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Developing methods for the field survey and monitoring of breeding Short-eared owls (*Asio flammeus*) in the UK: Final report from pilot fieldwork in 2006 and 2007

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Developing methods for the field survey and monitoring of breeding short-eared owls (*Asio flammeus*) in the UK: Final report from fieldwork in 2006 and 2007

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BACKGROUND

The short-eared owl is listed on Annex 1 of the EU Wild Birds Directive and is a qualifying species for six classified Special Protection Areas in the UK. There is a need to determine the appropriate methodology for national surveys of UK populations and to facilitate the most accurate and precise population estimates for the species within designated SPAs in the UK.

This report details the results of a two-year study during the 2006 and 2007 breeding seasons. The aims of the study were: (i) To identify the most appropriate times of day and stages of breeding for surveying and to translate the findings into feasible survey protocols; (ii) To carry out observations to assist in the differentiation of separate breeding territories and to translate these findings into feasible survey and analytical protocols; (iii) To evaluate the feasibility of, and encounter rates resulting from, more extensive field surveys and how these relate to numbers of breeding short-eared owls estimated from intensive observations in key study areas; and (iv) To make recommendations both for field protocols for use in producing a population estimate of short-eared owls in any given area in any given year, and for extensive methods for producing indices of abundance to monitor population changes and allow the results of a full survey in any given year to be placed in context.

MAIN FINDINGS

- The proportion of time for which breeding owls were visible during daylight hours was low (4.8% of the time for the season March – July) and there was a statistically significant effect of time of day and a marginally non-significant effect of stage of breeding on the duration of time for which owls were visible. Most reliable times were in the evenings during incubation (mid-April to mid-May), mornings and evenings during chick-rearing (June) and early morning and late evening during fledging (July). The likelihood of seeing key territorial behaviours was always low. This implies that the timing and interpretation of field surveys should take into account the variation in detection likelihoods with season and time of day and that some surveys may only be able to reliably identify pairs that successfully reach the chick rearing stage.

- Distances at which owls could be reliably detected suggest that a survey of any defined area will require vantage points separated by a minimum distance of about 1.5 km with allowance for topography and a 180° field of view.

With realistic expectations for resources, a survey that delivers a statistically robust national population estimate of breeding short-eared owls is perhaps not a practical proposition. However, robust monitoring of population trends could be achieved through surveys of key or representative areas in conjunction with more frequent but low intensity surveys that can deliver a more continuous index of abundance.

EXECUTIVE SUMMARY

1. The short-eared owl *Asio flammeus* is listed on Annex 1 of the EU Wild Birds Directive as a species considered vulnerable in Europe and is a qualifying species for six classified Special Protection Areas (SPA) in the United Kingdom. However, there is a need to determine the appropriate methodology for national surveys of the Scottish, and other UK populations and to facilitate the most accurate and precise population estimates for the species within designated SPAs in the UK. A previous review commissioned by SNH (Calladine *et al.,* 2005) concluded that there was inadequate information with which to assess reliably the conservation status and requirements of breeding short-eared owls, or from which to make recommendations for suitable survey techniques. In the UK, the species has been little studied previously, mainly due to its apparent nomadic nature, apparent large inter-annual population fluctuations (which may not be synchronised spatially) and the remoteness of some of its breeding habitat.

2. This report details the results of a two-year study involving pilot fieldwork during the 2006 and 2007 breeding seasons. The aims of the study were:

    i. To identify the most appropriate times of day and stages of breeding for surveying short-eared owls and to translate the findings into feasible survey protocols;
    ii. To carry out observations to assist in the differentiation of separate breeding territories and to translate these findings into feasible survey and analytical protocols;
    iii. To evaluate the feasibility of, and encounter rates resulting from, more extensive field surveys and how these relate to numbers of breeding short-eared owls estimated from intensive observations in key study areas;
    iv. To make recommendations both for field protocols for use in producing a population estimate of short-eared owls in any given area in any given year, and for extensive methods for producing indices of abundance to monitor population changes and allow the results of a full survey in any given year to be placed in context.

3. Intensive observations (vantage point watches) were carried out in three areas of Scotland in 2006 and 2007: the Borders, Perthshire and Ayrshire. In each study area in each year, watches, each of two hours duration, were made from four vantage points at least once in each of four survey periods through the breeding season. In 2006, observations were made in each of four times of day (two sampling periods in the first five hours after first light, and two sampling periods in the last five hours before dark). In 2007, two additional two-hour periods were sampled in the middle of the day. All observations of short-eared owls were recorded, together with details of their behaviour and their flight lines. These observations were analysed to assess: (a) whether the durations for which owls were visible (and those in which they displayed key behaviours indicative of territory holding) varied with time of day, stage of the breeding season and year; (ii) the distances at which owls could be detected from observers; and (iii) minimum ranging distances of the owls during the breeding season. In 2007 only, observations were also made from an array of 18 vantage points, incorporating two of the existing vantage points, in the Ayrshire study area, in order to test protocols thought to be practical for a national survey.

4. Within, or close to, each of the three study areas, two ‘transects’ were selected, each a series of roads or tracks that crossed habitat potentially suitable for breeding short-eared owls. Along each transect, between 14 and 21 suitable count points were identified, with a minimum distance of 1-km between count points. Each transect was surveyed once in each of the four stages of the breeding season, within the last three hours before dark in 2006, and once in each of the second and third survey periods in 2007. Timed counts (five minutes at each point) were made, to record all bird species seen or heard (which were recorded in one of five distance bands from points). In 2007, 17 volunteer surveyors carried out additional counts in Scotland, Wales and England following the same methods from 174 points on 19 road transects.

5. Overall, 186 individual observations of short-eared owls were made from vantage points in 2006 and 278 in 2007. These indicated that the proportion of time for which owls were visible during the hours of the day that were sampled was low: on average owls were visible for only 4.8% of the time. For all observations of short-eared owl activity combined, there was a statistically significant effect of time of day and a marginally non-significant effect of stage of breeding on the duration of time for which owls were visible but no significant difference in activity patterns between the two years. Sample sizes were too small to test for interaction effects but back-transformed estimates from the models suggested variation in the diurnal activity patterns with stage of breeding. In March (the settling period), encounter rates were extremely low. From mid-April to mid-May (incubation), most owl activity was observed in the four hours before dark, with a lesser peak in the four hours after first light. In June (main chick rearing period) owls were visible throughout the daylight hours that were sampled, whilst in July (main fledging period), lower rates of activity were recorded in the first two hours and last four hours of the day.

6. Key behaviours indicative of territoriality were observed very rarely: there were only 43 discrete observations of short-eared owls that included such activities in 2006 and 119 in 2007. Because of the rarity of these territorial activities, statistical power for testing the influence of time of day, stage of breeding or year on the duration of these behaviours was low. The patterns of variation in key behaviours with time of day and stage of breeding were very similar to those for all activity however, implying that their frequency was simply a function of overall owl activity.

7. Sub-sampling from the data collected in the two breeding seasons permitted the estimation of the likelihood of owls being seen under different scenarios of timing and duration of systematic watches. There was a greater than 75% likelihood of seeing owls during a combined total of two two-hour watches: only in the evenings during incubation; in either the mornings or the evenings during the main chick rearing period; and in the early morning or late evening during the fledging period. The likelihood of seeing key territorial behaviours did not exceed 75% with any combination of two two-hour watches in any stage of breeding. The data collected in 2006 and 2007 allow the likelihood of detection to be estimated for any proposed combination of timing and duration of observation visits.

8. Across all 10 vantage points from which owls were seen, the mean distance from an observer at which Short-eared owls were first detected in 2006 was 522 m (95% confidence limits: 473 – 570 m), and significantly greater in 2007: 702 m (95% confidence limits: 648 - 755 m). The greater detection distances in 2007 were also apparent in both the minimum and maximum distances at which owls were seen from vantage points.

9. The flight lines of short-eared owls observed at each site were grouped into ranges (using territorial interactions to differentiate ranges when available). The numbers of

ranges visible from each vantage point were largely consistent with the views of local independent raptor workers when these were available. From all independent vantage points, in both years, the majority of the observations were thought to refer to a single territory. In a few cases, birds from a neighbouring territory (or non-territorial birds) were thought to be seen occasionally. There was no statistically significant influence on ranging distance of year or stage of breeding season. The mean minimum ranging distance, estimated as the maximum arc of the minimum convex polygons (MCPs) drawn around the plotted flight lines derived from single independent vantage points was 2077 m (95% confidence limits: 1804 – 2351 m) and that derived from the array of neighbouring vantage points was 3616 m (3213 – 4019 m) however, about twice that apparent from a single vantage point.

10. Fourteen registrations of short-eared owls were recorded from 14 points on 5 (out of 6) of the transects surveyed by professional fieldworkers in 2006. In 2007, when surveys were only undertaken in the second (mid-April to mid-May) and third (June) survey periods, a total of 16 registrations were recorded from 15 points on 5 (out of the 6) of these same transects. Seventeen volunteers carried out timed surveys at 174 points on 19 additional transects in 2007 and recorded 19 owls at 16 points.

11. A total of 97 bird species was recorded during the point count surveys by both professional and volunteer surveyors between mid-April and June in 2006 and 2007. The encounter rates from the sample of transects covered suggested that the method could produce useful information for breeding population indexing purposes (complementary to that from existing surveys e.g. BBS) for a range of species, including: a number of breeding waders (e.g. curlew *Numenius arquata*, lapwing *Vanellus vanellus*, redshank *Trings totanus*, snipe *Gallinago gallinago* and oystercatcher *Haematopus ostralegus*); two widespread raptors (buzzard *Buteo buteo* and kestrel *Falco tinnunculus*); some gamebirds (e.g. pheasant *Phasianus colchicus*, possibly black *Tetrao tetrix* and red *Lagopus lagopus* grouse); and a range of passerines (e.g. meadow pipit *Anthus pratensis*, pied wagtail *Motacilla alba*, reed bunting *Emberiza schoeniclus* and sky lark *Alauda arvensis*).

12. We discuss, based on the views of the project steering group and existing knowledge, whether the owls in the three study areas sampled can be taken to be broadly representative of short-eared owls across Britain in the context of the parameters that we set out to measure in the current study.

13. The following recommendations are made concerning field protocols for a full (national) survey of breeding short-eared owls:

    - Sample contiguous areas of owl distribution and potential owl habitat, but use a more targeted approach for restricted areas (lowland marshes, coastal grassland and pre-thicket plantation/woodland) based on local knowledge.

    - Do not start surveys before early to mid-April (detection rates too low). If it is accepted that only an estimate of successful (to the chick-rearing stage) breeding attempts will be achieved, a survey period of June to July would be adequate.

    - Undertake surveys from vantage points that provide an adequate field of view, within an arc not exceeding 180°, 750 – 1,500 m distant from one another such that all areas to be viewed are within 750 m of the vantage point. Closer proximity of vantage points may be required where topography necessitates.

    - Undertake cumulative totals of 4 hours of watching from each vantage point within each of the following time periods: (i) mid-April to mid-May within the last four hours before dark (if a decision is made to attempt to record breeding attempts that may fail before hatching); (ii) in June between four and eight hours after first light or within four hours before dark; and (iii) in July, within the first four hours after first light or the last four hours before dark. Where practicalities necessitate sampling at other times of day, estimates could be corrected based on the 2006/2007 data.

- Fieldworkers should plot flight lines, including details of behaviour, of all short-eared owls seen, as well as providing their own assessments of the number of territories they detected.

- A range of population estimates should be derived based on different thresholds for assigning spatial locations of birds to different territories in the absence of observations of key territorial behaviours (e.g. simultaneous observations and territorial disputes): 1000 m, 2000m.

- Extensive point counts/transects should be undertaken for a period of at least five years during one of which the actual survey is undertaken, and used to complement BBS data and those from other recording schemes, in order to place intensive survey results into the context of between-year variations in short-eared owl numbers (and/or breeding success).

14. With realistic expectations for resources, a survey that delivers a statistically robust national population estimate of breeding short-eared owls is perhaps not a practical proposition. However, robust monitoring of population trends could be achieved through episodic surveys of key or representative areas in conjunction with more frequent but low intensity surveys that can deliver a more continuous index of abundance.

CRYNODEB

1. Rhestrir y dylluan glustiog *Asio flammeu*s ar Atodiad 1 o Gyfarwyddeb Adar Gwyllt y GE, fel rhywogaeth sydd mewn sefyllfa fregus yn Ewrop. Mae'n un o'r rhywogaethau sy'n gyfrifol am gymhwyso chwe Ardal Gwarchod Arbennig (AGA) yn y Deyrnas Unedig i gael eu rhestru. Ond mae angen penderfynu ar y fethodoleg fwyaf priodol ar gyfer cynnal arolygon cenedlaethol o'r boblogaeth yn yr Alban ac mewn rhannau eraill o'r DU a hefyd er mwyn hwyluso'r gwaith o wneud amcangyfrifon sydd mor benodol a manwl â phosib o faint y poblogaethau yn y gwahanol AGA a ddynodwyd yn y DU. Yn ôl canlyniadau adolygiad blaenorol a gomisiynwyd gan SNH (Calladine *et al.,* 2005), nid oedd digon o wybodaeth ar gael i allu gwneud asesiad dibynadwy o statws a gofynion cadwraethol tylluanod clustiog sy'n nythu. Nid oedd chwaith, yn ôl canlyniad yr adolygiad, digon o wybodaeth ar gael i wneud argymhellion ynglŷn â dulliau arolwg addas. Yn y DU nid yw'r rhywogaeth hon wedi cael ei hastudio yn y gorffennol, yn bennaf oherwydd bod yr adar yn ymddangos yn grwydrol o ran eu natur, a hefyd oherwydd bod y poblogaethau i'w gweld yn amrywio'n fawr o flwyddyn i flwyddyn (a hyn ddim o reidrwydd yn gydamserol o fan i fan). Mae natur bellennig peth o'r cynefin bridio hefyd wedi bod yn rhannol gyfrifol am y prinder gwaith astudio.

2. Mae'r adroddiad hwn yn rhoi manylion am astudiaeth ddwy flynedd a olygodd gynnal gwaith maes yn ystod tymor magu 2006 a 2007. Nod yr arolwg oedd:

   v. Adnabod yr adegau gorau o'r diwrnod, a'r cyfnodau yn y cylch magu, ar gyfer cynnal arolygon o dylluanod clustiog ac i droi'r canfyddiadau yn ganllawiau arolwg ymarferol;
   vi. I wneud arsylwadau er mwyn helpu gwahaniaethu rhwng gwahanol diriogaethau magu ac i droi'r canfyddiadau yn ganllawiau ymarferol ar gyfer gwaith arolwg a dadansoddi;
   vii. I werthuso ymarferoldeb cynnal gwaith maes mwy eang, a'r cyfraddau cyfarfyddiad sy'n deillio o hynny ac i ystyried y cysylltiad rhwng hyn a'r niferoedd bridio o dylluanod clustiog a'r amcangyfrifon o waith arolwg dwys mewn ardaloedd astudiaeth allweddol;
   viii. I wneud argymhellion ar gyfer canllawiau maes y gellid eu defnyddio i amcangyfrif poblogaeth tylluanod clustiog mewn unrhyw ardal, yn ystod unrhyw flwyddyn, ac i wneud argymhellion ar gyfer dulliau eang y gellid eu defnyddio i gynhyrchu mynegeion helaethrwydd er mwyn monitro newidiadau poblogaeth ac er mwyn gallu gosod canlyniadau arolwg llawn yn ystod unrhyw flwyddyn mewn cyd-destun.

3. Gwnaed arsylwadau dwys (arsylwadau gwylfannau) mewn tair ardal yn yr Alban yn ystod 2006 a 2007; ardal y Ffin gyda Lloegr, Swydd Perth a Swydd Ayr. Ym mhob un o'r ardaloedd astudiaeth, yn ystod y ddwy flynedd, bu'r arsylwyr yn gwylio am gyfnodau o ddwy awr ar y tro o 4 gwylfan o leiaf unwaith yn ystod pob un o'r pedwar cyfnod arolwg drwy gydol y cyfnod bridio. Yn 2006 gwnaed arsylwadau ym mhob un o'r pedwar cyfnod yn ystod y dydd (dau gyfnod samplo yn ystod y 5 awr gyntaf ar ôl iddi wawrio, a dau gyfnod samplo yn ystod y pum awr olaf cyn iddi dywyllu). Yn 2007, gwnaed arsylwadau yn ystod dau gyfnod dwy-awr ychwanegol yng nghanol y dydd. Cofnodwyd pob arsylwad o dylluanod clustiog, ynghyd â chofnodion o'u hymddygiad a'u llinellau ehediad. Cafodd yr arsylwadau hyn eu dadansoddi er mwy asesu (a) a oedd y cyfnodau hynny pan oedd modd gweld y tylluanod (a'r cyfnodau hynny pan oeddent yn ymddwyn fel pe baent yn dal tiriogaeth) yn amrywio yn ôl amser y dydd, yn ôl adeg y tymor magu a'r flwyddyn; (ii) pa mor agos oedd angen i dylluanod fod er mwyn i arsylwyr eu gweld; a (iii) beth oedd y

pellter lleiaf yr oedd tylluanod yn crwydro yn ystod y tymor magu. Yn 2007 yn unig, gwnaed arsylwadau ychwanegol o 17 gwylfan yn ardal astudiaeth Swydd Ayr, a oedd yn cynnwys dau o'r gwylfannau a oedd eisoes wedi eu sefydlu, a hynny er mwyn rhoi prawf ar y canllawiau a ystyriwyd yn ymarferol i'w defnyddio ar gyfer arolwg cenedlaethol.

4. O fewn, neu'n agos at y tair ardal astudiaeth, dewiswyd dau 'drawslin'. Roedd y ddau yn gyfres o ffyrdd neu draciau a groesai gynefin a allai fod yn addas fel ardal fridio i dylluanod clustiog. Dewiswyd rhwng 14 a 21 man cyfrif addas ar hyd bob trawslin, ac roedd pellter o 1km, fan lleiaf rhwng y mannau cyfrif. Yn 2006, cynhaliwyd arolwg ar hyd bob trawslin unwaith ym mhob un o'r pedwar cyfnod yn ystod y tymor magu, o fewn y tair awr olaf cyn iddi dywyllu, ac yn 2007 cynhaliwyd arolwg unwaith yn ystod yr ail a hefyd y trydydd cyfnod arolwg yn ystod 2007. Am bum munud ym mhob pwynt cyfrif, cofnodwyd pob rhywogaeth o adar a welwyd neu a glywyd (a chofnodwyd y rhain mewn un o bum band pellter o'r man cyfrif). Yn ystod 2007, defnyddiwyd yr un dull gan 17 arsylwr gwirfoddol i wneud rhagor o waith cyfrif yn yr Alban, Cymru a Lloegr o 174 pwynt ar hyd 19 trawslin.

5. Gwnaed 186 arsylwad unigol o dylluanod clustiog o wylfannau yn ystod 2006, a 278 yn ystod 2007. Roedd hyn yn dangos mai dim ond am gyfran isel o'r oriau yn ystod y dydd y llwyddwyd gweld y tylluanod yn y mannau a samplwyd; ar gyfartaledd, dim ond am 4.8% o'r amser yr oedd modd gweld y tylluanod. O gyfuno'r holl arsylwadau o weithgaredd tylluanod clustiog, roedd effaith amser y dydd ar hyd y cyfnod pan oedd modd gweld y tylluanod yn arwyddocaol yn ystadegol. O flewyn, nid oedd effaith adeg y tymor magu ar hyd y cyfnod pan oedd modd gweld y tylluanod yn arwyddocaol yn ystadegol. Ond nid oedd gwahaniaeth arwyddocaol rhwng y ddwy flwyddyn. Roedd maint y samplau yn rhy fychan i fedru rhoi prawf ar effeithiau rhyngberthynas ond drwy ddefnyddio modelau i drawsnewid amcangyfrifon am yn ôl, roedd awgrym bod adeg y tymor magu yn dylanwadu ar batrwm gweithgaredd dyddiol y tylluanod. Ym mis Mawrth (y cyfnod setlo) isel iawn oedd y cyfraddau cyfarfyddiad. Rhwng canol Ebrill a chanol Mail (gori), gwelwyd y rhan fwyaf o weithgaredd tylluanod yn ystod y pedair awr cyn iddi dywyllu, gydag uchafbwynt llai yn ystod y pedair awr wedi iddi wawrio. Yn ystod Mehefin (prif gyfnod magu cywion) roedd tylluanod i'w gweld drwy gydol yr oriau a samplwyd yn ystod y dydd, ond ym mis Gorffennaf (y prif gyfnod pan fydd cywion yn datblygu plu) cofnodwyd cyfraddau is o weithgaredd yn ystod y ddwy awr gyntaf a'r pedair awr olaf o'r dydd.

