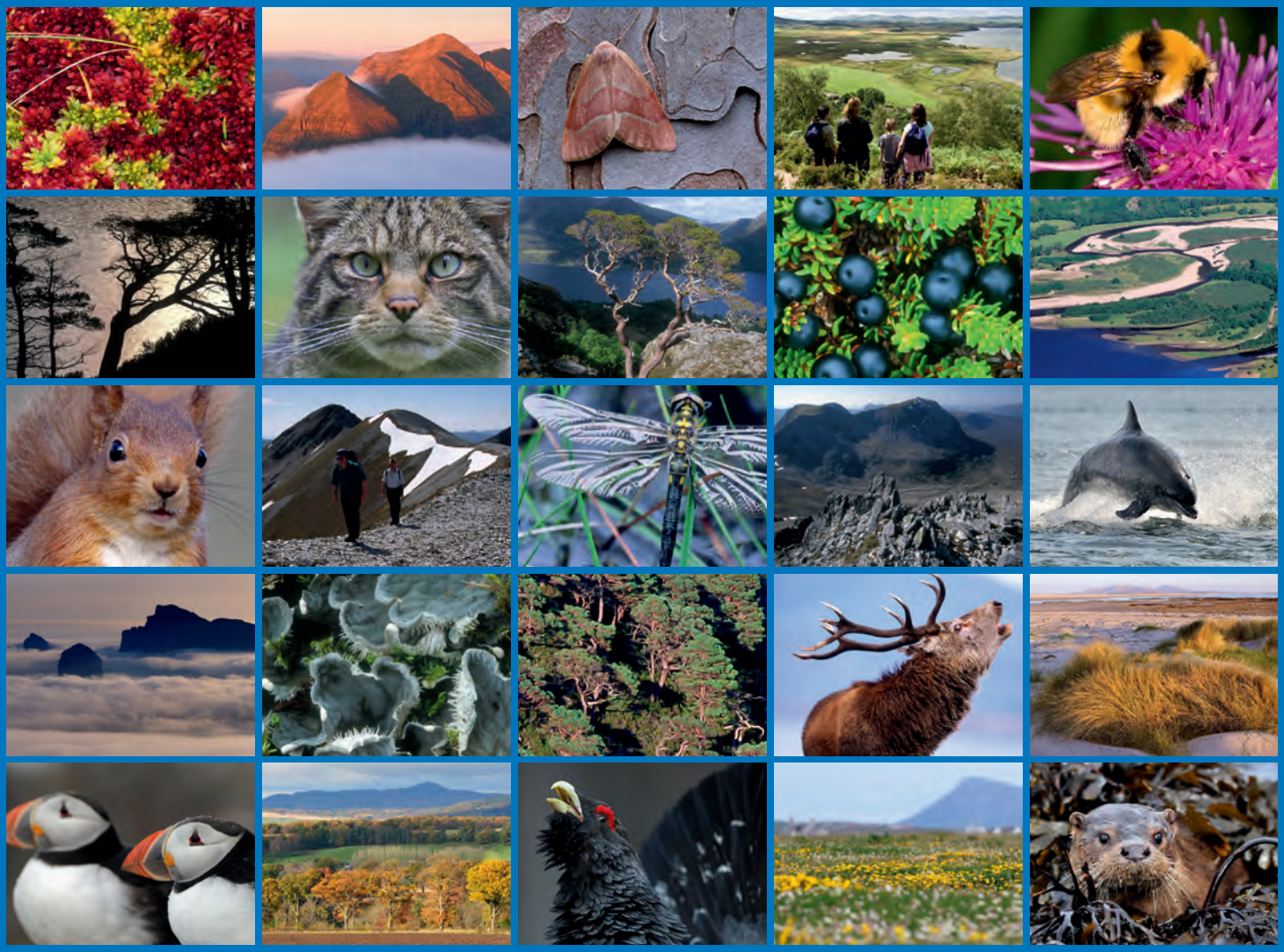
Scottish Natural Heritage
Commissioned Report No. 542

Raptors in Scotland – a methodology for developing trends and indicators



Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad

COMMISSIONED REPORT

Commissioned Report No. 542

Raptors in Scotland – a methodology for developing trends and indicators

For further information on this report please contact:

Simon Foster
Scottish Natural Heritage
Great Glen House
INVERNESS
IV3 8NW
Telephone: 01463 725282
E-mail: simon.foster@snh.gov.uk

This report should be quoted as:

Roos, S., Dobson, A., Noble, D., Haworth, P., Fielding, A., Carrington-Cotton, A., Etheridge, B. & Wernham, C. 2015. Raptors in Scotland – a methodology for developing trends and indicators. *Scottish Natural Heritage Commissioned Report* No. 542.

COMMISSIONED REPORT

Summary

Raptors in Scotland – a methodology for developing trends and indicators

Commissioned Report No. 542
Contractor: BTO Scotland
Year of publication: 2015

Keywords

Raptors; breeding; Natural Heritage Zone; trends; monitoring.

Background

Published statistics on trends in raptor populations in Scotland currently use data from three national bird atlases, State of the UK Birds assessments, national BTO/JNCC/RSPB Breeding Bird Surveys (BBS) and species surveys undertaken through SCARABBS (Statutory Conservation Agencies and RSPB Breeding Bird Survey). This report considers the prospects for producing more detailed Scotland-wide and regional trends for breeding raptors. The report focuses on assessments of the suitability of data and methods for producing trends at a range of spatial scales, from area based - e.g. Natural Heritage Zones - to the whole of Scotland, and for breeding numbers and appropriate breeding parameters - e.g. proportion of pairs fledging young or the number of young fledged.

The report meets three objectives: (i) produce and report trends in breeding numbers and productivity for the raptor species in Scotland at a range of spatial scales; (ii) evaluate the suitability of the existing schemes that are in place which may contribute to the monitoring of raptors (particularly EC Birds Directive Annex 1 species); and (iii) scope methods for producing a robust indicator or indicators of Scottish raptor populations, with the most appropriate indicator(s) dependent on end-user requirements.

The report draws largely on data collected under the auspices of the Scottish Raptor Monitoring Scheme (SRMS). This was established in 2002 to improve partnership working between organisations involved in raptor monitoring in Scotland. It has eight partners, is chaired by SNH, and currently focuses on the annual monitoring of the abundance, distribution and breeding success of diurnal birds of prey and owls native to Scotland. The data are primarily from the SRMS for the period 2003-2009, supplemented by other sources where appropriate.

Main findings

- Estimates of trends in numbers and/or breeding productivity, at least at the scale of individual study areas, can be calculated for 13 species of breeding raptors in Scotland.
- The most appropriate parameter for measuring breeding success for raptors, from the available data, is the number of fledglings produced per successful pair.

- Data were sufficient to produce national, Natural Heritage Zone and area trends in breeding numbers and breeding productivity for two species – red kite and white-tailed eagle. Both show steady increases in breeding numbers since they were re-introduced.
- For seven species with substantial annual monitoring coverage across Scotland (hen harrier, northern goshawk, common buzzard, golden eagle, merlin, peregrine falcon and barn owl), provisional area based trends in breeding numbers were produced. For these species, there is high potential to produce rigorous area-based trends in breeding success, and potentially also full national (Scottish) trends, in both breeding numbers and breeding success.
- For four other species (Eurasian sparrowhawk, common kestrel, tawny owl and common raven), partial trend information is available from study areas or from the BBS. However, this is not considered sufficient to report rigorous national trends, without further validation work or additional data collection.
- A further four species (European honey buzzard, black kite, Eurasian marsh harrier and Eurasian hobby) are too rare as breeding birds in Scotland to enable their trends to be calculated.
- Finally, for long-eared owls and short-eared owls, there is currently insufficient annual monitoring coverage to generate trends.
- Recommended enhancements to information collection under the SRMS include: submission of six-figure grid references for all breeding ranges; routine collection of information on survey coverage/effort, visit dates, and nest contents at each visit; and improved (on-line) software for standardized data entry.
- Given the data available, we cannot produce a national indicator for breeding raptors in Scotland. Once representative national trends are available for a broader suite of Scottish raptors, however, a national indicator of breeding raptor numbers is feasible, and should be considered further.

For further information on this project contact:
Simon Foster, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725282 or simon.foster@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research @snh.gov.uk

Table of Contents **Page**

Acknowledgements

We thank all of the members of the Scottish Raptor Monitoring Scheme for providing information on raptors throughout Scotland. We are grateful to Will George (RSPB Data Unit) for red kite and white-tailed eagle data for this project. Innes Sim and Yvonne Boles (RSPB) provided further information on the monitoring protocols for these species. We thank Arjun Amar (RSPB and currently Percy FitzPatrick Institute of African Ornithology) and Dave Leech, Simon Gillings and Ali Johnston (BTO) for fruitful discussions regarding raptor monitoring and analytical approaches.

We thank SRSG members Malcolm Henderson, Mick Marquiss, Ciril Ostroznik, Gordon Riddle, Chris Rollie and Ian Todd for additional information. We thank all those raptor workers who have contributed data to the Scottish Raptor Monitoring Scheme since 2003.

We are grateful to Des Thompson, Andrew Stevenson and Simon Foster (SNH) for funding the project and for comments on previous drafts of the report. Finally, we thank RSPB for allowing Staffan Roos to finalise the project report, and all members of the SRMG for their support in planning and delivering this research.

1. DETERMINING TRENDS IN BREEDING NUMBERS AND PRODUCTIVITY OF RAPTORS IN SCOTLAND

The aim of this report was to determine if it was possible to produce trends in numbers and appropriate breeding parameters for raptors in Scotland, using Scottish Raptor Monitoring Scheme (SRMS) data. For each species, we report the potential for production of trends, together with a summary of our current state of knowledge, any caveats attached to trends and any knowledge gaps and recommendations to enhance future production of trend information.

It should be noted that this is largely a methodological report and further work is required to identify the causes of the changes in trends for most of the species.

1.1 General methods

1.1.1 Data sources and data preparation

Data were mainly from the SRMS, covering the period 2003-2009. Additional data were provided by RSPB and BTO.

For red kite and white-tailed eagle, comprehensive information from the long-term RSPB database (including data prior to 2003) was used.

Four species (common buzzard, common kestrel, Eurasian sparrowhawk and common raven) are also monitored by the BTO/JNCC/RSPB Breeding Bird Survey (BBS). The BBS is designed to provide trend information on between-year variation in abundance during the breeding season at the national scale. It is a multi-species survey, in which volunteer observers visit 1-km squares twice during the breeding season (once mid-April to mid-May and once mid-May to mid-June) and record all sightings of birds in distance bands away from (preferably) two parallel transect lines. Observers distinguish adult and immature/juvenile birds where possible, and include only adults in their records. Survey squares are randomly selected within defined BTO regions, with sampling stratified according to the numbers of observers in each region (the sampling strategy is accounted for in analyses to produce national indices of change in abundance). In Scotland, around 300 squares are covered annually (Risely *et al*. 2011). Information from this survey is included in the relevant species sections of this report.

1.1.2 Selection of priority species for trend production

Selection of priority species was based on the summaries and guidance produced in a review of SRMS data to 2008 (see Table 1 for selected priorities and justification).

1.1.3 Principles for evaluating trend information

In contrast to a purpose-designed survey like BBS, SRMS data collection is not currently underpinned by a formal sampling strategy designed with the explicit aim of producing unbiased trends. Many of the studies on which current SRMS data collection is based were originally started to support the periodic national raptor surveys. These subsequently evolved, often following the interests of the individual observers, many of whom were volunteers.

We determined whether the monitoring of each species was sufficiently representative, in terms of the number and distribution of known breeding ranges surveyed of all in the spatial area under consideration (national, Natural Heritage Zone, or discrete study area). Particular attention was given to assessing whether the number of monitored breeding ranges changed over time within these spatial areas, and whether nest visits were carried

out at the appropriate time to record clutch size, brood size and number of fledglings with a high degree of certainty, to ensure that any trends produced were unbiased.

1.2 Trends in numbers of breeding pairs: general principles

Raptors are typically recorded in units of breeding pairs, which comprise territorially active birds in suitable nesting areas. Not all of these pairs initiate a clutch, and in some instances it is impossible to say whether a pair never initiated a clutch or if they failed at an early stage in the breeding season. Similarly, not all territorial pairs that initiate a clutch breed successfully in any given year. Many raptors use the same nest each year, but they can also move between sites. If the latter occurs, it is important to be able to differentiate this redistribution from actual loss from the population in the study area (e.g. through mortality or disturbance). Changes in numbers of breeding pairs can only be monitored with confidence, and be used to reflect actual changes in a study area, if the areas that are surveyed each year are known with certainty. Spatial coverage and survey effort (e.g. number of hours spent per unit area surveyed) should ideally be consistent from year to year. If not, any changes need to be taken into account in producing trends. Similarly, the potential for systematic redistribution of pairs within spatial units should be assessed carefully, as this could bias trends in numbers (e.g. if human disturbance were to cause pairs to move to alternative nesting sites at higher altitude, but annual survey effort was always focussed on the lower ground in a study area).

For all but the scarcer raptor species, it would be impossible to survey all the pairs within a large area (such as a whole region or the whole of Scotland) each breeding season. However, if a large enough sample of pairs is surveyed across a number of study areas, it is possible to demonstrate changes over larger areas (e.g. regional or national), as long as the pairs/areas that receive surveys are broadly representative of those within the region or country. To assess this effectively, up-to-date information on the distribution and abundance of the species within the larger spatial units under consideration is required (e.g. from a national survey of the species in question or from an appropriate multi-species survey like the BTO/BirdWatch Ireland/SOC *Bird Atlas* projects).

1.3 Trends in breeding productivity: general principles

Raptors monitored for breeding productivity tend to include at least some of the same pairs from one year to the next through time, and individual pairs/nesting ranges *may* be more or less likely to be successful, due to variation in individual and territory quality. It is important therefore that the breeding outcomes at individual nesting ranges can be tracked from one year to the next. When producing trends in breeding productivity, this is commonly achieved by specifying the name of the breeding range as a "random factor" in the statistical models, and this procedure was also used in this project. Even when the evidence for including individual ‘site’ effects in models of breeding productivity is weak, it is important that the turnover of nesting ranges surveyed through time is tracked. This enables checks of whether changes to the sample of nesting ranges could introduce systematic bias into trends (e.g. if less successful nesting ranges or areas that are difficult to access because of human disturbance issues drop out of the sample through time).

As with the monitoring of changes in breeding numbers, rigorous monitoring of breeding productivity needs to include either all pairs in a geographical area, or a sample that is sufficiently large and representative.

1.3.1 Selection of spatial scales

Where possible, the project aimed to report trends in breeding numbers and breeding productivity at the scale of Scottish regions (the established biogeographical regional classification of Natural Heritage Zones; see Figure 1) and at the national scale if data

allowed. Where survey coverage was not representative of whole NHZs, trends for smaller study areas with consistent coverage were reported, noting the NHZ(s) in which they lie.

To select appropriate spatial scales for analysis, for each species we compared the annual distribution of survey effort with best current knowledge of the overall distribution of the species across Scotland and in each NHZ. The latter was obtained from the most recent national survey if such a comprehensive survey has been carried out (e.g. golden eagle and peregrine falcon). For other species, distribution information from the last published UK Bird Atlas survey (1988-91; Gibbons *et al*. 1993) was used.

For red kite, for which there have been four spatially separated geographical areas of re-introduction, trends are presented for the largely discrete sub-populations and for relevant NHZs.

We produced national trends in numbers and breeding productivity for those species that have received annual monitoring of a high proportion of the Scottish population to date (red kite and white-tailed eagle). In future it should also be possible to produce national trend information for other species that receive wide coverage under the SRMS and for which current knowledge of overall distribution and spatial variation in abundance across Scotland is considered good (e.g. peregrine falcon, golden eagle, hen harrier and merlin; noted in the individual species accounts).

Some records contained in the database lacked full grid references. We were able to fill some of these for hen harrier, golden eagle and merlin by matching SRMS records with databases prepared for the hen harrier and golden eagle Conservation Framework projects (Whitfield *et al*. 2008, Fielding *et al*. 2011), and a recent SNH-funded project on merlins in Scotland (Fielding & Haworth 2011).

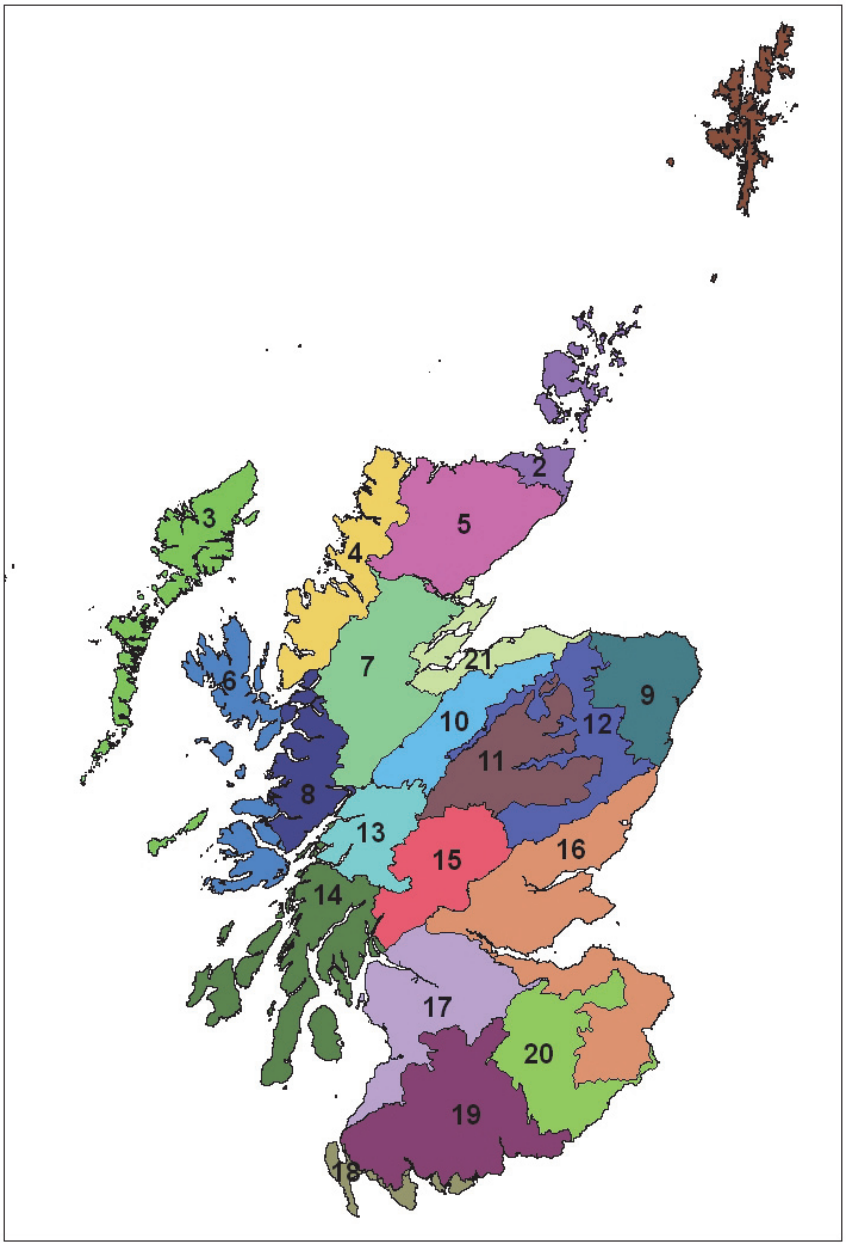


Figure 1. The Natural Heritage Zones (NHZs) of Scotland.

1= Shetland, 2 = North Caithness and Orkney, 3= Coll, Tiree and the Western Isles, 4 = North West Seaboard, 5 = The Peatlands of Caithness and Sutherland, 6 = Western Seaboard, 7 = Northern Highlands, 8 = Western Highlands, 9 = North East Coastal Plain, 10 = Central Highlands, 11 = Cairngorm Massif, 12 = North East Glens, 13 = East Lochaber, 14 = Argyll West and Islands, 15= Loch Lomond, the Trossachs and Breadalbane, 16 = Eastern Lowlands, 17 = West Central Belt, 18 = Wigtown machairs and Outer Solway Coast, 19 = Western Southern Uplands and Inner Solway, 20 = Border Hills and 21 = Moray Firth.

1.3.2 Selection of trends to model for each species

Species were selected for trends modelling based on a sample of at least 10 nesting ranges/nest sites in the selected geographical unit for which coverage and effort could be assumed to be approximately constant during the span of years considered.

For each species, the selection of breeding parameters for which to produce trends involved consideration of the field methods used to collect the data and any potential biases caused by either selection of study areas, selection of samples of nests to monitor through to fledging, or selective submission of data to the SRMS. We modelled trends in laying, hatching and fledging success, number of eggs laid (by pairs that are known to have laid eggs), brood size at hatching (for pairs known to hatch young) and number of fledged young (for pairs that fledged at least one young) for spatial areas with a sample of at least 10 nests for the parameter of interest, if we were confident that the sample was sufficiently representative of the spatial unit.

For species for which it can be difficult to record the exact number of fledged young once they have left the nest, we routinely included minimum estimates in the trends (e.g. in cases where the number fledged was recorded as 1+, 2+, 3+ and so on, the minimum number fledged was used in analyses).

1.3.3 Trends modelling

Trends in the numbers of breeding pairs from SRMS and RSPB data were based on raw counts and therefore did not require formal statistical modelling and do not have associated confidence limits. For the best available trends presented here, we have used raw counts so that annual breeding numbers from the various study areas and samples sizes available are clear.

National trends in relative abundance from BBS data use the standard BBS analytical methods (see Risely *et al*. 2011; Baillie *et al*. 2012).

All statistical analyses of trends from SRMS and RSPB data were carried out using Generalised Linear Mixed Models in PROC GLIMMIX in SAS 9.2 (SAS Institute Inc. 2008). Trends in the numbers of eggs laid (by pairs that are known to have laid eggs), young hatched (by pairs known to hatch young) and young fledged (by pairs that fledged at least one young) were modelled using a Poisson error distribution with a logit link. Note that these parameters all *exclude* pairs that did not lay, hatch or fledge young respectively, for the reasons given in Section 1.1.5. In the few cases where we considered it useful to estimate trends in whether or not pairs laid, hatched or fledged young, these were modelled using a binomial error term with a log link. In all analyses of breeding parameters, the unique nest site name (or nest site code for some species) was included in models as a random factor. For trends in individual breeding parameters, we used a general rule of thumb and attempted to model trends for any discrete region/study area with a minimum of 10 records per year for the parameter of interest. A few such sequences were interrupted by one or two years with lower sample sizes, but unless the model failed to converge we included these.

1.3.4 Reporting and interpretation of trend information and caveats

Wherever possible, we presented national, regional (NHZ) and/or study area specific trends for each species. For those species for which the majority of the Scottish breeding population is monitored each year (red kite and white-tailed eagle), these trends can be regarded as definitive. For most other species however, the trends should be regarded as the best currently available. Particularly with respect to trends in breeding numbers, there is an outstanding need to verify the extent to which coverage and effort in study areas has been consistent from one year to the next (See Section 1.3.3 and Table 3).

In each species account we give our best current assessment of the extent to which trends are representative of specific NHZs or the national population of each species. For some species for which substantial portions of the SRMS records are not linked to grid references, we could not complete this assessment. Assessment was not possible for species that lacked up-to-date information on distribution across Scotland for which we expect that distribution and spatial variation in relative abundance may have altered substantially since the last Bird Atlas project in 1988-91 (Gibbons *et al*. 1993). For these species, further assessment will be possible once the results of Bird Atlas 2007-11 are available.

All trends are reported as annual estimates with 95% confidence limits unless otherwise stated.

1.4 Species accounts

In this section we provide the best available trends in breeding numbers and breeding parameters for the 13 raptor species covered in this project (see Table 1 for rationale for selection of species). We provide a summary of the information on which trends are based, any caveats to trends or work pending, and we highlight any significant gaps in knowledge.

Note that because of potential variation in field and reporting methodologies by individual raptor workers, it is valid to derive trend information for individual studies or NHZs, but absolute values of breeding parameters should not be compared directly between study areas or NHZs.

Table 1. Summary of the state of monitoring of raptor species covered by the Scottish Raptor Monitoring Scheme.

Actions required to develop future monitoring and feasibility of producing trends in numbers and breeding parameters (from review of SRMS data 2003-2008): we have added column 4 in which we prioritise species for treatment in the current project and summarise our rationale for these priorities.

Raptor species	Summary of current state of monitoring and potential for trend production (from review of 2003-2008 SRMS data)	Priority actions for development (from review of 2003-2008 SRMS data)	PRIORITY FOR THE CURRENT PROJECT (and rationale)
European honey buzzard	Too few pairs breed for formal trend analysis.	N/A	EXCLUDED (too few pairs for trend production)
Red kite	Comprehensive monitoring of numbers and breeding parameters and trends in both feasible at NHZ and national scales.	Ensure all data are accessible to RSPB and SRMS. Check coverage/effort is constant and recorded.	HIGH (RSPB to produce trend information from their comprehensive database on this species)
Black Kite	Too few pairs breed for formal trend analysis.	N/A	EXCLUDED (too few pairs for trend production)
White-tailed eagle	Comprehensive monitoring of numbers and breeding parameters and trends in both feasible at NHZ and national scales.	Ensure all data are accessible to RSPB and SRMS. Check coverage/effort is constant and recorded.	HIGH (RSPB to produce trend information from their comprehensive database on this species)
Eurasian marsh harrier	Too few pairs breed for formal trend analysis.	N/A	EXCLUDED (too few pairs for trend production)
Hen harrier	Widespread monitoring across Scotland of both numbers and productivity (in discrete study areas). Trend production limited pending further work on coverage and distribution. Trends likely to be possible for at least some NHZs and national trends may be possible.	Obtain remaining 23% of grid-references. Obtain information on study area boundaries and coverage. Match with information from Conservation Framework (Fielding *et al*. 2011) to assess representativeness of coverage by NHZs and nationally.	HIGH (because this species is of high current conservation priority and information is available from the hen harrier Conservation Framework to support SRMS data in producing and assessing trends; Haworth Conservation to assist trend production for this species)

Raptor species	Summary of current state of monitoring and potential for trend production (from review of 2003-2008 SRMS data)	Priority actions for development (from review of 2003-2008 SRMS data)	PRIORITY FOR THE CURRENT PROJECT (and rationale)
Northern goshawk	Studies in 3 study areas only. Trend production limited by lack of grid-referencing, lack of coverage information and some information only in summary form.	Obtain data in full (not summary data). Obtain remaining 54% of grid-references. Obtain information on study area boundaries and coverage.	HIGH (because there is only a small number of discrete study areas with high quality information and observers that are keen to assist)
Eurasian sparrowhawk	Study in, and trend potential from, one area only.	Obtain outstanding productivity data for 2003 and 2004. SRMG to consider how to enhance monitoring in future.	HIGH (because there is only a small number of discrete study areas with high quality information and observers that are keen to assist; some information available from the Breeding Bird Survey but sample size does not meet standard reporting threshold for national BBS)
Common buzzard	Some high quality studies for trend production but unlikely to be representative nationally.	Obtain information on study area boundaries and coverage. Assess coverage against information from Bird Atlas 2007-11 when available.	HIGH (because there is a restricted number of discrete study areas with high quality information and observers that are keen to assist; plus national information from the Breeding Bird Survey)
Golden eagle	Widespread monitoring across Scotland of both numbers and productivity. Trend production limited pending further work on coverage and distribution. Trends likely to be possible for at least some NHZs and nationally.	Obtain remaining 49% of grid-references. Obtain information on study area boundaries and coverage. Match with information from Conservation Framework (Whitfield *et al*. 2008) to fully grid-reference and assess representativeness of coverage by NHZs and nationally.	HIGH (because this species is of high current conservation priority and information is available from the golden eagle Conservation Framework to support SRMS data in producing and assessing trends; Haworth Conservation to assist trend production for this species)

Raptor species	Summary of current state of monitoring and potential for trend production (from review of 2003-2008 SRMS data)	Priority actions for development (from review of 2003-2008 SRMS data)	PRIORITY FOR THE CURRENT PROJECT (and rationale)
Osprey	Coverage and data quality likely to be good. Trend production limited by lack of grid-referencing and lack of coverage information. Trends likely to be possible for at least some NHZs and national trends may be possible.	Obtain data in full (not summary data). Obtain remaining 76% of grid-references. Obtain information on study area boundaries and coverage.	LOW (because of state of impasse over key datasets for this species; this requires time not included in the project)
Common kestrel	Study in, and trend potential from, one area only. Data quality from this study will be high.	SRMG to consider how to enhance monitoring in future.	HIGH (only one suitable SRMS study plus national information from the Breeding Bird Survey)
Merlin	Widespread monitoring across Scotland of both numbers and productivity (in discrete study areas). Trend production limited pending further work on coverage and distribution. Trends likely to be possible for at least some NHZs and national trends may be possible.	Obtain remaining 47% of grid-references. Obtain information on study area boundaries and coverage. Assess coverage against national survey distribution (Ewing *et al*. 2011).	HIGH (because this species is of high current conservation priority and information is available from other recent work to support SRMS data in producing and assessing trends; Haworth Conservation to assist trend production for this species)
Eurasian hobby	Too few pairs breed for formal trend analysis.	N/A	EXCLUDED (too few pairs for trend production)
Peregrine falcon	Widespread monitoring across Scotland of both numbers and productivity. Trend production limited by lack of coverage information. Trends possible for at least some NHZs. SRMS dataset now almost fully grid-referenced through matching with the peregrine Conservation Framework dataset (during review of 2003-2008 SRMS data).	Draft trends with full explanation were produced during review of 2003-2008 SRMS data. Obtain remaining 7% of grid-references (NE Scotland). Obtain coverage information and formally assess against last national survey information.	HIGH (because most of the work to produce trends has been undertaken already and information assembled for the peregrine Conservation Framework and national surveys means a series of rigorous trends is possible).

Raptor species	Summary of current state of monitoring and potential for trend production (from review of 2003-2008 SRMS data)	Priority actions for development (from review of 2003-2008 SRMS data)	PRIORITY FOR THE CURRENT PROJECT (and rationale)
Barn owl	Trends in numbers and productivity likely to be possible from a number of study areas. National trends not feasible.	Obtain information on study area boundaries and coverage. Assess coverage against information from Bird Atlas 2007-11 when available.	HIGH (because there is only a small number of discrete study areas with high quality information and observers that are keen to assist)
Tawny owl	Trends in numbers and productivity likely to be possible from a small number of study areas. National trends not feasible.	Obtain information on study area boundaries and coverage. Assess coverage against information from Bird Atlas 2007-11 when available.	HIGH (because there is only a small number of discrete study areas with high quality information and observers that are keen to assist)
Long-eared owl	Monitoring too variable to produce any rigorous trends.	Obtain outstanding grid references (NHZ 20). SRMG to consider how to enhance monitoring in future.	LOW (monitoring too variable to produce trends)
Short-eared owl	Monitoring too variable to produce any rigorous trends.	SRMG to consider how to enhance monitoring in future.	LOW (monitoring too variable to produce trends; could look at crude abundance indices for some study areas)
Common raven	Widespread monitoring across parts of Scotland of both numbers and productivity (in discrete study areas). Trend production limited pending further work on coverage and distribution. Trends likely to be possible for some NHZs and national trends should be possible in future.	Obtain remaining 20% of grid-references. Obtain information on study area boundaries and coverage. Assess coverage against information from Bird Atlas 2007-11 when available.	MEDIUM (many study areas only have information for the most recent years; need Bird Atlas 2007-11 data to assess representativeness of coverage; should produce trends in future)

1.4.1 Red kite

Trends in breeding numbers

The Scottish red kite population has increased, showing sustained growth since re-introductions began in 1989, at national and regional scales (Figures 3-5; see Annex Tables B2 & B3 for the numbers of sites checked for occupancy by sub-population and component NHZs). The rate of increase has been slowest for the Black Isle sub-population (Northern Highlands and Moray Firth NHZs 7 and 21), where population growth has been slower because of poor survival rates of first year birds, largely due to persecution (Smart *et al*. 2010).

The Scottish breeding red kite population is confined to four main areas of Scotland: the Black Isle near Inverness; Aberdeenshire; Central Scotland; and Dumfries & Galloway; Figure 2). In these areas, a joint RSPB and SNH project has re-introduced birds since 1989. Releases took place on the Black Isle (89 birds between 1989 and 1993), in Central Scotland (103 birds between 1996 and 2001), Dumfries and Galloway (104 birds between 2001 and 2004) and, most recently, in Aberdeenshire (99 birds between 2007 and 2009; See Annex Table B1).

All four areas where red kites occur cover more than one NHZ. The Black Isle sub-population of red kites occurs in NHZ 7 (Northern Highlands) and NHZ 21 (Moray Firth). The Aberdeenshire sub-population occurs mostly in NHZ 9 (Northern Highlands) with one site in NHZ 12 (North East Glens). The Central Scotland sub-population occurs mainly in NHZ 15 (Loch Lomond, The Trossachs and Breadalbane) and NHZ 16 (Eastern Lowlands), with a smaller number of sites in NHZ 17 (West Central Belt) and the south-west of NHZ 12 (North East Glens). Finally, the Dumfries & Galloway sub-population occurs largely in NHZ 19 (Western Southern Uplands and Inner Solway), with two sites only in NHZ 18 (Wigtown Machairs and Outer Solway Coast).

Trends in breeding productivity

The national trend in fledging success shows no significant between-year differences ($p=0.57$, Figure 6). At the sub-population level, there are no significant differences between years in fledging success in the Black Isle sub-population ($p=0.08$), Central Scotland or the Dumfries & Galloway sub-populations ($p>0.39$; Figure 7). For the NHZ-specific trends in fledging success, there are no significant differences between years in NHZ 16 (Eastern Lowlands; $p=0.45$; Figure 8a); NHZ 19 Western Southern Uplands and Inner Solway ($p=0.50$; Figure 8b); or NHZ 21 (Moray Firth; $p=0.08$; Figure 8c).

The national, Black Isle and Central Scotland trends show no significant between-year differences in the mean number of fledglings produced per successful pair ($p=0.81$; Figure 9; $p=0.061$, Figure 10a; $p=0.11$, Figure 10b respectively). There was a significant between-year difference in the mean number of fledglings produced per successful pair for the Dumfries & Galloway population ($p=0.0031$; Figure 10c).

For the NHZ-specific trends in the number of fledglings produced per successful pair (Figure 11), there was a significant difference between years in NHZ 19 (Western Southern Uplands and Inner Solway; $p=0.0031$; Figure 11b). There were no significant differences between years in NHZ 16 (Eastern Lowlands; $p=0.45$; Figure 11a) or NHZ 21 (Moray Firth; $p=0.081$; Figure 11c). See Annex Tables B3 and B4 for sample sizes contributing to these trends.

Data sources, caveats, work pending and gaps

Trends were based on RSPB data, covering the years 1992 (when the first re-introduced pair was monitored) to 2010. The monitoring of red kites is almost comprehensive across Scotland, with most territories being monitored each year. Figures provided for the numbers of pairs are likely to be slight underestimates, particularly in the more recent years as the population has increased (e.g. Yvonne Boles, pers. comm.).

Breeding sites have been monitored comprehensively since the re-introductions began. However, the reporting of clutch and brood sizes was not encouraged due to risks of disturbance, and therefore calculation of trends in clutch and brood size at hatching was not possible. The monitoring of number of fledglings produced by successful pairs has been consistent, allowing trends in the number of fledglings produced per successful pair to be produced, both regionally and nationally.

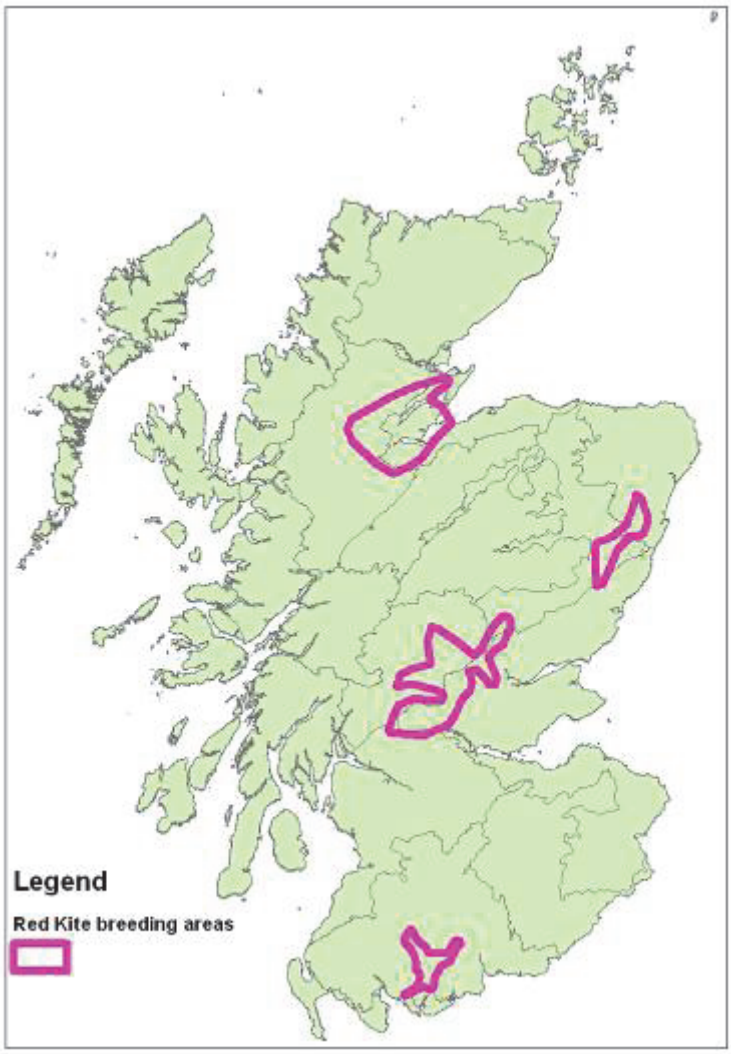


Figure 2. The current breeding areas of red kite sub-populations in Scotland. (Source: RSPB data).

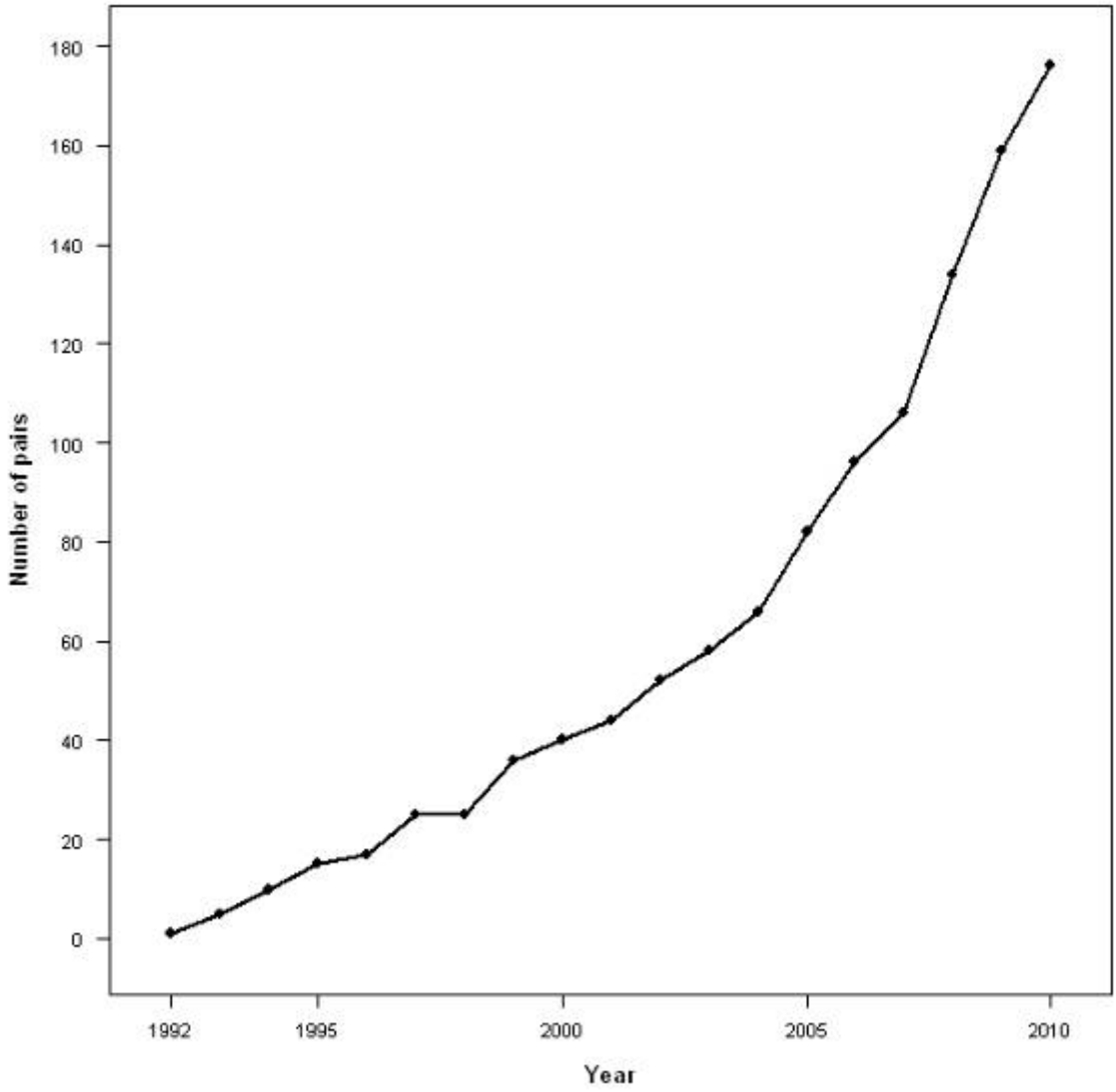


Figure 3. Trends in the number of breeding pairs of red kites in the whole of Scotland for the years 1992-2010.
(Source: RSPB data)

Note that numbers may be slightly underestimated in the most recent years.

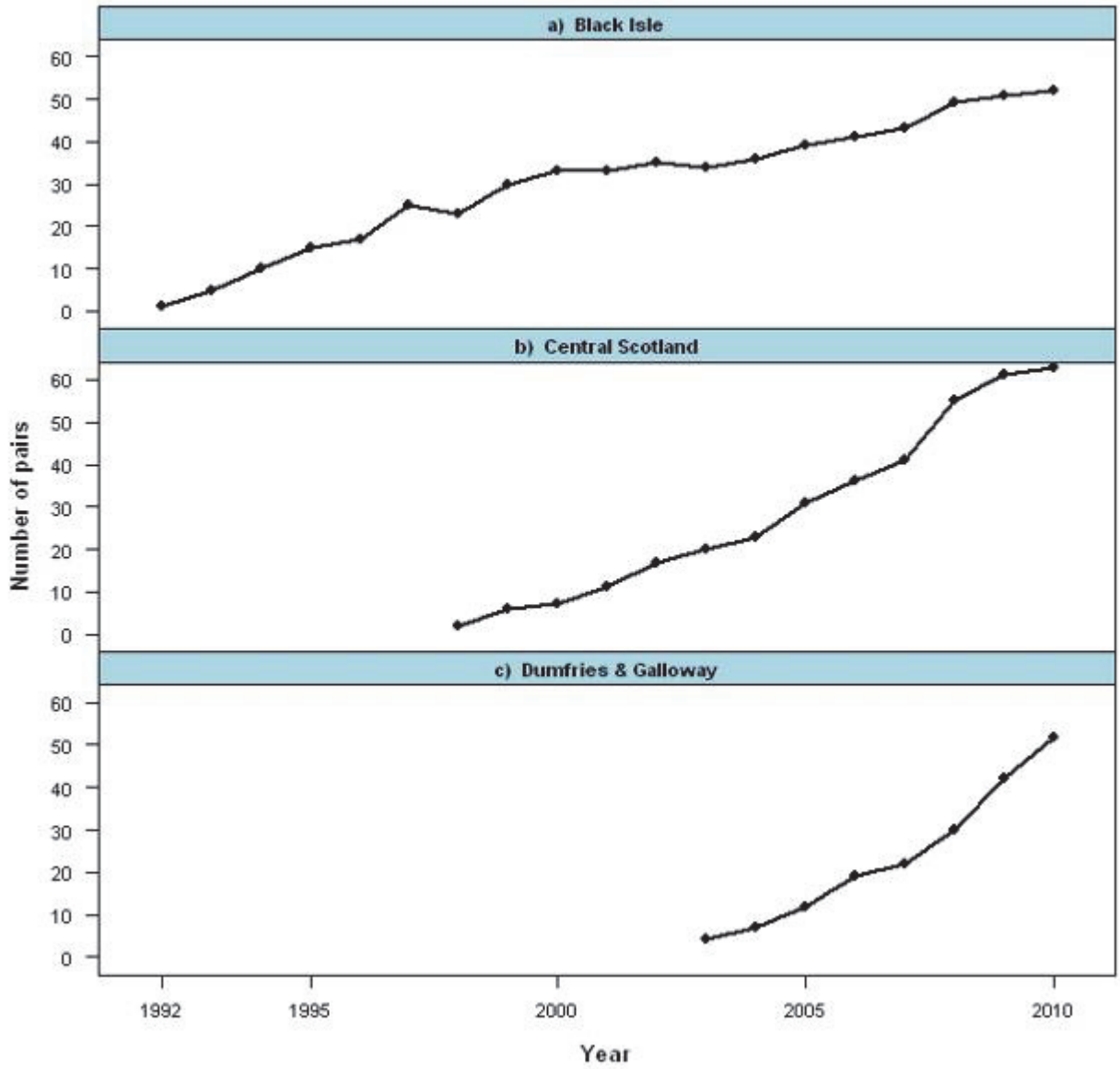


Figure 4. Trends in the number of breeding pairs of red kites in the three areas of Scotland where the reintroduced species has been breeding for more than five years during the period 1992-2010.

Black Isle (NHZs 7 & 21); Central Scotland (NHZs 12, 15, 16 & 17); and Dumfries & Galloway (NHZs 18 & 19). (Source: RSPB data)

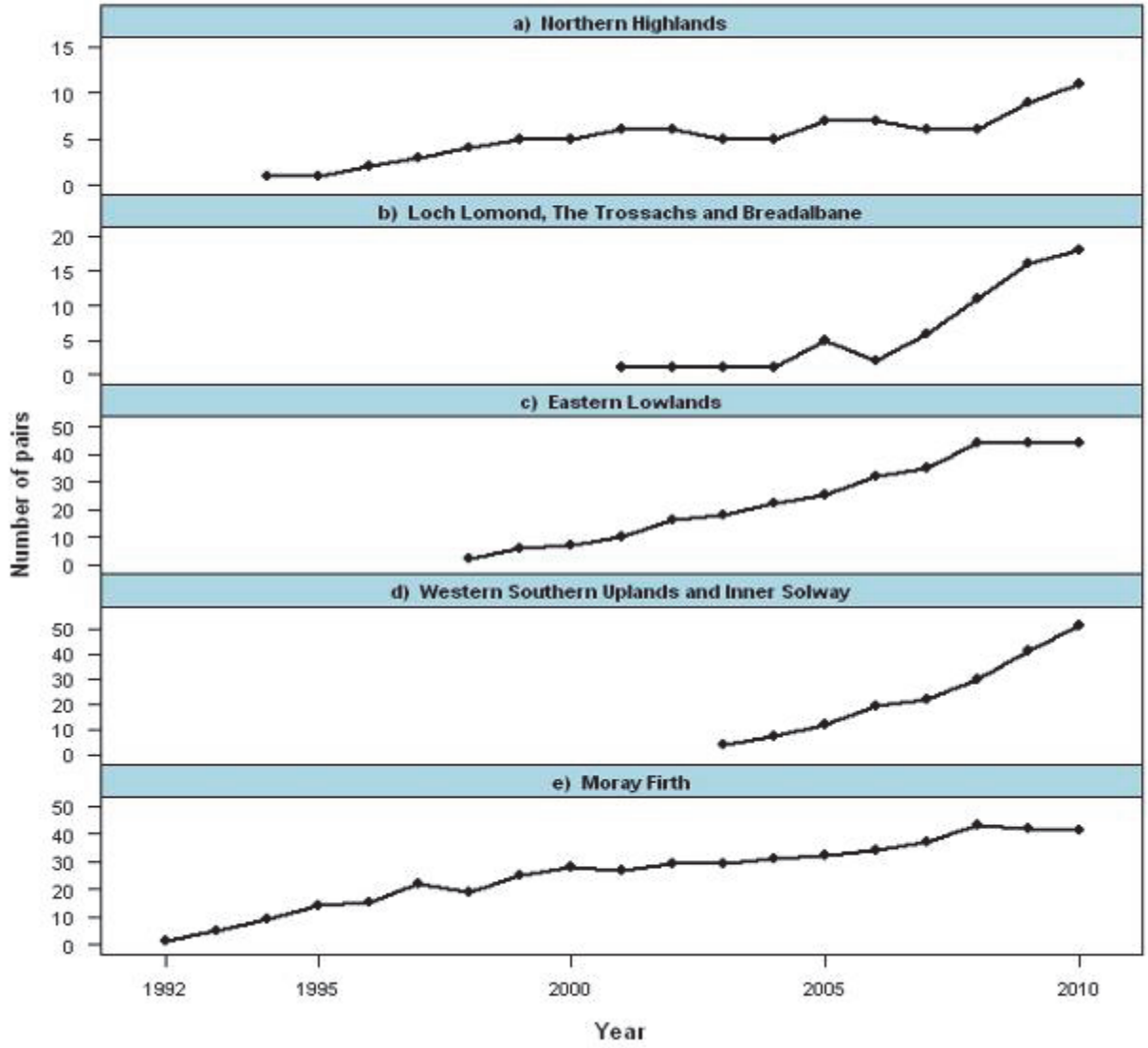


Figure 5. Trends in the number of breeding pairs of red kites in the five NHZs that held the majority of the Scottish population during the period 1992-2010.
(Source: RSPB data)

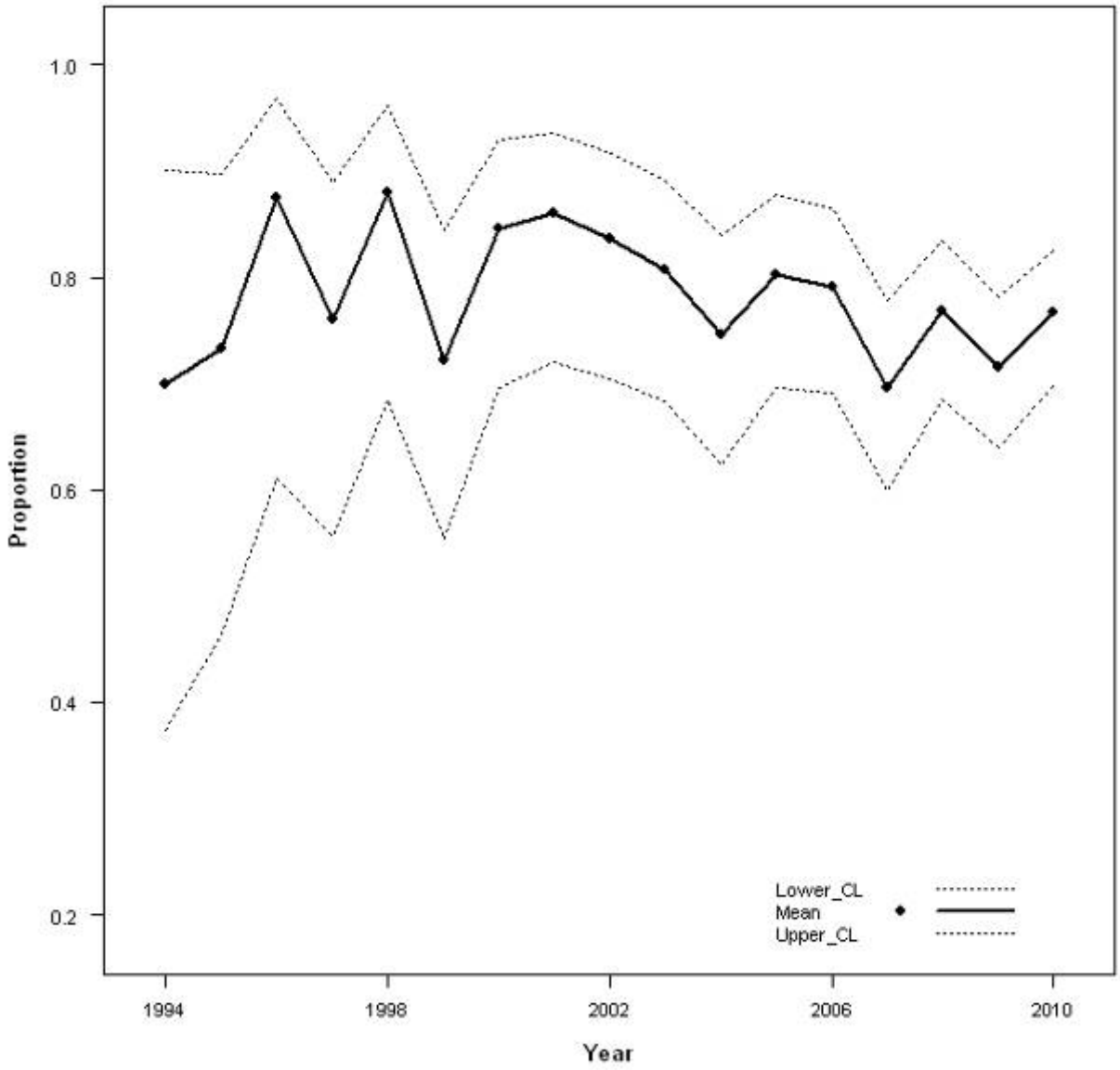


Figure 6. Trend in the fledging success (proportion of pairs known to hatch young that fledged at least one young) of red kites in the whole of Scotland between 1994 and 2010. (Source: RSPB data)

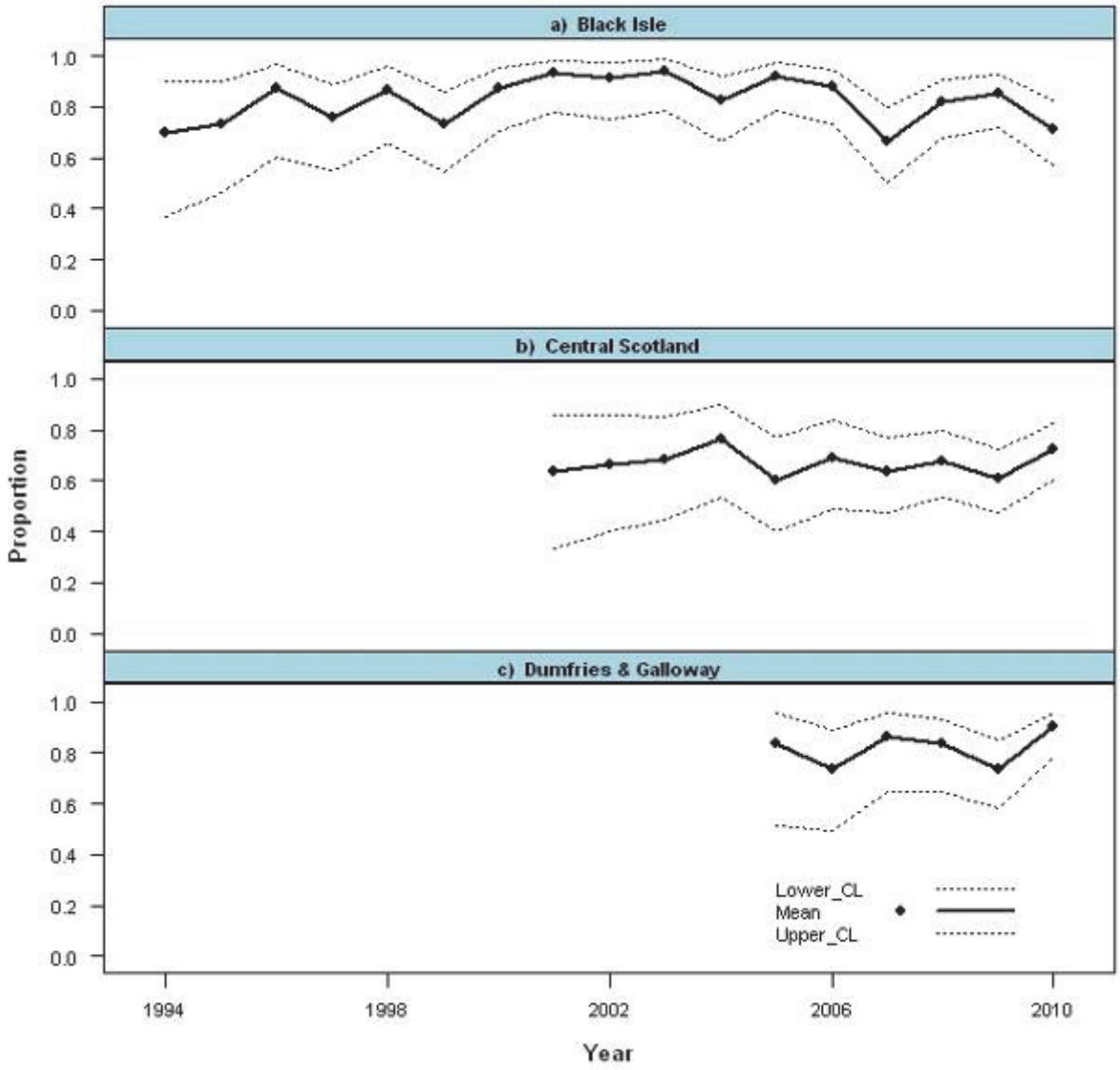


Figure 7. Trends in the fledging success (proportion of pairs known to hatch young that fledged at least one young) of red kites between 1994 and 2010 for the three sub-populations with sufficient sample sizes for trend analyses.

Black Isle (NHZs 7 & 21); Central Scotland (NHZs 15 & 16); and Dumfries & Galloway (mostly NHZ 19).
(Source: RSPB data)

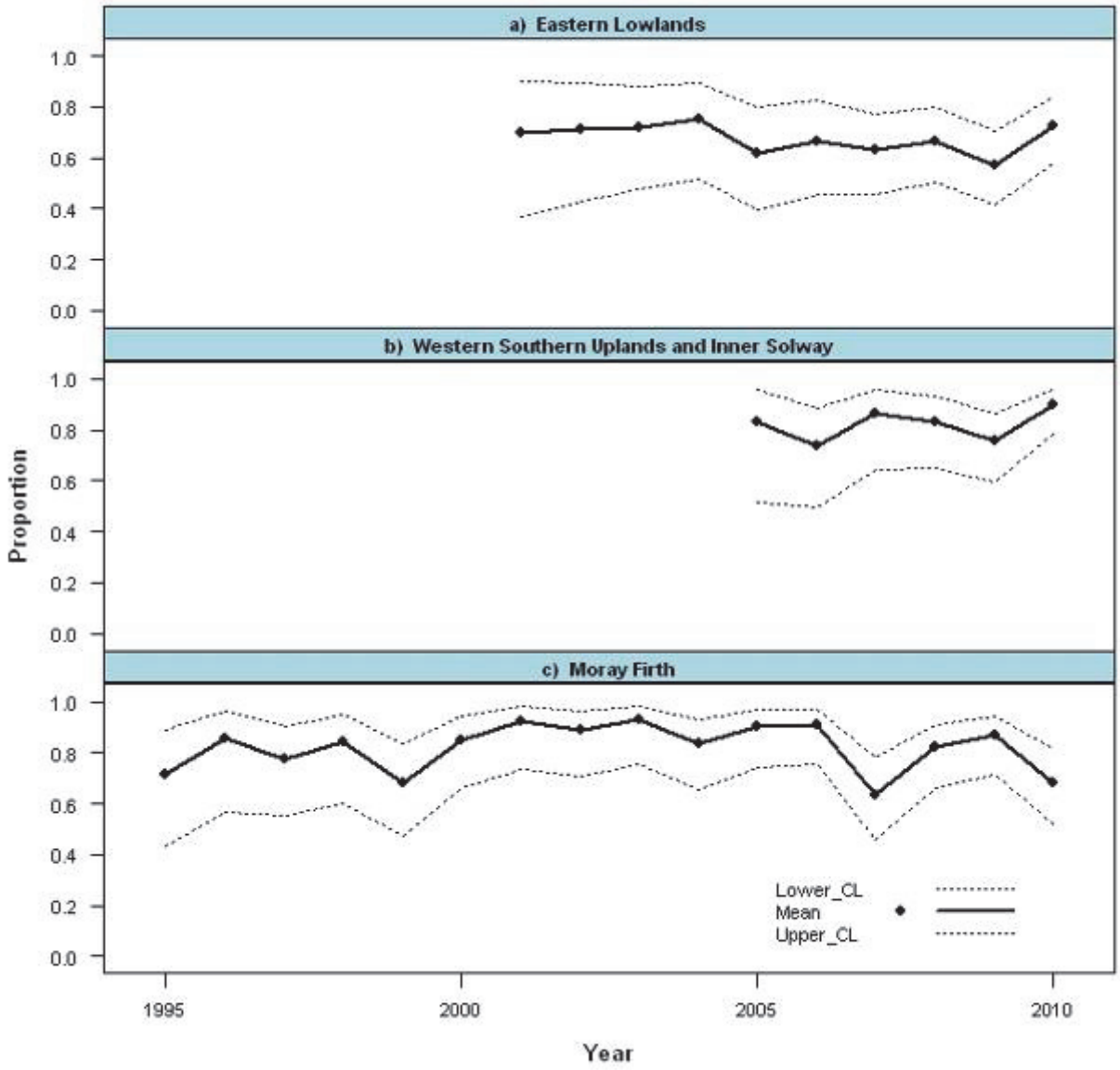


Figure 8. Trends in the fledging success (proportion of pairs known to hatch young that fledged at least one young) of red kites between 1995 and 2010 in the three Scottish NHZs with sufficient samples for analysis.
(Source: RSPB data)

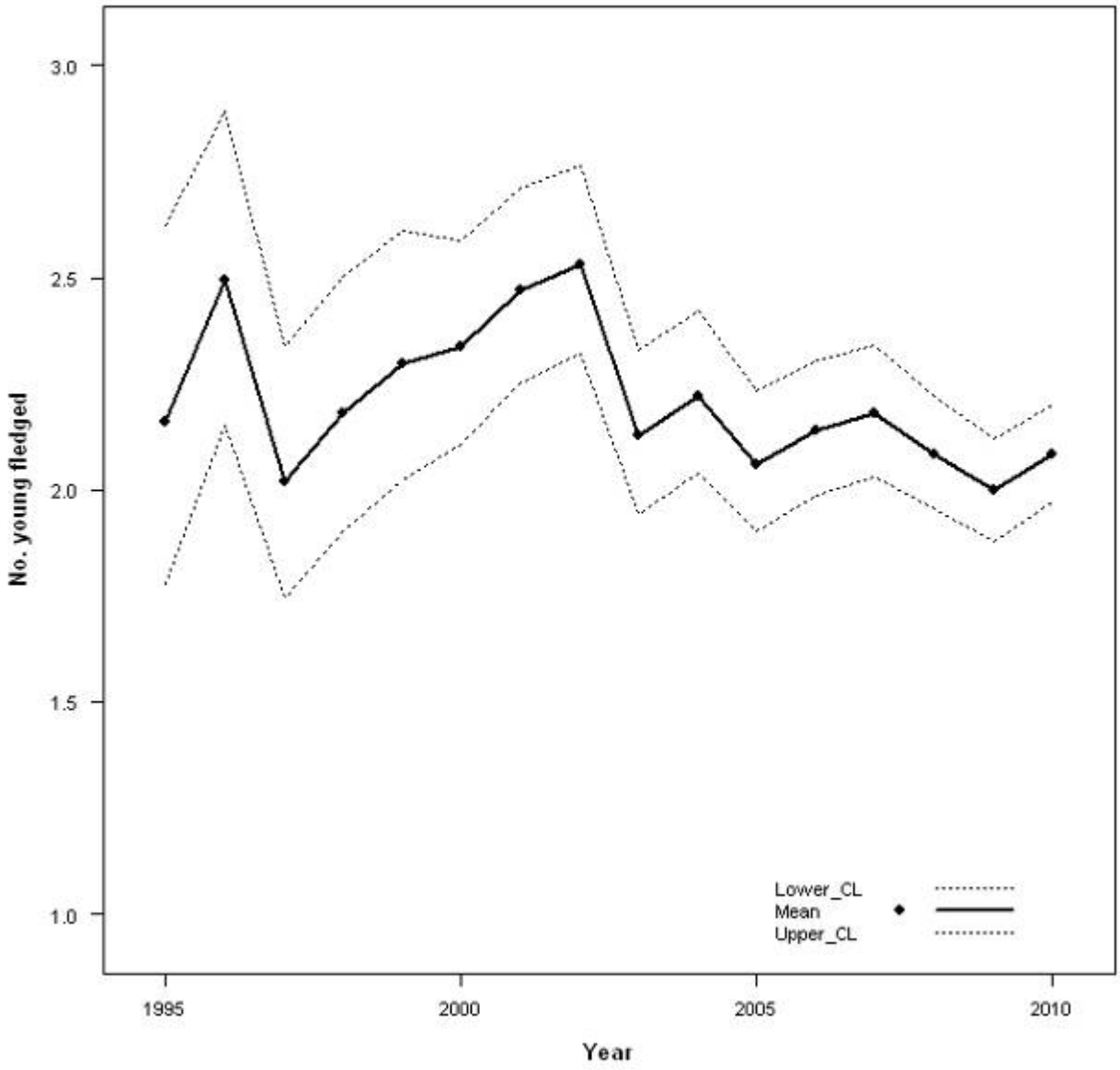


Figure 9. Trend in the number of fledglings produced per successful pair by red kites in the whole of Scotland between 1995 and 2010.
(Source: RSPB data)

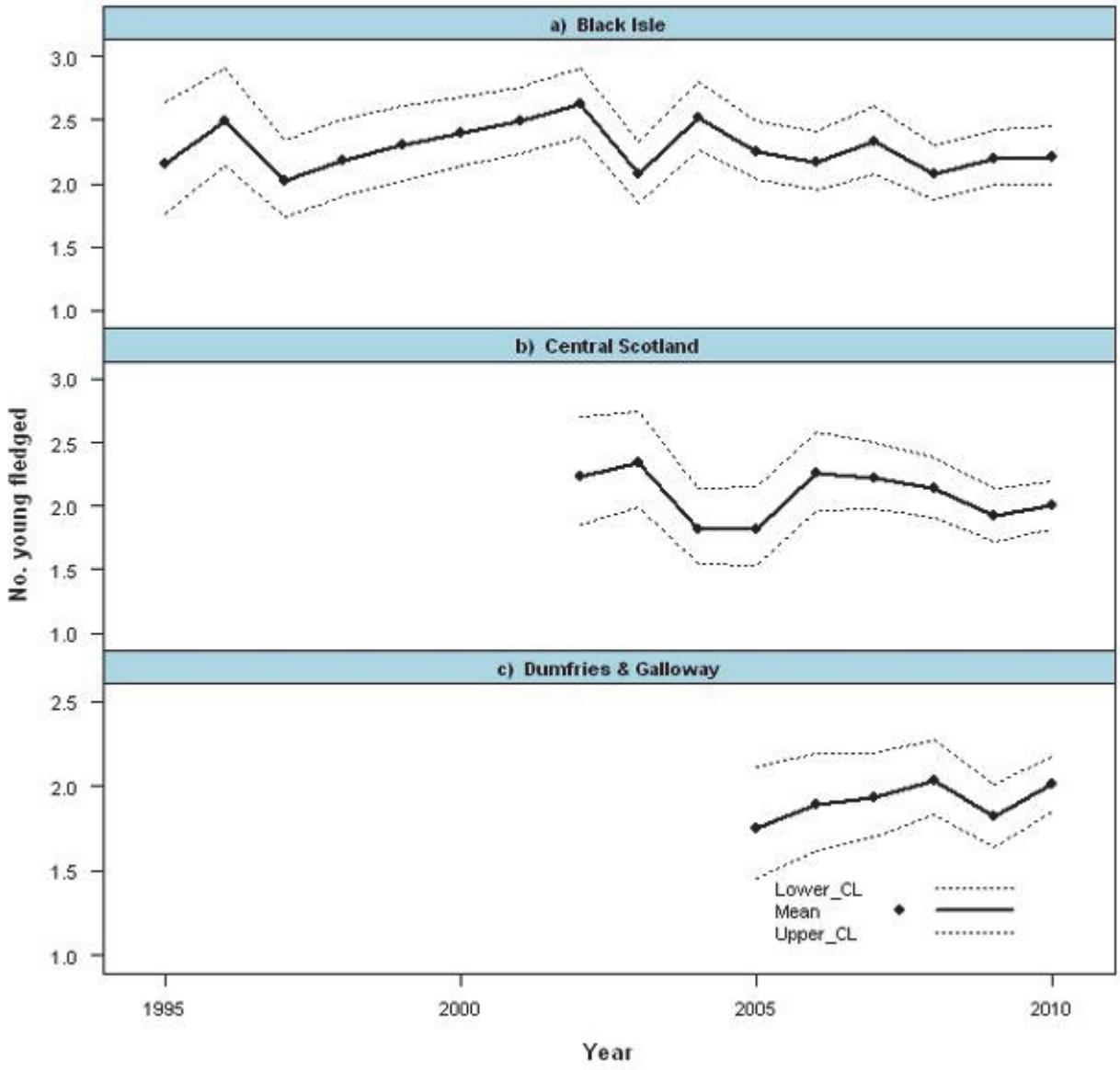


Figure 10. Trends in the number of fledglings produced per successful pair by red kites between 1995 and 2010 for the three sub-populations with sufficient sample sizes for trend analyses.

Black Isle (NHZs 7 & 21); Central Scotland (NHZs 15 & 16); and Dumfries & Galloway (mostly NHZ 19).
(Source: RSPB data)

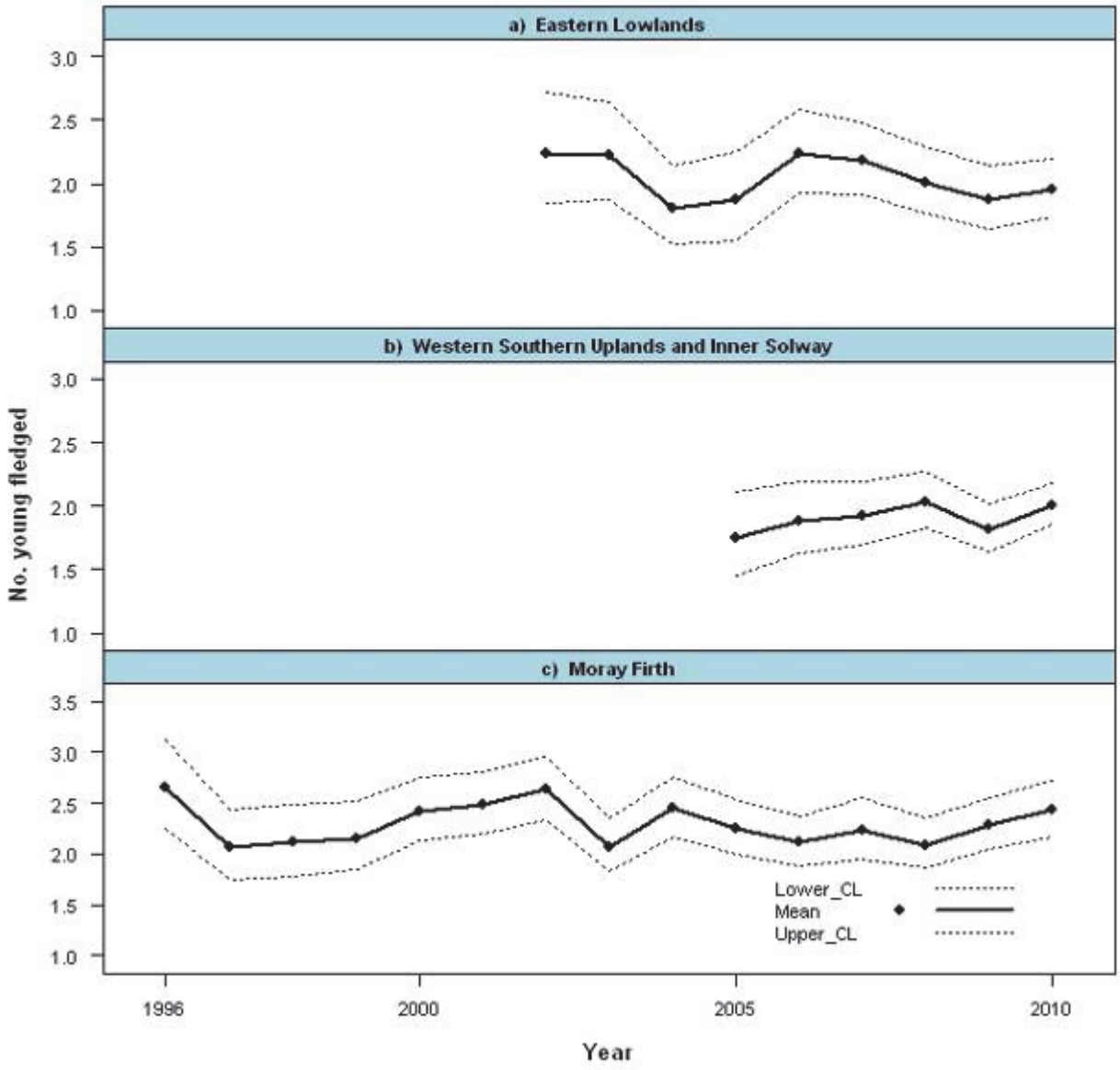


Figure 11. Trends in the number of fledglings produced per successful pair by red kites between 1995 and 2010 in the three Scottish NHZs with sufficient samples for analysis. (Source: RSPB data)

1.4.2 White-tailed eagle

Trends in breeding numbers
The Scottish white-tailed eagle population has increased nationally and regionally showing a steady population growth and range expansion (Figures 13 and 14 respectively; see Annex Table B8 for samples of sites checked and Evans *et al*. 2009 for projected future population growth rates).

