work is likely to need repeating over a number of years in order to measure the range of densities of short-eared owls that are likely to occur within any counted area. As population fluctuations are likely to vary on roughly 4 to 6-year ‘cycles’, it follows that such intensive work should be of at least similar duration. Alternatively, less intensive methods that monitor variations in abundance could be used to validate more intensive but shorter-term surveys. BBS data for short-eared owls does appear to identify variation in their abundance (Figure 5). The use of similar transect sampling, but targeted specifically within the breeding range of short-eared owls could potentially aid interpretation of short-term but intensive surveys. Approaches to be considered include randomly selected transects to be walked, similar to the BBS but using longer transects and stipulating morning or evening fieldwork. The efficacy of using vehicle transects on roads or tracks (as in some of the North American Monitoring programmes; Kirk & Hyslop 1998, Lehman ***et al.*** 1998) in Britain should also be considered. Studies of short-eared owls in Orkney and Galloway have used informal road-transects to determine local population sizes and behaviour (Shaw 1995, Reynolds ***et al.*** 1999). Assessment of these methods in terms of encounter frequencies and reliability of determined indices would need to be undertaken, but if successful could prove a resource-efficient approach to interpreting or validating more intensive survey work.

In order to develop and refine survey methodologies for short-eared owls in Britain, a number of approaches should be trialled to assess their efficacy. A pilot study should include a combination of intensive fieldwork such as vantage point observations and more extensive monitoring such as transects. Pilot vantage point observations will identify effective and efficient intensities of field work to reliably census short-eared owl populations. To achieve this, a pilot must include the whole potential breeding season (early March – late July) in order to assess rigorously any influence of early territory occupancy and also the likelihood of only detecting territories after the hatching of young.

Pilot transect monitoring will assess its feasibility as a resource-efficient approach to quantifying annual and regional variations in abundance and also long term trends. To achieve this, the pilot work should cover the period when territory occupancy is likely to be high (late March to late May). Considering the timing of such work (just after and approaching darkness), the remoteness of many areas and also the low encounter rates, point counts along road-transects (driving between points) would be an appropriate method to pilot. Point counts along road-transects may also prove an effective monitoring tool (at least in the specified habitats) for some other species that can occur at low densities and in similar habitats to short-eared owls, for example kestrel, grasshopper warbler, curlew and snipe. In addition, such a technique is likely to appeal to volunteer surveyors and could, if shown to be effective, ultimately provide a cost-effective monitoring approach for short-eared owl and a limited range of species. Inclusion of these other species would in any case enhance the interest of the survey for volunteers.

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FIGURES

Figure 1 ***The distribution of breeding short-eared owls in Britain and Ireland, 1988-91 (after Gibbons*** et al. ***1993). Squares symbols represent 10-km squares where evidence of breeding was observed. Small dots represent 10-km squares were birds were seen, but with no evidence of breeding.***