6. Dim ond yn anfynych iawn y gwelwyd ymddygiad allweddol tiriogaethol. Yn ystod 2006 dim ond 43 arsylwad unigol o dylluanod clustiog a oedd yn cynnwys y fath weithgaredd, a dim ond 119 yn 2007. Oherwydd bod y gweithgaredd tiriogaethol hwn yn digwydd mor anaml, nid oedd llawer o rym ystadegol i roi prawf ar y berthynas rhwng yr ymddygiad hwn ac amser y dydd, neu adeg y tymor magu neu'r flwyddyn. Roedd patrwm yr amrywiadau mewn ymddygiad allweddol, yn ôl amser y dydd ac adeg y tymor magu, yn debyg iawn i'r rhai a welwyd ar gyfer yr holl weithgaredd, sy'n awgrymu bod amlder yr ymddygiadau tiriogaethol hyn yn ddim byd ond ffwythiant gweithgaredd cyffredinol tylluanod.

7. Drwy is-samplo'r data a gasglwyd yn ystod y ddau dymor bridio roedd modd amcangyfrif pa mor debygol oedd hi y byddai tylluanod yn cael eu gweld o dan amodau a amrywiai yn ôl amseriad a hyd y cyfnod gwylio systematig. Roedd mwy na 75% o siawns o weld tylluanod yn ystod cyfanswm cyfun o ddwy sesiwn gwylio dwy awr; dim ond gyda'r min nosau yn ystod y cyfnod gori; un ai yn y boreau neu gyda'r min nosau yn ystod y prif gyfnod o fagu cywion; ac yn gynnar yn y bore neu'n hwyr gyda'r min nos yn ystod y cyfnod pan oedd cywion yn datblygu plu llawn. Nid oedd y tebygolrwydd o weld ymddygiad tiriogaethol allweddol yn fwy na 75% gydag unrhyw gyfuniad o ddwy sesiwn

gwylio dwy awr yn ystod unrhyw ran o'r cyfnod magu. Mae'r data a gasglwyd yn ystod 2006 a 2007 yn ei gwneud hi'n bosib amcangyfrif pa mor debygol yw hi y caiff tylluanod eu gweld dan unrhyw gyfuniad posib o amseriad a hyd sesiynau arsylwi.

8. Ar draws y 10 gwylfan o'r lle y gwelwyd tylluanod, y pellter cymedrig yn 2006 rhwng arsylwr a'r arsylwad cyntaf o dylluanod clustiog oedd 522 m (95% terfynau hyder: 473 - 570 m), ac roedd y pellter hwn yn fwy, yn arwyddocaol, yn 2007: 702 m (95% terfynau hyder: 648 - 755 m). Roedd y pellter mwy yn 2007 yn amlwg hefyd yn y pellteroedd lleiaf a mwyaf rhwng arsylwr a'r arsylwadau o'r gwylfannau.

9. Cafodd llinellau ehediad y tylluanod clustiog a welwyd ym mhob safle eu didoli mewn i grwpiau yn ôl ardaloedd ehediad (gan ddefnyddio rhyngweithiadau tiriogaeth i wahaniaethu rhwng ardaloedd ehediad lle'r oedd hynny'n bosib). Roedd nifer yr ardaloedd ehediad a oedd yn bosib i'w gweld o bob gwylfan yn gyson gyda barn bobl leol annibynnol a weithiai gydag adar ysglyfaethus (pan oedd y wybodaeth hon ar gael). Yn y ddwy flynedd, tybiwyd bod y rhan fwyaf o'r arsylwadau o'r holl wylfannau annibynnol yn cyfeirio at un diriogaeth. Mewn ambell achos, tybiwyd bod adar o diriogaeth gyfagos (neu adar di-diriogaeth) wedi cael eu gweld yn achlysurol. Nid oedd blwyddyn nac adeg y tymor magu yn dylanwadu mewn ffordd ystadegol arwyddocaol ar bellter ehediad yr adar. Cymedr y pellter ehediad lleiaf, a gafodd ei amcangyfrif fel arc fwyaf y polygonau amgrwm lleiaf ('MCP's) a luniwyd o gwmpas y llinellau ehediad (fel y plotiwyd hwy o'r gwylfannau unigol annibynnol) oedd 2077 m (95% terfynau hyder: 1804 - 2351 m) a'r cymedr pellter ehediad lleiaf a amcangyfrifwyd o'r casgliad o wylfannau cyfagos oedd 3616 m (3213 - 4019 m) , tua dwywaith yr hyn a oedd i'w weld o wylfan unigol.

10. Yn 2006 cofnodwyd pedwar cofrestriad ar ddeg o dylluanod clustiog o 14 pwynt ar 5 (allan o 6) o'r trawslinau lle cynhaliwyd arolygon gan weithwyr maes proffesiynol. Yn 2007, pan gynhaliwyd arolygon yn yr ail gyfnod arolwg (canol Ebrill – canol Mai) a'r trydydd cyfnod arolwg (Mehefin), cofnodwyd 16 cofrestriad o 15 pwynt ar 5 (allan o'r 6) o'r un trawslinau. Cynhaliwyd arolygon wedi eu hamseru gan 17 o wirfoddolwyr ar 174 pwynt ar hyd 19 trawslin ychwanegol yn 2007 ac fe wnaethon nhw gofnodi 19 tylluan ar 16 o'r pwyntiau.

11. Rhwng canol Ebrill a Mehefin yn 2006 a 2007 fe wnaeth gweithwyr maes proffesiynol a gwirfoddol gofnodi cyfanswm o 97 rhywogaeth o adar, fel rhan o'r gwaith arolwg a olygai cyfrif o bwynt. Roedd y cyfraddau cyfarfyddiad o'r sampl o'r trawslinau a ddefnyddiwyd yn awgrymu y gallai'r dechneg hon gynhyrchu gwybodaeth ddefnyddiol ar gyfer mynegai o boblogaethau bridio (yn ychwanegol at yr hyn a geir o arolygon sy'n bodoli eisoes e.e. BBS) ar gyfer nifer o rywogaethau ,yn cynnwys poblogaethau bridio o'r canlynol: nifer o adar rhydio (e.e. gylfinir *Numenius arquata*, cornchwiglen *Vanellus vanellus*, pibydd coesgoch *Trings totanus*, gïach *Gallinago gallinago* a phioden y môr *Haematopus ostralegus*); dau aderyn ysglyfaethus sydd â dosbarthiad eang (bwncath *Buteo buteo* a chudyll coch *Falco tinnunculus*); rhai adar gêm (e.e. ffesant *Phasianus colchicus*, ac efallai grugiar ddu *Tetrao tetrix* a grugiar goch *Lagopus lagopus*); ac amrywiaeth o adar cân bychain (e.e. corhedydd y waun *Anthus pratensis*, siglen fraith *Motacilla alba*, bras y cyrs *Emberiza schoeniclus* a'r ehedydd *Alauda arvensis*).

12. Ar sail barn grŵp llywio'r prosiect a gwybodaeth sydd eisoes yn hysbys, rydym yn trafod a fyddai'n briodol i gymryd bod y tylluanod yn y tair ardal astudiaeth a samplwyd yn cynrychioli, yn gyffredinol, y tylluanod clustiog sy'n byw ar hyd a lled Prydain, yng nghyd-destun y paramedrau a ddewiswyd i fesur yn yr astudiaeth bresennol.

13. Gwneir yr argymhellion canlynol ynghylch canllawiau maes ar gyfer arolwg llawn (cenedlaethol) o dylluanod clustiog sy'n bridio:

- Samplwch ardaloedd cyffiniol sydd â dosbarthiad o dylluanod a chynefin posib ar gyfer tylluanod, ond defnyddiwch ddull o weithio sydd wedi ei dargedu'n fwy penodol ar gyfer ardaloedd cyfyngedig (corstir ar dir isel, glaswelltir arfordirol a phlanhigfeydd/coetir sydd heb eto dyfu'n drwchus) yn seiliedig ar wybodaeth leol.

- Peidiwch dechrau ar y gwaith arolwg cyn dechrau-canol Ebrill (cyfraddau canfod yn rhy isel). Os derbynnir mai dim ond amcangyfrif o ymdrechion bridio llwyddiannus (hyd at y cyfnod magu cywion) y llwyddir ei gyflawni, byddai cyfnod arolwg o Fehefin i Orffennaf yn ddigonol.

- Gwnewch y gwaith arolwg o wylfannau sy'n cynnig digon o olygfa, o fewn arc sydd heb fod yn fwy na 180°, 750 - 1,500 m o bellter rhwng ei gilydd fel bod yr holl ardaloedd sydd i'w harchwilio o fewn 750m i'r wylfan. Efallai bydd y dopograffeg yn golygu y bydd angen i'r gwylfannau fod yn agosach er mwyn cyflawni hyn.

- Dylid gwylio am gyfanswm cronnol o 4 awr o bob gwylfan o fewn pob un o'r cyfnodau amser canlynol: (i) canol-Ebrill i ganol-Mai o fewn y pedair awr olaf cyn iddi dywyllu (os gwneir penderfyniad i geisio cofnodi ymdrechion bridio a allai fethu cyn deor); (ii) yn ystod Mehefin am bedair i wyth awr ar ôl iddi wawrio neu o fewn pedair awr cyn iddi dywyllu ; a (iii) yng Ngorffennaf fewn y pedair awr gyntaf ar ôl iddi wawrio neu'r pedair awr olaf cyn iddi dywyllu. Os bydd angen samplo ar adegau eraill o'r dydd oherwydd ystyriaethau ymarferol, gellid cywiro'r amcangyfrifon yn seiliedig ar y data 2006/2007.

- Dylai gweithwyr maes blotio llinellau ehediad, yn cynnwys manylion ymddygiad, yr holl dylluanod clustiog a welir. Hefyd, dylent gynnig eu hasesiadau eu hunain o nifer y tiriogaethau y maen nhw'n llwyddo eu hadnabod.

- Dylid llunio ystod o amcangyfrifon o faint poblogaeth yn seiliedig ar wahanol drothwyon ar gyfer priodoli lleoliadau gofodol adar i wahanol diriogaethau, yn absenoldeb arsylwadau o ymddygiad tiriogaethol allweddol (e.e. arsylwadau cydamserol ac ymrysonau tiriogaeth): 1000 m, 2000m.

- Dylid ymgymryd â gwaith helaeth i gyfrif o bwyntiau/trawslinau am gyfnod o bum mlynedd o leiaf. Yn ystod un o'r rhain dylai'r arolwg ei hun gael ei gyflawni a'i ddefnyddio i atodi data BBS a chynlluniau cofnodi eraill, er mwyn gallu gosod canlyniadau arolwg dwys yng nghyd-destun yr amrywiadau yn niferoedd (a/neu lwyddiant bridio) tylluanod clustiog o flwyddyn i flwyddyn.

15. O ystyried, yn realistig, y math o adnoddau a allai fod ar gael ar gyfer gwaith arolwg, nid yw efallai'n ymarferol i ddisgwyl cynnal arolwg a allai roi amcangyfrif ystadegol gadarn o faint y boblogaeth fagu o dylluanod clustiog yn y DU. Ond gellid monitro tueddiadau mewn poblogaethau mewn ffordd gadarn drwy gynnal arolygon bob hyn a hyn mewn ardaloedd allweddol neu gynrychioliadol ynghyd ag arolygon amlach ond llai dwys a allai roi indecs helaethrwydd mwy parhaus.

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1. BACKGROUND AND AIMS

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 six classified Special Protection Areas (SPA) in the United Kingdom: the Caithness and Sutherland Peatlands; Forest of Clunie; Muirkirk and North Lowther Uplands; Orkney Mainland Moors; Skomer and Skokholm; and the South Pennine Moors (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 unreliable and trends over time are unknown (Greenwood *et al.,* 2003, Park *et al.,* 2005). Ideally, there is a need both to improve national surveys of the UK population and facilitate the most accurate and precise population estimates for the species within designated SPAs in the UK.

1.1 Previous review of current knowledge

Given inadequate information with which to assess reliably the conservation status and requirements of short-eared owls, Scottish Natural Heritage (SNH) commissioned a review of literature and other available information, in order to make recommendations for developing and refining survey techniques for breeding short-eared owls. In addition to summarising published and 'grey' literature, the review (Calladine *et al.,* 2005) included new analyses of data collected for the BTO/SOC/IWC atlases of breeding bird distribution (Sharrock, 1976, Gibbons *et al.,* 1993), data from the BTO/JNCC/RSPB Breeding Bird Survey (BBS; e.g. Raven *et al.,* 2004) and observations of short-eared owls recorded during fieldwork for a national survey of hen harriers *Circus cyaneus* in 2004 organised by the RSPB. The main findings of that review were (taken from Calladine *et al.* 2005):

- 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 of the species is extensive in the 'uplands' but very localised in the 'lowlands'. Any national survey to estimate population size should sample the contiguous upland areas that are occupied but in the lowlands, specific targeting of sites is likely to be appropriate.

- The timing of breeding of short-eared owls in Britain 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) is likely to require inclusion of the earliest potential period of territory occupancy (early March) and it was recommended that pilot work should be carried out to investigate the proportion of territories that may only be detected once young have hatched.

- Population densities in any given geographical area can vary substantially between years and these variations may not be spatially synchronous; they probably occur as a result of variations in local vole abundance and conditions influencing immigration of owls from Scandinavia. The British breeding population of short-eared owls 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 BBS suggests a degree of synchronicity in population variations across Britain, however: counter to the expectation if population changes were driven solely by variations in vole abundance, which in turn are at least partly determined by local land management practices. Study of the relationships between vole and short-eared owl abundances across Britain could help to identify the relative importance of local, national and international determinants of owl abundance within Britain.

- Data on short-eared owls collected during a national hen harrier survey in 2004 (using field protocols designed for detecting harriers rather than the owls) may have underestimated their absolute population size for a number of reasons: late start of surveying; visits made during the middle of the day; and some areas of potentially suitable habitat omitted (e.g. areas within 500 m of occupied human dwellings and bracken-dominated areas).

The review concluded that a pilot study was essential to test potential field survey techniques for short-eared owls in advance of any national survey or intensive census of, for example, designated sites. It was recommended that such a survey should sample the range of densities of short-eared owls that are likely to be encountered across the UK, and that it should include both intensive fieldwork at a number of sites (to assess methods for obtaining absolute population size) and extensive but low-intensity surveys (for long-term monitoring purposes). The latter would aim to determine resource-efficient methods for monitoring population trends, which would then allow local intensive fieldwork at a smaller number of sites (e.g. sampled areas as part of a national survey or designated sites) in any given year to be placed in the context of any overall inter-annual fluctuations in population size. Because of the magnitude of potential population fluctuations for this species, without long-term monitoring data collected over a broad study area, censuses from discrete study areas in any given year might sample a very high or low stage of any population 'cycle', potentially providing a biased estimate of the overall importance of the study area for short-eared owls.

1.2 Aims of this pilot study

Following from the principal findings of the earlier review, a pilot field study described in this report was undertaken during the 2006 and 2007 breeding seasons. The main objectives were:

1. To identify the most appropriate times of day and dates of season for surveying breeding short-eared owls (by quantifying how encounter rates and the chances of detecting breeding attempts vary with time of date and stage of breeding, and any spatial variation in these relationships) and to translate the findings into feasible survey protocols.

2. To carry out observations to assist in the differentiation of separate breeding territories: (i) by assessing the frequency and timing of breeding behaviours that would inform the categorisation of breeding attempts (as e.g. 'definite', 'probable' and 'possible'), such as territorial disputes, carriage of prey and display flights; and (ii) by assessing the distances moved by focal birds of known breeding status that would provide further information on minimum foraging ranges during the breeding season. To translate these findings into feasible survey and analytical protocols.

3. To evaluate the feasibility of, and encounter rates resulting from, more extensive field surveys and how these relate to numbers of breeding short-eared owls estimated from intensive observations in key study areas. The majority of the monitoring of widespread bird species in the UK is undertaken by volunteer birdwatchers, notably the BBS (e.g. Raven *et al.,* 2004). Upland areas have tended to be under-sampled by such volunteer-based surveys to date, largely because they are remote from areas of dense human population (sources of volunteers) and the terrain requires birdwatchers with a certain level of fitness and motivation. The trial of extensive

methods to produce abundance indices for short-eared owls also aimed to test alternative methods for monitoring a broader suite of upland bird species, using a method that might attract a larger number of volunteers into the uplands.

4. To make recommendations for: (i) field protocols for use in producing a population estimate of short-eared owls in any given area in any given year; (ii) extensive methods for producing indices of abundance to monitor population changes and allow the results of a full survey in any given year to be placed in context; and (iii) survey design for a national survey of short-eared owls.

An interim report presented the findings for the first field season and discussed the need for, and design, of a second season of fieldwork (Calladine *et al.,* 2007). Here we present a final report on the results of two breeding seasons of fieldwork and make recommendations for any future survey and monitoring of breeding short-eared owls in the UK.

2. METHODS

2.1 Study areas

Fieldwork was undertaken in three broad study areas of Scotland: Perthshire, Ayrshire and the Borders (Figure 1). The selection of these areas was based on: (i) a known history of occupancy by breeding short-eared owls; (ii) the established presence of volunteer raptor workers who were able to give an independent assessment of the numbers and success of breeding short-eared owls; (iii) an adequate network of roads and tracks to allow relative ease of access between parts of the study areas; and (iv) correspondence with local raptor workers prior to, and during the early part of, the 2006 field season to assess short-eared owl occupancy levels in 2006. Using criteria (i) to (iii), six possible study areas were chosen (the three above, plus Mull, Glen App in Dumfries and Galloway, and the Pentland Hills in Lothian) and contact made with the local raptor worker with an interest in short-eared owls. It was necessary to consider a suite of potential study areas that was larger than the three that the project resources would allow us to cover because of the uncertainty that surrounds the number of breeding short-eared owls that will settle to breed in an area in any given year. Based on local information early in the breeding season (iv above), the sample of three study areas was selected from the six areas under consideration.

Following the 2006 field season, discussion amongst the Project Partners considered whether the 2006 study areas were representative in terms of three potentially influencing parameters: (i) variation in densities of breeding short-eared owls; (ii) variation in densities of prey and predators; and (iii) variation in habitat (Calladine *et al.,* 2007). These discussions considered the merits, or otherwise of using the same study areas in 2007, or using alternative sites in view of the above influencing parameters. In summary, it was considered that the sampling of lower densities of breeding short-eared owls would compromise the analytical and interpretive power of data collected. Thus, the pragmatic assumption was made that under-recording in low density areas during a survey would not have a large influence on an overall national or regional population estimate. In areas with higher breeding densities, a greater incidence of territorial activity (e.g. territorial aggression between neighbouring birds) would be expected, which should make the owls easier to detect and territories easier to separate; however, and conversely, in areas of high prey availability, owls might need to spend less time searching for prey, such that the duration of foraging activity, and therefore the ability to detect birds, could be reduced.

Concerns relating to variations in densities of prey and predators were also discussed in relation to the applicability of data collected at our mainland study areas for surveys on islands, where the suite of prey and predator populations can differ. In the absence of quantitative data or suggestions from local raptor experts to imply that diurnal activity would be less on islands with different prey and/or predators, it was considered that fieldwork on offshore islands should not be a priority with the limited resources available for the pilot study in 2007.

Two habitats were considered to have been under-sampled during fieldwork in 2006: unkeepered and unmanaged moorland; and newly planted forestry (Table 1). Of these, only the under-sampling of newly planted forestry was thought to be a potential influence on the objectives of the study, particularly on the assessment of owl detectability. Consultations with individuals with relevant experience of both short-eared owls and forestry habitats indicated that the area of pre-thicket plantations available to breeding short-eared owls now is very small in an historic context and that there was little to be gained from further pilot fieldwork involving the sampling of owl behaviour in such areas; rather, specific guidelines and recommendations for surveying in pre-thicket plantations were likely to be required when a survey protocol is written, in common with some other habitats of limited extent (e.g. coastal marshes and sand dunes (Calladine *et al.,* 2005)).