The Scottish breeding population is currently confined to the western part of Scotland (Figure 12), although recent reintroductions have occurred in the eastern part of the country. Currently these latter birds are sub-adults, and are not expected to start breeding for another 2-3 years. However, a sub-adult white-tailed eagle from the east bred with an adult individual in the west of Scotland in 2011, suggesting that the two populations are connected and that breeding may occur in the east of Scotland sooner than expected (Claire Smith, pers. comm.). Releases of white-tailed eagles in Scotland began in 1975, with 3-10 birds released annually on Rum between 1975 and 1985, 6-12 birds released annually in Wester Ross between 1993 and 1998, and 11-19 birds released annually in Fife between 2007 and 2011 (Evans *et al*. 2009; see Annex Table B7). No further releases are planned in the west of Scotland. The release programme in Fife aimed to release a total of 100 birds but a lack of broods with two chicks in the Norwegian source population in 2012 meant that only 85 birds were released (only single chicks from twin broods were allowed to be sourced; Rhian Evans, pers. comm.).

Trends are reported for the national population and four NHZs that hold the majority of the Scottish population. The strongholds of the species are in NHZ 3 (Coll, Tiree and the Western Isles) and NHZ 6 (the Western Seaboard).

Trends in breeding productivity
There were no significant between-year differences detected for any of the breeding productivity parameters at a national or regional scale:

- Number of eggs laid per pair that produced a clutch - national ($p=0.24$; Figure 15); regional ($p>0.22$; Figure 16).
- Hatching success - national ($p=0.30$; Figure 17); regional ($p>0.22$; Figure 18).
- Number of eggs hatched per laying pair - national ($p>0.22$; Figure 19); regional (both $p>0.15$; Figure 20).
- Fledging success - national ($p=0.30$; Figure 21); regional ($p>0.37$; Figure 22).
- Fledglings produced per successful pair - national ($p=0.75$; Figure 23); regional (both $p >0.44$; Figure 24).

See Annex Tables B9 and B10 for sample sizes contributing to these trends.

Trends in clutch size for pairs that laid, hatching success, brood size at hatching for pairs that hatched young, fledging success, and number of young fledged per successful pair are reported for the national population and the two NHZs that hold the majority of the Scottish population.

Data sources, caveats, work pending and gaps
Trends are based on RSPB data, covering the years 1981 to 2010. Monitoring coverage of the breeding population of this species is thorough, with all territories checked each year, allowing reporting of trends in numbers and breeding parameters at national and regional scales.

Monitoring during the early part of the breeding season is less intensive, to reduce the risk of disturbing the birds. Thus, it is not always clear whether a pair which is not seen to be

incubating eggs actually attempted to breeding, and therefore it is not possible to report trends in laying success. Figures for numbers of breeding pairs are likely to be slightly underestimated due to this uncertainty. Figures for total numbers of fledged young and successful pairs are thought to be precise.

Trends in appropriate breeding parameters were calculated for the whole of Scotland (Annex Table B10). Trends in breeding parameters were also calculated for NHZs where the number of records was greater than five records per year. This was a relaxation of the more general inclusion criteria used, as records for white-tailed eagle are comprehensive. The species is still rare, and low sample sizes restricted the calculation of trends in breeding parameters for five of the seven NHZs in which the species breeds (Annex Table B9).

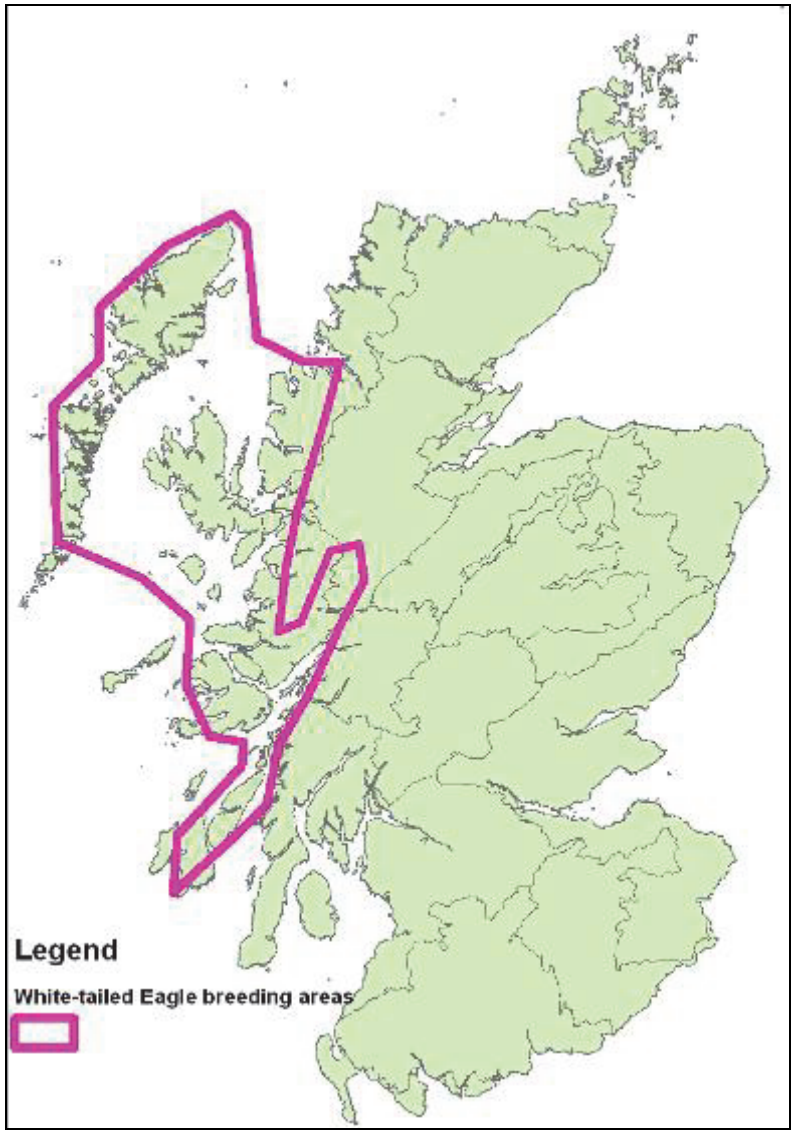


Figure 12. Breeding range of white-tailed eagles in Scotland by 2010. (Source: RSPB data)

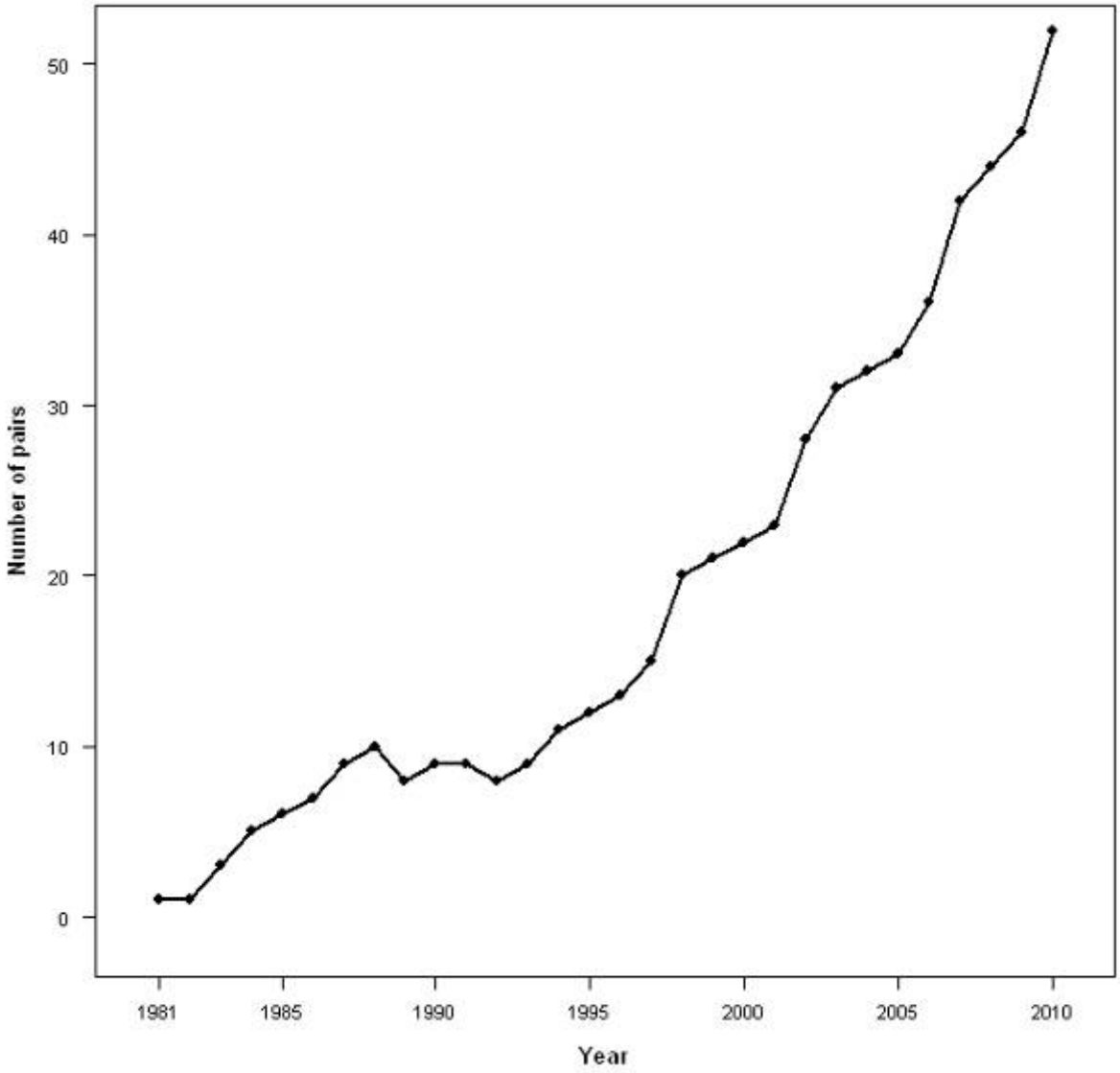


Figure 13. Trends in the number of breeding pairs of white-tailed eagles in the whole of Scotland for the years 1981-2010.
(Source: RSPB data)

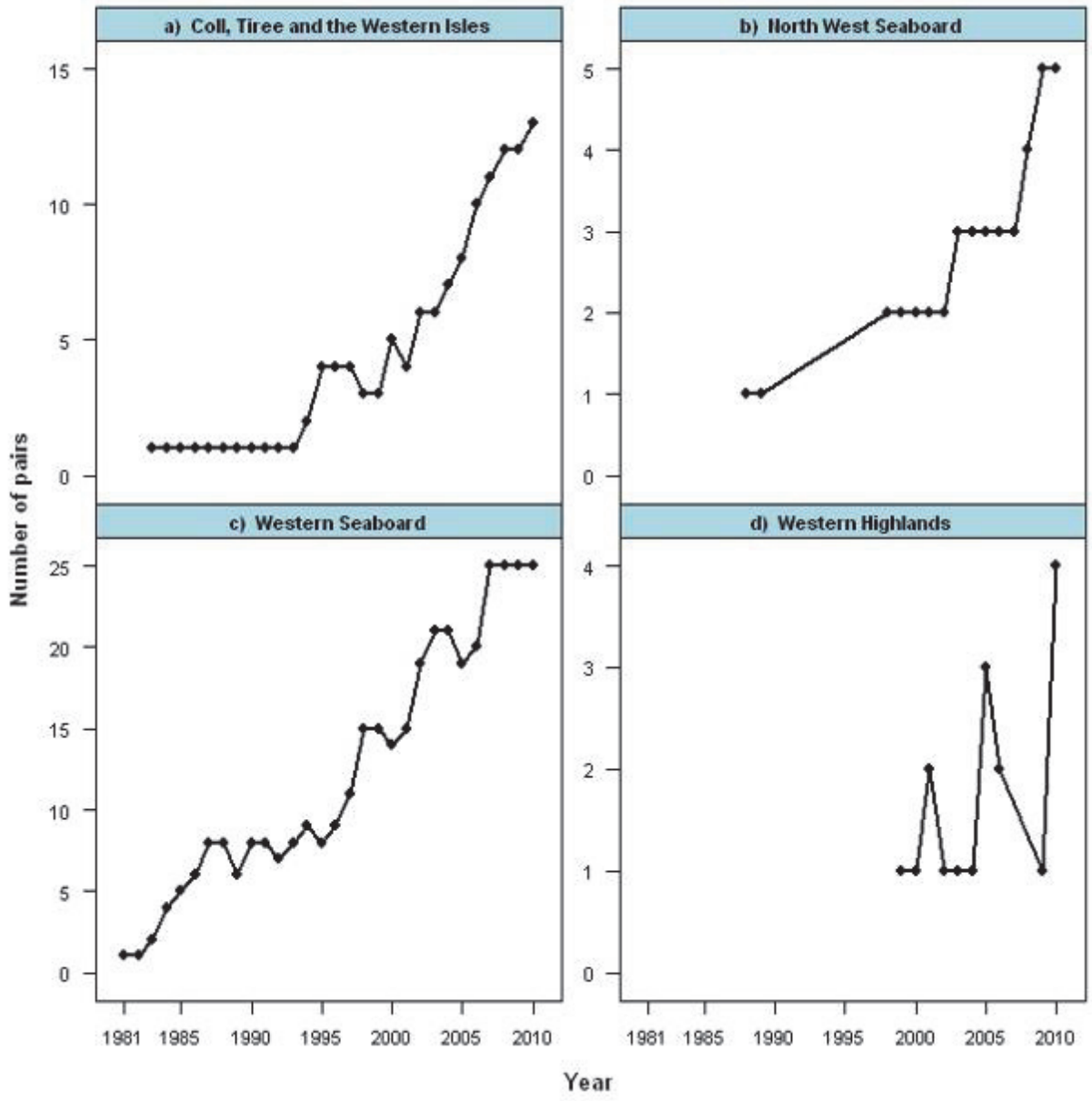


Figure 14. Trends in the number of breeding pairs of white-tailed eagle in the four NHZs holding the majority of the Scottish breeding population for the years 1981-2010.
(Source: RSPB data)

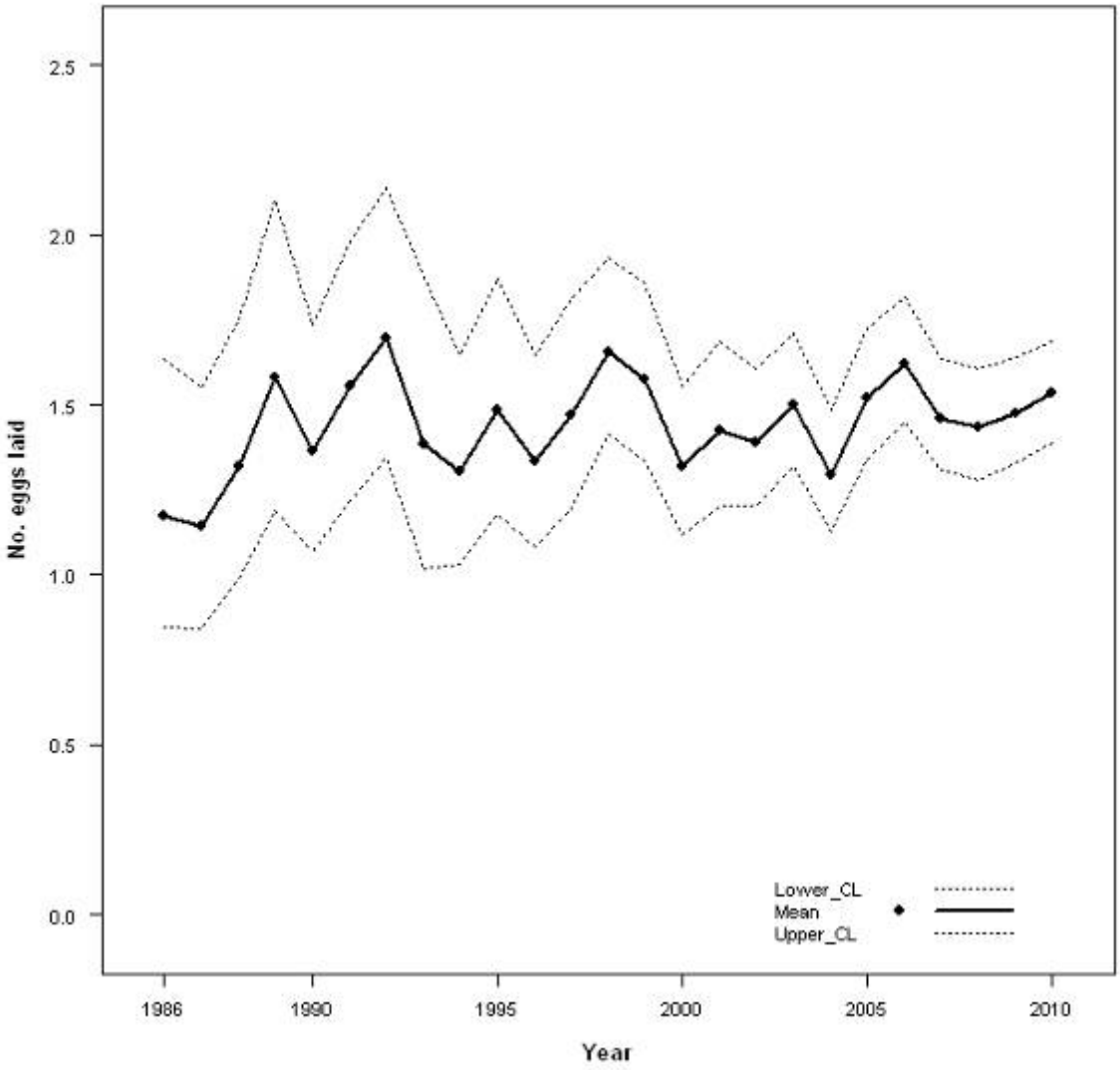


Figure 15. Trend in the mean clutch size of pairs that laid for white-tailed eagles in the whole of Scotland between 1986 and 2010.
(Source: RSPB data)

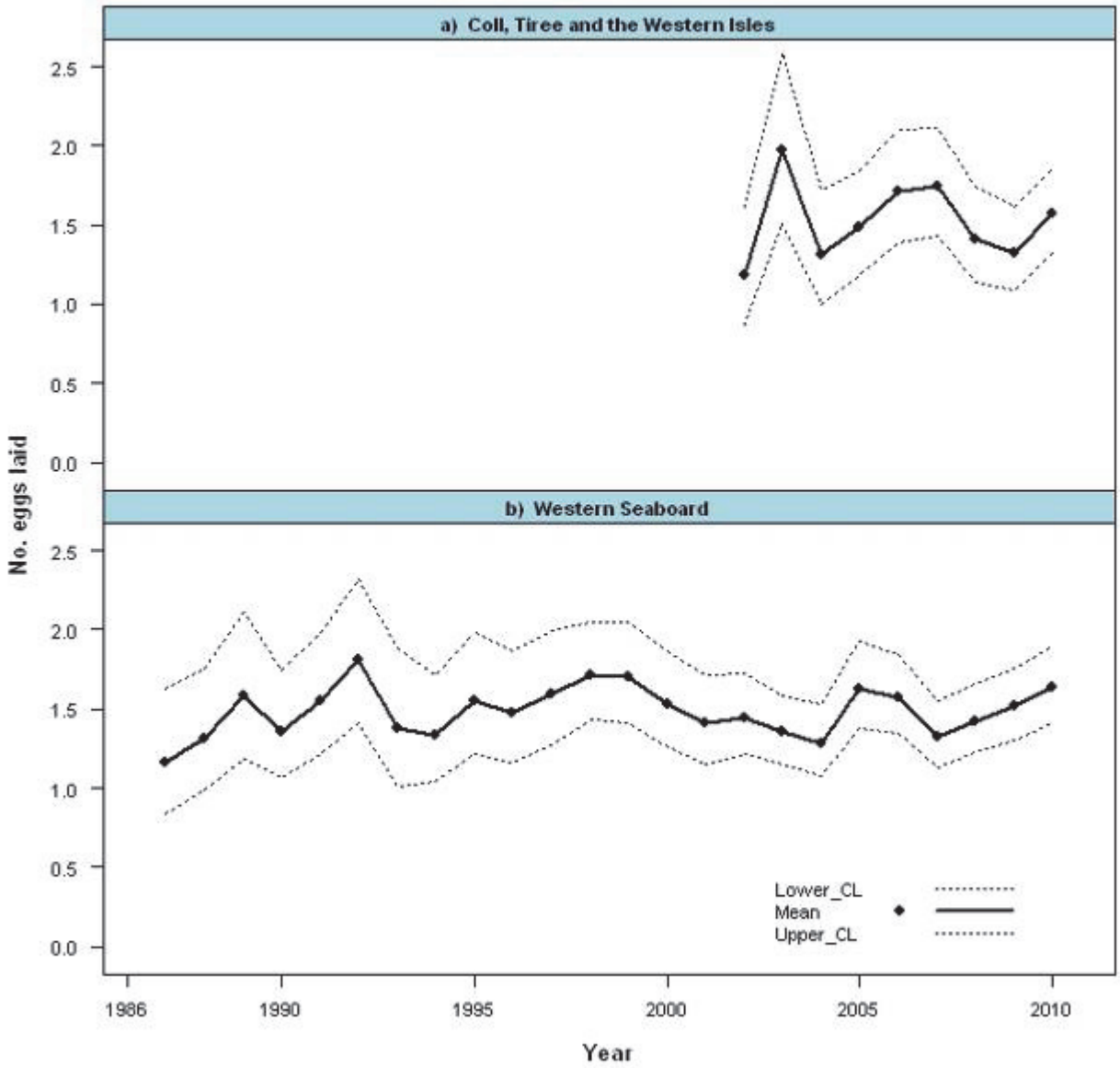


Figure 16. Trends in the clutch size of pairs that laid for white-tailed eagles between 1986 and 2010 in the two NHZs holding the majority of the Scottish breeding population. (Source: RSPB data)

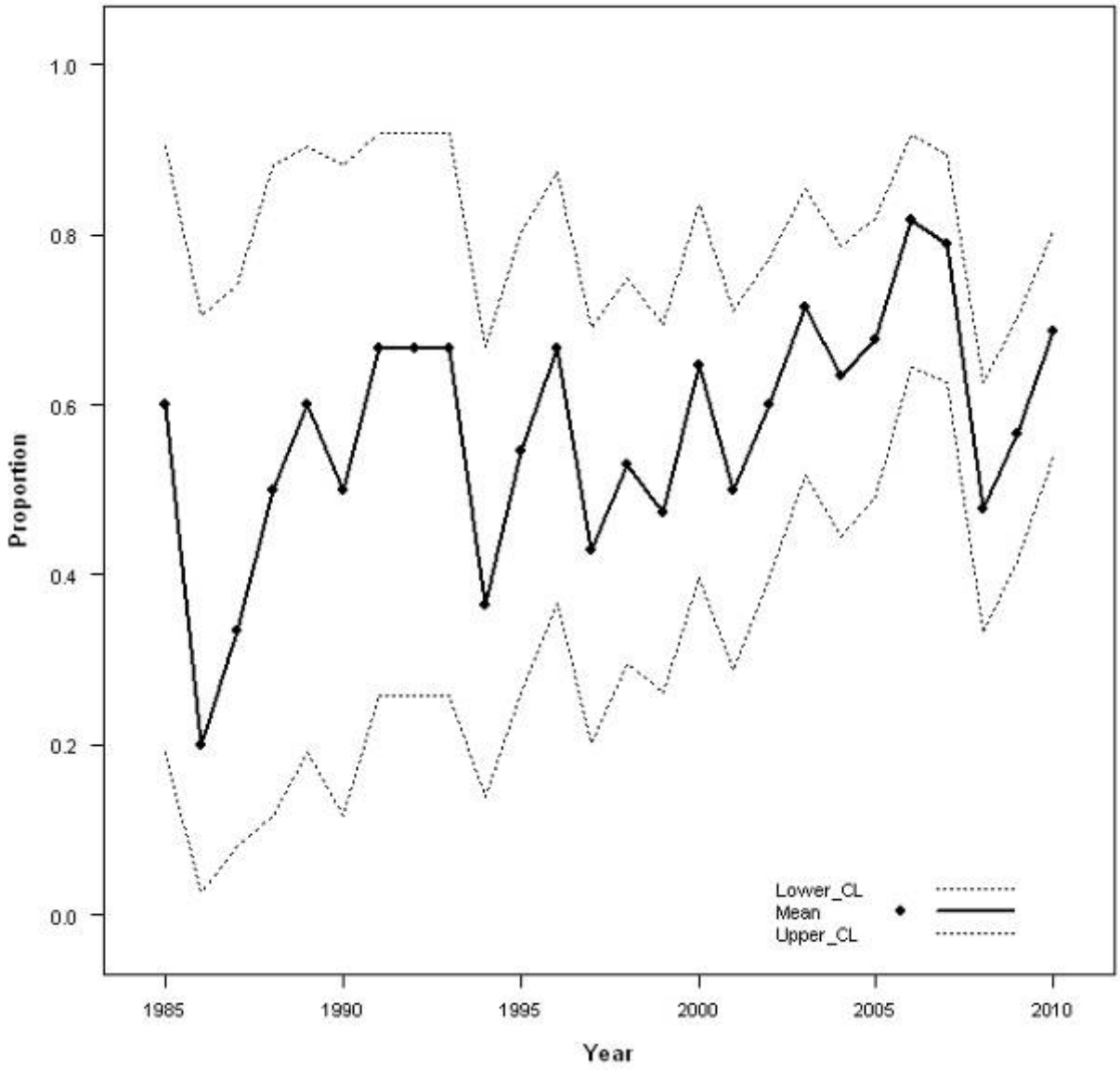


Figure 17. Trend in the hatching success (proportion of pairs known to lay that hatched at least one young) for white-tailed eagles in the whole of Scotland between 1985 and 2010. (Source: RSPB data)

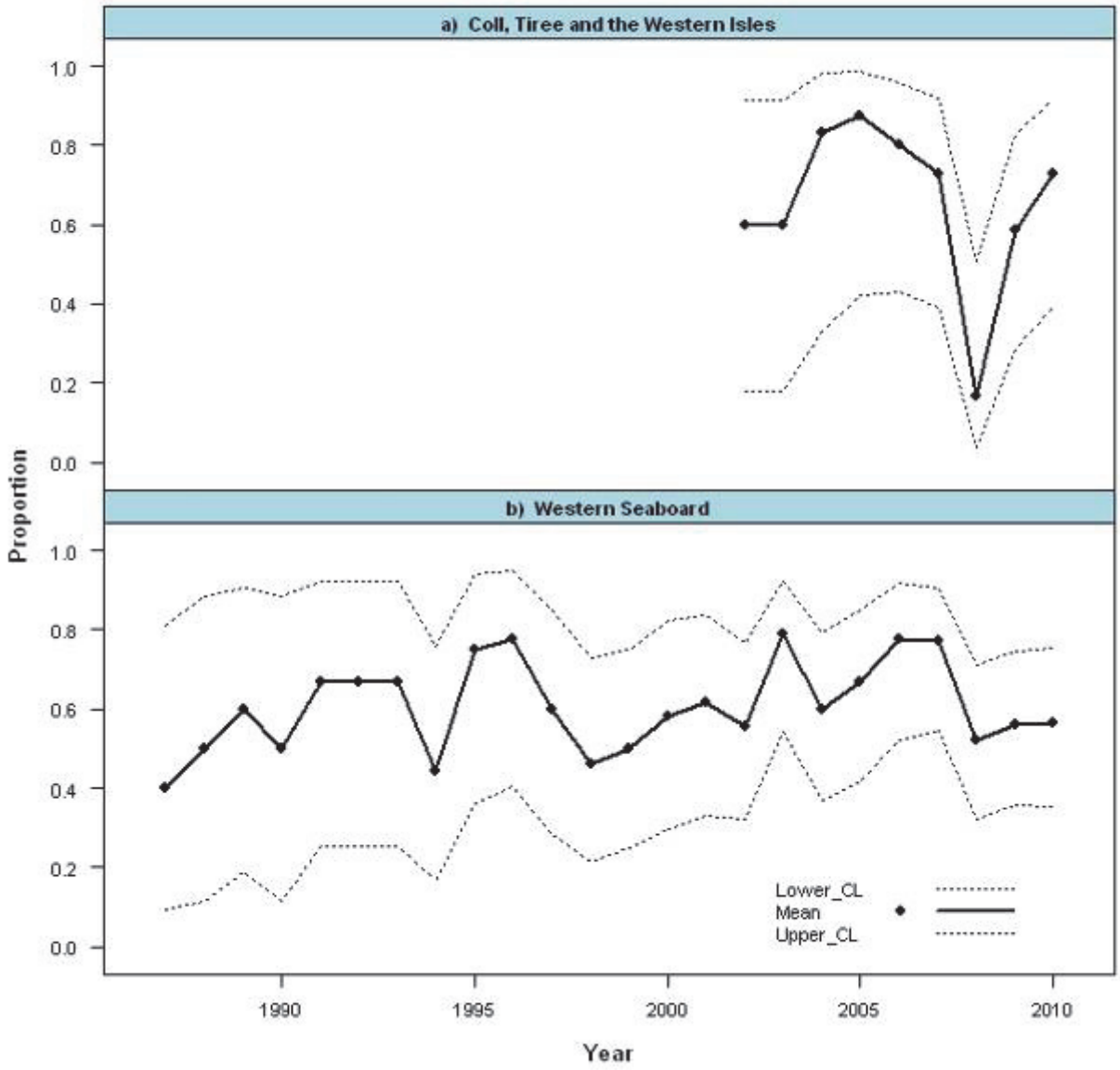


Figure 18. Trends in hatching success (proportion of pairs known to lay that hatched at least one young) for white-tailed eagles between 1986 and 2010 in the two NHZs holding the majority of the Scottish breeding population.
(Source: RSPB data)

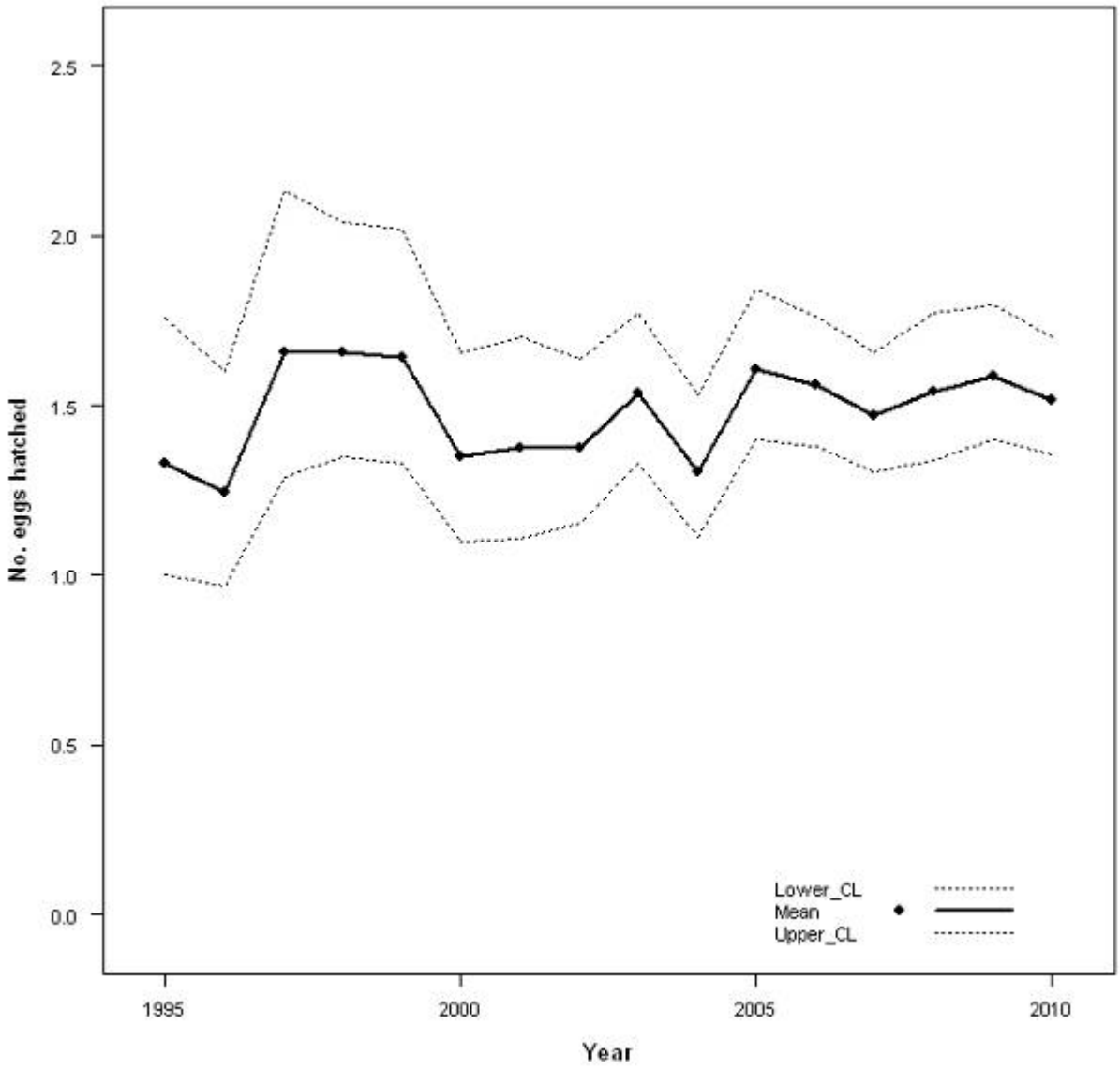


Figure 19. Trend in brood size at hatching of pairs that hatched young for white-tailed eagles in the whole of Scotland between 1995 and 2010.
(Source: RSPB data)

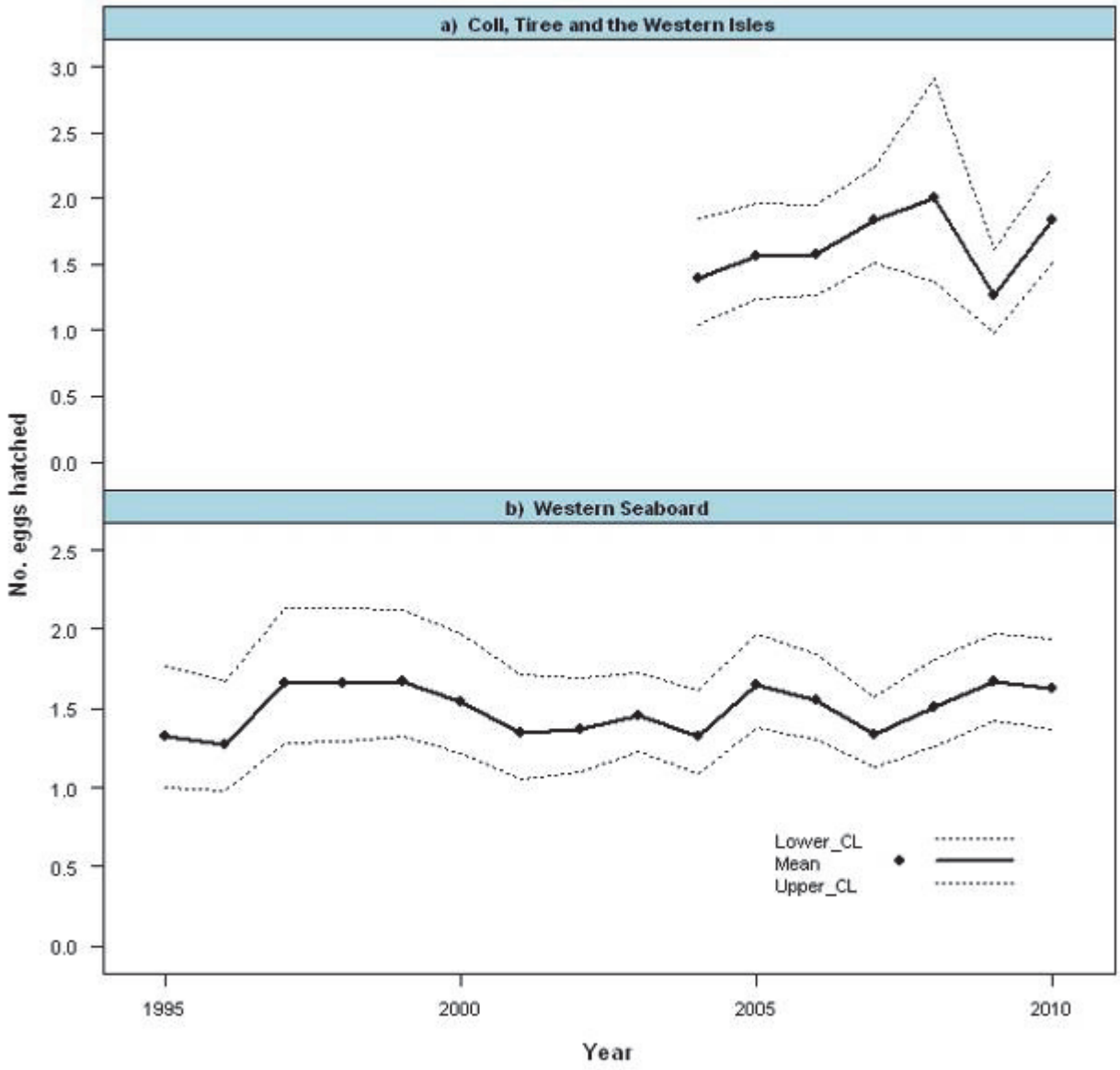


Figure 20. Trends in the brood size at hatching of pairs that hatched young for white-tailed eagles between 1995 and 2010 in two NHZs holding the majority of the Scottish breeding population.
(Source: RSPB data)

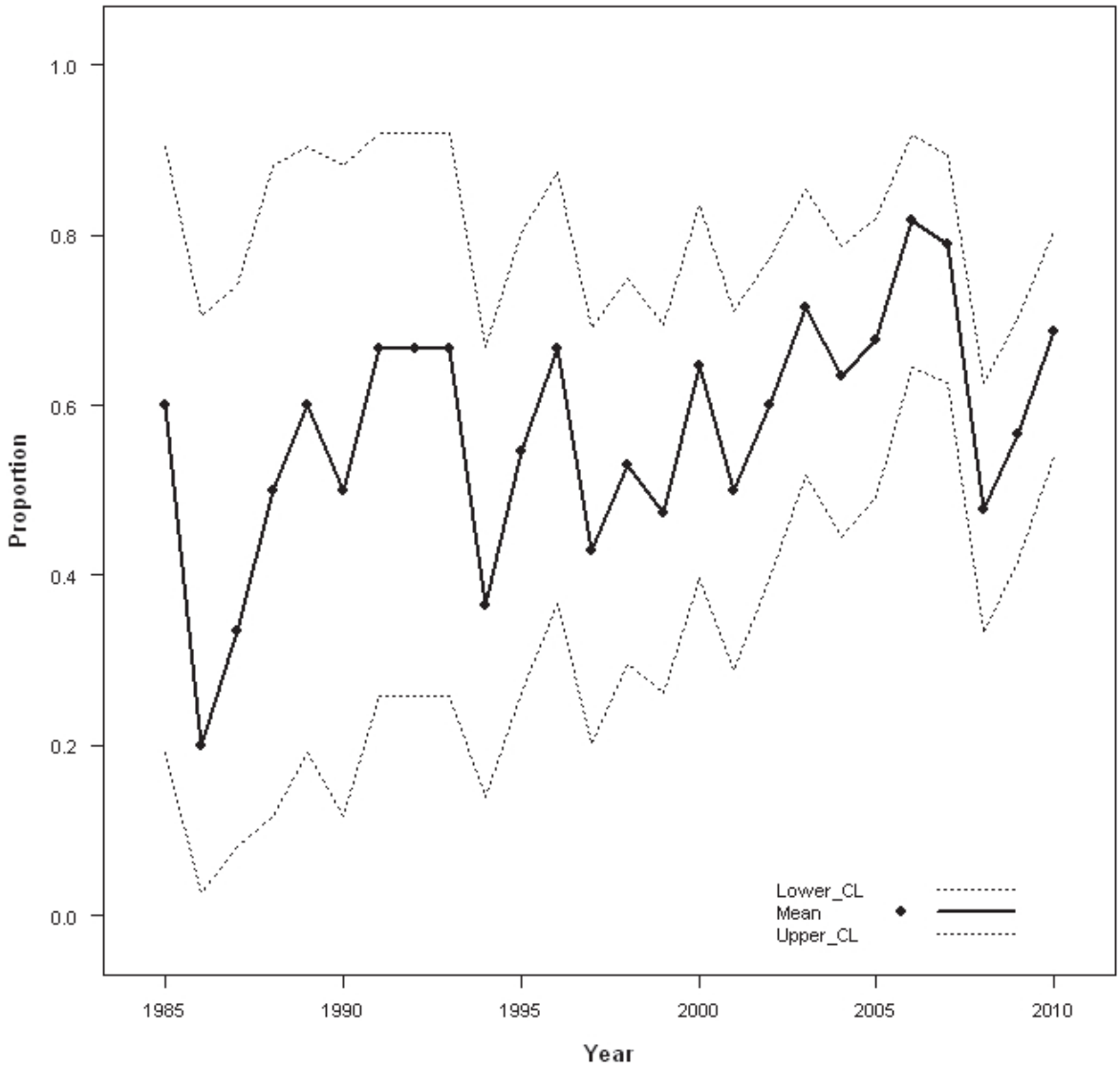


Figure 21. Trend in the fledging success (proportion of pairs known to hatch young that fledged at least one young) for white-tailed eagles in the whole of Scotland between 1985 and 2010.
(Source: RSPB data)

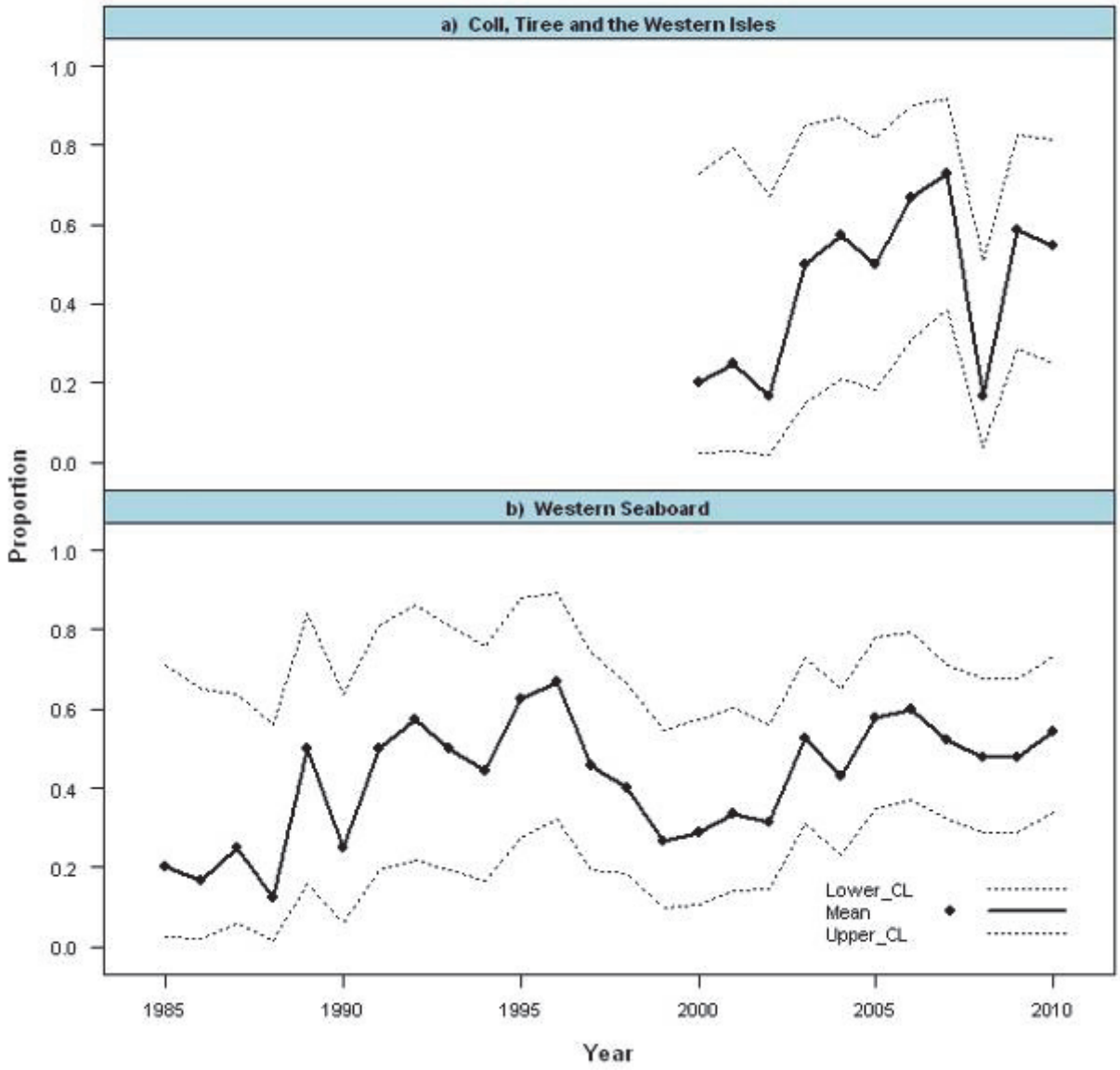


Figure 22. Trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for white-tailed eagles between 1985 and 2010 in the two NHZs holding the majority of the Scottish breeding population.
(Source: RSPB data)

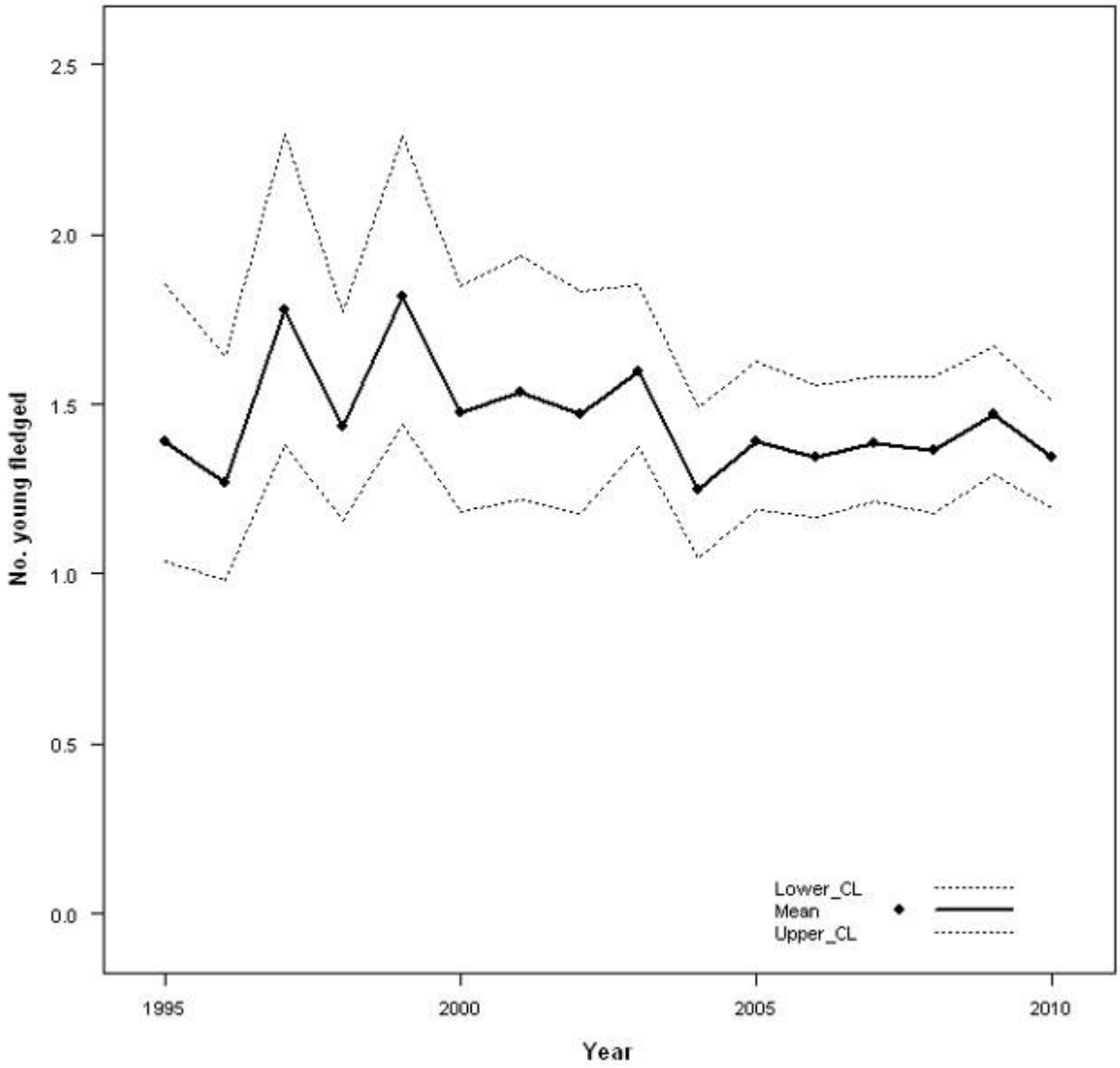


Figure 23. Trend in the number of fledglings produced per successful pair for white-tailed eagles in the whole of Scotland between 1995 and 2010.
(Source: RSPB data)

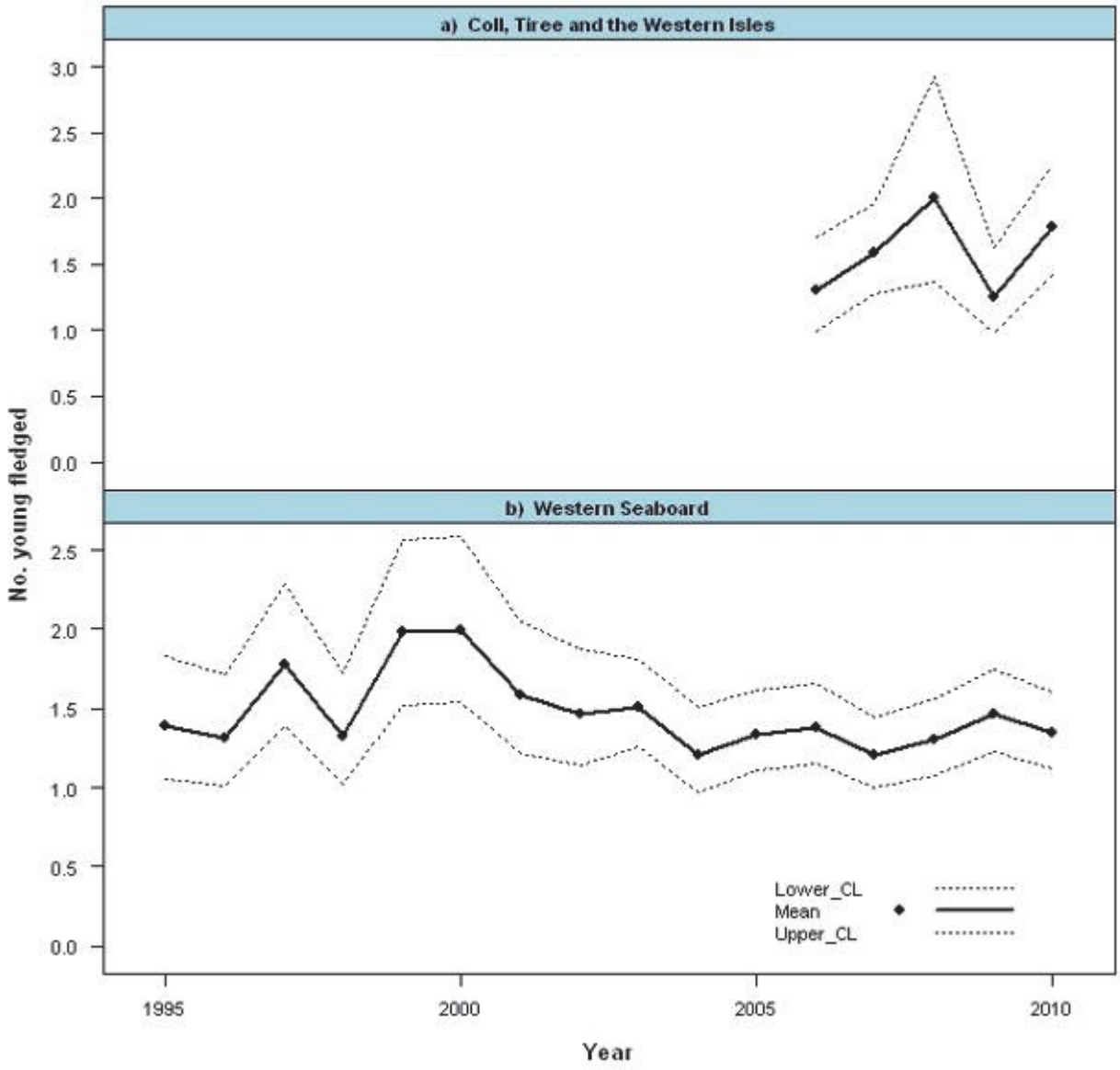


Figure 24. Trends in the number of fledglings produced per successful pair for white-tailed eagles between 1995 and 2010 in the two NHZs holding the majority of the Scottish breeding population.
(Source: RSPB data)

1.4.3 Hen harrier

Trends in breeding numbers
Trends in breeding numbers cannot be reported until further work to quantify coverage and compare this to current knowledge of the Scottish distribution of hen harriers is complete.

Trends in breeding productivity
There were no significant between-year differences detected for any of the breeding productivity parameters at a regional scale.

None of the provisional NHZ-specific trends in laying success (Figure 25), clutch size (Figure 26), hatching success (Figure 27), brood size at hatching (Figure 28), fledging success (Figure 29) or number of young fledged per successful pair (Figure 30) show statistically significant between-year differences since 2003.

Best available trends in laying success could be reported for one NHZ, clutch size of those pairs that laid for five NHZs, hatching success for three NHZs, brood size at hatching for pairs that hatch young for three NHZs, fledging success for four NHZs and number of young fledged per successful pair for three NHZs.

Data sources, caveats, work pending and gaps
Analyses were based on the 2,918 individual site-year records in the SRMS data for 2003-2009 that could be linked to individual NHZs (see Annex Tables B9 and B10). A breakdown of ranges surveyed under the SRMS 2003-2009 and the numbers found to be occupied by NHZ and Raptor Study Group (for those still without grid references) is available in Annex Table B13.

For this species, trends in breeding numbers cannot be produced until two further pieces of work are carried out: (a) to obtain coverage/effort information from observers; and (b) to compare annual monitoring coverage to our best knowledge of the current distribution and abundance of hen harriers in Scotland (and in each NHZ; information available from the most recent national survey in 2010, supplemented by Bird Atlas 2007-11). It is not possible to identify any key monitoring gaps until this additional analysis is undertaken.

We produced provisional trends in breeding parameters for up to five NHZs for which samples of at least 10 appropriate records exist for each parameter in each year (see Annex Table B14 for sample sizes). It was not possible to determine to what extent these trends are representative of each NHZ hen harrier population. Once coverage information for each NHZ is available, this can be compared with the up to date distribution information. The trends are provisional until checks have been made on the consistency of field methods employed by each hen harrier study that contributes to these trends.

Across Scotland, we are aware of several long-term hen harrier monitoring studies. For example, raptor workers on Orkney have collected hen harrier data since 1953 and more systematically since 1975. These data have been used to demonstrate the effects of sheep grazing on Orkney vole (*Microtus arvalis orcadensis)* abundance and hen harrier productivity (Amar *et al.* 2012). Other such datasets, collected before the inception of the SRMS, exist and future inclusion of these in trends work would be beneficial.

Given the number and distribution of hen harrier records submitted to the SRMS annually since 2003 (Annex Table B13), it should be possible to produce some national trends in future once the work pending (above) is complete.

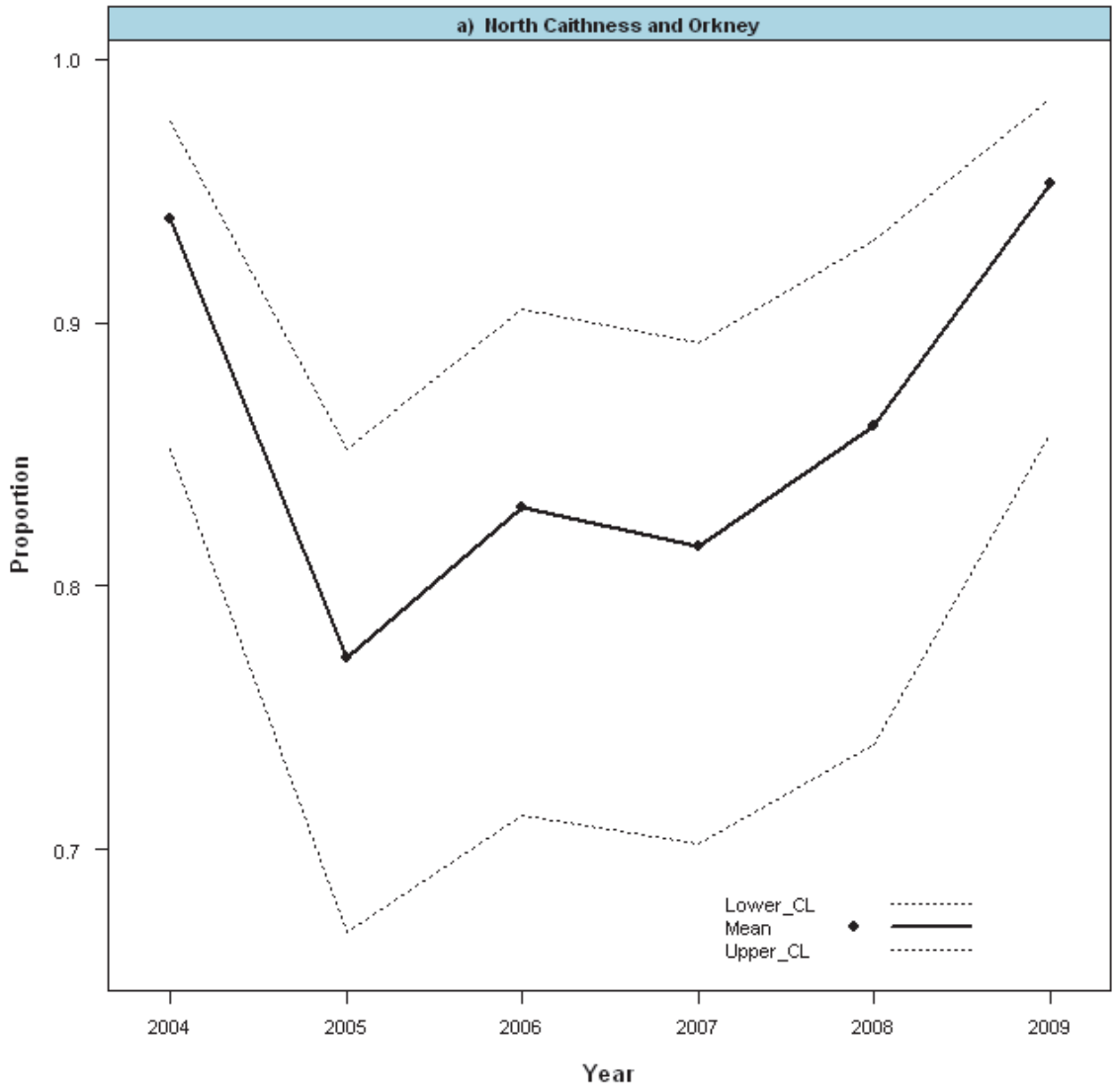


Figure 25. Best available trend in laying success (proportion of known breeding attempts in which at least one egg was laid) of hen harriers in the one NHZ for which a sufficient sample of data was available.
(Source: SRMS data)

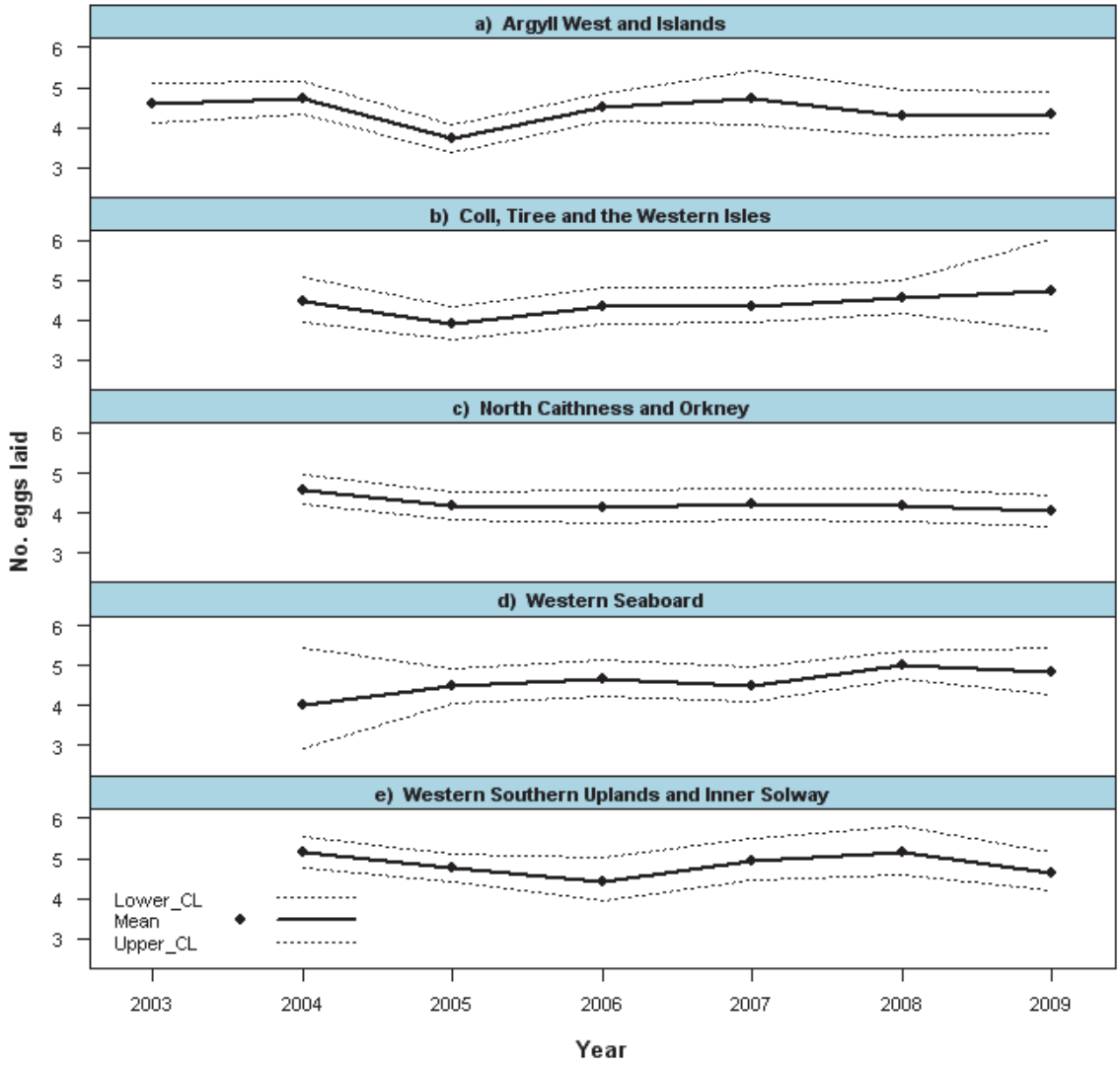


Figure 26. Best available trends in the clutch size of pairs laying eggs for hen harriers in five NHZs for which sufficient samples of data were available.
(Source: SRMS data)

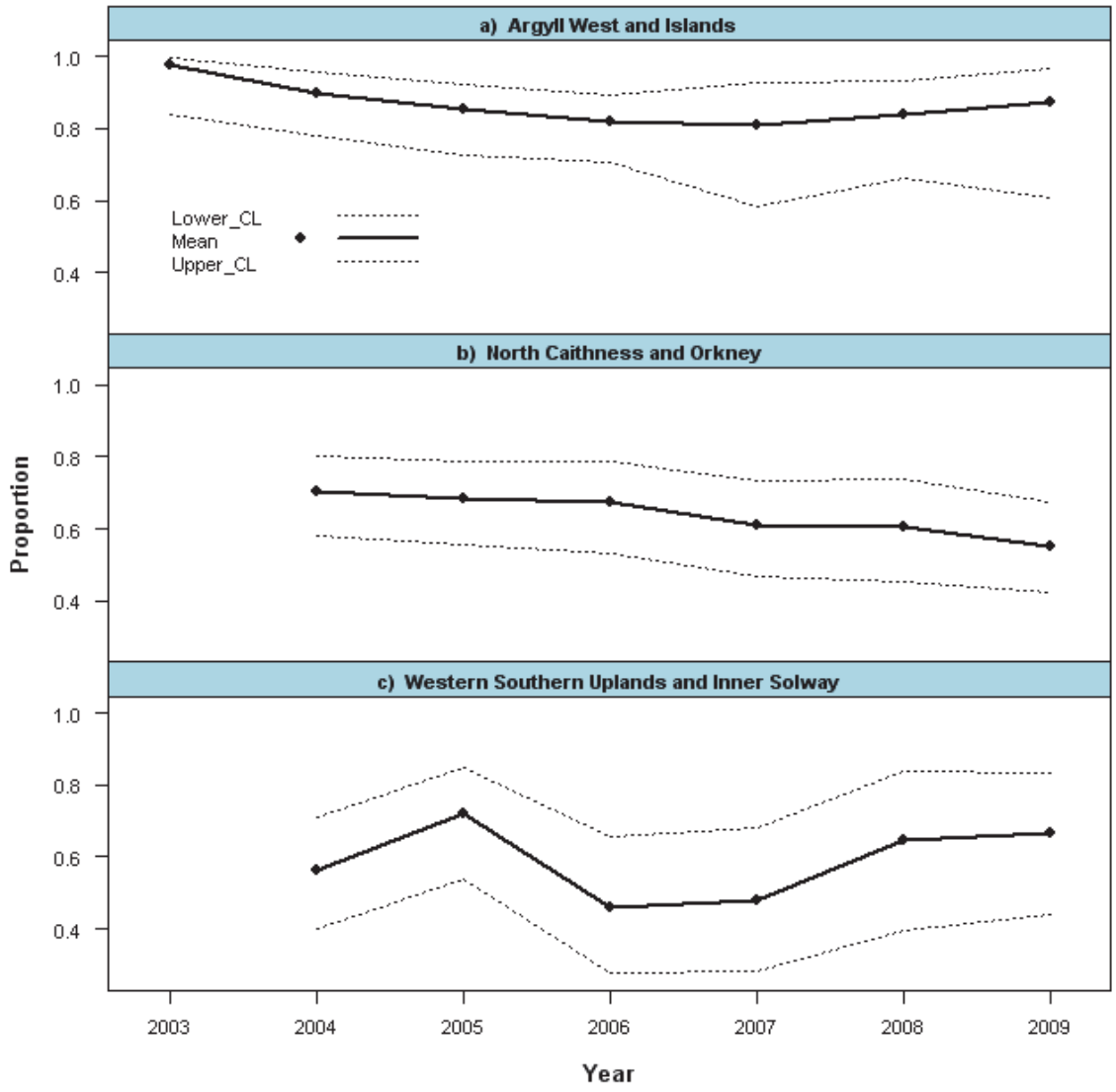


Figure 27. Best available trends in hatching success (proportion of pairs known to lay that hatched at least one young) for hen harriers in three NHZs for which sufficient samples of data were available.
(Source: SRMS data)

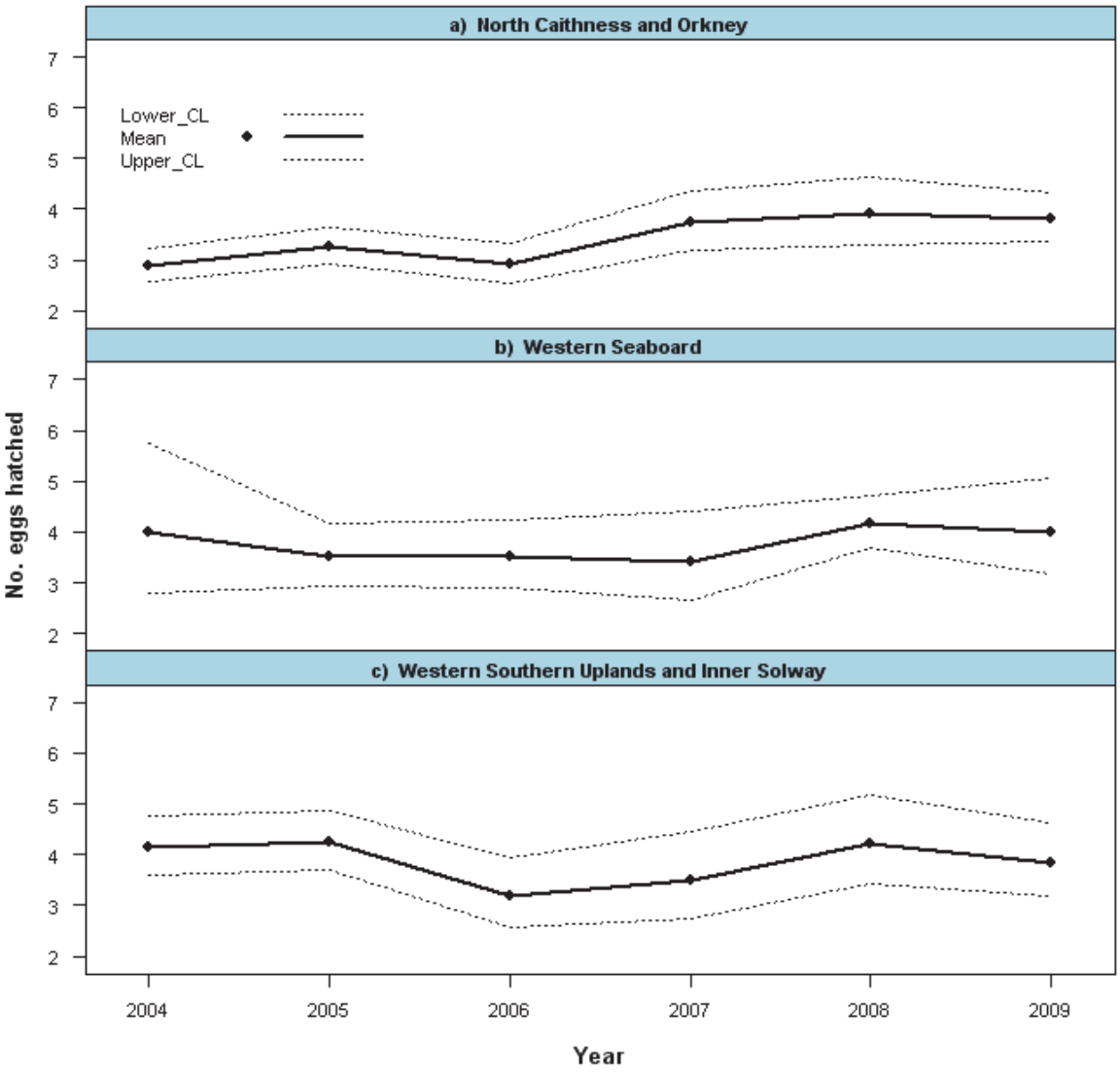


Figure 28. Best available trends in brood size at hatching of pairs hatching young for hen harriers in three NHZs for which sufficient samples of data were available.
(Source: SRMS data)

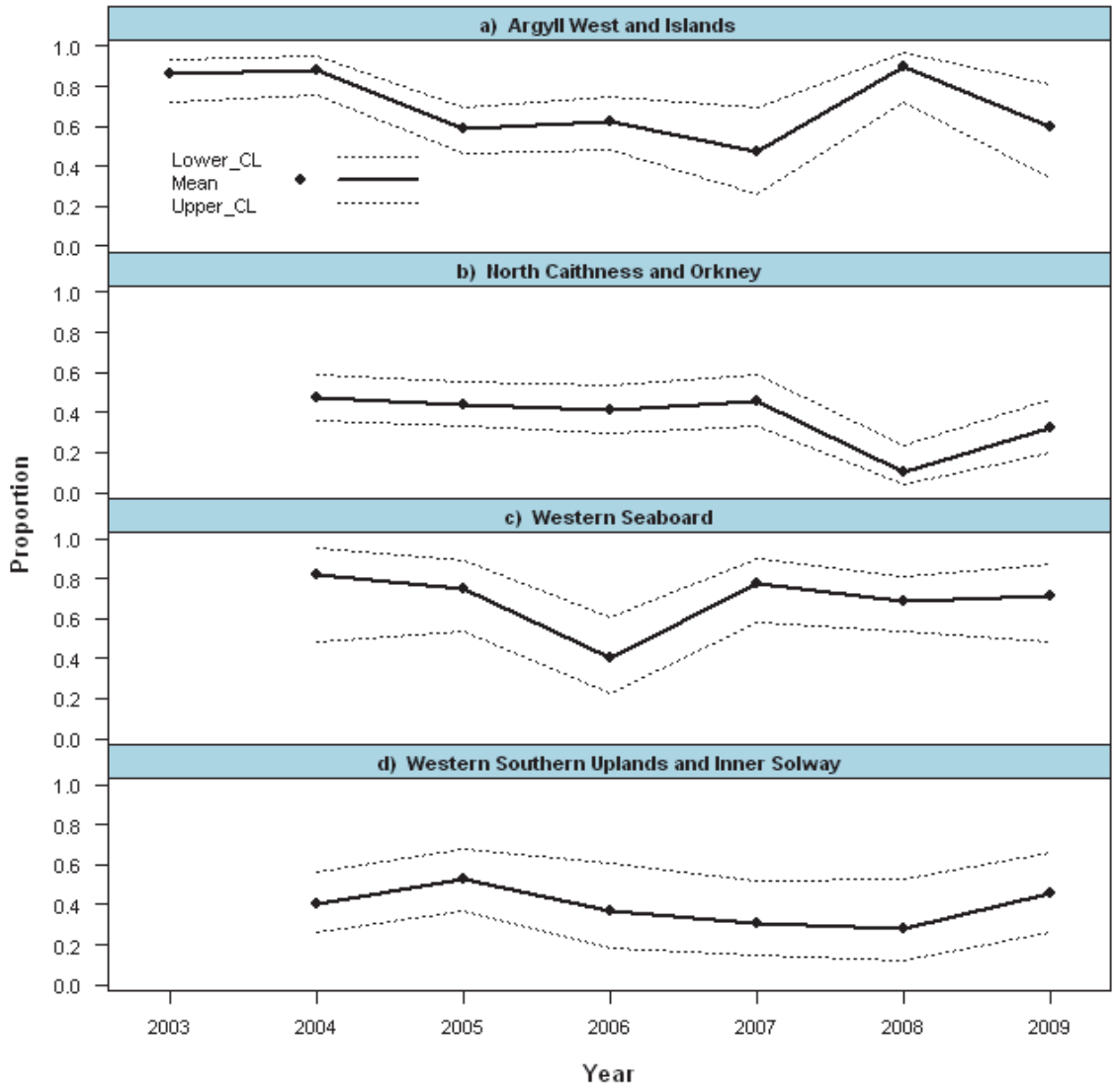


Figure 29. Best available trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for hen harriers in four NHZs for which sufficient samples of data were available.
(Source: SRMS data)

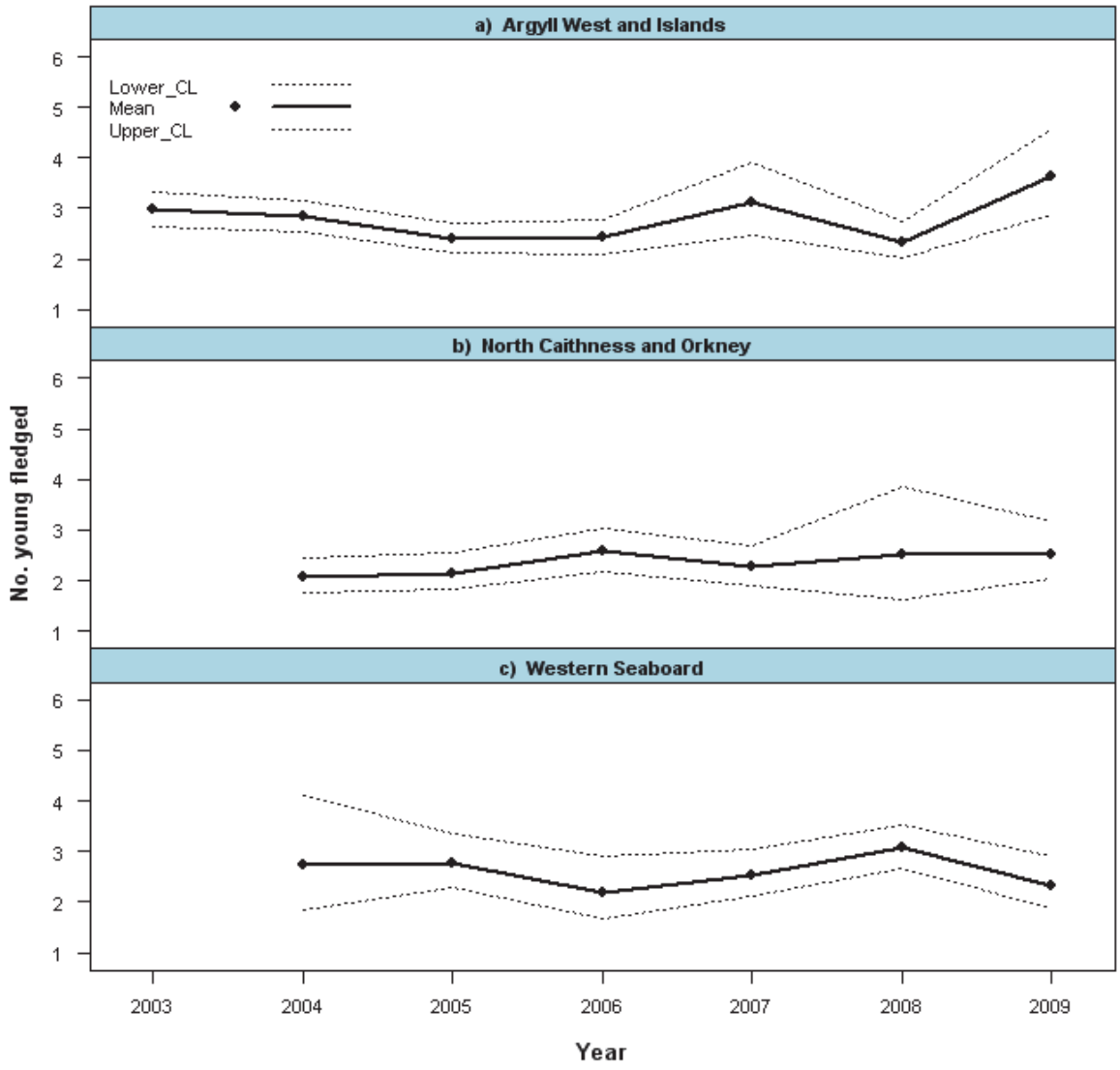


Figure 30. Best available trends in the number of young fledged per successful pair for hen harriers in three NHZs for which sufficient samples of data were available.
(Source: SRMS data)

1.4.4 Northern goshawk

Trends in breeding numbers
The best available trend for South-west Scotland shows a steady increase since 2003 (Figure 32) and that for North-east Scotland a marked increase since the mid-1990s (Figure 33; see also Marquiss *et al*. 2003; Marquiss 2011). The best available trend for the Border Hills and south Lothian suggests some recent decline in the part of the Scottish population in that study area (Figure 32).