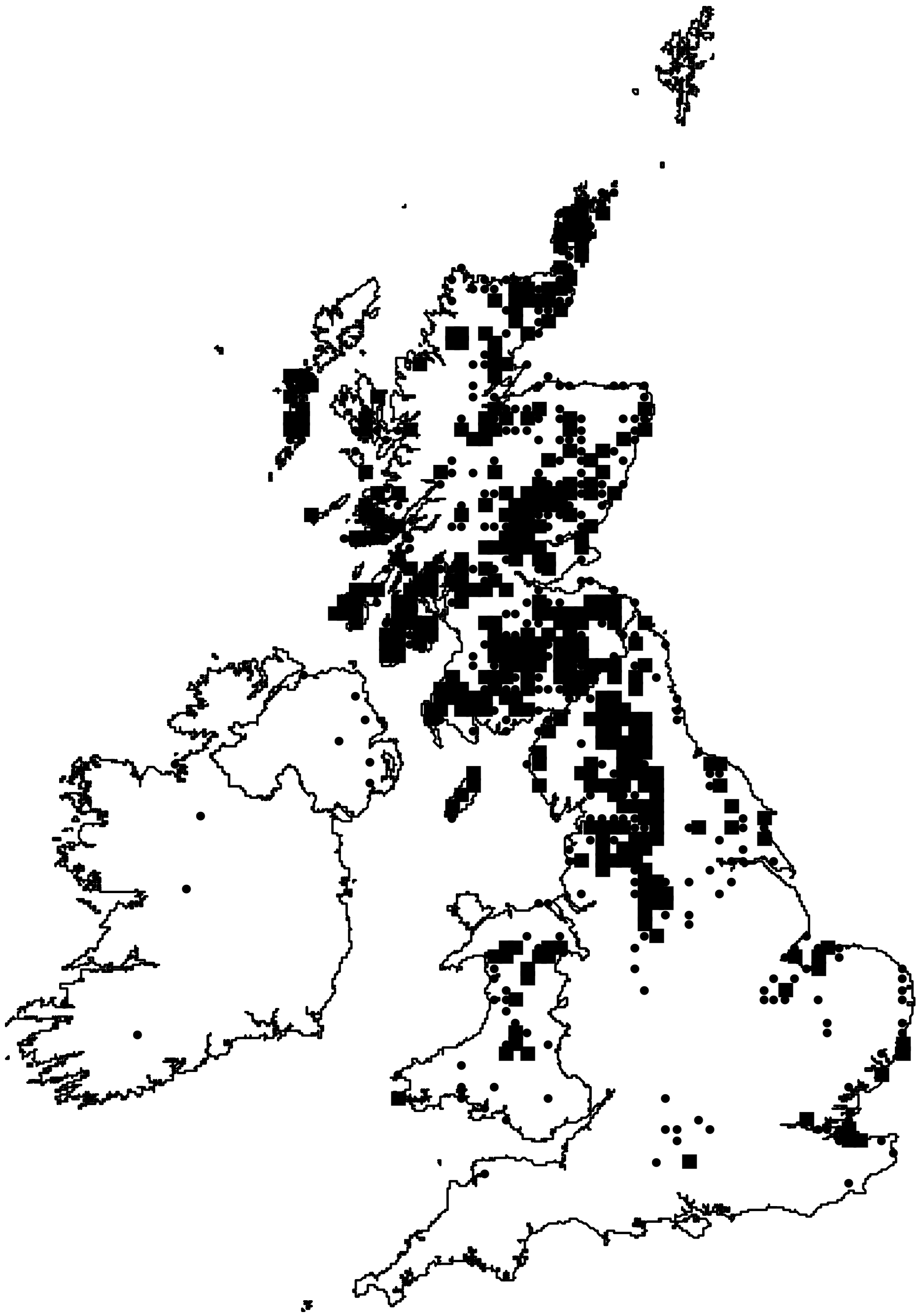


Figure 2. ***The dates of laying first eggs by short-eared owls from Nest Record Scheme data (NRS, n=19) and back calculated from ringing dates of nestlings assuming ringing at the mid-point of the nestling period (n=124). (after Moss*** et al. ***2005).***