Given finite resources available for the pilot study in 2007, the Project Partners considered that the advantages of using the same study areas in 2007 as in 2006 (to reduce the confounding of potential inter-annual effects with site-specific effects) outweighed any advantages of sampling owl behaviours at a suite of new study sites (for full discussion see Calladine *et al.,* 2007, Section 4.5). In 2007 some incidental observations of short-eared owls were made in early June on North Uist, and more extensive data collected by Haworth Conservation Ltd under contract to Scottish Natural Heritage from the Uists during 2005 – 2007 were made available to potentially provide further insight as to whether concerns about not sampling in areas with high densities of breeding owls and a restricted suite of ground predators were justified.

2.2 Seasonality of fieldwork

Based on existing knowledge of the breeding cycle of the Short-eared owl, fieldwork was undertaken in four study periods:

Period 1	March (to check for territory occupancy);
Period 2	mid-April – mid-May (to check for territory occupancy in the event of a late season and to check for males attending incubating females);
Period 3	June (to check for adults feeding young);
Period 4	July (to check for late or replacement broods and fledged young).

These timings were based on published information on breeding behaviour and the timing of breeding of short-eared owls (Goddard, 1935; Cramp, 1985; Roberts & Bowman, 1986; Shaw, 1995; Reynolds & Gorman, 1999), data held by the BTO's Nest Record Scheme and the British and Irish Ringing Scheme (Moss *et al.,* 2005), unpublished data from our Perthshire study area (Table 3) and consultations with other raptor workers familiar with short-eared owls. These timings are consistent with the provisional survey recommendations of Hardey *et al.,* (2006).

Very low encounter rates with owls in 2006 led to the questioning of how representative was that breeding season (Calladine *et al.* 2007); March 2006 was characterised by heavy and persistent snow cover across the study areas that could have potentially delayed the settling and breeding by short-eared owls and potentially also suppressed prey availability in the early part of the season with a resultant influence on the foraging activities of owls. Furthermore the latter part of the 2006 season was exceptionally warm and dry. Given the potentially unrepresentative weather conditions experienced in 2006, the Project Partners felt strongly that a further season of fieldwork undertaken at the same times of year should be completed in 2007. The weather conditions in 2007 turned out to be very different from those in 2006, with a dry and warm period in March and early April and unsettled cool and wet conditions for the remainder of the field season. All fieldwork was undertaken between 6 March and 28 July in the two years of the study (Table 2).

2.3 Fixed point observations

2.3.1 Data collection

Detailed behavioural observations of short-eared owls were made in each of the four study periods from 12 independent vantage points, four in each of the three study areas (Table 1). Vantage points were chosen as areas with an open aspect providing a good field of view over apparently suitable habitat for breeding short-eared owls (after Calladine *et al.,* 2005), with advice from raptor workers with local knowledge. The selection aimed to maximise the likelihood that owls would settle within view of the vantage points. Observations were made from the vantage points within a maximum arc of 180°. Once selected, the vantage points, and the search arc from them, remained constant through the study. The proportions of broad habitat types within the areas monitored from the vantage points were estimated by eye. For all vantage points combined, the proportions of habitats viewed were: heath and bog (*ca.* 60%), semi-natural grassland (*ca.* 32%), mature conifer plantation (*ca.* 3%), improved grassland (*ca.* 3%) and young pre-thicket plantation (*ca.* 2%; see Table 1). The vantage points ranged in altitude between 180 and 500 m above sea level (Table 1).

Fixed point observations were made in sampling periods of two hours in length. In 2006, these were within four to five hours after first light and the last four to five hours before dark. In 2007, two additional two-hour periods were sampled within the period that immediately followed from the two morning periods that were also sampled in 2006. This gave six sampling windows within each day as follows:

Period A	Within 2 hours of first light
Period B	Between 2 and 4 hours after first light
Period C	Between 4 and 6 hours after first light
Period D	Between 6 and 8 hours after first light
Period E	Between 2 and 4 hours before dark
Period F	Within 2 hours before dark

In the event of poor weather restricting observation efficiency, the above sampling periods were truncated. The start and end times of each observation period were recorded to the nearest minute. Inevitably, the above periods are not absolutely precise because of the vagaries and variation in determining the times of first and last light on any one day but were rigorous enough to permit analyses of diurnal variation in activity and their interpretation into practical field guidelines for surveys.

In 2006, each vantage point was sampled at least once during each of the four sampling windows (Periods A, B, E and F) within each of the four survey periods. In 2007, nine of these independent vantage points were sampled (three in each study area) but were sampled at least once in each of the six sampling windows within each of the four study periods. Every short-eared owl seen was recorded, together with details of its behaviour; the latter was used as evidence to determine the probability of breeding. The following categories of behaviour, in generally ascending order of evidence for a breeding attempt or holding territory (modified after Shaw, 1995), were used:

a.	Owls(s) seen in flight in transit (not hunting)	POSSIBLE BREEDING
b.	Owl(s) seen using an area for hunting	"
c.	Owl(s) seen perched (see Section 2.3.2)	PROBABLE BREEDING
d.	Owl(s) carrying prey	"
e.	Courtship display (wing clapping)	"
f.	Owl(s) giving alarm calls or mobbing potential predators	CONFIRMED BREEDING
g.	Owl(s) repeatedly carrying prey to an area (feeding an incubating female or young)	"
h.	Recently fledged young owl(s) seen	"

For each record of a short-eared owl, the start and end times of the observation were recorded, and the flight lines were plotted onto large scale maps. The flight-lines were transferred to GIS (Geographic Information System; ArcView 3.3) and cross-referenced with the behavioural data and any other notable observations. The distance from the observer at which each short-eared owl was first detected, the closest to which it approached, and the greatest distance to which it could be followed were estimated in the field and the estimates were checked against the flight-lines plotted in the GIS.

In 2007 only, observations of short-eared owls were also sampled from an array of 18 neighbouring vantage points. Incorporating two of the independent vantage points, this array covered approximately 20 km^2 in the Ayrshire study area. The aims of using the array of vantage points were to:

i) Assess the ranging distances of owls more rigorously than was possible from the independent vantage points;
ii) To inform the interpretation of data collected from neighbouring vantage points as would be collected during a targeted area survey of breeding short-eared owls;
iii) To gain experience of the practicalities of field survey and the interpretation of data collected from such an array as would be likely to be employed as part of a wider survey of breeding short-eared owls.

Within the array, the vantage points were spaced at approximately 1 km distant, based on the detection and ranging distances observed in 2006, although this was modified according to topography to ensure that coverage of the area was as comprehensive as possible (Figure 2). Observations from the array vantage points were only made during the first and last two survey periods of the day (Periods A, B, E and F) and only in the second and third survey periods (Period 2, mid-April to mid-May, and Period 3, June) based on the periods during which detection was highest during 2006. Each of the array vantage points was sampled twice in each of the seasonal survey periods, though not at the same times of day. Across the 18 points in the array, and excluding the two original independent vantage points (which were sampled more intensively, above), a total of 36 two-hour watches were completed in each of the two survey periods sampled. Otherwise, owls were recorded in an identical way as at the independent vantage points (above).

2.3.2 Analyses of variability in detection

The duration of all observations of short-eared owls, and those of some ‘key behaviours’, were analysed to assess the influences of stage of the breeding season, time of day and study area on the detection of short-eared owls. ‘Key behaviours’ were those considered to be most indicative of territory holding by short-eared owls: courtship display; alarming or mobbing potential predators; carriage of prey to likely nest sites; the presence of recently fledged young (i.e. e to h in the list in 2.3.1). In addition birds perched on moorland, or on posts in the open during daylight hours in survey periods 1 and 2 (March to May) were also considered as key behaviours as these are likely to have been male birds in close proximity to females during egg-laying or the early incubation period (Erkki Korpimäki pers. comm.).

Generalised linear models were used to test the influence on the length of time for which short-eared owls were observed within a 2-hour watch of: Season (n = 4 survey periods); Time of Day (6 classes); Site (n = 10 vantage points and fitted as a repeated measure; two vantage points from which short-eared owls were never seen - Perthshire D and Ayrshire A - were excluded from the analyses under the assumption that there were no owls at those sites during the season; and Year (n=2). The interactions between Season, Time of Day and Year were not included because of insufficient degrees of freedom (lack of model convergence). The models assumed a Poisson error distribution (appropriate for zero-inflated data) and a log-link function. The log duration of each vantage point watch (in hours) was introduced into the models as an offset to accommodate the watches that had to be truncated because of poor weather conditions.

The ‘Sites’ (individual vantage points) were entered as a repeated measure in the models because each was re-visited several times through the season (such that the sample of owls observed was not independent on each repeated visit to any given vantage point). It was assumed that an influence of ‘Site’ in the models could have arisen from a number of factors. First, there were likely to be differences in the proximity of vantage points to nesting owls, such that some were better placed to oversee the activities of a territorial owl or pair than others. The vantage points were necessarily selected prior to the owls setting up territory, and each was selected because it gave a clear field of view over an area of habitat suitable for breeding short-eared owls and also using the prior knowledge of the local raptor worker (when available) as to where nesting had occurred in previous years. Second, there were some differences in topography/chances of owls being visible between the individual sites, particularly as the three study areas were selected to provide topographic and habitat variation. Although the vantage points were selected to give a wide field of view, there were inevitably some areas within the viewing arc from each point that constituted ‘dead ground’, where owls would not have been seen. This would have included areas completely obscured from view due to physical topography but also areas in which visibility was affected in a more subtle way (e.g. because of habitat/background coloration/aspect). Because of the complexity of these effects, we did not attempt to quantify the between-site variation in ‘dead ground’ and control for it directly in the modelling process. Third, there could have been differences in the activity patterns of the individual owls/pairs that were observed from each vantage point. Finally, differences in the number of territorial owls/pairs visible from each vantage point could have had a direct effect on the amount of time for which any one owl was visible, and also potentially influence activity patterns, for example resulting in a greater need for territorial interaction at higher owl densities.

An actual nest site was found in only one case in 2006 and in four cases in 2007 (Table 4). Therefore, it generally was not possible to assess with certainty how the visibility of local territories varied between vantage points, although this was considered by field staff to be a major source of between-site variation. When the observations of field staff were considered together with those of independent raptor workers at some of the sites (Table 4), concentrations of flight lines and observations of behavioural interaction (Figure 3), most of the activity at each vantage point was concluded to be attributable to a single territory/pair of owls, with the exception of one site with two territories (Borders ‘C’ in 2006; see Figure 3). No weighting to control for the number of territories under observation was felt to be required in the models, however, as: (i) we could not state with certainty how many territories were being observed at each site; and (ii) the study was in any case designed to sample a range of owl densities if possible.

When more than one owl was visible at the same time, the durations of observations were taken as additive for modelling purposes, on the assumption that periods when more than one individual was visible could increase overall detectability (by creating more opportunity for conspicuous behaviours) and therefore should be given greater weighting in the data set. For the key behaviours indicative of territoriality, the length of observation used in the modelling was that for which an owl was visible to the observer at a vantage point during which time it performed at least one of the key behaviours and so was not necessarily indicative of the frequency of actual key behaviours.

2.3.3 Estimation of detection likelihoods

Data from the fixed vantage point watches were sampled to estimate the likelihoods of: (i) seeing a short-eared owl; and (ii) observing behaviour indicative of territoriality, under different scenarios of the number, timing (seasonal and diurnal) and duration of watches. Only data from the principal territories that could be observed from each vantage point were included in these sampling scenarios: observations of birds from territories that were peripheral to the field of view from the fixed points were omitted.

Each discrete watch was summarised to indicate whether any owls were seen and also, whether any ‘key’ behaviours indicative of territoriality (mobbing, alarming, wing-clapping, carrying prey, juvenile or perched in open) were observed. To assess the influence of reducing the duration of watches, each watch was split into two 1-hour intervals and similarly summarised as to whether an owl was seen or territorial behaviours observed. When the total duration of the watch was less than 2 hours (in 2007, a number of watches were shortened because of poor weather), only the first hour was included in the analyses.

Following the analyses of seasonal and diurnal variation in the detection of owls, scenarios with differing numbers and timing of watches were selected based on periods of similar likely detection or likely maximum detection. These scenarios also considered field survey practicalities, for example, how to maximise the window for undertaking fieldwork. For each scenario (of particular times of year and day, or combinations of these), 1000 random selections (with replacement) were made from across the data set for all vantage points and both study years. The proportion of times that an owl was seen, or a territorial behaviour observed, in those 1000 random selections was used as an estimate of the likelihood of detecting an owl (or observing a territorial behaviour) from any vantage point as part of a wider survey. The aims of this approach were: (i) to identify practical numbers and timings of watches that would maximise the likelihood of seeing owls; and (ii) to provide estimates of the proportions of birds, or territories that would likely be missed given any particular combination of watches in a survey protocol. For selected scenarios, the influence of increasing the number of discrete watches was also examined by using 1000 random samples of single watches (separately for one and two hour durations), two watches, three watches and so on up to a cumulative total of 10 hours of observations.

2.3.4 Analyses of detection distances

The distances at which short-eared owls were detected were analysed to provide an indication of the density of an array of vantage points that would be required to survey a given study area reliably. If the vantage points used for a survey were placed too far apart, then there would be a risk of missing birds and territories. The influences of Season (n=4 classes), Time of Day (n=6 classes) and Year (n=2) on the distances at which short-eared owls were first detected were examined using a generalised linear model. A normal error distribution was assumed (with identity link function) and site (vantage point) was included as a repeated measure (see Section 2.3.2). Comparable analyses were also carried out using the minimum distances at which owls were seen (i.e. the closest point to the observer that birds approached) and also maximum distances (i.e. the most distant point from the observer at which owls were observed) as the dependent variable.

2.3.5 Analyses of ranging distances

To give an indication of the distances ranged by short-eared owls during the breeding season, minimum convex polygons (MCPs) were drawn around the flight lines plotted within the GIS. When behavioural observations indicated that simultaneous observations of owls were of birds from different territories (e.g. an aggressive encounter between individuals, or birds seen hunting independently where one individual carried prey to a suspected nest site with an incubating female), these were used to define boundaries for polygons. In the absence of such distinguishing behaviours, clusters of flight lines were assumed to be made by bird(s) within the same territory. Using this approach, the derived MCPs from the independent vantage points are at least partly a function of visibility from each individual vantage point (Section 2.3.2) and, therefore, the maximum arc of each MCP (i.e. that most distant from the vantage point) was taken to be the most representative measure of the *minimum* distances ranged by breeding short-eared owls. The MCPs for the Ayrshire study area were derived from the combined observations from vantage points in the array, which were *ca* 1-km or more distant from each other.

The influences of Season (n=4 classes), Year (n=2) and Type of data (n=2; i.e. derived from single independent vantage points, or from an array) on the maximum arc distance (a measure of ranging distance) were examined using a generalised linear model. A normal error distribution was assumed (with identity link function) and site (vantage point) was included as a repeated measure (see 2.2.2). The dependent variable (distance) was weighted by the number of flight lines that contributed towards the MCP to give a greater emphasis to measures that were the result of a greater number of field observations.

2.4 Point counts

2.4.1 Data collection

Within, or close to, each of the three broad study areas, two ‘transects’ were selected (Figure 1b). Each transect was a series of roads or tracks that crossed habitat potentially suitable for breeding short-eared owls (moorland and moorland fringe; e.g Goddard, 1935; Roberts & Bowman, 1986; McGarry, 1998; Raw, 2000, Stott, 2002). Along each transect, suitable count points were identified that offered a relatively unobscured view, where a vehicle could be parked safely, and with a minimum distance of 1-km between count points (to ensure independence of data collected from different points); there were between 14 and 21 suitable count points on each of the six transects.

Each transect was surveyed once in each of the four stages of the breeding season in 2006 (section 2.1), but in 2007 only in the second and third survey periods (mid-April to June) within the last three hours before dark. Timed point counts (five minutes at each point) were used to measure the abundance of all bird species encountered (seen or heard). Surveyors used vehicles to drive between count points. From each count point, each registration of a bird was assigned to one of five distance bands from the count point (0-25 m, 25-100 m, 100-500 m, 500-1000 m and 1000+ m); the first distance at which each individual bird was seen was recorded, regardless of any subsequent movements. Birds seen or heard only in flight were also recorded separately, with the exception of displaying birds (e.g. skylark, meadow pipit and curlew) that were recorded within the respective distance bands above which they were flying. Care was taken in the field to try to avoid recording individuals more than once, either at neighbouring count points or anywhere along the transect (i.e. when individuals could be seen from multiple count points). Only birds in open habitats were recorded (those in any woodland present were excluded).

To increase the sample size and geographical spread of point counts, and also to assess the potential interest by volunteer birdwatchers in participating in such extensive monitoring, a general request was made for volunteers to undertake additional ‘transects’ of point counts in similar habitats across Britain. Informal ‘requests’ for volunteers were made through the network of regional representatives of the BTO (within the breeding range of short-eared owls in Britain) and also at the Scottish Raptor Study Groups’ Annual Conference and the BTO/SOC Scottish Birdwatchers’ Conference in February and March 2007 respectively. Volunteers were supplied with fieldwork instructions and recording forms (see Appendix 1).

3. RESULTS

3.1 Seasonal and diurnal variation in activity of breeding Short-eared owls

During the two years, a total of 464 individual observations of short-eared owls were made: 186 in 2006 and 278 in 2007. Overall, owls were visible for just 5 – 9% (95% confidence interval) of the duration of systematic watches. For all observations of short-eared owl activity combined, there was a statistically significant ($P < 0.05$) effect of time of day and a marginally non-significant ($0.05 > P < 0.10$) effect of time of year (Table 5). The interpretation of these results in the absence of any interaction terms (because of the relatively small sample of data collected within each season) presents difficulties, as it is reasonable to expect that the behaviour and activity patterns of the owls will vary with stage of breeding. For this reason, separate analyses of the influences of time of day and of year on the proportion of time for which owls were visible were undertaken within each period of the breeding season. Although no statistically significant differences were apparent (Table 5), most likely because of the small sample sizes and low statistical power, visual examination of the back-transformed estimates from these models suggested variation in the diurnal activity of owls through the breeding season (Figures 4 & 5). Encounter rates in March, when birds were expected to be settling onto the breeding areas, were very low, with a mean of less than one minute per hour of observation (Figure 4). Within that earliest part of the season, birds were seen so infrequently that models to investigate the influence of time of day on the duration of their activity failed to converge. During the main incubation period (mid-April to mid-May), most activity was observed during the period of four hours before dark, with a lesser peak during the four hours after first light (Figure 5). During the main chick-rearing period (June), owls were visible throughout the times of day that were sampled, with no apparent peaks of activity (Figure 5). In July, the main fledging period, most owls were seen between two and eight hours after first light, with lower rates of activity recorded within the first two hours after first light and the last four hours before dark.

Key behaviours indicative of territoriality were observed relatively infrequently: there were only 43 discrete observations of short-eared owls that included activities defined as key territorial behaviours in 2006 and 119 in 2007. No statistically significant influences of times of year or of season were apparent (Table 5) but data were sparse with associated low statistical power to detect such differences. The patterns of variation in the frequency of observing key behaviours were very similar to those for all observations however (Figures 4 & 6), implying that the frequency of 'key' observations is simply a function of overall activity by the owls rather than they being more likely to be observed at particular times of day or stage of the breeding season. Of particular interest, there was no apparent difference in the observed patterns of behaviour between the two study years, despite marked differences in weather conditions (Section 2.2).

3.2 Likelihood of detection

Sampling from the data collected during the two years of the study permitted the estimation of the likelihoods of seeing owls during different scenarios of timing and duration of systematic watches (Table 6). To illustrate these with an example, we assumed that a field protocol for surveying breeding short-eared owls might be feasible (i.e. 'acceptable' to volunteer surveyors) if it involved two 2-hour watches from each vantage point that was to be surveyed. Based on the pooled data collected in 2006 and 2007, simulations showed that the likelihood of seeing an owl during four hours of watches was greater than 75%: (i) in the evenings only during the main incubation period (mid-April to mid-May); (ii) in the late mornings and evenings during the main chick-rearing period (June); and (iii) in the early mornings and late evenings during the main fledging period (July) (Table 7). The likelihood of observing 'key' behaviour indicative of territoriality did not exceed 75% in any of the broad intervals examined (Table 7).