A trend in breeding numbers (back to the early 1970s) from a study in north-east Scotland (most in NHZ 12 but partly in NHZ 9), and best available trends since 2003 from two study areas: one in the Border Hills and south Lothian (parts of NHZs 16 and 20), and one in South-west Scotland (parts of NHZs 19 and 20), are reported. Together these three studies (Figure 31) are considered to cover a large proportion of the overall Scottish breeding population of this species, and are therefore broadly representative of the breeding pairs in each encompassing NHZ and nationally. See Annex Table B15 for numbers of territories checked each year.

Trends in breeding productivity
The best available trends in breeding productivity do not suggest any systematic changes through time in laying success (Figure 34), fledging success (Figures 35 & 36) or the number of fledglings produced per successful pair (Figures 37 & 38) in any of the three study areas.

Trends in the proportion of pairs laying, proportion fledging at least one young and number fledged per successful pair, back to 1996 for the North-east Scotland study area, and best available trends in fledging success and the numbers of young fledged per successful pair for the two other study areas are reported. Together these three studies are considered to cover a large proportion of the overall Scottish breeding population of this species, and changes in breeding parameters are therefore broadly representative of the breeding pairs in each encompassing NHZ and nationally. See Annex Table B16 for sample sizes contributing to trends in breeding parameters.

Data sources, caveats, work pending and gaps
SRMS data were used to produce trends in numbers and breeding parameters for this species, supplemented by data provided by Mick Marquiss for the North-east Scotland study area. Trends from the North-east Scotland study area are based on coverage and effort that is known to have been consistent during the time period reported here. Trends from the two other study areas should be regarded as provisional until coverage and effort have been further assessed.

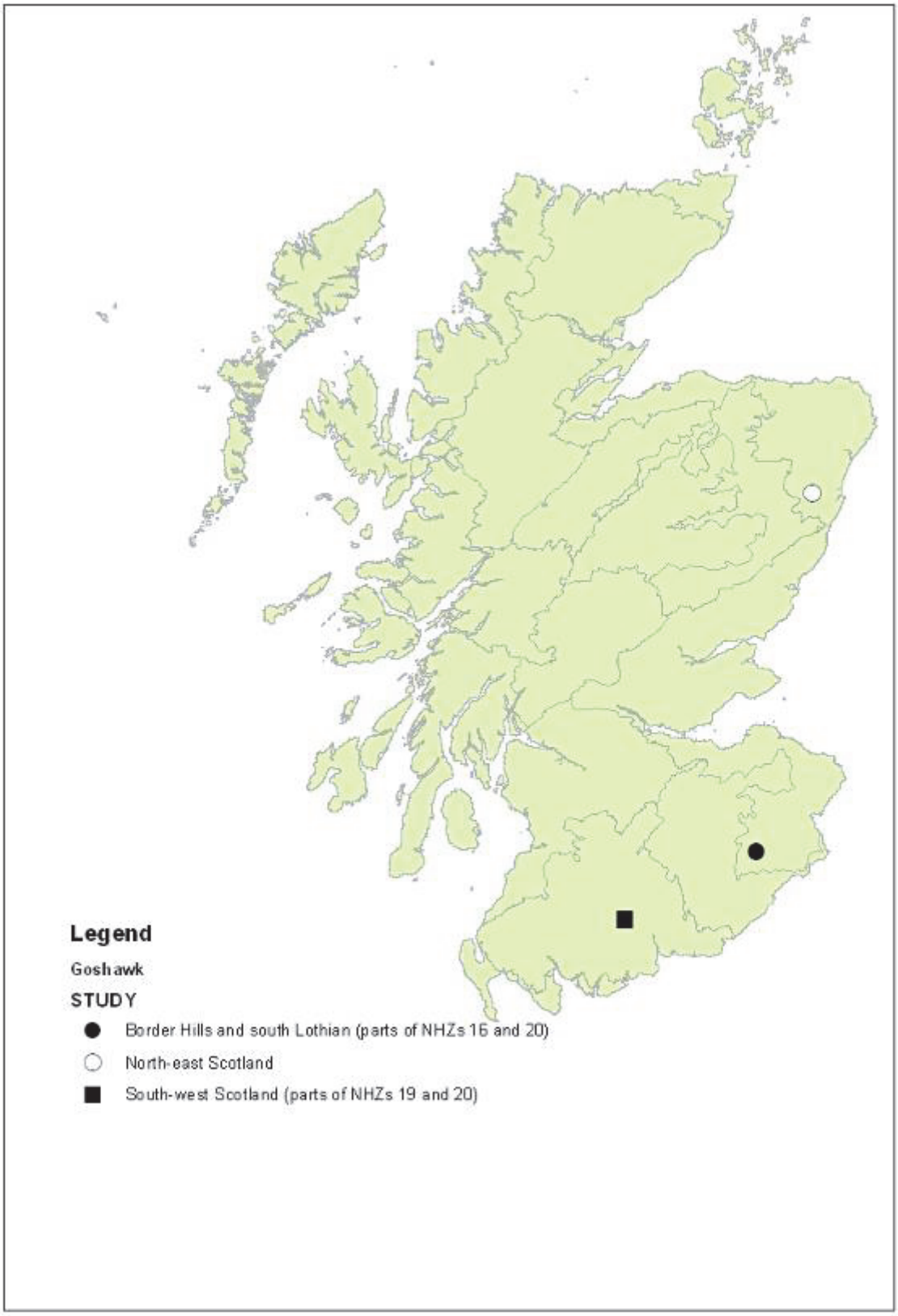


Figure 31. The locations of the three goshawk studies contributing information on trends.

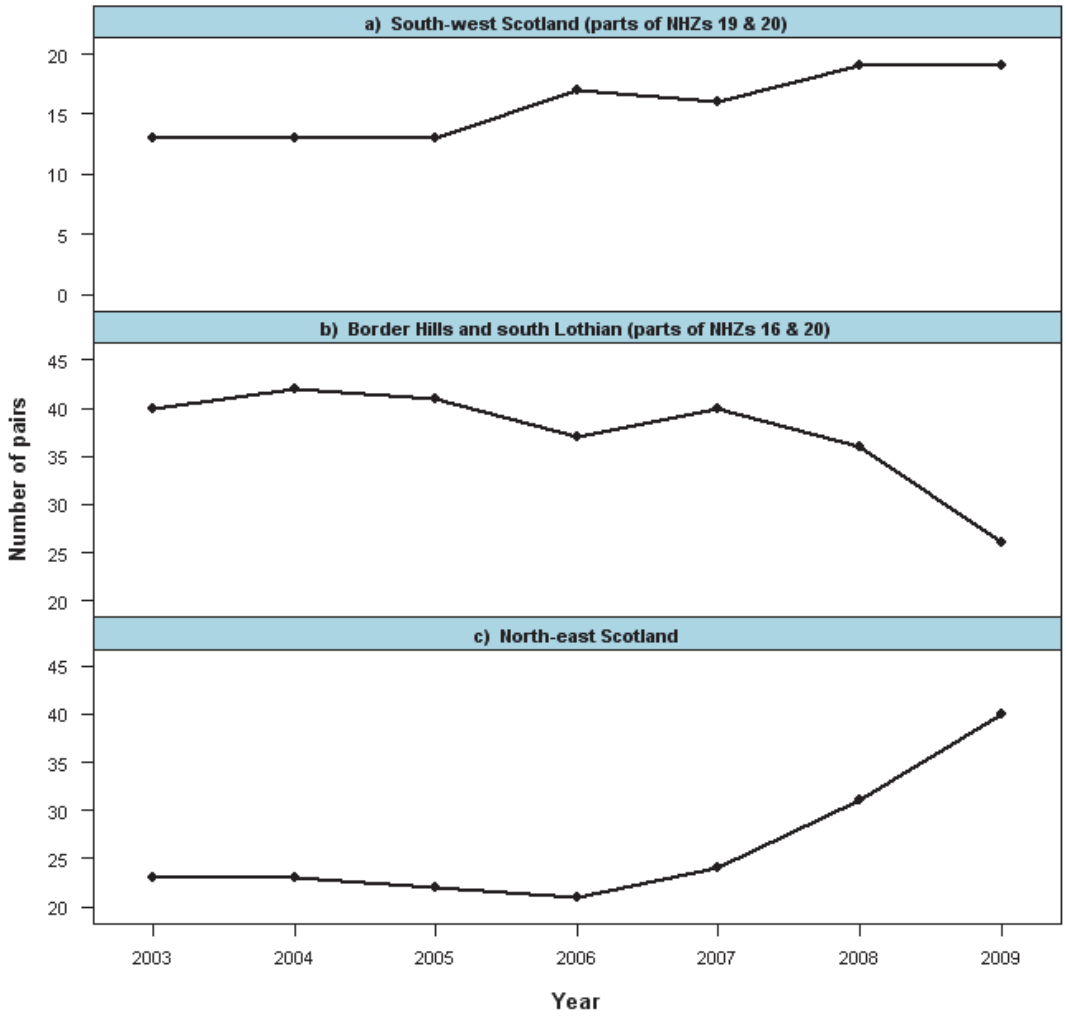


Figure 32. Best available trends in the number of breeding northern goshawks in three study areas in Scotland.
(Source: SRMS data, Mick Marquiss for North-east Scotland)

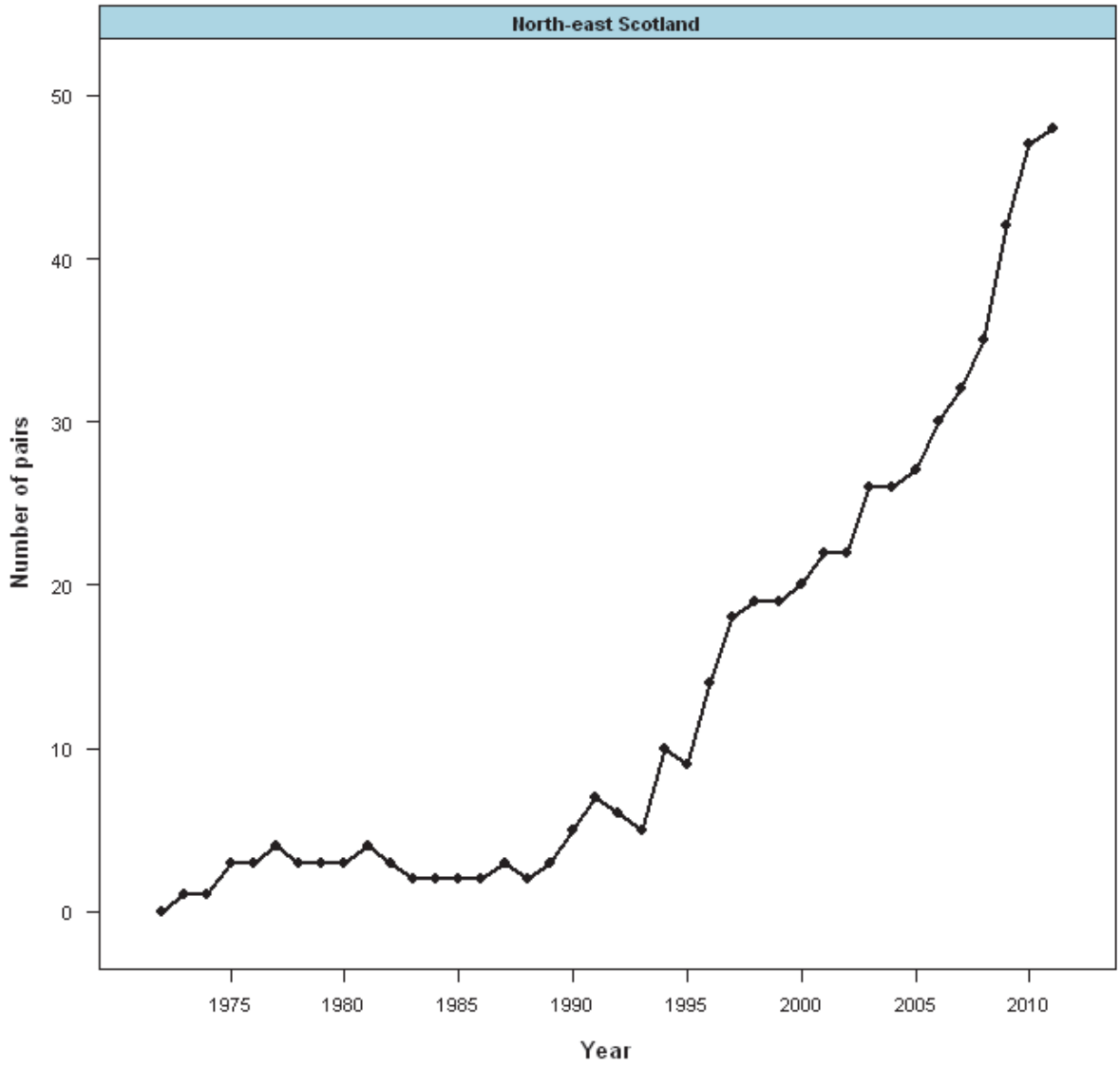


Figure 33. Trend in the number of breeding northern goshawks in a study area in North-east Scotland (mostly NHZ 12, with parts in NHZ 9) since 1973.
(Source: Mick Marquiss, pers. comm.)

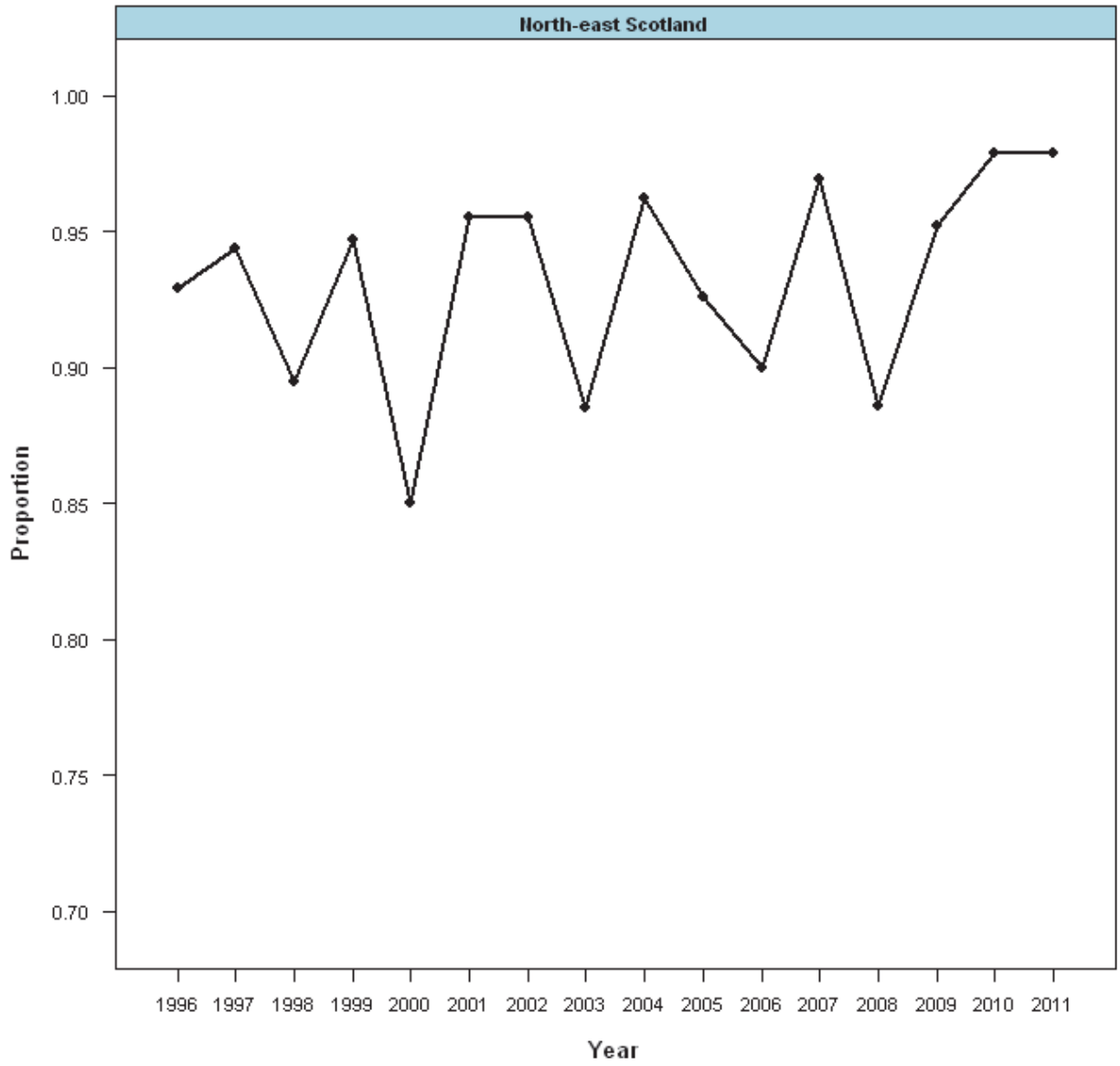


Figure 34. Trend in laying success (proportion of known pairs that laid at least one egg) for northern goshawks in a study area in North-east Scotland.
(Source: Mick Marquiss pers. comm.)

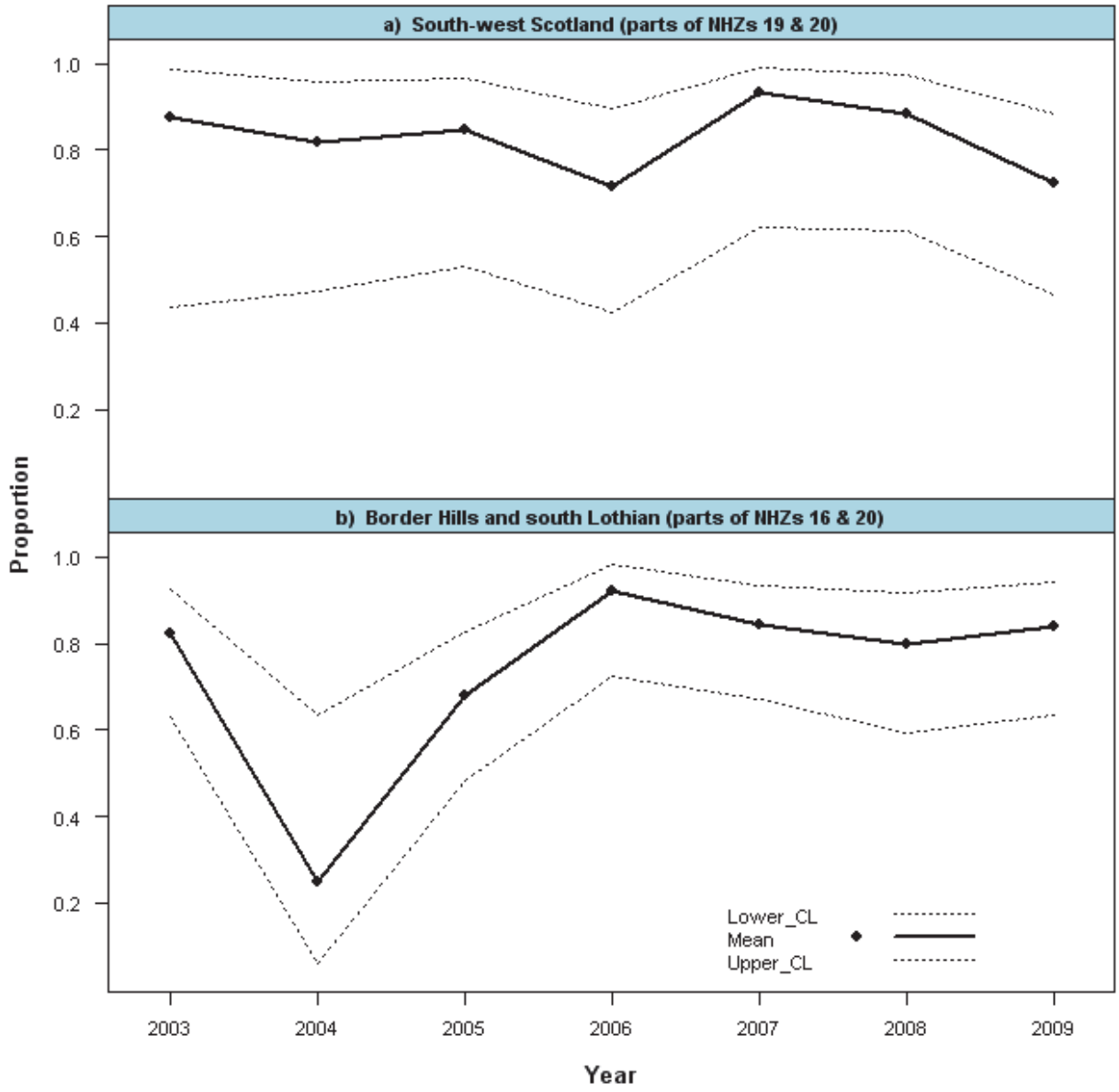


Figure 35. Best available trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for northern goshawks in two study areas of Scotland.
(Source: SRMS data)

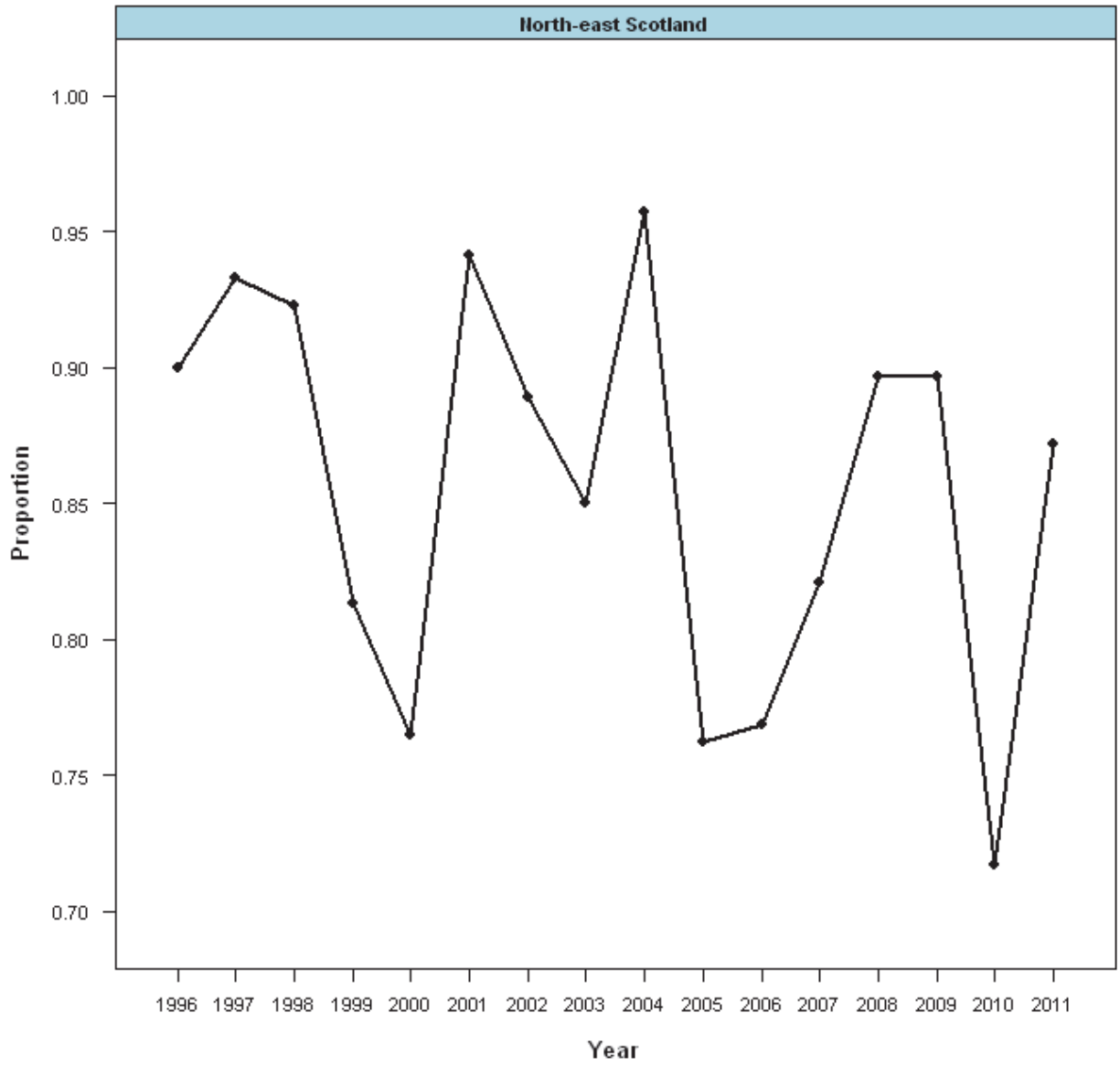


Figure 36. Trend in fledging success (proportion of pairs known to hatch young that fledged at least one young) for northern goshawks in a study area in North-east Scotland. (Source: Mick Marquiss pers. comm.)

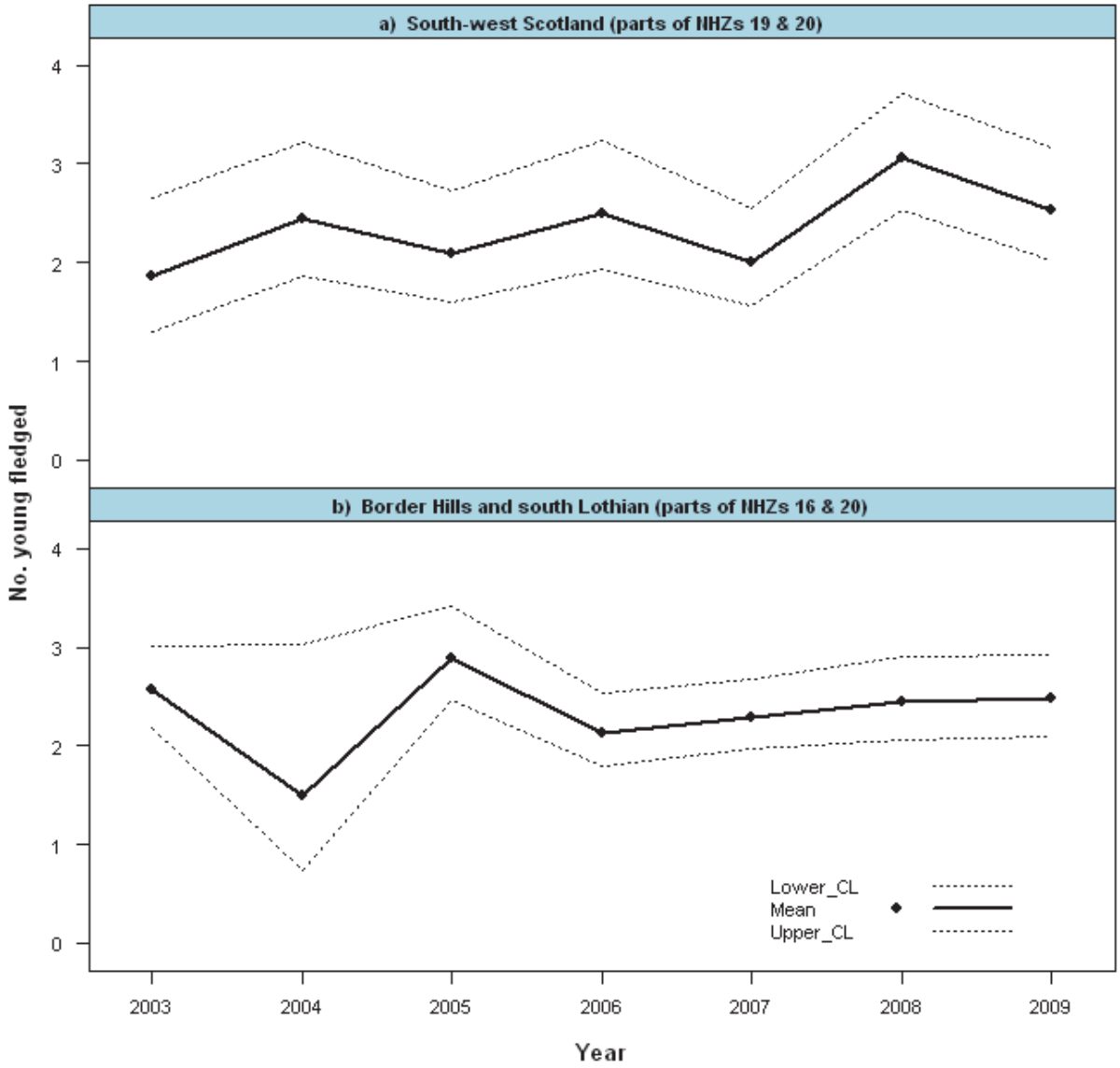


Figure 37. Best available trends in the number of fledglings produced per successful pair for northern goshawks in two study areas of Scotland.
(Source: SRMS data)

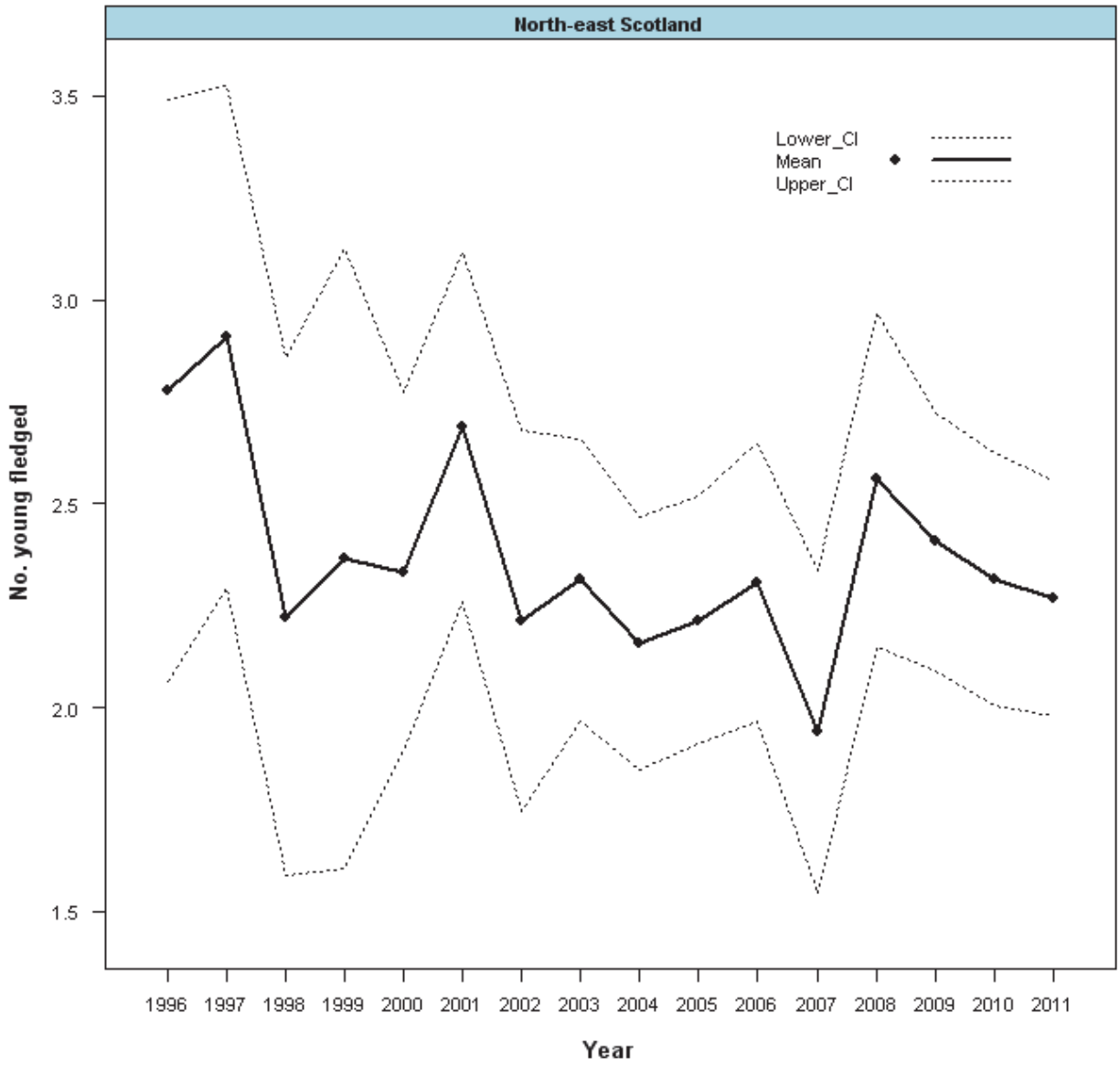


Figure 38. Trend in the number fledged per successful pair for northern goshawks in a study area in North-east Scotland.
(Source: Mick Marquiss pers. comm.)

1.4.5 Eurasian sparrowhawk

Trends in breeding numbers
The best available national trend (from BBS) suggests a small decline in the most recent years (Figure 40). The best available trend in breeding numbers for an Ayrshire study area (spanning NHZs 17 and 19) suggests some increase followed by decrease in the number of breeding pairs since 2003 (Figure 41). See Annex Table B17 for sample sizes available for analysis.

Trends in breeding productivity
The three best available trends for the Ayrshire study area - clutch size for pairs that laid (Figure 42); fledging success (Figure 43); and the number fledged per successful pair (Figure 44) - all suggest signs of decrease since 2003.

Data sources, caveats, work pending and gaps
The national trend in breeding abundance from the BTO/JNCC/RSPB Breeding Bird Survey should not be regarded as definitive because sparrowhawks are currently recorded on fewer survey squares in Scotland (Annex Figure A1) than the recommended lower threshold of 30 BBS squares required on an annual basis: a smoothed trend is not produced and statistical significance not currently tested routinely for this species. In addition, we cannot assess for certain to what extent the provisional breeding abundance trend from the BBS is representative of breeding sparrowhawks across Scotland as a whole until up-to-date sparrowhawk distribution data for Scotland are available (from Bird Atlas 2007-11).

The other analyses were based on SRMS data for 2003-2009. There are a number of areas of Scotland from which breeding attempts have been reported to the SRMS since 2003 but most have been ad hoc reports of individual breeding attempts. The single study in Ayrshire run by Ian Todd appears to have sufficient systematic annual coverage to permit the reporting of trends in breeding numbers (see Annex Table B17) or breeding parameters (Annex Table B18). There has been some minor variation in coverage across this study area since 2003; hence trends are currently provisional until this can be accounted for in analyses.

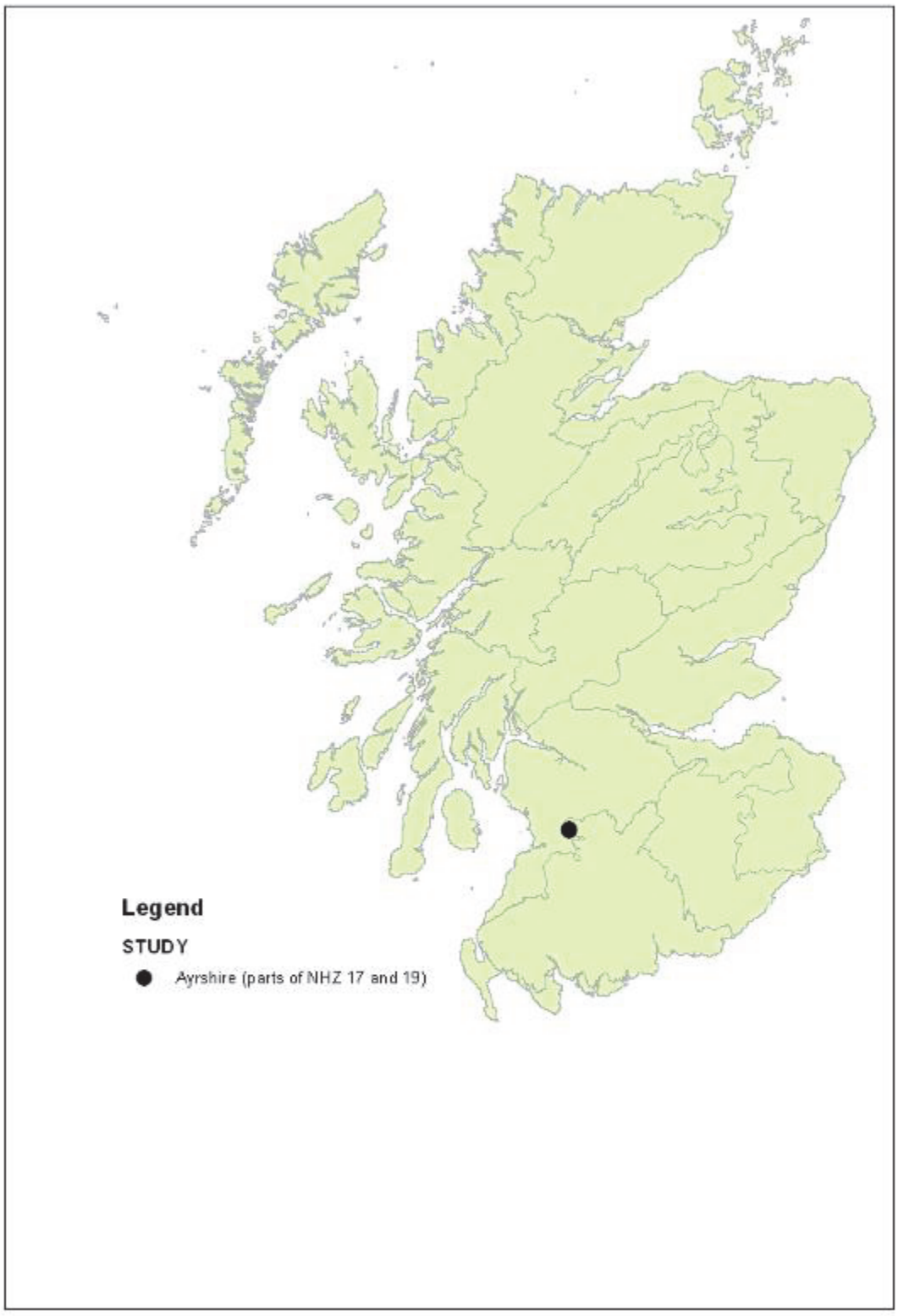


Figure 39. The location of the Ayrshire Eurasian sparrowhawk study contributing information on trends.

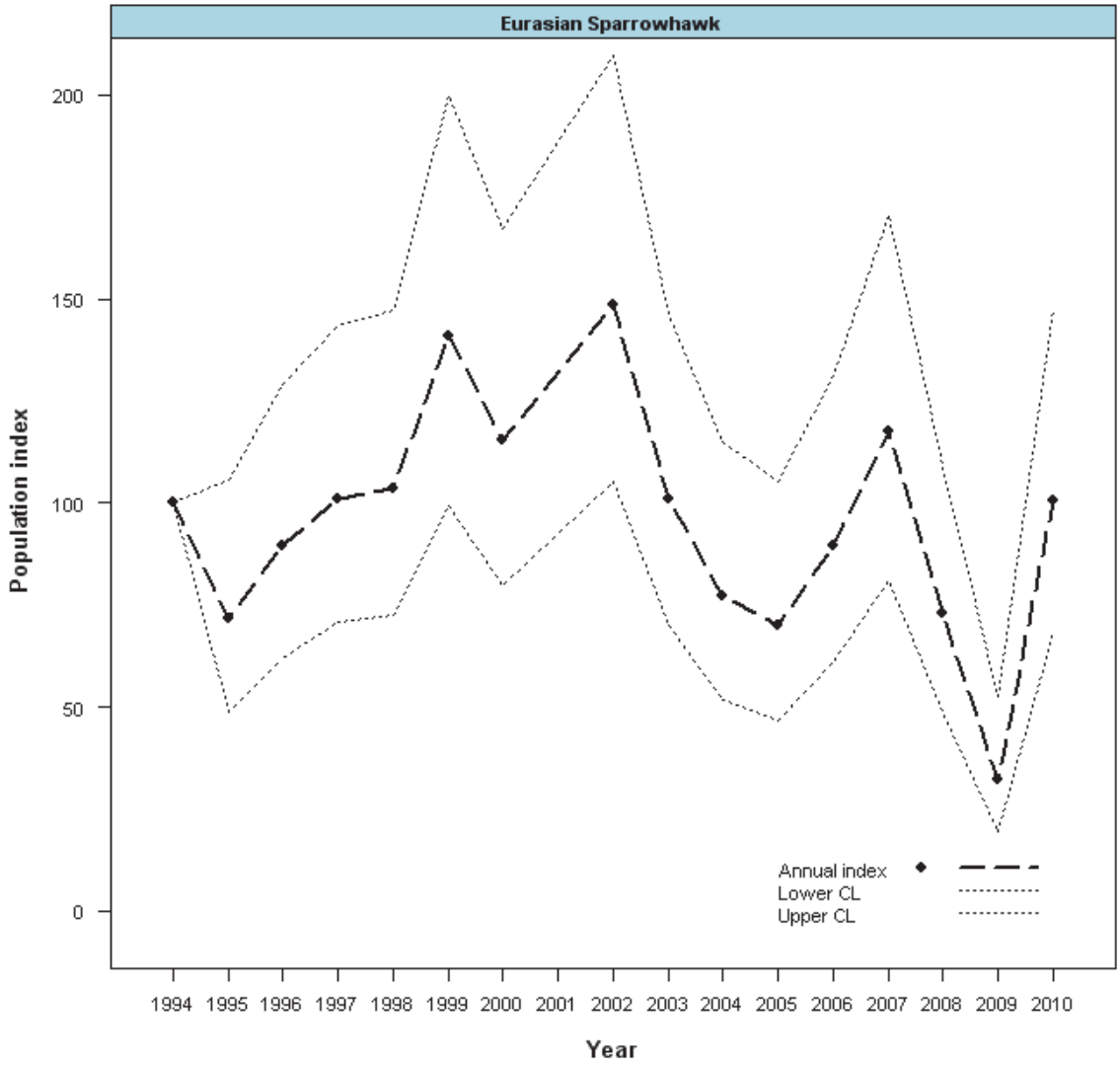


Figure 40. Best available trend in the breeding abundance of Eurasian sparrowhawks in Scotland between 1994 and 2010 (relative to index value set at 100 in 1994).

Note that sparrowhawks are currently recorded on fewer survey squares in Scotland than the lower threshold of 30 BBS squares routinely required on an annual basis to produce trends, such that a smoothed trend is not currently produced for this species.
(Source: BTO/JNCC/RSPB Breeding Bird Survey data)

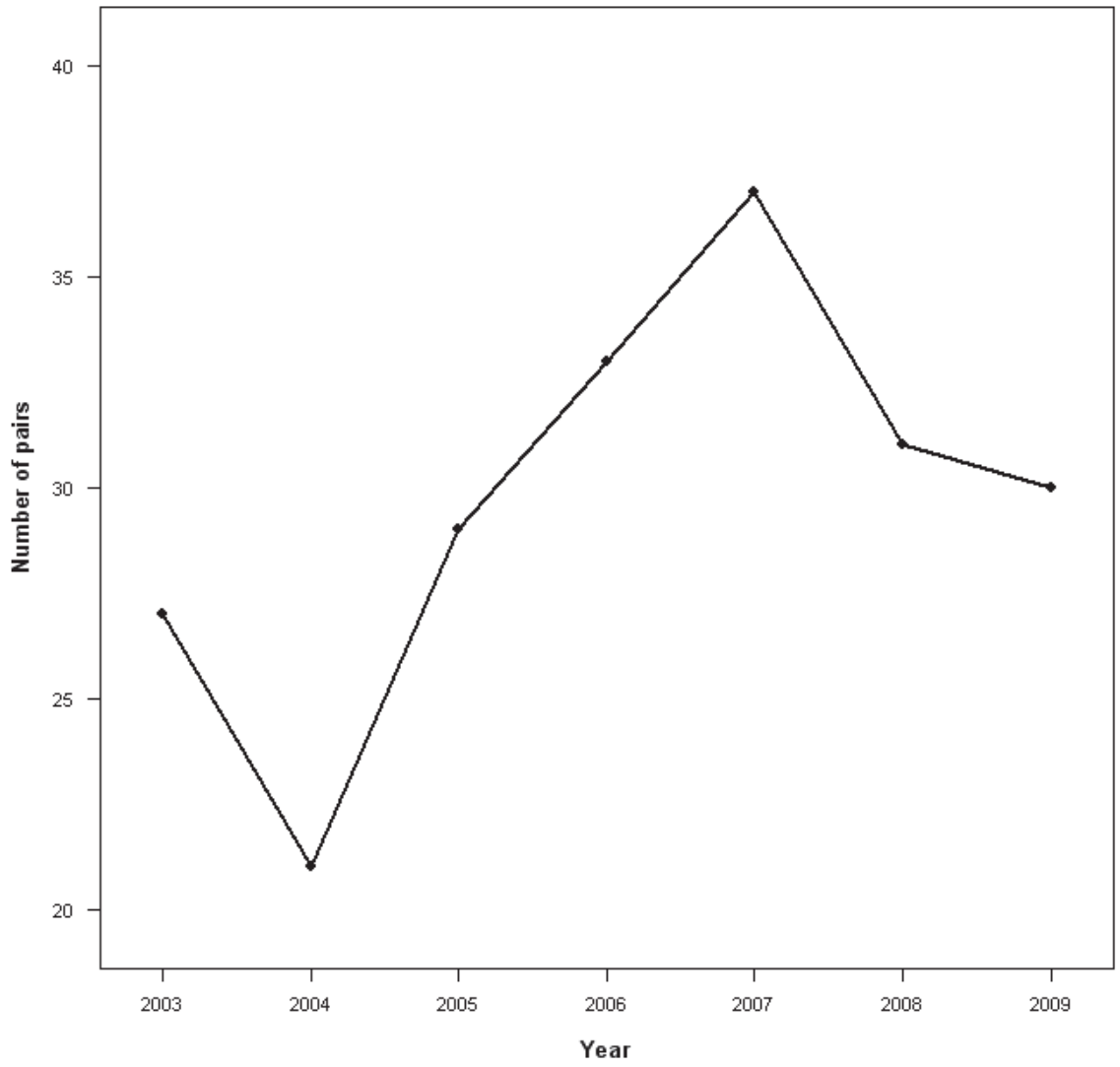


Figure 41. Best available trend in the number of breeding Eurasian sparrowhawks in a study area in Ayrshire (covering parts of NHZs 17 and 19).
(Source: SRMS data)

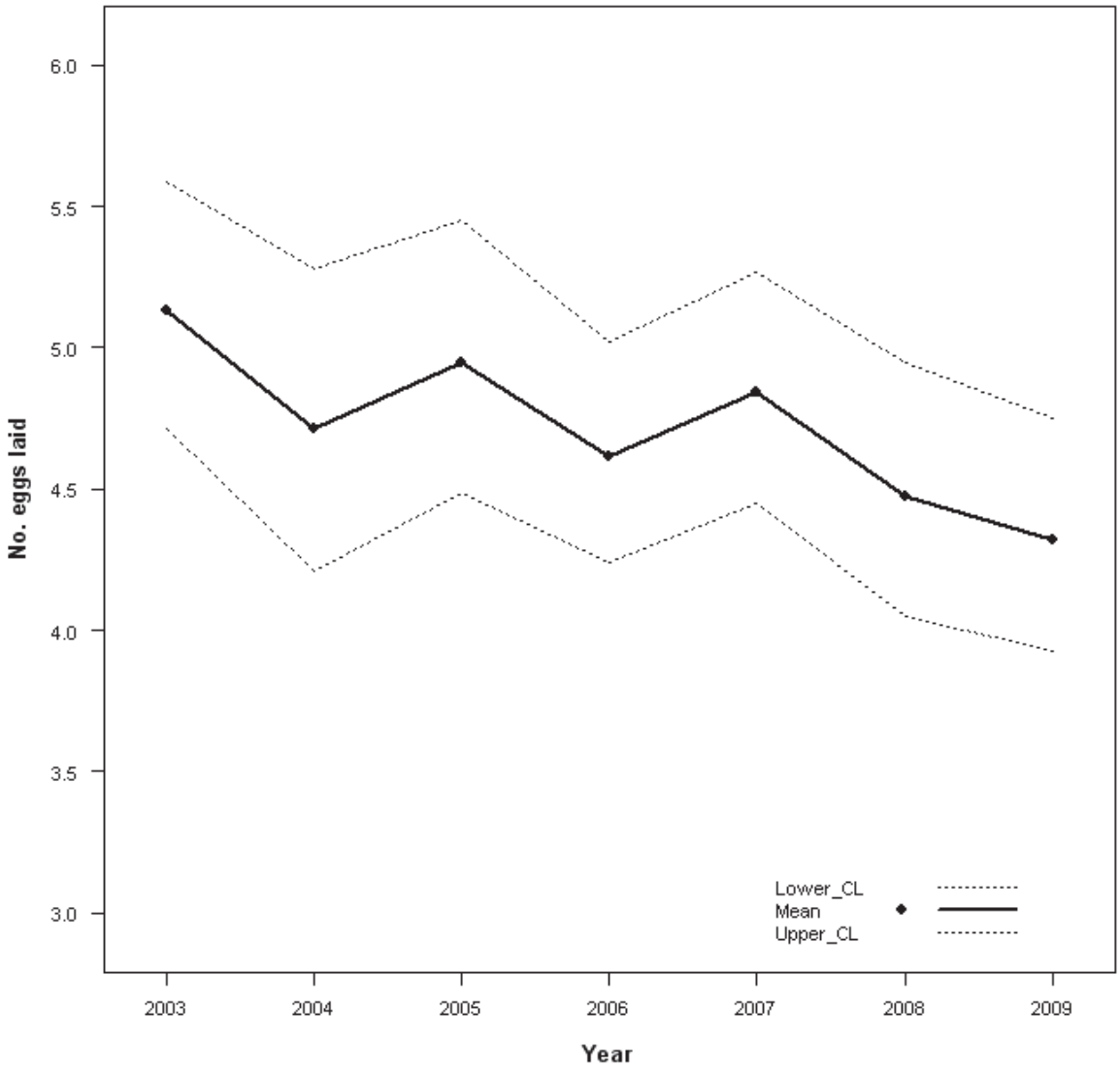


Figure 42. Best available trend in clutch size for pairs that laid for Eurasian sparrowhawks in a study area in Ayrshire (covering parts of NHZs 17 and 19).
(Source: SRMS data)

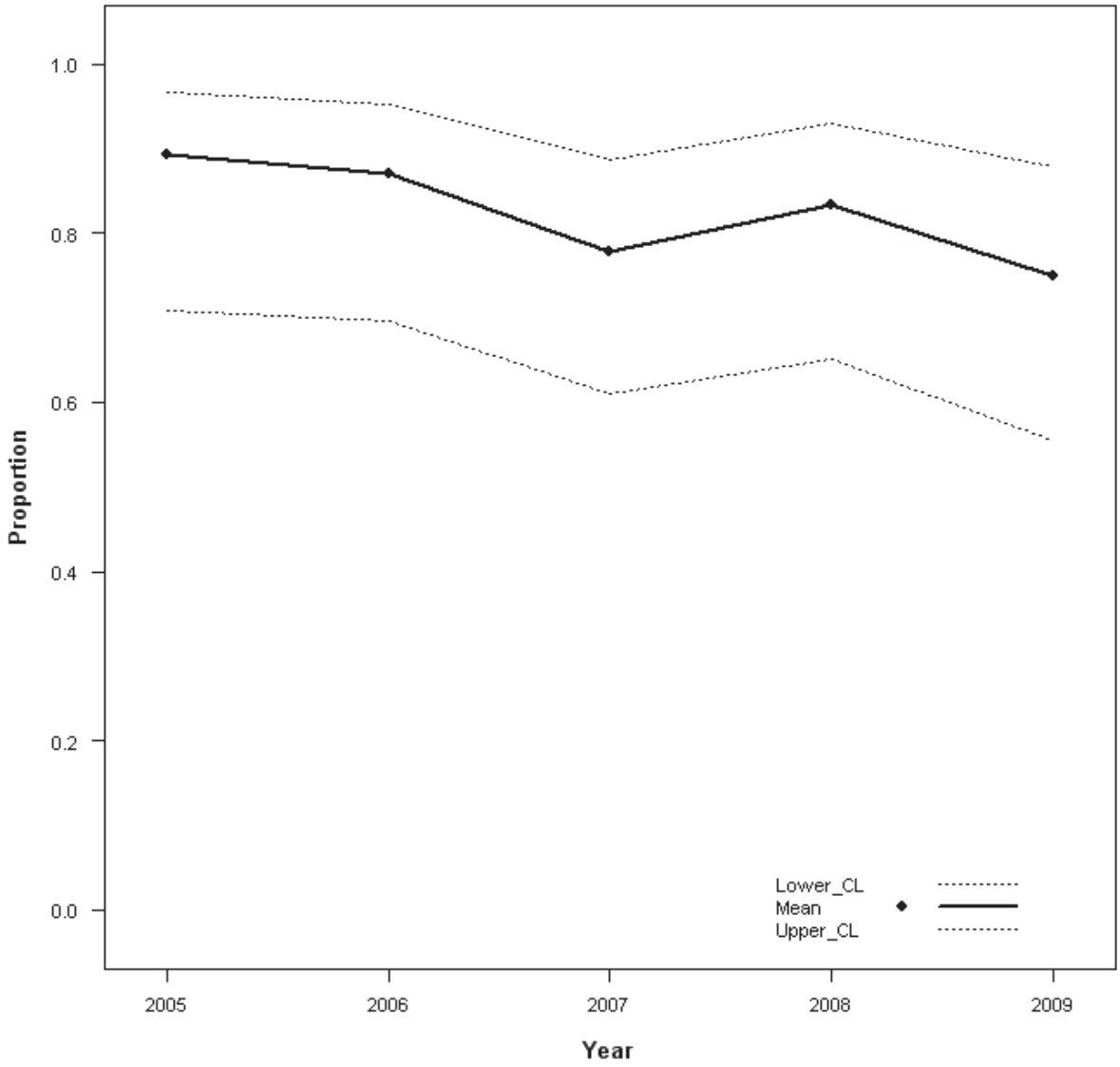


Figure 43. Best available trend in fledging success (proportion of pairs known to hatch young that fledged at least one young) for Eurasian sparrowhawks in a study area in Ayrshire (covering parts of NHZs 17 and 19).
(Source: SRMS data)

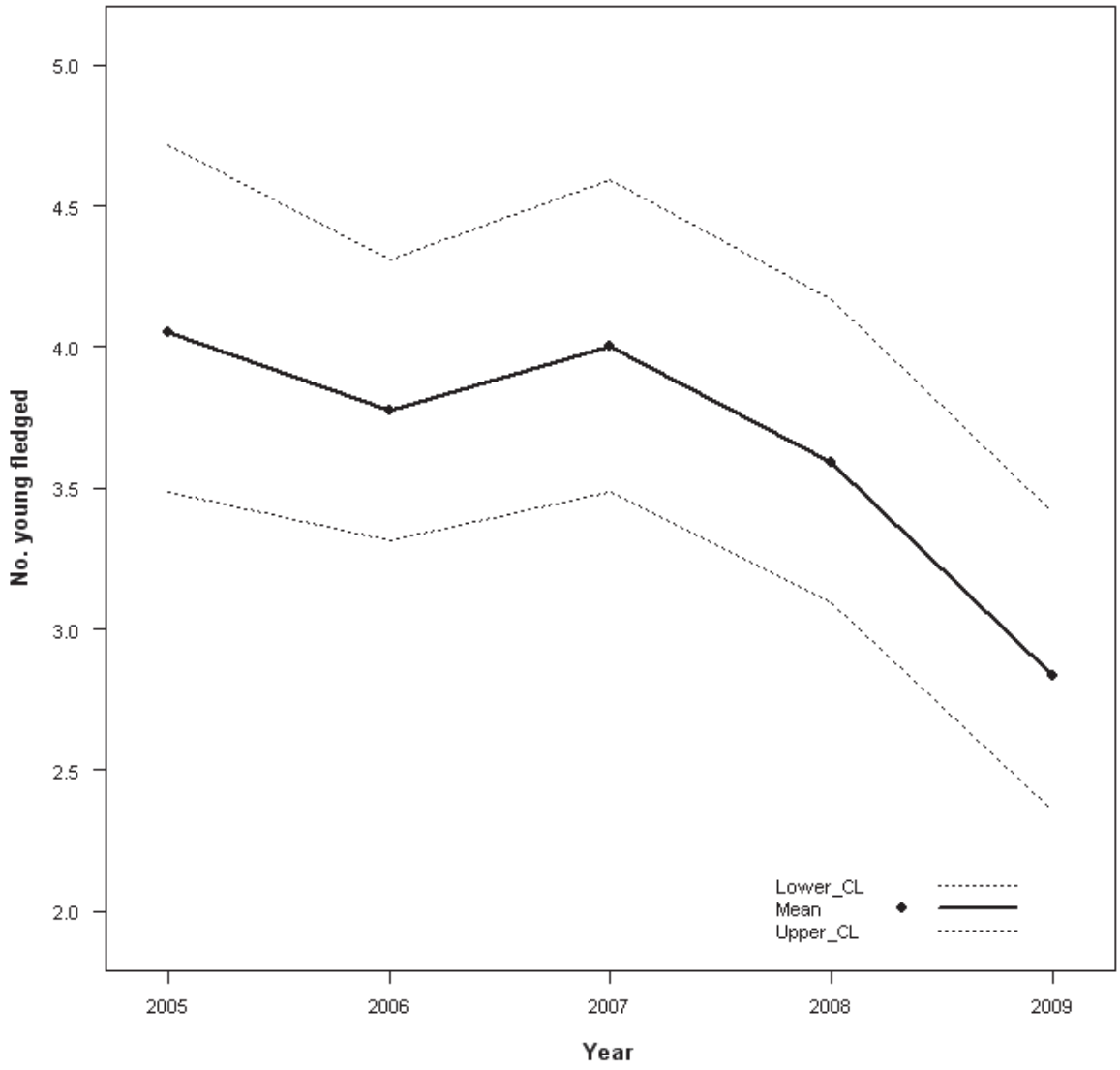


Figure 44. Best available trend in the number fledged per successful pair for Eurasian sparrowhawks in a study area in Ayrshire (covering parts of NHZs 17 and 19).
(Source: SRMS data)

1.4.6 Common buzzard

Trends in breeding numbers
The national trend in buzzard breeding abundance, from BBS results, (Figure 45) shows a sustained and statistically significant increase between 1994 and 2002, with some degree of stabilisation since 2002. Overall, the abundance index for Scotland increased by 36% (lower and upper confidence limits 11-76%) between 1995 and 2009 (Risely *et al*. 2011).

The best available trends in breeding numbers in the six study areas (Figure 46) across Scotland are highly variable from year to year, showing no consistent trends (Figure 47).

The six study areas (Cowal and Bute (part of NHZ 14); Moray and Dornoch (parts of NHZs 5, 7 and 21); Colonsay (part of NHZ 14); Stirling and the Trossachs (parts of NHZs 15, 16, and 17); Lothian (parts of NHZs 16, 17 and 20); and the Uists (part of NHZ 3)) are well spread across Scotland and include both traditional buzzard strongholds and areas of recent population recovery. See Annex Table B19 for sample sizes available for analysis.

Trends in breeding productivity
In general breeding productivity parameters have been relatively stable in the study areas across recent years. The best available trends in clutch size for pairs that laid (Figure 48) and brood size at hatching for pairs that hatched young (Figure 49) are reported for two of the six study areas, and fledging success (Figure 50) and the number fledged per successful pair (Figure 51) for four of the six study areas. See Annex Table B 20 for sample size information.

Data sources, caveats, work pending and gaps
Buzzards were recorded in 135 of the 329 squares surveyed for the BTO/JNCC/RSPB Breeding Bird Survey in Scotland in 2010 (Risely *et al*. 2011; see Annex Figure A2). We consider that the national trend in breeding abundance produced by the BBS may overestimate the overall increase in breeding buzzard numbers across Scotland as a whole because: (i) the survey squares covered are biased towards the areas in which the largest increases have occurred during the last 20 years (Simon Gillings, pers. comm.); and (ii) because BBS methodology is not designed to allow breeding pairs to be distinguished from non-breeding 'floaters', numbers of which may not vary in direct proportion to the numbers of breeding pairs in a population.

The other analyses were based on SRMS data for 2003-2009. Initial scoping of the SRMS datasets suggested that 10 widely distributed buzzard studies had the potential to be used in trend analyses. Some of these studies have been initiated relatively recently however, or include only a small sample of nests for several years, and thus it was only possible to report trends in numbers and breeding parameters from six of these studies. For three of these studies, the number of years included in trends analysis was restricted due to low sample sizes in the early years of the studies (see Annex Table B19). Trends from the six study areas must be regarded as provisional until annual coverage and effort is verified with the relevant observers. For example, in the study area on the Uists, the number of monitored nest sites decreased in 2009 (Annex Table B19) due to lack of monitoring on the island of Barra and outlying islands, whilst the core part of the study on the Uists appears to have been comprehensive in all years. For the Cowal and Bute study, the lower number of monitored nest sites in 2006 is probably due to an almost complete lack of coverage on mainland Argyll, whereas coverage of the Isle of Bute appears to have been comprehensive from 2004 to 2009. Conversely, for the study in Stirling and the Trossachs, visual inspection of the year-specific maps suggests that the increasing number of monitored nest sites is due to a shorter distance between neighbouring nests but we need to verify with observers whether this is due to population increase, leading to smaller territories, or increased monitoring effort.

Given the number of and geographical spread of studies of common buzzard that submit data to the SRMS currently (Annex Table B19), national trends should be possible in future once we have an improved picture of monitoring coverage.

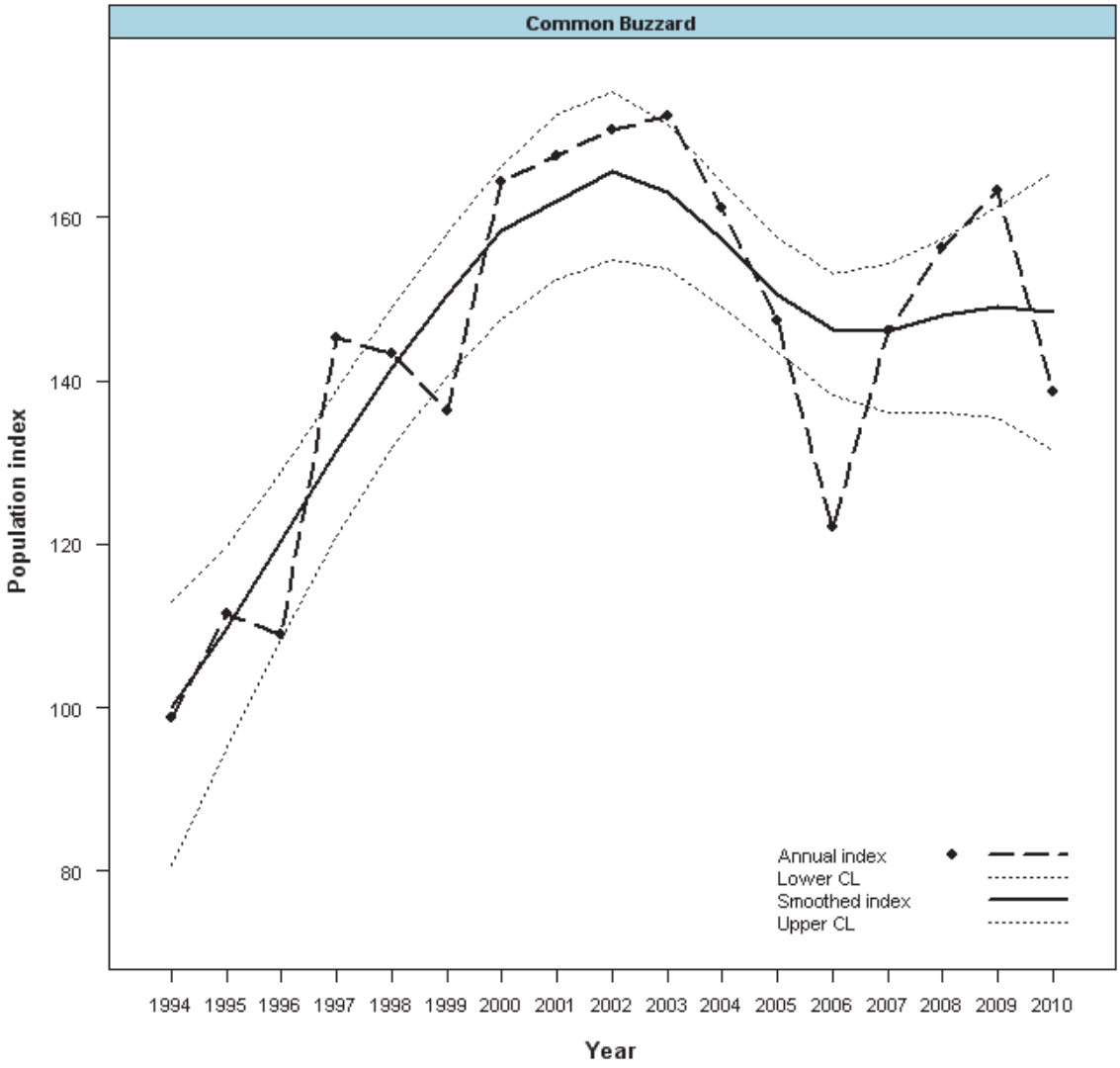


Figure 45. Trend in the breeding abundance of common buzzard in Scotland between 1994 and 2010 (relative to index value set to 100 in 1994).

Both the annual index values, and the smoothed index with associated 95% confidence limits, are shown. (Source: BTO/JNCC/RSPB Breeding Bird Survey data)

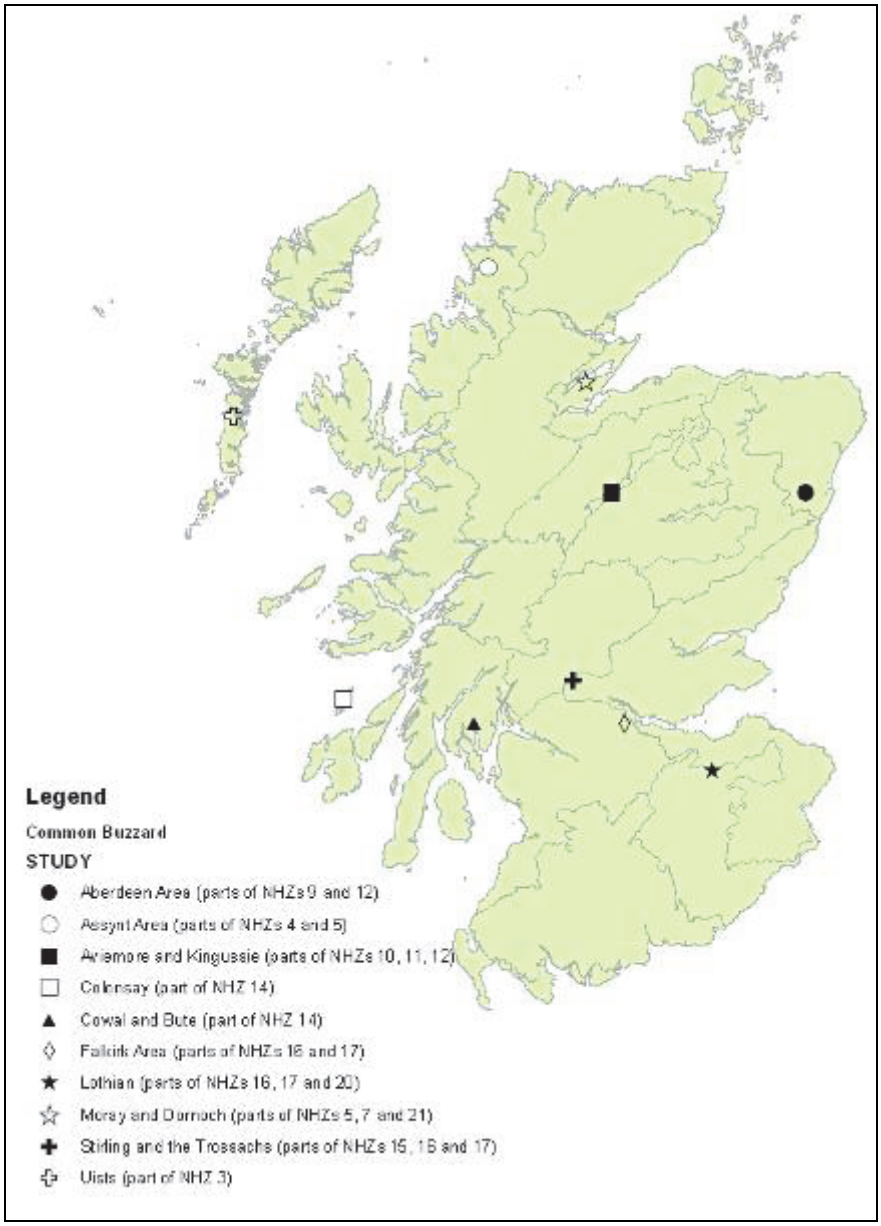


Figure 46. The locations of the six common buzzard studies contributing information on trends and four other studies considered as part of the current project.