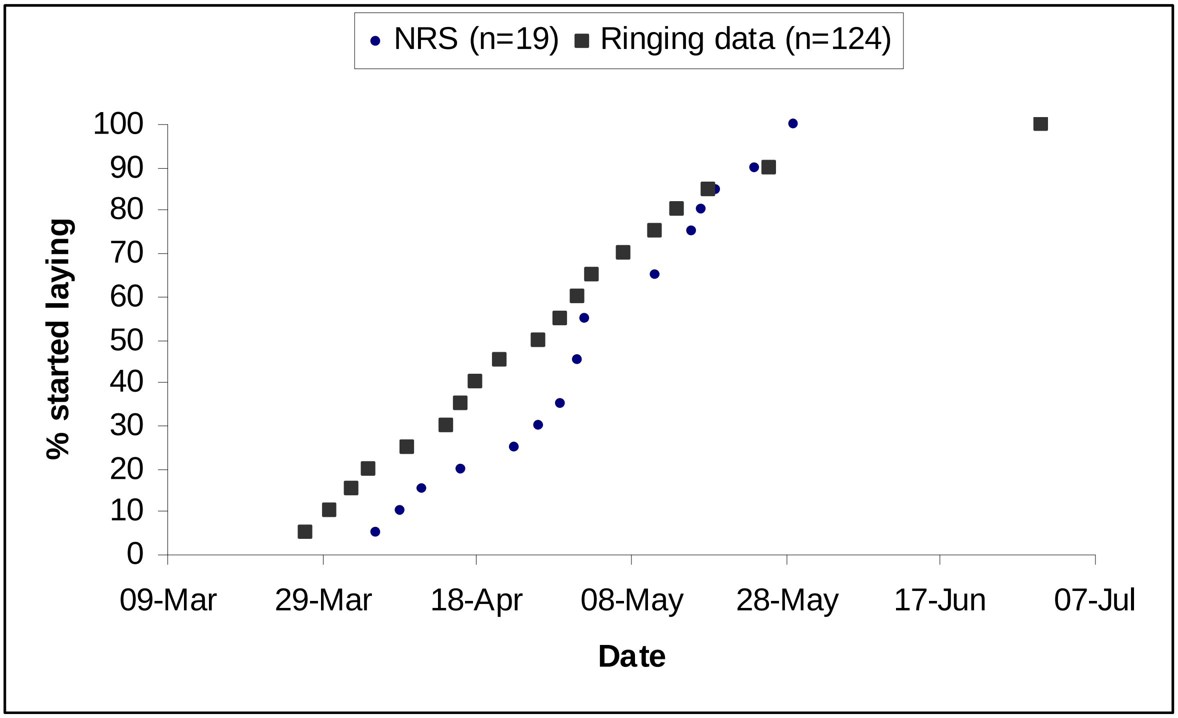


Figure 3 ***The number of apparently occupied territories (AOTs) of short-eared owls in the Borders (McGarry 1998, Knowler In prep) and on the Rinns, Islay (M. Ogilvie pers comm.)***