As expected, the likelihood of detecting owls increased with the cumulative duration of watches (Figure 8). For example, a 90% likelihood of detection was generally achieved with seven or eight hours of observations during the more favourable periods (after Table 7) for observing owls (Figure 8). Such a high level of detectability was not achieved for observing key territorial behaviours even after a cumulative 10 hours of observations (Figure 8). Conversely, a reduced cumulative watch duration necessarily resulted in a reduced likelihood of detection, with, for example, 40 – 60% likelihood of observing owls, and 30 – 40% likelihood of seeing a behaviour indicative of territoriality, during a single two-hour watch carried out during the periods of generally high detectability (Figure 8).

The data collected in 2006 and 2007 allow other scenarios to be readily modelled, in order to estimate the likely proportions of birds that could have been missed as part of a survey, if the survey effort is recorded precisely in terms of the times of day and stage of breeding, and watch duration.

3.3 Detection distances

The mean distance at which a short-eared owl was first detected was 522 m in 2006 and 702 m in 2007, a statistically significant difference (Tables 8 & 9). No statistically significant influences of times of year or stage of breeding on first detection distances were found. The greater detection distances in 2007 were also apparent in both the minimum and maximum distances at which owls were seen (Table 8). The overall increased distances from the vantage points in 2007 compared to 2006 were apparent at four (Perthshire A, Ayrshire B, and Borders A and B) out of the seven vantage points for which comparison could be made between the two years .

3.4 Ranging distances

When the flight lines of short-eared owls observed at each site were grouped into ranges (using territorial interactions to differentiate ranges when available), the numbers visible from each vantage point largely supported the views of the local independent raptor workers (Table 4). From all independent vantage points, in both years, the majority of the observations were thought to refer to a single territory. In a few cases, it was thought that birds from a neighbouring territory were seen occasionally but these comprised only a very small proportion of the total observations and some of these could have been of wandering or non-territorial birds that strayed within the range of the focal birds (Figure 3).

There was no statistically significant influence on ranging distance of year, stage of breeding season or whether the apparent territory was derived from observations from independent vantage points or from a combination of vantage points within an array (Table 10). As expected, there was a tendency for the ranging distances derived from the array of vantage points to be greater than those from single independent points but as there were only three apparent territories mapped from the array in just one of the study years, the power to detect a statistically significant difference was limited. The mean minimum ranging distance, estimated as the maximum arc of the MCPs drawn around the plotted flight lines derived from single independent vantage points was 2077 m (95% confidence limits: 1804 – 2351 m). That derived from the array of neighbouring vantage points was 3616 m (3213 – 4019 m), about twice that apparent from a single vantage point.

3.4 Point counts

In the four surveys of each transect in 2006 undertaken by professional fieldworkers, a total of 14 registrations of short-eared owls were recorded from 14 points on 5 (out of 6) transects (Table 11). In 2007, when surveys were only undertaken in the second (mid-April to mid-May) and third (June) survey periods, a total of 16 registrations were recorded from 15 points on 5 transects (Table 11). Within the same survey periods covered in both years, the total number of registrations of short-eared owls in 2006 was 10 (from 9 points) on the 5 (out of 6) transects.

Seventeen volunteers carried out timed surveys at 174 points on 19 transects in 2007 (Figure 9). They recorded 19 owls at 16 points, however seven of the registrations were recorded from points along a single transect on North Uist (Figure 9). Two of the volunteers' transects broadly overlapped with those that were also surveyed by professional fieldworkers. At one in the Ayrshire study area, professionals recorded five registrations of short-eared owls from 21 survey points while the volunteers recorded two registrations from 12 survey points. At the other overlapping transect in the Borders, professionals recorded one registration from 17 survey points and volunteers none from 15 survey points.

A total of 97 species were recorded during point count surveys by both professional and volunteer surveyors between mid-April and June in 2006 and 2007 (Table 12).

4. DISCUSSION

This study aims to inform the practicalities of surveying and monitoring breeding short-eared owls in the UK. The majority of the population, and perhaps the greatest challenge for their survey, is found in extensive areas of moorland and associated open habitats (Section 1.1, Figure 10). This discussion considers primarily the implications for surveys within those extensive habitats. Within the majority of the breeding range, we make the assumptions: (i) that a survey will not be comprehensive (because of prohibitive costs) but rather will involve extrapolation from sampled areas within the range; and (ii) that surveying will rely on the participation of many fieldworkers, a significant proportion of who will be volunteers.

Outside of their largely contiguous range, short-eared owls also breed in some marshes and coastal grasslands (Figure 10). Within these areas, the potential habitat for breeding short-eared owls will be restricted: much will be included within nature reserves, and the presence of breeding short-eared owls will often be known to local birdwatchers and reserve managers. Although pre-thicket forestry was under-sampled within the present study (Section 2.1), we are not aware of reasons for the diurnal activity of owls within such areas to differ from that of birds breeding on moorland. For any extensive areas of pre-thicket forestry, the survey methodology designed for extensive moorland should be directly applicable. For smaller areas of pre-thicket forestry, an alternative approach in common with other potentially occupied habitats of limited extent (marshes and coastal grassland) that utilises local knowledge (in this case of forestry staff) with some targeted surveys where needed will probably provide the best estimate for the numbers of birds present.

4.1 Variation in detectability and count units for a full area census

The intensive field work carried out from vantage points in 2006 and 2007 showed that across the breeding season short-eared owl activity during daylight hours was generally low. On average, owls were only visible for 4.8% of the observation time, despite there being good evidence that territorial birds were present in close proximity to most of the vantage points. This low level of activity will itself make surveying the species a real challenge. Of the 464 discrete observations of owls made during the 2006 and 2007 breeding seasons, 162 (35%) involved the owls carrying out activities that were indicative of holding a territory: the majority of observations simply involved foraging birds. The relative scarcity of such territorial activities increases the need to: (i) survey at a stage of the breeding season when the majority of birds seen can be assumed to be territory holders (as opposed to e.g. passage birds early in the breeding season); and (ii) find alternative methods for differentiating between birds from neighbouring territories (e.g. using knowledge of usual foraging ranges during the breeding season; see Section 4.3).

Detection rates were especially low in March, such that surveys within daylight hours in that earliest part of the breeding season may normally not be worthwhile. Analyses of data held by the BTO's Nest Record Scheme and the ringing dates of chicks held by the British and Irish Ringing Scheme suggest that a small proportion of short-eared owls will have initiated egg laying by late March (Figure 11). Eggs were laid in March in two out of seven years for which laying dates have been determinable within our Perthshire study area (Table 3). Clearly the occupation of breeding territories by short-eared owls in March is not unusual, and in all three study areas local gamekeepers reported seeing owls in March at night while lamping for foxes in both study years. Presumably most activity is nocturnal at that time of year. Given that an extensive survey is likely to require numerous surveyors, it is unlikely that the extensive provision of specialist night-vision equipment will be practical. This option could be considered for surveys of specific study areas of restricted extent however.

From mid-April through to July, there are periods when the detection of breeding short-eared owls can be reasonably reliable, but the favourable times of day for detection are not the same through the season. For example, the chances of seeing owls within a combined total of four hours of observation exceeded 75% in the evening only during the main incubation period (mid-April to mid-May) but in the late morning and late evening periods during the main chick-rearing period (June). Not only do the windows of opportunity for reliable detection vary through the season, the combined duration of the windows of opportunity differ through the season. During the main incubation period, there is only a single evening period of opportunity, but during the chick-rearing and fledging periods there are two 'periods' of reliable detection during the day (Table 7), which could influence the survey effort and sampling strategy employed as part of an extensive survey. Alternative approaches, which are not necessarily mutually exclusive, could include:

i) Varying the survey effort through the season, with more surveyors active during the main incubation period than during the rest of the surveying period;
ii) Use of different spatial sampling intensities at different stages of the breeding season. With finite manpower, a reduced density of sampling areas may be necessary during the incubation period when there is a relatively short period of high detectability.
iii) Employ correction for the estimated number of birds or territories that are expected to have been missed during surveys undertaken during periods of relatively low detection rates (e.g. Figure 8).

Amongst the territories that were studied during 2006 and 2007, no pair was known or suspected to have failed in its breeding attempt before hatching. As either detection rates are low, or the period of reliable detection is short, prior to the chick-rearing period, surveys that necessarily take a pragmatic approach based on realistic levels of manpower are likely to miss breeding attempts that fail before hatching. This implies that any survey may only be able to reliably detect breeding attempts that reach the chick-rearing period or potentially the late incubation period at best: the absolute population size (of owls/pairs capable of breeding) is likely to be underestimated, and the survey unit may necessarily be the number of pairs that hatch young successfully.

Low detection rates in the early part of the season have been reported from Angus and the Findhorn catchment (Mike Groves and Brian Bates, pers. comm.) and also from the Uists (data collected by Haworth Conservation Ltd. for SNH). The Uists data are particularly relevant as breeding densities there can be quite high: for example, 23, 25 and 30 likely breeding attempts were reported on the three main islands (North Uist, Benbecula and South Uist) in the three years 2005 – 2007 respectively, with a number of clusters where the nearest-neighbour distances between confirmed or likely nest sites was less than 1 km in 2007. Given this proximity of territorial birds, it might have been expected that interactions between neighbouring birds would have been relatively frequent, increasing their likelihood of being active and seen in daylight hours. Few short-eared owls were observed in the early part of the season (March and April) however, although nests with chicks or eggs were found in late May confirming their presence during the early part of the season (Haworth Conservation Ltd for SNH).

With seasonal differences in detectability, it is worth considering the advantages, or otherwise, of restricting survey effort to the latter part of breeding season (chick rearing and fledging) only, when detection is relatively reliable. The principal disadvantage is that this would inevitably miss pairs that fail to reach the chick rearing stage. Although the population estimates derived from such a survey would certainly be confounded with breeding success, there would be the potential advantage that there will be less variation associated with lower detection rates (and reduced reliable detection opportunities) during the incubation period. The more precise the estimates of population size (regardless of count unit) will lead to greater reliability in detecting trends between surveys (monitoring); therefore an estimate that includes just pairs that reach the chick rearing stage could potentially provide a more robust monitoring tool than one that attempts to include all territories with its greater imprecision. Any survey results that incorporate data from the full breeding season will also be confounded with breeding success in any one year to a degree, but could have the potential advantage of being able to assess the proportion of territories that might have been missed during the incubation period (by assessing the proportion of pairs that reached the chick rearing stage but remained undetected during incubation). Note that during our studies in 2006-07, we were unable to assess this as no pair was known or suspected to have failed in its breeding attempt before hatching (see above). Any decision on which approaches are adopted within a survey is also likely to be influenced by the availability of volunteers to undertake fieldwork and also their enthusiasm to participate. It has been suggested that enthusiasm from Raptor Study Group members to participate in additional surveys might be greater in the earlier part of the season (Wendy Mattingly pers. comm.) with the implication that there would be a lesser number of volunteers available for surveys in the latter parts of the season because of existing survey commitments. Conversely, low detection rates in the early part of the season may act as a disincentive for some individuals to undertake a full programme of fieldwork as it is perhaps inevitable that some volunteers will be disinclined to make repeat visits when their experiences are that they rarely record the target species. Although a volunteer surveyor would not need to be a member of a Raptor Study Group, as anyone that could identify a short-eared owl could participate, the same concerns are likely to apply.

On the Uists in 2007, Haworth Conservation Ltd. reported that most short-eared owls were observed during the evenings, particularly between 18:00 and 21:00 hours, with no apparent peak reported during late morning as found at our mainland study sites during comparable times of year (although we have no indication of the level of fieldwork effort). Ten and a half hours of observations at four apparent territories on North Uist in early June 2007 did not record any sightings between five and nine hours after first light or between seven and four fours before dark with frequent sightings in the earlier morning (two to five hours after first light) and later evening (from four hours before dark) periods sampled (John Calladine, pers. obs.). Although the latter observations were clearly restricted in duration, they do lend further support to an apparent absence of a period of relatively high detectability during four to eight hours after first light (as found at our mainland study sites) in this area, where breeding short-eared owls are probably consistently widespread and relatively abundant. We speculate that where breeding short-eared owl densities are high, the prey itself may be particularly abundant and the birds could have a reduced need to forage. It *may* be that opportunities for their reliable detection are reduced in some cases where densities are high.

4.2 Detection distances, potential observer disturbance and survey design

For any species, if the field protocols for a full census of a study area are to be based on watches from vantage points, then it is important to have some indication of the range at which individuals can be detected. An array of vantage points can then be selected to ensure that any ground with suitable habitat for the species is within range of one of the vantage points. Some guidance on the maximum distance between adjacent vantage points that should be adopted when observing the activities of breeding large- to medium-sized raptors has been provided with regard to the survey work required to underpin terrestrial wind farm planning proposals (SNH, 2005), where a maximum spacing of 4 km (such that no area of observation is more than 2 km from a vantage point) has been suggested.

The fieldwork carried out in the 2006 and 2007 breeding seasons was not designed specifically for assessing the detection distances for short-eared owls from vantage points. This was because the observation points needed to be selected before the location of individual owl territories was established but then maintained in the same positions so as to ensure that the observed durations of owl activity recorded in the first period of the breeding season were directly comparable with those in subsequent periods. The individual vantage points thus differed in terms of their proximity to an owl territory and a number of other environmental factors that could influence detection rates (topography, habitat, aspect etc). However, the design was considered representative of the situation when selecting vantage points for a census of breeding owls in any given study area. The mean first detection distances differed between the two years, being a just over half a kilometre in 2006 (95% confidence limits 473 – 570 m) compared to just over 700 m in 2007 (95% confidence limits 648 – 755 m). These differences were unlikely to be associated with observer differences between years as two fieldworkers were common to both seasons and both also tended to record greater first detection distances in the second season. The same differences were also apparent for both minimum and maximum distances to which the owls were seen from the observer. This suggests that there was a general tendency for the centres of activity of the owls to be at a greater distance from the observers in 2007 than in 2006. The same vantage points were used in both years, to ensure direct comparability, and there were no major changes in land use surrounding the vantage points between years. The implication is therefore that there may have been some effect of disturbance whereby some owls shifted their centres of activity away from the vantage points where observers were regularly positioned in 2006. Further evidence of a deterrence effect of observers on the activity patterns of owls is suggested by the fact that the owls rarely came within 200 m of the observers. Although this conclusion cannot be tested rigorously, the apparent deterrence effects, both within and between years, do support the need for survey methods to be as unobtrusive as possible. Although we can not state this categorically, the general consensus of the project partners was that although there appeared to be some influence of disturbance, the overall effect of sporadic one-off surveys (possibly at 10-year intervals) employing low intrusion methods (a maximum of a few hours watching from each vantage point) is likely to be negligible.

For the design of a field survey, the greater reliable detection distances are the most informative in that these will guide the spacing of vantage points in a way that is the most efficient use of resources. In 2007 the mean first detection distance was about 700 m. Whilst field staff were able to follow owls visually to around twice that distance from vantage points once they had first detected them (the maximum sighting distance was around 1.5 km), they might not have detected them (at least not in every case) had they first appeared much further away. These observations suggest that an array of vantage points (with a 180° field of view) at 750 – 1,500 m distant from one another (such that all areas to be viewed are within 750 m of the vantage point) might be appropriate when surveying an area of contiguous habitat suitable for short-eared owls.

In 2007, the array of vantage points established in the Ayrshire study area were spaced at around 1-km spacing, with allowance made for local topography, based on the generally lower detection distances recorded in 2006. Examination of the observations made from different vantage points in the array does show that territories were readily detected from neighbouring vantage points and that a greater separation distance of at least up to 1.5 km could be accommodated without a noticeable risk of missing birds where the topography was appropriate for continuous visibility.

4.3 Foraging ranges and interpretation of observations during a full area census

The intensity of observations carried out from the independent vantage points in 2006 and 2007 provided important information on the possible home range sizes of short-eared owls in Scotland during the breeding season. We have referred to these as *minimum* range sizes, and only quoted the maximum arc of each minimum convex polygon drawn around groups of flight lines, rather than quoting potential range areas. This is because the study design (watches from single vantage points at each site) will have placed artificial boundaries on the ranges (e.g. due to spatial variation in visibility, maximum distances at which owls could be seen, and/or potential biases due to disturbance from observers; 4.2 above). The polygons drawn around flight lines observed from the array of vantage points in Ayrshire may be more representative of true home range size but their small sample size (three ranges) from a single study does not permit judgement on how typical they were of the species as a whole across Britain.

Knowledge of home range size during the breeding season is likely to be very important when interpreting the results of a comprehensive survey of any given area because there will be a need to differentiate separate territories from discrete observations of individual birds. It is unlikely that enough volunteer birdwatchers could be persuaded to carry out the very long or large number of watches that we have shown would be likely to be required to differentiate individual territories directly or to search for nests (and indeed the latter might cause unnecessary disturbance). We have also shown that a high proportion of the observations made are likely to be of foraging birds (even at key stages of the breeding cycle), and that observations of specific behaviours that would confirm territory occupancy, and importantly territory boundaries, are likely to be rare. For these reasons, it is likely to be necessary to set some minimum threshold distance when interpreting individual sightings during a full survey of an area, based on the known spacing of territories and spatial extent of territorial behaviour in representative study areas.

In a previous analysis of short-eared owl observations collected during the 2004 Hen Harrier Survey, arbitrary separation distances between individual owl observations of 500 m, 1000 m and 2000 m (based on the published range of breeding densities recorded in Britain) were used to calculate the potential number of occupied territories in (the majority of) cases for which no specific owl activities that could be used to discriminate between separate territories had been recorded (Calladine *et al*., 2005). The observations during the 2006 and 2007 breeding seasons suggested that the individual home ranges of Scottish owls during the breeding season are often well over 100 ha in extent (see text and Table 1 in Calladine *et al.,* 2005 for comparison with published estimates of apparent territory size). Hence, in many cases, the use of a minimum separation distance of 1000 m between these apparent territories would have resulted in an overestimate of population size. Assuming that the apparent ranges recorded in 2006 and 2007 were not unduly biased by topography or limits to the detection distance of observers, a threshold minimum separation distance of 2000 m might be more appropriate for interpreting observations made during a full census of an area in the absence of observations of key behaviours or evidence of breeding to separate individual territories. However, whether these results from the pilot work in 2006 and 2007 can be used across all short-eared owl breeding areas in Britain depends on the extent to which the densities of owls sampled in were representative (4.5 below).

The results from any extensive survey would be best presented as a range of population estimates, based on range of separating distance thresholds for observations. An indication of the sensitivity of the estimates to different thresholds is given by the analysis of the short-eared owl data collected during the 2004 survey of hen harriers (Table 5 in Calladine *et al.,* 2005); for a separation threshold of 500 m, the extrapolated population estimate for Scotland was 658 territories, for 1000 m it was 536 territories and for 2000 m was 423 territories. Further scope for alternative interpretations of data will arise from overlapping ranges (e.g. Figure 2). As part of any survey, we would recommend that field workers plot their observations of short-eared owls onto large scale maps that will permit an independent and consistent interpretation of the data across the surveyed area. This will also permit reinterpretations if these are thought necessary following any improvements in knowledge of short-eared owl ranging behaviour and ensure that repeat surveys are as directly comparable as possible.

If we assume that ranging distance is inversely proportional to population density, at low population densities (when birds may range more extensively), the use of a single separating threshold distance may lead to an overestimation of population size. Therefore, a real population decline may not be detected. At high population densities, it may be expected that more interactions and simultaneous observations could be made; an increase in population size may therefore be more readily detected than a decline. These issues further emphasise the importance of recording flight line and behavioural observations that permit common interpretation across and between surveys.

Clearly, the precision of any population estimate would be enhanced by greater knowledge of the ranging behaviour of breeding short-eared owls and how that can vary. Radio-telemetry offers the greatest potential for the determination of range but in itself is resource intensive (e.g. Kenward, 1987). To reliably inform a survey, the variation in ranging distances across the breeding range of short-eared owls in the UK and the potential for inter-annual variations (in relations to a variable prey supply) would need to be investigated. The practicalities, not least the costs involved, are likely to exclude an extensive telemetry study as an integral part of any planned survey in the UK (Nigel Buxton pers. comm*.,* see Section 5.2). However, a survey itself that includes data collected from arrays of vantage points (as employed in our Ayrshire study area in 2007) and records flight lines of behaviours of birds observed is likely to deliver more information on actual ranging distances within the year of a survey and how it varies across the species' range. In the event this proves inadequate, the recording of flight lines during a survey will permit reinterpretation of data in the light of any subsequent improvements in knowledge on ranging behaviour.