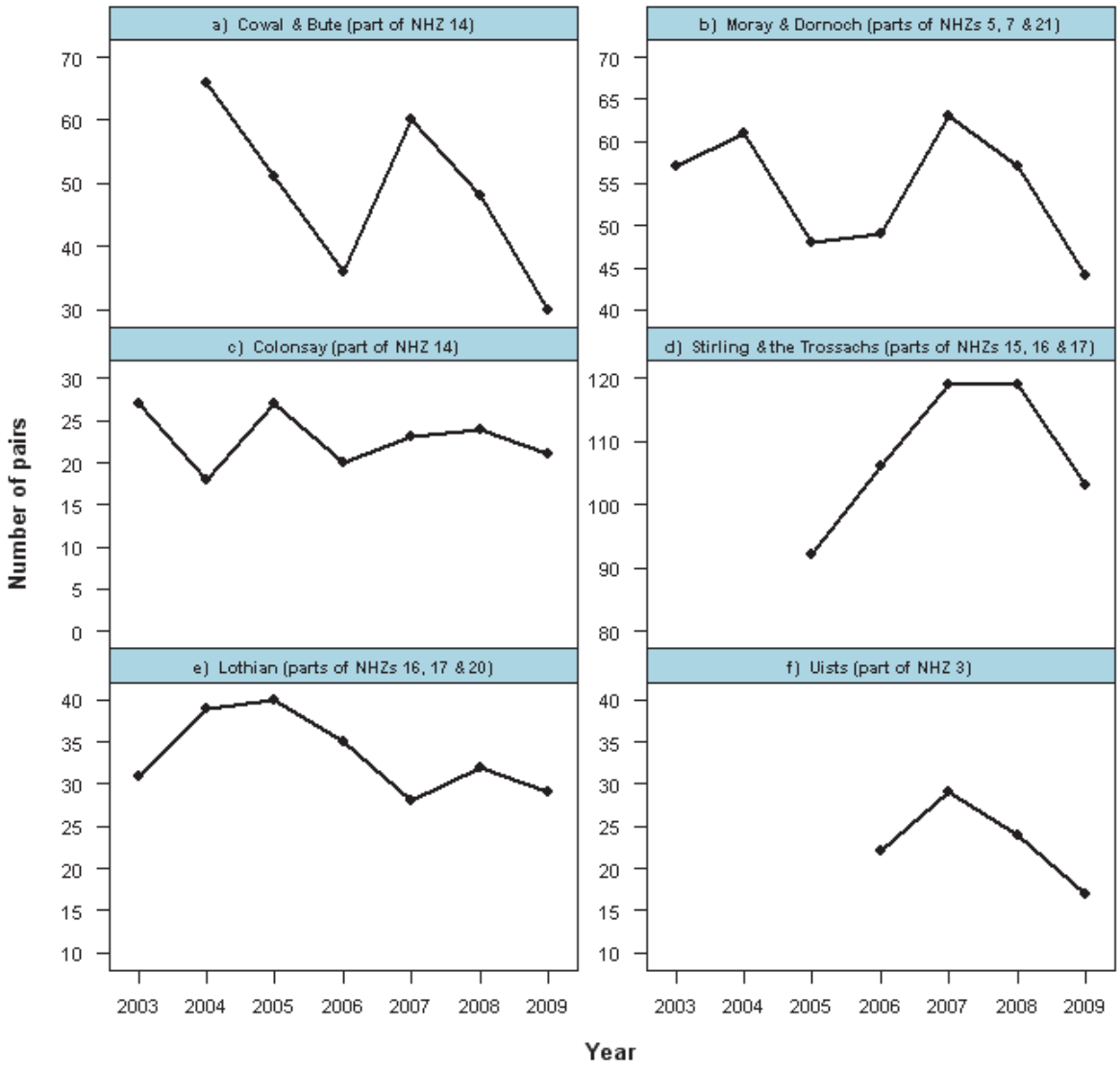


Figure 47. Best available trends in the number of breeding common buzzards in six study areas in Scotland between 2003 and 2009. (Source: SRMS data)

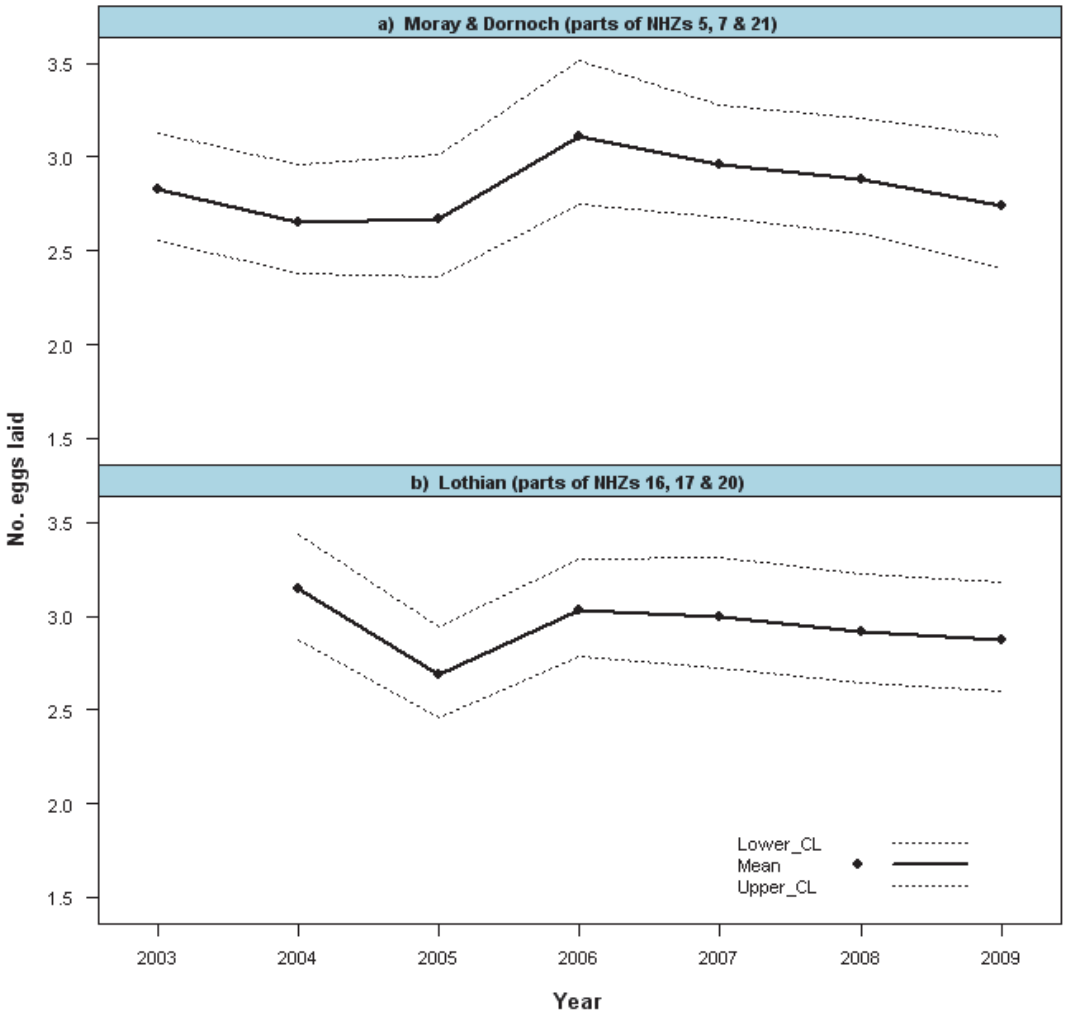


Figure 48. Best available trends in clutch size of pairs that laid eggs for common buzzards in two study areas of Scotland.
(Source: SRMS data)

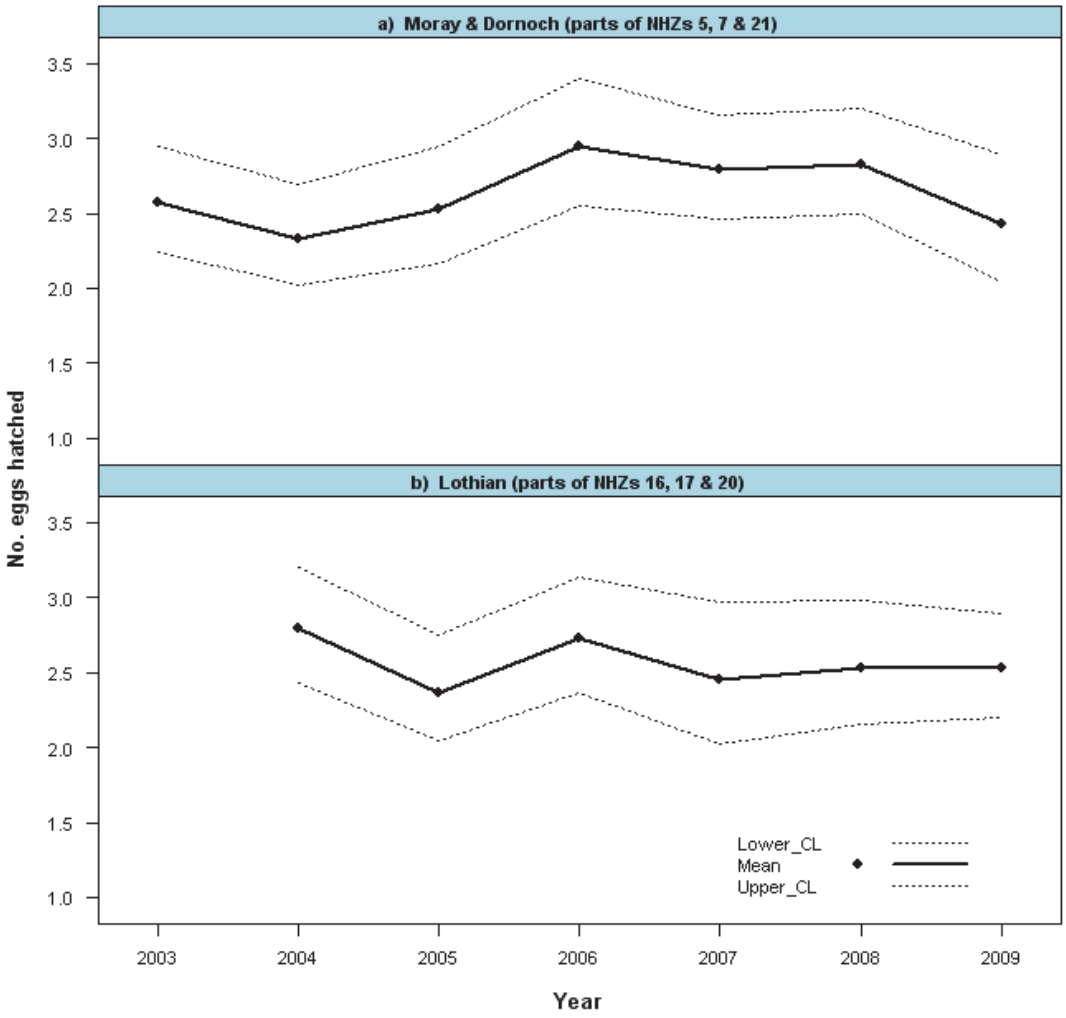


Figure 49. Best available trends in brood size at hatching of pairs that hatched young for common buzzards in two study areas of Scotland.
(Source: SRMS data)

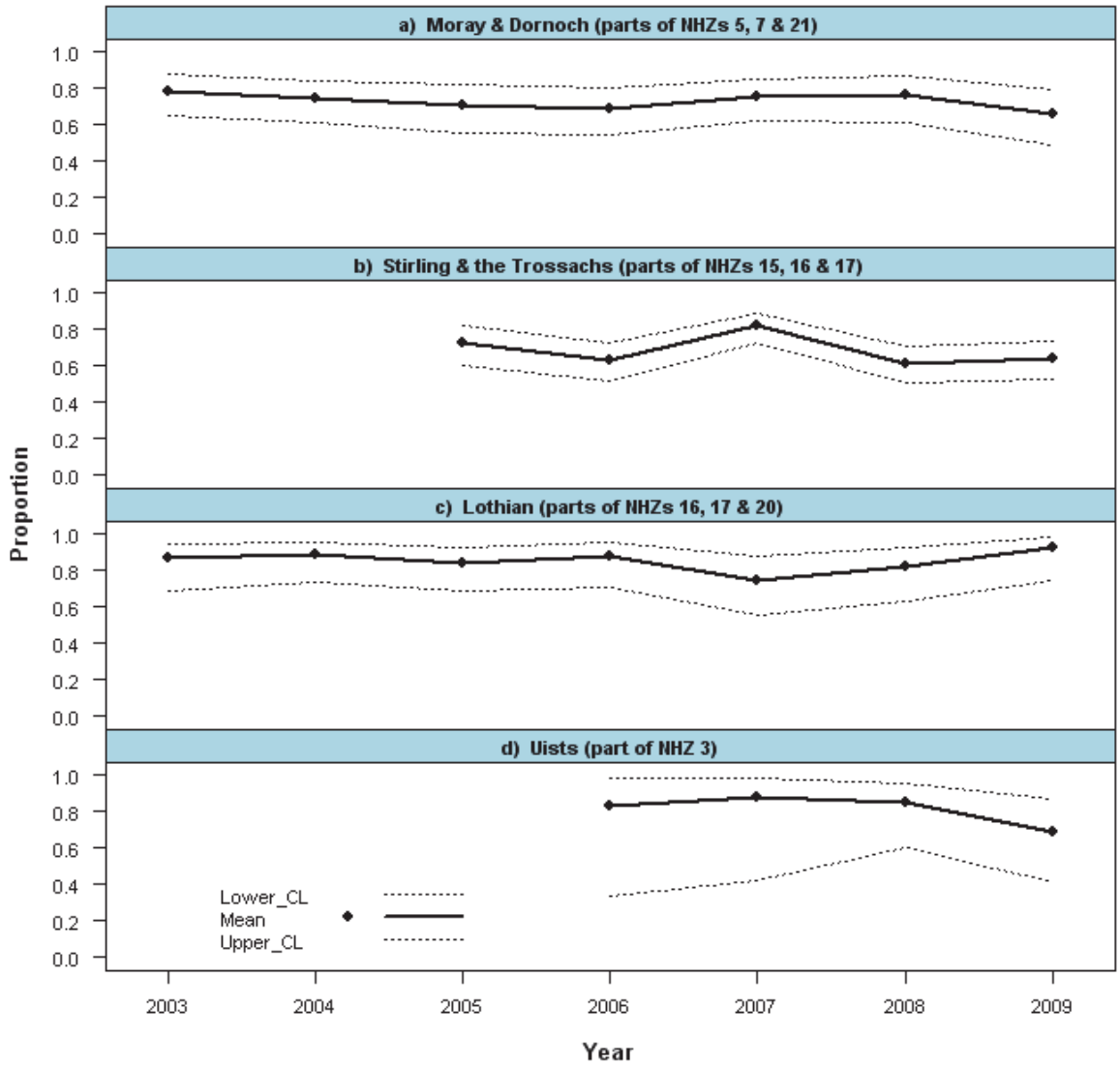


Figure 50. Best available trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for common buzzards in four study areas of Scotland. (Source: SRMS data)

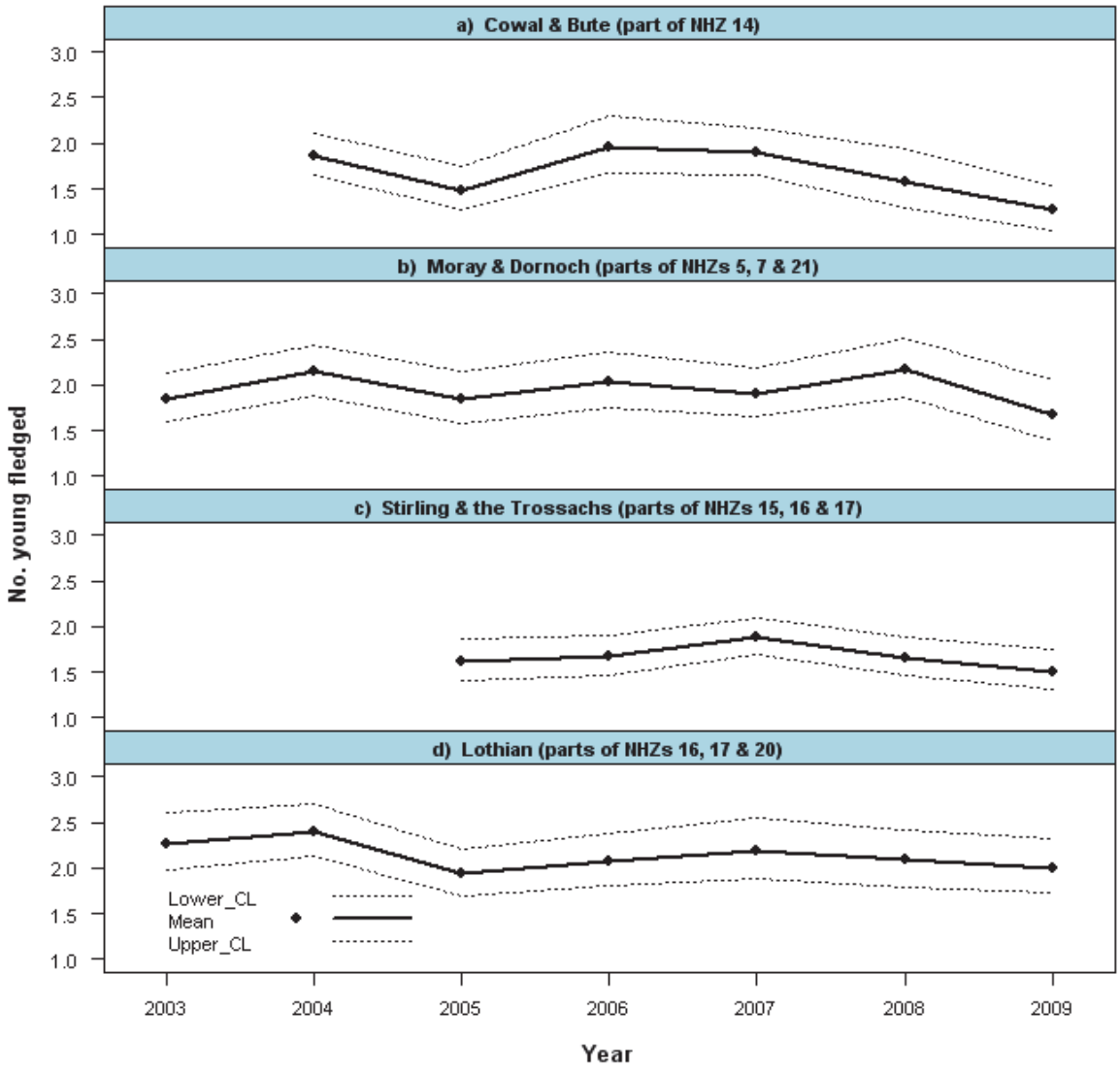


Figure 51. Best available trends in number fledged per successful pair for common buzzards in four study areas of Scotland.
(Source: SRMS data)

1.4.7 Golden eagle

Trends in breeding numbers
Trends in breeding numbers cannot be reported until further work to quantify coverage and compare this to current knowledge of the Scottish distribution is complete (see below).

Trends in breeding productivity
None of the breeding productivity measures shows any systematic trend over the duration of the SRMS.

Best available trends in laying success for three NHZs (Figure 52), clutch size of those pairs that laid for one NHZ (Figure 53), hatching success for two NHZs (Figure 54), brood size at hatching for those pairs hatching young for one NHZ (Figure 55), fledging success for two NHZs (Figure 56) and proportion fledging twins for one NHZ (Figure 57) are reported.

Data sources, caveats, work pending and gaps
Analyses were based on the 1,626 site-year records that were attributable to individual NHZs within the SRMS dataset for 2003-2009 (information was largely provided in summary form only in 2003). We were able to link 648 of these records to grid references and assign them to NHZs using site codes, site names and information supplied for the golden eagle Conservation Framework (Annex Table B 21). A comparison of the numbers of ranges that were known and active during the 2003 national survey (Whitfield *et al*. 2007) with numbers surveyed and information submitted to the SRMS in 2004-2009 is provided in Annex Table B22.

It was not feasible to produce trends in breeding numbers until two further pieces of work can be carried out: (a) to obtain coverage/effort information from observers that submit records to the SRMS; and (b) to compare that annual monitoring coverage to our best knowledge of the current distribution and abundance of golden eagles in Scotland (and in each NHZ; this should be available following the next national survey planned for 2015. It is not possible to identify key monitoring gaps with certainty until the above work is undertaken.

We have reported provisional trends in breeding parameters for up to five NHZs for which samples of at least five appropriate records exist for each parameter in each year (see Annex Table B23 for sample sizes). Many NHZs appear to have good sampling coverage on an annual basis and we have flagged six NHZs as likely to require further careful consideration because coverage of these is relatively poorer on an annual basis. Previous work to assess possible sampling strategies for annual monitoring of golden eagles in Scotland based on breeding data from intensively surveyed areas of Argyll, Mull, Lochaber and Skye suggested that (for monitoring trends in the mean number of young fledged per annum) a sample of around 40% of ranges covered gave an optimal balance between precision and practical effort (there was little additional precision to be gained by sampling more ranges annually based on that data set; see Annex C).

Given the number and distribution of golden eagle records submitted to the SRMS annually since 2003 (Annex Table B 22), it should be possible to produce national trends in future once a clearer picture of annual monitoring coverage in relation to overall Scottish distribution is available.

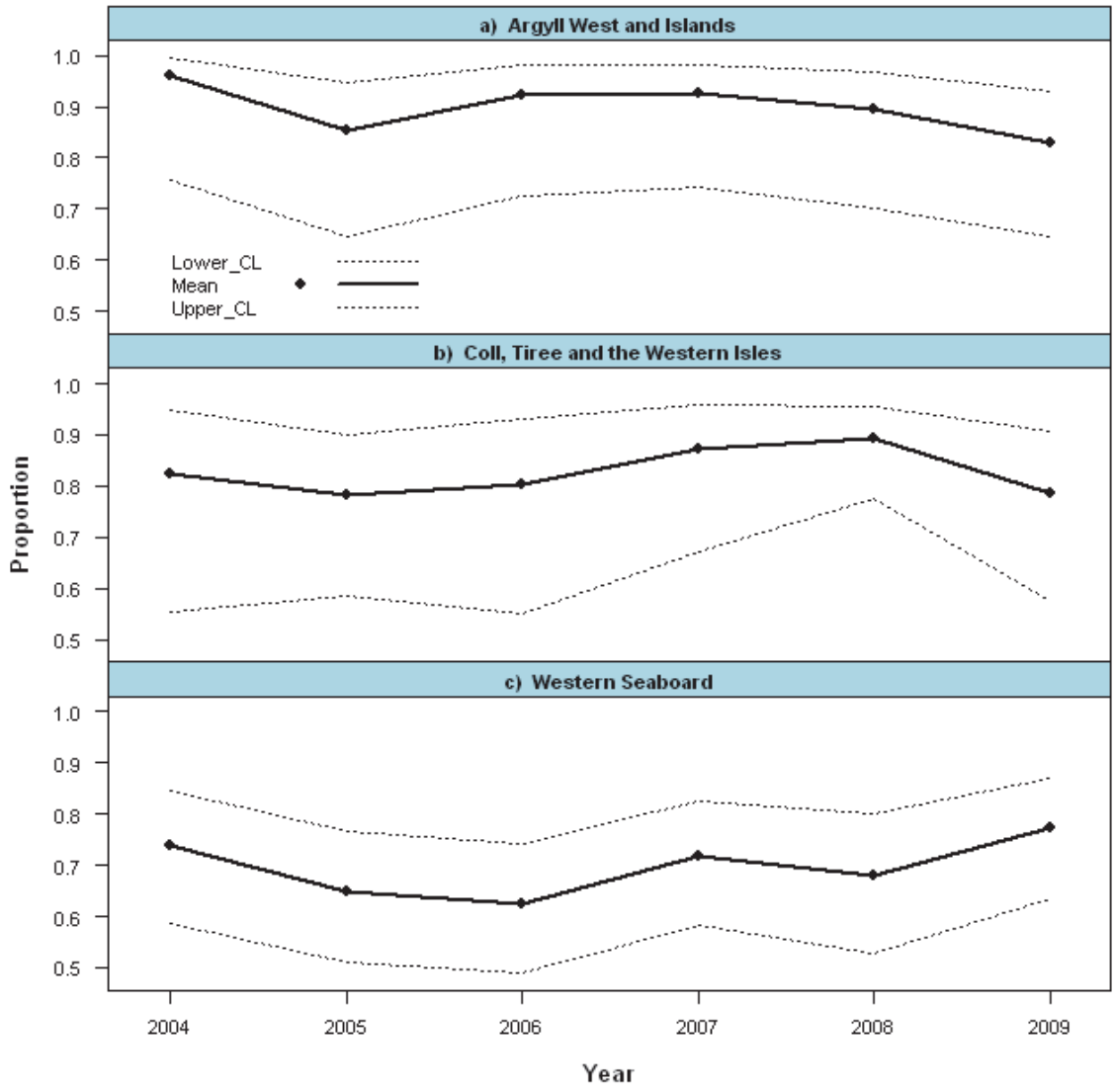


Figure 52. Best available trends in laying success (proportion of known pairs that laid at least one egg) for golden eagles in three NHZs of Scotland for which sufficient samples of data were available.
(Source: SRMS data)

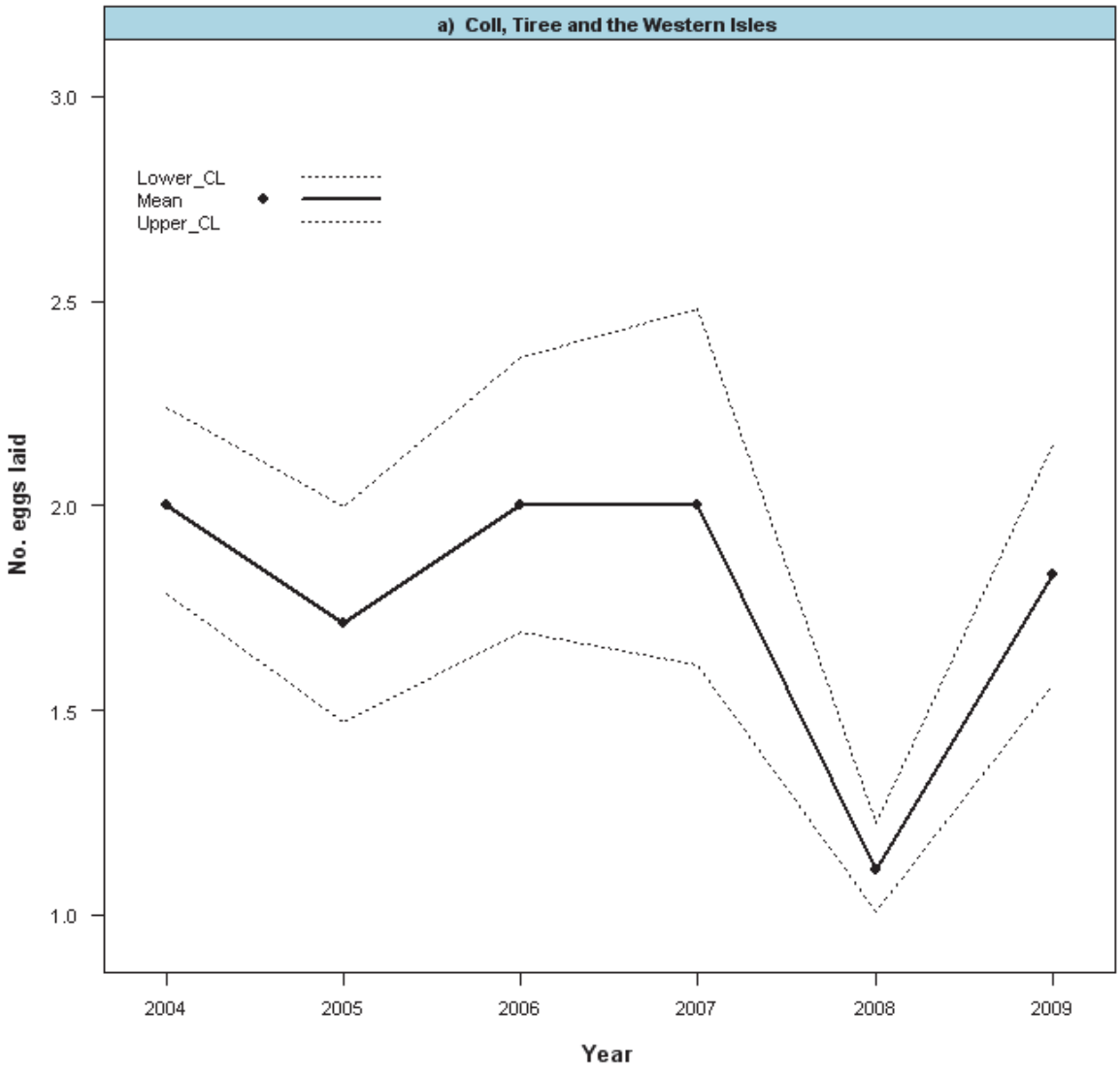


Figure 53. Best available trend in clutch size of pairs that laid for golden eagles in the one NHZ of Scotland for which a sufficient sample of data was available.
(Source: SRMS data)

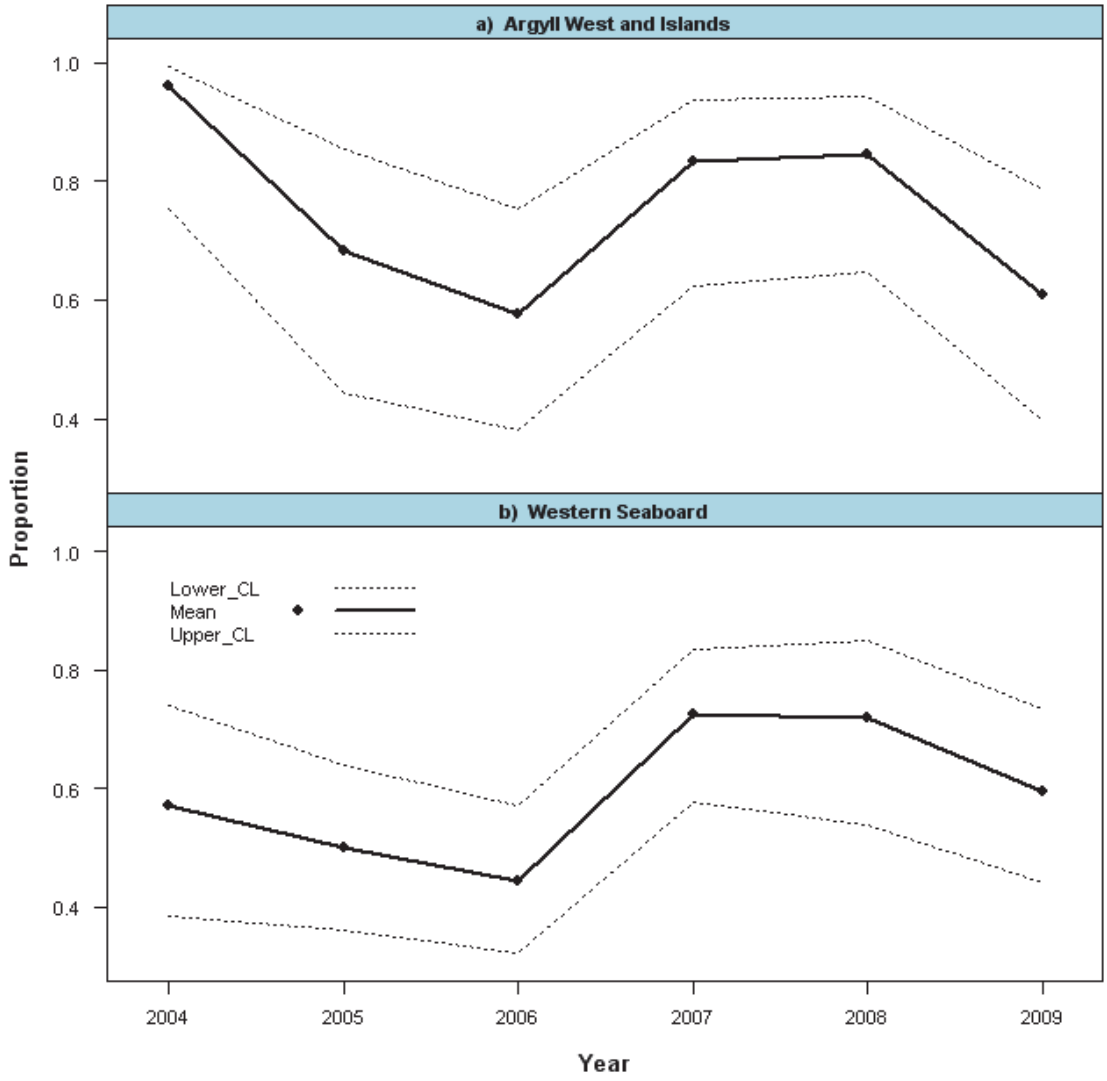


Figure 54. Best available trends in hatching success (proportion of pairs known to lay that hatched at least one young) for golden eagles in two NHZs of Scotland for which sufficient samples of data were available.
(Source: SRMS data)

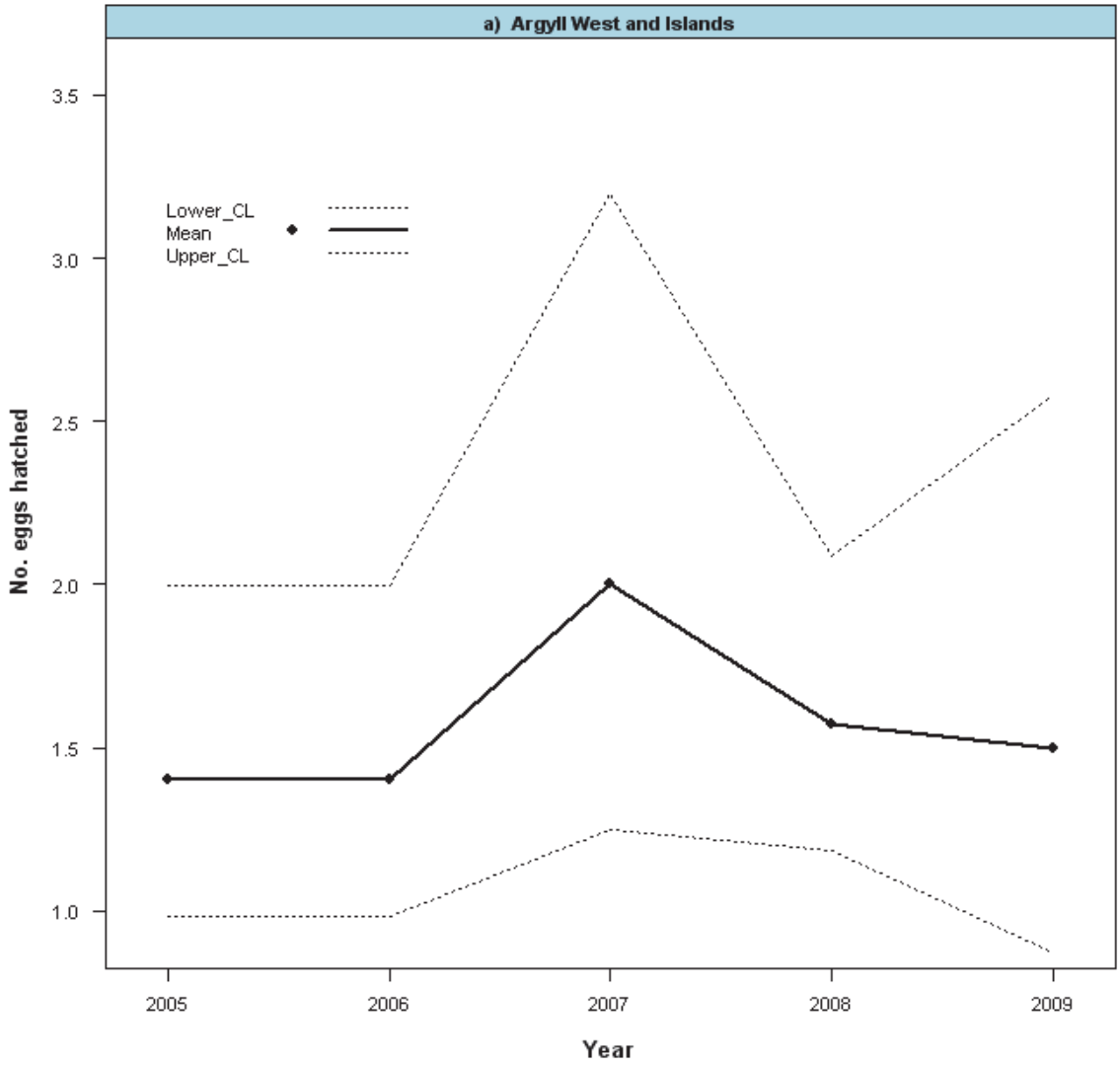


Figure 55. Best available trend in brood size at hatching of pairs that hatched young for golden eagles in one NHZ of Scotland for which a sufficient sample of data was available. (Source: SRMS data)

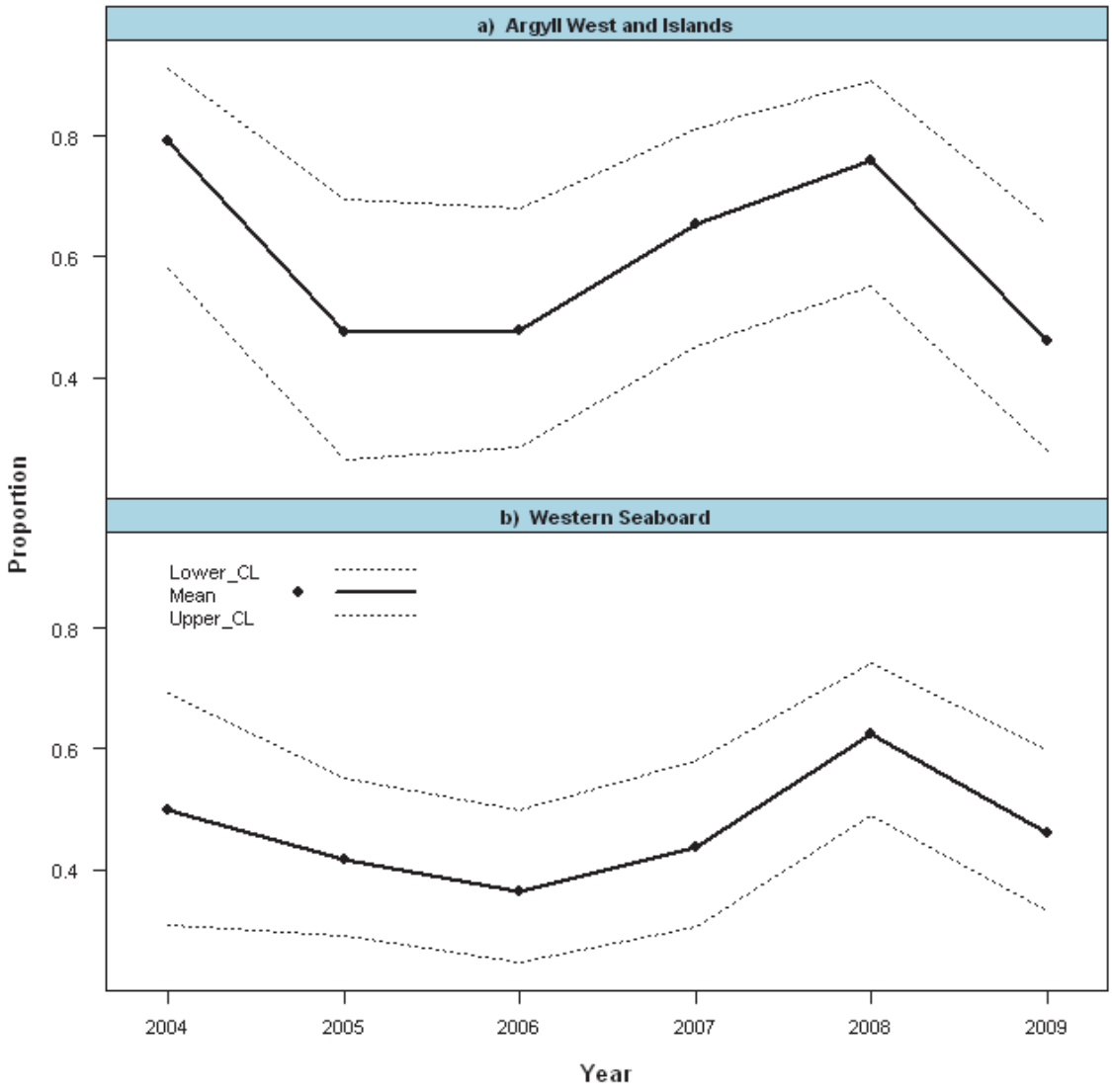


Figure 56. Best available trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for golden eagles in two NHZs of Scotland for which sufficient samples of data were available.
(Source: SRMS data)

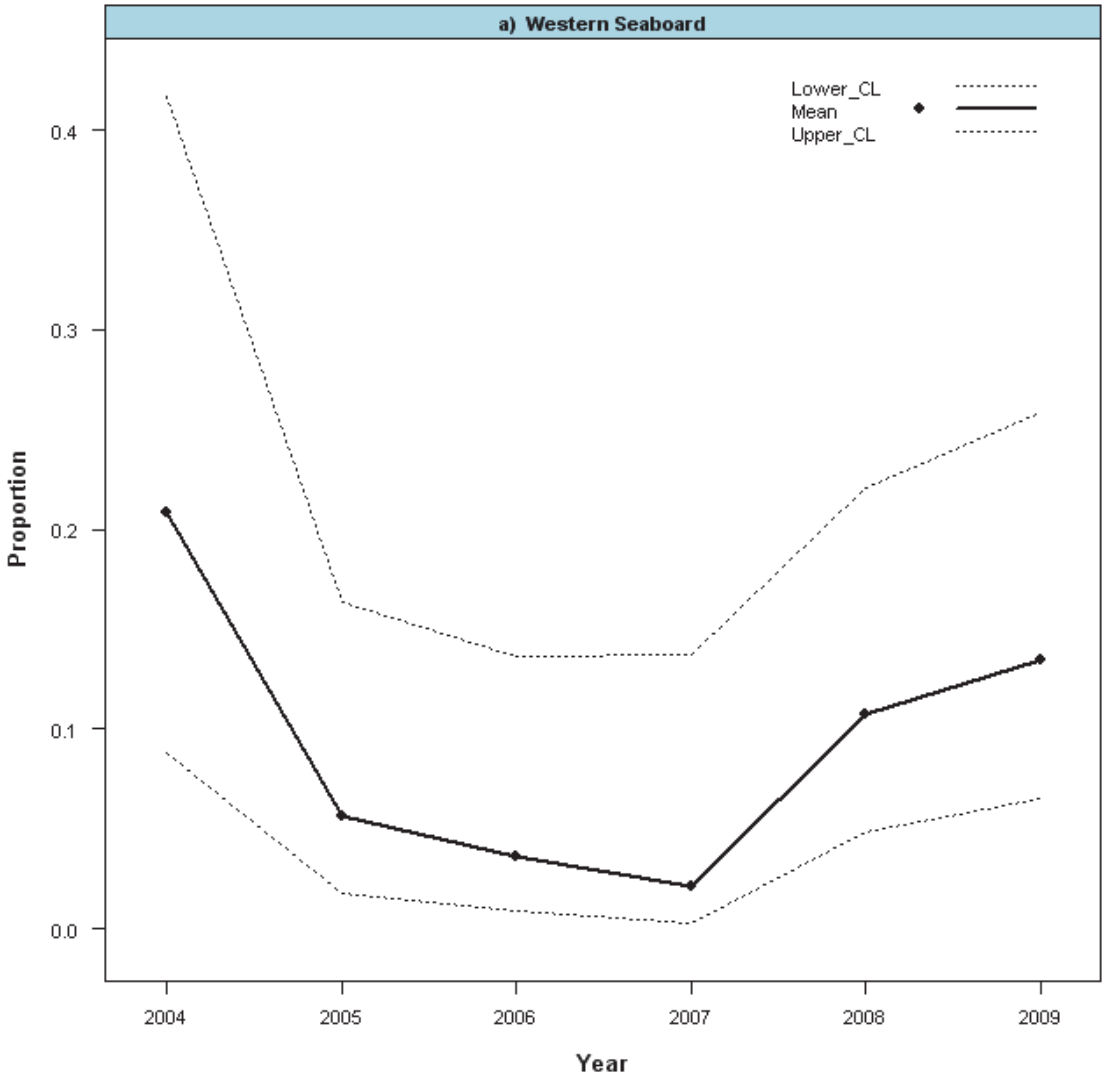


Figure 57. Best available trend in the proportion of pairs fledging twins for golden eagles in one Scottish NHZ for which a sufficient sample of data was available.
(Source: SRMS data)

1.4.8 Common kestrel

Trends in breeding numbers

The national trend, from BBS results, in kestrel breeding abundance (Figure 59) shows a sustained and statistically significant decrease since 1994. Overall, the abundance index for Scotland decreased by 58% (lower and upper confidence limits -73 and -36%) between 1995 and 2009 (Risely *et al*. 2011). Kestrel breeding numbers in the Ayrshire study area have shown fluctuations between years since 2003, related to annual changes in vole abundance (Riddle 2011) and 2009 saw the lowest number of pairs recorded since 2003 (Figure 60).

A trend in breeding numbers is reported from one study area in Ayrshire (and the border with Dumfries and Galloway; covering parts of NHZs 17 and 19; Figure 60). See Annex Table B24 for sample sizes available for analyses.

Trends in breeding productivity

Results for the single study area (Ayrshire) show marked annual fluctuations for the breeding productivity, related to vole abundance (Riddle 2011). No systematic trend since 2003 is apparent. Trends in the clutch size of pairs that laid (Figure 61), brood size at hatching of pairs that hatched young (Figure 62), fledging success (Figure 63), and the number fledged per successful pair (Figure 64) are reported for the Ayrshire study area. See Annex Table B25 for sample sizes. .

Data sources, caveats, work pending and gaps

Kestrels were recorded in 42 of the 329 squares surveyed for the BTO/JNCC/RSPB Breeding Bird Survey in Scotland in 2010 (Risely *et al*. 2011; Annex Figure A3). The national trend in breeding abundance produced by the BBS may not be representative of that for Scotland as a whole because the sample of squares in which kestrels are recorded is biased towards lowland areas of Scotland; this should be assessed further once updated information on distribution and spatial variation in relative abundance is available from the Bird Atlas 2007-11 project.

The other analyses were based on SRMS data for 2003-2009. There are a number of areas of Scotland from which kestrel breeding attempts have been reported to the SRMS since 2003 but many have been *ad hoc* reports of individual breeding attempts that do not lend themselves to trend analysis. Trends from the Ayrshire study run by Gordon Riddle are robust and data for years prior to 2003 may be available for analysis in the future. More details on the Ayrshire study can be found in Riddle (2011). There are at least two other studies that might provide trend information in future once coverage and effort have been further assessed (Annex Table B25).

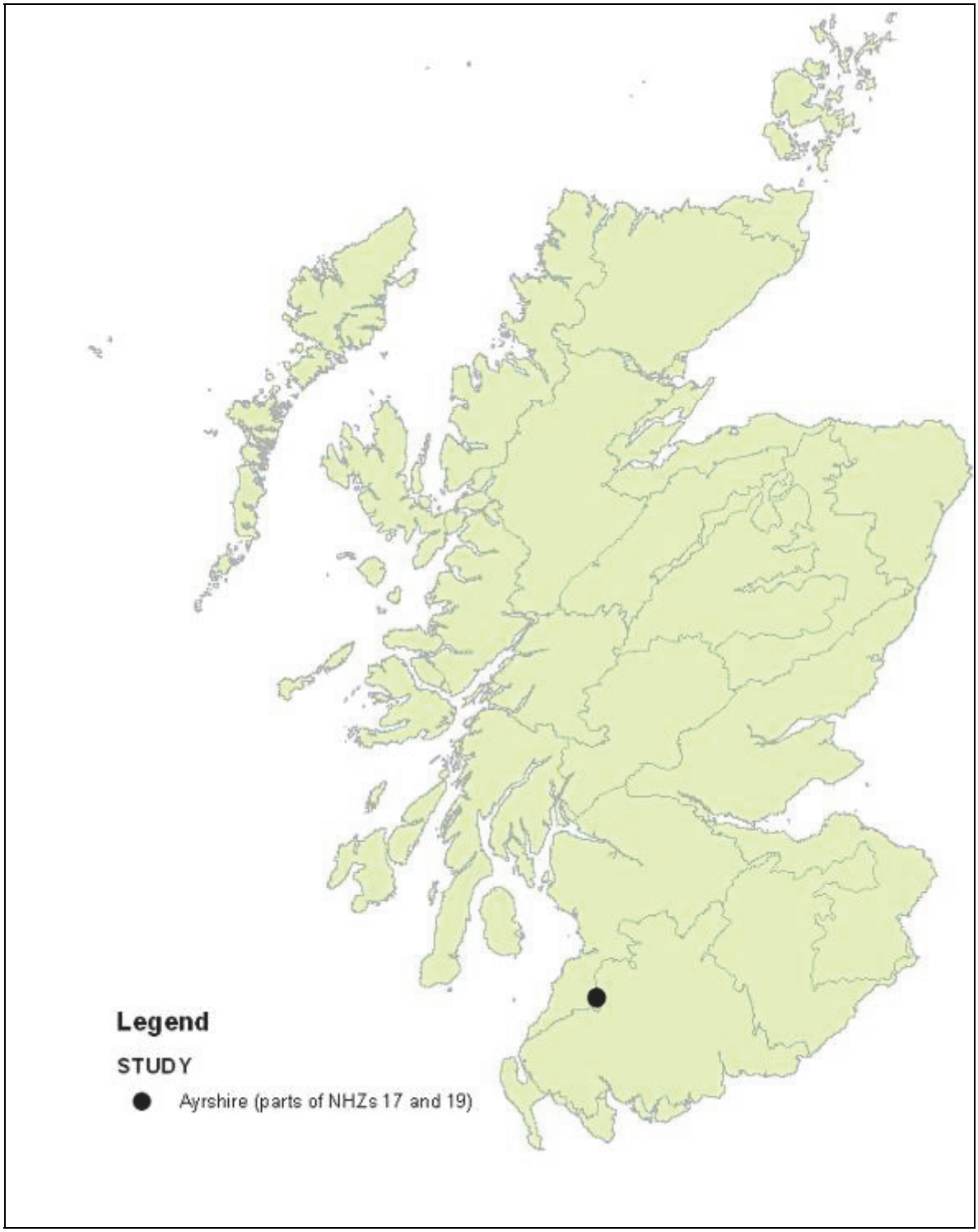


Figure 58. The location of the Ayrshire common kestrel study contributing information on trends.

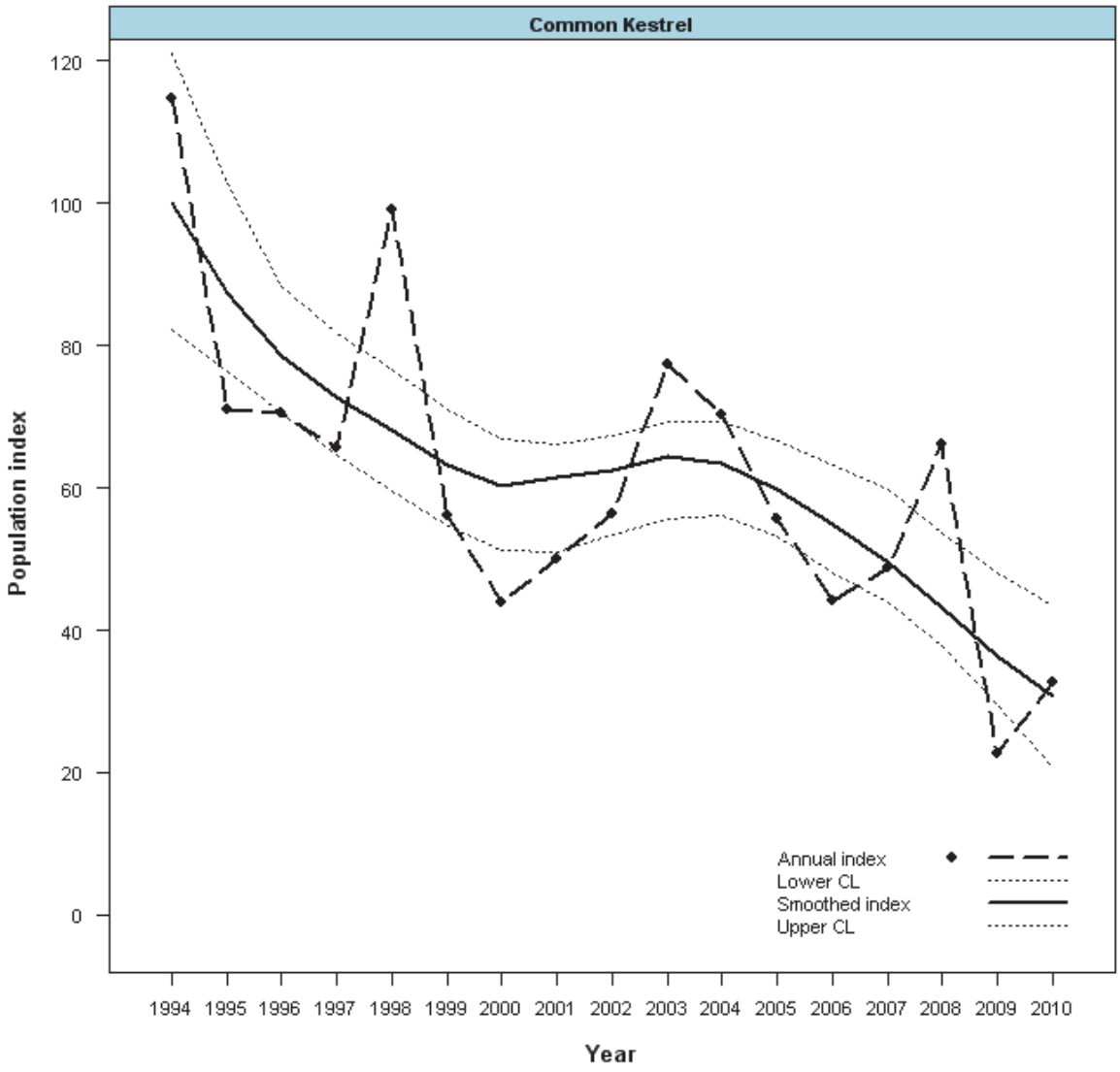


Figure 59. Trend in the breeding abundance of kestrels in Scotland between 1994 and 2010 (relative to index value set to 100 in 1994).
Both the annual index values, and the smoothed index with associated 95% confidence limits, are shown.
(Source: BTO/JNCC/RSPB Breeding Bird Survey data)

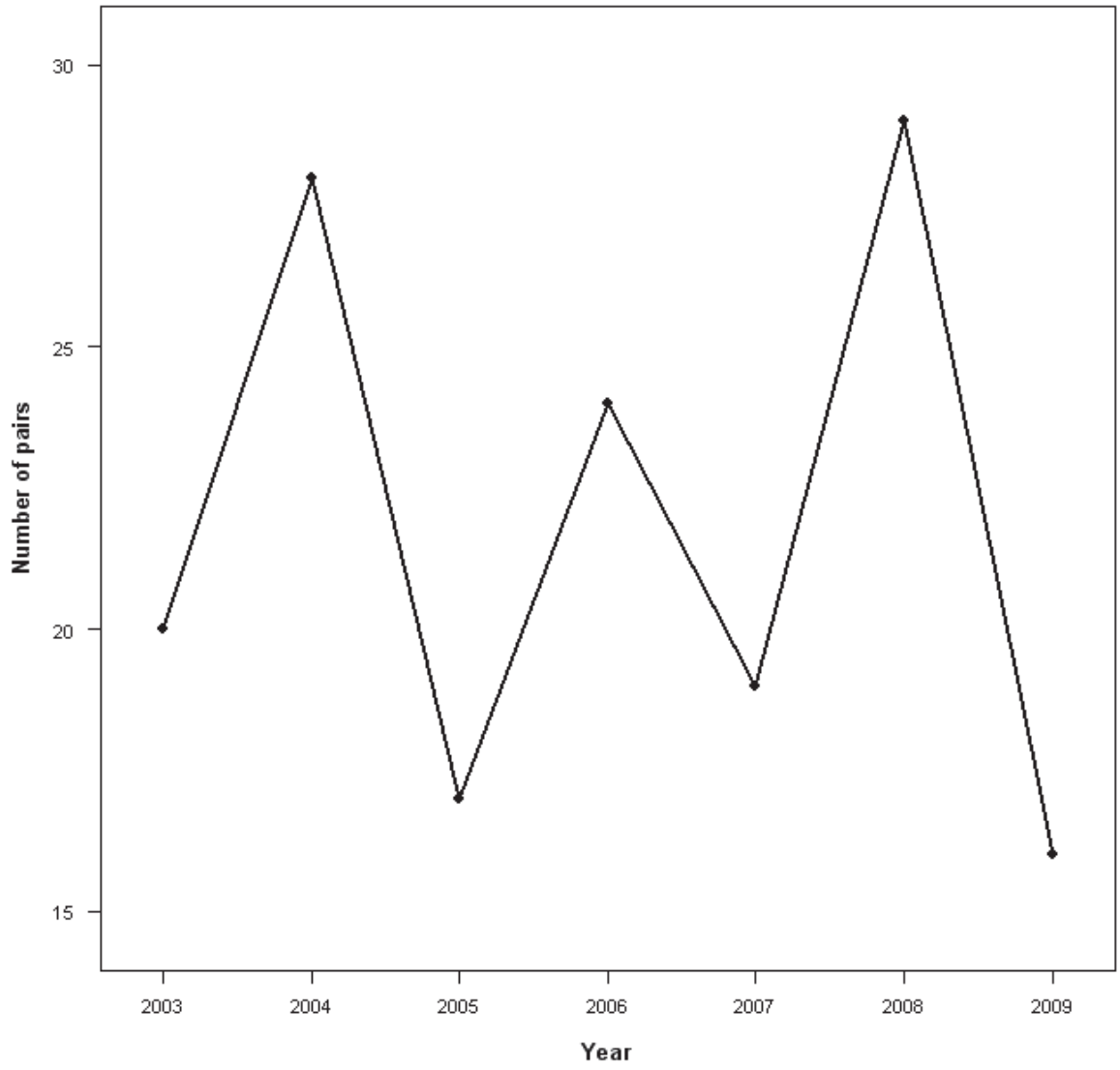


Figure 60. Trends in the number of breeding common kestrel in a study area in Ayrshire and bordering areas of Dumfries and Galloway (covering parts of NHZs 17 and 19).
(Source SRMS data)

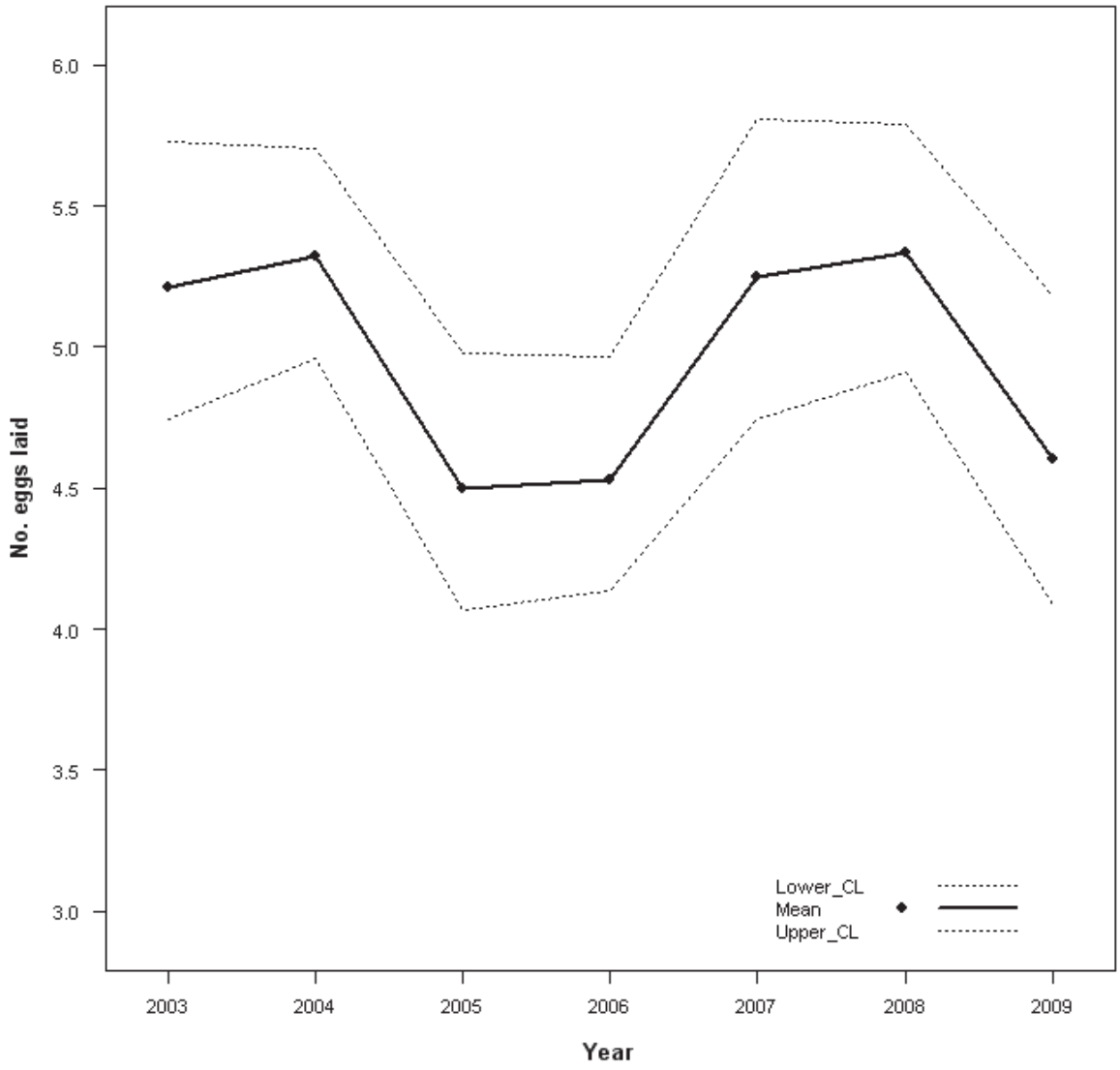


Figure 61. Trend in the clutch size of pairs that laid for common kestrels in a study area in Ayrshire and bordering areas of Dumfries and Galloway (covering parts of NHZs 17 and 19). (Source: SRMS data)

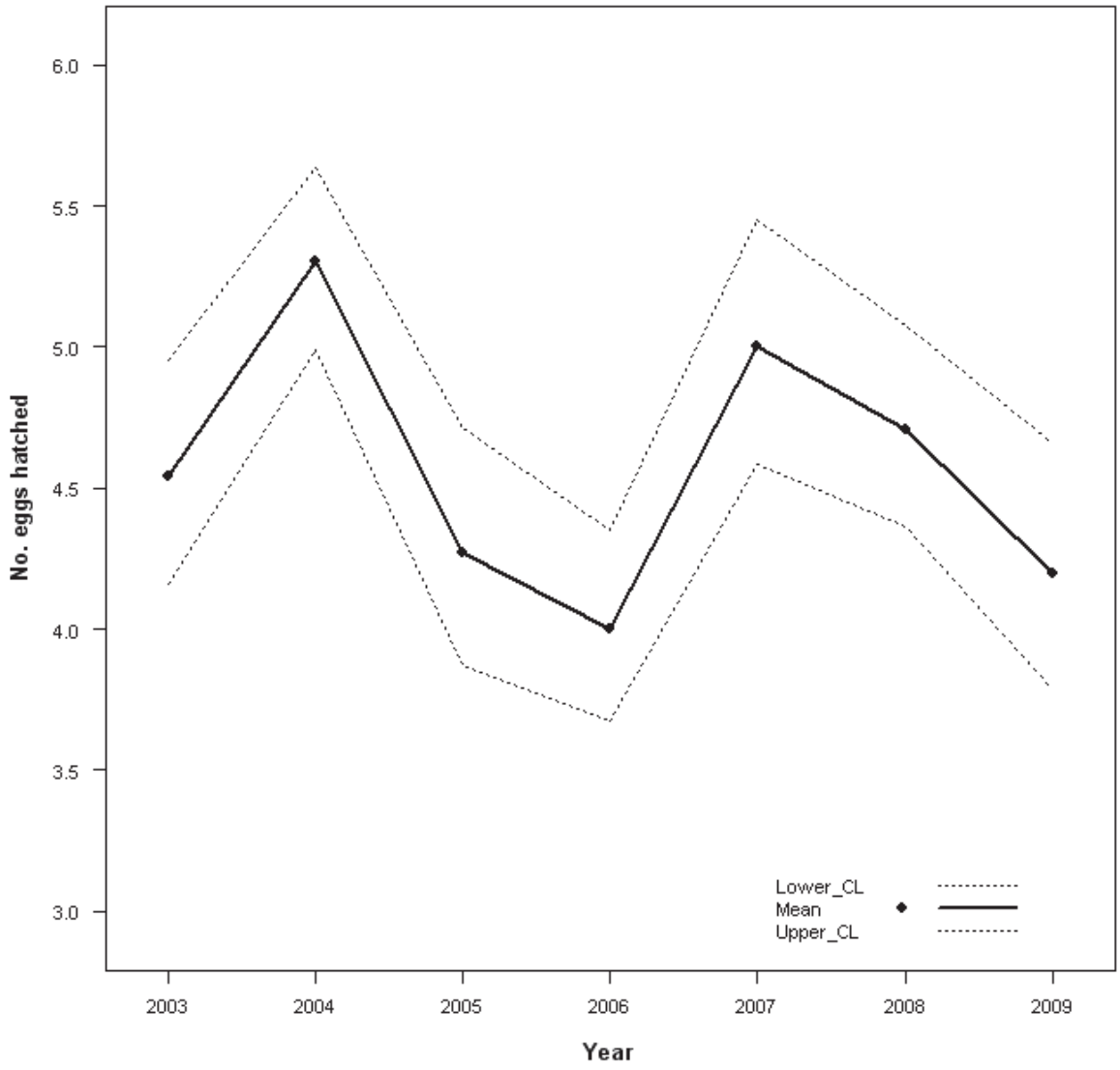


Figure 62. Trend in the brood size at hatching of pairs that hatched young for common kestrels in a study area in Ayrshire and bordering areas of Dumfries and Galloway (covering parts of NHZs 17 and 19).
(Source: SRMS data)

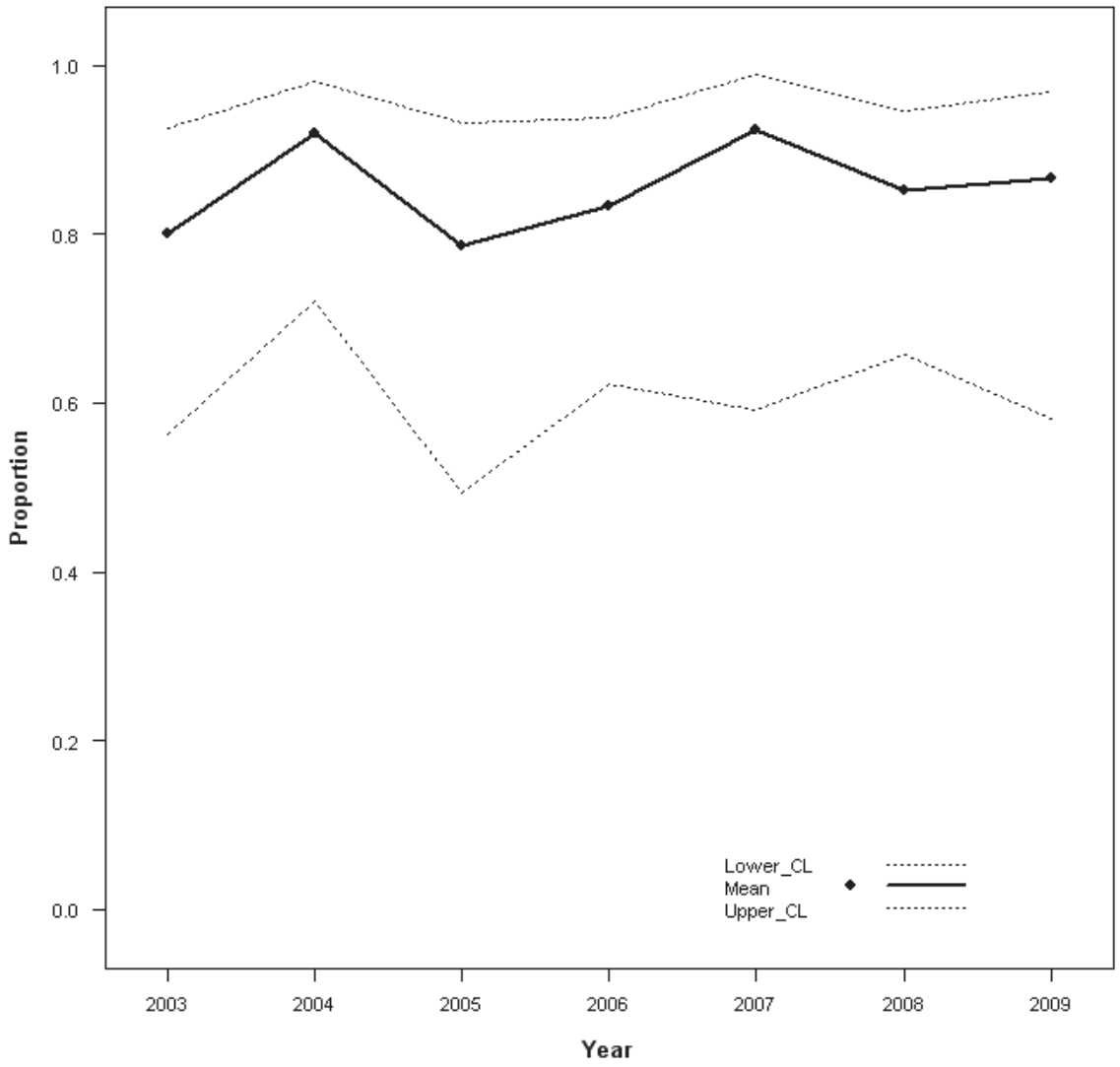


Figure 63. Trend in fledging success (proportion of pairs known to hatch young that fledged at least one young) for common kestrels in a study area in Ayrshire and bordering areas of Dumfries and Galloway (covering parts of NHZs 17 and 19).
(Source: SRMS data)

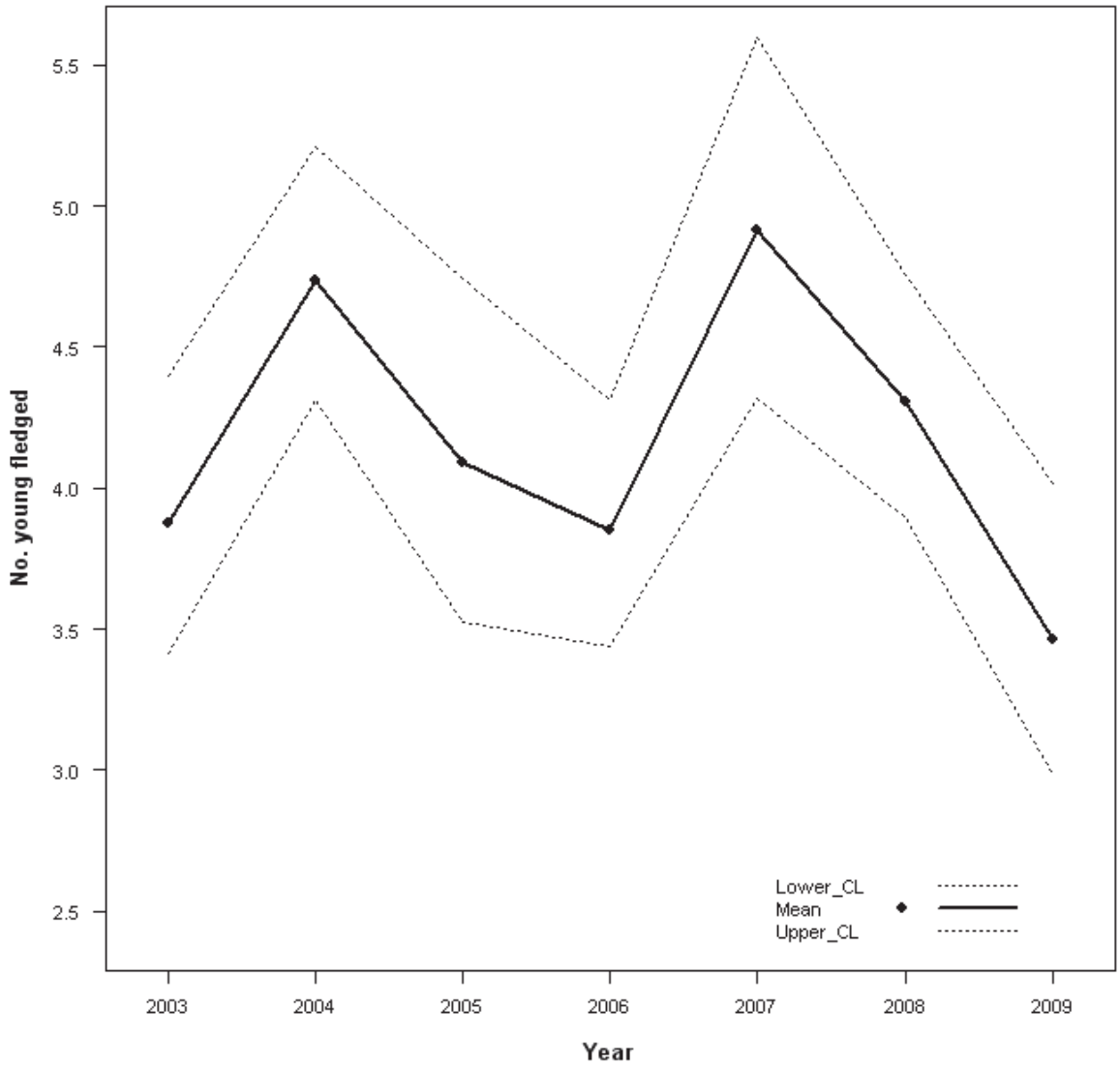


Figure 64. Trend in the number fledged per successful pair for common kestrels in a study area in Ayrshire and bordering areas of Dumfries and Galloway (covering parts of NHZs 17 and 19).
(Source: SRMS data)

1.4.9 Merlin

Trends in breeding numbers
Trends in breeding numbers cannot be reported until further work to quantify coverage and compare this to current knowledge of Scottish distribution is complete (see below).