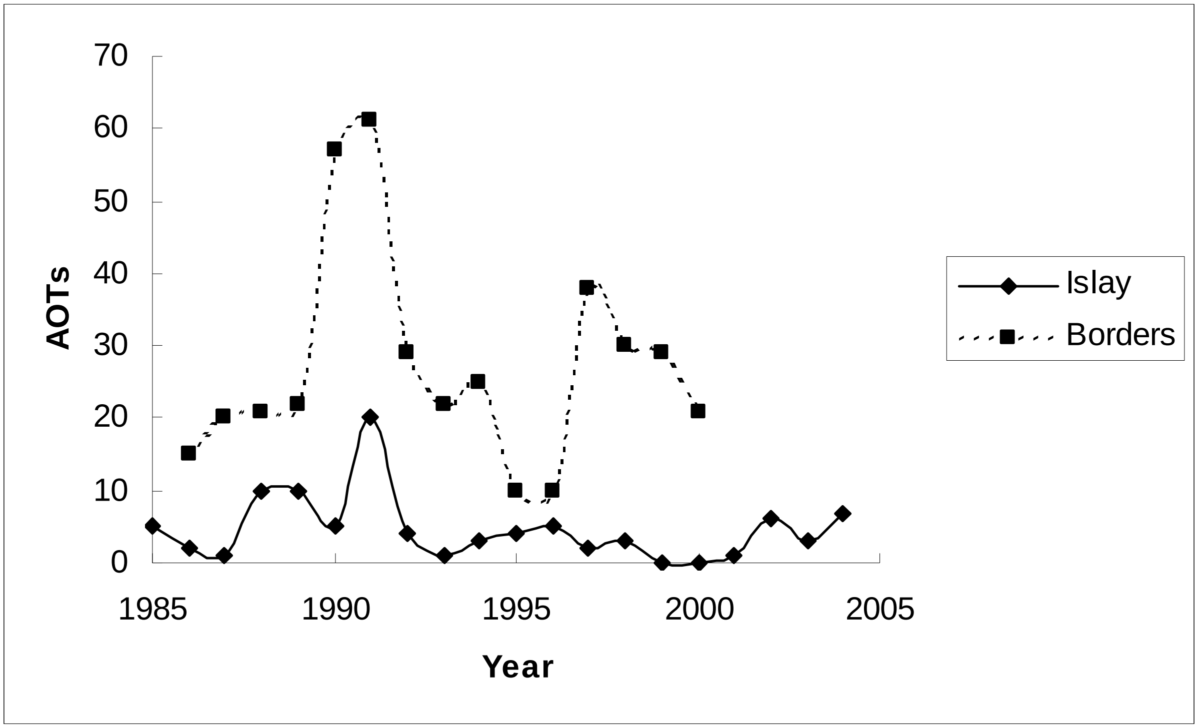


Figure 4 ***One-kilometre squares monitored by the Breeding Bird Survey (BBS) in which short-eared owls have been recorded at least once during 1994 – 2004. The small grey dots show BBS squares that were surveyed at least once during 1994 – 2004 and in which no short-eared owls were recorded. Note, 195 squares that have been surveyed in Northern Ireland, with no short-eared owls recorded, are not plotted.***