4.4 Representativeness of data

Two major environmental influences were considered in this context: (i) weather (and its effects on the timing and success of breeding); and (ii) the densities at which short-eared owls settled to breed (thought to be highly variable both geographically but also within any given breeding area between years; literature reviewed in Calladine *et al.,* 2005). Settling densities in Britain are thought to be determined by a combination of variation in local prey abundance (e.g. voles) between years (which may or may not be spatially synchronous across the UK (see evidence discussed in Calladine *et al*., 2005), and also variation in the numbers of immigrant owls from mainland Europe that remain to breed (which is likely to be at least partly a function of variation in the main prey species abroad; Calladine *et al.,* 2005).

Weather conditions in the two field seasons contrasted markedly: March and early April 2006 were characterised by heavy and long-lying snow while the latter part of that season was unusually warm and dry; the early part of the 2007 season was dry and settled but from early May onwards was generally unsettled, cool and wet. Despite this marked contrast in weather between the two breeding seasons, there were no observed differences in the seasonal and diurnal variations in the behaviour or detectability of the owls. The only statistically significant difference between seasons related to detection distances, and was thought to be associated potentially with disturbance (Section 4.2). Given the close similarity of diurnal activity patterns in the two contrasting years, and some supportive evidence from other areas (Uists, Angus and the Findhorn catchment), we have no evidence that suggests the data are untypical or unrepresentative.

4.5 Utility of the extensive monitoring technique

The extensive point counts along road transects produced a satisfactory rate of encounter with short-eared owls. For transects surveyed in both 2006 and 2007, the number of registrations was slightly greater in 2007 than in 2006 (17 compared to 13). This suggests that there may be some meaningful correlation with the number of territories apparent from the vantage points within the study areas (up to 13 in 2007 compared to up to 11 in 2006 for vantage points monitored in both years). Furthermore, the small number of coincident transects that were surveyed by both professional fieldworkers and by volunteers does suggest a degree of repeatability in the methods.

Uptake of point count surveys by volunteers in 2007 was modest. It is known that an additional six individuals (four from northern England and two from Wales) would have undertaken point count surveys had there not been an unfortunate technical problem emailing relevant details and at least four others (from Scotland) reported that persistent bad weather had prevented them from undertaking surveys. Interest from volunteers to participate in a 'full survey' rather than a pilot study would probably be greater. We consider that this approach could usefully supplement annual indices derived from the BTO/JNCC/RSPB Breeding Bird Survey (BBS) (e.g. Raven *et al.,* 2007) and potentially other sources such as regional bird recording network, the BTO/RSPB/BWI online bird recording system, BirdTrack (http://www.bto.org/birdtrack) and data collected annually by raptor study groups (e.g. Etheridge *et al.,* 2007) to generate indices of short-eared owl abundance over a number of years before, during and after a targeted national survey, that would be sufficiently robust to be able to put the survey results into context as a year of low, medium or high abundance (and/or breeding success, see Section 4.1). To inform a survey of breeding short-eared owls, the contextual information needs to include a measure of survey effort. Survey effort for the point count surveys as undertaken in the present study and the BBS is rigorously recorded in that it is an integral part of the survey methodology. For data submitted to BirdTrack, a measure of survey effort is also obtainable by assessing the proportion of submitted lists that include the species, however to date, very few records of short-eared owls from within the breeding range and breeding seasons are submitted (online database accessed 30 January 2008). Reports submitted through the regional bird recording network and to the Scottish Raptor Monitoring Scheme by raptor study group members do not include any measure of survey effort and therefore could only currently be used to add qualitative support to the more rigorously quantifiable data collected by other schemes. The project partners felt that it would be useful to trial asking raptor study groups to systematically record sightings of short-eared owls and time spent in suitable breeding areas from 2008.

As well as recording short-eared owls, these surveys provided encounter rates that would be likely to provide satisfactory information for monitoring trends (or for use in combination with data from other sources, e.g. the BBS) for a suite of other upland and marginal upland bird species, including a number of breeding waders (e.g. curlew, lapwing, redshank, snipe and oystercatcher), two widespread raptors (buzzard and kestrel), some gamebirds (e.g. pheasant, possibly black and red Grouse) and a range of passerines (e.g. meadow pipit, pied wagtail, reed bunting, sky lark).

5. RECOMMENDATIONS FOR A FIELD SURVEY

5.1 Field protocols

The following recommendations are made concerning field protocols for a survey of breeding short-eared owls:

1. Sample extensive contiguous areas of owl distribution and potential owl habitat, but use a more targeted approach for restricted areas (lowland marshes, coastal grassland and pre-thicket plantation/woodland) based on local knowledge;

2. Do not start surveys before early to mid-April (detection rates too low). If it is accepted that only an estimate of successful (to the chick-rearing stage) breeding attempts will be achieved, a survey period of June to July would be adequate;

3. Undertake surveys from vantage points that provide an adequate field of view, within an arc not exceeding 180°, 750 – 1,500 m distant from one another such that all areas to be viewed are within 750 m of the vantage point. Closer proximity of vantage points may be required where topography necessitates.

4. Undertake cumulative totals of 4 hours of watching from each vantage point within each of the following time periods: (i) mid-April to mid-May within the last four hours before dark (if a decision is made to attempt to record breeding attempts that may fail before hatching); (ii) in June between four and eight hours after first light or within four hours before dark; and (iii) in July, within the first four hours after first light or the last four hours before dark. Where practicalities necessitate sampling at other times of day, the estimates will need to be corrected because of expected lower detection rates.

5. Fieldworkers should plot flight lines, including details of behaviour (Section 4.3), of all short-eared owls seen onto large scale maps as well as providing their own independent assessment of the number of territories of owls that they detected.

6. Analyses should include a range of estimates based on different thresholds for assigning spatial locations of birds to different territories in the absence of observations of key territorial behaviours (e.g. simultaneous observations and territorial disputes): 1000 m, 2000 m.

7. Extensive point counts/transects should be undertaken and/or alternative quantifiable indices of short-eared owl abundance collected for a period of at least five years during one of which the actual survey is undertaken, in order to place the survey results into the context of between-year variations in numbers and/or breeding success.

5.2 Additional practical constraints for survey and monitoring

In addition to the constraints associated with the behaviour and resultant low detectability of the owls, the resources available to undertake a survey or monitoring programme will impose further practical constraints on what can be achieved. Principal amongst these additional constraints are the availability of volunteers to undertake survey work and the money that is available to employ professional surveyors, to fill gaps in volunteer coverage, and for analyses and interpretation. In estimating the effects of these additional constraints we have assumed:

- The range of breeding short-eared owls in the UK occupies 650 10-km squares. This is based on the two national atlases of breeding birds undertaken in 1968-72 (Sharrock, 1976) and 1988-91 (Gibbons *et al.,* 1993). In the latter period, short-eared owls were reported from 679 10-km squares (with breeding evidence reported from 381) compared to 801 in 1938-72 (with breeding evidence reported from 542). Most of the decline between the two atlas periods is attributed to losses from the fragmented range along the east coast of Britain and to the maturation of many conifer plantations thereby making them unsuitable for breeding short-eared owls (Glue, 1993). Ideally, a survey would sample from the occupied squares, possibly stratified by areas where breeding evidence was recorded in the latter atlas period, additional areas where the birds were recorded and areas where suitable habitat remains but birds were not recorded in the latter or both atlas periods. Note also that fieldwork for a third atlas of breeding birds in Britain and Ireland will be completed during 2008-11. The planning of a future survey of short-eared owls will benefit from the more recent data on distribution that will be available;

- Sampled survey units will be 5-km by 5-km squares based on the Ordnance Survey's national grid (this was the general consensus at a meeting of the project partners in January 2008). Vantage points with a maximum viewing arc of 180° will be used as the principal survey method and be spaced such as most parts of the survey area are within 750 m of a vantage point (Section 4.2). Based on an 'ideal' 5 km by 5 km square of contiguous suitable habitat and favourable topography, this would require 18 vantage points with equidistant spacing of 1500 m along an x-axis of a grid within the ideal survey square and 750 m spacing along the y-axis (note the difference because of the 180° field of view);

- On average, 50% of each potentially occupied 10-km square would constitute apparently suitable breeding habitat for short-eared owls (for which we have no sound basis) and therefore there will be 1300 potentially occupied 5-km squares (2 * 650, after assumption (a) above);

- Each vantage point will be sampled (one 2-hour watch) twice within the survey period;

- A professional surveyor will undertake an average three 2-hour watches in a full working day. This means that it will take 12 man-days to sample all vantage points in a single 5-km square twice;

- There will be 25 potential working days in each month but poor weather will prevent fieldwork for 25% of the time. This means that professional surveyors will be able to complete 18 days of fieldwork in one month;

- A volunteer surveyor will contribute four man-days to the main part of the survey and therefore, three volunteers will be required to survey the equivalent of a complete 5 km square;

- All background monitoring of trends in which to put a national survey into context would be undertaken by volunteers.

The field protocols designed for a survey of hen harriers in 2004 was able to sample 63% of the potentially occupied 10 km by 10 km squares in Scotland plus more intensive sampling, or a comprehensive census in England, Wales, Northern Ireland and the Isle of Man (Sim *et al.,* 2007). For short-eared owls, to sample 63% of the potentially occupied 5-km squares and assuming that 50 volunteers were available for the survey in addition to the above assumptions, it is expected that over 6,600 paid man days, or the equivalent 178 paid fieldworkers would be required for a three month field season (Table 13). If the survey were to be concentrated in the early part of the field season (in an attempt to estimate the number of all potential breeding pairs), the required number of paid field workers would rise to 535 (Table 13). With 25 professional fieldworkers, a three month surveying period and 50 volunteers, it might be expected that 10% of the breeding range of short-eared owls in Britain would be surveyed (Table 13). The expected requirement for professional fieldworkers under a range of scenarios of proportion of range to be surveyed and volunteer availability is given in Table 13.

With realistic expectations for resources (in the order of £100,000, Nigel Buxton pers. comm.), a survey that delivers a statistically robust national population estimate of breeding short-eared owls is perhaps not a practical proposition. Alternatively, with for example, 10 professional and 25 volunteer surveyors and a three month field season, a total of 1750 km^2 (70 five-km squares) could be effectively monitored at episodic intervals. The anticipated coverage with a range of scenarios of available professional and volunteer surveyors is given in Table 14. In conjunction with more continuous indexing of population abundances from low intensity extensive surveys (Section 4.5), the status of breeding short-eared owls within key or representative areas could be realistically monitored.

An alternative monitoring approach could sample a larger number of independent survey points rather than ‘clustered’ within the assumed 5 km by 5 km squares. With similar resources to those assumed above, a total of 1260 independent vantage points could be sampled (the equivalent of18 points within each of 70 survey squares). Such an approach would have the advantages of:

a) It is more likely to sample representatively the full range of densities at which breeding short-eared owls occur;
b) The greater sample of independent data points (1260 vantage points as opposed to 70 clusters) could likely deliver a more precise index of breeding short-eared owl abundance with greater power to reliably detect changes.

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TABLES

Table 1 *Habitats visible from the vantage points from which fixed point observations of short-eared owls were made during the 2006 and 2007 breeding seasons (180° field of view).*

Study area	Vantage Point	Altitude (m asl)	Habitats visible (approx. % cover)				
			Heath & bog	Semi-natural grassland	Mature conifers	Young plantations	Improved grassland
Perthshire	A	240	70	28	2	0	0
	B	300	50	46	0	2	2
	C	320	70	10	10	4	6
	D	500	95	0	5	0	0
Ayrshire	A	330	80	15	5	0	0
	B	320	55	40	5	0	0
	C	280	30	70	0	0	0
	D	180	70	20	0	4	6
Borders	A	400	25	70	5	0	0
	B	300	60	30	0	0	10
	C	480	80	20	0	0	0
	D	300	40	40	5	0	15

Table 2 *Fieldwork periods which during observations of short-eared owls were made in 2006 and 2007.*

Period	2006		2007	
	First date	*Last date*	*First date*	*Last date*
Period 1	6 March	31 March	13 March	31 March
Period 2	18 April	15 May	19 April	16 May
Period 3	1 June	22 June	28 May	21 June
Period 4	1 July	28 July	1 July	20 July

Table 3 *Some estimated first laying dates for short-eared owls from the Perthshire study area between 1996 and 2007 (Neil Morrison, pers. comm.). Each date corresponds to a single nest.*

Year	Estimated of dates of laying first eggs
1996	6 April
1997	before 21 April
1998	15 April, 18 April
2000	26 March, 29 March
2003	before 15 April
2004	20 March, 1 April, 2 April
2007	7 April, 8 April

Table 4 *Summary of conclusions regarding the number of territories of short-eared owls, and the outcomes of each breeding attempt, for each study area and vantage point used in the study in 2006 and 2007.These conclusions are based on a combination of observations from the intensive fieldwork, local raptor workers and local land managers.*

Study area	**Vantage point**	**Territory**	**Assumed outcome in 2006**[*]	**Assumed outcome in 2007**[*]
Borders	A	(i)	A food pass to an apparent nest site suggested that young hatched but no fledged young were seen. A fledged young was seen in the south of this range however late in the season by TD.	1+ fledged young. A successful nest site reported to the east of the vantage point (within the range recorded from the VP) by TD.
	B	(ii)	3+ fledged young. Nest site was found by TD. TD also thought there may be another territory adjacent to the south-west but the area was largely obscured from view (TD's suspicion was based only on observations of a post-fledged young that could have originated from our territory (ii) however).	Birds seen carrying prey and probable fledged young seen. Successful nest found by TD within core area of activity identified from vantage point watches.
	B	(iii)		Territory identified to the west of the principal area of observations only by occasional aggressive interactions with birds from core territory. Not seen by TD.
	B	(iv)		Territory identified to the east of the principal area of observations only by occasional aggressive interactions with birds from core territory. Not seen by TD.
	C	(v)	Site occupied but relatively few observations as largely obscured from view from the vantage point. TD suspected nest site to west of road.	
	C	(vi)	2+ fledged young. This territory was differentiated from '(iii) by the intensive fieldwork but not by TD's casual observations.	Birds seen carrying food but no fledged young seen during systematic observations. Successful nest found by TD.
	C	(vii)		Bird(s) hunting in an area some distance from the vantage point only when visibility very good. No independent observations from this area.
	D	(viii)	Breeding unlikely: only 2 observations of owls. Not seen by TD.	Not sampled in 2007. No owls reported by TD.

Table 4 (cont'd) *Summary of conclusions regarding the number of territories of short-eared owls, and the outcomes of each breeding attempt, for each study area and vantage point used in the study in 2006 and 2007.These conclusions are based on a combination of observations from the intensive fieldwork, local raptor workers and local land managers.*

Study area	Vantage point	Territory	Assumed outcome in 2006*	Assumed outcome in 2007*
Ayrshire	A	(i)	No owls seen.	Few systematic observations. No independent observations
	B	(ii)	Occasional observations of owls but none indicative of breeding. Similarly reported by GC and local shepherds.	Occasional observations of owls but none indicative of breeding. Similarly reported by GC.
	C	(iii)	Young hatched (repeatedly carrying food to one location) but no fledged young seen. No independent observations for this site.	Young hatched (repeatedly carrying food to one location) but no fledged young seen. No independent observations for this site.
	C	(iv)	Few observations: owls were distant and only seen when stimulated by a bird from territory (iii).	Few observations: owls were distant and only seen when stimulated by a bird from territory (iii).
	D	(v)	Few observations and no suggestion of breeding. BS had a series of observations here in March but not later in season, although he "didn't get there much".	Not sampled in 2007
	Array	(vi)	Not sampled in 2006.	Young hatched (repeatedly carrying food to one location) but no fledged young seen. No independent observations for this site.
	Array	(vii)	Not sampled in 2006.	Relatively few observations but includes antagonistic behaviour with birds from (v). No evidence of hatched or fledged young. Not reported by GC.

Table 4 (cont'd) *Summary of conclusions regarding the number of territories of short-eared owls, and the outcomes of each breeding attempt, for each study area and vantage point used in the study in 2006 and 2007.These conclusions are based on a combination of observations from the intensive fieldwork, local raptor workers and local land managers.*

Study area	**Vantage point**	**Territory**	**Assumed outcome in 2006***	**Assumed outcome in 2007***
Perthshire	A	(i)	Food carrying seen, suggesting that young hatched, but no fledged young seen. NM thinks there may have been 2 pairs here but his view was based on a single observation of birds seen at opposite ends of the single range identified by the intensive fieldwork.	Food carrying seen, suggesting that young hatched, but no fledged young seen. NM found a nest with 6 small young (plus 1 unhatched egg) on 12th May.
	B	(ii)	Food carrying seen, suggesting that young hatched. No fledged young seen. NM thinks breeding attempt here was unsuccessful (includes reports from the local keeper).	Food carrying seen, suggesting that young hatched, but no fledged juveniles seen. NM found a nest with 6 small young on 13th May. Not known to have fledged young.
	B	(iii)	NM considered there was another territory in the area of site B but the area he described was mostly out of range of the vantage point. NM thought it did not fledge young (includes reports from local keeper).	Occasional sightings from vantage point including antagonistic behaviour with (ii). NM considered another territory present in the area but nest not found and not known to have fledged young.
	C	(iv)	Few observations: unlikely to have bred. NM thought similarly (including reports from local keeper).	Few observations: May have attempted breed at some distance from the vantage point (NM).
	D		No owls seen.	Not sampled in 2007.

Note * Observers: TD=Tom Dougall; GC=Graeme Clelland; BS=Bob Stakim; NM=Neil Morrison

Table 5 *The influence of Season, Time of Day and Year on the duration of all observations of short-eared owls and of behaviours indicative of territory holding, from generalised linear models assuming a Poisson error distribution and using a log link function.*

	Season[a]		**Time of day**[b]		**Year**[c]	
All observations[d]	χ^2	*P*	χ^2	*P*	χ^2	*P*
All season	6.33	0.09	11.48	0.04	0.22	0.64
March				*Model would not converge*		
Mid-April to mid-May			6.41	0.26	0.20	0.65
June			2.60	0.76	3.84	0.05
July			6.14	0.29	0.13	0.72
Key behaviours[e]						
All season	4.11	0.25	7.02	0.22	0.44	0.51
March				*Model would not converge*		
Mid-April to mid-May			3.91	0.56	0.25	0.62
June			5.10	0.40	2.11	0.15
July			4.99	0.41	0.09	0.77

Notes:
- a) Season refers to the four periods of the breeding season.
- b) Time of Day refers to either the six time-of-day classes (four two-hour periods after first light and two two-hour periods before dark).
- c) Year refers to the two years in which observations were made, 2006 and 2007.
- d) Includes all observations of Short-eared owls.
- e) Includes only observations of Short-eared owls that included behaviour(s) indicative of holding a territory (see Section 2.3.1).

Table 6 *The estimated likelihoods of seeing a short-eared owl, and of observing behaviour indicative of territoriality, under some selected scenarios of times of day and season. The estimated likelihoods are the proportions of times that owls were seen (or included territorial behaviour) during 1000 random selections of each scenario from data collected from all study sites during 2006 and 2007. The scenarios shown are all for two 2-hour watches within the times of day and season indicated.*

Time of day[1]	SEEN[2]	KEY[3]
MARCH (site occupation)		
All	17%	6%
mid-APRIL to mid-MAY (main incubation)		
a + b	61%	38%
e + f	86%	59%
a + b + e + f	74%	46%
All	72%	45%
JUNE (main chick-rearing)		
a + b	64%	46%
e + f	86%	48%
c + d	78%	64%
c + d + e + f	84%	52%
All	73%	46%
JULY (main fledging)		
a	60%	30%
b	86%	73%
c + d	66%	66%
e + f	82%	52%
b + c + d	75%	70%
b + c + d + e + f	80%	63%
All	76%	55%

Notes:

1. ‘a’, ‘b’, ‘c’ and ‘d’ refer to successive two-hour periods after first light and ‘e’ and ‘f’ refer the two two-hour periods before dark.
2. Refers to all sightings of Short-eared owls.
3. Refers to observations that included of behaviour indicative of territoriality.