Trends in breeding productivity
No significant between-year differences were detected for any of the breeding productivity parameters at regional scale. Best available trends in clutch size of pairs that laid for one NHZ and one Raptor Study Group area (North-east Scotland) (Figure 65), hatching success for one Raptor Study Group area (Figure 66), brood size at hatching of pairs that hatched young for one NHZ and one Raptor Study Group area (Figure 67), and number fledged per successful pair for one NHZ and one Raptor Study Group area (Figure 68) are reported.

Data sources, caveats, work pending and gaps
Analyses were based on SRMS data for 2003-2009, involving 1,874 site-year records that could be assigned to individual NHZs. We were able to link a further 137 records to grid references and assign NHZs to these records, using site codes, site names and additional information supplied to SNH for other purposes (e.g. Fielding & Haworth 2011 and see Annex Tables B 26 and B 27). A breakdown of ranges surveyed under the SRMS 2003-2009 and the numbers found to be occupied by NHZ or Raptor Study Group is given in Annex Table B 28. A sub-set of records did not have sufficient spatially explicit location information to allow them to be linked to specific NHZs, and trends are only reported by Raptor Study Group area for this sub-set.

Trends in breeding numbers cannot be produced for this species until three further pieces of work are carried out: (a) to obtain coverage/effort information from observers that submit records to the SRMS; (b) to obtain outstanding spatially explicit location information from observers; and (c) to compare annual monitoring coverage against best current knowledge of the distribution and abundance of merlins in Scotland (and in each NHZ), based on the most recent national survey in 2008 (Ewing *et al*. 2011), perhaps complemented by the forthcoming results of Bird Atlas 2007-11 and that from other recent work collating knowledge of the species distribution in Scotland (Fielding & Haworth 2011). There is a further constraint that some merlin breeding attempts are recorded when observers are searching more specifically for hen harriers – hence the degree of annual coverage in some areas may be dependent to an extent on the distribution and abundance of harriers. It is not possible to identify key monitoring gaps for this species until the above work is undertaken.

We have presented the best available trends in breeding parameters for one NHZ and one Raptor Study Group area for which samples of at least 10 appropriate records exist for each parameter in each year (see Annex Table B 29 for sample sizes). It is not possible to indicate to what extent these trends are fully representative of the part of the Scottish merlin population in each area until survey coverage is established and compared with an up-to-date picture of merlin distribution (above). The trends must also remain provisional until checks have been made on the consistency of field methods employed by each contributing study, through liaison with observers.

It should be possible to produce national trends in future once the work described above is complete. The annual monitoring of merlins is also carried out in Shetland; these data are not currently submitted to the SRMS but their inclusion will be discussed ahead of future work on merlin trends.

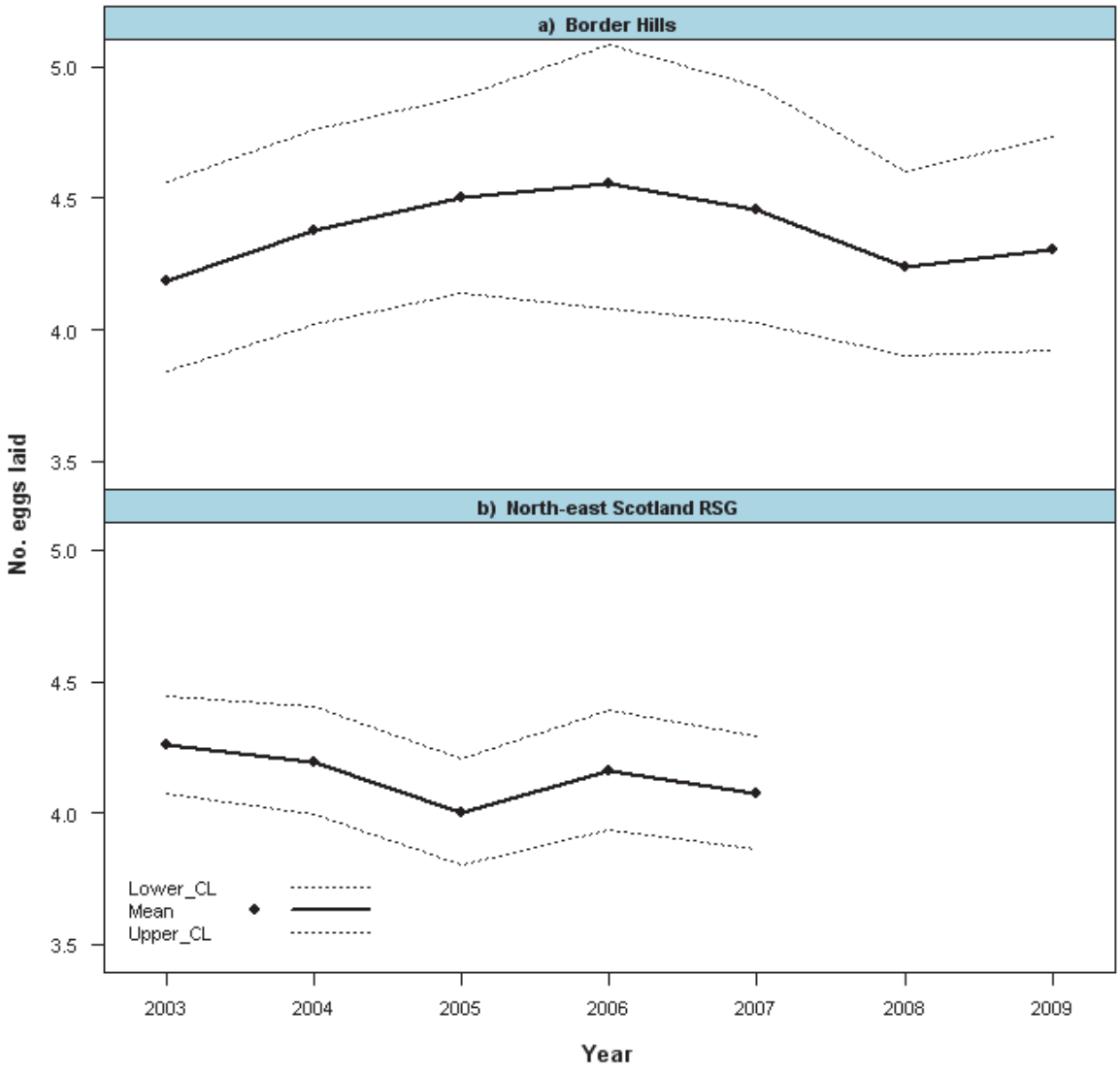


Figure 65. Best available trends in the clutch size of pairs laying eggs for merlins in one NHZ and one Raptor Study Group area of Scotland for which sufficient samples of data were available.
(Source: SRMS data)

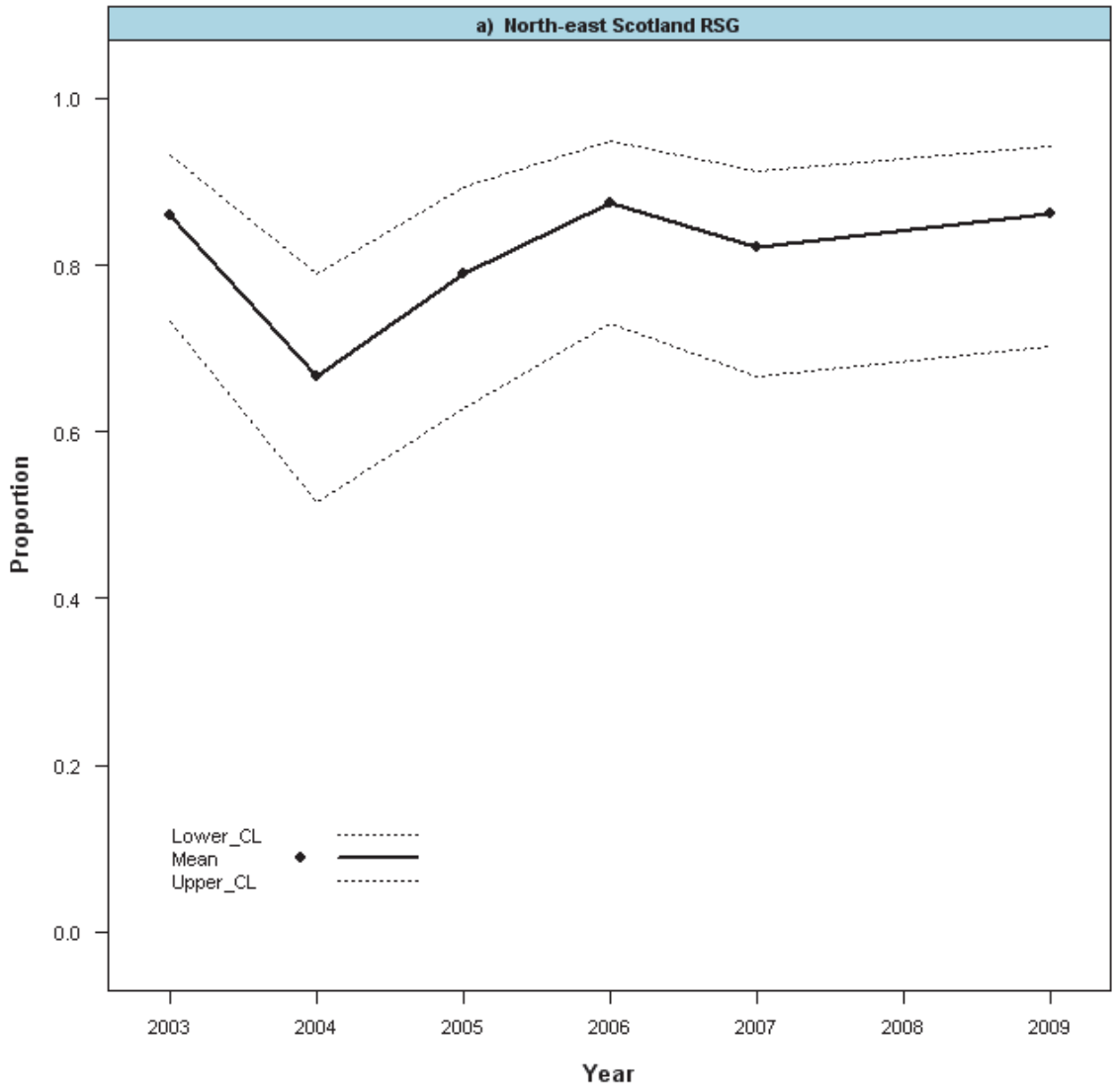


Figure 66. Best available trend in hatching success (proportion of pairs known to lay that hatched at least one young) for merlins in one Raptor Study Group area of Scotland for which a sufficient sample of data was available.
(Source: SRMS data)

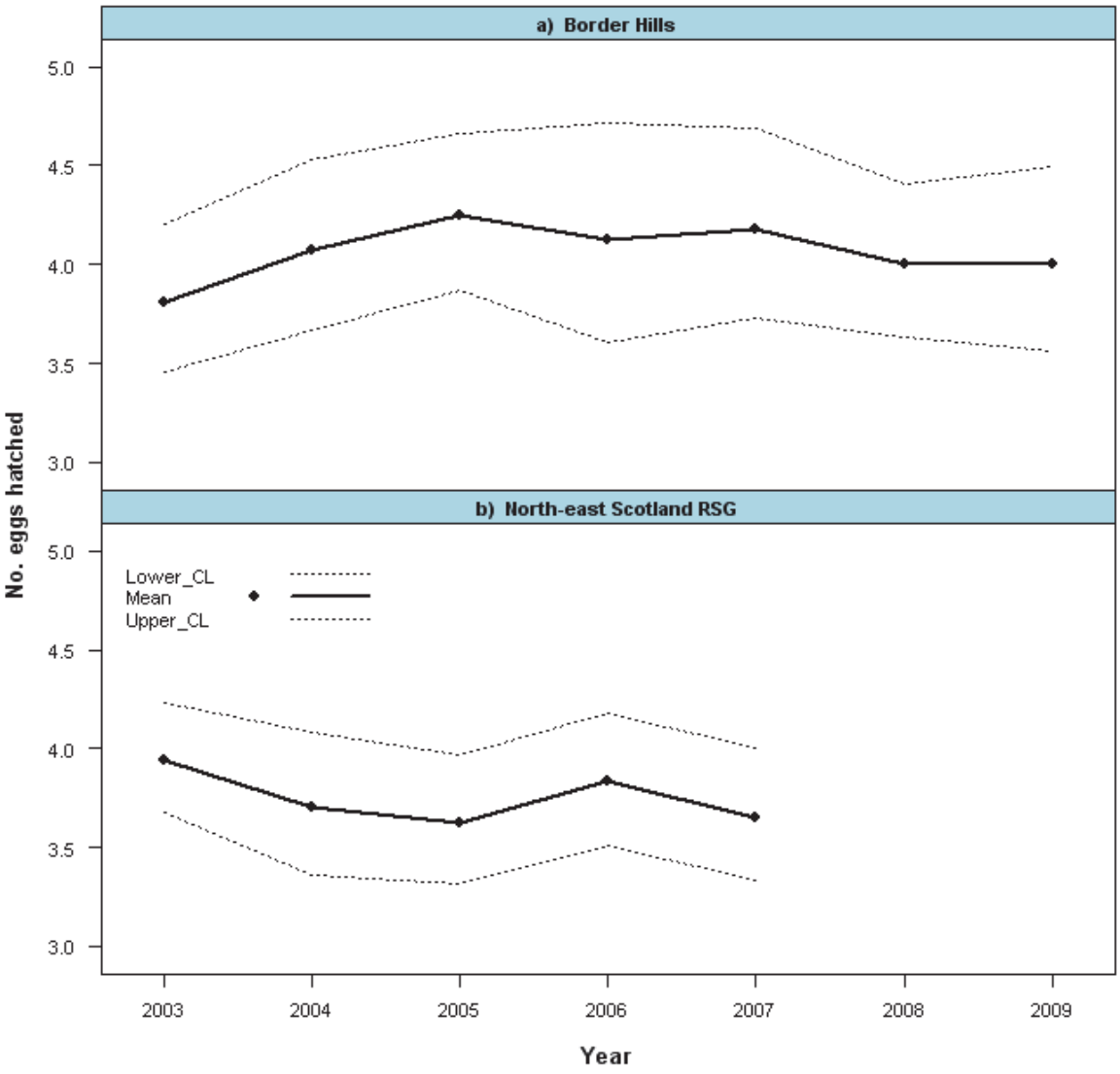


Figure 67. Best available trends in brood size at hatching of pairs that hatched young for merlins in one NHZ and one Raptor Study Group area of Scotland for which sufficient samples of data were available.
(Source: SRMS dataset 2003-2009)

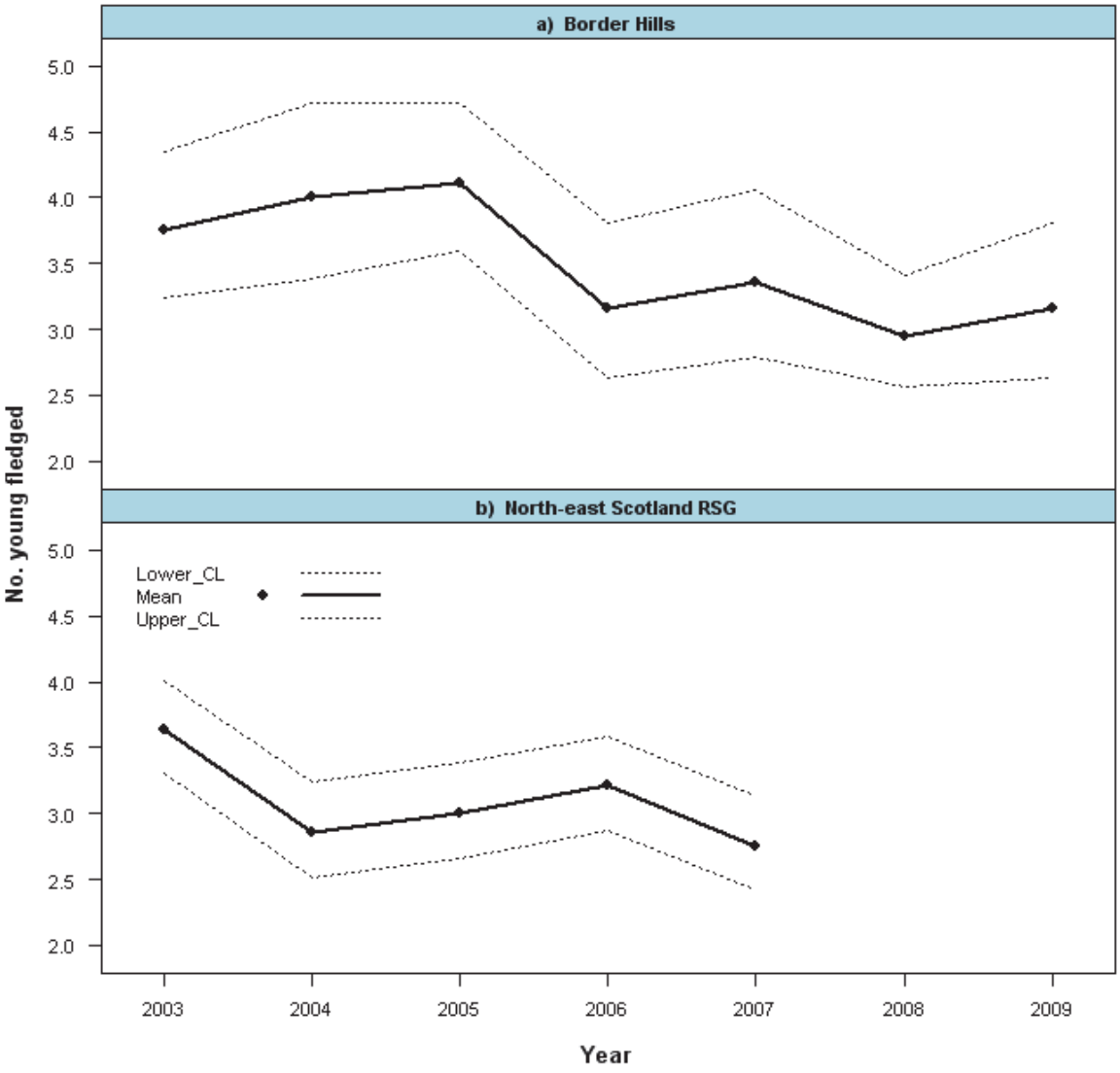


Figure 68. Best available trends in number of young fledged per successful pair for merlins in one NHZ and one Raptor Study Group area of Scotland for which sufficient samples of data were available.
(Source: SRMS dataset 2003-2009)

1.4.10 Peregrine falcon

Trends in breeding numbers
In most of the NHZs for which best available trends can be reported, breeding numbers have shown only minor changes (and are generally stable or increasing) since 2003 (Figure 70). There are suggestions of decreases in the Cairngorm Massif and North East Glens (NHZs 11 and 12), and perhaps Loch Lomond, the Trossachs and Breadalbane (NHZ 15) and the Western Southern Uplands and Inner Solway (NHZ 19).

Trends in breeding numbers are reported for 11 NHZs or parts of NHZs (Figure 69): the North-east Coastal Plain (NHZ 9); the Cairngorm Massif (NHZ 11) and a separate trend for the Tayside sub-area of NHZ 11; the southern part of the North-east Glens (part of NHZ 12); the Cowal (part of NHZ 14); Loch Lomond, the Trossachs and Breadalbane (NHZ 15); the Eastern Lowlands (NHZ 16); the West Central Belt (NHZ 17); Wigtown Machairs and Outer Solway Coast (NHZ 18); Western Southern Uplands and Inner Solway (NHZ 19); and Border Hills (NHZ 20). Sample sizes available for analyses are given in Annex Table B 30. Together these NHZs cover a large part of the species' range in Scotland, with the exception that the far north and west of mainland Scotland and the outer islands are not represented in the regional trends available to date.

Trends in breeding productivity
None of the provisional trends in breeding productivity parameters shows significant systematic change since 2003. Best available trends in the clutch size of laying pairs for three NHZs (Figure 71), hatching success for three NHZs (Figure 72), brood size at hatching of pairs that hatch young for two NHZs (Figure 73), fledging success for seven NHZs or part of NHZs (Figure 74) and the number fledged per successful pair for eight NHZs or part of NHZs (Figure 75) are reported. Sample sizes available for analyses are given in Annex Table B 31. The information available on fledging success and numbers fledged covers a moderate part of the species' range in Scotland (with comprehensive coverage of central and southern Scotland), but areas further north, the far north and west of mainland Scotland, and the outer islands are not represented in the regional trends available to date.

Data sources, caveats, work pending and gaps
Analyses were based on SRMS data for 2003-2009. We assessed the extent to which annual coverage in each NHZ is representative of each NHZ as a whole (Annex Table B 32) by comparison with results from the 2002 National Survey dataset (including enhanced geo-referencing based on the peregrine Conservation Framework dataset). Although NHZ 11 had large enough sample sizes, the spatial coverage of the monitoring appeared to change between years, and we considered that rigorous trend analyses could only be carried out for a subset of the NHZ 11 data (termed Tayside NHZ 11; see Figure 69). Based on our current understanding of annual survey coverage for this species, we consider that caveats should be attached to trends from the following study areas:

- **NHZ 9**: Trends in numbers are probably generally representative for the years 2003-2008. No records were received for 2009 by the time of data compilation for this project.
- **NHZ 11**: Poor coverage in the northern part of the NHZ in 2009.
- **Tayside NHZ 11**: Relatively consistent coverage across years, but the study area only covers approximately one-third of the whole NHZ.
- **Southern NHZ 12**: Relatively consistent coverage across years, but the study area only covers approximately 50% of the whole NHZ.
- **Cowal NHZ 14**: Only part of the mainland (Cowal) is covered consistently each year.

The trends for this species should be regarded as provisional until between-year variation in coverage and survey effort has been assessed further in liaison with observers. Coverage

should also be compared with the results of the 2014 national peregrine survey. Once this further work has been carried out, it should be feasible to produce national trends.

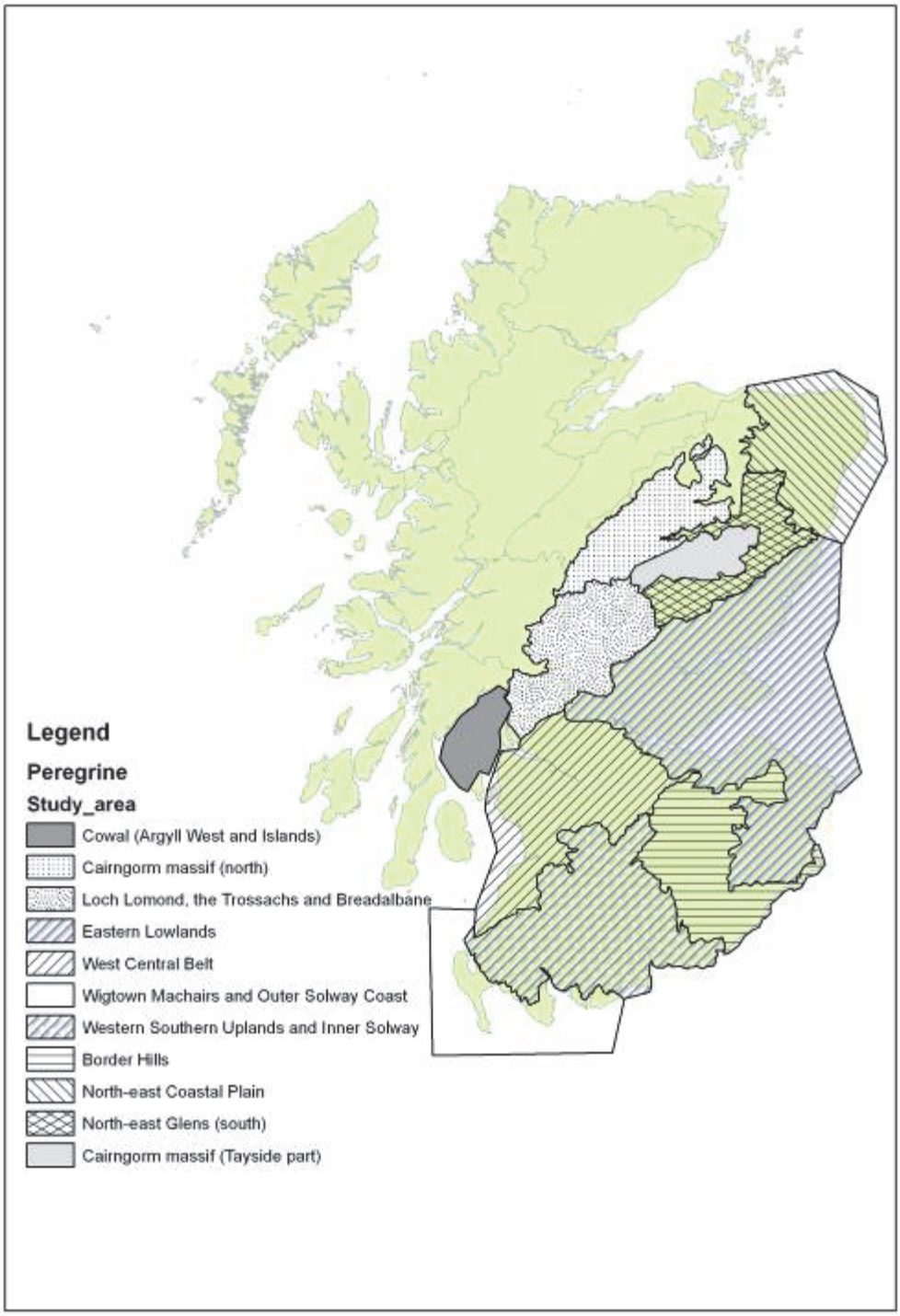


Figure 69. Potential NHZs and areas within NHZs from which trends in peregrine breeding numbers and breeding parameters might be produced from SRMS data 2003-2009. Further assessment revealed that sample sizes were too small for trend analyses for some of these study areas.

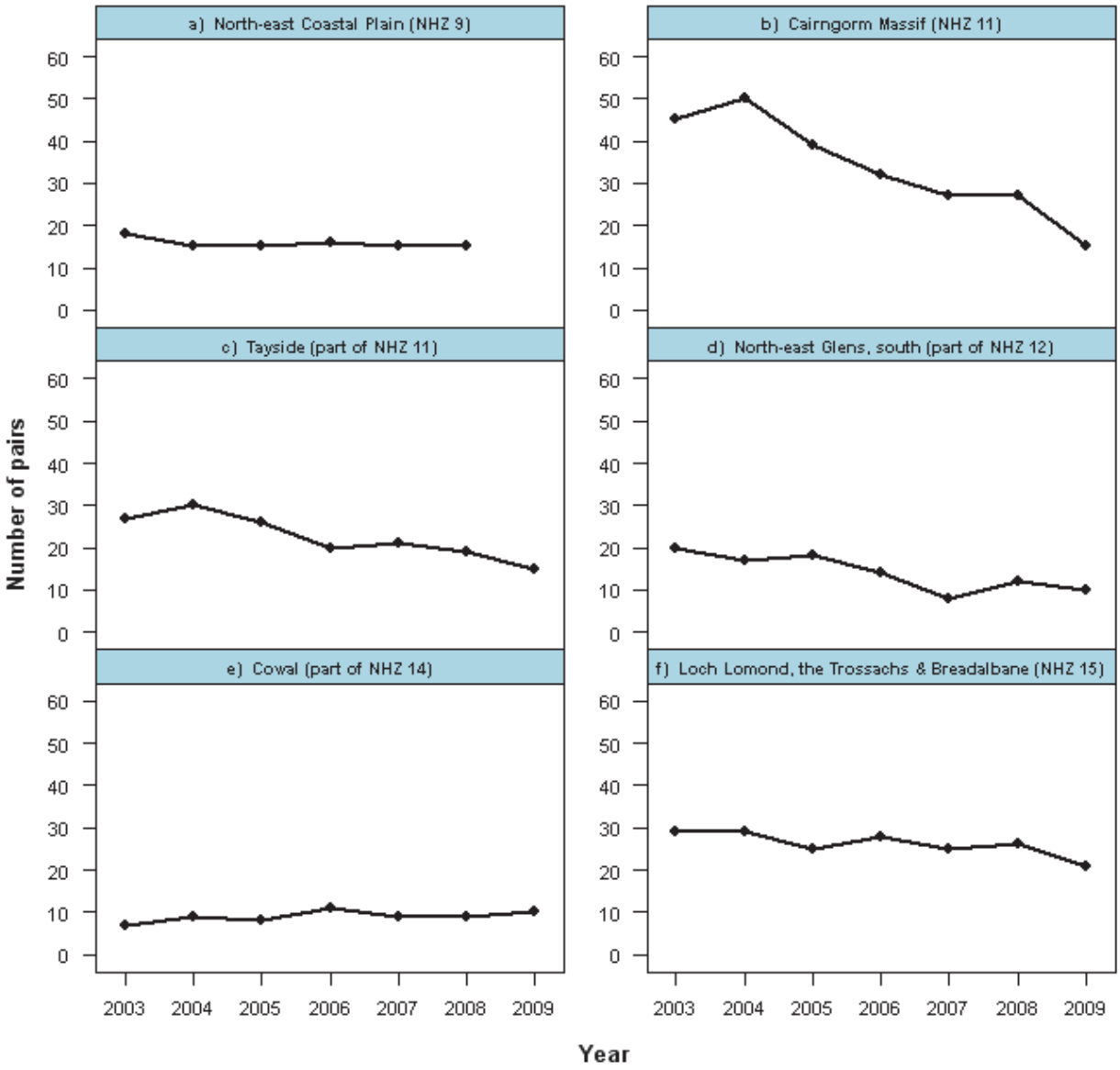


Figure 70. Best available rends in numbers of breeding peregrines in 11 NHZs or part of NHZs in Scotland for which annual coverage is thought to have been comprehensive each year.
(Source: SRMS data)

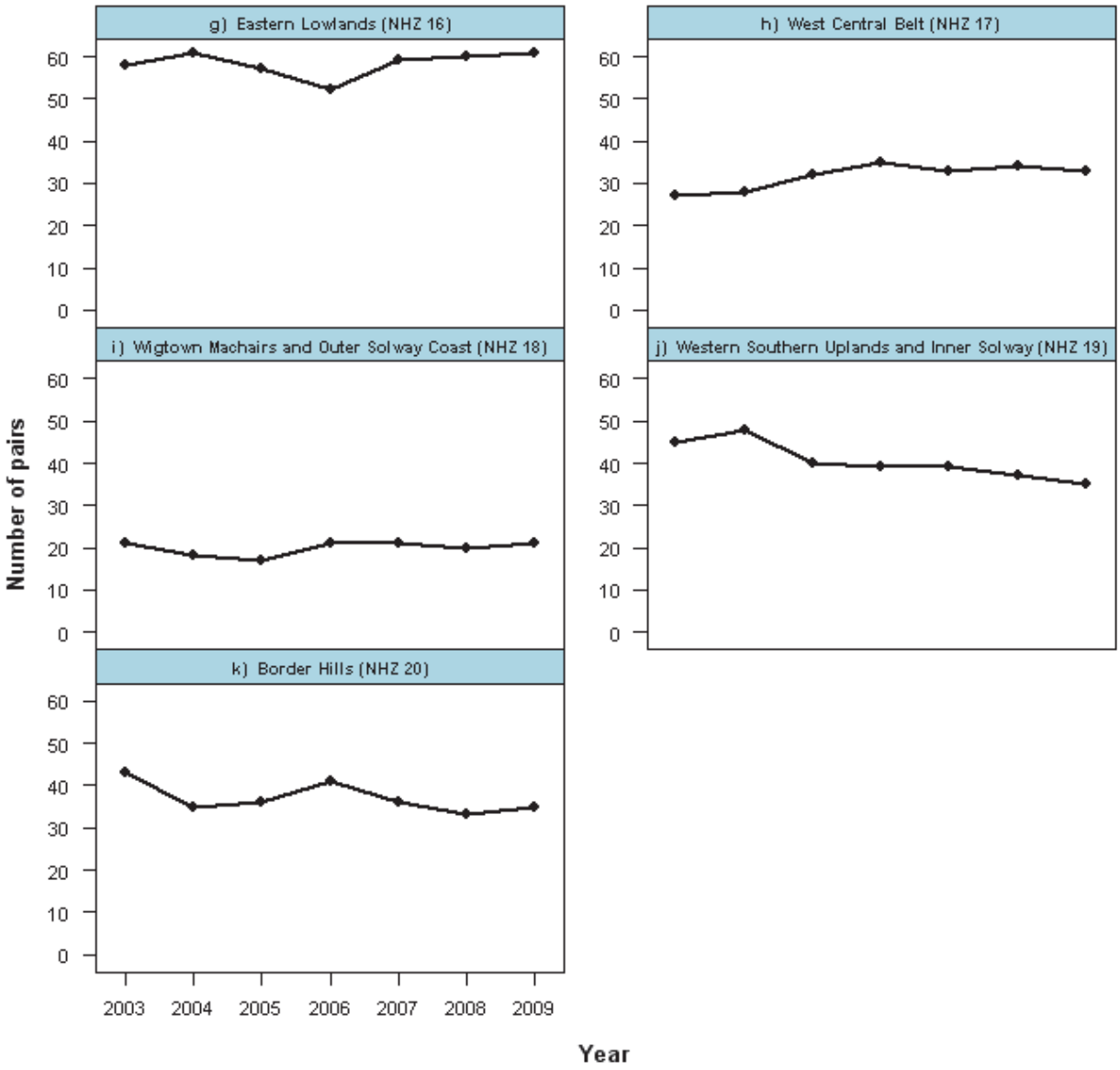


Figure 70 Continued. Best available trends in numbers of breeding peregrines in 11 NHZs or part of NHZs in Scotland for which annual coverage is thought to have been comprehensive each year.
(Source: SRMS data)

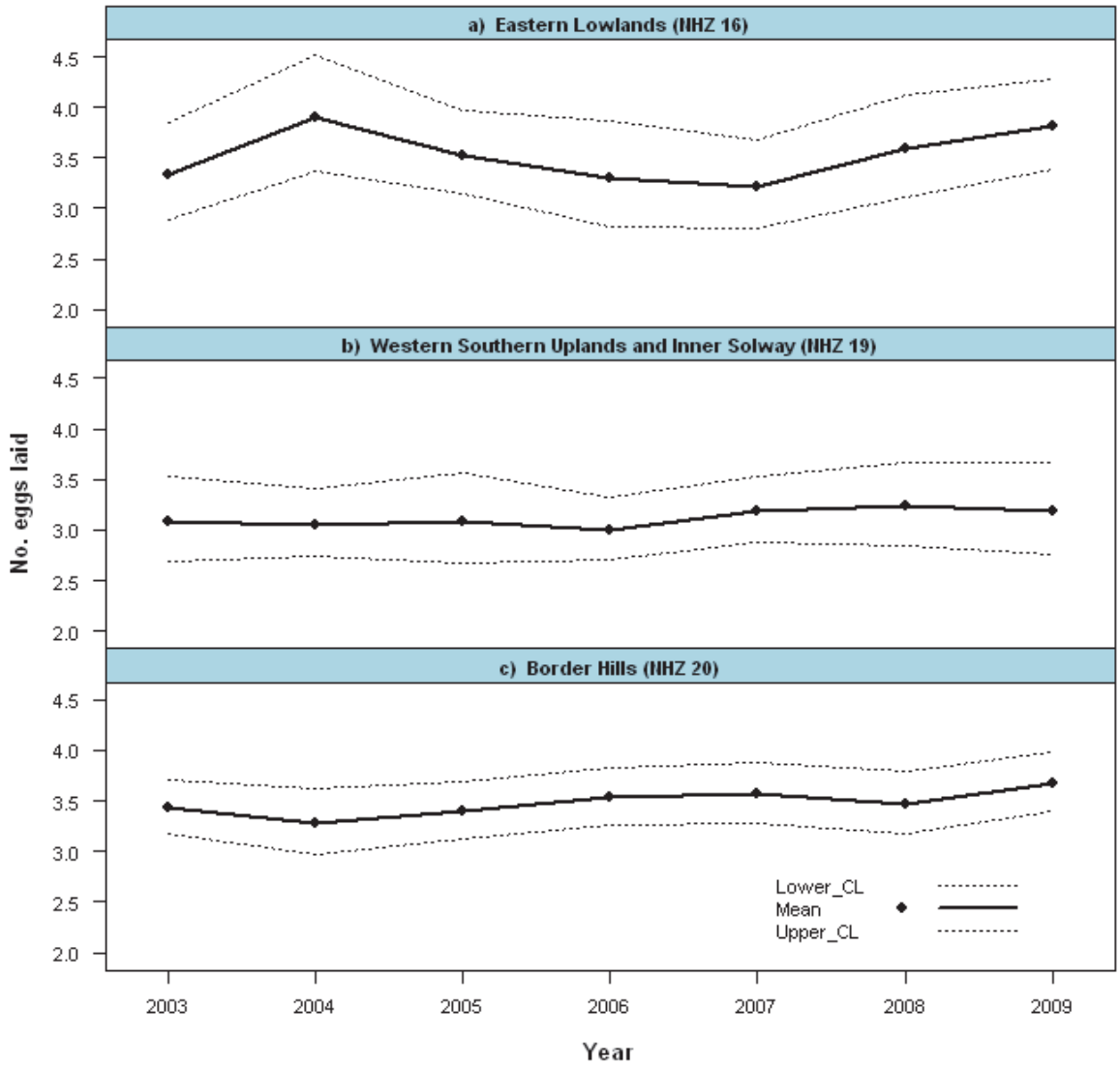


Figure 71. Trends in the clutch size of pairs that laid for peregrines in three Scottish NHZs for which there were sufficient samples for analysis.
(Source: SRMS data)

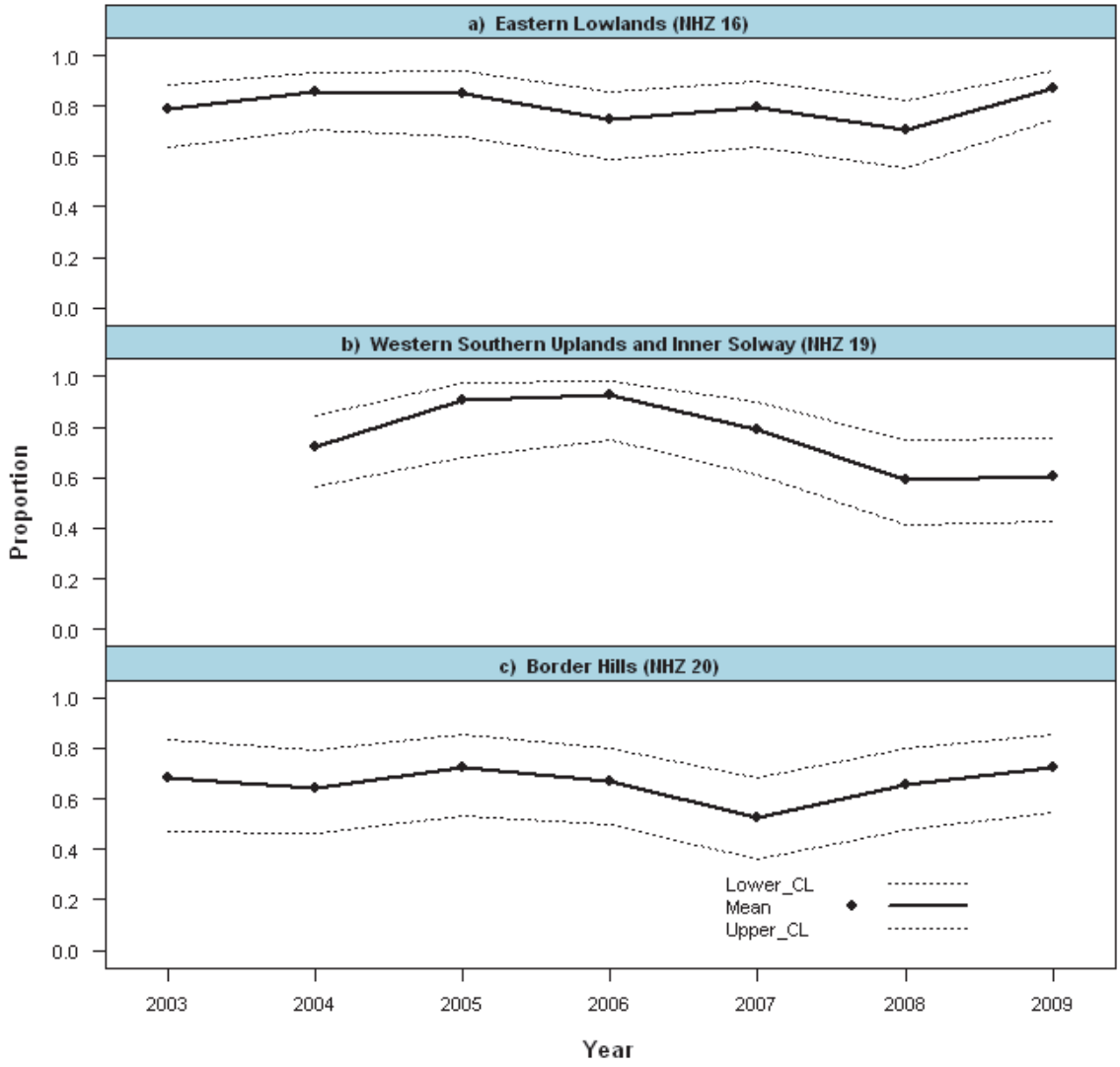


Figure 72. Trends in hatching success (proportion of pairs known to lay that hatched at least one young) for peregrines in three Scottish NHZs for which there were sufficient samples for analysis.
(Source: SRMS data)

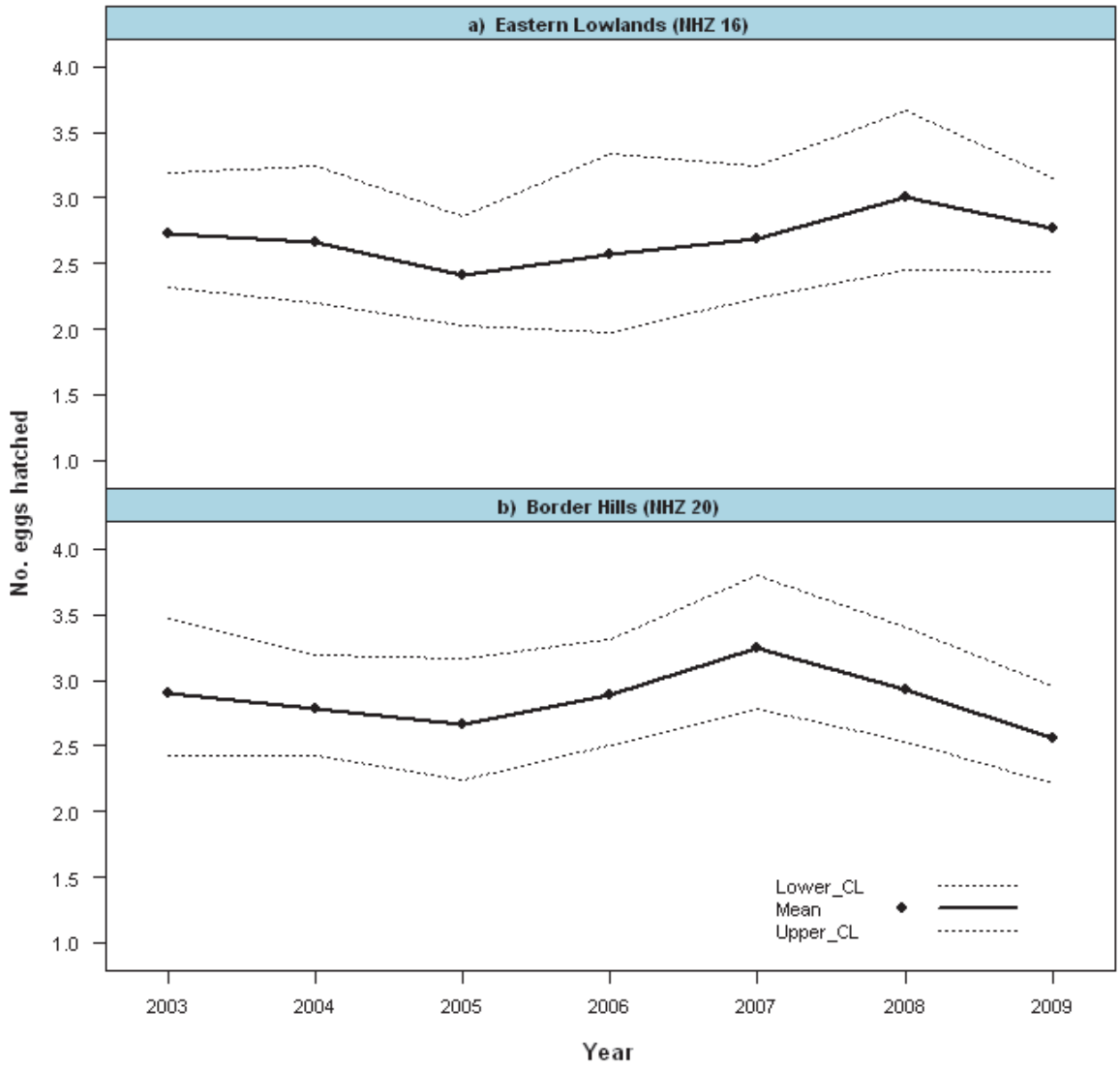


Figure 73. Trends in brood size at hatching of pairs that hatched young for peregrines in two Scottish NHZs for which there were sufficient samples for analysis.
(Source: SRMS data)

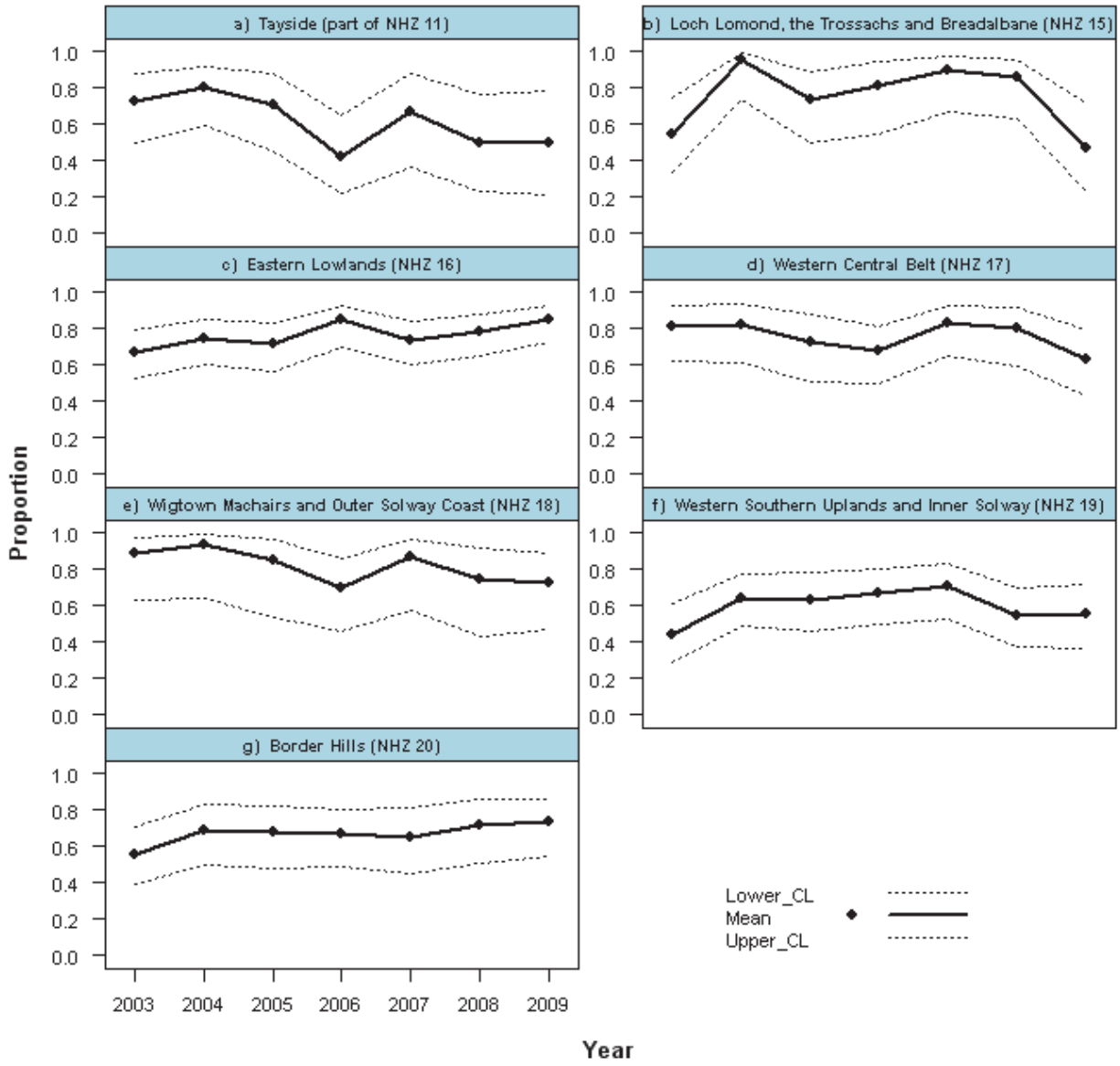


Figure 74. Trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for peregrines in seven Scottish NHZs or parts of NHZs for which there were sufficient samples for analysis.
(Source: SRMS data)

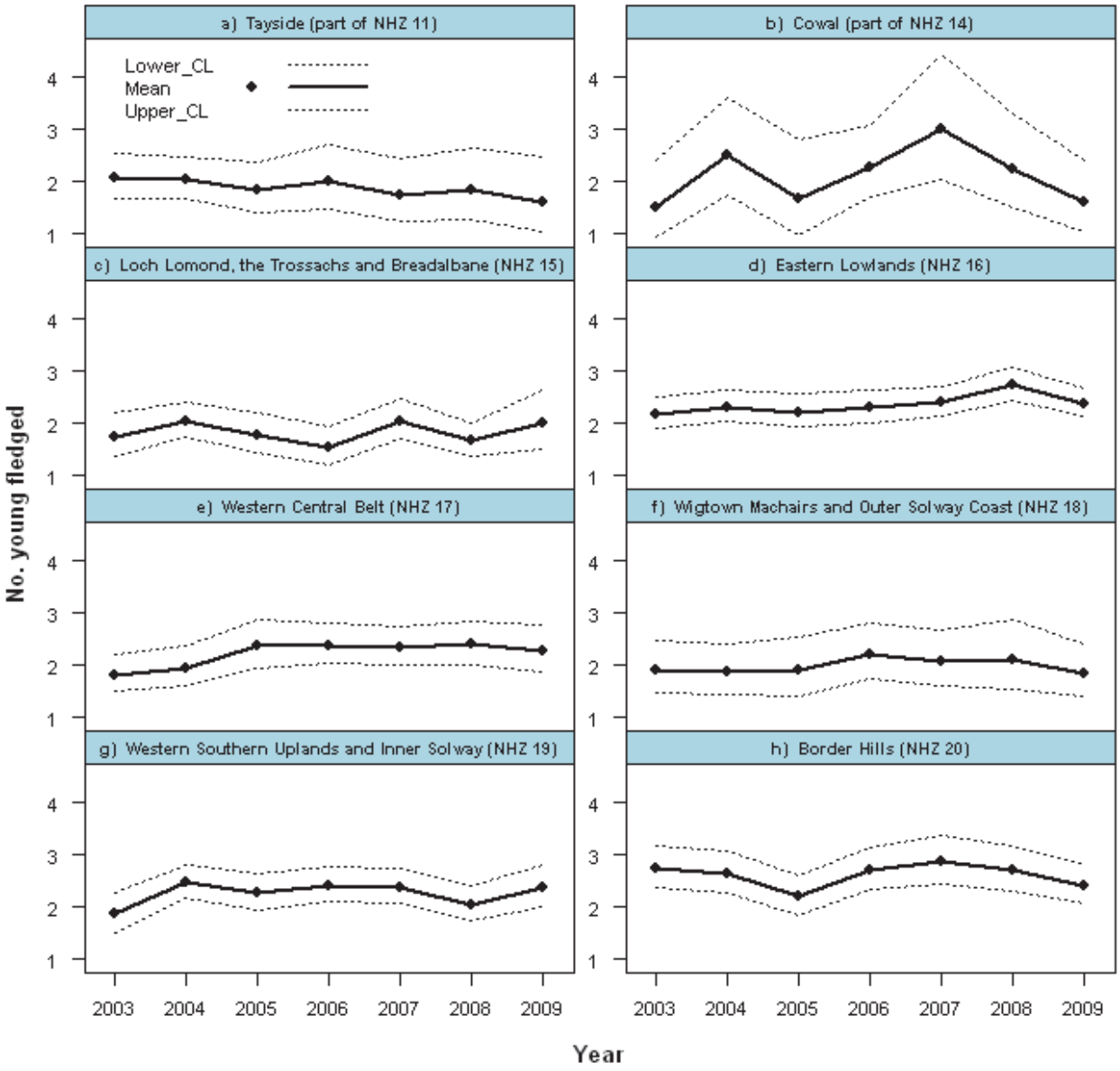


Figure 75. Trends in the number fledged per successful pair for peregrines in eight Scottish NHZs or parts of NHZs for which there were sufficient samples for analysis.
(Source: SRMS data)

1.4.11 Barn owl

Trends in breeding numbers
The best available trends in breeding numbers at regional scale since 2003 show variable changes, with suggestions of declines in some of the southern studies, and some increase in Stirlingshire (Figure 77).

Best available trends in breeding numbers are reported for seven study areas across Scotland (Figure 76): North-east Highlands (parts of NHZs 5, 7, 10 and 21); Southern Uplands (parts of NHZs 19 and 20); West Galloway (parts of NHZs 18 and 19); Central Galloway (part of NHZ 19); Mid-Argyll and Kintyre (part of NHZ 14); Stirlingshire (parts of NHZs 15, 16 and 17); and Aberdeenshire (parts of NHZs 9, 11 and 12). These seven study areas are distributed across Scotland but concentrated in the southern part of the country, reflecting the traditional strongholds of barn owl distribution in Scotland but probably not representing fully the current distribution. Sample sizes available for analyses are given in Annex Table B 33.

Trends in breeding productivity
The breeding productivity parameters showed marked fluctuations across the study areas, probably due to a combination of changes in prey abundance and severity of winter weather (e.g. Taylor 1989, 1994).

Best available trends in clutch size of pairs that laid for three studies (Figure 78), hatching success for one study (Figure 79), fledging success for four studies (Figure 80) and the number fledged per successful pair for six studies (Figure 81) are reported. See Annex Table B 34 for sample sizes available for analyses.

Data sources, caveats, work pending and gaps
Analyses are based on the SRMS dataset for 2003-2009. Initial scoping of the datasets suggested 11 study areas distributed across Scotland that had the potential to be used in trend analyses (Figure 76). Some of the identified studies were initiated relatively recently, or have a low sample size, and thus provisional trends in numbers and productivity are reported for only seven of the studies. For two of these studies, it was necessary to restrict the years to 2004-2009 and for one study to 2005-2009 (Annex Table B 33). Most of the seven study areas had comprehensive monitoring of productivity across years, but large enough sample sizes of productivity parameters were achieved for only some of the studies and some years (Annex Table B 34).

Trends from the seven study areas should be regarded as provisional until annual coverage and survey effort have been verified with observers. Provisional year-on-year comparisons suggested that the spatial coverage of monitoring has been relatively consistent across years in at least five of the seven study areas. However, in one study area (Southern Uplands) for example, the high number of monitored nest boxes in 2003 and 2009 appears to be due mainly to the monitoring of sites in the eastern part of the study area, which were not covered in all years. In the core (western) part of the same study area, monitoring appears to have been comprehensive in all years, without apparent changes in coverage. In another study (Stirlingshire), the number of checked nest sites shows a pronounced peak in 2007 and 2008 and appears to reflect a higher density of nest boxes and/or natural nests in the central part of the study area. For several of the studies, the results suggest that in the early years of the SRMS (mainly 2003-2005) there was a positive correlation between the number of checked nest sites and the number of sites occupied by breeding pairs (see Annex Table B 33 and Figure 77) but this relationship was less evident for the later years. This may have occurred due to a lack of reporting of sites that were checked but not occupied during the earlier study years but we need to confirm this through further liaison with observers.

Given the number and geographical spread of studies of barn owl that submit data to the SRMS currently (Annex Table B 33), it may be possible to produce some national trends in future once the work described above is complete.

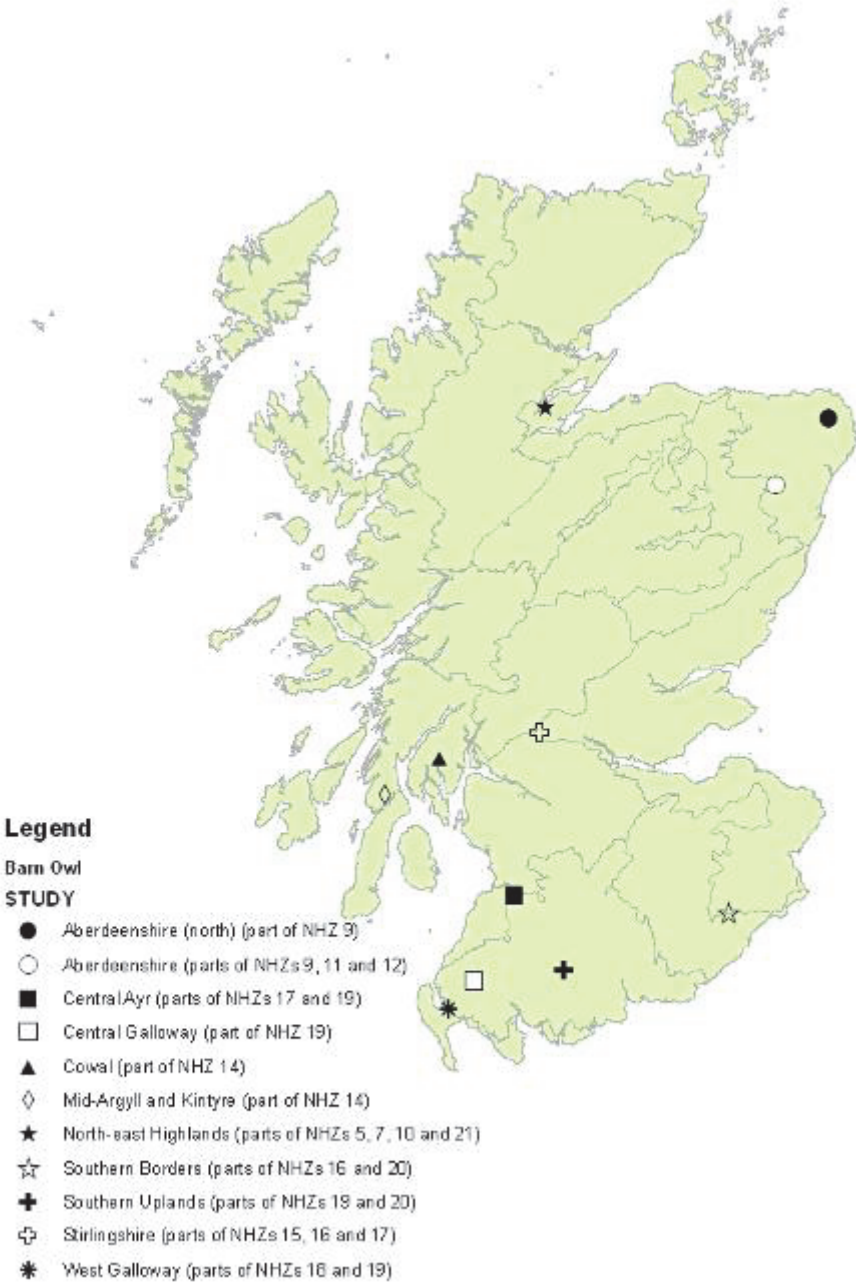


Figure 76. The locations of the seven barn owl studies contributing information on trends, and other study areas considered for inclusion in the current project.

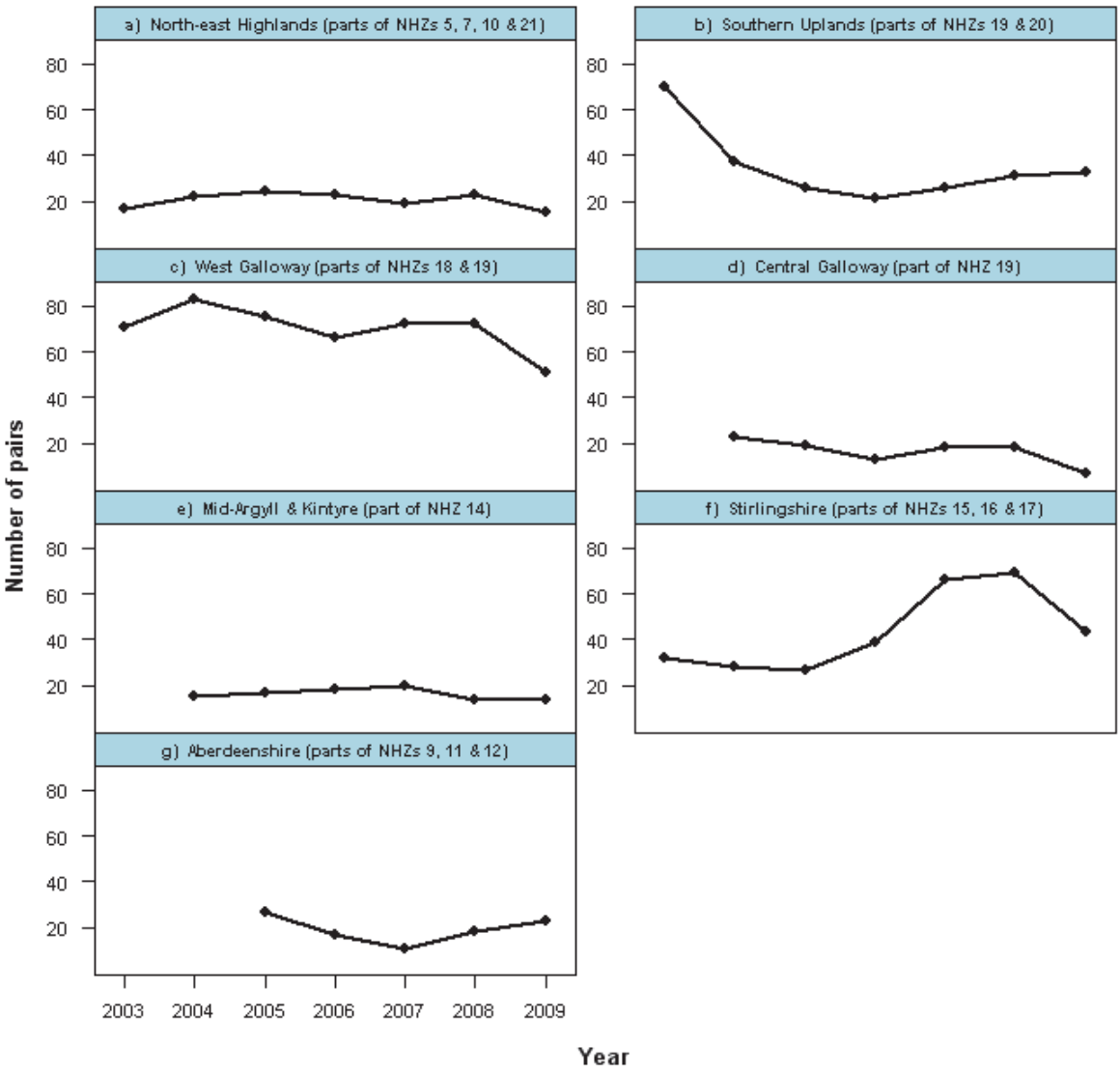


Figure 77. Best available trends in the number of breeding barn owls in seven study areas in Scotland.
(Source: SRMS data)

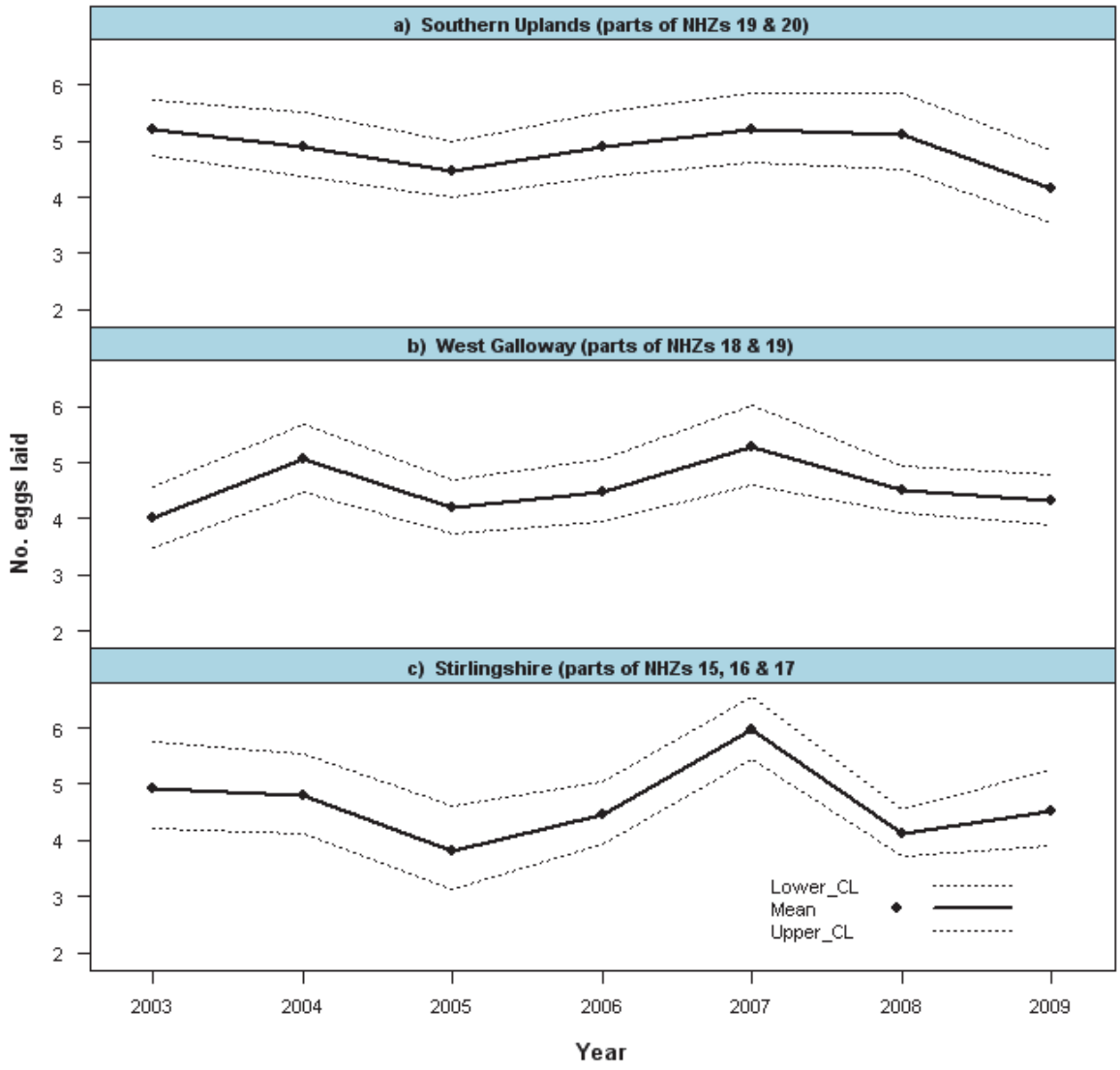


Figure 78. Best available trends in clutch size of pairs that laid for barn owls in three Scottish study areas for which sufficient samples were available for analysis.
(Source: SRMS data)

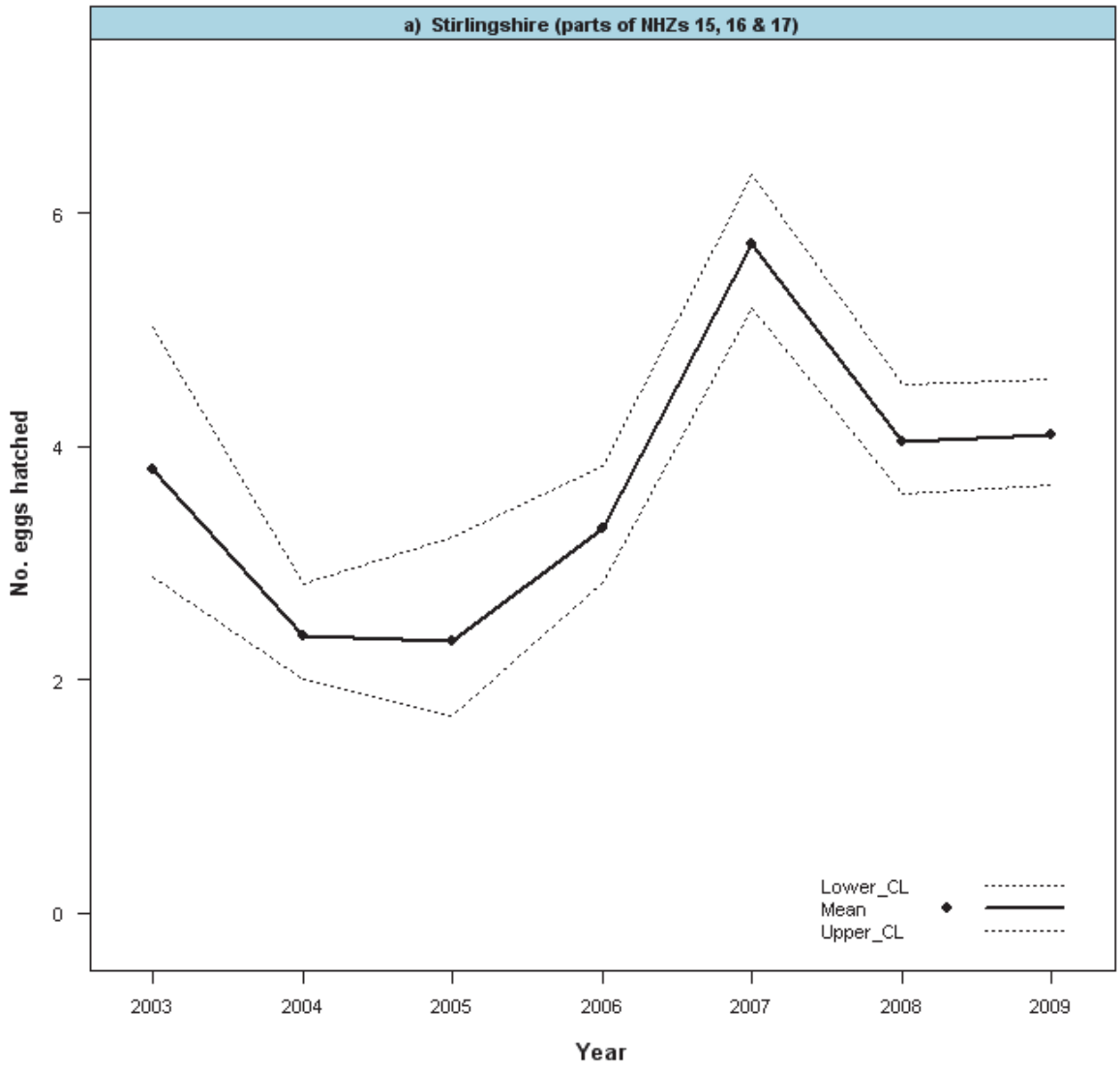


Figure 79. Best available trend in brood size of pairs that hatched young for barn owls in the one Scottish study area for which a sufficient sample was available for analysis.
(Source: SRMS data)

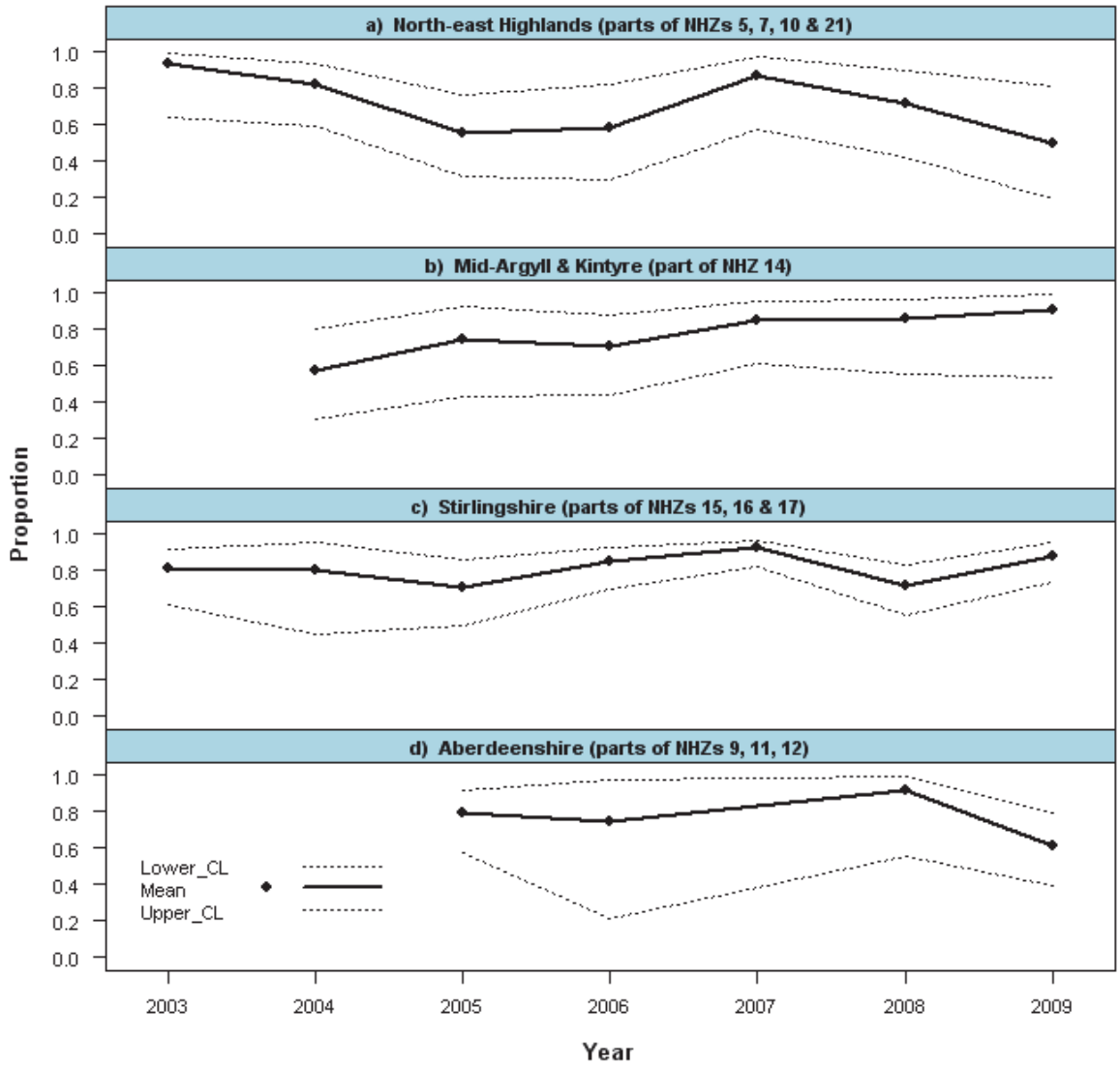


Figure 80. Best available trends in fledging success (proportion of pairs known to hatch young that fledged at least one young) for barn owls in four Scottish study areas for which sufficient samples were available for analysis.
(Source: SRMS data)

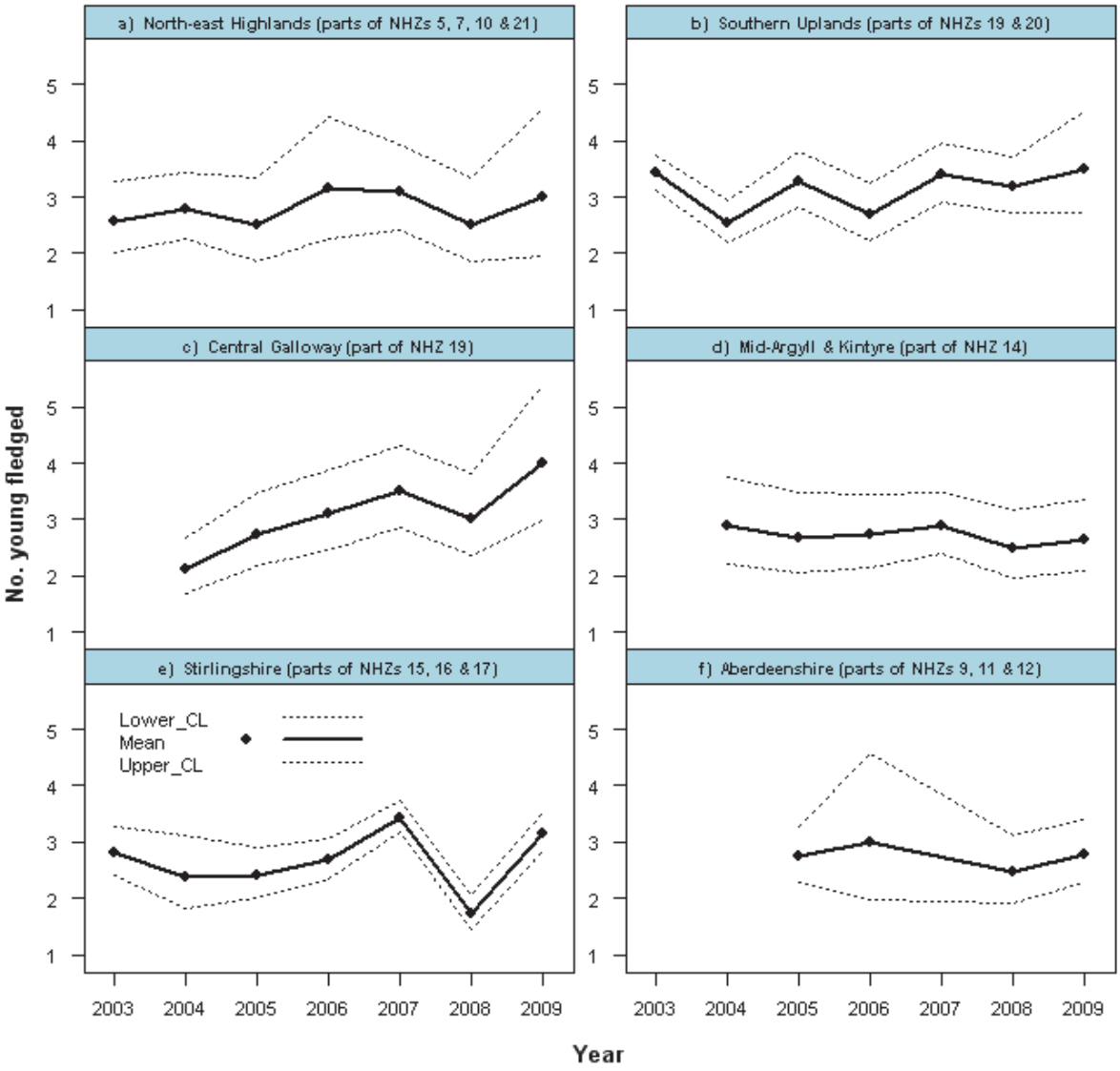


Figure 81. Best available trends in the number fledged per successful pair for barn owls in six Scottish study areas for which sufficient samples were available for analysis.
(Source: SRMS data)

1.4.12 Tawny owl

Trends in breeding numbers
The best available trends in breeding numbers from four Scottish study areas suggest possible declines since 2003 (Figure 83).