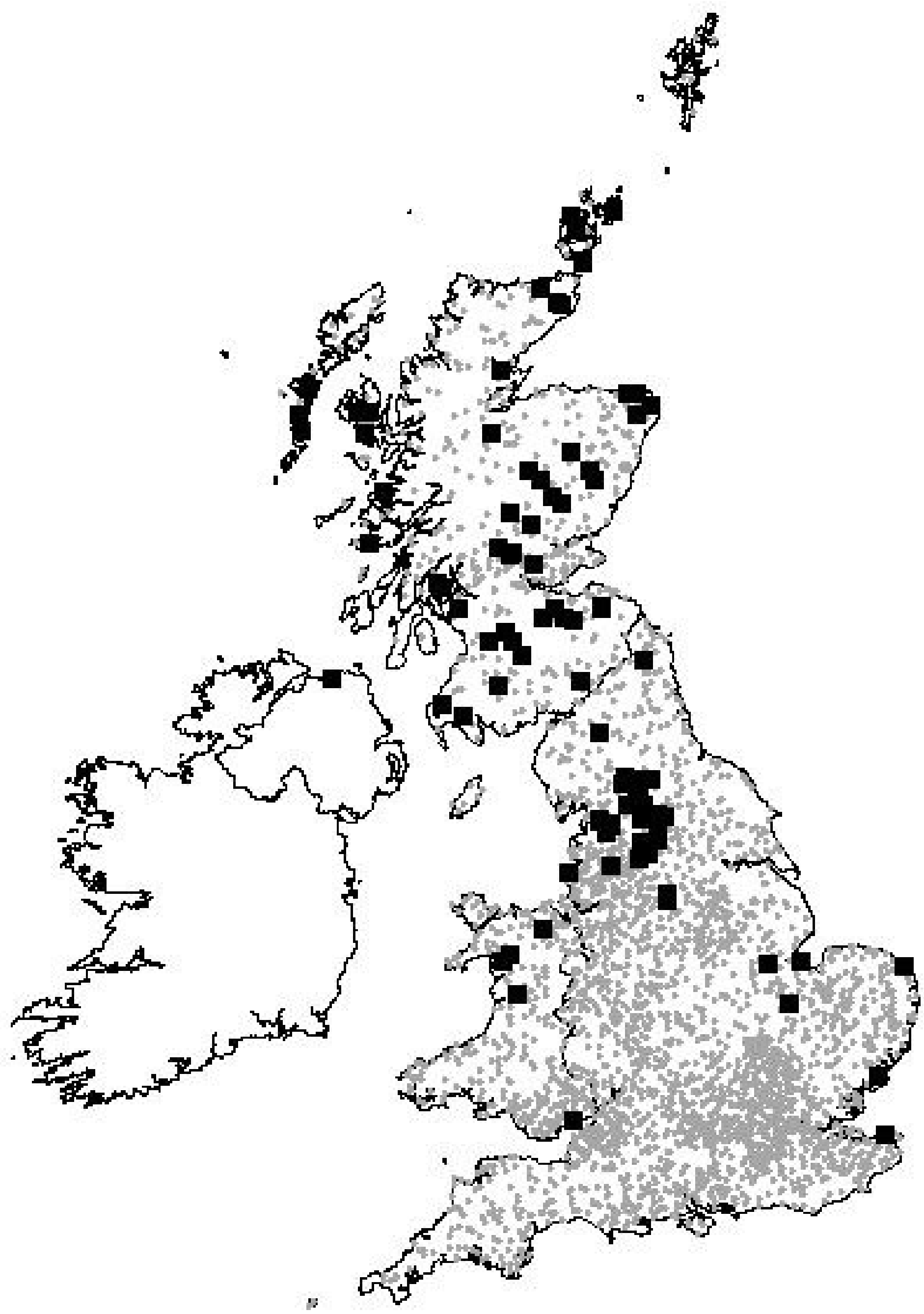


Figure 5 ***The mean number of registrations of short-eared owls recorded by the BBS, 1994-2003. The figures are derived from all squares in which short-eared owls were recorded at least once (n=83), although the number of those squares actually surveyed in any one year varied (48-66 per annum, excluding 2001 when access restrictions due to foot and mouth disease severely limited survey effort).***

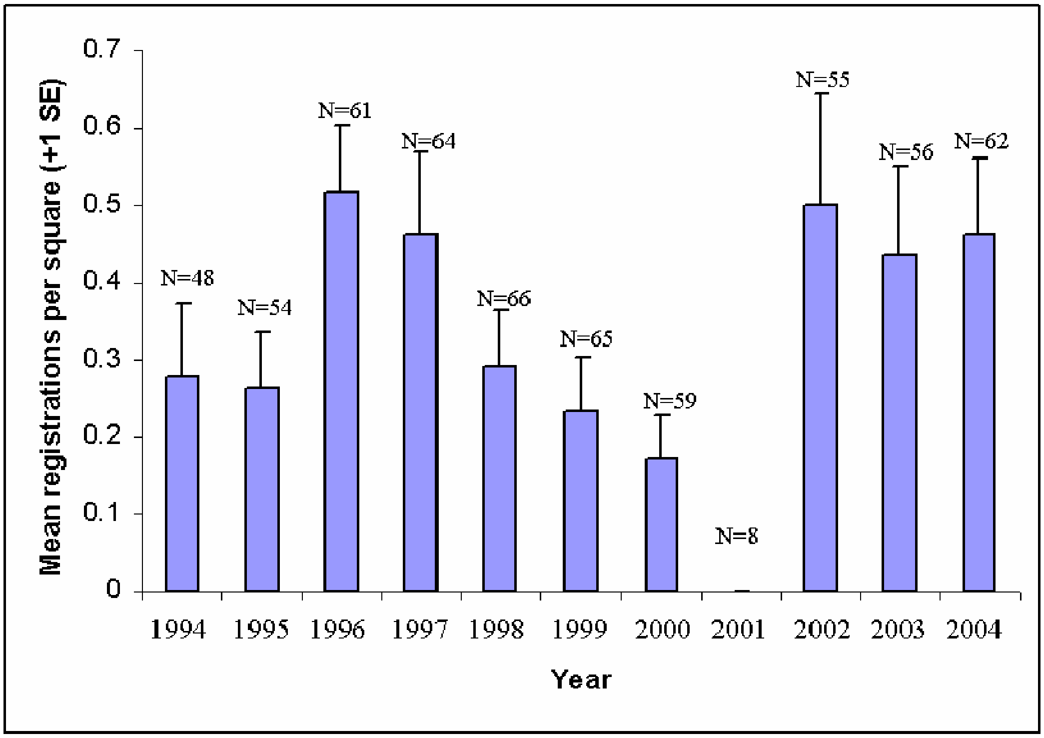
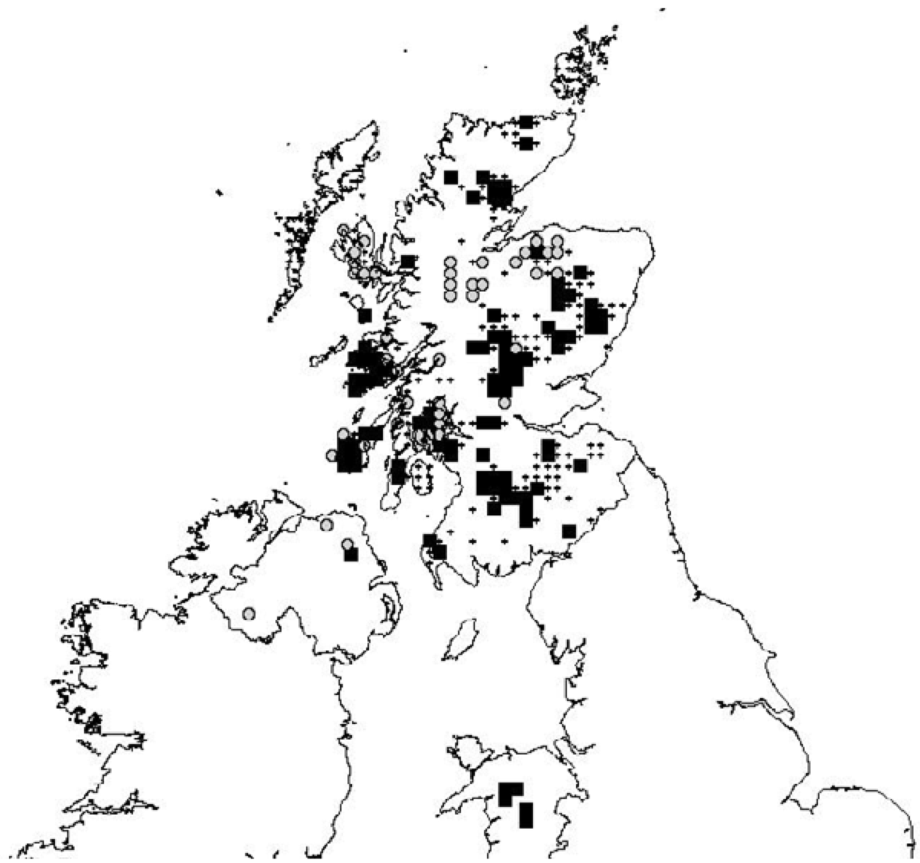