Table 7 *The likelihoods of seeing short-eared owls (All observations) and of their including territorial behaviour (Key observations) at least once during two 2-hour watches (i.e. fours in total) within the times of day and season indicated.*

	After first light		Before dark
	0 – 4 hours	4 – 8 hours	0 – 4 hours
All observations			
MARCH	Very poor	Very poor	Very poor
mid-APRIL – mid-MAY	Moderate	Poor	Good
JUNE	Moderate	Good	Good
JULY	Good	Moderate	Good
Key observations			
MARCH	Very poor	Very poor	Very poor
mid-APRIL – mid-MAY	Poor	Poor	Poor
JUNE	Poor	Moderate	Poor
JULY	Moderate	Moderate	Moderate

Note: Very poor – <25% chance of an observation.
Poor – 25 – 50% chance of an observation.
Moderate – 50 – 75% chance of an observation.
Good – >75% chance of an observation.

Table 8 *The influence of season, time of day and of year on the distances at which breeding short-eared owls were seen. Site (vantage point) was included in the models as a repeated measure.*

	First distance[1]		Minimum distance[2]		Maximum distance[3]	
	χ^2	*P*	χ^2	*P*	χ^2	*P*
Season	5.24	0.16	5.49	0.14	5.14	0.16
Time of day	7.68	0.17	5.49	0.36	8.00	0.16
Year	7.28	0.01	6.19	0.01	7.80	0.01

[1] The distance at which an owl was first detected from the observer.

[2] The minimum distance to which the owl approached the observer during the recorded observation.

[3] The greatest distance from the observer at which the owl was seen.

Table 9 *The distances (m) at which breeding short-eared owls were seen from fixed vantage points in 2006 and 2007.*

	Mean	95% confidence interval	Range
2006			
First distance[1]	522	473 – 570	10 – 2000
Minimum distance[2]	399	350 – 449	10 – 2000
Maximum distance[3]	656	603 – 709	10 – 2200
2007			
First distance[1]	702	648 – 755	30 – 2500
Minimum distance[2]	603	549 – 656	10 – 2500
Maximum distance[3]	858	805 – 912	100 – 2700

[1] The distance at which an owl was first detected from the observer.

[2] The minimum distance to which the owl approached the observer during the recorded observation.

[3] The greatest distance from the observer at which the owl was seen.

Table 10 *The influence of season, year and type of vantage point on the minimum ranging distances of short-eared owls estimated from fixed vantage points.*

	Season[a]		Year[b]		Type[c]	
	X^2	*P*	χ^2	*P*	χ^2	*P*
All season[d]	NA	NA	0.31	0.58	3.24	0.07
By season[e]	3.47	0.33	0.30	0.59	2.89	0.09

Notes:

a) Season refers to the four periods of the breeding season.
b) Year refers to the two years in which observations were made, 2006 and 2007.
c) Type refers to ranges having been estimated from either single independent vantage points or from an array of neighbouring vantage points.
d) Model includes Year (n=2) and Type (n=2) as independent variables and the MCP (the minimum arc of which is the dependent variable) derived from all the plotted flight lines in each year.
e) Model includes Season (n=4), Year (n=2) and Type (n=2) as independent variables and the MCP (the minimum arc of which is the dependent variable) derived from the plotted flight lines separately for each season in each year. The individual territories are introduced into the models as repeated measures.

Table 11 *The frequency of short-eared owl registrations, and the number of points at which they were seen, during timed point counts by professional fieldworkers in 2006 and 2007.*

Area	Transect	Period	2006		2007	
			Birds	Points	Birds	Points
Perthshire	1	A	0	0	nc	
	1	B	2	1	3	2
	1	C	3	3	0	0
	1	D	0	0	nc	
	2	A	0	0	nc	
	2	B	2	2	3	3
	2	C	0	0	0	0
	2	D	0	0	nc	
Ayrshire	1	A	2	2	nc	
	1	B	0	0	1	1
	1	C	0	0	4	4
	1	D	0	0	nc	
	2	A	0	0	nc	
	2	B	0	0	0	0
	2	C	0	0	5	4
	2	D	0	0	nc	
Borders	1	A	1	1	nc	
	1	B	0	0	0	0
	1	C	3	3	1	1
	1	D	0	0	nc	
	2	A	1	1	nc	
	2	B	0	0	0	0
	2	C	0	0	0	0
	2	D	0	0	nc	

Table 12 *The number of registrations recorded for each species during point count surveys in 2006 and 2007.*

Species	2006[1]	2007[1]	2007[2]	Species	2006[1]	2007[1]	2007[3]
Mute Swan	0	0	3	Tawny Owl	0	0	2
Greylag Goose	2	0	44	Short-eared owl	13	17	19
Greater Canada Goose	3	10	3	Common Swift	2	1	16
Common Shelduck	0	1	2	Sky Lark	68	102	211
Eurasian Wigeon	1	0	0	Sand Martin	31	90	8
Eurasian Teal	1	5	3	Barn Swallow	50	93	46
Mallard	22	31	22	House Martin	8	19	6
Tufted Duck	1	3	4	Tree Pipit	0	2	1
Red-breasted Merganser	0	1	0	Meadow Pipit	202	219	447
Goosander	2	5	0	Grey Wagtail	3	1	8
Common Eider	0	0	16	White/Pied Wagtail	35	42	29
Willow Ptarmigan (Red Grouse)	24	42	22	White-throated Dipper	5	4	2
Black Grouse	17	64	34	Winter Wren	34	34	56
Red-legged Partridge	6	13	9	European Robin	1	1	3
Grey Partridge	1	0	5	Whinchat	4	5	8
Common Pheasant	50	69	56	Stonechat	21	31	34
Red-throated Diver	0	0	2	Northern Wheatear	16	27	39
Little Grebe	0	0	2	Ring Ouzel	3	2	6
Great Crested Grebe	0	1	1	Common Blackbird	1	1	1
Great Cormorant	0	0	1	Fieldfare	1	0	0
Grey Heron	9	15	14	Song Thrush	1	3	9
Red Kite	1	1	0	Mistle Thrush	4	5	9
Hen Harrier	1	4	9	Common Grasshopper Warbler	5	5	0
Eurasian Sparrowhawk	1	0	2				
Common Buzzard	53	37	40	Sedge Warbler	3	1	2
Golden Eagle	0	0	3	Blackcap	0	1	1
Osprey	3	1	0	Willow Warbler	6	33	33
Common Kestrel	37	17	26	Common Chiffchaff	0	2	0
Merlin	0	5	1	Goldcrest	0	0	5
Peregrine Falcon	1	0	3	Blue Tit	0	0	1
Eurasian Oystercatcher	85	154	78	Great Tit	0	0	2
Ringed Plover	1	4	0	Black-billed Magpie	0	1	2
European Golden Plover	1	4	12	Eurasian Jackdaw	11	142	89
Northern Lapwing	102	231	191	Rook	11	468	83
Dunlin	0	0	1	Carrion Crow	88	83	135
Common Snipe	32	30	48	Hooded Crow	0	0	2
Eurasian Curlew	149	213	298	Common Raven	5	6	9
Common Redshank	14	19	33	Common Starling	14	74	89
Common Greenshank	0	0	2	House Sparrow	0	1	0
Common Sandpiper	16	18	11	Chaffinch	1	23	15
Black-headed Gull	25	110	481	European Greenfinch	1	10	1
Mew Gull	6	50	31	European Goldfinch	0	2	3
Lesser Black-backed Gull	9	41	18	Eurasian Siskin	2	8	2
Herring Gull	3	0	114	Common Linnet	2	7	8
Feral Pigeon/Rock Dove	0	0	5	Twite	0	2	3
Stock Pigeon	0	0	5	Lesser Redpoll	3	13	3
Common Wood Pigeon	11	35	47	Common Crossbill	1	7	2
Common Cuckoo	5	6	16	Yellowhammer	0	1	0
Barn Owl	2	1	0	Reed Bunting	18	14	20

1. By professional fieldworkers during the second and third survey periods only.
2. By volunteers.

Table 13 *The estimated requirements for professional fieldworkers to undertake a survey of breeding short-eared owls with different scenarios of proportions of their range to be sampled and availabilities of volunteer surveyors. Note these estimations follow the assumptions described in Section 5.2.*

Proportion of range to be surveyed	Number of volunteer surveyors	Man-days of professional fieldwork required	Equivalent professional staffing requirement for survey periods of:	
			1 month	3 months
10%	100	1160	64	21
	75	1260	70	23
	50	1360	76	25
	25	1460	81	27
30%	100	4280	238	79
	75	4380	243	81
	50	4480	249	83
	25	4580	254	85
63%	100	9428	524	175
	75	9528	529	176
	50	9628	534	178
	25	9728	540	180

Table 14 *The estimated area with a single year in which breeding short-eared owls could be monitored with different scenarios of numbers of professional and volunteer surveyors. Note these estimates follow the assumptions described in Section 5.2.*

Number of professional surveyors	Number of volunteer surveyors	Area that could be monitored in a single year (km^2) with a field season of:	
		1 month	3 months
5	25	450	975
	50	675	1175
	75	875	1400
	100	900	1600
10	25	725	1750
	50	925	1975
	75	1125	2175
	100	1350	2400
20	25	1250	3325
	50	1450	3525
	75	1650	3750
	100	1875	3950

FIGURES

Figure 1 *Location of the three study areas used in 2006-07: A – Perthshire; B – Ayrshire; C – Borders.*

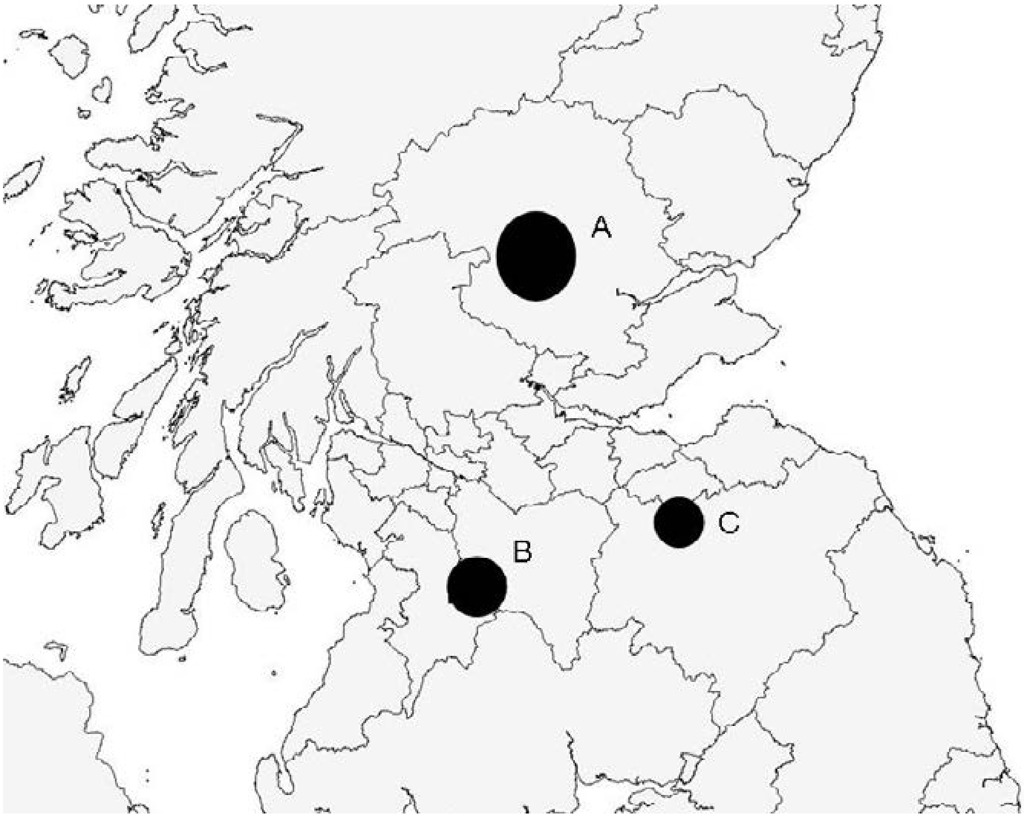


Figure 2 *The array of vantage points in the Ayrshire study area. Minimum convex polygons drawn around the outer limits of the flight lines of short-eared owls during the 2007 breeding season. Observations in which behaviours indicative of territorial interaction were noted (when available) were used to establish boundaries between adjacent ranges (see text for further details). The position of the vantage point is shown by the black point on each map. The grid shows 1-km squares of the National Grid*

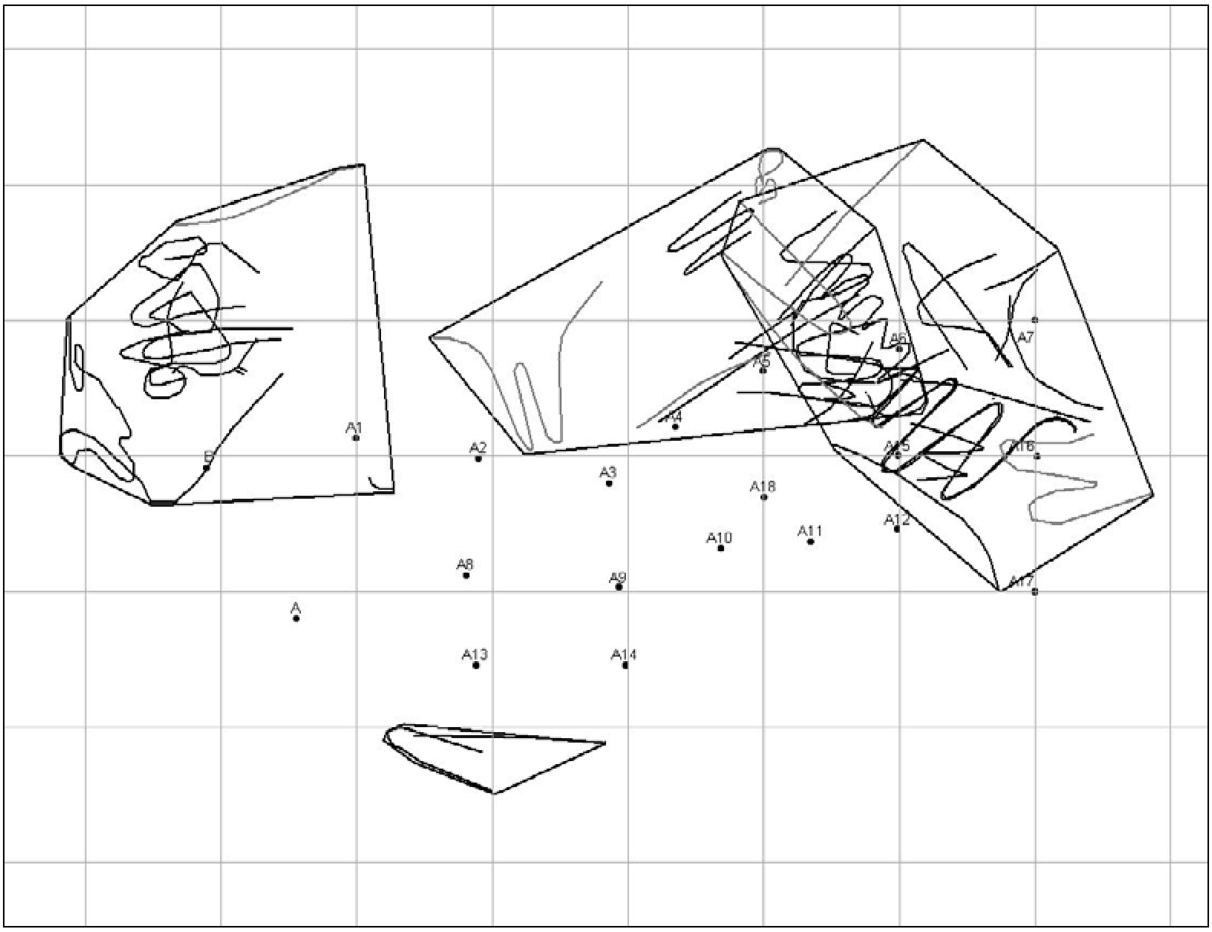


Figure 3 *Minimum convex polygons drawn around the outer limits of the flight lines of Short-eared owls during the 2006 and 2007 breeding seasons at 10 sites within three study areas: (a) the Borders; (b) Ayrshire; and (c) Perthshire. Observations in which behaviours indicative of territorial interaction were noted (when available) were used to establish boundaries between adjacent ranges (see text for further details). The position of the vantage point is shown by the black point on each map. The grid shows 1-km squares of the National Grid.*