Best available trends in breeding numbers are reported for four Scottish study areas (Figure 82): Easter Ross (parts of NHZs 5, 7 and 21); the Black Isle (parts of NHZs 7 and 21); Borders (parts of NHZs 16 and 20); and Southern Uplands (parts of NHZs 19 and 20). These four study areas are distributed across Scotland but probably do not represent fully the current distribution of the species. Sample sizes available for analyses are given in Annex Table B 35.

Trends in breeding parameters
The breeding success parameters, clutch size, brood size and fledging success from the Easter Ross study show general stability since 2003. A decline in the number of young fledged per successful pair is suggested for Easter Ross. Information from the Southern Uplands and Borders study areas spans only a small number of years, and sound interpretation of trends requires a longer series of data.

Best available trends in clutch size of pairs that laid (Figure 84), brood size at hatching for pairs that hatched young (Figure 85) and fledging success (Figure 86) are reported for one study, and the number fledged per successful pair for three studies (Figure 87). See Annex Table B 36 for sample sizes available for analyses.

Data sources, caveats, work pending and gaps
Analyses are based on the SRMS dataset for 2003-2009. Initial scoping of the datasets suggested six study areas distributed across Scotland that had the potential to be used in trend analyses. One of these identified studies had low sample sizes, however, and another study had several years with gaps in the monitoring. Therefore provisional trends in numbers were reported for four studies (Annex Table B 35). Low sample sizes for breeding parameters further restricted the number of studies from which trends in these could be reported, and for three studies the number of years was limited due to low sample sizes (Annex Table B 36).

Trends from the four study areas should be regarded as provisional until annual coverage and survey effort has been verified with observers. Preliminary year-on-year comparisons suggested that the spatial coverage of monitoring has been relatively consistent across all years 2003-2009 for at least one of the four study areas (Easter Ross; Figure 82). The other three studies identified as having large enough samples of checked nest sites for a subset of the years showed no obvious changes in spatial coverage during those years selected for analysis. For several of the study areas, records showed that in the first year of the SRMS (i.e. 2003, and for one study all the years 2006-2008) the number of checked nest sites and the number of sites occupied by breeding pairs were the same (Annex Table B 35 and Figure 83) but this relationship was not evident for the other years of these studies. This could have occurred due to a lack of reporting of sites that were checked but not occupied during the earlier study years and this needs to be checked through liaison with observers.

The current number and geographical spread of studies of tawny owl that submit data to the SRMS (Annex Table B 35) is unlikely to be sufficient to permit production of national trends in the near future.

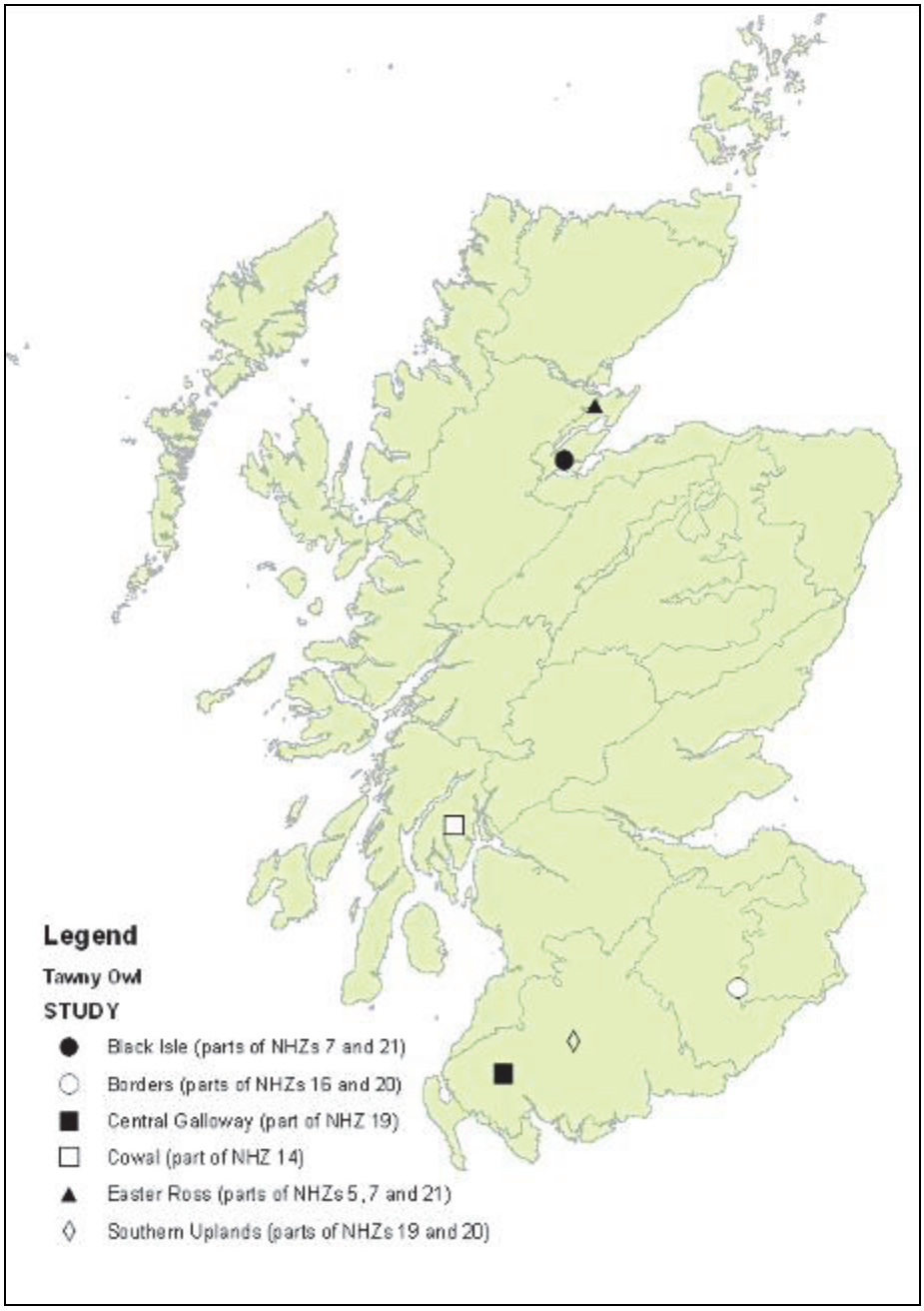


Figure 82. Locations of the four tawny owl studies contributing information on trends, and other study areas considered as part of the current project.

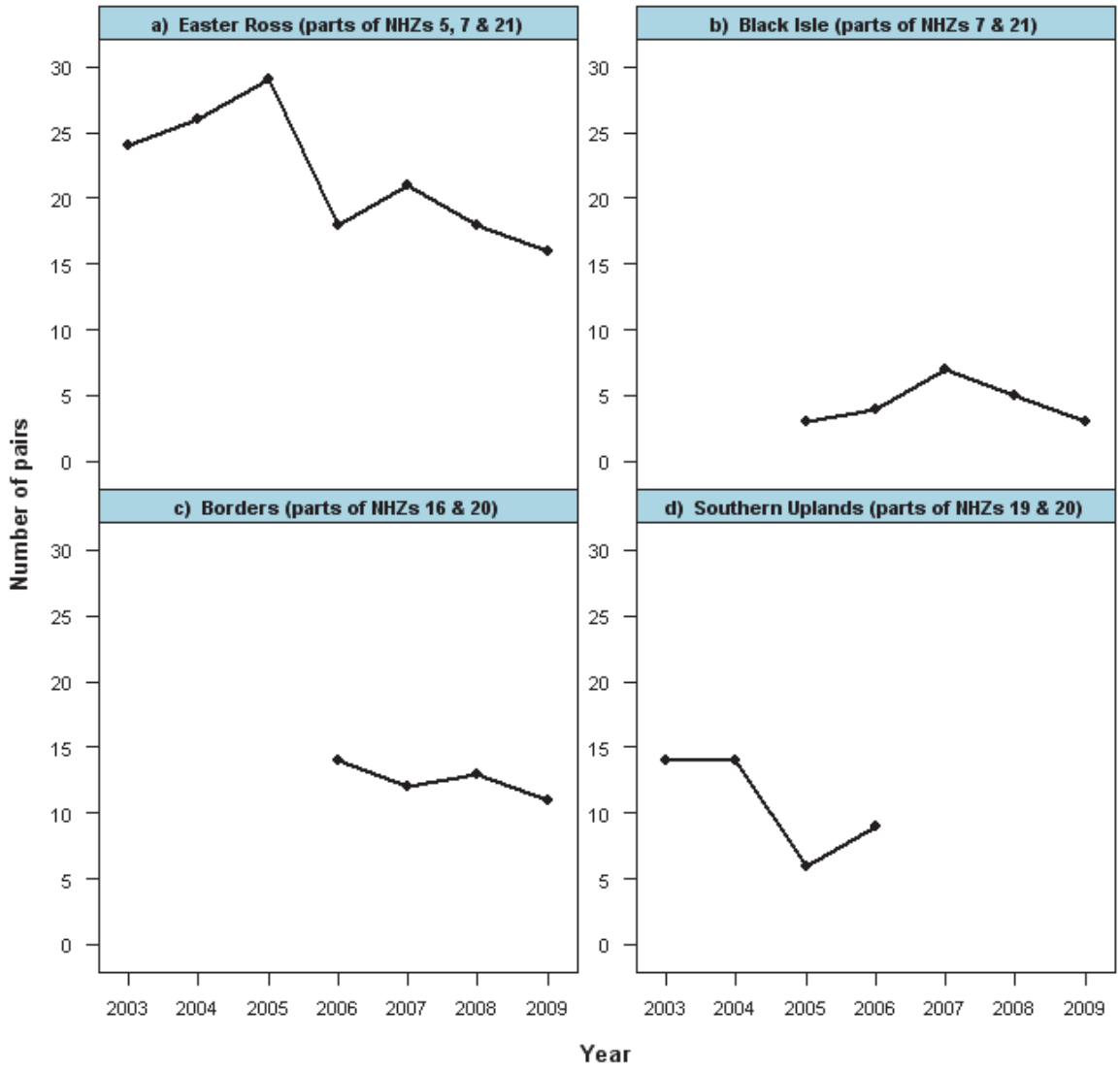


Figure 83. Best available trends in the number of breeding tawny owls in four Scottish study areas between 2003 and 2009.
(Source: SRMS data)

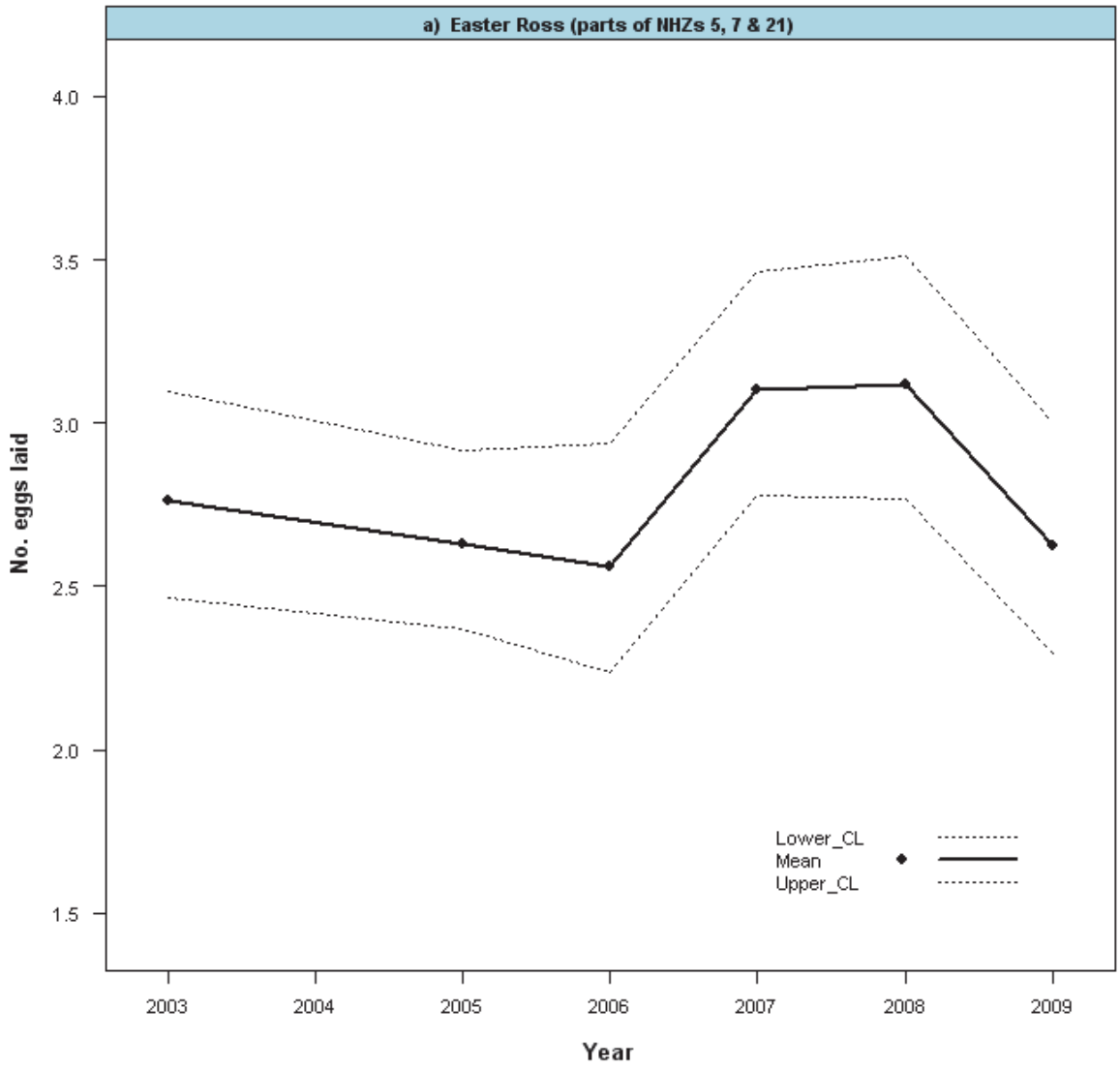


Figure 84. Best available trend in the clutch size of pairs that laid for tawny owls in the one Scottish study for which there was a sufficient sample for analysis.
(Source: SRMS data)

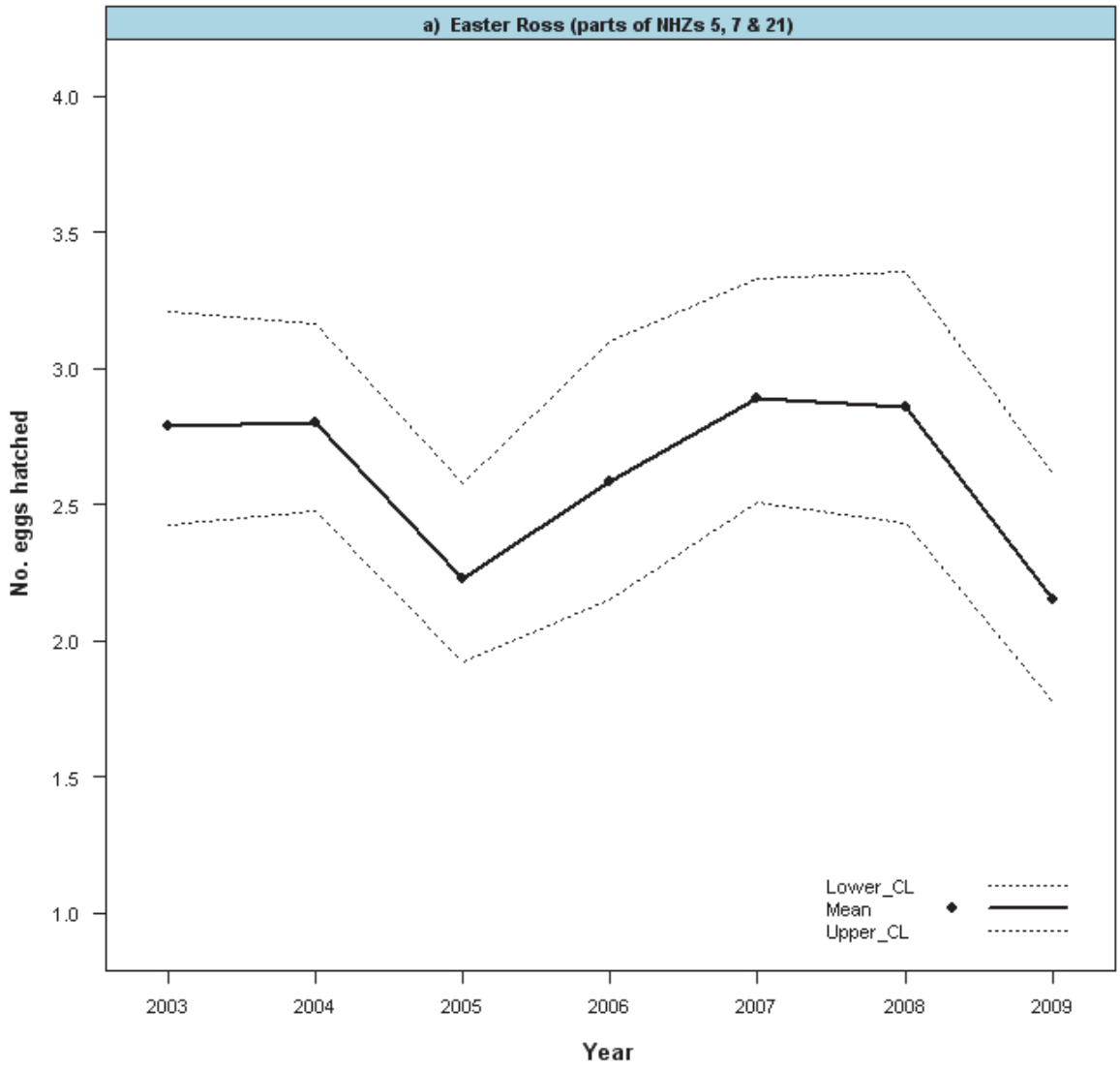


Figure 85. Best available trend in the brood size at hatching of pairs that hatched young for tawny owls in the one Scottish study for which there was a sufficient sample for analysis. (Source: SRMS data)

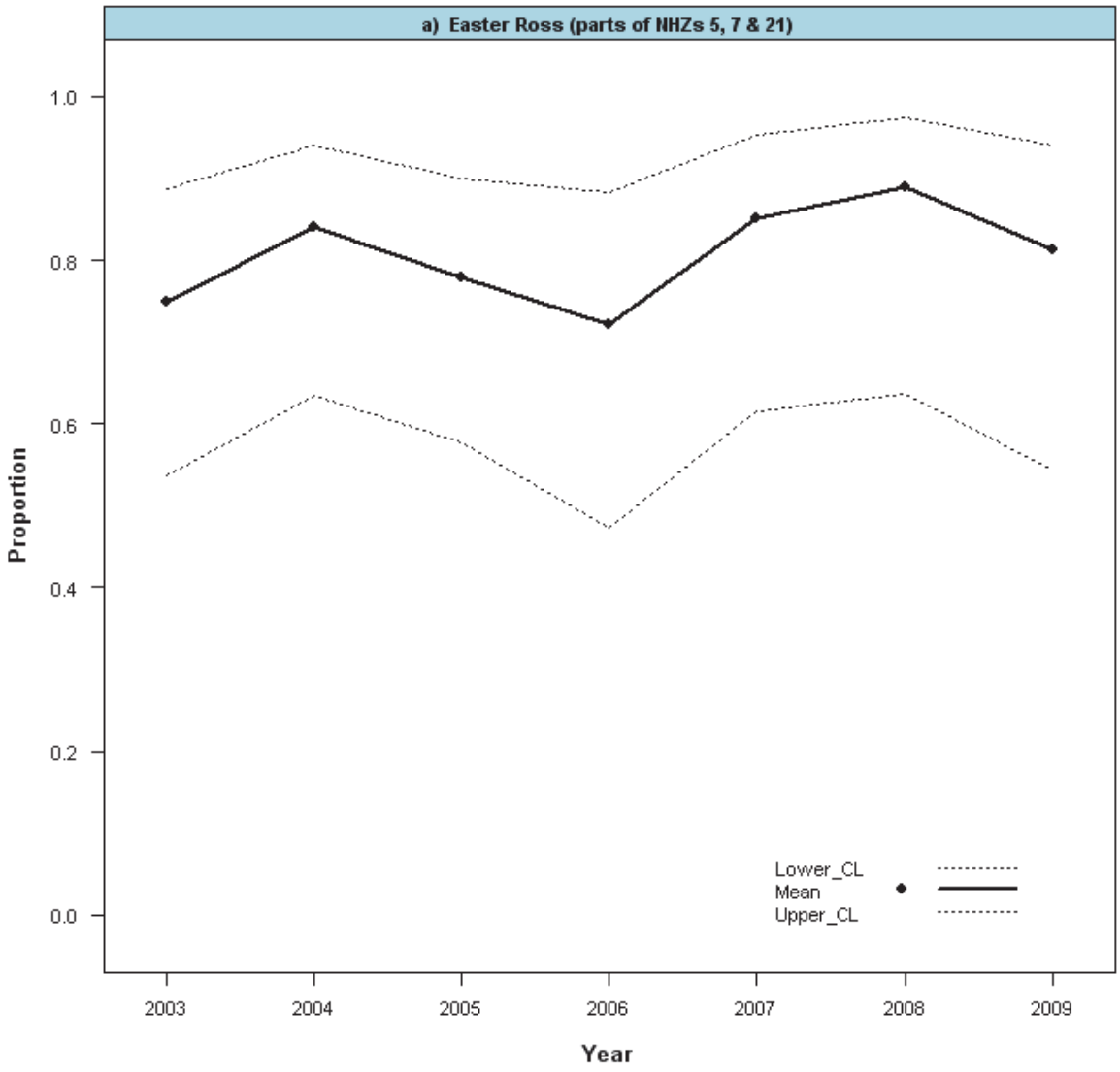


Figure 86. Best available trend in fledging success (proportion of pairs known to hatch young that fledged at least one young) for tawny owls in the one Scottish study for which there was a sufficient sample for analysis.
(Source: SRMS data)

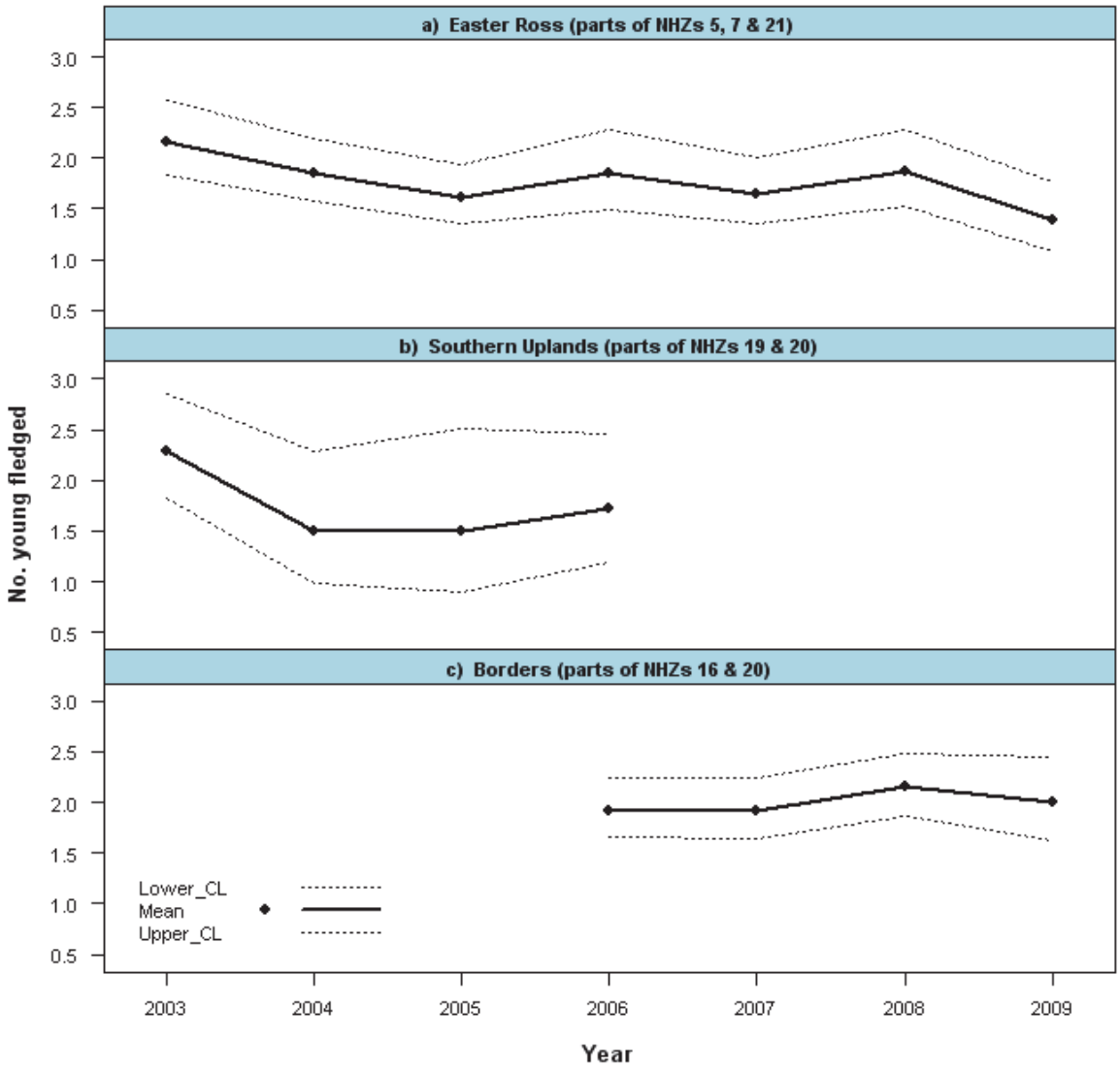


Figure 87. Best available trends in the number fledged per successful pair for tawny owls in three Scottish studies for which there were sufficient samples for analysis.
(Source: SRMS data)

1.4.13 Common raven

Trends in breeding numbers
The national trend in raven breeding abundance, from BBS results, shows some increase between 1994 and 2002, particularly in the early 2000s, and perhaps some degree of stabilisation subsequently (Figure 88). Overall, the smoothed abundance index for Scotland increased by 65% between 1995 and 2009 but the overall increase was not significant (lower and upper confidence limits -10 to 160%; Risely *et al*. 2011). This trend may not be fully representative of changes in breeding numbers across Scotland as a whole (see below). It is not currently possible to report regional trends in breeding numbers.

Trends in breeding parameters
It is not currently possible to report regional or national trends in breeding parameters.

Data sources, caveats, work pending and gaps
Ravens were recorded in 43 of the 329 squares surveyed for the BTO/JNCC/RSPB Breeding Bird Survey in Scotland in 2010 (Risely *et al*. 2011; Annex Figure A4). The trend in breeding abundance produced by the Breeding Bird Survey may not be representative of changes in breeding raven numbers across Scotland as a whole because: (i) the survey squares covered could be biased towards the areas in which the largest increases in the breeding raven population have occurred during the last 20 years (Simon Gillings pers. comm.); (ii) because BBS methodology is not designed to allow breeding pairs to be distinguished from non-breeding 'floaters', numbers of which are likely to vary with population density but not in direct proportion to the number of breeding pairs; and (iii) because non-territorial individuals and family groups can move around large areas during the breeding season and after breeding (from late May onwards), with non-territorial pairs sometimes displaying well away from possible nest sites (W. Mattingley, pers. comm.).

The SRMS data for raven were not analysed for trends in the current project because studies with sample sizes sufficient for analyses were only established in the most recent years (see Table 1). There is a need to obtain coverage and survey effort information from these studies, and compare coverage with the overall distribution and relative abundance of the species across Scotland (using Bird Atlas 2007-11 information), before it will be possible to assess the extent to which these can produce representative regional or national trends in future.

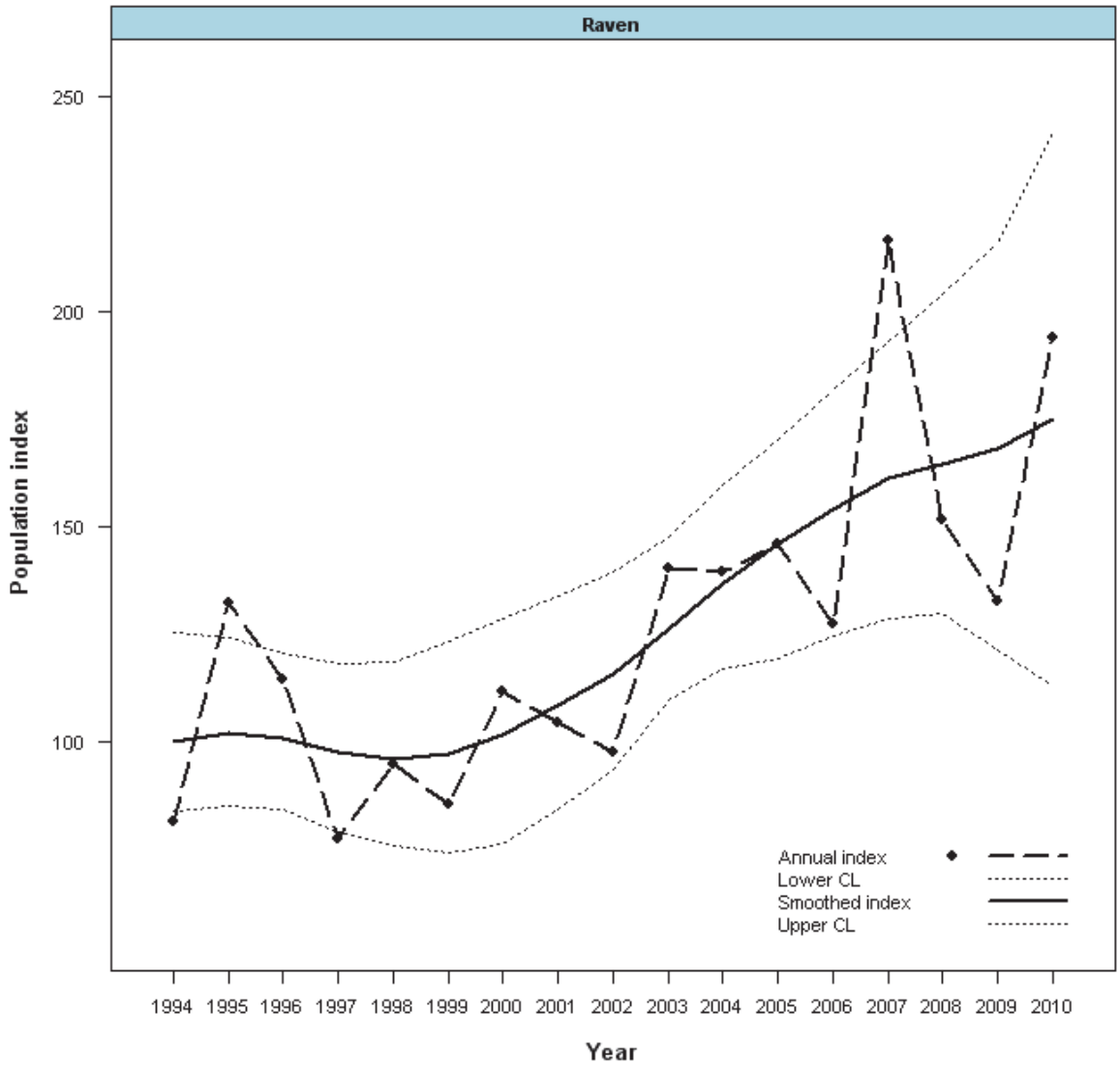


Figure 88. Trend in the breeding abundance of ravens in Scotland between 1994 and 2010 (relative to index value set to 100 in 1994).
Both the annual index values, and the smoothed index with associated 95% confidence limits, are shown.
(Source: BTO/JNCC/RSPB Breeding Bird Survey data.)

1.5 Raptor trends: discussion and future directions

1.5.1 Extent of available trend information from annual monitoring efforts

The current project has allowed a clear picture of the potential for production of temporal trends in breeding numbers and breeding productivity for raptors covered by the SRMS to be developed.

Trends are rigorous at the regional and national scale for species that receive comprehensive or near-comprehensive monitoring on an annual basis and for which full location information is available (red kite and white-tailed eagle).

There is also the potential to produce rigorous trend information for a number of other species that receive dedicated monitoring effort each year (e.g. golden eagle, peregrine falcon, hen harrier, merlin, and perhaps common buzzard and barn owl; see Table 2). For these species, we have produced the best available trends, pending further work to establish whether/how coverage of study areas and monitoring effort may have varied since establishment of the SRMS (see Section 1.3.3), and to what extent annual coverage is representative at the required spatial scale.

For other species (e.g. common kestrel, Eurasian sparrowhawk and tawny owl), trend information is available from a small number of intensive studies that are limited in their geographical extent. These cannot be expected to produce trend information that is more widely representative of Scottish populations as a whole but they currently produce rigorous trend information at a local or regional scale.

For some species and study areas, notably osprey, golden eagle and merlin, trend analysis at any scale is restricted because of a lack of grid reference information being supplied to the SRMS from some survey areas.

In general, it is the more widespread species that have received lower monitoring coverage (e.g. common kestrel, Eurasian sparrowhawk, common buzzard and common raven; see Table 2). Information on changes in the breeding relative abundance of these species is available from the BTO/JNCC/RSPB Breeding Bird Survey but the extent to which such trends are representative of Scottish populations deserves further assessment (e.g. using Bird Atlas 2007-11 data to clarify current range and spatial variation in relative abundance across Scotland). The SRMG is currently considering more generally other ways in which monitoring of numbers and breeding parameters could be improved for the more widespread raptor species in Scotland (see also Section 1.3.4).

We did not carry out any formal tests of statistical significance for the trends produced from SRMS data as part of this project, first, because data were generally only available from 2003 onwards (a short time series) and, second, because many of the trends should be regarded as provisional under survey coverage/effort is verified with observers. The SRMS aims to start requesting data from observers for years prior to 2003.

1.5.2 Parameters for which trends from SRMS data are feasible

For the species for which further work is still required on changes in SRMS survey coverage and effort, the trends presented in this report must be regarded as provisional and subject to modification. This is more so for trends in numbers, where a change in coverage can directly influence the annual count of breeding birds, than for the productivity measures. We have reported trends in numbers as the absolute number of breeding pairs in study areas each year, so that the sample sizes contributing to studies are explicit. In future, once the extent of annual coverage is clear, it may be preferable to convert these trends to population indices (where counts are standardised to a baseline value in a given year; *e.g.* 2003 or the most

recent year). This would facilitate comparisons of changes between spatial areas and ensure that the numbers of breeding pairs contributing to the trends (the sample) are not confused with total population size.

For longer-lived raptor species, breeding numbers might be expected to change relatively slowly through time, such that a trend in the number of breeding pairs might not be the most sensitive indicator of either adverse environmental change or positive conservation action over shorter timescales. For some species, for example golden eagle, white-tailed eagle and peregrine, for which individual birds can be aged by experienced surveyors, the SRMS could encourage more observers to routinely collect information the age of breeding pairs, as an indicator of potential changing age structure of populations (Whitfield *et al.* 2008). Changes in population age structure can be indicative of age-specific mortality (e.g. Whitfield *et al*. 2008; Smart *et al*. 2010) and can provide information on recruitment into the breeding population.

Across the species covered by the SRMS, the number of young fledged *per successful pair* was the breeding success parameter for which we considered it feasible to produce unbiased trends for the most species. Whilst temporal trends in clutch size and brood size at hatching were feasible for some species and some particular studies, it would not be possible for the SRMS to encourage the collection of larger samples of data on these parameters for many species (due to risks of disturbance; current guidance is given in Hardey *et al*. 2013). In addition, for longer-lived species with smaller clutch/brood sizes, low annual variation in such parameters means that trends will not function as sensitive indicators of environmental change. For longer-lived species with small brood sizes, the parameters *proportion of pairs that lay*, *proportion of pairs that hatch young* and *proportion of pairs that rear at least one young successfully* are likely to be more sensitive indicators of environmental change (and deliberate human disturbance; e.g. Amar *et al*. 2012). To give the maximum potential to produce trends in these parameters from SRMS data in future, observers need to routinely record the dates of all survey visits and nest contents/stage of breeding information at each visit.

1.5.3 Current SRMS data collation and recommendations

The current project has reinforced the findings of a previous review of SRMS data (2003-2008), highlighting areas of current SRMS data collation that should be enhanced so that the Scheme can deliver effectively and efficiently in relation to the aims of the SRMS (Anon. 2002 & revised SRMS Agreement 2014) and the needs of its stakeholders.

Table 3 outlines the recommended enhancements that could be made to the SRMS, based on this study. In summary, these are:

(i) Full details of individual breeding attempts should be submitted to the SRMS (not summary data) in the form required by the bespoke SRMS MS Excel recording spreadsheet, including full six-figure grid references, all visit dates, details of all sites (including those not checked in any given year) and definite breeding outcomes. Assessment of the extent to which samples surveyed annually are representative of populations in specific spatial units (e.g. NHZs) requires location information to allow nesting ranges to be linked to specific NHZs but not all records have associated grid-references that allow this linking to be carried out (the extent of the problem varies between species; see Table 1).

(ii) In the short-term, observers should be encouraged to use master spreadsheets, available from the Scottish Raptor Monitoring Coordinator, to ensure that they supply data in a format consistent with the SRMS dataset (2003-2009) and include a 'return' for each of their sites each year (even if not checked). This will ensure that the

substantial cleaning and standardisation of the 2003-2009 dataset that has been undertaken to date will not be diminished, and checking for site turnover between years (which is required for trends work) can be carried out efficiently.

(iii) Coverage/effort information should be obtained from all SRMS contributors. Once study area boundaries have been established, little work will be required on the part of volunteer raptor workers annually to update the information but the annual update must occur to allow rigorous trends to be produced in future. The SRMG needs to achieve an appropriate balance between recording suitable measures of effort without making this too onerous for volunteer raptor workers each year.

(iv) We recommend that a process begins to request historical (pre-2003) survey data from SRMS contributors that have carried out consistent monitoring of core study areas and have the data in a form that can be submitted. This will enable longer-term trends to be reported in future.

(v) The SRMS needs to develop bespoke, fit-for-purpose software to collect SRMS data more efficiently and effectively. A number of current BTO-organised monitoring schemes employ, or are in the process of developing, on-line applications (including off-line upload modules) that encapsulate most if not all of the functionality that would be required for a similar SRMS application, such that it should be possible to develop a cost-effective system for the SRMS in the near future. It is important that any new system captures information on annual survey coverage and effort, as well as full details of individual breeding attempts through records made at each visit. The SRMG has already initiated appropriate discussion and a preliminary software specification has been drafted. In future, such a system could allow automated feedback of monitoring results on an annual basis, and functionality for volunteer observers (and SRSG Species Coordinators/Chairs) to store, manage, query and report on their own data, as is the case with other on-line recording software (such as. the BTO/RSPB/BWI/SOC/WOS BirdTrack system; see http://www.bto.org/volunteer-surveys/birdtrack).

1.5.4 Current gaps in SRMS data collection and overall recommendations

We consider that there is now a logical progression of future work that is required to finalise our understanding of gaps in monitoring effort across the range of species covered by the SRMS, and to take forward the aims of the SRMS, which we suggest as follows:

(i) Build the complete picture of annual survey coverage/effort through liaison with all regular SRMS observers;

(ii) Finalise assessment of the extent to which current survey coverage is representative (at NHZ and national scale) by comparison with key datasets (particularly with the latest hen harrier, golden eagle and merlin national survey data and Bird Atlas 2007-11 data for appropriate species);

(iii) Using the current report and the above as a basis, hold appropriate meetings (including SRMG partners and other organisations and individuals with relevant expertise) to agree priorities for enhanced survey effort (species and geographical areas) and suitable survey design(s) to achieve the agreed priorities;

(iv) Consider ways of working with existing SRSG observers to move current monitoring efforts towards more rigorous study design where necessary, and to make most effective use of new volunteer effort; and

(v) Consider development of entry-level and supplementary survey(s) that would assist development of monitoring of more widespread species (e.g. a grid-based common raptor survey, as discussed previously by the SRMG) and ways to encourage a wider audience of potential volunteers (e.g. BTO, SOC and RSPB members) to get involved in these via co-ordinated promotion and training events. This might involve an element of mentoring, with experienced raptor observers volunteering to supervise less experienced volunteers, as is done informally by a number of SRSGs already. These ideas are already being developed by the SRMG.

1.5.5 Expansion of coverage and future survey design considerations

Once the SRMG has a clear picture of current survey coverage and the distribution of each SRMS species (Section 1.3.4), it will be possible to produce a targeting strategy for the SRMS, showing which regions are most in need of additional survey work for each species. In general, long-term study areas will require little or no shift in survey coverage but it would be valuable for the SRMG and SRSGs to be able to provide guidance to new members on the most useful species to cover in their chosen geographical area of study. It will also be possible to advise existing observers about small changes to their current study design that could have important positive effects on the usefulness of the data they collect.

To maintain and enhance SRMS coverage, it is vital that new volunteers are found to continue monitoring of raptors across Scotland. We cannot assume that new volunteers will necessarily be able to commit the substantial amounts of time each breeding season committed by some of the existing RSG members, and it is important that this is taken into consideration when thinking about future survey design. Whilst a small number of new volunteers might be persuaded to take on large study areas with substantial numbers of pairs to check and monitor for breeding success each year, others might be willing to contribute smaller amounts of time. Perhaps individuals with large amounts of time to commit should be encouraged to get involved in existing long-term studies (with a view to continuing them when the current observers need to hand them on). Attempts to expand survey coverage could then focus on other new groups of volunteers (perhaps with less time to contribute) by asking them to survey smaller areas comprehensively each year, focussing these for any given species in regions, or areas of particular habitat within regions, with poor current coverage whenever possible.

Once coverage information is available for the main studies identified in the current project (Section 1.3.4), so that areas that receive comprehensive coverage each year are established, simple modelling scenarios should be run to assess the optimal study area size and/or number of nesting ranges checked each year to produce robust trends in numbers and key breeding parameters (see Figure 89 for illustration). This would be achieved by sub-sampling the results from areas with comprehensive coverage and comparing trends thus derived with those from the whole sample, and would allow the SRMG to then set guidance for each SRMS species.

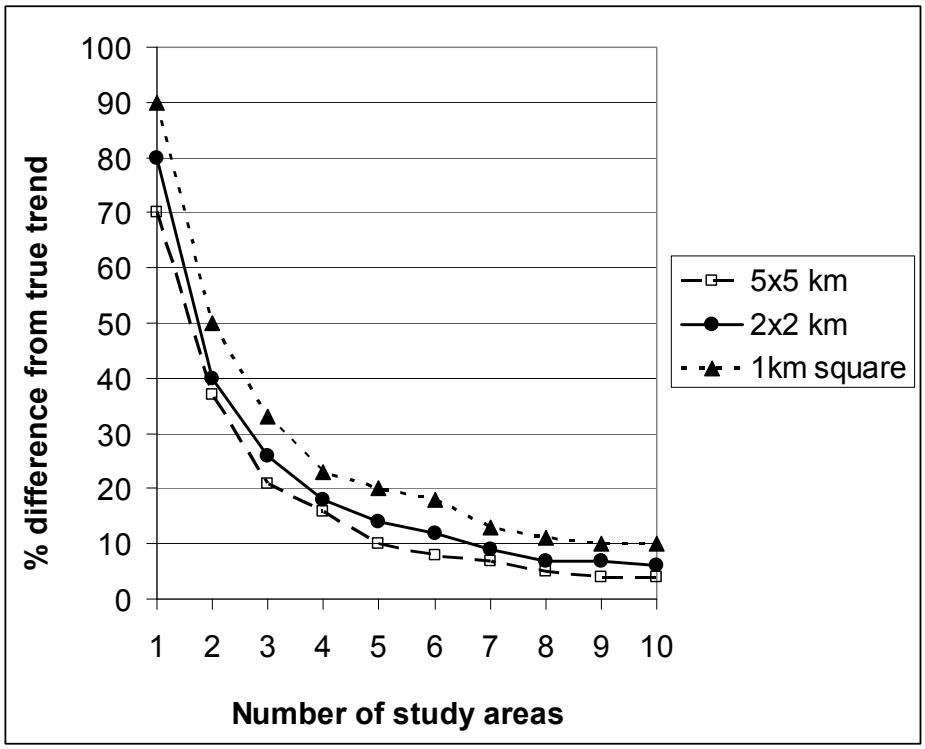


Figure 89. Hypothetical example to show how combinations of variation in study area size and number of study areas might influence the precision of the trends produced.
As study area size and/or the number of study areas increases, any derived trend approximates nearer to the 'true' trend for the whole population. These relationships could be established for a range of SRMS species by sub-sampling from study areas that currently receive comprehensive coverage.

Table 2. Summary of the current state of production of trends in breeding numbers and productivity parameters for raptor species covered by the Scottish Raptor Monitoring Scheme (at close of the current project) and actions required to move forward in future.

Raptor species	Summary of current state of trend production	Summary of caveats to current trends	Future requirements for enhancing trend production
Honey buzzard	EXCLUDED (too few pairs for formal trend production)	N/A	N/A
Red kite	Trends in absolute numbers of breeding pairs available by area/NHZ and for the whole of Scotland.	Breeding numbers may be slightly underestimated in the most recent years (but at least 90% of pairs still thought to be detected annually).	Ensure annual coverage and effort is recorded as numbers continue to increase.
	Trends in the number fledged per successful pair available for three areas/NHZs and the whole of Scotland.	Not feasible to produce trends in the proportion of pairs that lay or hatch young because pairs are not followed intensively at this time.	Ensure annual monitoring of sufficient sample of nests in each of the four areas of reintroduction to maintain the national index of numbers fledged per successful pair.
Black kite	EXCLUDED (too few pairs for formal trend production)	N/A	N/A
White-tailed eagle	Trends in absolute numbers of breeding pairs available by area/NHZ and for the whole of Scotland.	Breeding numbers may be slightly underestimated because of difficulties of establishing breeding for pairs that fail early.	Ensure annual coverage and effort is recorded as numbers continue to increase.
	Trends in clutch size, brood size and number fledged per successful pair available for the whole of Scotland, and clutch size and number fledged for the two principal NHZs.	Cannot produce trends in the proportion of pairs that lay because visits are restricted early in the season to minimise disturbance.	Ensure annual monitoring of sufficient sample of nests across the breeding range to maintain at least the national trends in clutch size, brood size and number fledged per successful pair.
Eurasian marsh harrier	EXCLUDED (too few pairs for formal trend production)	N/A	N/A

Raptor species	Summary of current state of trend production	Summary of caveats to current trends	Future requirements for enhancing trend production
Hen harrier	Matching with the hen harrier Conservation Framework dataset added 126 grid references and good numbers of records are submitted annually from at least 8-10 NHZs but trends in breeding numbers cannot be taken further until coverage/effort information is obtained from observers.	Trend production limited by lack of grid-referencing and lack of coverage/effort information.	Obtain outstanding grid-references[1]. Obtain information on study area boundaries and coverage.
	Best available trends in breeding parameters are reported for 1-5 NHZs.	Some national trends should be possible in future at current level of SRMS coverage.	Match with information from last (2010) national survey and Bird Atlas 2007-11 to assess representativeness of coverage by NHZs and nationally.
Goshawk	Best available trends in breeding numbers are reported from three study areas (in NHZs 9+12; 19+20; and 16+20). National trend in breeding numbers probably not appropriate.	Trends are provisional until coverage/effort information is complete.	Obtain data in full if possible (not summary data). Obtain outstanding grid-references.
	Trends in number of young fledged per successful pair available for three study areas.	Need to check to what extent the three study areas are representative of Scottish population as a whole.	Complete information on study area boundaries and coverage/effort. Assess coverage against information from Bird Atlas 2007-11 when available.
Eurasian sparrowhawk	Best available trend in breeding numbers available from one study area only (in NHZs 17+19). Provisional BBS trend available.	BBS trend still marginal as currently recorded in less than 30 BBS squares annually.	Obtain outstanding productivity data for 2003 and 2004.
	Trends in clutch size, brood size and number fledged per successful pair available from one study area only (in NHZs 17+19).		SRMG to consider how to enhance monitoring in future.

[1] Note that for hen harrier and merlin in particular, six-figure grid references will not always be appropriate for pairs that either fail early in their nesting attempts or do not breed (when a nest site is not found). In these situations, four-figure grid references may be more appropriate.

Raptor species	Summary of current state of trend production	Summary of caveats to current trends	Future requirements for enhancing trend production
Common buzzard	Best available trends in breeding numbers reported from six study areas. National trend in breeding numbers from SRMS data probably not appropriate yet. BBS national trend available.	Trends from study areas are provisional until coverage/effort information is obtained. Current study areas probably not completely representative of overall Scottish population.	Obtain information on study area boundaries and coverage/effort.
	Trends in clutch size and brood size from two study areas, and fledging success and numbers fledged per successful pair available from four study areas.	BBS may overestimate recent increases because of regional biases in sampling effort. Study areas probably not representative of overall Scottish population.	Assess coverage against information from Bird Atlas 2007-11 when available.
Golden eagle	Matching with the golden eagle Conservation Framework dataset added 648 grid references and good numbers of records are submitted annually from 6-8 NHZs but trends in breeding numbers cannot be taken further until coverage/effort information is obtained from observers.	Trend production limited by lack of grid-referencing, lack of coverage/effort information, and some information still only provided in summary form annually[2].	Obtain outstanding grid-references (mostly in NE Scotland). Obtain information on study area boundaries and coverage/effort.
	Best available trends in breeding parameters are reported for 1-3 NHZs.	Some national trends should be possible in future at current level of SRMS coverage.	Finalise assessment of representativeness of annual coverage by NHZs and nationally by comparison with most recent national survey data.

[2] Note however that change in the number of breeding pairs is likely to be slow for a long-lived species with delayed maturity like the Golden Eagle, and more sensitive parameters should be considered for this and other long-lived species (e.g. proportion of immature birds in pairs).

Raptor species	Summary of current state of trend production	Summary of caveats to current trends	Future requirements for enhancing trend production
Osprey	Progression of data sharing and trend production for this species requires time to work with observers/data holders which was not included in the current project.	N/A	Try to obtain data in full (not summary data) by working with main observers. Obtain outstanding grid-references. Obtain information on study area boundaries and coverage/effort. Assess annual monitoring coverage against know distribution and abundance (Bird Atlas 2007-11 data?).
Common kestrel	Trend in breeding numbers available from one study area only (in NHZs 17+19). National BBS trend available. Trends in clutch size, brood size and number fledged per successful pair available from one study area only (in NHZs 17+19).	Need to check further whether national BBS trend is representative.	Gordon Riddle may be able to supply SRMS with pre-2003 monitoring information for the same study area. Assess whether BBS trend is representative by comparison with Bird Atlas 2007-11 data. SRMG to consider how to enhance monitoring in future.
Merlin	Haworth Conservation managed to add 137 grid references through matching with their merlin database. Good numbers of records may be collected annually from up to 10 NHZs but trends in breeding numbers cannot be taken further coverage and distribution information is obtained from observers. Best available trends in breeding parameters are reported for one NHZ and one RSG area.	Trend production limited by lack of grid-referencing and lack of coverage/effort information.	Obtain remaining grid-references (1234 records to 2009)[1]. Obtain information on study area boundaries and coverage/effort. Assess coverage against most recent national survey distribution and any other data sources (e.g. Bird Atlas 2007-11).

Raptor species	Summary of current state of trend production	Summary of caveats to current trends	Future requirements for enhancing trend production
Hobby	EXCLUDED (too few pairs for formal trend production)	N/A	N/A
Peregrine falcon	Best available trends in breeding numbers are reported for 11 NHZs or parts of NHZs. Best available trends in breeding parameters are reported for 1-8 NHZs or parts of NHZs.	Trends from NHZs/study areas are provisional until coverage/effort information is obtained. In total, the study areas are probably not representative of the overall Scottish population (data from the north and west of the peregrine range are sparse). National trend in breeding numbers from SRMS data would not be fully representative but can be produced in future. National trends in breeding parameters should also be possible.	Obtain the few outstanding grid-references. Obtain coverage information and finalise assessment against 2014 national survey information. High quality information is already collected from a number of study areas and continuation of this effort must be encouraged.
Barn owl	Best available trends in breeding numbers are reported from seven study areas across Scotland. Best available trends in breeding parameters are reported from 1-6 study areas.	Trends from the study areas are provisional until coverage/effort information is obtained. Need to assess whether a national trend in breeding numbers might be feasible. Need to assess whether a national trend in numbers fledged per successful pair might be feasible.	Obtain information on study area boundaries and coverage/effort. Assess coverage against information from Bird Atlas 2007-11 when available.
Tawny owl	Best available trends in breeding numbers are reported from four study areas across Scotland. Best available trends in breeding parameters are reported for 1-3 study areas.	Trends from the study areas are provisional until coverage/effort information is obtained.	Obtain information on study area boundaries and coverage/effort. Assess coverage against information from Bird Atlas 2007-11 when available.

Raptor species	Summary of current state of trend production	Summary of caveats to current trends	Future requirements for enhancing trend production
Long-eared owl	Monitoring too variable to produce any rigorous trends.	N/A	Obtain outstanding grid references (NHZ 20). SRMG to consider how to enhance monitoring in future.
Short-eared owl	Monitoring too variable to produce any rigorous trends. Might be possible to look at crude abundance indices for some study areas but this would need further work to liaise with observers.	N/A	SRMG to consider how to enhance monitoring in future.
Common Raven	Not considered in the current project because samples have only been adequate in very recent years in most study areas. Should be possible to produce study-area based trends for a number of NHZs in future.	N/A	Encourage established studies to continue and expand. Obtain remaining ca. 20% of grid-references. Obtain information on study area boundaries and coverage/effort.
	National BBS trend available.	Need to check further whether national BBS trend is representative.	Assess coverage against information from Bird Atlas 2007-11 when available.

Table 3. Recommended enhancements to SRMS data curation to improve efficiency, cost-effectiveness and biological value. (Modified from previous review of SRMS data 2003-2008.)

Current shortfall	**Explanation of importance**	**Required actions for improvement and progress to date**
Lack of routine recording by SRMS of important information types		
1 Summary breeding information only provided to the SRMS (not details of individual breeding attempts)	Cannot assess coverage annually. Cannot produce rigorous trends. Cannot link information to specific regions or designated sites.	1a Encourage submission of full records by all observers. 1b REQUIRED QUICKLY: General onus that SRMS collects full records (and acceptance that summary data are of low utility). **NOW IMPLEMENTED BY SRMS**
2 Lack of grid references for some home ranges checked annually	Cannot assess coverage annually. Cannot produce rigorous trends. Cannot link information to specific regions or designated sites.	2a Work with observers to encourage submission of grid references that are lacking currently. 2b REQUIRED QUICKLY: SRMG to encourage ALL observers to submit grid references (including when new sites enter the annual monitoring sample). **NOW IMPLEMENTED BY SRMS**
3 Inconsistent recording of Source, Observer, Site Code, Site Name and Area/District (and link to grid-reference)	Cannot produce rigorous trends in breeding parameters. Cannot track coverage/effort changes. Incomplete recording of negative returns. Cannot automatically check annual data and revert to observers with queries.	3a REQUIRED QUICKLY BUT SHORT-TERM ONLY: Create master spreadsheets for all major contributors/coordinators (will improve but not solve problem and is a labour intensive approach). 3b. Provide recording software that is fit for purpose. **SRMS HAS AGREED TO DO THIS**
4 Lack of recording of objective breeding outcome codes	Cannot produce rigorous trends in breeding parameters. Cannot report objectively on causes of failure (including persecution).	4a REQUIRED QUICKLY: Enhance current spreadsheet to record outcome objectively according to major causes of failure. 4b Recording software that is fit for purpose. **SRMS HAS AGREED THIS**

Current shortfall	Explanation of importance	Required actions for improvement and progress to date
Lack of routine recording by SRMS of important information types		
5 Lack of recording of visit dates / nest contents at each visit	Cannot assess extent of negative returns. Cannot produce rigorous trends in breeding parameters.	5a SHORT-TERM ONLY: Encourage ALL observers to complete existing spreadsheet with visit dates. 5b Provide recording software that is fit for purpose, such that observers enter nest contents and date of each visit. **SRMS HAS AGREED TO DO THIS**
6 Lack of knowledge and recording of true monitoring spatial coverage and effort	Cannot produce rigorous trends in numbers. Cannot assess to what extent trends in breeding parameters are representative.	6a REQUIRED QUICKLY: Implement a process to collate coverage/effort information from all regular observers. **IN PROGRESS BY SRMS** 6b Provide recording software that ensures that coverage/effort is recorded annually and that details of study areas are complete when new observers start raptor recording. **SRMS HAS AGREED TO DO THIS**
Overall inadequacy of MS Excel software		
7 MS Excel software does not force consistency of recording across years	Much manual matching and checking of data sets is required annually prior to reporting. Problems 1-6 above will continue to occur.	7 Need to move to recording software where the format of data entry is more controlled and quality-checked at the point of submission. **SRMS HAS AGREED TO DO THIS**
8 MS Excel not fit for purpose for recording coverage efficiently	Could be done but the ideal would be a system that could handle mapping to make storage of information more efficient.	8 Move to recording software that is fit for purpose for storing coverage and effort information (including study area boundaries on maps). **SRMS HAS AGREED TO DO THIS**

2. DATASETS AVAILABLE TO CONTRIBUTE TO SCOTTISH RAPTOR MONITORING

2.1 Background

There are ten raptor species listed under Annex 1 of the EC Birds Directive: golden eagle, hen harrier, honey buzzard, Eurasian marsh harrier, merlin, osprey, peregrine falcon, red kite, short-eared owl and white-tailed eagle. The data for these species have been scoped in detail (see Section 1). Here we consider other potential sources of breeding raptor information (Table 4) and their future potential for contributing to surveillance.

2.2 Surveillance of changes in breeding numbers

The periodic SCARABBS (Statutory Conservation Agencies and RSPB Breeding Bird Surveys) surveys of breeding raptors are designed to provide updated population estimates and measures of population change for the whole of the UK, Scotland and sometimes for limited regional populations (see Table 4). The periodic (rather than annual) nature of these surveys means that they provide a less sensitive measure of population change than annual monitoring and, if carried out in a single breeding season, the results can be biased by environmental conditions in that one year (e.g. weather, vole abundance). To date, the SCARABBS surveys have not been designed specifically to provide robust estimates of breeding population size or change at the NHZ-scale. The near-comprehensive surveys (golden eagle and peregrine falcon) have been able to provide this information for most NHZs however, via the Conservation Framework projects (Whitfield *et al*. 2008 for golden eagle; Roos *et al*. 2009 for peregrine falcon) but those SCARABBS surveys with a random sampling element (merlin and hen harrier) would require more intensive sampling to deliver this additional aim. The SCARABBS surveys that have achieved near comprehensive coverage of known breeding territories to date (golden eagle and peregrine falcon) provide an important baseline against which to assess the extent to which annual monitoring coverage of each species (SRMS coverage) is representative of the Scottish or NHZ-scale population (see Sections 1.2.6 and 1.2.9).

The periodic BTO/BWI/SOC Bird Atlas 2007-11 project (Balmer *et al*. 2013) provides up-to-date distribution and relative abundance information for all regularly occurring raptors in Scotland at the 10-km resolution, and change measures comparable with the previous breeding atlas survey in 1988-91. The breeding season fieldwork for this project was carried out over four years, so that variable environmental conditions are taken into consideration (at least at a broad spatial scale). The results provide important baseline information on distribution and relative abundance against which to assess the extent to which annual SRMS monitoring coverage of each species is representative. It will also be possible to analyse for changes in relative abundance over the last 20 years at regional (NHZ) resolution.

The BTO/JNCC/RSPB Breeding Bird Survey (see Section 1.1.1) reports trends in breeding abundance for widespread raptor species at the whole of Scotland scale (common buzzard, common kestrel and common raven are routinely reported annually, and Eurasian sparrowhawk is close to the required number of sample squares for annual reporting at national scale). The fieldwork methodology of this survey is not suitable for recording absolute breeding numbers of raptors, and (variable) proportions of non-breeding individuals will be included in the records each year (see Sections 1.2.5 and 1.2.13 for further information). For the BBS to be capable of delivering NHZ-specific trends, even for widespread raptor species, there would need to be a large increase in the annual sample of random 1-km squares surveyed by volunteers. This would be very difficult to achieve in practice, although such a change would deliver widespread benefits in terms of monitoring a range of other widespread bird species at smaller spatial scales (e.g. NHZ-scale).

Each year, specific surveys of breeding raptor numbers are also undertaken, for example for SNH Site Condition Monitoring (SCM) of designated sites, and as part of the monitoring required for development consenting (e.g. in relation to onshore wind farms). The SNH SCM summary database shows around 40 SPA/SSSIs for which assessments for raptors are made periodically: in 2011 these include golden eagle (9 sites covered); hen harrier (22 sites); Eurasian marsh harrier (2 sites); merlin (7 sites); osprey (12 sites); peregrine falcon (6 sites); and short-eared owl (5 sites). The raw data are not currently held in a central database but it would be useful to cross-check and ensure that the information collected annually as part of the SCM process is fed through to the main SRMS dataset. SCM and specific development monitoring data, if collated and made available, could play a useful part in building up a comprehensive picture of the distribution and relative abundance of raptor species across Scotland. It is unlikely, however, that they could contribute extensively to rigorous monitoring of changes in breeding numbers because of the sporadic nature of the surveys (although post-consent monitoring as a condition of development consent could contribute to long-term monitoring if methods are rigorous and consistent across a period of years, monitoring is annual or near-annual and data were submitted to the SRMS annually). This potential should be explored further in liaison with the Scottish Windfarm Bird Steering Group (see http://www.swbsg.org/).

2.3 Surveillance of changes in breeding parameters

Surveillance of changes in breeding parameters does not necessarily require such comprehensive survey effort as surveillance of breeding numbers but it is nonetheless important: (i) to assess the extent to which samples are representative of the spatial population under surveillance; (ii) to understand any implications of the turnover of sites in the sample; and (iii) to ensure that the field methodology and reporting is adequate for recording the parameter(s) of interest (see Sections 1.2.3-1.2.6).

Of the schemes additional to the SRMS in Table 4, the BTO Nest Record Scheme (NRS) has the most potential to deliver additional rigorous monitoring of breeding parameters. A breakdown of Scottish raptor records submitted electronically to the NRS since 2007 is provided in Annex Table B 37. Most (but not all) of these data are also submitted to the SRMS (at least in summarised form). A further cross-check between the NRS and the SRMS would be useful, however, and pathways of ensuring appropriate flows of information between the NRS and SRMS should be explored further in future. A closer future relationship with the NRS will be beneficial given the need for the SRMS to develop its data collation/submission processes (Section 1.3.3), and also ongoing development of the NRS towards more integrated demographic monitoring of numbers in study areas as well as breeding performance (Dave Leech, BTO, pers. comm.).

Table 4. Schemes to consider for provision of information on trends for Scotland's (Annex 1) raptor populations.

Source of information	Species covered to date	Details of data curators	Summary of data
Scottish Raptor Monitoring Scheme 2003 onwards	All 10 Annex 1 species, plus other species	Covered in Objective 1 above	Breeding numbers and various breeding parameters. Covered in detail in Objective 1 above and summarised in Table 2.
National, periodic SCARABBS surveys of breeding raptors (currently on 6- or 12-year repeat cycle)	Golden eagle	Master dataset curated by RSPB	Most recent national survey in 2003 (Eaton *et al*. 2007). Breeding numbers and various measures of breeding success. Comprehensive coverage of all known territories in Scotland. Provides measure of change in breeding numbers since previous survey in 1992 for Scotland and eight Scottish regions. Provides the basis against which to assess annual monitoring coverage. Next national survey will take place in 2015.
	Hen harrier	Master dataset curated by RSPB	Most recent national survey in 2010 (Hayhow *et al*. 2013). Comprehensive coverage of some core RSG areas (Orkney and NE Scotland) and sample squares covered elsewhere.
	Merlin	Master dataset curated by RSPB	Most recent national survey in 2008 (Ewing *et al*. 2011). Breeding numbers only. Comprehensive coverage of some core RSG areas (Orkney and NE Scotland) and sample squares covered elsewhere. Provides measure of change since previous survey in 1993-94 for Scotland and the two core Scottish areas.
	Peregrine falcon	Master dataset curated by BTO	Most recent published national survey in 2002 (Banks *et al*. 2010). Next national survey undertaken in 2014. Data on breeding numbers comprehensive for most regions and fully grid-referenced following work for the peregrine Conservation Framework project (Roos *et al*. 2009). Productivity data not comprehensive and one year only: SRMS data of greater utility for productivity trends (see Objective 1 above).
Single-species monitoring	Osprey	Individual raptor workers.	Breeding numbers and various breeding parameters. See Table 2. A small number of other individuals hold the key data required to monitor trends in this species (in particular site locations).

Source of information	Species covered to date	Details of data curators	Summary of data
	Red kite	RSPB/SNH (Covered in Objective 1 and master dataset curated by RSPB)	Breeding numbers and various breeding parameters. Covered in detail in Objective 1 above and summarised in Table 2.
	White-tailed eagle	RSPB/SNH (Covered in Objective 1 and master dataset curated by RSPB)	Breeding numbers and various breeding parameters. Covered in detail in Objective 1 above and summarised in Table 2.
Rare Breeding Birds Panel (RBBP)	Rarer species	Master dataset held by Mark Holling (RBBP Secretary)	All relevant information for Scotland is currently shared with the SRMS.
BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1994 onwards	Widespread (non-Annex 1) species	Organised and data curated by BTO	Abundance data for common buzzard, sparrowhawk, kestrel and raven covered in Objective 1 above.
SNH Site Condition Monitoring surveys (SCM)	Annex 1 species	Data curated by SNH	Summary of data holdings held centrally by SNH but raw data not held in central electronic database.
Wind farm pre- and post-construction monitoring	Focus on Annex 1 species	No central database at present; raptor data from a small number of consultants is submitted to the SRMS annually.	The recently established Scottish Wind farm Bird Steering Group will be addressing collation of wind farm monitoring data as part of its remit.
Nest Record Scheme (NRS)		BTO/JNCC (organised and data curated by BTO)	A summary of current data holdings for Scottish raptor species is given in Annex Table B 37. Most records are also submitted to the SRMS.
BTO/BWI/SOC Bird Atlas 2007-11	All breeding and wintering species in Scotland	Organised and data curated by BTO for Scotland	Periodic survey of breeding distribution and spatial variation in relative abundance (*ca* every 20 years), directly comparable with 1988-91 atlas survey for most raptor species. Of great value in assessing current range and spatial variation in relative abundance of raptors (against which to assess current monitoring effort; see Table 2) and potentially for generating improved national and regional population estimates (particularly if used together with information from intensive studies).