Figure 6 ***Reports of short-eared owls from the 2004 Hen Harrier survey. Larger squares represent 10-km squares where short-eared owls were reported. Small circles represent 10-km squares with nil returns. Crosses represent 10-km squares targeted by the survey but for which no short-eared owl data was returned.***



APPENDIX 1

The short-eared owl recording form circulated to fieldworkers for the 2004 Hen Harrier Survey.

NEAREST PLACE NAME	OBSERVERS	Office Use Only
		PAGE [ ] OF [ ]

10KM GRID REFERENCE eg SX12	COUNTY OR REGION	STUDY GROUP NAME
[ ] [ ] [ ] [ ]		

RECORD NUMBER	GRID REFERENCE eg SX123234								DATE				TIME OF DAY	NO. OF SEOs	SIGNS (P M O)	BEHAVIOUR (M A W P H O)	HABITAT (H G Y R M O)	NESTING EVIDENCE		
									d	d	m	m						No. Eggs	No. Yng	Fledged

COMMENTS

SIGNS CODES

P - Pellets

M - Moulted feathers

O - Other (state:..)

BEHAVIOUR CODES

M - Mobbing

A - Alarm

W - Wing clapping

P - Adult carrying prey

H - Hunting

O - Other (state:...)

HABITAT CODES

H - Heather dominated moorland

G - Grass dominated moorland

Y - Young plantation

R - Rough grazing

M - Marsh

O - Other (state:..................…………………..……..)

PLEASE RETURN COMPLETED FORMS BY 31 AUGUST 2004 TO:

INNES SIM
RSPB
DUNEDIN HOUSE
25 RAVELSTON TERRACE
EDINBURGH, EH4 3TP