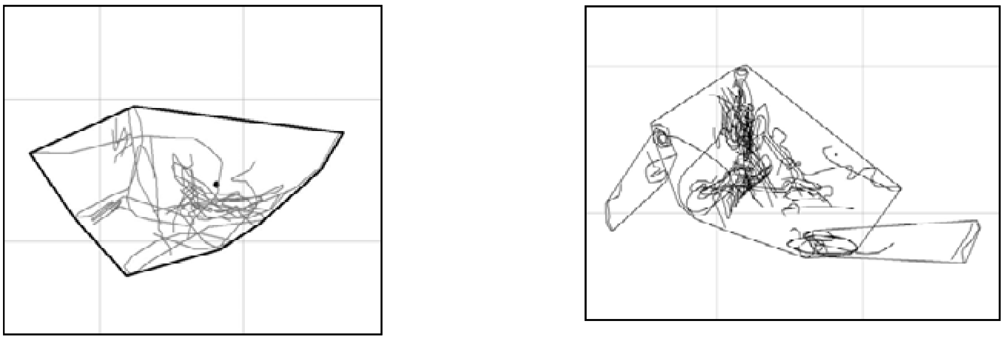
a) **Borders**

Vantage point A

2006

2007

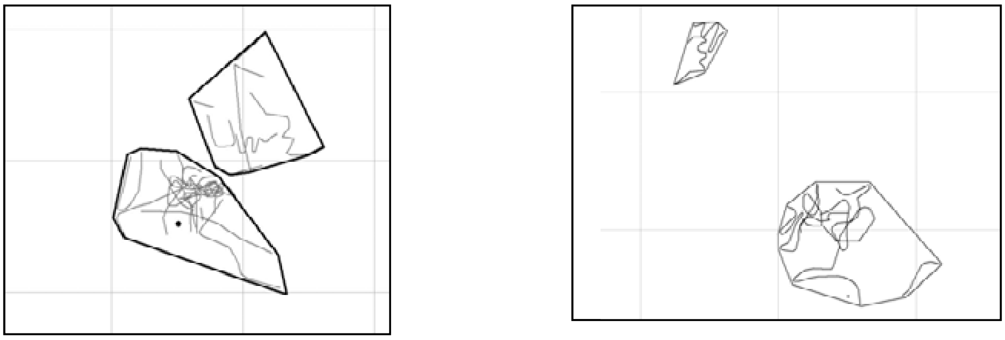
Vantage point B



2006

2007

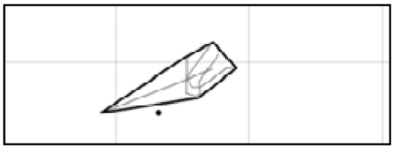
Vantage point C



2006

2007

Vantage point D

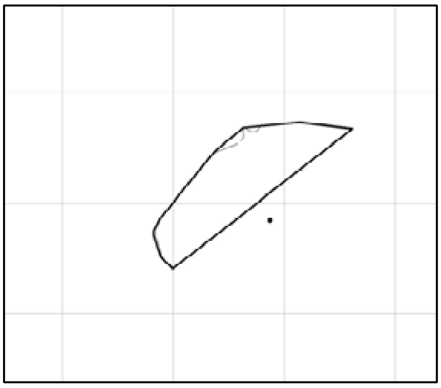


2006

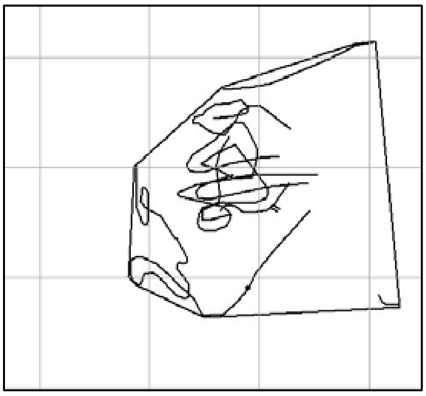
(b) Ayrshire

Vantage point B

2006



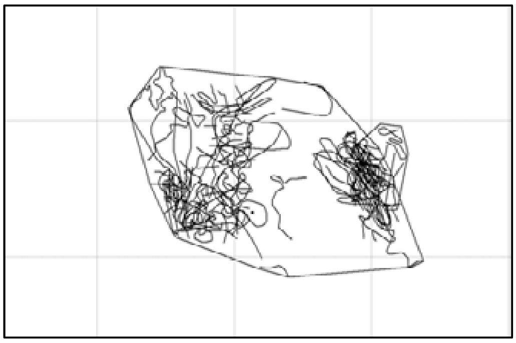
2007



Vantage point C

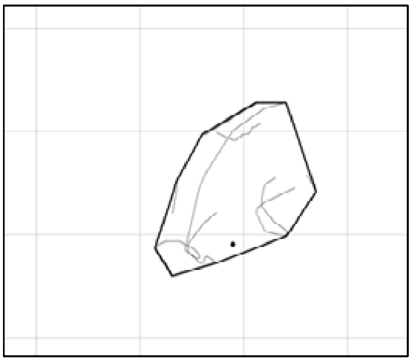
2006

2007



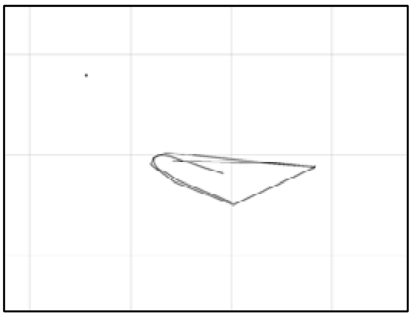
Vantage point D

2006



Vantage point A

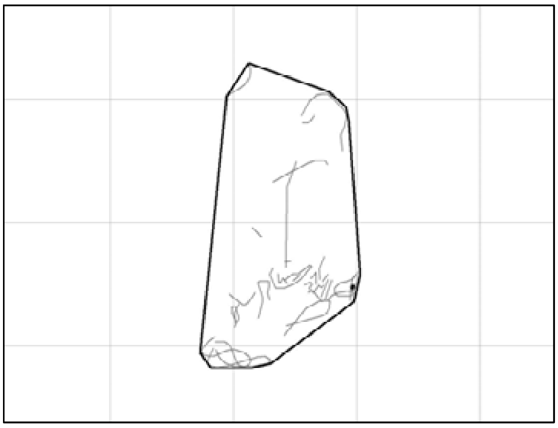
2007



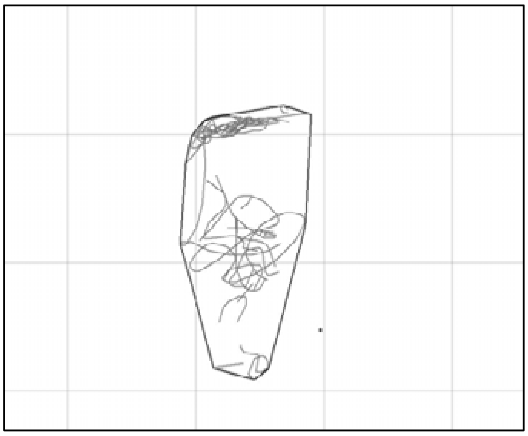
(c) Perthshire

Vantage point A

2006

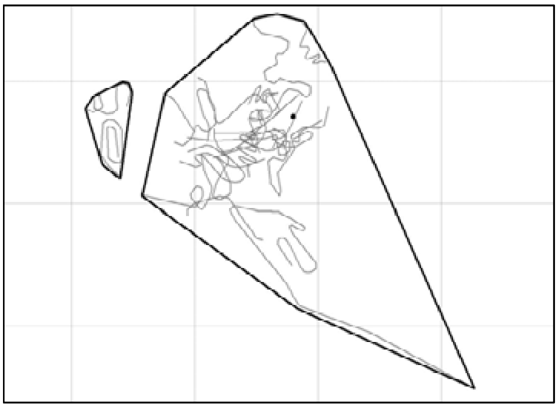


2007

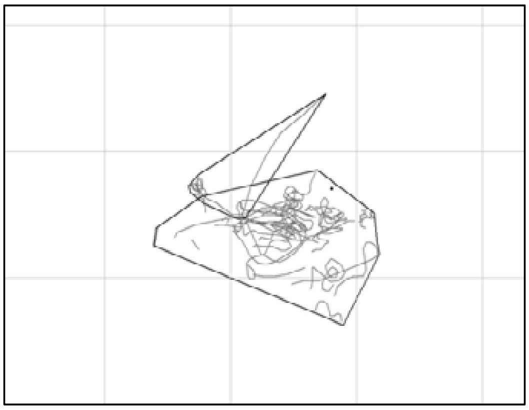


Vantage point B

2006

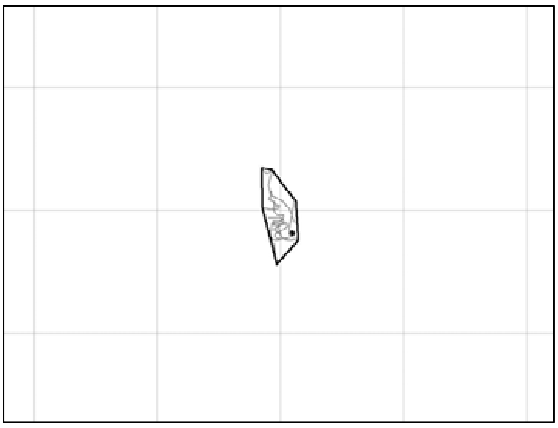


2007



Vantage point C

2006



2007

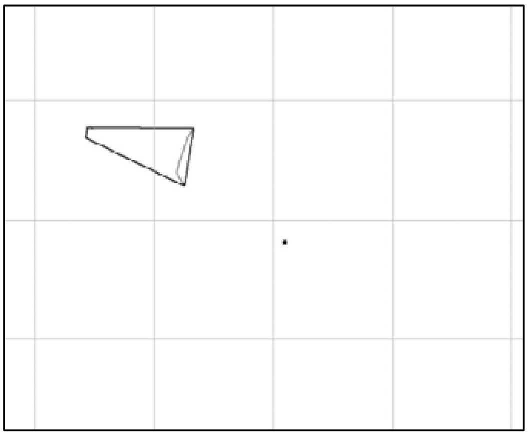


Figure 4 *The duration of time for which short-eared owls were visible during the four survey periods in the 2006 and 2007 breeding seasons. Means and 95% confidence limits (back-transformed from estimates from the generalised linear model in Table 5) are shown.*

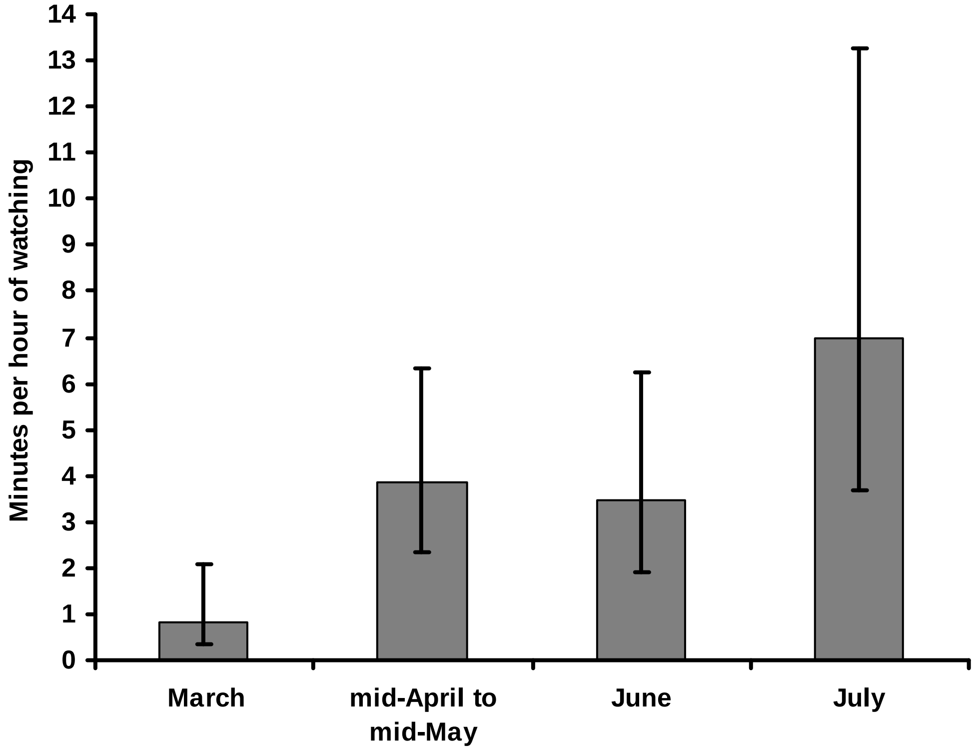
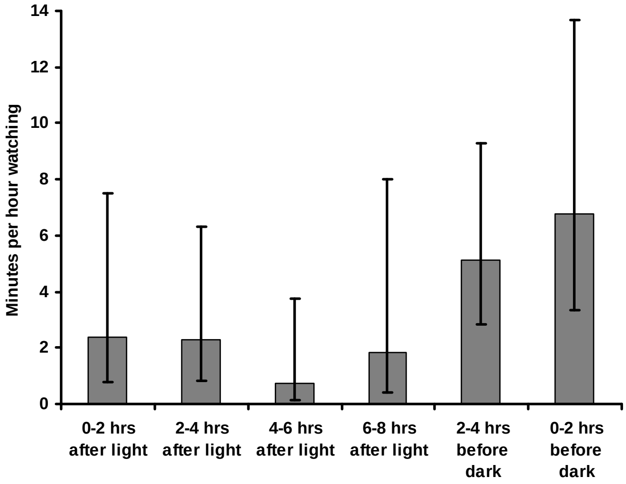
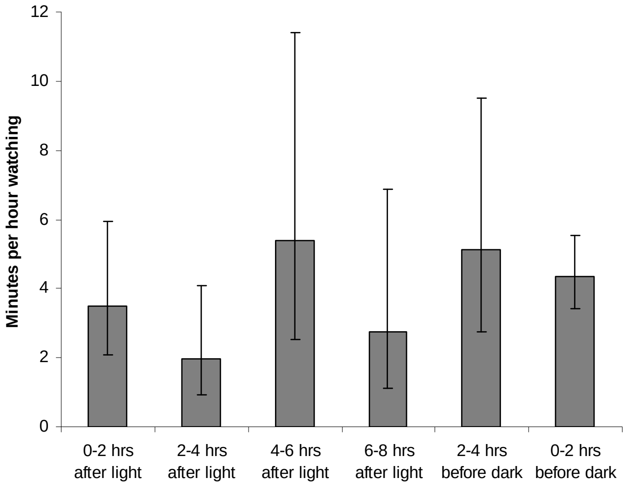


Figure 5 *The duration of time for which short-eared owls were visible during two-hour periods within daylight hours during (a) mid-April to mid-May, (b) June, and (c) July in 2006 and 2007. Means and 95% confidence limits (back-transformed from estimates from the generalised linear model in Table 5) are shown.*

a) mid-April to mid May



b) June



c) July

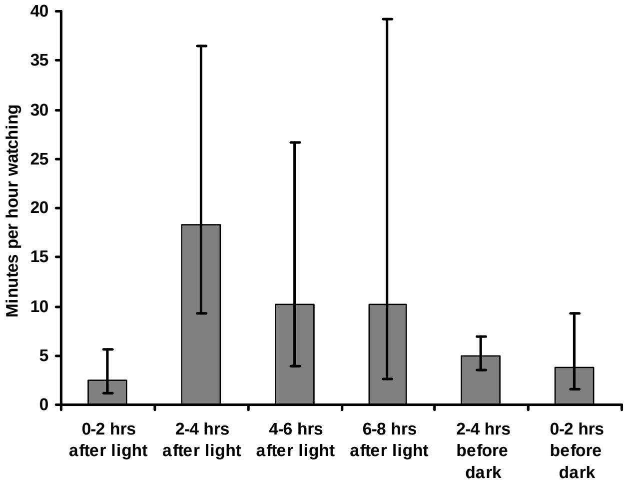


Figure 6 *The duration of time for which short-eared owls were visible and were seen to show behaviour indicative of territoriality during the four survey periods in the 2006 and 2007 breeding seasons. Means and 95% confidence limits (back-transformed from estimates from the generalised linear model in Table 5) are shown.*

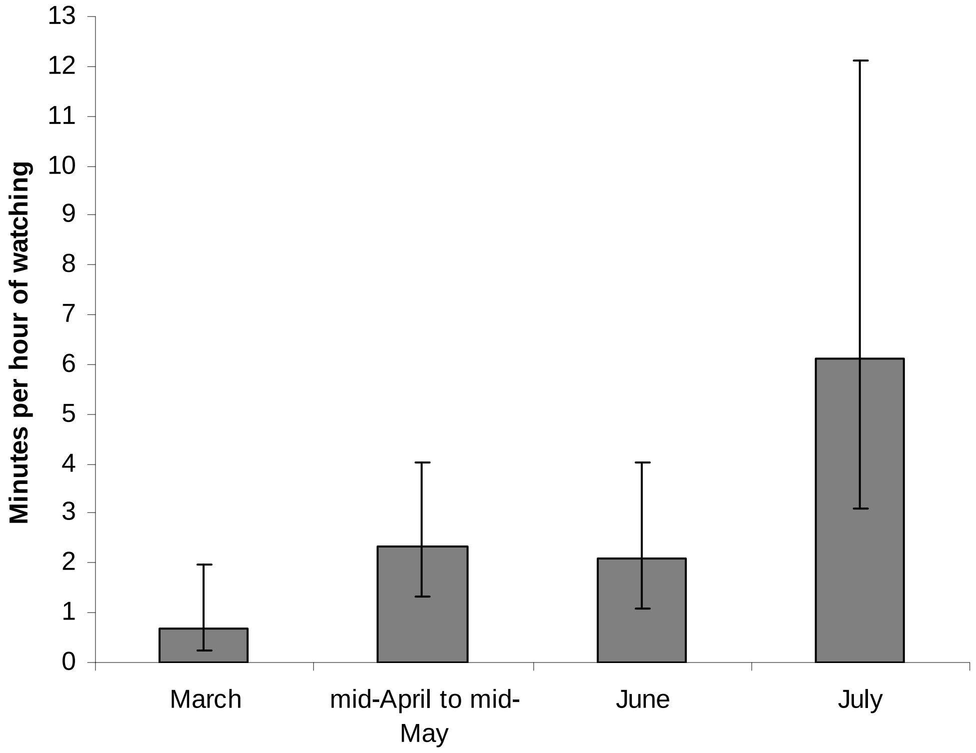


Figure 7 *The duration of time for which short-eared owls were visible and seen to show behaviour indicative of territoriality during two-hour periods within daylight hours during (a) mid-April to mid-May, (b) June, and (c) July in 2006 and 2007. Means and 95% confidence limits (back-transformed from estimates from the generalised linear model in Table 5) are shown.*

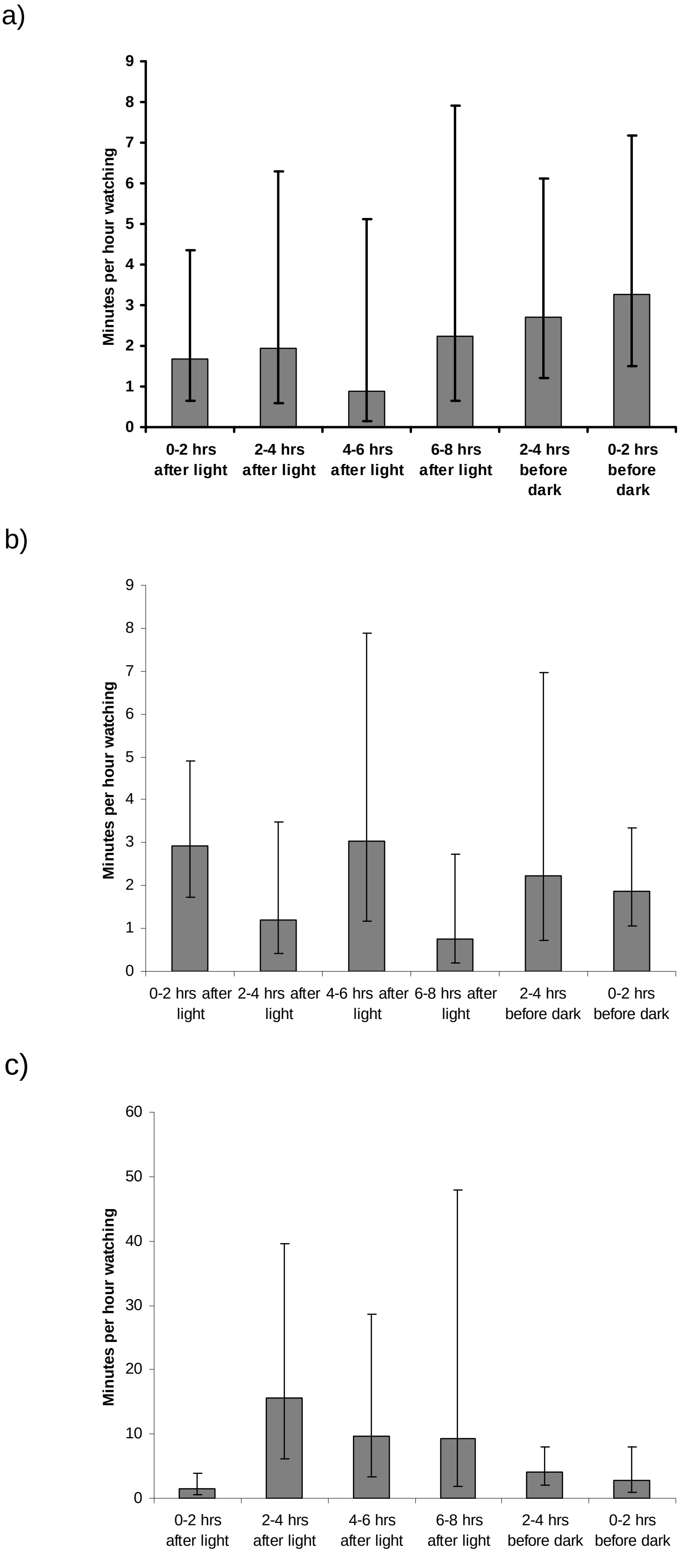
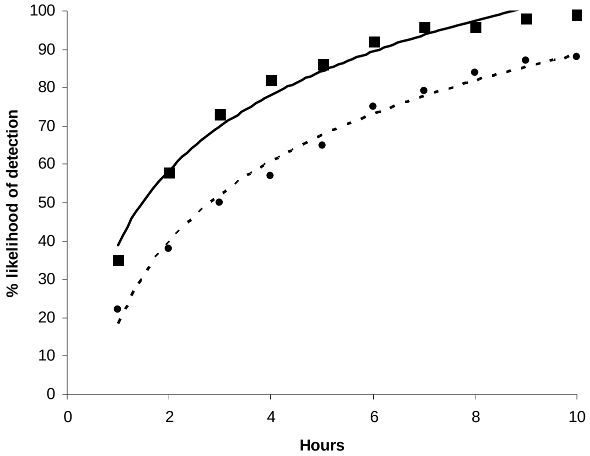
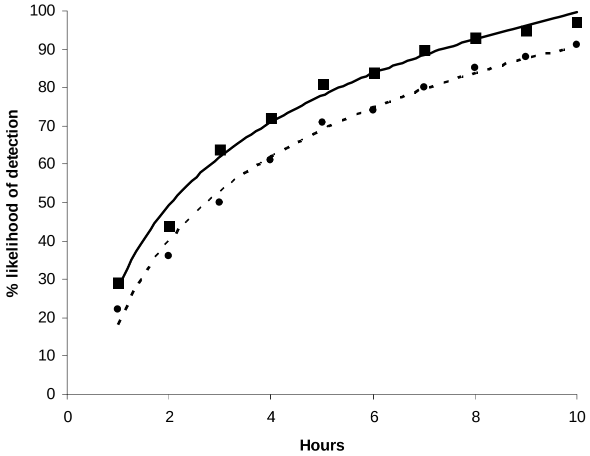


Figure 8 *The estimated detection rates of breeding short-eared owls with different duration of watches in (a) mid-April to mid-May, within the last four hours before dark; (b) June, between 4 and 8 hours after first light, and (c) July, within 4 hours after first light. Squares and solid lines represent the detection rates derived from all observations of Short-eared owls. Circles and dotted lines represent the detection rates of observations that include behaviours indicative of territoriality. Detection rates are estimated by random sampling 1000 times from all data within the different time and date scenarios.*

a)



b)



c)

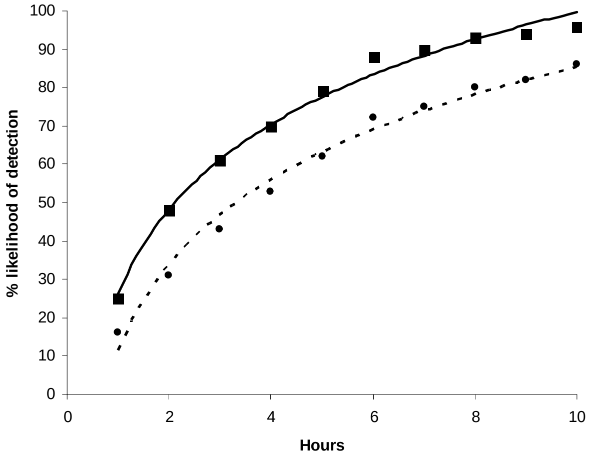


Figure 9 *The locations of timed point counts undertaken by volunteers in 2007 (grey squares). The black stars refer to the points where short-eared owls were recorded during the timed surveys.*

Figure 10 *The distribution of breeding short-eared owls in Britain and Ireland, 1988-91 (after Gibbons et al., 1993). Square 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.*

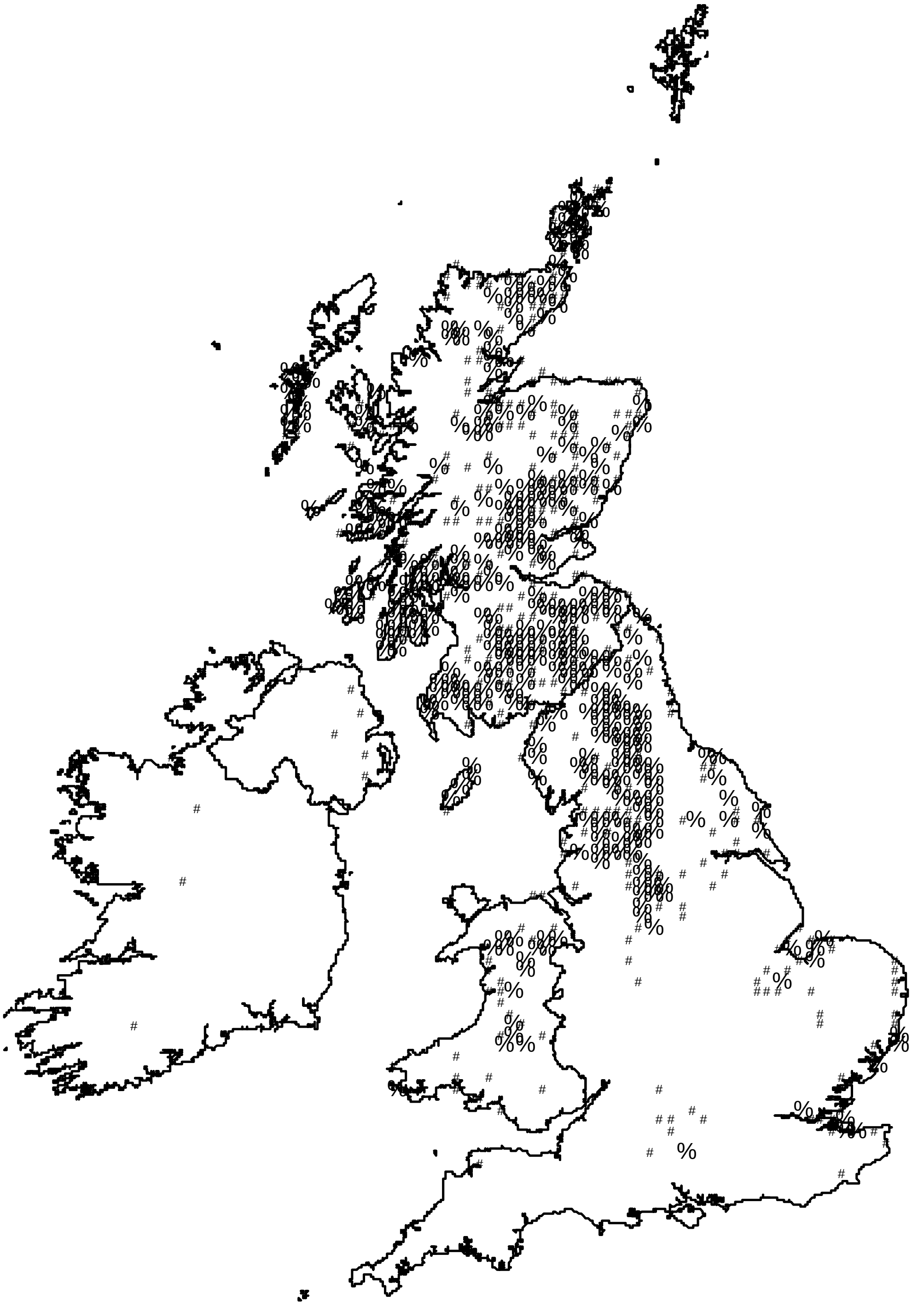
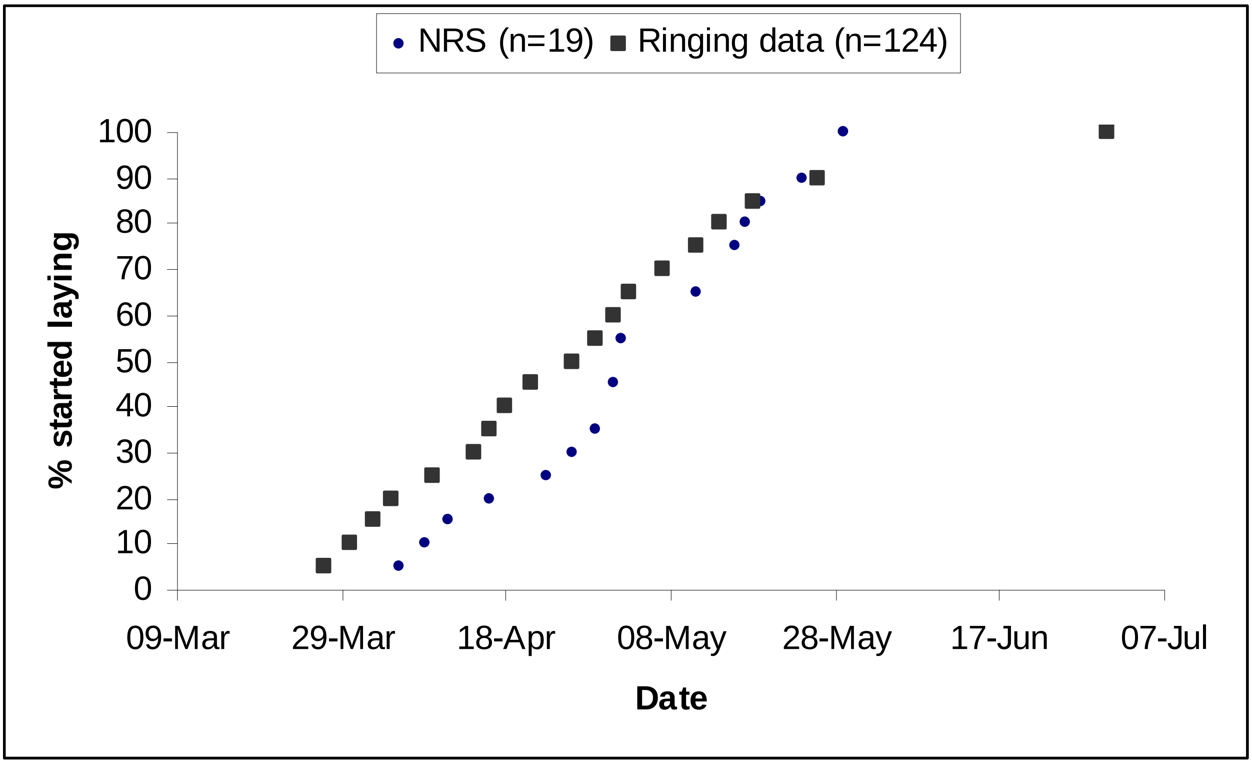


Figure 11 *The dates of laying first eggs by short-eared owls from Nest Record Scheme data (NRS, n=19) and back calculated from ringing dates of nestlings assuming ringing at the mid-point of the nestling period (n=124) (after Moss et al., 2005).*



Appendix 1 *Volunteer survey forms and recording forms*

SHORT-EARED OWL AND UPLAND BIRD POINT COUNTS

BACKGROUND

In 2007 we are looking for volunteers to trial a series of point counts to test a method for monitoring breeding birds in the uplands and specifically to trial a method for extensive background monitoring for Short-eared owls. The method involves a series of timed (five minute) point counts along roads or tracks that cross moorland or other hill ground and form part of a wider project that is developing methods for the survey and monitoring of breeding Short-eared owls. However, this also provides an opportunity to investigate alternative methods for supplementing surveys such as the Breeding Bird Survey in monitoring upland birds.

We are looking for volunteers who can undertake two counts per route during early mornings or in the evenings between mid April and the end of June. Each series of point counts could take up to 3 hours of fieldwork, or if you wish, less.

SURVEY ROUTES

Volunteers can select their own survey routes but if you wish check if anyone else is covering your choice, please contact Anne Cotton (01786 466560 or anne.cotton@bto.org). Some duplicate counts from different observers could be useful, however. Choose a road or track along which you can drive that crosses moorland or other hill ground. Along the route find a number of points where you can safely park and stand to count birds. Each count point must be at least 1 km distant from its neighbours. The number of count points will depend on the length of the survey route but up to 20 can be completed usually within two to three hours. It is worth finalising your route and count points in advance of undertaking any bird survey.

SURVEY TIMING

For each survey route please carry out two surveys, one between 20th April and 28 May and the second anytime in June. Each survey should be undertaken during either the three hours after first light in the morning or in the evenings within three hours before getting dark. Do NOT survey in wind speeds greater Beaufort Scale 4, in persistent or heavy rain or mist, or other conditions that you consider would adversely affect your ability to see or hear birds.

SURVEY METHOD

Drive along your survey route from point to point. At each point, get out of your vehicle and record all the birds you see or hear in ‘open habitats’ within a timed period of five minutes. *Please ignore birds in any woodland*.

Use two-letter species codes (Appendix 3) and standard activity codes (Appendix 1) on the recording forms (Appendix 2).

All registrations (i.e. a bird seen and/or heard) should be allocated to one of five distance bands, that is the distance band from the count point to where the bird was *first* detected (ignore any subsequent movements by individual birds) in any direction.

Distance bands to be used are 0 – 25 m, 25 – 100 m, 100 – 500 m, 500 m – 1 km, 1km +. It is unlikely that many registrations will be detected in the final 1 km + band.

Record individuals only once and try to avoid recording the same individuals from more than one count point even though you may be able to see or hear them. There will certainly be instances when it is difficult to say with certainty that a bird is the same individual, if this is the case, err on the side of caution and record from both count points.

WHAT TO RECORD

1. Survey route and count points

Please give 6-figure grid references (plus the two letter codes) for each count point on the appropriate form (*design one*) and include a place name to which the area could be identified. In addition, if at all possible, please submit a copy of a map on which your survey route and count points are marked. Please also include the start time for each count at each point.

2. Birds

Please use the recording forms for the recording the birds and their activities within the appropriate distance bands (see above). Make copies or ask us for additional ones.

The project is a formal partnership between BTO, SNH, CCW, JNCC, Scottish Raptor Study Groups and RSPB
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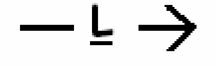
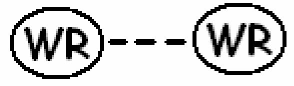
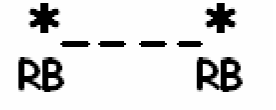
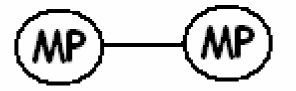
APPENDIX 1 BTO ACTIVITY CODES

BTO Standard Activity Recording Codes

The standard BTO list of conventions is designed to help you make your field notes clear and unambiguous, and the following are examples of their use. Symbols can be combined where necessary (se *Bird Census Techniques*). Additional activities of territorial significance, such as display or mating, should be noted using an appropriate clear abbreviation. In all cases the standard BTO species recording codes should be used.

RB♂, RB♀ 3RBjuvs	Reed Bunting sight records, with age, sex or number of birds if appropriate.
	A pair of Reed Buntings
PW fam	Juvenile Pied Wagtail with parent(s) in attendance
RG	A calling Red Grouse
RG	A Red Grouse repeatedly giving alarm calls or other vocalisations (not song) thought to have strong territorial significance
ä	A Skylark in song
	An aggressive encounter between two Short-eared owls
✱ MP	An occupied nest of Meadow Pipits; do not mark unoccupied nests, which are of no territorial significance by themselves
	Kestrels nesting in a specially provided site (e.g. nestbox)
✱ PW on	Pied Wagtail nest with an adult sitting
PW mat	Pied Wagtail carrying nest material
PW food	Pied Wagtail carrying food

Movements of birds can be indicated using the following conventions:

	A calling Lapwing flying over (seen only in flight)
	A singing Curlew perched then flying away (not seen to land)
	A male Black Grouse flying in and landing (first seen in flight)
	A Wren moving between two perches. The solid line indicates that is was definitely the same bird.
	Two Wrens in song at the same time, i.e. definitely different birds. The dotted line indicates a simultaneous registration and is of very great value in separating territories
	Two Reed Bunting nests occupied simultaneously and thus belonging to two different pairs. This is another example of the value of dotted lines. Only adjacent nests need be marked in this way.
	The solid line indicates that registrations definitely refer to the same bird.
	A question-marked solid line indicates that the registrations probably relate to the same bird. This convention is of particular use when the census route returns to an area already covered – it is possible to mark new positions of (probably the same) birds recorded before, without the risk of double-recording. If birds are recorded without using the question-marked solid line, overestimation of territories will result
	When there is no line joining the registrations, this indicates that the birds are probably different. (It is possible to use a question-marked dotted line, indicating that the registrations were almost certainly of different birds.)
✱S ✱S	Where adjacent nests are marked without a line, it will often be assumed that they were first and second broods, or a replacement nest following an earlier failure.

APPENDIX 2 POINT COUNT RECORDING FORM

SHORT-EARED OWL PILOT STUDY 2006
TRANSECT/ POINT COUNT RECORDING FORM

STUDY AREA: _______________ ___ DATE: _________ OBSERVER: _______________

TRANSECT: _________________ TIME (start-end): ___________ - ________________

Weather conditions (Wind speed, cloud cover, visibility, precipitation etc.):

Points **(Grid Refs)**	***Start time***	***0-25m***	***25-100m***	***100-500m***	***500m-1km***	***1km+***

APPENDIX 3 – TWO-LETTER SPECIES CODES

AC Arctic Skua
AE Arctic Tern
AV Avocet
BO Barn Owl
BY Barnacle Goose
BA Bar-tailed Godwit
BR Bearded Tit
BS Bewick's Swan
BI Bittern
BK Black Grouse
TY Black Guillemot
BX Black Redstart
BJ Black Tern
B. Blackbird
BC Blackcap
BH Black-headed Gull
BN Black-necked Grebe
BW Black-tailed Godwit
BV Black-throated Diver
BT Blue Tit
BU Bluethroat
BL Brambling
BG Brent Goose
BF Bullfinch
BZ Buzzard
CG Canada Goose
CP Capercaillie
C. Carrion Crow
CW Cetti's Warbler
CH Chaffinch
CC Chiffchaff
CF Chough
CL Cirl Bunting
CT Coal Tit
CD Collared Dove
CM Common Gull
CS Common Sandpiper
CX Common Scoter
CN Common Tern
CO Coot
CA Cormorant
CB Corn Bunting
CE Corncrake
CI Crested Tit
CR Crossbill
CK Cuckoo
CU Curlew
DW Dartford Warbler
DI Dipper
DO Dotterel
DN Dunlin
D. Dunnock
EG Egyptian Goose
E. Eider
FP Feral Pigeon
ZL Feral/hybrid goose
ZF Feral/hybrid mallard type
FF Fieldfare
FC Firecrest
F. Fulmar
GA Gadwall
GX Gannet
GW Garden Warbler
GY Garganey
GC Goldcrest
EA Golden Eagle
OL Golden Oriole
GF Golden Pheasant
GP Golden Plover
GN Goldeneye
GO Goldfinch
GD Goosander
GI Goshawk
GH Grasshopper Warbler
GB Great Black-backed Gull
GG Great Crested Grebe
ND Great Northern Diver
NX Great Skua
GS Great Spotted Woodpecker
GT Great Tit
GE Green Sandpiper
G. Green Woodpecker
GR Greenfinch
GK Greenshank
H. Grey Heron
P. Grey Partridge
GV Grey Plover
GL Grey Wagtail
GJ Greylag Goose
GU Guillemot
FW Guineafowl (Helmeted)
HF Hawfinch
HH Hen Harrier
HG Herring Gull
HY Hobby
HZ Honey Buzzard
HC Hooded Crow
HP Hoopoe
HM House Martin
HS House Sparrow
JD Jackdaw
J. Jay
K. Kestrel
KF Kingfisher
KI Kittiwake
KN Knot
LM Lady Amherst's Pheasant
LA Lapland Bunting
L. Lapwing
TL Leach's Petrel
LB Lesser Black-backed Gull
LS Lesser Spotted Woodpecker
LW Lesser Whitethroat
LI Linnet
ET Little Egret
LG Little Grebe
LU Little Gull
LO Little Owl
LP Little Ringed Plover
AF Little Tern
LE Long-eared Owl
LT Long-tailed Tit
MG Magpie
MA Mallard
MN Mandarin
MX Manx Shearwater
MR Marsh Harrier
MT Marsh Tit
MW Marsh Warbler
MP Meadow Pipit
MU Mediterranean Gull
ML Merlin
M. Mistle Thrush
MO Montagu's Harrier
MH Moorhen
MS Mute Swan
N. Nightingale
NJ Nightjar
NH Nuthatch
OP Osprey
OC Oystercatcher
PX Peafowl/Peacock
PE Peregrine
PH Pheasant
PF Pied Flycatcher
PW Pied Wagtail
PG Pink-footed Goose
PT Pintail
PO Pochard
PM Ptarmigan
PU Puffin
PS Purple Sandpiper
Q. Quail
RN Raven
RA Razorbill
RG Red Grouse
KT Red Kite
ED Red-backed Shrike
RM Red-breasted Merganser
RQ Red-crested Pochard
FV Red-footed Falcon
RL Red-legged Partridge
NK Red-necked Phalarope
LR Lesser Redpoll
RK Redshank
RT Redstart
RH Red-throated Diver
RE Redwing
RB Reed Bunting
RW Reed Warbler
RZ Ring Ouzel
RP Ringed Plover
RI Ring-necked Parakeet
R. Robin
DV Rock Dove
RC Rock Pipit
RO Rook
RS Roseate Tern
RY Ruddy Duck
RU Ruff
SM Sand Martin
SS Sanderling
TE Sandwich Tern
VI Savi's Warbler
SQ Common Rosefinch
SP Scaup
CY Scottish Crossbill
SW Sedge Warbler
NS Serin
SA Shag
SU Shelduck
SX Shorelark
SE Short-eared owl
SV Shoveler
SK Siskin
S. Skylark
SZ Slavonian Grebe
SN Snipe
SB Snow Bunting
ST Song Thrush
SH Sparrowhawk
AK Spotted Crake
SF Spotted Flycatcher
DR Spotted Redshank
SG Starling
SD Stock Dove
SC Stonechat
TN Stone-curlew
TM Storm Petrel
SL Swallow
SI Swift
TO Tawny Owl
T. Teal
TK Temminck's Stint
TP Tree Pipit
TS Tree Sparrow
TC Treecreeper
TU Tufted Duck
TT Turnstone
TD Turtle Dove
TW Twite
WA Water Rail
W. Wheatear
WM Whimbrel
WC Whinchat
WG White-fronted Goose
WH Whitethroat
WS Whooper Swan
WN Wigeon
WT Willow Tit
WW Willow Warbler
OD Wood Sandpiper
WO Wood Warbler
WK Woodcock
WL Woodlark
WP Woodpigeon
WR Wren
WY Wryneck
YW Yellow Wagtail
Y. Yellowhammer