3. INDICATORS OF SCOTTISH RAPTOR POPULATIONS

3.1 Background and aims

Indicators have become much-used in conservation and land-use management in recent decades as a means of synthesizing simplified and useful information from complex systems, often integrating multiple sources of data (Jackson *et al*. 2000). The terms 'indicator', 'indicator species', 'signal species', 'bio-indicator' or 'bio-monitor' have all become widely used and their relative meanings and merits debated in the literature (e.g. Landres *et al*. 1988; Simberloff 1998; Caro & O'Doherty 1999; Hilty & Merenlender 2000; Lindenmayer *et al*. 2000; Gregory *et al*. 2005).

Birds are widely used in indicators of environmental health because of their conspicuousness, their mobility across landscapes (and hence rapid response to pressures compared to some other taxa), the diversity of species, their appeal to the public, the availability of suitable data and their potential loyalty to specific habitat types (Gregory *et al*. 2004; Gregory *et al*. 2005).

Further useful background to the various types of indicator that have been used and their development in the UK and Scotland to date is provided in Annex D.

Here we consider the usefulness and feasibility of producing a robust indicator, or indicators, specifically for Scottish raptor populations, potential methods for doing so, and the data sets available (from Sections 1 and 2).

3.2 Considerations specific to raptors in Scotland

The future development of Scottish raptor indicators needs to involve the following considerations:

(i) selection of target geographical areas (scale of reporting), habitats, or drivers of interest;
(ii) identification of the type of indicator required;
(iii) selection of appropriate datasets (species and parameters of interest) from the evidence base of species associated with these habitats, areas or drivers; and
(iv) selection of statistical rules for calculation of indicators.

Raptors pose some special problems in their use in composite (and habitat-specific) indicators. Firstly, although some are restricted to particular habitats, many, like common buzzard, have broad habitat preferences. Second, the assumption that species with very small population sizes are likely to be restricted to a small area does not hold true for most raptors, which due to their position at the top of the food chain, mobility and large territories, can be both scarce and widespread (e.g. merlin, golden eagle, northern goshawk). Thirdly, numbers of some species, such as red kite and white-tailed eagle, have been strongly influenced by specific conservation interventions such as reintroductions. Changes in their numbers are therefore unlikely to be indicative of wider ecosystem or guild processes.

3.2.1 Choice of geographical scale

If a Scottish raptor national headline indicator were desirable, it is important to consider that headline indicators are a unique type of indicator, intended to provide simple immediate information to policy makers, decision makers and the general public. Headline indicators are meant to communicate the general story rather than provide detailed information. They are not a substitute for the detailed knowledge needed to assess the causes of change in individual species, or ecosystems, and then to formulate strategies in response (Bibby 1999). Moreover, headline indicators will only work effectively when they are few in number.

There is a risk that an overall composite raptor indicator for Scotland could suffer from lack of interpretability. For example, the inclusion of data from red kites or white-tailed eagles – both of which are increasing in number after reintroduction schemes – could cause declines in other species to be masked. The inclusion of recent hen harrier population data might skew an upland indicator downward whilst reflecting a driver (human persecution) that does not necessarily affect, to the same extent, other species in the habitat or guild. The inclusion of common buzzard data might be questionable purely because the influences behind the species' recent and substantial expansion are not fully understood. It is important to be clear about what additional information such an overall composite indicator would provide and thus of its utility as a headline indicator. This does not mean that population trends for individual species' trends lack utility however; as a collective – as opposed to a composite – they provide a comprehensive and varied reflection of a wide variety of external drivers operating in the Scottish natural environment. For example, the simultaneous inspection of productivity and/or population trends for both merlin and hen harrier could provide an indication of the degree to which human persecution affects the latter, given that the overlap of environmental influences of the species is otherwise considerable. The comparison of indices of northern goshawks and common kestrels in the same regions would give insight into the potential role of the expansion of the former in the decline of the latter (e.g. Petty *et al.* 2003). For any given species' trends, the performance of others will help to identify which drivers are exerting the most influence, by offering additional evidence, in the manner of a (qualitative) simultaneous equation.

National indicators can only be drawn from species with satisfactory monitoring coverage across their Scottish range. In addition, in order to produce satisfactory ecological indicators, the selected species should exist in relatively stable populations of appreciable size (i.e. not white-tailed eagle, red kite, European honey buzzard). Species/parameters for inclusion must be carefully chosen so as to reliably represent the environmental condition/driver that the indicator is designed to indicate. Regional variability across Scotland in environmental conditions may be considerable, with several of the key issues affecting raptor populations (e.g. commercial forestry, over-grazing, agricultural intensification, persecution, prey depletion) showing strong spatial variation. In this sense, indicators limited to certain regions or habitats might be more meaningful and interpretable than those that attempt to capture the overall 'state' of raptor populations in Scotland (and thereby over-arching environmental conditions). Regional bird indicators have been developed for Government Office Regions in England and trialled for Natural Heritage Zones in Scotland, but there are often practical problems in generating trends from so much smaller data sets, as well as in achieving comparable indicators across regions.

3.2.2 Selection of habitat(s)

The association of species with habitat types has been central to the development of composite bird indicators in the UK and Europe to date. In developing bird indicators for Scotland (Noble *et al*., 2007), habitat information recorded on BBS sites was used to firstly classify species as habitat generalists or specialists and, secondly, to derive habitat-specific trends for species found in more than one major habitat (e.g. farmland and woodland). Trends for individual bird species selected as representative of habitats were then amalgamated into composite indicators using methods consistent with other bird indicators for the UK and Europe. Within these composite UK and Scottish wild bird indicators, widespread and annually-monitored raptor species such as Eurasian sparrowhawk (in woodland) and common kestrel (in farmland) are included, along with other bird species associated with the same habitats. In the Scottish Terrestrial Breeding Bird Indicator, BBS count data for species showing preferences for more than one major habitat are analysed separately to generate habitat-specific population trends. Hence, a woodland-specific common buzzard trend contributes to the Scottish woodland bird indicator and a farmland-specific common buzzard trend contributes to the farmland bird indicator. Population trends

for less common raptors such as peregrine falcon and golden eagle, monitored only periodically, are generated by interpolation between census years, and these trends contribute to the overall indicator and to woodland or upland indicators as appropriate, according to the classification of raptors in Gibbons *et al.* (1993).

Due to their position near the top of food webs, there could be utility in using changes in populations of one or a small number of raptor species to reflect wider environmental quality for specific Scottish habitats. For example, the merlin might be a particularly suitable indicator species for upland habitats, being relatively widespread, well-monitored, and mostly free from persecution. It is also relatively short-lived and hence numerically responsive to change, although migration away from the uplands in the winter might complicate the drivers of changes in abundance. A reliable productivity metric such as mean number of fledglings per successful clutch might be preferred to abundance in this context. Scottish data for merlin could feasibly be combined with those from hen harrier and/or golden eagle to produce an indicator of upland quality, although the interpretability of such an indicator might still be influenced by spatial and interspecific variation in drivers. Current data on merlin (and other species) would first need to be validated by reference to the observer coverage, which is not yet fully documented (Section 1). There is, for example, possible concern that in some study areas merlin breeding attempts may be recorded when observers are searching more specifically for hen harriers – hence the coverage in some areas may be dependent to an extent on the distribution and abundance of the latter species.

3.2.3 Drivers of change

The approach taken to date in developing the suite of composite wild bird indicators for different habitat types is that they are not intended to reflect specific pressures, but rather to reflect the cumulative impacts of multiple pressures at a landscape scale (overall state indicators). Raptor populations in Scotland are subject to a wide range of ecological and environmental drivers including afforestation, changes in agricultural land use and land management of other habitats, deliberate persecution by humans, incidental poisoning and disturbance, impacts of pollutants, changes in fisheries, changes in prey species abundance, effects on wintering areas, climate change and interactions with other raptors and mammalian predators. It might in theory therefore be possible to construct raptor indicators that link populations at national or regional scales to the strength or likelihood of these pressures (these could also be developed in a similar manner to the climate change indicators for Europe, in which the strengths of both negative and positive responses to particular drivers are used in the indicator). Note that single-pressure indicators, designed to reflect ecological response to individual pressures, for example, aquatic invertebrate community measures that reflect point sources of sewage treatment effluent (Wright *et al*., 1998), cannot safely be extrapolated to conclusions about other attributes of ecosystem health (Boon and Howell, 1997).

3.2.4 Suitability of demographic parameters for inclusion

Information on changes in the breeding abundance of Scottish raptors is available for a number of species, based on counts using a rigorous sampling design (e.g. BBS for common buzzard and kestrel), annual counts in study areas or nationally (e.g. SRMS datasets), or interpolation between periodic censuses (e.g. SCARABBS datasets; see Sections 1 and 2). Abundance data will vary in utility for indicator production from species to species. Use of abundance change as an indicator of environmental drivers, whether comprised of data from single or multiple species, makes the tacit assumption that the species exist(s) at or close to the carrying capacity of the environment (or at least exhibits long-term population stability), such that overall numbers will be susceptible to changes in one or more environmental drivers. The numerical response of a species with a population reduced to well below carrying capacity by human intervention (for example a species

recovering from historical persecution and pesticide effects like peregrine falcon) may be negligible or slow, highly variable geographically, or conversely very rapid, which may render it harder to either detect or to ascribe to any given driver than a change. In the early stages of recovery from such human intervention, a rapid rate of population increase may indicate that the suppressive effects of the human intervention factor have been removed but, if included in an ecological indicator, could give a falsely positive impression of overall ecological conditions. Human persecution of widespread and established species in Scotland, such as golden eagle and hen harrier, therefore provides a challenge in the development of ecological indicators, given that the scale and effect of this source of mortality is difficult to quantify, and sometimes cannot therefore be easily separated from other potential drivers of population change. If illegal human interference is one of the key drivers of change for particular species, the abundance of these raptors may be wholly unrelated to that of other species in the same habitat, thereby rendering an ecological indicator based on abundance of limit utility.

Raptors are relatively long-lived, and thus their numerical response to certain environmental drivers is likely to be delayed, particularly for the larger species. For such species, changes in breeding parameters may provide a more immediate measure of changes in environmental quality than abundance. The current Seabird Indicator (now included in the UK headline indicator) is based upon the monitoring of numbers at breeding colonies, but as long-lived seabirds may not show the population-level impact of reduced breeding success for some years, a complementary indicator based on annual productivity has also been developed. This makes use of good information on year-to-year changes in productivity, and serves to illustrate clearly illustrating the trend for widespread breeding failure across multiple species in recent years.

For raptors, there is a risk that for some species data collection may be biased towards successful pairs/sites/territories (Section 1). In this case, breeding parameters must be chosen carefully to minimise any potential bias from this observer behaviour. Within current SRMS data, the mean number of fledglings per successful clutch is likely to be more reliable than overall fledging rate (though may still be biased towards higher quality pairs, since those pairs that rear the smallest clutches may also be those most likely to have failed in previous years, and hence dropped off the list of monitored territories). The mean number fledged per successful clutch may also have the advantage of being largely independent of any effects of illegal human activity, since it is unlikely that only a fraction of a given brood would be destroyed whilst still in the nest. Productivity parameters have the additional advantage over abundance that they are much less influenced by factors outside the breeding season. Individuals of species such as merlin, hen harrier and osprey (as well as the rarer species such as European honey buzzard and Eurasian hobby) may over-winter some distance from the breeding grounds, such that annual abundance indices at least partly reflect environmental conditions in areas that may not even be within Scotland, let alone the habitat or region of interest. Individual raptors in some low-density populations may suffer less from intra-specific competition, and hence achieve higher productivity, than those with more neighbours, so that the use of productivity data from species existing well below carrying capacity may still be problematic. Ideally, any indicator based upon productivity data needs to be considered alongside simultaneous population abundance data to ensure that increased productivity is not a function merely of increasing rarity, and resulting reduction in competition – and hence a negative rather than positive response.

For many of the longer-lived raptors, individuals may not breed until their second, third or even fourth year. In a stable population with relatively stable adult survival rates, the age structure of breeding birds is likely to remain fairly stable also, such that the proportion of immature breeders in the population may provide a good indication of external change. Unusually frequent occurrence of sub-adults in the Scottish golden eagle breeding population (and non-breeding occupancy of vacant territories) has been related to poor

survival of adults, and hence illegal human activity (Whitfield *et al*. 2004a, b), a phenomenon noted in other long-lived species such as Bonelli's eagle (*Aquila fasciata*) and the Spanish imperial eagle (*Aquila adalberti*) (Balbontin *et al*. 2003; Ferrer *et al*. 2003). The age structure of breeding hen harriers may not be so obviously related to adult survival rates, due to the occurrence of polygyny, the extent of which varies temporally and spatially for reasons most likely related to food supplies (Simmons *et al*. 1986; Simmons 2000; Amar *et al*. 2003; Redpath *et al*. 2006). The type of change signified by changes in breeding age structure will once again depend upon the initial population conditions; species in a phase of population/range expansion may contain a higher proportion of immature breeders as a result of reduced competition with territory-holding adults, although the extent to which this occurs will be species-specific (immature common buzzards, for example, disperse relatively short distances and seem to prefer natal areas with adults present to empty suitable habitat further afield; Walls & Kenward 1998). At the national level, the proportion of immatures in the northern goshawk population might reflect either reduced adult survival (negative) or population expansion (positive). It would be necessary in this instance to relate this parameter to observer coverage and population density in order to distinguish between these disparate inferences. We consider that raptor workers should be further encouraged to record information on the age of individual birds occupying breeding sites for species that can be aged with reasonable certainty in the field (e.g. golden eagle and peregrine falcon), as changes in age structure provide complementary information to other changes in overall breeding numbers and productivity.

3.2.5 Statistical decisions

The statistical power to detect change in trends of this type, whether single species or composite indicators, is affected by count variability in space and time, the magnitude of observed changes, the length of the time series, the number of survey plots, and sampling error associated with the survey design. It is important to think very carefully about sensible combinations of species groups, taking into account differences in such issues as precision and accuracy of the underlying data, species response times, numbers of species per group, and the need for weighting. A problem particular to developing a Scottish raptor indicator is the relatively small number of species and hence fewer possible combinations of species that are possible.

3.3 Conclusions

Raptors are a small guild with relatively little overlap in terms of niche; i.e. each species tends to be more distinct from any other than would be the case with a suite of granivorous passerines, for example. This relative lack of overlap lessens the scope for a suite of species to provide a robust guild-level indicator as opposed to a set of disparate trends that probably become less meaningful when combined. Careful consideration must therefore be given to what inferences might be drawn from an indicator or indicators taken from a suite of Scottish raptors.

Trends in abundance for some of the more widespread raptor species are already included in the Scottish terrestrial breeding bird indicator. As the SRMS moves towards the production of more national species trends from its data holdings (which are likely to be more accurate than some of the trends used in the indicators currently; Section 1), it will be important that these then become part of the national indicators, where the trends can be broken down appropriately by habitat (either for species restricted to one habitat, or habitat-specific trends for less specialised species). In order to achieve the latter, SRMS records will need to be fully spatially referenced at an appropriate resolution for use with land classification data sets (six-figure grid references will be important).

Changes in bird abundance are already used as headline indicators of overall wildlife health because birds in general are wide-ranging in habitat use, tend to be at, or near, the top of the food chain, have great public resonance, and hence were judged to be an excellent way to raise awareness of biodiversity issues. Whether an indicator for raptors alone would add anything further to this needs careful consideration but there may well be merit in such an indicator. Populations of a range of raptor species (some of which are top predators) that were stable or fluctuating around equilibria would be broadly indicative of a healthy, balanced ecosystem (e.g. Newton 1979; Rodríguez-Estrella *et al*. 1998). Now, or in the near future, it should be possible to produce broadly representative national trends in abundance for a good number of the Scottish raptor species (red kite; white-tailed eagle; hen harrier; northern goshawk; common buzzard; golden eagle; merlin; peregrine falcon; and barn owl). National trends may also be possible for osprey, common kestrel (from BBS only), common raven and for the small number of Eurasian marsh harriers; but not for Eurasian sparrowhawk, tawny owl, long-eared owl or short-eared owl in the near future (Table 2). It is questionable whether the two species (red kite and white-tailed eagle) with rapidly growing populations as a result of ongoing reintroductions should be included in a headline raptor indicator (see Annex D for equivalent considerations for rare species within the UK wildbird indicators). If an indicator were to include these species, their rapid population growth could mask adverse declines in other species unless some appropriate weighting were specifically applied. Moreover, the interpretation of the indicator would require not only knowledge of the reintroduction schemes, but also an understanding of the notions of carrying capacity and population stability. These issues could mean that the indicator would be potentially misleading (due to masking of declines) and difficult for non-specialists (e.g. the public) to interpret.

At the time of undertaking this study it was not possible to produce an indicator for raptor populations in Scotland. Once data have been analysed for a greater range of species an indicator or indicators should be given more detailed consideration.

4. REFERENCES

Adams, S.M. (ed.). 2002. *Biological Indicators of Aquatic Ecosystem Stress*. Wallingford, Cab Publishing.

Amar, A., Redpath, S. & Thirgood, S. 2003. Evidence for food limitation in the declining hen harrier population on the Orkney Islands, Scotland. *Biological Conservation* **111**, 377-384.

Amar, A., Court, I.R., Davidson, M., Downing, S., Grimshaw, T., Pickford, T. & Raw, D. 2012. Linking nest histories, remotely sensed land use data and wildlife crime records to explore the impact of grouse moor management on peregrine falcon populations. *Biological Conservation* **145(1)**, 86-94.

Anonymous. 2002. *Scottish Raptor Monitoring Scheme Agreement*. Scottish Natural Heritage.

Austin, G.E., Rehfisch, M.M. & Banks, A. 2007. Natural Heritage Trends: developing a Scottish Wintering Waterbird Indicator. *Scottish Natural Heritage Commissioned Report* No. 227.

Baillie, S.R., Marchant, J.H., Leech, D.I. *et al*. 2012*. BirdTrends 2011.* BTO Research Report No. 609. BTO, Thetford. Available at: http://www.bto.org/birdtrends.

Balbontin, J., Penteriani, V. & Ferrer, M. 2003. Variations in the age of mates as an early warning signal of changes in population trends? The case of Bonelli's eagle in Andalusia. *Biological Conservation* **109**, 417-423.

Balmer, D.E., Gillings, S., Caffrey, B.J. & Swann, R.L. 2013. *Bird Atlas 2007-11: the breeding and wintering birds of Britain and Ireland.* BTO Books, Thetford.

Banks, A. N., Crick, H. Q. P., Coombes, R. *et al*. 2010. The breeding status of peregrine falcons *Falco peregrinus* in the UK and Isle of Man in 2002. *Bird Study* **57**, 421-436.

Bibby, C.J. 1999. Making the most of birds as environmental indicators. *Ostrich* **70**, 81-88.

Boon, P. J. and Howell, D. L. (eds.). 1997. *Freshwater Quality: Defining the Indefinable*? The Stationery Office, Edinburgh.

Butchart, S.H.M., Stattersfield, A.J., Bennun, L.A. *et al*. 2004. Measuring Global Trends in the Status of Biodiversity: Red List Indices for Birds. PLoS Biol **2(12)**, e383. doi:10.1371/journal.pbio.0020383.

Butchart, S.H., Resit Akçakaya, H., Chanson, J. *et al*. 2007. Improvements to the Red List Index. PLoS ONE **2(1),** e140. doi:10.1371/journal.pone.0000140

Caro, T.M. & O'Doherty, G. 1999. On the use of surrogate species in conservation biology. *Conservation Biology* **13**, 805-814.

Dayton, P.K. 1972. Toward an understanding of community resilience and the potential effects of enrichments to the benthos of McMurdo Sound, Antarctica. In: Parker, B.C. (Ed). *Proceedings of the colloquium on conservation problems in Antarctica*. Lawrence, KS: Allen Press.

Defra. 2014. *Wild birds populations in the UK, 1970 to 2013*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372755/UK_Wild_birds_1970-2013_final_-_revision_2.pdf

Eaton, M.A., Dillon, I.A., Stirling-Aird, P.K. & Whitfield, D.P. 2007. Status of the golden eagle *Aquila chrysaetos* in Britain. *Bird Study* **54**, 212-220.

Evans, R.J., Wilson, J.D., Amar, A. *et al*. 2009. Growth and demography of a re-introduced population of White-tailed Eagles *Haliaeetus albicilla*. *Ibis* **151**, 244–254.

Everard, M. 2008. Viewpoint: Selection of taxa as indicators of river and freshwater wetland quality. *Aquatic Conservation: Marine and Freshwater Ecosystems* **18**, 1052-1061.

Ewing, S.R., Rebecca, G.W., Heavisides, A. *et al*. 2011. Breeding status of merlins *Falco columbarius* in the UK in 2008. *Bird Study* **58(4)**, 379-389.

Ferrer, M., Penteriani, V., Balbontin, J. & Pandolfi, M. 2003. The proportion of immature breeders as a reliable early warning signal of population decline: evidence from the Spanish imperial eagle in Donana. *Biological Conservation* **114**, 463-466.

Fielding, A. & Haworth, P. 2011. The Identification of Important Localities for Breeding Merlins in Scotland. *Report by Haworth Conservation to Scottish Natural Heritage* (Contract SNH PO No. 33426).

Fielding, A., Haworth, P., Whitfield, P., McLeod, D. & Riley, H. 2011. *A Conservation Framework for Hen Harriers in the United Kingdom.* JNCC Report 441. Joint Nature Conservation Committee, Peterborough.

Furness, R.W. & Greenwood, J.J.D. (eds.). 1993. *Birds as Monitors of Environmental Change.* London, Chapman & Hall.

Garibaldi, A. & Turner, N. 2004. Cultural keystone species: implications for ecological conservation and restoration. *Ecology and Society* **9(3)**, 1.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.* T & AD Poyser, London.

Gregory, R.D., Noble, D., Field, R. *et al*. 2003. Using birds as indicators of biodiversity. *Ornis Hungarica* **12–13**, 11-24.

Gregory, R.D., Noble, D. & Custance, J. 2004. The state of play of farmland birds: population trends and conservation status of lowland farmland birds in the United Kingdom. *Ibis* **146**, 1-13.

Gregory, R.D., van Strien, A., Vorisek, P. *et al*. 2005. Developing indicators for European birds. *Philosophical Transactions of the Royal Society B,* **360**, 269-288.

Grime, J.P. 1984. Dominant and subordinate components of plant communities: implications for succession, stability and diversity. In: Gray, A.J. and Crawley, M.J. (eds.) *Colonization, succession and stability*. Oxford, Blackwell.

Hanski, I. 1982. Dynamics of regional distribution: the core and satellite species hypothesis. *Oikos* **38**, 210-221.

Hardey, J., Crick, H., Wernham, C. *et al*. 2013. *Raptors. A Field Guide for Surveys and Monitoring*. 3rd Edition. The Stationery Office, Edinburgh.

Hayhow, D.B., Eaton, M.A., Bladwell, S. *et* al. 2013. The status of the Hen Harrier, *Circus cyaneus*, in the UK and Isle of Man in 2010. *Bird Study*, **60**, 446-458.

Hilty, J. & Merenlender, A.M. 2000. Faunal indicator taxa selection for monitoring ecosystem health. *Biological Conservation* **92**,185-197.

Huston, M.A. 1994. *Biological Diversity: The Coexistence of Species on Changing Landscapes*. Cambridge, UK: Cambridge University Press.

Jackson, L.E., Kurtz, J.C. & Fisher, W,S. 2000. *Evaluation Guidelines for Ecological Indicators*. Environmental Protection Agency, Washington DC, Report No. EPA/620/R-99/0005. 110pp.

Jones, C.G., Lawton, J.H. & Shachak, M. 1994. Organisms as ecosystem engineers. *Oikos* **69**, 373-386.

Jones, G., Jacobs, D.S., Kunz, T.H., Willig, M.R. & Racey, P.A. 2009. Carpe noctem: the importance of bats as bioindicators. *Endangered Species Research* **8**, 93-115.

Landres, P.B., Verner, J. & Thomas, W.J. 1988. Ecological uses of vertebrate indicator species: a critique. *Conservation Biology* **4**,316-32.

Leader-Williams, N. & Dublin, H.T. 2000. Charismatic megafauna as 'flagship species'. In Entwhistle, A. & Dunstone, N. (eds.) *Priorities for the Conservation of Mammalian Diversity: Has the Panda had its Day?* pp 53-81 Cambridge: Cambridge University Press.

Lindenmeyer, D.B., Margules, C.R. & Botkin, D.B. 2000. Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology* **14(4)**, 941-950.

McKinney, M.L. & Lockwood, J.L. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Trends in Ecology and Evolution* **14**, 450-453.

Marquiss, M. 2011. Goshawk *Accipiter gentilis*. In Francis, I. & Cook, M. (eds.) *The Breeding Birds of North-East Scotland*. pp. 138-139. Scottish Ornithologists' Club, Aberdeen.

Marquiss, M., Petty, S.J., Anderson, D.I.K & Legge, G. 2003. Contrasting population trends of the northern goshawk (*Accipiter gentilis*) in the Scottish/English borders and north-east Scotland. In Thompson, D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M. & Galbraith, C.A. (eds.). *Birds of Prey in a Changing Environment.* pp 143-148. The Stationery Office, Edinburgh.

McGeoch, M.A. 1998. The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews of the Cambridge Philosophical Society*, **73**, 181-201.

Newton, I. 1979. *Population Ecology of Raptors.* T & AD Poyser, Berkamsted.

Niemeijer, D. & de Groot, R.S. 2007. A conceptual framework for selecting environmental indicator sets. *Ecological Indicators* **8**, 14-25.

Noble, D.G., Joys, A.C. and Eaton, M.A. 2007. Natural Heritage Trends: A Scottish Biodiversity Indicator for Terrestrial Breeding Birds. *Scottish Natural Heritage Commissioned Report* No.245.

OECD. 1999. *Environmental Indicators for Agriculture: Volume 1. Concepts and Frameworks*. Organisation for Economic Cooperation and Development, Paris, 45pp.

Paine, R.T. 1969. A note on trophic complexity and community stability. *The American Naturalist* **103**, 91-93.

Petty, S.J., Anderson, D.I.K., Davison, M. *et al*. 2003. The decline of Common Kestrels *Falco tinnunculus* in a forested area of northern England: the role of predation by Northern Goshawks *Accipiter gentilis. Ibis* **145**, 472-483.

Redpath, S., Leckie, F.M., Arroyo, B., Amar, A. & Thirgood, S.J. 2006. Compensating for the costs of polygyny in hen harriers Circus cyaneus. *Behavioral Ecology and Sociobiology*, **60**, 386-391.

Riddle, G. 2011. *Kestrels for Company.* Dunbeath, Caithness, Whittles Publishing.

Risely, K., Renwick, A.R., Dadam, D. *et al*. 2011. The Breeding Bird Survey 2010. *BTO Research Report* No. 597.

Rodríguez-Estrella, R., Donázar, J.A. & Hiraldo, F. 1998. Raptors as indicators of environmental change in the scrub habitat of Baja California Sur, Mexico. *Conservation Biology* **12**, 921-925.

Roos, R., Humphreys, L. & Wernham, C. 2009. Breeding occupancy and productivity of the Scottish population of peregrine falcon (Falco peregrinus): a comparison between the 1991 and 2002 national peregrine surveys by biogeographical region of Scotland. *Report to Scottish Natural Heritage and the Scottish Raptor Monitoring Group*. BTO Scotland, Stirling.

SAS Institute Inc. 2008. *SAS/STAT 9.2. Users Guide*. Cary, NC, US.

Sergio, F., Newton, I. & Marchesi, L. 2008. Top predators and biodiversity: much debate, few data. *Journal of Applied Ecology* **45**, 992-999.

Simberloff, D. 1998. Flagships, umbrellas and keystones: is single-species management *passé* in the landscape era? *Biological Conservation* **83(3)**, 247-257.

Simmons, R. E. 2000. *Harriers of the World.* Oxford University Press, Oxford.

Simmons, R., Barnard, P., MacWhirter, B. & Hansen, G.L. 1986. The influence of microtines on polygyny, productivity, age, and provisioning of northern harriers: a 5 year study. *Canadian Journal of Zoology* **64**, 2447-2456.

Smart, J., Amar, A., Sim, I.M.W. *et al*. 2010. Illegal killing slows population recovery of a re-introduced raptor of high conservation concern – the red kite *Milvus milvus*. *Biological Conservation* **143**, 1278-1286.

Taylor, I.R. 1989 *The Barn Owl.* Shire Publications, Aylesbury.

Taylor, I.R. 1994. *Barn Owls: Predator-Prey Relationships and Conservation.* Cambridge University Press, Cambridge.

Ten Brink, B.J.E. 2000. *Biodiversity indicators for the OECD*. Environmental Outlook and Strategy. RIVM Rapport, 402001014, Globo Report Series 25.

Van Strien, A. J. 1999. From monitoring data to policy-relevant summary statistics. Bird Numbers 1998. *Vogelwelt* **120**, 67-71.

Walls, S.S. & Kenward, R.E. 1998. Movements of radio-tagged buzzards *Buteo buteo* in early life. *Ibis* **140**, 561-568.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. & Haworth, P.F. 2004a. The effects of persecution on age of breeding and territory occupation in golden eagles in Scotland. *Biological Conservation* **118**, 249-259.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. & Haworth, P.F. 2004b. Modelling the effects of persecution on the population dynamics of golden eagles in Scotland. *Biological Conservation* **119**, 319-333.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. *et al*. 2007. Factors constraining the distribution of golden eagles *Aquila chrysaetos* in Scotland. *Bird Study* **54**, 199-211.

Whitfield, D.P., Fielding, A.H., McLeod, D.R.A. & Haworth, P.F. 2008. A conservation framework for golden eagles: implications for their conservation and management in Scotland. *Scottish Natural Heritage Commissioned Report* No.193.

Wright, J.F., Armitage, P.D., Furse, M.T. & Moss, D. 1988. A new approach to the biological surveillance of river quality using macroinvertebrates. *Verh. int. theor. angew. Limnol*. **23**, 1548-1552.

ANNEX A: BBS MAPS

Figure A1. Map showing the distribution of squares in Scotland surveyed under the BTO/JNCC/RSPB Breeding Bird Survey in 2010 in which no sparrowhawks were recorded (open circles) and those in which sparrowhawks were recorded (solid circles).
(Source: Kate Risely, BTO, pers. comm.)

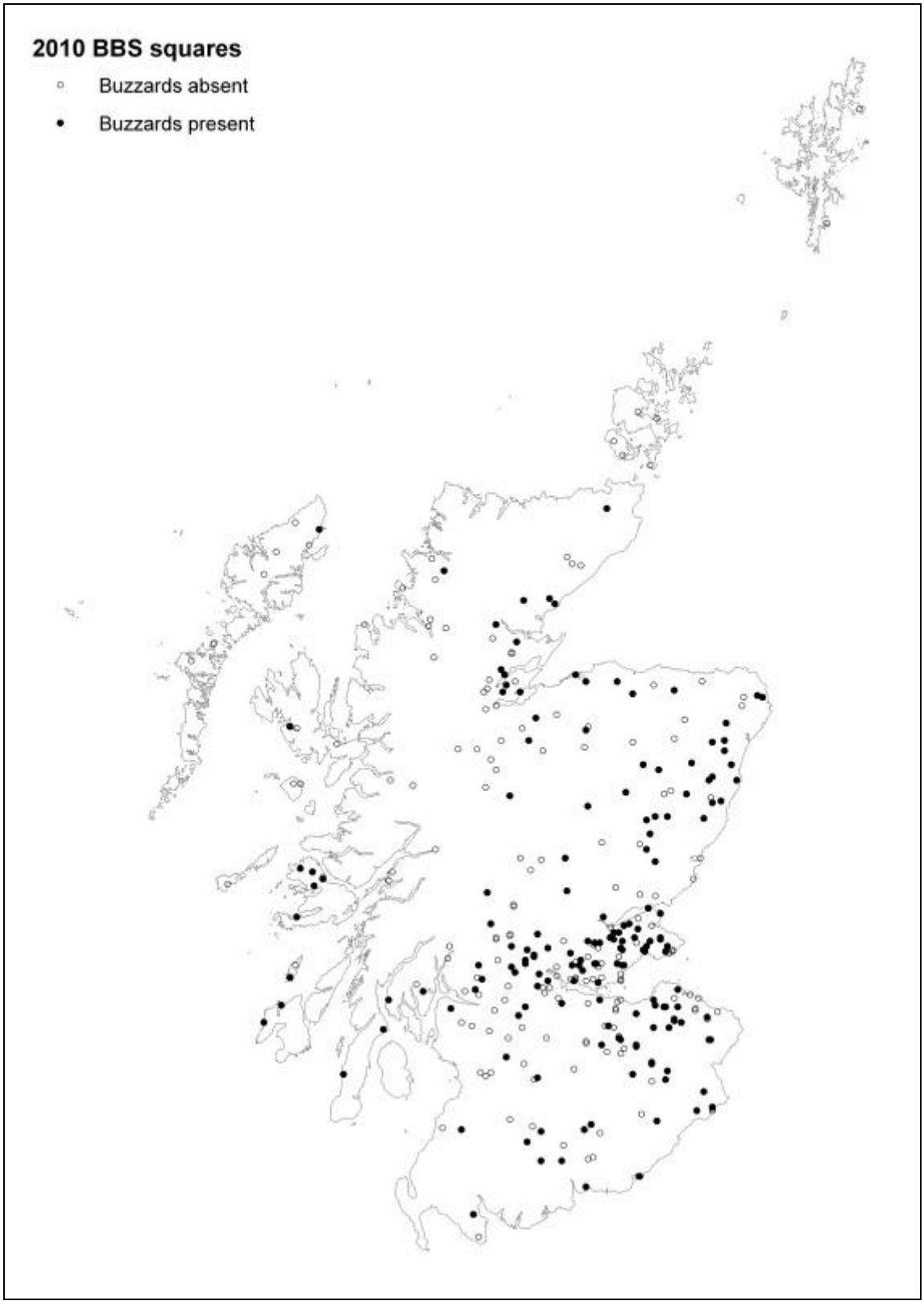


Figure A2. Map showing the distribution of squares in Scotland surveyed under the BTO/JNCC/RSPB Breeding Bird Survey in 2010 in which no common buzzards were recorded (open circles) and those in which common buzzards were recorded (solid circles). (Source: Kate Risely, BTO, pers. comm.)

Figure A3. Map showing the distribution of squares in Scotland surveyed under the BTO/JNCC/RSPB Breeding Bird Survey in 2010 in which no common kestrels were recorded (open circles) and those in which common kestrels were recorded (solid circles) (Source: Kate Risely, BTO, pers. comm.)

Figure A4. Map showing the distribution of squares in Scotland surveyed under the BTO/JNCC/RSPB Breeding Bird Survey in 2010 in which no common ravens were recorded (open circles) and those in which common ravens were recorded (solid circles).
(Source: Kate Risely, BTO, pers. comm.)

ANNEX B: SUPPORTING TABLES

Table B1. The number of red kites released in Scotland between 1989 and 2009. (Source: RSPB dataset.)

Year	Geographical area of release[1]				Total
	Black Isle	Central Scotland	Dumfries & Galloway	Aberdeenshire	
1989	6	0	0	0	6
1990	19	0	0	0	19
1991	20	0	0	0	20
1992	20	0	0	0	20
1993	24	0	0	0	24
1994	0	0	0	0	0
1995	0	0	0	0	0
1996	0	19	0	0	19
1997	0	18	0	0	18
1998	0	20	0	0	20
1999	0	20	0	0	20
2000	0	20	0	0	20
2001	0	6	33	0	39
2001	0	0	24	0	24
2002	0	0	33	0	33
2003	0	0	10	0	10
2004	0	0	4	0	4
2005	0	0	0	0	0
2006	0	0	0	0	0
2007	0	0	0	30	30
2008	0	0	0	35	35
2009	0	0	0	34	34
Total	**89**	**103**	**104**	**99**	**395**

[1] The regions where the releases occurred correspond to the following NHZs: Black Isle = NHZs 7 & 21; Central Scotland = NHZs 15 & 16; Dumfries & Galloway = NHZ 19; and Aberdeenshire = NHZ 9.

Table B2. The number of red kite nest sites that were checked for occupancy in the different areas where the species occurs in Scotland between 1992 and 2010.
(Source: RSPB dataset.)

Sub-population	Aberdeenshire	Black Isle	Central Scotland	Dumfries & Galloway	Total
1992	0	1	0	0	1
1993	0	5	0	0	5
1994	0	10	0	0	10
1995	0	15	0	0	15
1996	0	17	0	0	17
1997	0	25	0	0	25
1998	0	23	2	0	25
1999	0	30	6	0	36
2000	0	35	8	0	43
2001	0	34	12	0	46
2002	0	35	20	0	55
2003	0	34	23	4	61
2004	0	36	31	7	74
2005	0	39	41	12	92
2006	0	70	57	19	146
2007	0	75	71	22	168
2008	0	84	89	31	204
2009	5	82	101	42	230
2010	9	86	113	54	262
Total	**14**	**736**	**574**	**191**	**1515**

Table B3. The number of red kite nest sites that have been checked for occupancy in each NHZ by sub-population within Scotland between 1992 and 2010.
(Source: RSPB dataset.)

Sub-population	NHZ	Number of sites checked
Black Isle	7	117
	21	619
		736
Aberdeenshire	9	13
	12	1
		14
Central Scotland	12	7
	15	87
	16	465
	17	15
		574
Dumfries & Galloway	18	2
	19	189
		191

Table B4. The number of records for red kites for which the actual number of eggs laid, eggs hatched and young fledged was reported for each sub-population.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey. (Source: RSPB dataset.)

Sub-population	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
Aberdeenshire	2009	5	5	3
Aberdeenshire	2010	6	5	5
Black Isle	1992	1	1	1
Black Isle	1993	5	3	3
Black Isle	1994	10	7	7
Black Isle	1995	9	11	10
Black Isle	1996	14	12	15
Black Isle	1997	10	7	19
Black Isle	1998	10	10	20
Black Isle	1999	8	6	22
Black Isle	2000	6	7	29
Black Isle	2001	3	16	31
Black Isle	2002	1	29	32
Black Isle	2003	1	15	32
Black Isle	2004	4	2	30
Black Isle	2005	2	1	36
Black Isle	2006	3	5	36
Black Isle	2007	3	4	28
Black Isle	2008	0	0	38
Black Isle	2009	0	0	41
Black Isle	2010	0	0	38
Central Scotland	2000	2	0	5
Central Scotland	2001	0	7	7
Central Scotland	2002	0	0	10
Central Scotland	2003	0	0	14
Central Scotland	2004	6	17	17
Central Scotland	2005	3	15	15
Central Scotland	2006	1	19	19
Central Scotland	2007	2	7	26
Central Scotland	2008	0	32	33
Central Scotland	2009	0	0	37
Central Scotland	2010	1	1	45
Dumfries & Galloway	2003	4	1	1
Dumfries & Galloway	2004	3	2	2
Dumfries & Galloway	2005	12	10	10
Dumfries & Galloway	2006	17	14	14
Dumfries & Galloway	2007	21	19	19
Dumfries & Galloway	2008	30	27	25
Dumfries & Galloway	2009	40	33	31
Dumfries & Galloway	2010	51	48	47
Total		**294**	**398**	**853**

Table B5. The number of records for red kites for which the actual number of eggs laid, eggs hatched and young fledged was reported for each Scottish NHZ.
The year-NHZ combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey. (Source: RSPB dataset.)

NHZ	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
7 Northern Highlands	1994	1	1	1
7 Northern Highlands	1995	1	1	1
7 Northern Highlands	1996	1	1	2
7 Northern Highlands	1997	0	0	2
7 Northern Highlands	1998	1	1	4
7 Northern Highlands	1999	1	1	5
7 Northern Highlands	2000	0	1	5
7 Northern Highlands	2001	0	4	6
7 Northern Highlands	2002	0	6	6
7 Northern Highlands	2003	0	4	5
7 Northern Highlands	2004	0	0	4
7 Northern Highlands	2005	1	0	7
7 Northern Highlands	2006	0	0	5
7 Northern Highlands	2007	0	0	5
7 Northern Highlands	2008	0	0	5
7 Northern Highlands	2009	0	0	7
7 Northern Highlands	2010	0	0	9
9 North East Coastal Plain	2009	5	5	3
9 North East Coastal Plain	2010	6	5	5
12 North East Glens	2009	0	0	1
15 Loch Lomond, Trossachs & Breadalbane	2003	0	0	1
15 Loch Lomond, Trossachs & Breadalbane	2004	0	1	1
15 Loch Lomond, Trossachs & Breadalbane	2005	1	2	2
15 Loch Lomond, Trossachs & Breadalbane	2006	0	2	2
15 Loch Lomond, Trossachs & Breadalbane	2007	1	1	4
15 Loch Lomond, Trossachs & Breadalbane	2008	0	7	8
15 Loch Lomond, Trossachs & Breadalbane	2009	0	0	11
15 Loch Lomond, Trossachs & Breadalbane	2010	0	0	13
16 Eastern Lowlands	2000	2	0	5
16 Eastern Lowlands	2001	0	7	7
16 Eastern Lowlands	2002	0	0	10
16 Eastern Lowlands	2003	0	0	13
16 Eastern Lowlands	2004	6	16	16
16 Eastern Lowlands	2005	2	13	13
16 Eastern Lowlands	2006	1	17	17
16 Eastern Lowlands	2007	1	6	22
16 Eastern Lowlands	2008	0	25	25
16 Eastern Lowlands	2009	0	0	25
16 Eastern Lowlands	2010	1	1	32

Table B5 Continued.

NHZ		Year	Sample size		
			Eggs laid	Eggs hatched	Fledged young
18	Wigtown Machairs & Outer Solway Coast	2009	1	0	0
18	Wigtown Machairs & Outer Solway Coast	2010	1	1	1
19	W Southern Uplands & Inner Solway	2003	4	1	1
19	W Southern Uplands & Inner Solway	2004	3	2	2
19	W Southern Uplands & Inner Solway	2005	12	10	10
19	W Southern Uplands & Inner Solway	2006	17	14	14
19	W Southern Uplands & Inner Solway	2007	21	19	19
19	W Southern Uplands & Inner Solway	2008	30	27	25
19	W Southern Uplands & Inner Solway	2009	39	33	31
19	W Southern Uplands & Inner Solway	2010	50	47	46
21	Moray Firth	1992	1	1	1
21	Moray Firth	1993	5	3	3
21	Moray Firth	1994	9	6	6
21	Moray Firth	1995	8	10	9
21	Moray Firth	1996	13	11	13
21	Moray Firth	1997	10	7	17
21	Moray Firth	1998	9	9	16
21	Moray Firth	1999	7	5	17
21	Moray Firth	2000	6	6	24
21	Moray Firth	2001	3	12	25
21	Moray Firth	2002	1	23	26
21	Moray Firth	2003	1	11	27
21	Moray Firth	2004	4	2	26
21	Moray Firth	2005	1	1	29
21	Moray Firth	2006	3	5	31
21	Moray Firth	2007	3	4	23
21	Moray Firth	2008	0	0	33
21	Moray Firth	2009	0	0	34
21	Moray Firth	2010	0	0	29
	Total		**294**	**398**	**853**

Table B6. The number of records for red kites for which the actual number of eggs laid, eggs hatched and young fledged was reported from the whole of Scotland.
The years deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey. Despite the high numbers of records for the variables Eggs Laid and Eggs Hatched, the sample sizes from some of the contributing areas were low, and there was a risk of biasing the national trends towards the sub-population in Dumfries & Galloway (cf. Table B 3); we therefore decided not to produce a national trend for these variables. (Source: RSPB dataset.)

Year	Sample size		
	Eggs Laid	Eggs hatched	Fledged young
1992	1	1	1
1993	5	3	3
1994	10	7	7
1995	9	11	10
1996	14	12	15
1997	10	7	19
1998	10	10	20
1999	8	6	22
2000	8	7	34
2001	3	23	38
2002	1	29	42
2003	5	16	47
2004	13	21	49
2005	17	26	61
2006	21	38	69
2007	26	30	73
2008	30	59	96
2009	45	38	112
2010	58	54	135
Total	**294**	**398**	**853**

Table B7. The number of white-tailed eagles released in Scotland between 1975 and 2011. Further releases are planned in Fife (see text).
(Source: RSPB dataset.)

Year	Location	Birds released	Location total
1975	Rum	3	
1976	Rum	9	
1977	Rum	4	
1978	Rum	7	
1979	Rum	6	
1980	Rum	8	
1981	Rum	5	
1982	Rum	10	
1983	Rum	10	
1984	Rum	10	
1985	Rum	10	82
1986		0	
1987		0	
1988		0	
1989		0	
1990		0	
1991		0	
1992		0	
1993	Wester Ross	10	
1994	Wester Ross	10	
1995	Wester Ross	6	
1996	Wester Ross	10	
1997	Wester Ross	10	
1998	Wester Ross	12	58
1999		0	
2000		0	
2001		0	
2002		0	
2003		0	
2004		0	
2005		0	
2006		0	
2007	Fife	11	
2008	Fife	15	
2009	Fife	14	
2010	Fife	19	
2011	Fife	16	75
Total			**215**

Table B8. The number of white-tailed eagle nest sites that were checked for occupancy in Scotland between 1981 and 2010.
(Source: RSPB dataset.)

Year	NHZ							Total
	3 Coll, Tiree and the Western Isles	4 North West Seaboard	6 Western Seaboard	7 Northern Highlands	8 Western Highlands	13 East Lochaber	14 Argyll West and Islands	
1981	0	0	1	0	0	0	0	**1**
1982	0	0	1	0	0	0	0	**1**
1983	1	0	2	0	0	0	0	**3**
1984	1	0	4	0	0	0	0	**5**
1985	1	0	5	0	0	0	0	**6**
1986	1	0	6	0	0	0	0	**7**
1987	1	0	8	0	0	0	0	**9**
1988	1	1	9	0	0	0	0	**11**
1989	1	1	8	0	0	0	0	**10**
1990	1	0	8	0	0	0	0	**9**
1991	1	0	8	0	0	0	0	**9**
1992	1	0	8	0	0	0	0	**9**
1993	1	0	9	0	0	0	0	**10**
1994	2	0	9	0	0	0	0	**11**
1995	4	0	9	0	0	0	0	**13**
1996	4	0	9	0	0	0	0	**13**
1997	4	0	11	0	0	0	0	**15**
1998	3	2	15	0	0	0	0	**20**
1999	3	2	15	0	1	0	0	**21**
2000	5	2	15	0	1	0	0	**23**
2001	5	2	15	0	2	0	0	**24**
2002	6	2	19	0	1	0	0	**28**
2003	6	3	21	0	1	0	0	**31**
2004	7	3	21	0	1	0	0	**32**
2005	8	3	19	0	3	0	0	**33**
2006	10	3	20	0	2	1	0	**36**
2007	12	3	26	1	0	0	2	**44**
2008	13	4	26	1	0	1	1	**46**
2009	13	5	26	1	1	1	1	**48**
2010	14	5	26	1	4	1	3	**54**

Table B9. The number of records for white-tailed eagles from each NHZ for which the actual number of eggs laid, eggs hatched and young fledged was reported.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey.
(Source: RSPB dataset.)

NHZ		Year	Sample size		
			Eggs laid	Eggs hatched	Fledged young
3	Coll, Tiree & Western Isles	1984	1	0	0
3	Coll, Tiree & Western Isles	1985	1	1	0
3	Coll, Tiree & Western Isles	1986	1	0	0
3	Coll, Tiree & Western Isles	1987	1	0	0
3	Coll, Tiree & Western Isles	1988	0	0	0
3	Coll, Tiree & Western Isles	1989	0	0	0
3	Coll, Tiree & Western Isles	1990	0	0	0
3	Coll, Tiree & Western Isles	1991	0	0	0
3	Coll, Tiree & Western Isles	1992	1	0	0
3	Coll, Tiree & Western Isles	1993	0	0	0
3	Coll, Tiree & Western Isles	1994	1	0	0
3	Coll, Tiree & Western Isles	1995	1	0	0
3	Coll, Tiree & Western Isles	1996	3	1	1
3	Coll, Tiree & Western Isles	1997	2	0	0
3	Coll, Tiree & Western Isles	1998	2	1	1
3	Coll, Tiree & Western Isles	1999	2	1	1
3	Coll, Tiree & Western Isles	2000	4	1	1
3	Coll, Tiree & Western Isles	2001	2	1	1
3	Coll, Tiree & Western Isles	2002	5	3	1
3	Coll, Tiree & Western Isles	2003	4	3	3
3	Coll, Tiree & Western Isles	2004	6	5	4
3	Coll, Tiree & Western Isles	2005	8	7	4
3	Coll, Tiree & Western Isles	2006	8	8	6
3	Coll, Tiree & Western Isles	2007	9	8	8
3	Coll, Tiree & Western Isles	2008	9	2	2
3	Coll, Tiree & Western Isles	2009	11	7	7
3	Coll, Tiree & Western Isles	2010	13	8	6
4	North West Seaboard	1998	2	2	2
4	North West Seaboard	1999	2	1	1
4	North West Seaboard	2000	2	2	2
4	North West Seaboard	2001	0	0	0
4	North West Seaboard	2002	1	1	1
4	North West Seaboard	2003	2	2	2
4	North West Seaboard	2004	2	2	2
4	North West Seaboard	2005	3	2	2
4	North West Seaboard	2006	3	2	2
4	North West Seaboard	2007	3	2	2
4	North West Seaboard	2008	3	3	3
4	North West Seaboard	2009	4	3	3
4	North West Seaboard	2010	5	4	4

Table B9 Continued.

NHZ		Year	Sample size		
			Eggs laid	Eggs hatched	Fledged young
6	Western Seaboard	1983	2	0	0
6	Western Seaboard	1984	1	0	0
6	Western Seaboard	1985	3	2	1
6	Western Seaboard	1986	4	1	1
6	Western Seaboard	1987	5	2	2
6	Western Seaboard	1988	6	2	1
6	Western Seaboard	1989	5	3	3
6	Western Seaboard	1990	8	2	2
6	Western Seaboard	1991	7	4	4
6	Western Seaboard	1992	6	4	4
6	Western Seaboard	1993	5	4	4
6	Western Seaboard	1994	8	4	4
6	Western Seaboard	1995	7	6	5
6	Western Seaboard	1996	8	7	6
6	Western Seaboard	1997	8	6	5
6	Western Seaboard	1998	12	6	6
6	Western Seaboard	1999	11	7	4
6	Western Seaboard	2000	11	7	4
6	Western Seaboard	2001	12	8	5
6	Western Seaboard	2002	15	10	6
6	Western Seaboard	2003	19	15	11
6	Western Seaboard	2004	17	12	9
6	Western Seaboard	2005	14	12	11
6	Western Seaboard	2006	17	14	12
6	Western Seaboard	2007	20	17	13
6	Western Seaboard	2008	20	13	12
6	Western Seaboard	2009	20	14	12
6	Western Seaboard	2010	19	13	13
7	Northern Highlands	2007	1	1	0
7	Northern Highlands	2008	1	1	1
7	Northern Highlands	2009	1	0	0
7	Northern Highlands	2010	1	1	1
8	Western Highlands	2000	1	1	1
8	Western Highlands	2001	2	1	1
8	Western Highlands	2002	1	1	0
8	Western Highlands	2003	0	0	0
8	Western Highlands	2004	1	0	0
8	Western Highlands	2005	1	0	0
8	Western Highlands	2006	2	2	0
8	Western Highlands	2007	0	0	0
8	Western Highlands	2008	0	0	0
8	Western Highlands	2009	1	1	1
8	Western Highlands	2010	4	4	4

Table B9 Continued.

NHZ		Year	Sample size		
			Eggs laid	Eggs hatched	Fledged young
13	East Lochaber	2006	1	1	1
13	East Lochaber	2007	0	0	0
13	East Lochaber	2008	1	1	1
13	East Lochaber	2009	1	0	0
13	East Lochaber	2010	1	0	0
14	Argyll West and Islands	2007	2	2	1
14	Argyll West and Islands	2008	1	1	1
14	Argyll West and Islands	2009	1	1	1
14	Argyll West and Islands	2010	3	3	3
	Total		**445**	**300**	**249**

Table B10. The number of records for white-tailed eagles for which the actual number of eggs laid, eggs hatched and young fledged was reported for the whole of Scotland. The years deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey. (Source: RSPB dataset.)

Year	Sample size		
	Eggs Laid	Eggs hatched	Fledged young
1981	0	0	0
1982	0	0	0
1983	2	0	0
1984	2	0	0
1985	4	3	1
1986	5	1	1
1987	6	2	2
1988	6	2	1
1989	5	3	3
1990	8	2	2
1991	7	4	4
1992	7	4	4
1993	5	4	4
1994	9	4	4
1995	8	6	5
1996	11	8	7
1997	10	6	5
1998	16	9	9
1999	15	9	6
2000	18	11	8
2001	16	10	7
2002	22	15	8
2003	25	20	16
2004	26	19	15
2005	26	21	17
2006	31	27	21
2007	35	30	24
2008	35	21	20
2009	39	26	24
2010	46	33	31
Total	**445**	**300**	**249**

Table B11. Comparison of the number of hen harrier ranges in Natural Heritage Zones. (Source: SRMS dataset 2003-2009 and additional data supplied by Haworth Conservation.)

Natural Heritage Zone	NHZ number	Number in Zone		
		SRMS	SRMS+HC	Change
Raptor Study Group (Unassigned to an NHZ)		355	229	-126
North Caithness and Orkney	2	440	442	2
Coll, Tiree and the Western Isles	3	198	278	80
The Peatlands of Caithness and Sutherland	5	127	134	7
Western Seaboard	6	364	382	18
Northern Highlands	7	40	40	0
Western Highlands	8	2	2	0
North East Coastal Plain	9	1	1	0
Central Highlands	10	102	102	0
Cairngorm Massif	11	81	81	0
North East Glens	12	94	96	2
East Lochaber	13	16	16	0
Argyll West and Islands	14	476	487	11
Loch Lomond, The Trossachs and Breadalbane	15	164	167	3
Eastern Lowlands	16	8	8	0
West Central Belt	17	107	109	2
Wigtown Machairs and Outer Solway Coast	18	18	18	0
Western Southern Uplands and Inner Solway	19	261	261	0
Border Hills	20	61	62	0
Moray Firth	21	3	3	0
Totals (excluding unassigned)		**2563**	**2689**	**+126**

Table B12. Hen harrier range records submitted to the SRMS 2003-2009 that remain unassigned to Natural Heritage Zones because of a lack of grid references. (Source: SRMS dataset 2003-2009.)

Source (Raptor Study Group)	Number of range-year records unassigned to NHZs
Central Scotland RSG	19
Dumfries & Galloway RSG	11
Highland RSG	11
Lothian & Borders RSG	18
North-east Scotland RSG	54
South Strathclyde RSG	69
Tayside RSG	47
Total	**229**

Table B13. The number of hen harrier ranges surveyed and occupied within the SRMS dataset 2003-2009 by Natural Heritage Zone (or source for those that cannot be assigned to NHZs because of a lack of grid references).
(Source: SRMS dataset 2003-2009 and additional data supplied by Haworth Conservation.)

		Surveyed									Occupied							
Dataset	NHZ	2003	2004	2005	2006	2007	2008	2009	All	NHZ	2003	2004	2005	2006	2007	2008	2009	All
North Caithness and Orkney	2	0	75	86	71	72	65	72	441	2	0	75	75	71	71	65	72	429
Coll, Tiree and the Western Isles	3	32	43	47	45	45	46	20	278	3	29	40	37	37	45	41	15	244
The Peatlands of Caithness and Sutherland	5	20	28	26	8	17	16	19	134	5	14	22	14	7	12	15	18	102
Western Seaboard	6	13	48	52	52	61	71	57	354	6	11	42	42	29	30	50	31	235
Northern Highlands	7	5	8	3	5	5	8	6	40	7	4	6	3	4	4	7	6	34
Western Highlands	8	0	0	0	0	2	0	0	2	8	0	0	0	0	0	0	0	0
North East Coastal Plain	9	0	0	0	0	0	1	0	1	9	0	0	0	0	0	1	0	1
Central Highlands	10	9	12	12	7	15	17	17	89	10	8	8	9	7	6	9	8	55
Cairngorm Massif	11	7	5	3	9	18	20	16	78	11	6	4	3	7	16	15	13	64
North East Glens	12	8	11	12	12	11	28	10	92	12	8	10	12	12	8	14	7	71
East Lochaber	13	2	1	0	4	2	3	4	16	13	1	1	0	4	2	3	3	14
Argyll West and Islands	14	57	108	94	106	34	53	35	487	14	48	103	84	95	27	39	23	419
Loch Lomond, The Trossachs and Breadalbane	15	10	13	19	24	29	41	20	156	15	7	10	11	14	25	21	15	103
Eastern Lowlands	16	0	0	0	4	1	3	0	8	16	0	0	0	3	1	1	0	5
West Central Belt	17	5	15	7	25	20	14	23	109	17	4	15	3	5	4	3	4	38
Wigtown Machairs and Outer Solway	18	2	7	7	2	0	0	0	18	18	2	5	7	2	0	0	0	16
Western Southern Uplands and Inner Solway	19	4	48	46	38	37	23	65	261	19	4	43	45	34	26	19	27	198
Border Hills	20	1	6	8	10	13	7	17	62	20	1	6	8	8	11	6	10	50
Moray Firth	21	1	0	0	0	0	0	1	2	21	1	0	0	0	0	0	1	2
All NHZ		**176**	**428**	**422**	**422**	**382**	**416**	**382**	**2628**		**148**	**390**	**353**	**339**	**288**	**309**	**253**	**2080**
Central Scotland RSG	32	1	2	0	9	0	0	7	19	32	0	2	0	0	0	0	0	2
Dumfries & Galloway RSG	33	11	0	0	0	0	0	0	11	33	11	0	0	0	0	0	0	11
Highland RSG	34	2	0	1	0	0	0	0	3	34	0	0	1	0	0	0	0	1
Lothian and Borders RSG	35	2	8	4	1	0	3	0	18	35	2	5	1	1	0	0	0	9
North-east Scotland RSG	36	18	12	12	12	0	0	0	54	36	17	12	11	10	0	0	0	50
South Strathclyde RSG	37	68		1					69	37	45		1					46
Tayside RSG	38	19	5	4	5		12	1	46	38	10	3	4	5		1	0	23
All Others		**121**	**27**	**22**	**27**	**0**	**15**	**8**	**220**		**85**	**22**	**18**	**16**	**0**	**1**	**0**	**142**
All (NHZ + Others)	**All**	**297**	**455**	**444**	**449**	**382**	**431**	**390**	**2848**	All	**233**	**412**	**371**	**355**	**288**	**310**	**253**	**2222**

Table B14. Sample sizes of breeding parameters available for hen harriers by NHZ or Raptor Study group for those records not currently grid-referenced within the dataset.
(Source: SRMS data 2003-2009.)

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2003	Argyll West and Islands	19	19	44	12	11	40	37	36	45	48
2004	Argyll West and Islands	48	42	94	23	22	90	57	51	78	104
2005	Argyll West and Islands	27	26	60	12	12	54	40	40	70	84
2006	Argyll West and Islands	36	36	79	18	18	66	31	28	53	95
2007	Argyll West and Islands	10	10	23	6	6	21	9	9	21	27
2008	Argyll West and Islands	13	13	35	2	2	31	24	19	30	39
2009	Argyll West and Islands	15	15	17	9	9	16	8	8	15	23
2003	Border Hills	1	1	1	1	1	1	1	1	1	1
2004	Border Hills	1	1	5	0	0	4	2	2	6	6
2005	Border Hills	3	3	8	1	1	6	5	4	8	8
2006	Border Hills	7	7	8	3	3	7	2	2	8	8
2007	Border Hills	8	8	10	6	6	10	3	3	9	11
2008	Border Hills	5	5	5	4	4	4	4	3	4	6
2009	Border Hills	5	5	7	4	4	7	5	4	7	10
2003	Cairngorm Massif	1	1	3	0	0	3	3	3	6	6
2004	Cairngorm Massif	2	2	4	2	2	4	4	4	4	4
2005	Cairngorm Massif	0	0	3	0	0	3	2	1	3	3
2006	Cairngorm Massif	2	2	6	1	1	6	4	2	7	7
2007	Cairngorm Massif	4	4	11	2	2	10	6	6	12	16
2008	Cairngorm Massif	0	0	8	0	0	9	4	3	10	16
2009	Cairngorm Massif	7	7	10	5	5	6	4	3	11	13
2003	Central Highlands	4	4	8	5	5	8	7	7	8	8
2004	Central Highlands	7	7	8	5	5	8	7	7	8	8
2005	Central Highlands	4	4	9	2	2	9	6	6	9	9
2006	Central Highlands	7	7	7	7	7	7	6	6	7	7
2007	Central Highlands	5	5	5	5	5	5	5	5	5	6

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2008	Central Highlands	7	7	9	6	6	9	5	5	9	9
2009	Central Highlands	6	6	7	5	5	6	4	4	7	8
2004	Central Scotland RSG	0	0	2	0	0	1	0	0	1	2
2003	Coll, Tiree and the Western Isles	13	13	18	9	9	16	13	13	18	29
2004	Coll, Tiree and the Western Isles	15	15	25	11	11	24	21	21	24	40
2005	Coll, Tiree and the Western Isles	25	25	37	31	31	35	25	25	35	37
2006	Coll, Tiree and the Western Isles	23	23	32	17	17	31	11	11	19	37
2007	Coll, Tiree and the Western Isles	26	26	31	18	18	31	24	24	30	45
2008	Coll, Tiree and the Western Isles	29	29	32	18	18	31	22	22	32	41
2009	Coll, Tiree and the Western Isles	4	4	13	3	1	8	4	4	5	15
2003	Dumfries & Galloway RSG	7	7	11	5	5	11	6	6	11	11
2003	East Lochaber	0	0	1	0	0	1	1	1	1	1
2004	East Lochaber	1	1	1	0	0	1	0	0	1	1
2006	East Lochaber	1	1	3	1	1	3	0	0	3	4
2007	East Lochaber	1	1	2	0	0	2	2	2	2	2
2008	East Lochaber	1	1	3	1	1	3	1	1	2	3
2009	East Lochaber	2	2	2	2	2	2	2	2	2	3
2006	Eastern Lowlands	2	2	3	1	1	3	2	1	3	3
2007	Eastern Lowlands	0	0	0	0	0	1	0	0	1	1
2008	Eastern Lowlands	0	0	0	0	0	1	0	0	1	1
2005	Highland RSG	0	0	1	0	0	0	0	0	0	1
2003	Loch Lomond, Trossachs & Breadalbane	1	1	6	1	1	4	3	3	5	7
2004	Loch Lomond, Trossachs & Breadalbane	4	4	9	6	6	9	9	9	9	10
2005	Loch Lomond, Trossachs & Breadalbane	6	6	10	6	6	10	6	6	10	11
2006	Loch Lomond, Trossachs & Breadalbane	5	5	14	4	4	13	11	9	14	14
2007	Loch Lomond, Trossachs & Breadalbane	9	9	17	0	0	16	15	12	17	25
2008	Loch Lomond, Trossachs & Breadalbane	7	7	17	8	7	16	12	8	17	21
2009	Loch Lomond, Trossachs & Breadalbane	6	5	12	7	7	10	8	8	14	15

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2003	Lothian & Borders RSG	1	1	2	0	0	2	1	1	2	2
2004	Lothian & Borders RSG	0	0	5	0	0	4	4	4	4	5
2005	Lothian & Borders RSG	0	0	0	0	0	0	0	0	0	1
2006	Lothian & Borders RSG	0	0	1	0	0	0	0	0	1	1
2003	Moray Firth	1	1	1	1	1	1	1	1	1	1
2009	Moray Firth	1	0	1	0	0	1	0	0	1	1
2004	North Caithness and Orkney	53	53	66	33	33	67	33	33	70	75
2005	North Caithness and Orkney	57	57	75	32	32	60	32	29	73	75
2006	North Caithness and Orkney	39	39	56	25	25	52	28	28	68	71
2007	North Caithness and Orkney	45	45	61	15	15	51	11	11	44	71
2008	North Caithness and Orkney	38	38	49	11	11	43	4	4	46	65
2009	North Caithness and Orkney	38	32	55	22	17	58	15	9	48	72
2008	North East Coastal Plain	0	0	0	0	0	1	0	0	0	1
2003	North East Glens	6	6	8	0	0	5	5	5	8	8
2004	North East Glens	7	7	7	6	6	7	5	5	7	10
2005	North East Glens	8	8	8	7	7	8	6	6	8	12
2006	North East Glens	8	8	10	6	6	10	8	7	10	12
2007	North East Glens	6	6	7	0	0	7	6	6	7	8
2008	North East Glens	9	9	12	7	7	10	6	6	11	14
2009	North East Glens	4	3	4	4	3	4	3	3	3	7
2003	North-east Scotland RSG	0	0	9	0	0	9	9	9	12	17
2004	North-east Scotland RSG	0	0	6	0	0	7	3	3	9	12
2005	North-east Scotland RSG	0	0	10	0	0	8	8	8	11	12
2006	North-east Scotland RSG	0	0	3	0	0	3	2	2	8	10
2003	Northern Highlands	2	2	3	2	2	3	3	2	4	4
2004	Northern Highlands	3	3	5	2	2	4	3	3	4	6
2005	Northern Highlands	1	1	3	0	0	3	2	2	3	3
2006	Northern Highlands	2	2	3	2	2	3	1	1	1	4

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2007	Northern Highlands	1	1	2	0	0	2	1	1	3	4
2008	Northern Highlands	3	3	5	1	1	5	1	1	5	7
2009	Northern Highlands	3	3	6	3	3	5	4	3	6	6
2003	South Strathclyde RSG	14	14	41	10	10	30	18	18	43	45
2005	South Strathclyde RSG	0	0	0	0	0	0	0	0	1	1
2003	Tayside RSG	4	4	10	3	3	8	6	6	10	10
2004	Tayside RSG	1	1	3	0	0	2	1	1	3	3
2005	Tayside RSG	4	4	4	2	2	4	2	2	4	4
2006	Tayside RSG	2	2	2	1	1	2	1	1	3	5
2008	Tayside RSG	0	0	0	0	0	0	0	0	0	1
2003	The Peatlands of Caithness and Sutherland	9	9	13	6	6	13	7	7	14	14
2004	The Peatlands of Caithness and Sutherland	16	16	23	8	8	21	14	14	23	23
2005	The Peatlands of Caithness and Sutherland	8	8	13	4	4	13	8	8	14	14
2006	The Peatlands of Caithness and Sutherland	4	4	6	3	3	6	3	3	6	7
2007	The Peatlands of Caithness and Sutherland	4	4	7	3	3	6	4	4	8	10
2008	The Peatlands of Caithness and Sutherland	6	6	12	3	3	12	6	5	12	15
2009	The Peatlands of Caithness and Sutherland	12	12	15	9	9	13	6	6	17	18
2003	West Central Belt	0	0	4	0	0	4	4	4	4	4
2004	West Central Belt	8	8	14	6	6	14	7	7	15	15
2005	West Central Belt	1	1	3	1	1	3	2	2	3	3
2006	West Central Belt	3	3	4	2	2	3	0	0	4	5
2007	West Central Belt	3	3	3	3	3	3	2	2	3	4
2008	West Central Belt	0	0	2	0	0	2	2	2	3	3
2009	West Central Belt	4	4	4	4	4	4	0	0	4	4

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2003	Western Seaboard	0	0	7	1	1	5	3	3	9	11
2004	Western Seaboard	8	4	37	10	10	33	15	8	27	43
2005	Western Seaboard	17	17	27	14	14	25	18	18	25	42
2006	Western Seaboard	17	17	24	12	12	20	10	10	27	29
2007	Western Seaboard	18	18	27	7	7	27	21	21	30	30
2008	Western Seaboard	31	31	42	24	24	41	29	28	43	50
2009	Western Seaboard	11	11	21	7	7	20	15	15	21	31
2003	Western Southern Uplands & Inner Solway	3	3	4	2	2	4	1	1	4	4
2004	Western Southern Uplands & Inner Solway	29	29	34	20	20	39	16	16	41	43
2005	Western Southern Uplands & Inner Solway	35	35	39	20	20	32	21	21	42	46
2006	Western Southern Uplands & Inner Solway	14	14	25	11	11	26	7	7	24	34
2007	Western Southern Uplands & Inner Solway	18	18	20	8	8	23	7	7	23	26
2008	Western Southern Uplands & Inner Solway	13	13	17	9	9	17	5	5	18	19
2009	Western Southern Uplands & Inner Solway	20	19	25	12	12	21	10	10	24	27
2003	Wigtown Machairs and Outer Solway Coast	2	2	2	1	1	2	1	1	2	2
2004	Wigtown Machairs and Outer Solway Coast	5	5	5	2	2	5	2	2	5	5
2005	Wigtown Machairs and Outer Solway Coast	7	7	7	7	7	7	7	7	7	7
2006	Wigtown Machairs and Outer Solway Coast	0	0	0	0	0	2	0	0	1	2

Table B15. The number of northern goshawk nest sites that were checked for occupancy between the years 2003-2009 in the three SRMS goshawk study areas in Scotland. (Source: SRMS dataset 2003-2009.)

Study area	2003	2004	2005	2006	2007	2008	2009
SW Scotland	19	21	22	24	30	30	34
Border Hills and south Lothian	56	62	53	56	59	59	50
NE Scotland	32	34	31	30	38	45	53

Table B16. The number of records for northern goshawks for which the actual number of eggs laid, eggs hatched and young fledged was reported from each study area. The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey. (Source: SRMS dataset 2003-2009.)

Study area	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
SW Scotland	2003	5	3	7
	2004	8	0	9
	2005	12	0	11
	2006	12	0	10
	2007	8	2	14
	2008	6	8	15
	2009	8	12	13
Border Hills and south Lothian	2003	13	0	23
	2004	10	1	2
	2005	6	2	19
	2006	7	1	23
	2007	3	0	27
	2008	1	0	20
	2009	1	0	21
Total		**100**	**29**	**214**

Table B17. The number of breeding Eurasian sparrowhawk ranges checked for occupancy in a study area in Ayrshire (covering parts of NHZs 17 and 19) where monitoring has been comprehensive and consistent for the years 2003-2009.
(Source: SRMS dataset 2003-2009.)

Number of checked ranges	2003	2004	2005	2006	2007	2008	2009
Ayrshire	27	21	49	64	59	62	61

Note that Ian Todd has explained that the number of checked sites has remained approximately constant, but it was not made clear during the early years of SRMS (2003 and 2004), that checked but unoccupied territories should also be reported to the SRMS. Thus, for these early years the number of checked territories in his study area that were reported to the SRMS equals the number of occupied territories. Ian Todd has agreed to supply the SRMS with the true number of checked sites for the years 2003 and 2004.

Table B18. The number of records for Eurasian sparrowhawk for which the actual number of eggs laid, eggs hatched and young fledged was reported from each study area.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey.
(Source: SRMS dataset 2003-2009.)

Study area	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
Argyll and Central Scotland	2004	3	3	7
	2005	2	3	12
	2007	0	0	2
	2009	0	0	2
Southern Scotland	2008	0	0	2
Colonsay	2004	0	0	2
	2006	1	0	0
Orkney	2004	0	1	2
	2008	4	3	2
	2009	0	0	3
Ayrshire	2003	23	13	0
	2004	14	5	2
	2005	18	8	19
	2006	26	18	27
	2007	25	19	23
	2008	19	20	22
	2009	22	15	18
Total		**157**	**108**	**145**

Table B19. The number of common buzzard nest sites that were checked for occupancy between 2003 and 2009 in 10 study areas in Scotland.
As the sample sizes were low for some studies and some studies were only recently initiated, we decided to analyze trends only for the studies and years highlighted in grey in the table below.
(Source: SRMS dataset 2003-2009.)

Study area	2003	2004	2005	2006	2007	2008	2009
Cowal and Bute	29	66	64	49	71	72	82
Falkirk area	8	0	0	0	0	35	38
Assynt	13	10	2	6	11	12	16
Moray and Dornoch	61	69	62	63	67	57	60
Colonsay	53	52	55	54	58	58	58
Aviemore and Kingussie	13	11	9	12	12	16	10
Stirling and the Trossachs	21	34	101	125	138	133	142
Lothian	32	39	42	36	30	34	32
Aberdeen	0	0	0	0	128	104	32
Uists	0	8	3	22	29	24	18
Total	**230**	**289**	**338**	**367**	**544**	**545**	**488**

Note that for several of the studies, the results suggest that in the early years of the SRMS (mainly 2003 and 2004), the raptor workers only submitted records for nests that were occupied. For the study on the Uists, this problem has remained, and because of this lack of "negative reporting" it is difficult to assess the spatial coverage of the monitoring effort on Uist without further consultation with relevant observers.

Table B20. The number of records for common buzzard for which the actual number of eggs laid, eggs hatched and young fledged was reported from each study area. The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey.
(Source: SRMS dataset 2003-2009.)

Study area	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
Cowal and Bute	2004	9	9	44
	2005	2	9	35
	2006	5	5	27
	2007	3	1	38
	2008	0	2	19
	2009	3	6	26
Moray and Dornoch	2003	29	21	39
	2004	26	21	41
	2005	21	17	33
	2006	18	17	33
	2007	28	25	40
	2008	26	23	31
	2009	19	14	22
Colonsay	2003	1	2	9
	2004	2	0	8
	2005	2	1	1
	2006	7	8	2
	2007	3	4	5
	2008	5	4	1
	2009	2	1	0
Stirling and the Trossachs	2005	6	7	47
	2006	1	1	54
	2007	3	3	77
	2008	0	0	55
	2009	0	0	47
Lothian	2003	4	3	26
	2004	28	19	32
	2005	33	21	32
	2006	31	18	28
	2007	24	11	21
	2008	24	15	23
	2009	25	22	25
Uists	2006	2	1	5
	2007	3	0	7
	2008	3	2	17
	2009	6	7	11
Total		**404**	**320**	**961**

Table B21. Comparison of the number of golden eagle ranges in Natural Heritage Zones. (Source: SRMS dataset 2003-2009 and additional information supplied by Haworth Conservation.)

Natural Heritage Zone		Number in Zone		
Name	NHZ number	SRMS	SRMS+HC	Change
Raptor Study Group (Unassigned to an NHZ)		799	151	-648
Coll, Tiree and the Western Isles	3	183	208	25
NorthWest Seaboard	4	55	58	3
The Peatlands of Caithness and Sutherland	5	18	18	0
Western Seaboard	6	92	457	365
Northern Highlands	7	89	90	1
Western Highlands	8	198	200	2
Central Highlands	10	43	46	3
Cairngorm Massif	11	97	107	10
North East Glens	12	16	16	0
East Lochaber	13	31	51	20
Argyll West and Islands	14	113	205	92
Breadalbane and East Argyll	15	32	147	115
Western Southern Uplands and Inner Solway	19	8	12	4
Border Hills	20	3	11	8
Totals (excluding unassigned)		**978**	**1626**	**+648**

Table B22. Comparison of 2004-2009 SRMS golden eagle data against the 2003 National Survey data. Figures are the number of checked ranges. National Survey data for 2003 are from Whitfield et al. (2007). NHZs highlighted in grey are considered by Haworth Conservation to have relatively poor (or variable) SRMS coverage.
(Source: SRMS dataset 2004-2009 and additional information supplied by Haworth Conservation.)

	Active		Vacant	Surveyed									Surveyed as a % 2003 active ranges						
NHZ	1992	2003	2003	NHZ	2003	2004	2005	2006	2007	2008	2009	All	NHZ	2004	2005	2006	2007	2008	2009
2	0	0	1	2									2						
3	62	81	12	3	0	24	28	25	30	55	44	206	3	29.6	34.6	30.9	37.0	67.9	54.3
4	45	46	25	4	0	9	4	7	9	8	20	57	4	19.6	8.7	15.2	19.6	17.4	43.5
5	13	18	13	5	0	5	0	1	4	3	5	18	5	27.8	0.0	5.6	22.2	16.7	27.8
6	74	74	24	6	0	43	82	86	81	81	83	456	6	58.1	110.8	116.2	109.5	109.5	112.2
7	45	43	47	7	8	11	10	11	17	15	15	87	7	25.6	23.3	25.6	39.5	34.9	34.9
8	54	51	16	8	8	24	30	33	33	31	40	199	8	47.1	58.8	64.7	64.7	60.8	78.4
10	12	12	14	10	0	6	6	0	8	12	14	46	10	50.0	50.0	0.0	66.7	100.0	116.7
11	32	28	43	11	0	16	17	14	17	17	24	105	11	57.1	60.7	50.0	60.7	60.7	85.7
12	6	3	14	12	0	2	2	0	3	2	7	16	12	66.7	66.7	0.0	100.0	66.7	233.3
13	28	25	11	13	1	9	7	13	5	3	10	48	13	36.0	28.0	52.0	20.0	12.0	40.0
14	44	44	15	14	0	31	31	33	33	37	38	203	14	70.5	70.5	75.0	75.0	84.1	86.4
15	20	12	15	15	8	19	22	24	21	22	17	133	15	158.3	183.3	200.0	175.0	183.3	141.7
16	0	1	0	16									16	0.0	0.0	0.0	0.0	0.0	0.0
19	3	2	2	19	0	0	4	4	2	0	2	12	19	0.0	200.0	200.0	100.0	0.0	100.0
20	1	3	1	20	1	1	2	0	2	2	1	9	20	33.3	66.7	0.0	66.7	66.7	33.3
Total	**439**	**443**	**253**	**All**	**26**	**200**	**245**	**251**	**265**	**288**	**320**	**1595**	**All**	**45.1**	**55.3**	**56.7**	**59.8**	**65.0**	**72.2**

Table B23. Sample sizes of breeding parameters available for golden eagles by NHZ or Raptor Study group for those records not currently grid-referenced within the dataset.
(Source: SRMS data 2003-2009.)

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs laid binomial	Young fledged numbers (+)	Young fledged numbers	Young Fledged binomial	Total pairs
2004	Argyll West and Islands	0	0	25	0	0	25	19	19	25	25
2005	Argyll West and Islands	3	3	24	5	5	19	9	8	22	25
2006	Argyll West and Islands	5	5	25	5	5	26	11	11	24	27
2007	Argyll West and Islands	2	2	28	2	2	24	17	17	28	28
2008	Argyll West and Islands	3	3	27	7	7	26	18	18	27	32
2009	Argyll West and Islands	4	4	32	2	2	23	12	12	31	34
2005	Argyll RSG	0	0	1	0	0	1	0	0	1	1
2004	Cairngorm Massif	1	1	8	4	4	12	7	7	12	12
2005	Cairngorm Massif	2	2	13	3	3	12	6	6	13	14
2006	Cairngorm Massif	3	3	8	3	3	8	7	7	8	9
2007	Cairngorm Massif	2	2	10	3	3	10	5	5	11	12
2008	Cairngorm Massif	4	4	12	2	2	10	6	6	12	14
2009	Cairngorm Massif	6	3	13	3	0	14	5	5	14	18
2004	Central Highlands	2	2	4	1	1	3	2	2	4	5
2005	Central Highlands	0	0	4	0	0	3	3	3	4	4
2007	Central Highlands	1	1	6	5	5	5	3	3	4	6
2008	Central Highlands	0	0	5	0	0	5	3	3	7	7
2009	Central Highlands	1	1	8	1	1	6	5	5	8	9
2008	Central Scotland RSG	0	0	1	0	0	1	1	1	1	1
2004	Coll, Tiree and the Western Isles	11	11	14	5	5	12	8	8	14	21
2005	Coll, Tiree and the Western Isles	7	7	26	0	0	21	5	5	21	27
2006	Coll, Tiree and the Western Isles	5	5	16	3	3	12	4	4	14	24
2007	Coll, Tiree and the Western Isles	3	3	23	5	5	16	10	10	21	28
2008	Coll, Tiree and the Western Isles	27	27	50	13	13	46	22	19	49	52
2009	Coll, Tiree and the Western Isles	6	6	42	18	15	39	23	23	40	44

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs laid binomial	Young fledged numbers (+)	Young fledged numbers	Young Fledged binomial	Total pairs
2003	East Lochaber	0	0	1	0	0	0	0	0	1	1
2004	East Lochaber	2	2	7	1	1	7	4	4	7	7
2005	East Lochaber	0	0	7	1	1	6	2	2	6	7
2006	East Lochaber	0	0	11	0	0	10	1	1	10	11
2007	East Lochaber	0	0	5	0	0	5	3	3	5	5
2008	East Lochaber	0	0	2	0	0	2	2	2	2	2
2009	East Lochaber	1	0	3	1	0	3	1	1	3	6
2005	Highland RSG	0	0	0	0	0	0	0	0	0	1
2003	Lothian & Borders RSG	0	0	1	0	0	1	0	0	1	1
2004	Lothian & Borders RSG	0	0	1	0	0	1	1	1	1	1
2005	Lothian & Borders RSG	1	1	2	0	0	2	1	1	2	2
2006	Lothian & Borders RSG	0	0	3	0	0	1	1	1	3	3
2003	L Lomond, Trossachs & Breadalbane	0	0	5	1	1	3	3	3	5	5
2004	L Lomond, Trossachs & Breadalbane	1	1	11	0	0	8	5	5	10	12
2005	L Lomond, Trossachs & Breadalbane	0	0	16	0	0	11	4	4	15	18
2006	L Lomond, Trossachs & Breadalbane	0	0	12	1	1	11	7	7	14	14
2007	L Lomond, Trossachs & Breadalbane	0	0	13	1	1	12	9	9	15	15
2008	L Lomond, Trossachs & Breadalbane	1	1	15	1	1	11	7	7	16	16
2009	L Lomond, Trossachs & Breadalbane	1	0	11	1	1	5	4	3	12	13
2004	North-east Scotland RSG	0	0	13	1	1	16	9	9	13	16
2005	North-east Scotland RSG	0	0	15	4	4	14	4	4	14	15
2006	North-east Scotland RSG	2	2	16	0	0	16	6	6	15	16
2007	North-east Scotland RSG	0	0	7	7	7	7	4	4	14	15
2008	North-east Scotland RSG	1	1	15	5	5	13	5	5	15	15
2009	North-east Scotland RSG	7	7	13	7	7	13	7	7	13	13
2004	North East Glens	0	0	1	0	0	0	0	0	1	1
2008	North East Glens	0	0	1	0	0	0	0	0	1	1
2009	North East Glens	0	0	1	0	0	2	0	0	0	2

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs laid binomial	Young fledged numbers (+)	Young fledged numbers	Young Fledged binomial	Total pairs
2004	North West Seaboard	2	2	6	2	2	5	2	2	6	7
2005	North West Seaboard	0	0	4	0	0	3	1	1	3	4
2006	North West Seaboard	1	1	4	1	1	5	3	3	5	5
2007	North West Seaboard	2	2	4	2	2	2	1	1	4	6
2008	North West Seaboard	0	0	3	2	2	3	2	2	3	4
2009	North West Seaboard	2	2	10	1	1	10	2	2	9	12
2003	Northern Highlands	4	4	4	2	2	4	0	0	6	6
2004	Northern Highlands	1	1	4	1	1	4	4	4	5	5
2005	Northern Highlands	2	2	5	2	2	5	2	2	3	5
2006	Northern Highlands	0	0	5	0	0	5	1	1	5	5
2007	Northern Highlands	2	2	8	5	5	5	4	4	8	9
2008	Northern Highlands	5	5	6	1	1	6	3	3	6	7
2009	Northern Highlands	2	2	7	0	0	3	1	1	7	7
2003	Southern Scotland	2	2	4	1	1	2	1	1	3	4
2004	Southern Scotland	0	0	3	0	0	1	0	0	4	4
2005	Southern Scotland	0	0	1	0	0	0	0	0	1	1
2007	Southern Scotland	1	1	1	0	0	0	0	0	2	2
2008	Southern Scotland	0	0	1	0	0	1	1	1	1	1
2008	Tayside RSG	0	0	1	0	0	0	0	0	0	1
2004	Peatlands of Caithness & Sutherland	0	0	4	0	0	1	1	1	5	5
2006	Peatlands of Caithness & Sutherland	0	0	1	0	0	0	0	0	0	1
2007	Peatlands of Caithness & Sutherland	0	0	3	3	3	3	3	3	3	3
2008	Peatlands of Caithness & Sutherland	0	0	1	0	0	1	0	0	0	1
2009	Peatlands of Caithness & Sutherland	0	0	4	1	1	4	4	4	4	4
2003	Western Highlands	4	4	6	4	4	4	1	1	6	6
2004	Western Highlands	1	1	15	1	1	16	7	7	15	18
2005	Western Highlands	7	7	17	8	8	20	5	5	19	22
2006	Western Highlands	1	1	25	1	1	26	5	5	25	27
2007	Western Highlands	9	9	24	15	15	15	3	3	23	24

Year	NHZ or RSG	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs laid binomial	Young fledged numbers (+)	Young fledged numbers	Young Fledged binomial	Total pairs
2008	Western Highlands	3	3	21	2	2	20	6	6	20	21
2009	Western Highlands	2	2	19	2	2	20	3	3	20	27
2004	Western Seaboard	3	3	32	3	3	28	12	12	30	35
2005	Western Seaboard	3	3	49	7	7	48	22	22	67	73
2006	Western Seaboard	0	0	60	2	2	61	18	18	61	78
2007	Western Seaboard	17	17	62	25	25	47	18	18	63	66
2008	Western Seaboard	1	1	33	2	2	32	34	34	66	69
2009	Western Seaboard	2	2	44	3	3	42	24	24	63	69
2005	W Southern Uplands and Inner Solway	0	0	0	0	0	1	0	0	1	1
2006	W Southern Uplands and Inner Solway	0	0	0	0	0	2	0	0	2	2
2007	W Southern Uplands and Inner Solway	1	1	1	0	0	0	0	0	0	1
2009	W Southern Uplands and Inner Solway	1	1	1	0	0	1	1	1	1	1

Table B24. The number of common kestrel nest sites that were checked for occupancy between the 2003 and 2009 in an Ayrshire study area.
(Source: SRMS dataset 2003-2009.)

Study area	2003	2004	2005	2006	2007	2008	2009
Ayrshire	30	33	35	36	36	43	40

Table B25. The number of records for common kestrel for which the actual number of eggs laid, eggs hatched and young fledged was reported from each study area.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey.
(Source: SRMS dataset 2003-2009.)

Main observer	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
Stirling and the Trossachs	2004	3	2	2
	2005	0	0	1
	2007	1	1	1
	2009	1	0	0
Ayrshire	2003	14	13	16
	2004	25	23	23
	2005	14	11	11
	2006	17	16	20
	2007	12	12	12
	2008	18	17	23
	2009	10	10	13
Other areas	2003	7	9	15
	2004	20	16	43
	2005	16	11	35
	2006	4	5	17
	2007	6	3	21
	2008	8	4	25
	2009	5	4	26
Dumfries and Galloway	2003	12	13	16
	2004	22	20	19
	2005	10	9	10
	2006	11	9	9
	2008	7	5	7
Total		**243**	**213**	**365**

Table B26. Comparison of the number of merlin ranges in Natural Heritage Zones. (Source: SRMS dataset 2003-2009 and additional information supplied by Haworth Conservation.)

Natural Heritage Zone		Number in Zone		
Name	NHZ number	SRMS	SRMS+HC	Change
Raptor Study Group (Unassigned to an NHZ)		1371	1234	-137
Shetland	1	3	3	0
North Caithness and Orkney	2	70	100	30
Coll, Tiree and the Western Isles	3	97	172	75
North West Seaboard	4	40	43	3
The Peatlands of Caithness and Sutherland	5	432	436	4
Western Seaboard	6	74	76	2
Northern Highlands	7	84	84	0
Western Highlands	8	6	6	0
Central Highlands	10	282	283	1
Cairngorm Massif	11	104	107	3
North East Glens	12	64	64	0
East Lochaber	13	22	22	0
Argyll West and Islands	14	19	19	0
Loch Lomond, The Trossachs and Breadalbane	15	127	127	0
Eastern Lowlands	16	36	36	0
West Central Belt	17	18	20	2
Western Southern Uplands and Inner Solway	19	73	73	0
Border Hills	20	309	326	17
Moray Firth	21	14	14	0
Totals (excluding unassigned)		**1874**	**2011**	**+137**

Table B27. Merlin nesting range records submitted to the SRMS that remain unassigned to Natural Heritage Zones because of a lack of grid references.
(Source: SRMS dataset 2003-2009.)

Source (Raptor Study Group)	Number of range-year records unassigned to NHZs
Argyll RSG	19
Central Scotland RSG	51
Dumfries & Galloway RSG	65
Highland RSG	51
Lewis & Harris RSG	3
Lothian & Borders RSG	44
North-east Scotland RSG	676
Other	6
RBBP	9
RSPB	1
South Strathclyde RSG	67
Tayside RSG	242
Total	**1234**

Table B28. The number of merlin nesting ranges surveyed and occupied within the SRMS dataset 2003-2009 by Natural Heritage Zone (or source for those that cannot be assigned to NHZs because of a lack of grid references).
(Source: SRMS dataset 2003-2009 and additional information supplied by Haworth Conservation.)

	Surveyed									Occupied								
NHZ name	NHZ	2003	2004	2005	2006	2007	2008	2009	All	NHZ	2003	2004	2005	2006	2007	2008	2009	All
Shetland	1	0	0	0	0	1	0	2	3	1	0	0	0	0	1	0	2	3
North Caithness and Orkney	2	0	22	22	21	21	0	14	100	2	0	18	21	20	17	0	11	87
Coll, Tiree & Western Isles	3	10	0	59	27	28	38	9	171	3	9	0	39	21	19	34	9	127
North West Seaboard	4	6	5	3	1	1	1	3	20	4	3	5	1	0	0	1	3	13
Peatlands – Caithness, Sutherland	5	47	40	32	26	42	40	23	250	5	32	20	18	13	11	19	17	130
Western Seaboard	6	6	4	12	11	14	12	9	68	6	4	3	8	5	6	5	4	35
Northern Highlands	7	4	5	6	5	3	5	7	35	7	4	5	5	4	3	3	4	28
Western Highlands	8	0	0	0	0	2	0	0	2	8	0	0	0	0	1	0	0	1
Central Highlands	10	20	21	23	20	20	24	19	147	10	9	9	11	7	8	6	5	55
Cairngorm Massif	11	9	9	8	3	13	15	13	70	11	6	3	3	1	6	7	6	32
North East Glens	12	10	11	8	0	9	11	10	59	12	7	6	7	0	8	9	6	43
East Lochaber	13	6	2	2	0	3	4	4	21	13	2	1	1	0	1	1	0	6
Argyll West and Islands	14	5	0	3	4	1	3	3	19	14	1	0	2	1	0	1	1	6
L Lomond, Trossachs & B'bane	15	20	17	19	0	22	27	17	122	15	11	11	14	0	7	12	8	63
Eastern Lowlands	16	5	5	6	5	4	6	1	32	16	4	4	2	1	1	0	0	12
West Central Belt	17	1	2	1	1	5	6	4	20	17	1	0	0	0	5	2	2	10
W Southern Uplands; Inner Solway	19	3	6	16	10	9	9	12	65	19	3	6	15	8	8	8	12	60
Border Hills	20	31	32	43	37	54	61	56	314	20	21	23	18	20	25	28	22	157
Moray Firth	21	2	2	2	2	2	2	2	14	21	2	1	0	1	0	0	0	4
All NHZ		**185**	**183**	**265**	**173**	**254**	**264**	**208**	**1532**		**119**	**115**	**165**	**102**	**127**	**136**	**112**	**872**

Table B29 Continued.

	Surveyed									Occupied								
NHZ name	NHZ	2003	2004	2005	2006	2007	2008	2009	All	NHZ	2003	2004	2005	2006	2007	2008	2009	All
Argyll RSG	31	2	13	1	0	2	1	0	19	31	2	10	0	0	2	0	0	14
Central Scotland RSG	32	0	1	1	0	24	24	1	51	32	0	1	0	0	1	4	1	7
Dumfries & Galloway RSG	33	20	13	1	3	1	2	2	42	33	9	8	1	3	1	2	2	26
Highland RSG	34	2	15	0	1	1	6	0	25	34	1	14	0	1	0	4	0	20
Lewis & Harris RSG	35	0	0	0	0	0	3	0	3	35	0	0	0	0	0	3	0	3
Lothian & Borders RSG	36	14	9	9	9	1	2	0	44	36	11	4	2	3	1	1	0	22
North-east Scotland RSG	37	103	103	90	96	74	74	70	610	37	50	45	39	41	41	0	36	252
Other	38	0	0	1	3	0	2	0	6	38	0	0	1	2	0	2	0	5
RBBP/RSPB	39	0	0	0	0	10	0	0	10	39	0	0	0	0	7	0	0	7
South Strathclyde RSG	40	7	7	11	9	7	8	0	49	40	7	6	7	2	5	6	0	33
Tayside RSG	41	33	39	33	0	30	36	26	197	41	18	21	16	0	13	13	7	88
All RSG Data	**All**	**181**	**200**	**147**	**121**	**150**	**158**	**99**	**1056**	All	**98**	**109**	**66**	**52**	**71**	**35**	**46**	**477**
All data		**366**	**383**	**412**	**294**	**404**	**422**	**307**	**2588**	All	**217**	**224**	**231**	**154**	**198**	**171**	**158**	**1349**

Table B30. Sample sizes of breeding parameters available for merlins by NHZ or Raptor Study group for those records not currently grid-referenced within the dataset.
(Source: SRMS data 2003-2009.)

Year	NHZ	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2003	Argyll RSG	0	0	0	0	0	0	0	0	1	2
2004	Argyll RSG	0	0	1	0	0	1	1	0	1	10
2007	Argyll RSG	0	0	2	0	0	0	0	0	0	2
2003	Argyll West and Islands	0	0	1	0	0	2	0	0	2	2
2005	Argyll West and Islands	0	0	2	0	0	2	2	1	2	2
2006	Argyll West and Islands	0	0	1	0	0	1	1	1	1	1
2008	Argyll West and Islands	1	1	1	1	1	1	1	1	1	1
2009	Argyll West and Islands	1	1	1	1	1	1	1	1	1	1
2003	Border Hills	16	16	20	16	16	20	16	16	21	21
2004	Border Hills	16	16	24	13	13	19	12	12	25	26
2005	Border Hills	16	14	19	16	16	17	17	16	19	20
2006	Border Hills	9	9	13	8	8	13	12	10	14	21
2007	Border Hills	11	11	18	11	11	18	9	9	15	26
2008	Border Hills	17	17	26	16	16	25	21	13	25	29
2009	Border Hills	13	13	19	11	11	20	12	10	15	22
2003	Cairngorm Massif	3	3	4	1	1	4	2	2	4	6
2004	Cairngorm Massif	1	1	3	1	1	3	1	1	3	5
2005	Cairngorm Massif	1	1	3	1	1	3	2	1	4	4
2006	Cairngorm Massif	0	0	1	0	0	1	1	1	1	1
2007	Cairngorm Massif	2	2	5	2	2	5	5	3	5	7
2008	Cairngorm Massif	1	1	5	1	1	7	3	1	5	7
2009	Cairngorm Massif	5	5	7	4	4	5	4	1	7	8
2003	Central Highlands	2	2	8	1	1	8	7	7	8	10
2004	Central Highlands	8	8	9	5	5	9	4	4	9	9
2005	Central Highlands	8	8	11	5	5	11	9	8	11	12

Year	NHZ	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2006	Central Highlands	6	6	7	4	4	7	4	4	7	8
2007	Central Highlands	8	8	8	6	6	8	2	2	8	8
2008	Central Highlands	4	4	4	3	3	5	2	2	6	6
2009	Central Highlands	5	4	5	5	5	5	5	5	5	5
2004	Central Scotland RSG	0	0	0	0	0	0	0	0	0	1
2007	Central Scotland RSG	0	0	0	0	0	0	0	0	0	1
2008	Central Scotland RSG	0	0	0	0	0	0	0	0	0	5
2009	Central Scotland RSG	0	0	1	0	0	1	1	1	1	1
2003	Coll, Tiree and the Western Isles	4	4	5	0	0	5	4	4	5	10
2005	Coll, Tiree and the Western Isles	23	23	33	13	13	35	12	11	26	35
2006	Coll, Tiree and the Western Isles	12	12	18	4	4	11	7	7	9	27
2007	Coll, Tiree and the Western Isles	6	6	8	4	4	5	1	1	1	11
2008	Coll, Tiree and the Western Isles	11	11	20	11	11	20	14	7	17	34
2009	Coll, Tiree and the Western Isles	3	3	5	2	2	5	4	2	5	9
2003	Dumfries & Galloway RSG	1	1	3	1	1	4	2	2	4	9
2004	Dumfries & Galloway RSG	1	1	8	0	0	8	8	1	8	9
2005	Dumfries & Galloway RSG	0	0	0	0	0	0	0	0	0	1
2006	Dumfries & Galloway RSG	0	0	3	0	0	2	0	0	2	3
2007	Dumfries & Galloway RSG	0	0	0	0	0	1	0	0	1	1
2008	Dumfries & Galloway RSG	0	0	1	0	0	0	0	0	1	2
2009	Dumfries & Galloway RSG	1	1	1	1	1	1	1	1	1	2
2003	East Lochaber	0	0	3	0	0	2	0	0	2	3
2004	East Lochaber	0	0	0	0	0	0	0	0	0	1
2005	East Lochaber	0	0	1	0	0	1	0	0	1	1
2007	East Lochaber	0	0	1	0	0	1	1	1	1	2
2008	East Lochaber	0	0	1	0	0	1	1	1	1	1
2009	East Lochaber	0	0	0	0	0	0	0	0	1	1
2003	Eastern Lowlands	2	2	3	1	1	4	2	2	4	4
2004	Eastern Lowlands	1	1	3	1	1	2	1	1	3	4

Year	NHZ	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2005	Eastern Lowlands	0	0	1	1	1	1	1	1	1	2
2006	Eastern Lowlands	1	1	1	1	1	1	1	1	1	1
2007	Eastern Lowlands	0	0	1	0	0	1	0	0	1	1
2003	Highland RSG	0	0	0	0	0	0	0	0	0	1
2004	Highland RSG	0	0	2	0	0	1	0	0	2	15
2006	Highland RSG	0	0	1	1	1	1	0	0	1	1
2008	Highland RSG	1	1	1	0	0	0	0	0	1	4
2008	Lewis & Harris RSG	1	1	1	0	0	1	0	0	0	3
2003	L Lomond, Trossachs & Breadalbane	0	0	9	0	0	9	5	5	11	13
2004	L Lomond, Trossachs & Breadalbane	2	2	11	0	0	11	8	7	11	11
2005	L Lomond, Trossachs & Breadalbane	2	2	14	1	1	12	10	8	14	15
2007	L Lomond, Trossachs & Breadalbane	0	0	5	0	0	8	5	5	8	8
2008	L Lomond, Trossachs & Breadalbane	1	1	12	2	2	11	9	4	11	12
2009	L Lomond, Trossachs & Breadalbane	3	0	5	3	2	6	4	2	6	8
2003	Lothian & Borders RSG	9	9	9	9	9	10	9	9	10	11
2004	Lothian & Borders RSG	2	2	3	2	2	4	3	3	3	4
2005	Lothian & Borders RSG	1	1	1	1	1	1	1	1	1	3
2006	Lothian & Borders RSG	1	1	2	1	1	2	2	2	2	3
2007	Lothian & Borders RSG	0	0	0	0	0	0	0	0	0	1
2008	Lothian & Borders RSG	0	0	0	0	0	0	0	0	0	1
2003	Moray Firth	1	1	2	0	0	2	2	2	2	2
2004	Moray Firth	1	1	1	1	1	1	0	0	1	1
2006	Moray Firth	0	0	1	0	0	1	0	0	1	1
2004	North Caithness and Orkney	12	12	18	8	8	18	8	8	17	19
2005	North Caithness and Orkney	13	13	16	12	12	16	12	3	17	21
2006	North Caithness and Orkney	13	13	17	10	10	17	5	4	14	21
2007	North Caithness and Orkney	13	13	16	6	6	16	1	1	7	18
2009	North Caithness and Orkney	4	4	8	4	4	8	6	5	10	14

Year	NHZ	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2003	North East Glens	5	5	7	3	3	6	3	3	7	7
2004	North East Glens	5	5	6	2	2	6	4	4	6	7
2005	North East Glens	4	4	6	5	5	6	6	6	6	7
2007	North East Glens	3	3	7	3	3	7	7	4	7	8
2008	North East Glens	4	4	8	4	4	8	7	5	7	9
2009	North East Glens	4	4	5	3	3	3	3	3	3	6
2003	North West Seaboard	1	1	2	0	0	1	1	1	1	3
2004	North West Seaboard	0	0	3	1	1	3	1	1	2	5
2005	North West Seaboard	0	0	0	0	0	0	0	0	0	1
2008	North West Seaboard	0	0	1	0	0	1	0	0	1	1
2009	North West Seaboard	1	1	3	0	0	3	2	2	3	3
2003	North-east Scotland RSG	39	39	50	36	36	50	39	39	51	51
2004	North-east Scotland RSG	31	31	48	20	20	45	28	28	47	48
2005	North-east Scotland RSG	31	31	40	24	24	38	29	28	40	41
2006	North-east Scotland RSG	25	25	39	24	24	40	33	30	40	41
2007	North-east Scotland RSG	28	28	40	23	23	39	28	28	40	41
2009	North-east Scotland RSG	0	0	36	0	0	36	0	0	5	36
2003	Northern Highlands	1	1	3	1	1	3	3	3	3	4
2004	Northern Highlands	1	1	5	1	1	5	5	5	5	5
2005	Northern Highlands	2	2	5	2	2	5	5	2	5	5
2006	Northern Highlands	2	2	4	1	1	3	2	2	4	4
2007	Northern Highlands	1	1	1	1	1	1	1	1	1	3
2008	Northern Highlands	1	1	3	1	1	3	1	1	3	3
2009	Northern Highlands	1	1	2	0	0	2	1	1	3	4
2005	Other	0	0	0	0	0	0	0	0	0	1
2006	Other	1	1	2	1	1	1	0	0	2	2
2007	Other	3	3	5	1	1	3	0	0	1	7
2008	Other	1	1	1	0	0	1	0	0	1	2
2007	Shetland	1	1	1	0	0	1	0	0	0	1

Year	NHZ	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2009	Shetland	2	2	2	2	1	2	1	1	1	2
2003	South Strathclyde RSG	2	2	6	1	1	5	4	4	4	7
2004	South Strathclyde RSG	2	2	2	2	2	6	0	0	5	7
2005	South Strathclyde RSG	4	4	5	3	3	4	4	4	4	7
2006	South Strathclyde RSG	2	2	2	1	1	2	1	1	2	2
2007	South Strathclyde RSG	2	2	4	2	2	4	4	4	4	5
2008	South Strathclyde RSG	2	2	5	2	2	5	2	0	4	6
2003	Tayside RSG	10	10	14	7	7	17	10	10	18	21
2004	Tayside RSG	7	7	14	8	8	13	10	10	13	22
2005	Tayside RSG	2	2	8	1	1	8	8	6	11	16
2007	Tayside RSG	0	0	9	0	0	7	3	0	5	13
2008	Tayside RSG	0	0	6	0	0	6	1	1	7	14
2009	Tayside RSG	5	5	7	4	4	6	5	2	5	7
2003	Peatlands of Caithness and Sutherland	14	14	26	11	11	19	4	4	20	34
2004	Peatlands of Caithness and Sutherland	6	6	18	7	7	15	7	7	21	28
2005	Peatlands of Caithness and Sutherland	8	8	12	3	3	9	7	6	9	15
2006	Peatlands of Caithness and Sutherland	5	5	8	4	4	6	5	5	6	13
2007	Peatlands of Caithness and Sutherland	5	5	9	4	4	9	7	6	9	12
2008	Peatlands of Caithness and Sutherland	8	8	12	4	4	9	7	6	10	19
2009	Peatlands of Caithness and Sutherland	8	8	13	1	1	11	8	3	12	16
2003	West Central Belt	1	1	1	1	1	1	0	0	1	1
2007	West Central Belt	0	0	4	0	0	3	2	1	4	5
2008	West Central Belt	0	0	2	0	0	2	1	0	1	2
2009	West Central Belt	1	0	1	1	0	1	1	1	1	2
2007	Western Highlands	0	0	0	0	0	0	0	0	0	1
2003	Western Seaboard	1	1	4	0	0	4	2	2	4	4
2004	Western Seaboard	2	2	2	1	1	2	2	2	3	3
2005	Western Seaboard	2	2	7	2	2	7	7	7	8	9
2006	Western Seaboard	4	4	5	3	3	5	3	3	5	5

Year	NHZ	Eggs laid numbers (+)	Eggs laid numbers	Eggs laid binomial	Eggs hatched numbers (+)	Eggs hatched numbers	Eggs hatched binomial	Young fledged numbers (+)	Young fledged numbers	Young fledged binomial	Total pairs
2007	Western Seaboard	4	4	7	4	4	6	3	3	5	7
2008	Western Seaboard	3	3	5	2	2	5	4	3	5	5
2009	Western Seaboard	3	2	4	3	3	4	3	3	5	5
2003	W Southern Uplands & Inner Solway	0	0	3	0	0	2	2	2	3	3
2004	W Southern Uplands & Inner Solway	2	2	6	1	1	6	5	1	6	6
2005	W Southern Uplands & Inner Solway	5	5	11	4	4	11	11	11	11	15
2006	W Southern Uplands & Inner Solway	4	4	7	4	4	6	4	2	7	8
2007	W Southern Uplands & Inner Solway	2	2	6	4	4	5	3	2	5	8
2008	W Southern Uplands & Inner Solway	1	1	6	0	0	6	3	2	6	8
2009	W Southern Uplands & Inner Solway	4	3	5	1	1	3	1	0	4	12

Table B31. The number of checked peregrine falcon nesting ranges in each potential study area (NHZ or sub-area) from which to derive trends between the years 2003 and 2009. (Source: SRMS dataset 2003-2009.)

Study area (see Figure 59)	2003	2004	2005	2006	2007	2008	2009
NHZ 9	20	20	19	20	20	18	0
NHZ 11	94	93	78	77	69	70	37
Tayside NHZ 11	50	51	42	40	39	42	33
Southern NHZ 12	46	38	42	34	29	37	23
Cowal NHZ 14	10	13	16	14	15	12	13
NHZ 15	39	41	40	44	40	38	32
NHZ 16	73	78	80	80	120	123	127
NHZ 17	36	39	38	42	42	49	49
NHZ 18	29	26	22	33	31	26	31
NHZ 19	86	87	86	87	91	89	87
NHZ 20	64	61	64	70	76	74	79
Total	**547**	**547**	**527**	**541**	**572**	**578**	**511**

Table B32. The number of records for peregrine falcon for which outcomes at each stage of the breeding cycle (laying, hatching and fledging) and the actual number of eggs laid, eggs hatched and young fledged was reported from each study area.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey. (Source: SRMS dataset 2003-2009.)

Study area	Year	Sample size					
		Eggs laid binomial	Eggs laid numbers	Eggs hatched binomial	Eggs hatched numbers	Outcome binomial	Fledged young numbers
Cowal NHZ 14	2003	5	1	4	0	5	4
Cowal NHZ 14	2004	7	1	6	3	7	4
Cowal NHZ 14	2005	3	1	3	1	3	3
Cowal NHZ 14	2006	8	1	7	0	9	7
Cowal NHZ 14	2007	6	0	4	0	6	3
Cowal NHZ 14	2008	7	1	4	0	6	4
Cowal NHZ 14	2009	6	2	6	2	7	5
NHZ 11	2003	34	6	26	8	37	25
NHZ 11	2004	36	7	32	4	40	31
NHZ 11	2005	13	1	7	1	28	20
NHZ 11	2006	26	2	15	0	26	14
NHZ 11	2007	12	3	8	0	18	12
NHZ 11	2008	11	1	8	0	13	7
NHZ 11	2009	6	0	5	0	10	5
NHZ 15	2003	19	1	12	1	22	12
NHZ 15	2004	26	0	7	0	23	22
NHZ 15	2005	20	1	3	0	19	14
NHZ 15	2006	15	0	13	0	16	13
NHZ 15	2007	20	1	18	1	20	17
NHZ 15	2008	21	0	18	0	21	18
NHZ 15	2009	15	0	7	0	15	7
NHZ 16	2003	46	12	33	22	49	33
NHZ 16	2004	45	10	35	13	51	37
NHZ 16	2005	38	17	28	17	43	31
NHZ 16	2006	39	10	32	7	39	33
NHZ 16	2007	39	14	31	13	53	39
NHZ 16	2008	39	12	31	10	47	37
NHZ 16	2009	49	17	46	27	54	46
NHZ 17	2003	25	4	1	1	27	22
NHZ 17	2004	22	5	19	2	23	19
NHZ 17	2005	25	8	21	6	22	16
NHZ 17	2006	31	10	26	3	34	23
NHZ 17	2007	28	9	26	2	30	25
NHZ 17	2008	24	8	21	3	25	20
NHZ 17	2009	24	10	21	5	27	17
NHZ 18	2003	19	2	0	0	18	14

Study area	Year	Sample size					
		Eggs laid binomial	Eggs laid numbers	Eggs hatched binomial	Eggs hatched numbers	Outcome binomial	Fledged young numbers
NHZ 18	2004	18	2	16	2	16	15
NHZ 18	2005	13	2	11	2	13	11
NHZ 18	2006	20	10	16	2	20	14
NHZ 18	2007	16	6	14	6	15	13
NHZ 18	2008	18	8	14	5	12	9
NHZ 18	2009	18	6	14	8	18	13
NHZ 19	2003	34	12	1	0	36	15
NHZ 19	2004	39	19	29	8	42	27
NHZ 19	2005	32	11	19	5	33	21
NHZ 19	2006	35	22	26	1	36	24
NHZ 19	2007	32	21	26	17	34	24
NHZ 19	2008	28	13	19	7	35	19
NHZ 19	2009	25	12	20	10	29	16
NHZ 20	2003	34	28	17	14	38	20
NHZ 20	2004	26	18	20	18	29	20
NHZ 20	2005	27	25	21	12	28	19
NHZ 20	2006	32	26	24	17	33	22
NHZ 20	2007	25	23	19	12	26	17
NHZ 20	2008	25	21	21	15	25	18
NHZ 20	2009	31	26	24	19	30	22
NHZ 9	2003	8	2	5	1	16	6
NHZ 9	2004	13	2	13	0	14	13
NHZ 9	2005	0	0	0	0	15	8
NHZ 9	2006	8	0	8	0	8	8
NHZ 9	2007	0	0	0	0	12	5
NHZ 9	2008	2	2	3	3	2	0
Southern NHZ 12	2003	13	3	12	0	15	12
Southern NHZ 12	2004	14	2	12	0	17	11
Southern NHZ 12	2005	4	0	4	0	15	11
Southern NHZ 12	2006	12	1	11	3	11	10
Southern NHZ 12	2007	2	1	2	1	7	6
Southern NHZ 12	2008	8	2	5	0	6	5
Southern NHZ 12	2009	7	2	6	2	9	6
Tayside NHZ 11	2003	22	4	17	5	22	16
Tayside NHZ 11	2004	24	4	21	3	25	20
Tayside NHZ 11	2005	13	1	7	1	17	12
Tayside NHZ 11	2006	19	2	8	0	19	8
Tayside NHZ 11	2007	12	3	8	0	12	8
Tayside NHZ 11	2008	8	0	6	0	12	6
Tayside NHZ 11	2009	6	0	5	0	10	5
Total		**1532**	**520**	**1108**	**351**	**1705**	**1194**

Table B33. The number of checked and occupied peregrine falcon territories in the national survey 2002 and the number of nesting ranges checked and occupied (by pairs) between 2003 and 2009, divided by the nesting ranges that were known and unknown (i.e. new since 2002) in 2002. (Source: SRMS dataset 2003-2009 and national peregrine survey 2002 dataset held by BTO.)

	NHZ	Formal trends possible?	No. of checked NRs (No. of NRs checked >1 time) in 2002	No. of NRs occupied by pairs (Best case scenario) [a] in 2002	No. of unoccupied NRs (No. of NRs checked >1 time)	2003		2004		2005		2006		2007		2008		2009	
						Known in 2002	Unk	Known in 2002	Unk	Known in 2002	Unk	Known in 2002	Unk	Known in 2002	Unk	Known in 2002	Unk	Known in 2002	Unk
1	Shetlands	No	42 (14)	0 (28)	42 (14)														
2	North Caithness & Orkney	No	41 (39)	15 (18)	11 (9)	3	1	14	0	5	0	1	0	4	0	10	0	0	0
3	Coll, Tiree & Western Isles	?	30 (29)	16 (16)	10 (10)	16	1	5	1	15	1	11	0	6	0	10	0	8	0
4	North West Seaboard	No	33 (26)	2 (9)	23 (16)	4	1	1	1	1	0	1	0	2	0	1	0	0	0
5	Peatlands of Caithness & Sutherland	No	35 (30)	11 (15)	15 (12)	3	2	2	3	4	1	4	2	1	0	0	0	0	0
6	Western Seaboard	No	37 (33)	5 (9)	24 (21)	1	1	2	1	1	1	1	0	3	0	4	0	0	0
7	Northern Highlands	No	26 (23)	7 (10)	15 (13)	6	4	4	2	5	2	3	3	2	2	1	2	2	0
8	Western Highlands	No	13 (10)	6 (9)	6 (3)														
9	North East Coastal Plain	Part	22 (0)	19 (22)	3 (0)	17	1	14	1	14	1	15	1	14	1	14	1	0	0
10	Central Highlands	No	16 (14)	7 (7)	7 (7)	2	1	2	3	1	1	1	1	1	1	1	1	0	1
11	Cairngorm Massif	Part	108 (55)	55 (90)	46 (13)	42	3	47	3	34	5	28	4	25	2	24	3	15	0
12	North East Glens	Part	54 (19)	22 (43)	26 (7)	19	1	15	2	17	1	13	1	7	1	11	1	9	1
13	East Lochaber	No	24 (21)	11 (14)	12 (9)	2	0	2	0	1	0	1	0	1	0	0	0	0	0
14	Argyll West & Islands	Cowal only	98 (87)	48 (53)	35 (30)	18	1	16	1	18	0	28	0	14	0	18	0	16	0
15	L Lomond, Trossachs & B'bane	Part	74 (58)	46 (60)	22 (9)	29	0	29	0	25	0	28	0	25	0	26	0	21	0
16	Eastern Lowlands	Yes	66 (48)	56 (58)	6 (5)	54	4	54	7	49	8	41	12	46	13	46	14	47	14
17	West Central Belt	Yes	39 (21)	28 (28)	9 (9)	24	3	25	3	25	7	26	9	25	8	27	7	26	7
18	Wigtown Machairs & Outer Solway Coast	Yes	32 (6)	23 (26)	8 (5)	21	2	18	1	17	0	21	0	21	0	18	0	20	0
19	W Southern Uplands & Inner Solway	Yes	78 (28)	46 (51)	28 (24)	45	1	47	1	39	1	38	1	38	3	34	4	31	0
20	Border Hills	Yes	54 (37)	35 (37)	12 (10)	41	2	34	1	33	3	33	8	29	7	27	6	27	8
21	Moray Firth	No	9 (7)	5 (6)	3 (2)	2	2	3	2	3	2	3	2	4	2	4	2	2	2
	Total		**931 (591)**	**463 (609)**	**363 (228)**	**349**	**31**	**334**	**33**	**307**	**34**	**297**	**44**	**268**	**40**	**276**	**41**	**224**	**33**

Table B34. The number of barn owl nest sites that were checked for occupancy between 2003 and 2009 in the 11 study areas of Scotland.
As the sample sizes were low for some studies and some studies were only initiated recently, we were able to produce preliminary trends only for the studies and years highlighted in grey.
(Source: SRMS dataset 2003-2009.)

Study area	2003	2004	2005	2006	2007	2008	2009
Cowal	0	5	8	19	14	25	22
NE Highlands	18	29	27	39	27	34	28
Southern Uplands	79	40	36	32	41	45	70
West Galloway	80	95	99	104	99	94	101
Central Galloway	3	26	32	17	31	29	36
Central Ayrshire	0	0	0	0	33	21	54
Mid-Argyll and Kintyre	0	15	17	21	23	18	16
Aberdeenshire (B)	0	0	0	4	13	8	2
Southern Borders	0	3	0	0	23	47	96
Stirlingshire	32	28	36	39	67	70	45
Aberdeenshire (main)	0	0	29	30	17	25	33
Total	**212**	**241**	**284**	**305**	**388**	**416**	**503**

Table B35. The number of records for barn owl for which the actual number of eggs laid, eggs hatched and young fledged was reported from each study area.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey.
(Source: SRMS dataset 2003-2009.)

Study area	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
NE Highlands	2003	8	7	14
	2004	9	10	18
	2005	13	3	10
	2006	10	10	6
	2007	9	9	12
	2008	11	12	10
	2009	4	3	4
Southern Uplands	2003	15	16	66
	2004	11	7	33
	2005	13	8	25
	2006	11	2	19
	2007	10	13	23
	2008	8	4	23
	2009	7	3	8
West Galloway	2003	19	21	6
	2004	20	12	1
	2005	26	4	44
	2006	21	4	1

	2007	15	0	6
	2008	38	13	6
	2009	46	42	0
Central Galloway	2004	10	7	16
	2005	7	6	12
	2006	3	3	11
	2007	10	7	12
	2008	5	3	10
	2009	2	2	5
Mid-Argyll and Kintyre	2004	11	6	8
	2005	17	11	9
	2006	6	14	11
	2007	18	15	17
	2008	3	12	12
	2009	6	5	11
Stirlingshire	2003	12	5	20
	2004	14	21	8
	2005	10	6	17
	2006	22	20	31
	2007	28	26	59
	2008	36	27	25
	2009	15	31	37
Aberdeenshire (main)	2005	14	11	19
	2006	4	0	3
	2008	1	0	11
	2009	9	1	14
Total		**587**	**442**	**713**

Table B 36. The numbers of tawny owl nest sites that were checked for occupancy between 2003 and 2009 in six study areas of Scotland.
As the sample sizes were low for some studies and some studies were initiated only very recently, we decided to analyze trends only for the studies and years highlighted in grey in the table below.
(Source: SRMS dataset 2003-2009.)

Study area	2003	2004	2005	2006	2007	2008	2009
Cowal	0	0	12	0	21	5	17
Easter Ross	24	33	34	28	29	25	16
Southern Uplands	14	16	14	12	8	6	0
Black Isle	2	2	24	24	25	21	25
Central Galloway	9	11	10	4	8	0	4
Borders	0	0	0	14	12	13	19
Total	**49**	**62**	**94**	**82**	**103**	**70**	**81**

Table B37. The number of records for tawny owl for which the actual number of eggs laid, eggs hatched and young fledged was reported from each study area.
The year-study area combinations deemed to have sufficient sample sizes for trend analyses in productivity are highlighted in grey.
(Source: SRMS dataset 2003-2009.)

Study area	Year	Sample size		
		Eggs laid	Eggs hatched	Fledged young
Easter Ross	2003	21	23	24
	2004	25	25	25
	2005	27	26	27
	2006	17	16	18
	2007	20	20	20
	2008	17	16	17
	2009	16	16	16
Southern Uplands	2003	4	3	14
	2004	14	5	8
	2005	0	2	6
	2006	4	3	9
Black Isle	2005	3	3	3
	2006	4	4	4
	2007	7	7	7
	2008	4	4	0
	2009	3	1	2
Borders	2006	0	0	14
	2007	0	0	12
	2008	13	0	13
	2009	11	11	11
Total		**210**	**185**	**250**

Table B38. Scottish raptor records submitted to the BTO Nest Record Scheme 2007-2010 by area of Scotland. (Source: Dave Leech, BTO, pers. comm.)

Species	Old County Name (BTO county)	2007	2008	2009	2010	Totals 2007-2010
Barn owl	Border Region		1		1	2
Barn owl	Central Region				3	3
Barn owl	Dumfries & Galloway	129	144	84	61	418
Barn owl	Fife	7	6	7	10	30
Barn owl	Grampian			1		1
Barn owl	Highland Region	16	24	11	9	60
Barn owl	Lothian	7	4	4	4	19
Barn owl	Strathclyde Region	60	68	43	39	210
Barn owl	Tayside Region		2		1	3
		219	**249**	**150**	**128**	**746**
Common buzzard	Border Region				2	2
Common buzzard	Dumfries & Galloway				1	1
Common buzzard	Fife				1	1
Common buzzard	Highland Region	60	52	46	63	221
Common buzzard	Lothian	4	1	5	2	12
Common buzzard	Strathclyde Region	34	14	14	11	73
Common buzzard	Tayside Region		1		1	2
Common buzzard	Western Isles			2	3	5
		98	**68**	**67**	**84**	**317**
Golden eagle	Highland Region	13	10	11	15	49
Golden eagle	Western Isles			8	5	13
		13	**10**	**19**	**20**	**62**
Northern goshawk	Border Region				1	1
Northern goshawk	Dumfries & Galloway		1		1	2
Northern goshawk	Highland Region			1		1
Northern goshawk	Tayside Region				1	1
		0	**0**	**0**	**3**	**5**
Hen harrier	Border Region	1	1			2

Species	Old County Name (BTO county)	2007	2008	2009	2010	Totals 2007-2010
Hen harrier	Grampian				1	1
Hen harrier	Highland Region	2	10	8	4	24
Hen harrier	Strathclyde Region	7	3	4	5	19
Hen harrier	Western Isles			1		1
		10	**14**	**13**	**10**	**47**
Common kestrel	Border Region			1		1
Common kestrel	Central Region				1	1
Common kestrel	Fife		1			1
Common kestrel	Grampian				2	2
Common kestrel	Highland Region	4	7	4	5	20
Common kestrel	Lothian	1				1
Common kestrel	Strathclyde Region		1	1		2
Common kestrel	Tayside Region		3			3
		5	**12**	**6**	**8**	**31**
Long-eared owl	Border Region				1	1
Long-eared owl	Fife			1		1
Long-eared owl	Grampian	2				2
Long-eared owl	Highland Region	2	4	1	1	8
		4	**4**	**2**	**2**	**12**
Merlin	Border Region	2	5	1		8
Merlin	Dumfries & Galloway		1			1
Merlin	Grampian				1	1
Merlin	Highland Region	5	13	3	2	23
Merlin	Lothian	3	6	5		14
		10	**25**	**9**	**3**	**47**
Osprey	Grampian			1	1	2
Osprey	Highland Region	3	11	8	12	34
Osprey	Tayside Region				1	1
		3	**11**	**9**	**14**	**37**
Peregrine falcon	Border Region			1	1	2

Species	Old County Name (BTO county)	2007	2008	2009	2010	Totals 2007-2010
Peregrine falcon	Dumfries & Galloway				2	2
Peregrine falcon	Fife		1			1
Peregrine falcon	Grampian				2	2
Peregrine falcon	Highland Region	6	7	2	7	22
Peregrine falcon	Strathclyde Region		1	1	1	3
Peregrine falcon	Western Isles			3	2	5
		6	**9**	**7**	**15**	**37**
Red kite	Highland Region		1	1	1	3
		0	**1**	**1**	**1**	**3**
Short-eared owl	Border Region	1		1	2	4
Short-eared owl	Highland Region	1		1		2
Short-eared owl	Western Isles		1			1
		2	**1**	**2**	**2**	**7**
Eurasian sparrowhawk	Highland Region	1	2	3	2	8
Eurasian sparrowhawk	Lothian	2	2	5		9
Eurasian sparrowhawk	Strathclyde Region				1	1
		3	**4**	**8**	**3**	**18**
Tawny owl	Border Region		1			1
Tawny owl	Dumfries & Galloway	15	4	3	2	24
Tawny owl	Fife		1	1		2
Tawny owl	Grampian	72	92	32	75	271
Tawny owl	Highland Region	35	31	22	39	127
Tawny owl	Lothian	1		2	1	4
Tawny owl	Strathclyde Region	3	3	4	3	13
Tawny owl	Tayside Region	1		1	5	7
		127	**132**	**65**	**125**	**449**
White-tailed eagle	Highland Region	2	2	1	2	7
White-tailed eagle	Strathclyde Region		1	1		2
White-tailed eagle	Western Isles			3	3	6
		2	**3**	**5**	**5**	**15**

ANNEX C: AN EMPIRICAL TEST OF MONITORING EFFORT FOR GOLDEN EAGLES

From Fielding, A.H., Haworth, P.F. and Whitfield, D.R.A. 2002. ANALYTICAL FOUNDATION FOR CONSERVATION FRAMEWORK FOR THE GOLDEN EAGLE (Oct 31st 2002). CONTRACT NO: BAT/AC309/01/02/46 (Note this section is not in SNH report 193).

C.1 Background

The lack of any systematic national monitoring programme makes it very difficult to obtain precise, unbiased estimates of population parameters or to identify regional and temporal differences that can be attributed to particular processes. While it is unrealistic, and possibly unethical (because of the increased disturbance), to expect an annual national census, it is possible to determine the resources needed to achieve an accurate, precise and efficient monitoring programme.

C.2 Method

C.2.1 Data

Comprehensive breeding data are available for >100 ranges from Argyll, Mull, Lochaber and Skye (Figure C1). The coverage is so good that they approximate to 20 consecutive annual censuses. Using these data different sampling strategies can be simulated and the results compared to the reality. In this way it should be possible to rank different strategies and determine the required sampling effort.

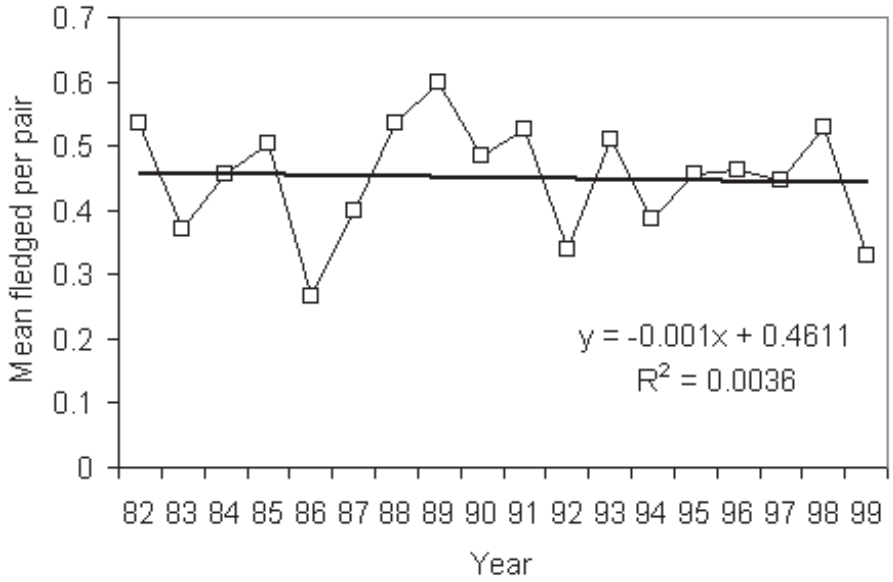


Figure C1. Mean number fledged per pair between 1982 and 1999 for 110 ranges in Argyll, Mull, Lochaber and Skye

C.2.2 Sampling strategies

In a *simple random sampling* approach each range should have an equal chance of being included in the sample. The probability that a range will be included should be *1/N* where *N* is the number of ranges. Thus, each range should have a 1/673 chance of being included. Random sampling is easy to implement when the sampling frame is explicit, i.e. we have a list of ranges.

However, the ranges are associated with NHZ and it was shown in section 5.3.2 that population characteristics differ between NHZ. If the NHZ are used as a stratification variable and the eagle range characteristics are closely related this should result in a more representative sample which in turn will ensure increased precision of estimates obtained from the samples. If a stratified sampling technique is applied, the number of ranges included from each NHZ would be proportional to its representation in the population.

Simple random sampling of the ranges could cause logistical problems, with the surveyors spending more time travelling between ranges than sampling ranges. Cluster sampling was developed to deal with this type of problem, in particular reducing the cost of data collection. In cluster sampling:

- the population is divided into geographically-defined clusters
- the clusters are sampled randomly
- all members of the sampled clusters are measured.

In stratified or *quota* sampling, the population is divided into strata and a random sample is obtained from *every* stratum, i.e. each NHZ. In cluster sampling, the population is divided into groups called clusters (NHZ in this example), not all of the clusters are sampled. If a cluster (a NHZ or NHZ subset) is included in the sample *all* of the cases in the cluster are surveyed. Stratified sampling works best if the strata are homogeneous so that relatively few points can represent each stratum well. Sampling error will arise primarily from variability within the strata. Cluster sampling works best if the clusters are as heterogeneous as possible. Sampling error will occur because of variability between clusters. There should be no sampling error within the clusters if each member is included.

Normally, cluster sampling produces greater sampling error than random or stratified sampling. However, the loss of precision may be outweighed by the efficiency of data collection. Sampling methods may be combined into a multi-stage sampling programme. For example, cluster sampling may be initially employed as an efficiency measure. Each of the clusters, if they are sufficiently large, can then be subject to random, stratified or systematic sampling. For the purpose of this exercise the Kintyre data were separated from the Argyll data.

C.2.3 The sampling simulation

An Excel macro was written that could simulate three sampling strategies at different sampling efforts (proportion of ranges sampled). There were ten simulations for each sampling scenario, enabling an estimate to be made of its accuracy and precision (reliability). Accuracy was measured by calculating, for each sampling simulation, a sum of the squared residuals (differences between actual and estimated annual productivity, Figure C2). If the sample effort is insufficient the sum will be large, whereas an appropriate sampling effort would result in a small sum. It is also important to determine the reliability of all estimates, i.e. if a sample was repeated using different ranges would a similar estimate be obtained? Precision was estimated by calculating confidence intervals for the mean sum of squared residuals. If the confidence intervals are wide then even an accurate estimate may not be reliable. The ideal sampling strategy would be:

- accurate (small sum of squared residuals);
- precise (narrow confidence interval) and
- efficient (minimum number of ranges sampled.

Figure C2 shows the results from a single sampling simulation and Figure C3 is a summary of the results from the quota sampling simulation. In order to simplify comparisons between the three strategies power curves were fitted to the results (Figure C4).

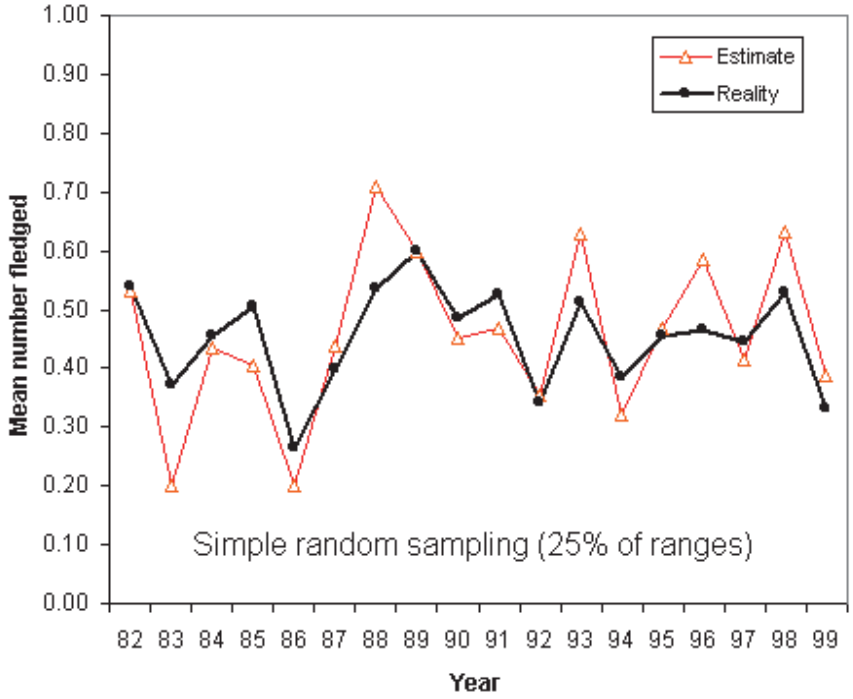


Figure C2. Simple random sampling simulation results.

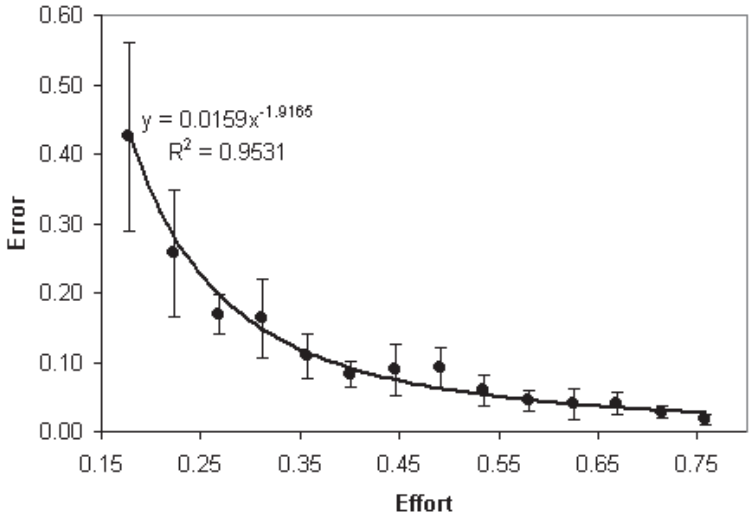


Figure C3. Results from the quota sampling simulation with fitted power curve

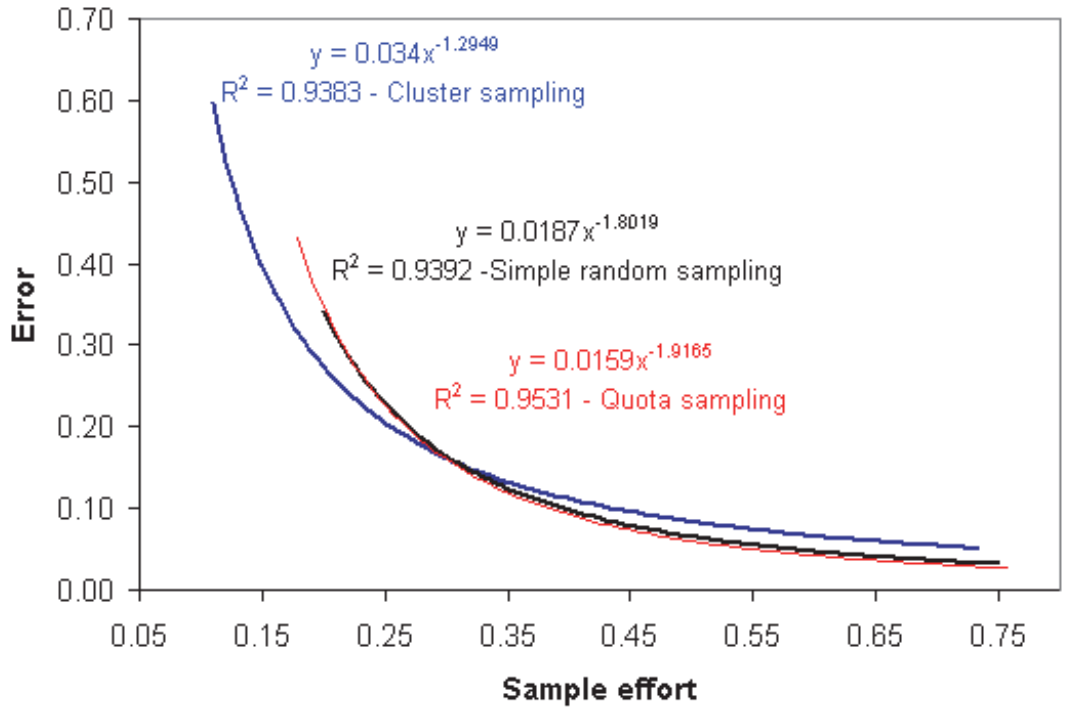


Figure C4. Power curves for the accuracy of three sampling strategies.

C.3 Summary

As expected, increased sample effort produced more accurate and precise estimates of the annual productivity. There was little difference in results from the three strategies. Interestingly, cluster sampling produced similar levels of accuracy to the other two methods. The combination of clusters used did not alter the accuracy, other than that caused by differences in the overall sampling effort. This is interesting because it is the most efficient method in logistic terms.

There is little to be gained by sampling more than 40% of the ranges. Nonetheless this amounts to 270 ranges per year if all known ranges are surveyed or 180 ranges per year if only active ranges are surveyed. However, if only active ranges are surveyed then this could lead to an underestimate if some vacant ranges are reoccupied.

C.4 Caveats

The choice of NHZs for a national sampling strategy may be more sensitive than was apparent in this simulation which used data from contiguous western ranges. This will be particularly true if there are large and uncorrelated differences in the annual productivity.

With the exception of simple cluster sampling there is a requirement for random selection of ranges. Any monitoring that preferentially surveys only productive ranges will produce a biased estimate.

ANNEX D: FURTHER BACKGROUND INFORMATION ON INDICATORS

D.1 Introduction to biological / environmental indicators

A common definition of an indicator is as a surrogate for a parameter that is too ephemeral or too difficult technically, practically or too expensive, to measure directly (Landres *et al*. 1988, Hilty and Merenlender 2000, Lindenmeyer *et al*. 2000, Gregory *et al*. 2005). Good examples are lichens indicating air quality (McClenahen *et al*. 2007), plant species indicating soil moisture or soil fertility, or birds of prey populations reflecting pesticide contamination (Furness and Greenwood 1993).

Such indicators are often used in research and wildlife management as diagnostic tools to gain specific knowledge about the environment. Currently, however, the terms indicator, indicator species, signal species, bio-indicator or bio-monitor, can have different meanings and functions, which can be confused (Caro & O'Doherty 1999, Hilty & Merenlender 2000, Landres *et al*. 1988, Lindenmayer *et al*. 2000, Gregory *et al*. 2005, 2007). A review by Simberloff (1998) found no consensus on what they are supposed to indicate.

Leader-Williams and Dublin (2000) recognise two types of indicator: (i) one that reflects community composition, and (ii) one that reflects environmental change.

A frequently used categorisation in a more legislative context is the DSR model, where indicators are described as driving force indicators (D), state indicators (S) or response indicators (R). Of these, state indicators, which measure the quality of the environment or ecosystem, are most relevant in the context of assessing the impact of a suite of ecological and environmental pressures on a particular species, group of species, or habitat. Driving force indicators are used to assess the pressures that might conceivably cause these effects, whilst response indicators are more process-oriented, for example reflecting the actions being taken by policy makers to respond to driving forces.

Another distinction followed by some authors (e.g. Jones *et al*. 2009) is to categorise indicators as biological, ecological or environmental. Biological, or biodiversity, indicators capture the responses of a range of taxa and reflect components of biological diversity such as species richness, species diversity, and evenness. Ecological indicators consist of taxa or assemblages that are sensitive to identified environmental factors, that demonstrate the effects of those factors on biota, and whose responses reflect the responses of at least a subset of other taxa present. Environmental indicators respond in predictable ways to specific environmental disturbances, for example, the presence of dung beetle assemblages in savannahs (McGeoch, 1998). Many of the indicators used to assess the condition or quality of aquatic ecosystems (see Adams, 2002; Everard, 2008) fall into this category.

Many biological indicators are based on ‘surrogate species’ selected to reflect different aspects of ecosystem structure, function or stress. These include ‘keystone species’ (Paine, 1969), ‘flagship species’ (Dayton, 1972), ‘core species’ and ‘satellite species’ (Hanski, 1982), ‘dominant species’ (Grime, 1984), ‘structural species’ (Huston, 1994), ‘ecosystem engineers’ (Jones *et al*., 1994) and ‘cultural keystone species’ (Garibaldi and Turner, 2004) and the relative value of predator or prey species as best indicators of ecosystem health (Sergio *et al*., 2008). The theory is that indicator species, through their distribution, presence, changing numbers, size, etc, provide us with a means to determine ecosystem health, since their life cycles, habitat, and responses to a variety of conditions have already been intensively studied and are well known. Caro and O'Doherty (1999) review the relevance of many of these surrogate species to different ecological problems.

The plethora of definitions aside, indicators have assumed significance in conservation and land-use management as they synthesise simplified and useful information from complex systems, often integrating multiple sources of data (Jackson *et al*. 2000). They help to guide decision-making as well as monitoring and evaluation, but despite their increasing influence in management and policy-making at all scales, the lack of formal criteria often applied to the selection of ecological indicators potentially compromises their utility as analytical tools (Niemeijer and de Groot, 2007).

Birds are widely seen as appropriate for use in indicators of the quality of different environments based on a number of factors including their conspicuousness, mobility across landscapes and hence rapid response to pressures, place near the top of food chains, diversity of species, appeal to the public, availability of data and potential loyalty to specific habitat types (Gregory *et al*., 2004; Gregory *et al*., 2005).

D.2 Bird indicators already in use in the UK

In the UK, the idea of developing a wildlife indicator came from an expert group set up by the Department of Environment, Food and Rural Affairs (Defra) to review suitable indicators to underpin the 1999 UK Sustainable Development Strategy (Gregory et al. 2004). This group identified a number of wildlife indicators reflecting traditional conservation issues, such as the number and condition of special sites, the number and status of priority species and habitats, and so forth. A key gap, however, was the lack of broader indicators reflecting the general health of common and widespread wildlife in the countryside. Although initial discussions focussed on target-based indicators (Bibby et al. 1999), the Royal Society for the Protection of Birds (RSPB), the British Trust for Ornithology (BTO) and Defra developed the idea to create a state indicator: one that reflected the broad state of nature without requiring targets for individual species. Birds were chosen because they are regarded as good general indicators of the state of wildlife; they were wide-ranging in habitat use and tend to be at, or near, the top of the food chain; there is good trend information available from the early 1960s; and they have great public resonance, and hence were judged to be an excellent way to raise awareness for biodiversity issues. These indicators, first adopted by the UK in 1999 and subsequently by the devolved governments (e.g. Scotland), are comprised of population trends of bird species aggregated according to their associations with broad habitats such as farmland, woodland and uplands. Methods are described in Gregory *et al*. (2003). Data for constituent species are analysed, usually in a GLM modelling framework, to provide annual parameter estimates of abundance. Values for missing years are estimated by interpolation and values for years outside the period covered by the survey are estimated by extrapolation, using pre-defined rules to maintain sufficient robustness. The annual indices for each species are then standardised to a common start year, and the annual indicator values are determined from the geometric mean of the constituent species values. Geometric means are used so that an index change from 100 to 200 (a doubling) is equivalent, but opposite to, an index change from 100 to 50 (a halving).

Arguably, one of the weaknesses of the current indicators in terms of biodiversity as a whole is that the rare and scarce species are underrepresented. In the wild bird indicators developed in the UK and Europe, rare species are excluded because: (i) they are found in relatively few locations and hence do not represent broader biodiversity; and/or (ii) their population status is likely to be more strongly influenced by dedicated conservation action rather than the drivers affecting all species (Gregory *et al*. 2003). Currently, the UK Biodiversity Indicators exclude all species with a national population of fewer than 500 pairs, and species with fewer than 300 pairs are excluded from the England Biodiversity Strategy and Scottish Terrestrial bird indicators. These thresholds for excluding species are clearly arbitrary, and when developing bird indicators for the scarcer habitats, it might be appropriate to include rare but characteristic species of these habitats such as great bittern and Eurasian marsh harrier for reed beds in England. However, it does mean that the

current wild bird indicator misses an important component of biodiversity, emphasising the need for complementary measures that focus on rare species (e.g. van Strien 1999, Butchart *et al*. 2004, 2007). In fact, a rare bird indicator developed by Gregory *et al*. (2003) showed populations to have more than doubled in the UK in the last thirty years, reflecting considerable investment of time and money in proactive and largely successful conservation initiatives. It would therefore be misleading to assume that rare bird populations are representative of the countryside in general.

In summary, wild bird indicators composed of the trends of species associated with key British landscapes (such as farmland and woodland) are reported annually by the UK government and have raised public awareness about the conservation problems which many of these species face, in particular as a result of agricultural change. Another key pattern that has emerged is the difference between increases among the generalist species and declines in the specialists in a process called biotic homogenisation.

D.3 Other methodological considerations

A range of methods have been used to date to produce biological indicators. Most wild bird indicators currently produced in the UK are composite indicators constructed from national or regional population trends in bird numbers. One of the benefits of this approach is that diverse data sources and census methodologies among species can be easily accommodated. The approach can be modified however, to produce indicators designed for particular threats or ecological niches. For *Terrestrial Breeding Birds* in the Scottish Biodiversity Indicator set, separate habitat-specific trends are generated and used for species that occupy more than one habitat (*e.g.* song thrushes *Turdus philomelos* in woodland versus those on farmland). In the UK, this approach was taken further in a comparison of habitat-specific indicators constructed solely from habitat-specific trends with standard composite indicators. In Scotland, a *Wintering Waterbird Indicator* has been developed to allow for habitat and regional biases in data collection (Austin *et al.* 2007), as well as a novel 'conservation performance indicator' to assess the relative contribution of a focal region in terms of national or international biodiversity. Other potential approaches to indicator development trialled by the BTO have included those based on land designations (*e.g.* national parks or designated sites), woodland type (broadleaved versus coniferous woodland), or ecological groupings such as residents versus migrants (see Noble *et al.* 2007). It is also possible to construct more sophisticated indicators of impact by weighting the constituent species trends by the strength of the relationship (positive or negative) to particular drivers, as for climate change indicators used in Europe and being developed in the UK. Lastly, where appropriate, the method of combining constituent species trends can be dropped in favour of constructing indicators directly from aggregated data across species within ecological groupings.

The manner in which composite indicators are constructed is open to modification. The population trends for Defra's farmland and woodland birds composite indicators reflect the average behaviour of their constituent species, all of which are weighted equally (Gregory *et al*. 2004). Weighting by population size or conservation status would have led the indicator into being dominated by the most abundant species or by those judged to be the most threatened. Indicators of wintering waterbirds developed for the Scottish Biodiversity Strategy, for example, include a provisional version based on 'conservation value' as measured by the proportion of the flyway population (Austin *et al*. 2007), but these have not yet been adopted. Other possible criteria for weighting include level of precision and degree of habitat specialisation. However, given that many of these criteria could change over the time series, neutral weighting appears to best serve the purpose of a general 'barometer' of broad-scale change in the countryside.

Another possibility is a return to ideas based on an approach of combining data series reflecting 'distance to target' for key species and habitats (Bibby 1999). One of the advantages of the distance to target approach is that it allows data on different taxa to be combined with data on the condition of different habitats. Another advantage is that it is possible to set targets for both increase and decrease (for example for when we judge populations are too large), or for pest species, which may even benefit from modifications in the landscape (McKinney & Lockwood 1999). The disadvantages include the need to define targets, which are problematical both on theoretical and practical grounds, and the need for high quality trend data for a range of species and habitats. Underhill and Crawford (2005) successfully used a target-based approach to index environmental health for breeding seabirds in the Benguela ecosystem. Similarly, van Strien (1999) and Ten Brink (2000) described an Ecological Capital Index that combined information on the quality and quantity of a habitat in a single statistic. Rare and common species were included and their current densities were contrasted with a reference situation in the past, which is equivalent to the distance to target indices above. Two of the practical issues with this index were the choice of the reference period, which must to some degree to be a subjective judgement, and the selection of the habitat-specific species.

www.snh.gov.uk

ISBN: 978-1-85397-911-8

Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

You can download a copy of this publication from the SNH website.

recycle

Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad