Scottish Raptor Monitoring Scheme Trends for 2009-2018

Methods and Analysis of Gaps
(A report to the SRMG)

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Common Buzzard (John Harding/BTO Images)

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Summary

This report summarises the first comprehensive analyses of data from the Scottish Raptor Monitoring Scheme (SRMS) to provide trends in breeding numbers and productivity measures, for all species covered by the scheme since its inception in 2002. It extends the approaches, and builds on the reviewing, carried out by Roos et al. (2013), both to produce as many rigorous trends as can be supported by existing SRMS data up to 2018, and to summarise gaps in the current trends portfolio to inform further enhancements of SRMS monitoring in future.

The raptor survey work that takes place annually and results in the data on which the trends are based is mostly undertaken by skilled volunteers, and much of it was originally established for purposes other than production of long-term trends. For this reason, more details of which are explained in Roos *et al.* (2013), it has taken many years of intensive and detailed work to prepare the datasets, in consultation with those who collected them, to allow rigorous trends to be developed. The approaches and analytical methods used to develop trends are covered in detail in this report.

Trends in some combination of breeding numbers and four productivity measures (breeding success, clutch size, brood size and numbers of fledged young) are now available for 14 of the SRMS species but not all trends are available for all species in all geographical regions.

A fully representative national (all-of-Scotland) trend in breeding numbers could only be produced for White-tailed Eagle (due to the comprehensive monitoring of almost all pairs across Scotland that took place until 2018). Representative national trends in breeding success could only be produced for three species (Osprey, Golden Eagle and White-tailed Eagle). Despite the limited number of national trends that could be produced currently, trends at regional scale (SRMS regions and Natural Heritage Zones) are available for a broad suite of species-region combinations.

The report summarises monitoring gaps for each species, and other enhancements to monitoring approaches and data collection that would allow expansion of the portfolio of available trends, and the development of more national trends, in future. For some species (such as Peregrine and Hen Harrier) relatively modest expansion of coverage or more consistent coverage in a small number of regions would make national trends achievable, while for other species, and particularly those that are very widespread (such as Buzzard, Kestrel, Sparrowhawk and Raven), effective monitoring is likely to benefit from more areas covered via a patch-based multi-species approach in future.

Finally, the report summarises positive progress with modernising data management since the review by Roos *et al.* (2013) and a small number of continuing enhancements to SRMS data submission and management that will improve the timely and cost-effective production of trends.

1 Aims of this report

This report summarises the first comprehensive analyses of data from the Scottish Raptor Monitoring Scheme (SRMS) to provide trends in numbers and productivity measures, for all species covered by the scheme since its inception in 2002.

Specific objectives are:

- To summarise the availability or otherwise of national and regional trends for each SRMS species (the latter at the scale of Natural Heritage Zones – NHZs; and Scottish Raptor Monitoring Scheme – SRMS – regions).
- To summarise caveats associated with trends and explain why these have arisen.
- To explain the relationship of regional and national trends with the availability of trends from individual study areas for each SRMS species.
- To summarise gaps in coverage/trends (regional and national) for each species and for the SRMS overall.
- To suggest options for enhancements to SRMS monitoring in future to improve data for the production of trends [IN DEVELOPMENT WITH SRMG].
- To present options for addressing gaps in coverage, including the role of patch-based monitoring (and the SRMS *Raptor Patch* initiative) [IN DEVELOPMENT WITH SRMG].

2 Background

Since its inception in 2002, one of the principle aims of the Scottish Raptor Monitoring Scheme (SRMS) has been to collate, curate and report on data on breeding raptors, owls and raven in Scotland, including moving towards the production of trends in breeding numbers and suitable measures of breeding productivity at a range of spatial scales.

Many other national biodiversity long-term monitoring schemes (such as the BTO/JNCC/RSPB Breeding Bird Survey) deploy standardised data collection methods that have been designed specifically with rigorous trend production as the objective from the outset. In contrast to this, data collection for the SRMS necessarily built on annual survey work already being carried out by many volunteer raptor workers across Scotland (mostly members of the Scottish Raptor Study Group). SRMS data collection was not therefore 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 periodic national surveys of raptors, and often these subsequently evolved into local studies, often following the particular interests of the individual observers, many of whom were volunteers.

A first formal review of data submitted to the SRMS between 2003 and 2009 (Roos *et al.* 2015) demonstrated the potential of the Scheme to provide long-term trend information on breeding numbers and productivity measures, concluding that:

- 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;
- 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 was 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 in future;
- For four other species (Eurasian sparrowhawk, common kestrel, tawny owl and common raven), partial trend information was available from study areas or from the BTO/JNCC/RSPB Breeding Bird Survey. However, this was 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; and
- For long-eared owls and short-eared owls, there was insufficient annual monitoring coverage to generate trends.

Roos *et al.* (2015) also made a series of recommendations to enhance SRMS data collection in order to improve the potential to produce unbiased trends, including the need for:

- comprehensive 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.

All of these recommendations have been progressed by the SRMS since 2015, with progress dependent on the goodwill of observers to understand the needs of SRMS and adapt their data collection and curation methods accordingly, and also the time and funding required to develop a bespoke on-line data entry system (*SRMS Online*), which provides an improved framework for capturing all the information required to produce unbiased trends.

This current report builds on the findings and approaches of Roos *et al.* (2015) to provide: (a) an updated assessment of the extent to which data from the SRMS (collected between 2003 – 2018) can provide unbiased trends in breeding numbers and productivity at a range of spatial scales (from study-area based to national); and (b) options for further enhancements to the SRMS to improve trend production in future.

3 Methods

3.1 Characteristics of SRMS data

Due to the lack of underpinning formal design for SRMS data collection, approaches to trend production needed to take account of several important characteristics of the data:

- Six-figure grid references are not provided for all breeding attempts each year – much checking work has been carried out over the years to improve the proportion of records with accurate location information, and the proportion of breeding attempts that are linked to a precise grid reference has increased markedly since around 2009. Records without such information cannot be used in trend analyses (because lack of precise location information undermines the ability to reliably link records from different years deriving from the same home ranges; home ranges cannot be linked spatially to regions for analysis; and home ranges cannot be checked for duplication).
- The majority of records consist of a summary across a breeding attempt (without information on timing or number of visits per breeding season, or nest contents at each visit) – again much manual checking work has been carried out over the years to render each record as complete as possible (e.g. through adding information contained as notes in text fields) but the lack of information captured on a visit by visit basis limits the range of breeding parameters on which unbiased trend information can be obtained.
- There has not been a routine method to capture details of areas surveyed each year, the amount of effort spent making checks (number of visits and time per visit) and how these vary through time. Some individual raptor workers record some information of this sort on an annual basis but it is not held centrally and most have not kept detailed records of areas checked/not checked annually. Over the years, the SRMS has tried a number of different approaches to capture this information retrospectively from observers but it has proven very time-consuming (requiring too much SRMS resource to allow it to be carried out comprehensively across all SRMS contributors). The lack of standard information on annual variation in coverage/effort places limitations on use of the data, particularly with respect to producing trends in breeding numbers through time.

3.2 Methods to produce trends for individual study areas (clusters)

Due to the lack of centrally held information on annual coverage of study areas, the approach to production of trends had to first identify (from within the data for individual breeding attempts) areas with apparently similar coverage from one year to the next. This was followed by a consultation process that attempted to get relevant observers to check the trends produced for individual study areas and the assumptions made about coverage/effort variation within those study areas.

For each species, we started with all records submitted to the Scottish Raptor Monitoring Scheme (SRMS) between 2003 and 2018 that indicated that area or site-based checks for territorial occupancy had been carried out.

3.2.2. Distribution of records across Scotland

For each SRSG branch area, we tabulated the total number of records in each year, relative abundance from Bird Atlas 2007-2011 (Balmer et al. 2013; henceforth referred to as 'the Atlas'), and the recent rate of checks (average between 2014 and 2018) per relative abundance unit. Atlas relative abundance was used to gauge the approximate proportion of the Scottish population in each region, and was calculated from mean TTV (Timed Tetrad Visit) counts. These counts were averaged at the 10 km level across hours, visits and tetrads, and summed across all 10 km squares in each region.

Regional estimates of absolute population (number of breeding pairs/females) were used to contextualise variation in monitoring effort between species and regions. For Peregrines, regional population estimates were taken directly from the most recent national survey. For other species, where we refer to the number of pairs breeding in a region this was estimated as the product of national breeding population estimates and the proportional abundances derived from Bird Atlas 2007-11 for the region in question. It should be noted that these estimates are intended principally to provide context for comparing completeness of coverage between species, and should not be taken as exact or authoritative assessments of regional population size in their own right.

We used maps to illustrate how spatial variation in monitoring effort corresponded with the breeding distribution of each species. Each 10 km square was shaded to reflect the number of SRMS records in the square for three different periods (2003-2008, 2009-2013 and 2014-2018). SRMS record information was superimposed on red dots whose size reflected the level of breeding evidence, based on breeding distribution information from the Atlas, so as to inspect visually areas of known breeding distribution from which SRMS data were scarce or absent.

3.2.3 Identification of 'clusters' for trends

In order to identify putative 'clusters' (areas of relatively consistent monitoring coverage across years) from which local, 'study' scale trends (and some measure of confidence in these) could be calculated, we first identified the boundaries of areas within which monitoring appeared to be reasonably comprehensive. To do this, we first calculated nearest neighbour distances between all SRMS records with 4-figure (1 km resolution) or better grid references. These were used to identify subsets of records pertaining to nest sites that were all within a maximum distance of the nearest neighbouring site. Maximum neighbour distances of sites for each species are based broadly on the range of inter-nest site distances observed from records of each species (Table 1). These are based on the distribution of records in the SRMS dataset, drawing also on information from published reference works such as Hardey et al. 2013, Cramp 1982 and Perrins & Brooks 1994. For each species, we have selected threshold distances close to the top end of the observed range. This is in order to reduce the risk that home range clusters where monitoring effort has been high are excluded due to factors such as unusual configuration of suitable habitats, or inaccurately recorded grid references.

Table 1. For each of the species for which provisional trend analysis can be carried out from SRMS data, approximate typical spacing between neighbouring nest sites, and maximum nearest neighbour distance for sites used to define clusters for trend analysis. Typical spacing entries marked with asterisks are based primarily on observed spacing in SRMS data, there being a paucity of useful information on spacing (or a lack of consensus on this matter) in the literature.

Species	Typical spacing	Maximum distance
Barn Owl	0.5 – 2 km*	2 km
Buzzard	0.5 – 1.7 km	2 km
Golden Eagle	3 – 15 km	10km
Goshawk	1 – 4 km	5 km
Hen Harrier	1 - 5 km	5 km
Kestrel	1 – 3 km*	2 km
Merlin	0.5 km – 4.5 km	5 km
Osprey	1 – 4 km*	5 km
Peregrine	2 – 9 km	7.5 km
Raven	2 – 8 km	7.5km
Red Kite	1 – 4 km	5 km
Sparrowhawk	0.5 – 2 km	2 km
Tawny Owl	0.5 – 4 km	2 km
White-tailed Eagle	3 – 15 km	10 km

From these subsets, candidate clusters for trends analysis (hereafter 'trends clusters') were selected on the basis of their satisfying a threshold level of monitoring intensity. In order to qualify for trends analysis, clusters had to comprise at least 5 home ranges with 3 or more records in both the first and the last half of the period covered by trend analysis. Clusters were first assessed to see if they qualified for trend analysis on all 16 years of data (2003 to 2018). Clusters that didn't qualify for trend analysis over the full period were then assessed to see if they qualified for the 10-year period from 2009 to 2018. We also identified 'new clusters' comprising 5 or more home ranges where 3 checks had been carried out within the last five years (indicating that recent levels of monitoring could, if maintained, enable trend analysis within the next five years).

The area covered by each trends cluster and new cluster was calculated as a concave polygon using function **concaveman** in the R package of the same name, with concavity set to 3, around all nest sites within the cluster. The concave polygons created are designed to capture groups of points in as small an area as can be achieved with relatively simple shapes. Each of these shapes was 'buffered' (i.e. surrounded) by a strip whose width was half the maximum neighbour distance used to identify clusters for that species. The R package **tmap** was used to plot the polygons for trends clusters on a map, and (on a separate map) the polygons for new clusters.

3.2.4 Variables for which trends were presented for cluster-based trends

We assessed changes in population by looking at changes over time in two variables related to breeding population density: occupancy (the proportion of records reporting occupancy by pairs) and number of pairs (the number of pairs found to be breeding within the cluster area). Occupancy can change due to variation in surveyor effort and behaviour. For example, at the start of a study, when territories are being identified, occupancy is likely to be very high, because territories will nearly always be occupied when they are first found. Occupancy may subsequently decline, even if a population is stable, due to turn over of territories. This refers to the process of old, known sites falling vacant as new ones, yet to be found, are occupied. Territory turnover can be a consequence of established territorial birds being replaced by others that nest in different locations – or may simply be a result of the same pair breeding in different locations from one year to the next. Trends based on the number of pairs recorded, on the other hand, should be robust when monitoring effort is sufficiently high, but may be unreliable when monitoring effort is variable or low.

For the purposes of assessing the concordance of cluster-based trends with the understanding of data contributors and other local experts, we present trends relating to two aspects of breeding productivity. These are: breeding success (the proportion of monitored pairs with known breeding outcome successfully rearing one or more offspring each year); and fledged brood size (the average number of young recorded as fledging from successful nests each year).

3.2.5 Calculation of trends

These trends were modelled as simple generalised linear models (GLMs) in which year (specified as a continuous numeric variable) was the only explanatory variable. These models assume that the size and direction of the trend doesn't change over the period being considered, and are appropriate for assessing whether (and at what rate) a parameter has changed over the period being considered. We also used generalised additive models (GAMs), with a smoothing term (a thin-plate regression spline) applied to year. This smoothing term allows the fitted relationship to vary in a non-linear manner, making GAMs appropriate for modelling trends in which the rate or direction of change in a parameter does not remain constant over the period being considered. The 'wiggliness' of the line (i.e. it's ability to reflect changes in the direction or steepness of a trend over time) is determined by a parameter called degrees of freedom. We specified a maximum of 6 degrees of freedom, it being standard practice in GAM modelling to restrict degrees of freedom to one third the length of a time series. Occupancy and breeding success were modelled using binomial GLMs and GAMs, while pair number and fledged brood size were modelled using Poisson GLMs and GAMs.

In previous work to assess trends from SRMS data (Roos et al. 2015), home range was included as a random effect because of the repeated measures nature of the monitoring design (the sample of home ranges monitored each year is not independent of those in previous years because the same ranges are monitored across years). However, this study also found that, particularly when datasets are small, models including a random effect often fail to converge. The current trend models did not include home range as either a fixed or a random effect, but the potential for uneven distribution of individual home ranges over the sampling period to skew trends in occupancy over time will be reduced by the fact that these models were limited to data from home ranges supplying a minimum of two years data in each half of the period (i.e. at least four years of data).

For each trends cluster, trends in each of the four variables were summarised in a table that included the period over which trends were calculated, the main region or locality in which the cluster area was located, and the maximum number of records in any one year. For cluster-trend combinations where the linear (GLM) change over time was statistically significant (i.e. $P < 0.05$), the average annual rate of change and direction of the change during the trend period was reported in the table. This provides a simple means of assessing whether and to what extent the metric increased or decreased over the period being considered. For all cluster-trend combinations where the linear change was not statistically significant, but the non-linear (GAM) change was, the overall shape of the trend over the relevant period was reported. For clusters with insufficient records of pairs to robustly evaluate trends in breeding success, or insufficient records of successful pairs to calculate robust trends in fledged brood size, this was indicated in the table. In both cases, the threshold sample size below which trends were deemed to be unreliable was a minimum of three years in both the first and second halves of the period in which there were at least 5 records from the cluster that could contribute to the trend.

All trends were also illustrated with plots of the modelled relationship over the relevant trend period (either 2003 to 2018 or 2009 to 2018). For all trends for which the smoothed model (GAM) was statistically significant, the predicted values from the model were plotted as a line graph. All other trends were represented by line graphs of predicted values from the linear model (GLM). Trend graphs also include 95% confidence intervals for the predicted values, a scatterplot showing the mean of the observed value in each year and, at the top of the graph, the size of the sample on which each of these means was based. For breeding success and fledged brood size trends based on insufficient records for these trends to be robust, graphs were greyed out with a label indicating 'Insufficient data' displayed over them.

3.2.6 Sample size and robustness

The criteria used to identify clusters of home ranges are intended to flag all potential studies of each species for which SRMS holds enough data to produce robust trends. As such, they are very much bare minimums in terms of the species-specific thresholds for proximity between home ranges, the numbers of home ranges in each year, and the levels of monitoring coverage within these. It is likely that many of the clusters for which these parameters are close to the minimum values allowed will, after consultation with observers to clarify any uncertainty about levels of monitoring effort, prove unsuited to production of trends for the periods we consider here. However, for at least some of these trends, it is possible that discussion with stakeholders will identify alternative periods for which trends could be calculated now, or for which the data could be compared with data collected by future monitoring efforts.

For parameters related to productivity, sample sizes tend to be more constrained than they are for occupancy or number of pairs. When analysing patterns of breeding success, only home ranges occupied by a pair (or, in the case of Hen Harriers, a breeding female) contribute data. Sample sizes for analyses of fledged brood size are further constrained to home ranges where breeding attempts successfully fledged one or more offspring. As a result, some of the clusters we identified have limited data available for generating trends of these productivity measures. For both of these metrics we specified that there had to be 5 or more records in each of 3 or more years in both the first and second halves of the trend period for trends to be robust. This ensures that relationships estimated for these variables were comparably robust to those estimated for occupancy and pair number.

3.2.7 Low density clusters

If observers have undertaken studies of a species in areas where pairs of this species are sparsely distributed, the number of pairs they report may bely high intensities of monitoring. In such cases, while it is unlikely that the areas covered by these observers will have been identified as trends clusters, we would be keen to hear from these observers with details of the spatial and temporal extent of their studies. Robust information about trends in numbers and productivity from parts of a species range where breeding densities are low (whether due to declines, recent colonisation, lack of nest sites or poor availability of food) is very valuable, and usually harder to come by than information drawn from more areas where a species breeds at relatively high densities. However, we do want to be careful to distinguish between areas where large swathes of potentially suitable habitat are assumed to be unoccupied (and therefore not checked) and areas where monitoring is sufficiently thorough that, were more pairs to settle there, they would likely be detected (at least within a few years).

3.2.8 Consultation process with observers and outcomes

Draft trends from the data submitted to the SRMS since 2003 (and up to 2018) were produced for 98 different 'clusters' (groups of territories in a more or less contiguous geographical area) across Scotland, in which the coverage was considered high enough to calculate trends for at least 10 years up to 2018. We also identified a number of other areas from which it will likely be possible to calculate local trends in the future, provided that recent levels of monitoring are maintained.

In Autumn 2020, key data contributors within the twelve Scottish Raptor Study Group branches were consulted to help to sense check the draft trends, based on their local knowledge. Data contributors to asked to check:

- Did draft trends produced for areas and species with which they were familiar concur with their own understanding of patterns of change in numbers or productivity of the relevant populations?

- If they had any concerns about the trends produced, were these related to known variations over the years in survey coverage/effort for specific study areas?

- Were they aware of any areas of consistently good coverage for which it might be possible to produce trends that we had not included?

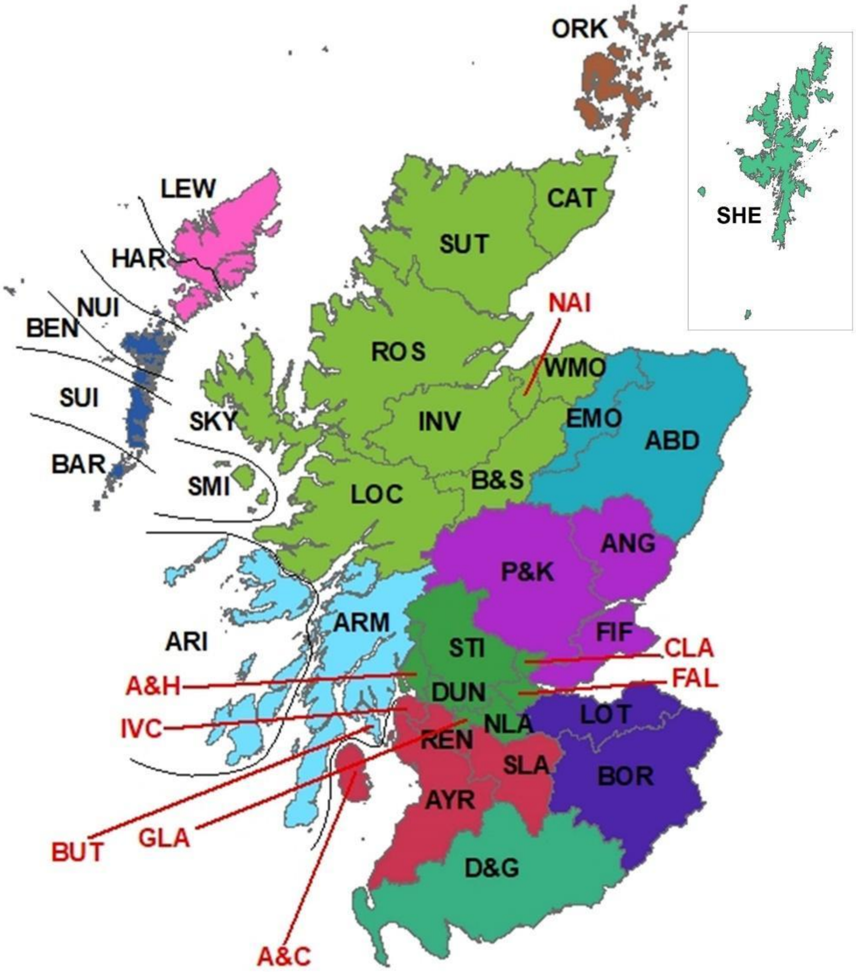
We were extremely grateful to receive some really helpful general feedback on the draft cluster-based trends, and also to receive specific feedback about 26 of the 98 clusters. All of this feedback was considered carefully ahead of producing the regional and national trends documented in the current report. However, given limits to the staff time available for further processing of data, we were not able to completely address all the suggestions made, particularly where these required input and processing of data not currently held by the SRMS.

In due course we aim to use the feedback received more fully, to enable us to revise the draft study-level trends and to publish all of these on the SRMS website. This will require further conversations with those that have already provided feedback so that we can ensure that we make the right decisions, as well as providing the opportunity for feedback on the 72 clusters for which we have not yet had feedback from observers. As well as allowing us to revise local study area trends, this feedback will also allow us to ensure that regional and national trends are as robust and comprehensive as possible, when these are updated again as scheduled in 3-years time.

Trends from individual clusters are not reported in the current report but the intention is to make these available via the SRMS website once they have been verified by appropriate observers.

3.3 Methods for producing national and regional trends

We aimed to produce all feasible region trends for 12 SRSG/SRMS regions (see Figure 1) and 21 Natural Heritage Zones of Scotland (accepted biogeographical zones; see Figure 2).



A&C = Arran & Cumbrae
A&H = Arrochar & Helensburgh
ABD = Aberdeenshire
ANG = Angus
ARI = Argyll Islands
ARM = Argyll Mainland
AYR = Ayrshire
B&S = Badenoch & Strathspey
BAR = Barra
BEN = Benbecula
BOR = Scottish Borders
BUT = Bute
CAT = Caithness
CLA = Clackmannanshire
D&G = Dumfries & Galloway
DUN = Dunbartonshire
EMO = East Moray
FAL = Falkirk
FIF = Fife
GLA = Glasgow
HAR = Harris
INV = Inverness-shire
IVC = Inverclyde
LEW = Lewis
LOC = Lochaber
LOT = Lothian
NAI = Nairn
NLA = North Lanarkshire
NUI = North Uist
ORK = Orkney
P&K = Perth & Kinross
REN = Renfrewshire
ROS = Ross-shire
SHE = Shetland
SKY = Skye
SLA = South Lanarkshire
SMI = Small Isles
STI = Stirlingshire
SUI = South Uist
SUT = Sutherland
WMO = West Moray

Figure 1. The 12 Scottish Raptor Monitoring Scheme regions of Scotland (showing grouping of local authority areas within each SRMS region): Dumfries & Galloway (lower, green); South Strathclyde (red); Lothian & Borders (purple); Central (middle green); Argyll (light blue); Tayside & Fife (dark pink); North-East Scotland (teal blue); Highland (upper green); Orkney (brown); Shetland (top green); Lewis & Harris (pink); Uists (dark blue).

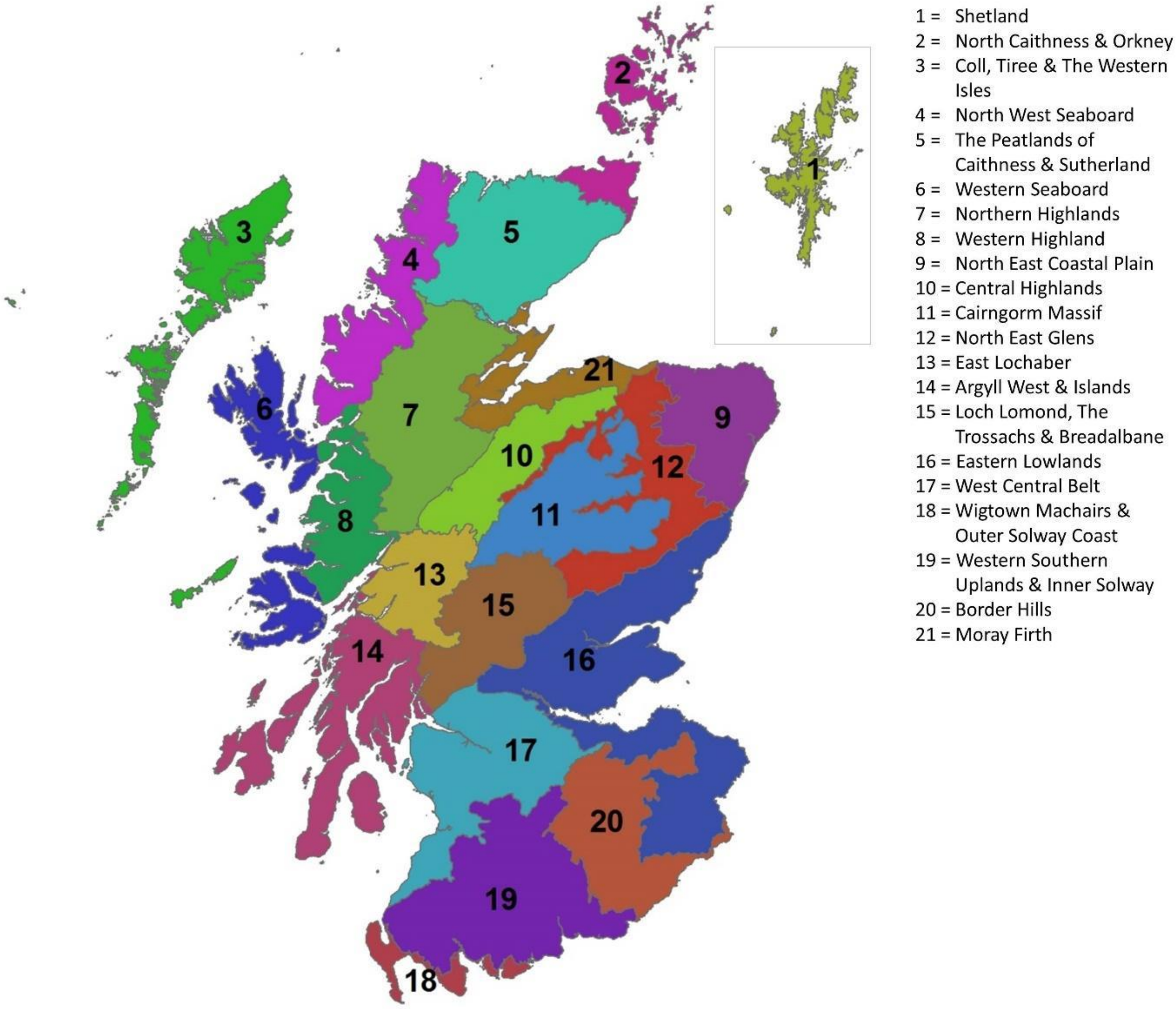


Figure 2. The 21 Natural Heritage Zones (NHZs) – biogeographical zones - of Scotland.

3.3.1 Sample sizes for analysis

Consultation with a number of observers over the production of study-area based trends (above) suggested that monitoring protocols were less likely to be rigorous for home ranges that were only surveyed once or in a small number of years. Home ranges surveyed across a group of years were more likely to be part of a more consistent longer-term study. We therefore set minimum criteria for inclusion of home ranges when producing regional and national population trends to strike a balance between minimising this problem but also including as much of the available SRMS data as possible.

The following criteria were used to filter data for inclusion:

- Individual home ranges only contributed to regional and national trends if records from them had been submitted for at least 5 years;
- Trends were not run for regions where fewer than 10 home ranges contributed data in 5 or more years;
- Regional or national trends were only calculated for a region where there was at least one year in which 10 or more ranges in that region contributed information to the relevant statistic. For these trend/region combinations, all years with 8 or more home ranges contributed to the trend. Years in which 7 or fewer home ranges contributed data were excluded from the trend.
- No trend was run unless at least 5 years of data were available to contribute (meeting all the other criteria above).

3.3.2 Variables for which regional and national trends have been produced

Number of breeding pairs: The number of breeding pairs observed in monitored home ranges for each region and combined for the whole of Scotland. For regional trends we only include home ranges in clusters in which monitoring spans most years, and we only produce national trends by combining regional trends that span most years in the time series (for these reasons we have not converted raw breeding numbers to indices).

Clutch size: The number of eggs per monitored pair known to lay.

Brood size: The number of young known to hatch per monitored pair known to lay.

Number of fledglings: The number of young assumed to have fledged by successful pairs.

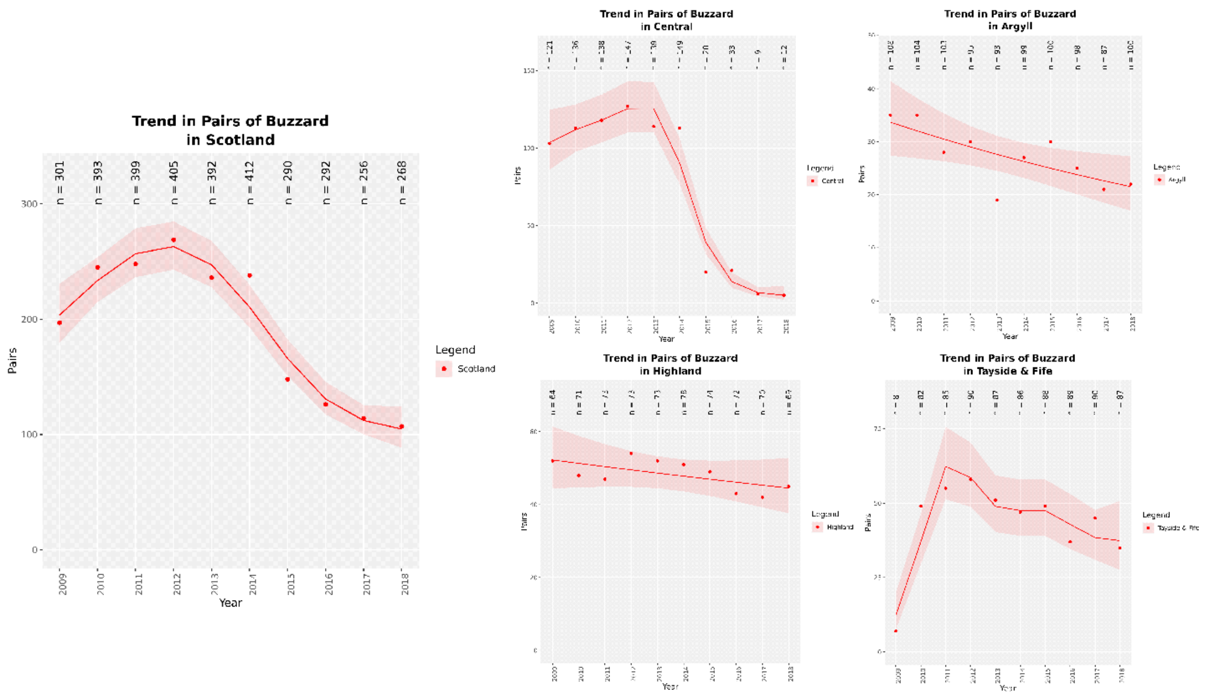
Breeding success: The proportion of monitored pairs (for which breeding outcome is known) that successfully fledge at least one young.

3.3.3 Methods for trends in breeding numbers

In a standardised monitoring scheme designed to have comprehensive and consistent survey coverage of sample areas each year, raw breeding numbers (active home ranges, pairs, or individuals for polygamous species) can be used with confidence as the basis for producing trends. However, given the nature of SRMS data collection, we explored modelling of trends using both breeding numbers but also whether home ranges were occupied or not in any year. Trends in occupancy can provide a useful indication of whether, and to what extent, apparent trends in breeding numbers are influenced by variation in monitoring effort. For example, if the number of pairs recorded each year decreases over time, but occupancy during the same period increases, this suggests a contraction of monitoring effort to a core of regularly occupied territories. However, occupancy should never be used on its own (i.e. without referring to trends in breeding numbers) to inform an assessment of population change. This is because it depends on the distribution of territories over a study area, how thoroughly this is understood, and whether all the potential nest sites in each territory are known or checked. Over the course of raptor studies taking a traditional approach, it is not uncommon for all of these variables to change. This means that variation in recorded levels of occupancy cannot be interpreted straightforwardly as a reliable signal of population change.

For trends in breeding numbers, only records from areas where coverage appeared relatively consistent through time (largely restricted to home ranges within clusters) were used. Regional samples were obtained following the sample size criteria above applied only to home ranges that were part of identified clusters. These draft regional trends in numbers graphs were then scrutinised further for any additional evidence of major changes in survey effort across the period for which each regional trend was available. As an example of this, consider the draft trends for Buzzard in Figure 3. The draft trend for Central Scotland demonstrates an extreme example of a major change in survey effort, as shown by the sample size for home ranges contributing dating (which drops from 149 in 2014 to only 28 in 2015). A more minor change can be seen for Fife & Tayside region, where the sample of home ranges increases from only eight in 2009 to 82 in 2010 but is then reasonably consistent from 2010 to 2018. It is that latter consistency that we need to allow us to be reasonably confident that trends reflect changes in the numbers of breeding pairs present, rather than just changes in survey effort. In this extreme example, a national trend produced by bringing together the trends from each region would result in a false decrease in breeding numbers, because of the large drop in survey effort during the period (e.g. from 412 home ranges reporting data in 2014 to only 290 in 2015; largely reflecting the drop in survey effort in Central Region between those years). Hence we needed to scrutinise all draft trends by eye and adjust sample sizes manually to produce revised trends in which there is greater confidence that survey effort has not changed markedly. In the case of these draft trends for Buzzard, this involved: removing the first year (2009) for Tayside & Fife; removing data from 2015-2019 for Central; and a decision that presentation of a Scottish trend for Buzzard was not feasible unless the trend period was restricted to 2010-2014 only, or the two regions with missing years were both dropped from the national trend (leaving the trend a poor representation of the Scottish population as a whole). Note that Argyll and Highland showed no major step changes or systematic trends in sample sizes of home ranges contributing data across the period, so those trends were retained without the need for modification.

Figure 3 Draft regional and national trends for Common Buzzard breeding numbers – before scrutiny for evidence of changes in survey coverage/effort through time.



3.3.4 Methods for trends in productivity measures

Particularly early on in the life of the SRMS, many unsuccessful breeding attempts had no formal outcome recorded, and so ostensibly appeared to be unmonitored. For this reason, we initially explored two versions of productivity trends for comparison; one using records of monitored pairs, the other using all records where pairs were recorded, regardless of formal monitoring status. However, it soon became apparent that interpretation of trends based on all recorded pairs (and therefore the level of confidence we could place on them) was problematic because it was not possible to differentiate pairs that were genuinely unsuccessful from those for which breeding outcome was not recorded. For the purpose of these trends, home ranges with unknown outcomes (due to insufficient follow-up monitoring) would have been treated as unsuccessful, even though some (unknown) proportion of them would have been successful. Consequently, the levels of breeding success indicated by trends using all recorded pairs would have tended to be underestimates. This could have introduced systematic bias into trends due to the fact that recording of outcomes improved markedly during the later years of the SRMS, following introduction of a revised SRMS recording spreadsheet (ahead of the 2009 breeding season), which largely addressed this shortfall in recording. For this reason, we took the decision to restrict trend production to SRMS data collected from 2009 onwards, and to records for which breeding outcome was explicitly recorded.

For clutch size, brood size and numbers of fledged young, raptor workers often necessarily record the nest contents as a minimum estimate (e.g. 2+, 3+, 4+) because they cannot be sure they have seen every egg, nestling or large/fledged young bird. For records of this sort, we have used the minimum quoted (e.g. 2+ becomes 2) as conservative measures of the appropriate parameter. This means that the absolute values of these parameters shown in graphs are likely to be underestimates (and can vary between studies/areas because different observers take slightly different approaches) but this assumption should not introduce any large systematic bias into trends. However, minimum estimates ('+') are probably more likely to be recorded against smaller clutches and broods than against large ones, such that the overall impact of using minimal ('+') estimates may be to reduce the real variation in each parameter and therefore slightly reduce the overall power to detect trends.

For many raptor species, it can be very difficult to be certain about the exact number of young that fledge, due to the behaviour of the young once they leave the nest. This means that the number of 'large young' at the nest site in the days before fledging (or at the time of ringing) is routinely used as a reasonable measure of the numbers that go on to fledge. We used the largest count from either of the 'Large_Young' or 'Young_Fledged' categories of the SRMS spreadsheet as the estimate of the actual number that went on to fledge. This may overestimate the absolute value for number fledged (and can vary between studies/areas because different observers take slightly different approaches) but again should not introduce any systematic bias into trends. Related to this, breeding attempts for which large young were observed but outcome was recorded as unknown (typically because no post-fledging observation visits were carried out) were assumed to have fledged successfully.

In all productivity trends, there is potential for variation in timing of first visits, between home ranges and across years, to affect apparent rates of failure (due to under-reporting of nesting attempts that fail early). In the majority of SRMS data, such bias may be less extensive than in other datasets, due to clear messaging in the relevant guidance (e.g. Hardey *et al.* 2013) about the importance of early visits to check for occupancy. However, variation between observers and between years (e.g. due to bad weather or most recently due to COVID restrictions on travel) on timing of first visits could still affect comparisons between regions, as well as trends over time. We should be clear, however, that the move to the visit-based data collection system of SRMS Online will yield clear benefits in this regard, enabling us to be more rigorous about screening records that contribute to trend production, and/or correct for any relevant variation in first visit dates (and also make use of some records with unknown outcomes) by employing Mayfield-type adjustments to productivity estimates. Trends based entirely on SRMS Online data (and so able to fully take advantage of these improvements) will not be available for a minimum of 5 years from now however. However, we assume that any remaining bias in the dataset used to produce trends will be minimised because many raptor workers do routinely build the important early survey visits into their monitoring activities due to the fact that the standard raptor monitoring practices they follow include early visits to ensure reliable recording of occupancy even when breeding attempts fail early on (Hardey et al. 2013).

3.3.5 Assessment of the extent to which trends are representative and unbiased

General issues and caveats associated with trends in breeding numbers

1. **Uncertainty over consistency of annual monitoring coverage and effort through time**
   Rigorous regional and national trends in numbers of breeding raptors can only be derived from areas that are known to have consistent monitoring coverage and approximately similar annual effort through time. Obviously if the area checked for breeding pairs each year is not consistent, changes in numbers of pairs recorded will be confounded with changes in area covered. Large changes in the amount of time spent surveying a given area (i.e. in the number or overall length of visits) will also result in variation in the proportion of pairs that are detected each year. In the absence of specific recording of coverage and effort in the SRMS dataset to date, we had to take the approach of seeking to identify study areas or 'clusters' in which numbers of home ranges were apparently covered through time (see methods above) and then consult with the main observers for each species, in the hope they could validate (or otherwise) our assumptions around consistent coverage. Therefore, we have excluded from analyses home ranges that have not been monitored over a series of years (using only those that are contained in defined clusters), and have used some specific observer feedback to verify some larger areas where coverage has been consistent through time (e.g. Chris Rollie pers. comm.). Some of the feedback we received indicates that more such areas can probably be identified, and incorporated into trends production, following further guidance from observers and with sufficient analytical time available in future. **Currently some trends in breeding numbers have the caveat that not all observers have responded to our consultation exercise, and we have also not been able to deal with all feedback from those observers who did respond (particularly if their suggestions for improving trends involved use of data not currently held within the master standardised SRMS dataset). We intend to address these outstanding caveats and draw in as much additional data as possible ahead of the next scheduled trends update.**

2. **Sample size caveats**
   We did not produce trends for regions/nationally where a very small number of home ranges contributed data (see sample size selection methods above, and individual trend graphs/tables for the sample sizes available for each trend). Despite this filtering, some regional and national trends are still based on sample sizes that are less than ideal – either because they represent a very small proportion of the regional or national breeding population (and so by definition are less representative of the whole) and/or because with smaller samples, any inconsistencies across years in survey coverage/effort (that we may not have been able to identify currently) will have more of an influence on a trend than if a much larger sample of home ranges (and study areas) can be included. **We have highlighted trends based on smaller samples of data (mean of <20 home ranges contributing data).**

3. **Caveats for species with expanding populations**

For species with expanding populations (e.g. Red Kite, White-tailed Eagle; also possibly Osprey, Goshawk) the selection criterion of excluding home ranges contributing to fewer than 4 years of trends does not work. Where overall range is increasing, rigorous trends can only be produced using appropriately selected sample plots based on areas currently with and without the species present (trends based on monitoring individual home ranges without expansion of monitored areas will obviously underestimate true increases in numbers). For Red Kite and White-tailed Eagle, SRMS trends produced previously (Roos *et al.* 2015), and updated by Staffan Roos (RSPB) for the SRMS website, assumed fully comprehensive monitoring of numbers, which we consider to be a sound assumption at that time. Monitoring coverage has become less comprehensive since that time, however, so that trends in breeding numbers are difficult to update without much further consultation with those doing the monitoring. **For SRMS species undergoing range expansion, updated trends in numbers can therefore only be reported for specific study areas (in which the potential for population increase may be limited) and, due to the lack of an appropriate sampling design, are unlikely to reflect changes in the whole regional or national population.**

4. **Caveats specific to nest-box species**
   Where monitoring is focused on pairs in nest boxes, numbers recorded are dependent on the number of boxes available. In order for numeric trends to represent those in the wider population, areas need to be 'super-saturated' with boxes (i.e. many more available than those actually occupied); boxes need to be maintained in good condition; and pairs outside boxes also ideally need to be monitored as well.

5. **Species for which key SRMS information is lacking**
   For some species (e.g. Osprey) there are significant numbers of records for which home range code information is lacking or inconsistent, and for which this cannot be inferred from other information such as site name or grid reference; these records could not contribute to analyses.

   There are also some species for which SRMS does not hold records for individual breeding attempts from the most important studies (e.g. Goshawk in North East Scotland), so trends cannot be updated. For Goshawk, we retain the previous trend information (provided by Roos *et al.* 2015 through detailed consultation with Mick Marquiss) but cannot update these trends currently.

   There are some species for which more information is available from some regions, which will enable trends to be extended to longer time series, or made more robust, in future once we have additional time for processing these data (e.g. Merlin in Orkney and several species in Shetland).

6. **Value and use of occupancy information**
   Due to the lack of information on survey coverage and effort held by the SRMS, as well as producing trends in the numbers of breeding pairs we have also looked at trends in occupancy (from study area or 'cluster' to national scales). At national scale in particular, but

also in some regions, occupancy trends from mixed models that take into account the influence of individual home ranges depart markedly from the raw levels of occupancy in each year. In the vast majority of cases, modelled occupancy levels are higher than observed levels. This is probably because home ranges are less likely to have records submitted for them when they are not occupied. Home ranges that are only monitored for a few years, while they are occupied, continue to influence the trend even in years where no records are submitted for them. In contrast, the influence of home ranges that are monitored solidly through periods of occupancy and vacancy is (relatively) down-weighted in the model, creating the impression that occupancy was higher than observed, while in reality, if anything, the opposite is probably true. This is a particular problem for rapidly expanding species like Red Kite. Given that the main value of occupancy is to help interpret trends in numbers of pairs, and that occupancy as a statistic is heavily influenced by subjective judgements by observers (and analysts) about what is or is not a home range, we have used occupancy statistics alongside sample sizes in tables or in the pair number graphs to aid interpretation of trends and filtering out of cases where coverage/effort may have changed, and have not reported occupancy as a trend in its own right.

General issues and caveats associated with trends in productivity measures

1. **Implications of combining data from individual study areas**
   Ideally unbiased trends in productivity for regions (and nationally) would be derived by monitoring the same representative sample of home ranges/home ranges within a suite of sample plots across years, meaning that most of the variation through time can be attributed to factors other than individual variation between home ranges. In any long-term monitoring scheme there will be some turnover in study plots however, which needs to be accounted for within analytical methods. To maximise the information on trends in productivity from SRMS data, we have not restricted analysis to home ranges from clusters but have rather included data from any home range that has provided monitoring information for at least 5 years. This is because there is evidence within the dataset that home ranges that are not monitored regularly but from which data submitted have been submitted more as 'casual' records may not always be monitored from the start of the breeding season (such that success can be overestimated; successful pairs are more likely to be located). It was also important to exclude data collected prior to 2009 because outcomes were recorded less rigorously prior to introduction of the updated SRMS spreadsheet in that year. By taking these steps to select appropriate data, and by scrutinising the resultant sample sizes contributing to each regional trend to remove any step changes in sample sizes across years, we hope to have minimised the chance of a major change in a productivity measure being an artefact of a change in the sample of nests contributing to any given trend. The same consideration is also important (exacerbated) when producing a national trend from a number of regional trends, if the component regional trends span different time periods and productivity parameters vary between regions. This is highlighted as an important caveat for national trends where this could be an issue.

2. **Recording of minimum estimates**
During standard raptor monitoring, clutch size, brood size and numbers of fledged young are often recorded as minimum estimates (e.g. '1+', '2+', '3+' etc) to recognise that not all eggs or young may be visible to the observer. If we were to exclude these minimum estimates, we would unduly limit the sample sizes for analysis; therefore, such records are included in all our trends (e.g. '1+' becomes '1', '2+' becomes '2' and so on). Inclusion of records of this type provides conservative measures of clutch size, brood size and numbers of fledged young. Conversely, if they had been excluded, measures would likely be overestimated because '+'s are probably more likely to be recorded against smaller clutches and broods than against larger ones). We assume that the proportion of breeding parameters recorded in this way will not change systematically through time within any given study area, or overall within the SRMS, such that trends will not be unduly affected by this issue.

3. **Assumed rather than observed fledging outcome**
For fledging outcome and number of fledglings (brood size at fledging), in several species this needs to be assumed from the number of large young in the nest, or in the nest surrounds, prior to fledging. This is because young can be hard to find immediately post-fledging, and in some cases observers therefore make final visits to nesting territories at the stage when young (often of age suitable for ringing) are still present in the nest. For these reasons, we have the used the largest count from either of the Large_Young or Young_Fledged categories in the recording sheet. Once again, we assume that the proportion of breeding outcomes recorded in this way will not change systematically through time within any given study area, or overall within the SRMS, such that trends will not be unduly affected by this issue.

4. **Sample size caveats**
We did not produce trends for regions/nationally where a very small number of home ranges contributed data (see sample size selection methods above, and individual trend graphs/tables for the sample sizes available for each trend). Despite this filtering, some regional and national trends are still based on sample sizes that are less than ideal – either because they represent a very small proportion of the regional or national breeding population (and so by definition are less representative of the whole) and/or because smaller samples provide reduced statistical power to detect trends. **We have highlighted trends based on smaller samples of data (mean of <20 home ranges contributing data).**

5. **Implications of combining data from different observers where methods may vary**
In the sections above, we have highlighted the potential for differences in survey methods (leading to differences in the absolute value of breeding parameters measured between study areas) to lead to systematic bias in trends if studies included in regional and national trends span different time periods. This is also the potential for changes in observer behaviour to lead to systematic bias, for example if an observer starts to make more, or earlier, visits to their sample of home ranges through time (e.g. so that they are more likely to record early breeding failures, which could manifest as a false decrease in the fledging success of monitored pairs through time). Some communications with raptor workers have

flagged this as a possible issue for some species. We have tried to minimise this risk by excluding SRMS data collected prior to 2009, when guidance and the recording spreadsheet were updated.

3.3.6 Presentation of regional trends

For the presentation of regional trends, combinations of species and regions for which the SRMS currently does not hold any data were categorised either as 'Absent' or as 'No SRMS data'. The distinction between these categories was decided using Bird Atlas (Balmer et al. 2013) 10-km resolution distribution data. In regions where these data included no records of 'Confirmed' or 'Probable' breeding for a species, and no more recent breeding records were held by the SRMS, the species was classed as 'Absent'. Where Bird Atlas data indicated that one or more 10-km squares in a region held 'Confirmed' or 'Probable' breeding pairs of a species, but no breeding records for this species-region combination were held by the SRMS to allow trends production, entries are categorised as 'No SRMS data'.

4 Summary of national and regional trends and caveats

Full details of all the trends available for the period 2009-2018 are available on the SRMS website, and a summary is provided in Challis *et al.* (2022). The links to the individual document summaries available are:

Trends summary 2009-2018 (Challis et al. 2022)

Trends for individual species (Species Accounts)

Trends by SRMS and NHZ regions (Regional Accounts)

Trends for each of the five measures (Breeding Numbers, four Productivity measures)

Interactive tool to explore the trends graphs and tables

5 Species Accounts

In this section we present the material for an example species account (Peregrine). Trends accounts for all the other species can be accessed on the SRMS website ([Trends for individual species (Species Accounts)](#)).

Within the species accounts, trends are presented sequentially at two different geographic scales – firstly national (i.e. Scotland) and then for two different regional scales (SRMS Regions & Natural Heritage Zone Regions). Within each section the following points should be taken into consideration:

Interpreting trend graphs: The graphs show how the number of breeding pairs and parameters related to breeding productivity (breeding success, clutch size, brood size, and number of fledglings) have changed over the relevant trend period. The purple dots show the average value of the relevant parameter for each year. The numbers at the top of the graph show the number of records from each year contributing to the trend. The purple line delineates the predicted values for the trend, illustrating the steepness and direction of change over time. The pale purple shading shows the 95% confidence interval around these predicted values. Where there were significant directional changes in numbers or breeding success parameters, trends are described as increases or decreases. Where start and end values were not significantly different, but there was still statistical evidence for change during the period (e.g. a 'peak' being an increase followed by a decrease, or a 'trough' being a decrease followed by an increase) trends are described as non-linear. It should be noted that, where a trend is reported as not significant, this simply means that we cannot be confident that the trend either increased or decreased over the relevant period. It does NOT mean that there was no change over this time. What it does mean is that, if there was a change, it was too small to detect robustly with the available data.

Threshold criteria for trends: Individual home ranges only contributed to regional or national trends if they were checked for occupancy during five or more years of the trend period. Numerical trends only include home ranges that are included in defined clusters (in which monitoring coverage and effort is assumed to be consistent across the defined series of years). For breeding productivity trends, all records (not just those from clusters) were considered for inclusion. Trends are only presented for regions in which ten or more home ranges contributed data in at least one year. Data from individual years in which fewer than five home ranges were checked were excluded from numerical trends, with the equivalent threshold being seven home ranges, for breeding productivity trends. No trend was produced if fewer than five years of suitable data were available for inclusion. Regional trends were also scrutinised for any major changes in sample size during the trend period for each (which could indicate major changes in survey coverage/effort) and years of apparently inconsistent coverage were excluded from the final trend.

For trends in clutch size, brood size and numbers of fledged young, records with minimum estimates (e.g. 2+, 3+, 4+) were included as the minimum quoted (e.g. 2+ becomes 2) as conservative measures of the appropriate parameter. For all breeding attempts with successful or unknown outcomes, the largest count from either of the 'Large_Young' or 'Young_Fledged' categories of the SRMS spreadsheet was used as the estimate of the actual number that went on to fledge. This may slightly overestimate the actual number of young that go on to fledge. The numbers of young recorded at different stages may also vary slightly between different studies/areas due to variation in recording decisions and monitoring effort between data contributors.

Any caveats that need to be considered when interpreting trends are noted below each of the tables and graphs, both in this report and in the various accounts available via the SRMS website. These caveats, together with their potential implications for the observed trend, are detailed below:

- 'a' – All data used – these are trends based on all available data for the period but, unlike national trends, are not considered to be robustly representative of the national population. This is due to under-representation of particular regions, habitats, demographic cohorts, or some combination of these.
- 'n' – Nest box based – a large proportion of monitored individuals are based in nest boxes. If nest boxes tend to be preferred over natural sites or vice versa, numerical trends may not be representative unless a high proportion of pairs nesting in natural sites are also found and monitored. Moreover, because only a small proportion of the population of any Scottish raptor breeds in nest boxes, if any measures of productivity differ between nesting attempts in boxes and those in natural sites, estimates of and trends in productivity may also be unrepresentative.
- 'r' – No home range random effect – inclusion of the home range as a random effect in a productivity trend model caused the results of that model to depart unrealistically from the observed range of variation for that trend, so this variable was removed from the model. This could make the trend more prone to being unduly influenced by variation between individual home ranges; particularly when the home ranges contributing to the trend changed over time.

- 's' – Sample sizes small – mean annual sample size is less than 20. This is likely to decrease the precision of annual estimates, and to increase the influence of 'noise' (random variation) on apparent change from one year to the next. This is not based on any formal power analyses but simply highlights that trends based on samples of more than 20 home ranges are likely to be more robust/representative than those based on smaller samples.

- 'v' – Variable effort – variation in sample size between years suggests that variable monitoring effort could result in inter-annual variation in the location and nature of home ranges that are monitored, or in the effort put into collecting data from these. Such variable effort could result in 'noise' (random variation between years) or, if effort increases or decreases over time, introduce bias into the trend.

- 'x' – Expanding population – population of a recently re-introduced species, known to be undergoing rapid expansion. This means that traditional approaches to raptor monitoring (focussing on known home ranges or discrete study areas) are likely to underestimate rates of population growth, and may bias measures of breeding productivity towards older, more experienced pairs.

Peregrine

Juvenile Peregrines in South Ayrshire (Photo: Angus Hogg, South Strathclyde RSG).

Peregrine is one of the most comprehensively monitored raptor species in Scotland, with around 65-76% of the estimated breeding population surveyed each year. Monitoring coverage is not consistent across Scotland however. Despite much monitoring information being collected across the large Highland Region, which supports a substantial part of the Scottish population, the lack of consistency of coverage and effort across years in that region currently limits the production of representative national trends.

Peregrine has also been subject to periodic national survey via The Statutory Conservation Agency/RSPB Annual Breeding Bird Scheme (SCARABBS) programme. Scottish population estimates since the 1960s are available from six national surveys in: 1961/62 (Ratcliffe 1963) 388 pairs; 1971 (Ratcliffe 1972) 366 pairs; 1981 (Ratcliffe 1984) 442 pairs; 1991 (Crick & Ratcliffe 1995) 626 pairs; 2002 (Banks *et al.* 2010) 571 pairs; and 2014 (Wilson *et al.* 2018) 523 pairs.

Our latest analysis of SRMS Peregrine data for the period 2009-2018 has produced no national trends in breeding numbers or productivity, but has produced trends for eight of the 12 SRMS regions and for ten of the 21 NHZ regions for which the SRMS holds Peregrine records.

When interpreting the published trends, users should be aware that records for trends in breeding numbers are mostly drawn from upland areas, with lowland (and, particularly, urban areas) perhaps somewhat under-represented in comparison.

National trends

No SRMS trends in breeding numbers or breeding productivity are available for Peregrine at a national level.

SRMS regional trends

Breeding numbers of Peregrine decreased in two regions (Argyll and Tayside & Fife) and did not change significantly in the remaining six regions (Central, Dumfries & Galloway, Lothian & Borders, North-east Scotland, Orkney and South Strathclyde). Breeding success of Peregrine decreased in Lothian & Borders and Orkney, increased in North East Scotland, did not change significantly in Argyll, Central Scotland, Dumfries & Galloway or Tayside & Fife), and showed non-linear variation in South Strathclyde. Clutch and brood size did not change significantly in either Dumfries & Galloway or Lothian & Borders. Number of fledglings decreased in Dumfries & Galloway, but did not change significantly in Central, Dumfries & Galloway, Lothian & Borders, South Strathclyde or Tayside & Fife.
Trends for this species are not yet available for Highland, Lewis & Harris, Shetland or Uist.

NHZ regional trends

Breeding numbers of Peregrine decreased in three regions (NHZs 11, 14 and 15) and did not change significantly in the remaining seven regions (NHZs 02, 12 and 16-20). Breeding success of Peregrine decreased in NHZs 02 and 16, did not change significantly in NHZs 12, 14, 15 and 17-20, and showed non-linear variation in NHZ 11.
Clutch size, brood size and number of fledglings of Peregrine did not change significantly in NHZs 16 and 20. Number of fledglings did not change significantly in a further three regions (NHZs 17-19).

Trends for this species are not yet available for NHZs 01, 03-10, 13 and 21.

Details of contributing records

6,625 (534 to 1,072 per year, mean: 663 records per year) from 2009-2018 contributed to this trends analysis.

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M. W. Wilson, D. E. Balmer, K. Jones, V. A. King, D. Raw, C. J. Rollie, E. Rooney, M. Ruddock, G. D. Smith, A. Stevenson, P. K. Stirling-Aird, C. V. Wernham, J. M. Weston & D. G. Noble (2018) The breeding population of Peregrine Falcon *Falco peregrinus* in the United Kingdom, Isle of Man and Channel Islands in 2014, Bird Study, 65:1, 1-19, DOI: 10.1080/00063657.2017.1421610

Summary of SRMS regional trends for Peregrine during 2009-2018. Figures in parentheses indicate the annual change, with significant increases highlighted in green, significant decreases highlighted in blue and non-significant changes highlighted in grey. 'Non-linear' indicates non-linear trends. '—' indicates where the species occurs but no trend is available. 'No SRMS data' indicates where the SRMS does not hold any records for the region of interest. 'Absent' indicates where the species is not known to breed.

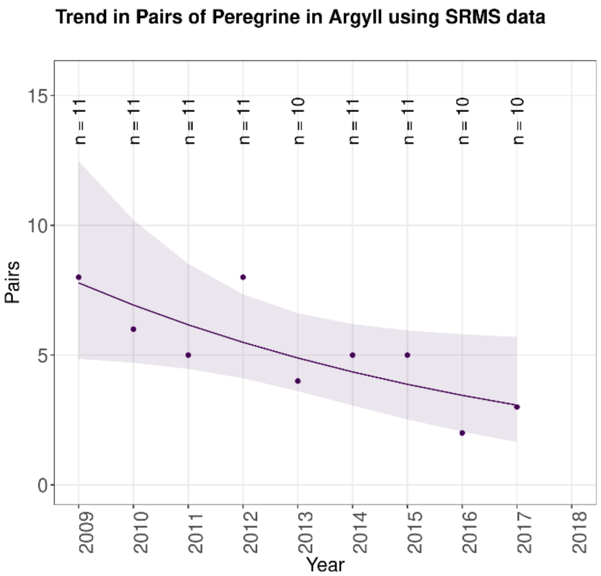
SRMS Region	Pairs	Success	Clutch size	Brood size	Number of fledglings
Argyll	**Decrease [s] (-11%)**	Not significant [s]	—	—	—
Central	Not significant [s]	Not significant [s]	—	—	Not significant [s]
Dumfries & Galloway	Not significant	Not significant	Not significant [s]	Not significant [s]	**Decrease (-2.4%)**
Highland	—	—	—	—	—
Lewis & Harris	—	—	—	—	—
Lothian & Borders	Not significant	**Decrease (-2.1%)**	Not significant	Not significant [s]	Not significant
North East Scotland	Not significant	**Increase (8.3%)**	—	—	—
Orkney	Not significant [s]	**Decrease [s] (-2.4%)**	—	—	—
Shetland	—	—	—	—	—
South Strathclyde	Not significant	Non-linear	—	—	Not significant
Tayside & Fife	**Decrease (-4.1%)**	Not significant	—	—	Not significant
Uist	—	—	—	—	—

[s] *Sample sizes small.*

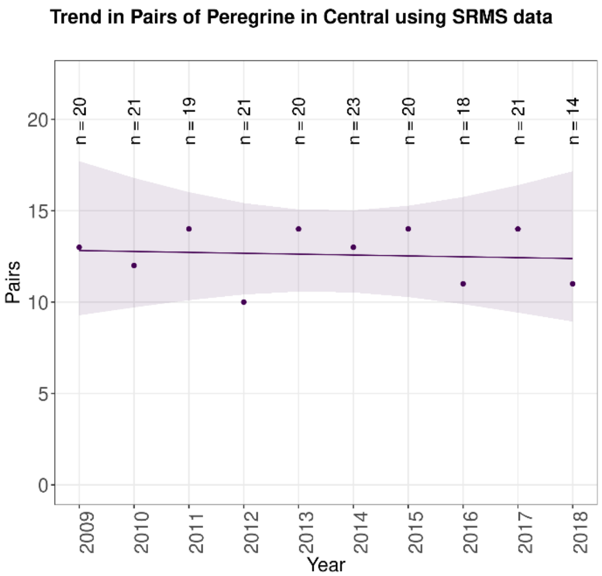
Summary of NHZ regional trends for Peregrine during 2009-2018. Figures in parentheses indicate the annual change, with significant decreases highlighted in blue and non-significant changes highlighted in grey. 'Non-linear' indicates non-linear trends. '—' indicates where the species occurs but no trend is available. 'No SRMS data' indicates where the SRMS does not hold any records for the region of interest. 'Absent' indicates where the species is not known to breed.

NHZ Region	Pairs	Success	Clutch size	Brood size	Number of fledglings
01. Shetland	—	—	—	—	—
02. North Caithness and Orkney	Not significant [s]	**Decrease [s] (-2.4%)**	—	—	—
03. Coll, Tiree and the Western Isles	—	—	—	—	—
04. North West Seaboard	—	—	—	—	—
05. The Peatlands of Caithness and Sutherland	—	—	—	—	—
06. Western Seaboard	—	—	—	—	—
07. Northern Highlands	—	—	—	—	—
08. Western Highlands	—	—	—	—	—
09. North East Coastal Plain	—	—	—	—	—
10. Central Highlands	—	—	—	—	—
11. Cairngorm Massif	**Decrease (-6.7%)**	Non-linear	—	—	—
12. North East Glens	Not significant [s]	Not significant [s]	—	—	—
13. East Lochaber	—	—	—	—	—
14. Argyll West and Islands	**Decrease [s] (-11%)**	Not significant [s]	—	—	—
15. Loch Lomond, The Trossachs and Breadalbane	**Decrease (-11.1%)**	Not significant [rs]	—	—	—
16. Eastern Lowlands	Not significant	**Decrease (-1.3%)**	Not significant [rs]	Not significant [rs]	Not significant
17. West Central Belt	Not significant	Not significant	—	—	Not significant [rs]
18. Wigtown Machairs and Outer Solway Coast	Not significant	Not significant [s]	—	—	Not significant
19. Western Southern Uplands and Inner Solway	Not significant	Not significant	—	—	Not significant [r]
20. Border Hills	Not significant	Not significant	Not significant [rs]	Not significant [rs]	Not significant [rs]
21. Moray Firth	—	—	—	—	—

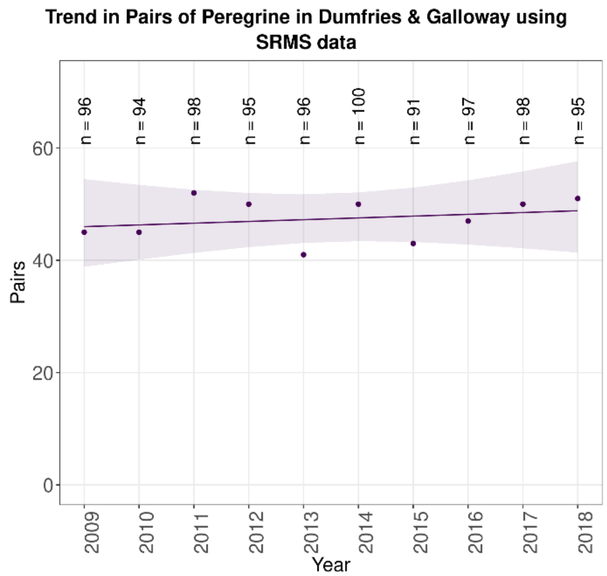
[r] No home range random effect, [s] Sample sizes small.



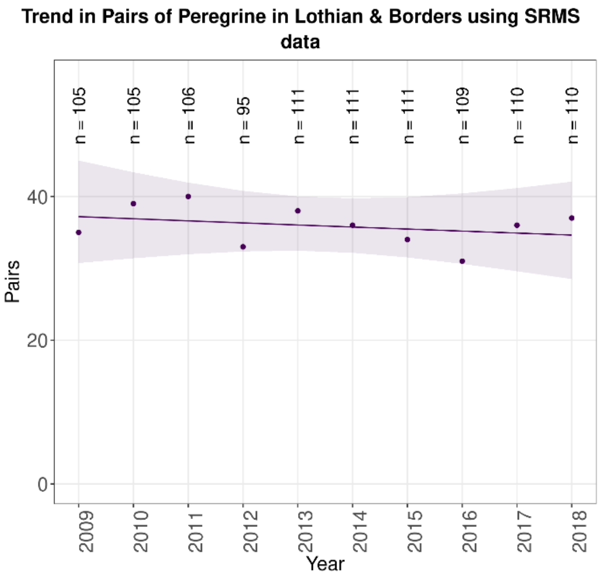
Argyll trend: Decrease (caveats: Sample sizes small)



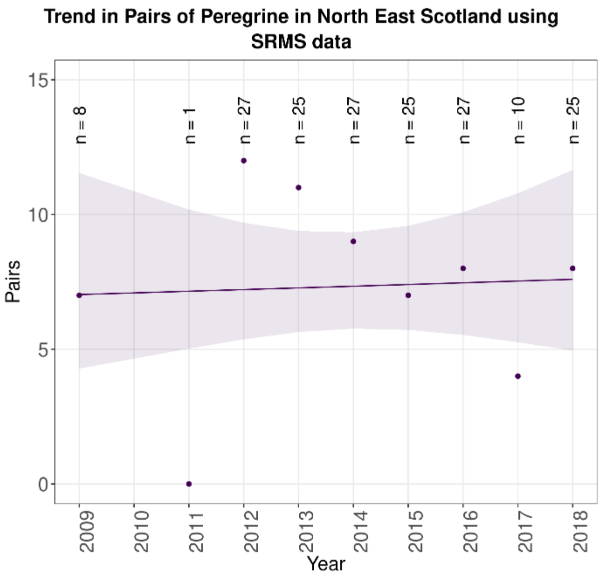
Central trend: Not significant (caveats: Sample sizes small)



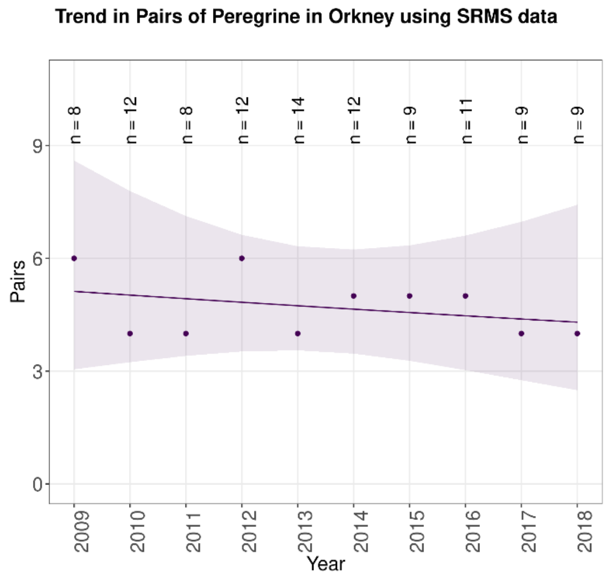
Dumfries & Galloway trend: Not significant



Lothian & Borders trend: Not significant

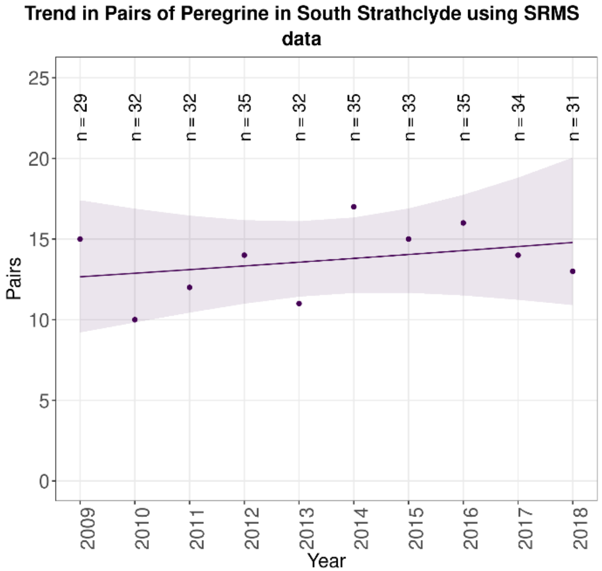


North East Scotland trend: Not significant

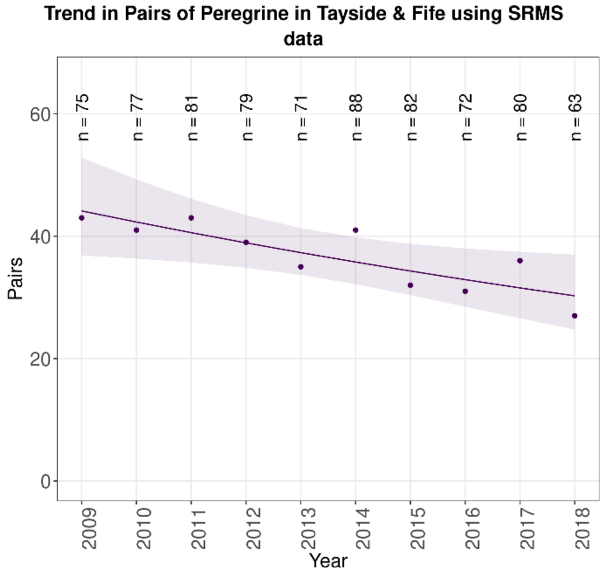


Orkney trend: Not significant (caveats: Sample sizes small)

Trends in numbers of breeding pairs of Peregrine by SRMS region during 2009-2018.



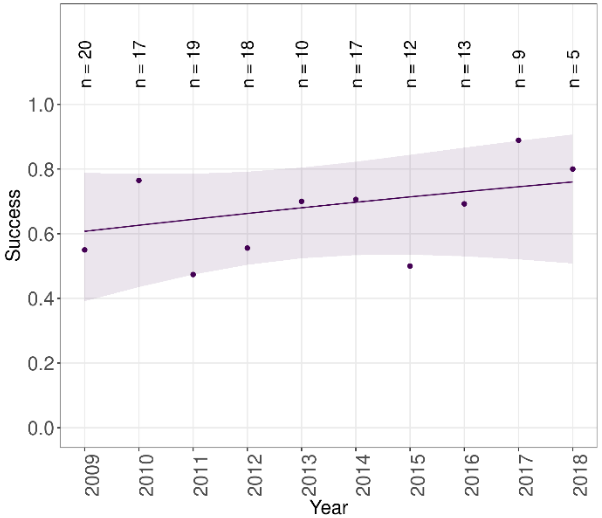
South Strathclyde trend: Not significant



Tayside & Fife trend: Decrease

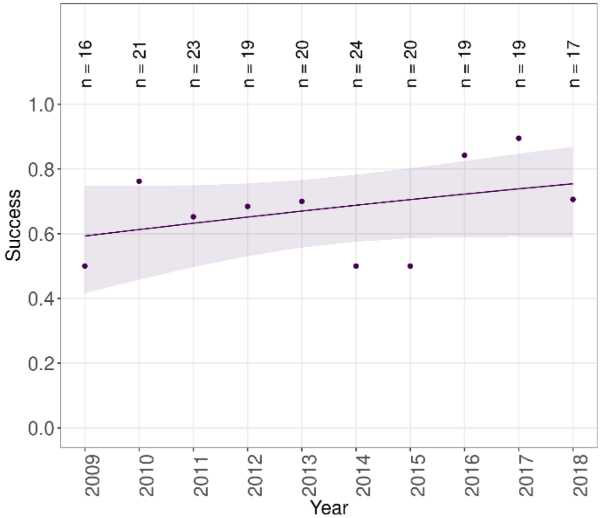
Trends in numbers of breeding pairs of Peregrine by SRMS region during 2009-2018.

Trend in Success of Peregrine in Argyll using SRMS data



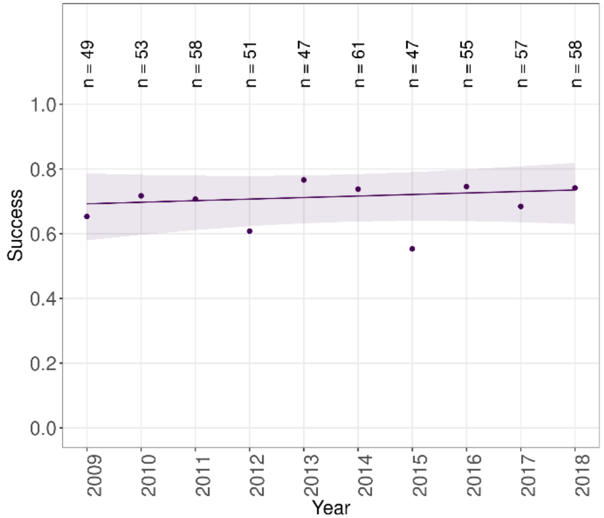
Argyll trend: Not significant (caveats: Sample sizes small)

Trend in Success of Peregrine in Central using SRMS data



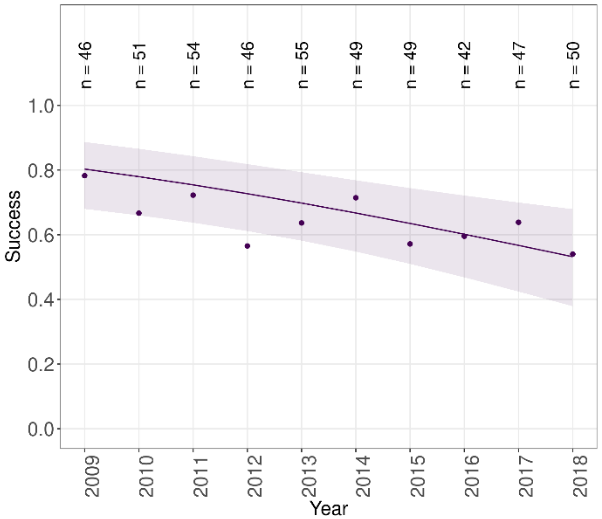
Central trend: Not significant (caveats: Sample sizes small)

Trend in Success of Peregrine in Dumfries & Galloway using SRMS data



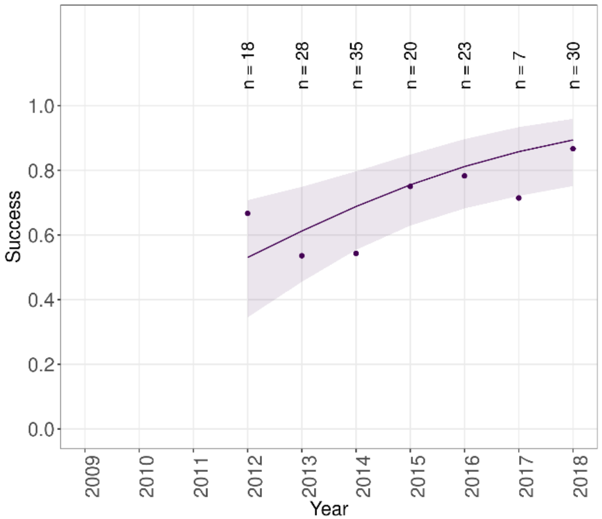
Dumfries & Galloway trend: Not significant

Trend in Success of Peregrine in Lothian & Borders using SRMS data



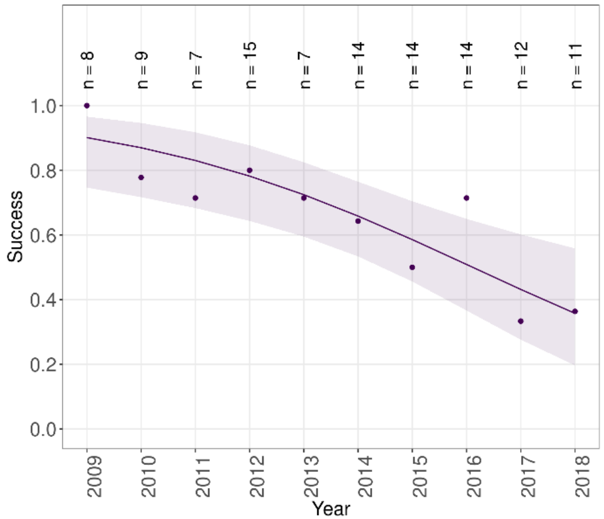
Lothian & Borders trend: Decrease

Trend in Success of Peregrine in North East Scotland using SRMS data



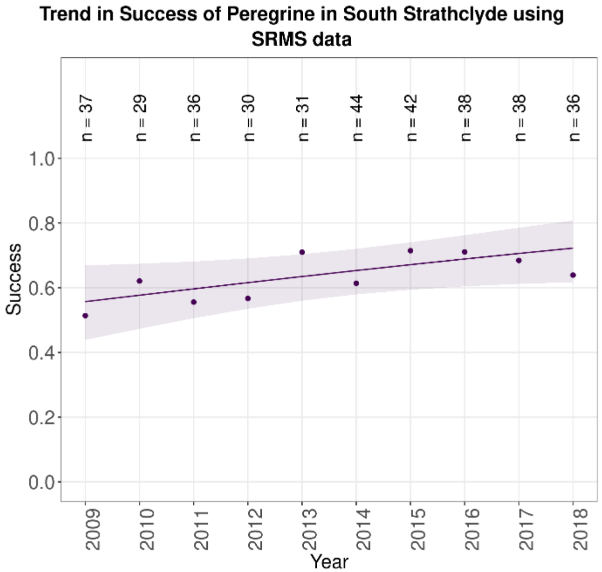
North East Scotland trend: Increase

Trend in Success of Peregrine in Orkney using SRMS data

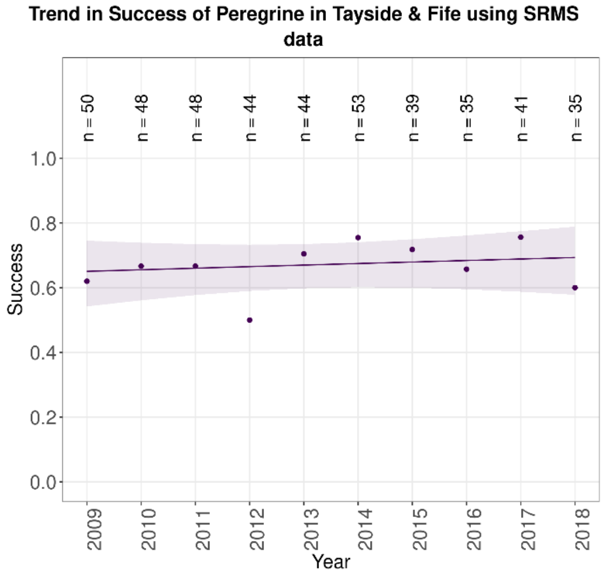


Orkney trend: Decrease (caveats: Sample sizes small)

Trends in breeding success of Peregrine by SRMS region during 2009-2018.

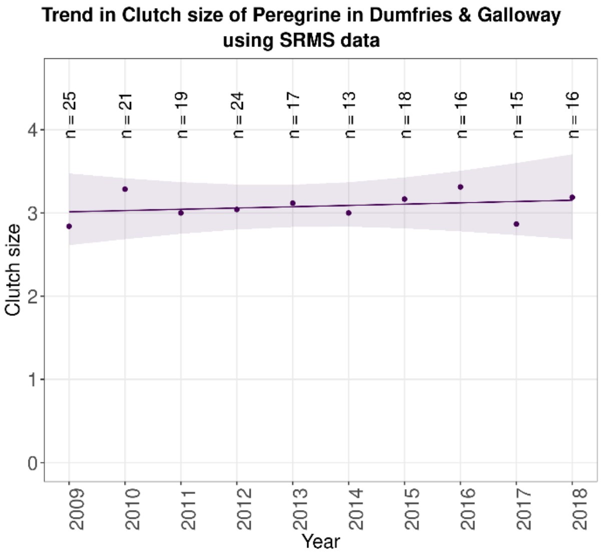


South Strathclyde trend: Non-linear

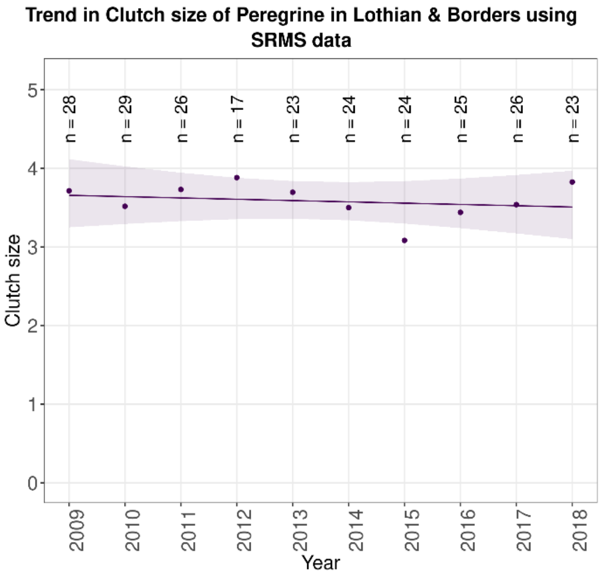


Tayside & Fife trend: Not significant

Trends in breeding success of Peregrine by SRMS region during 2009-2018.

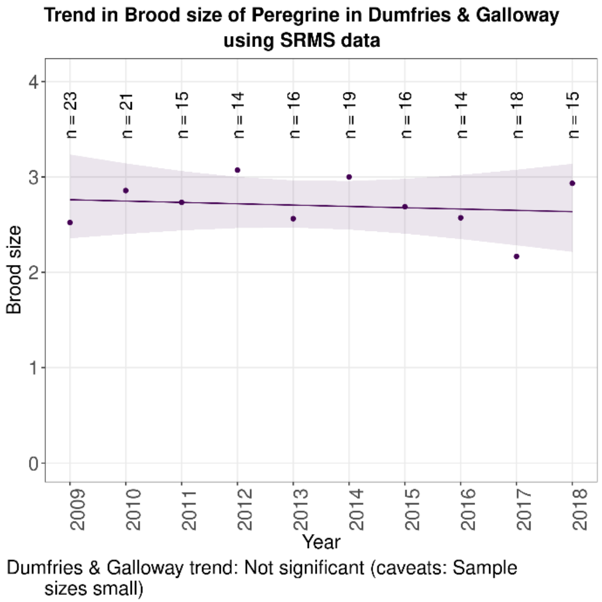


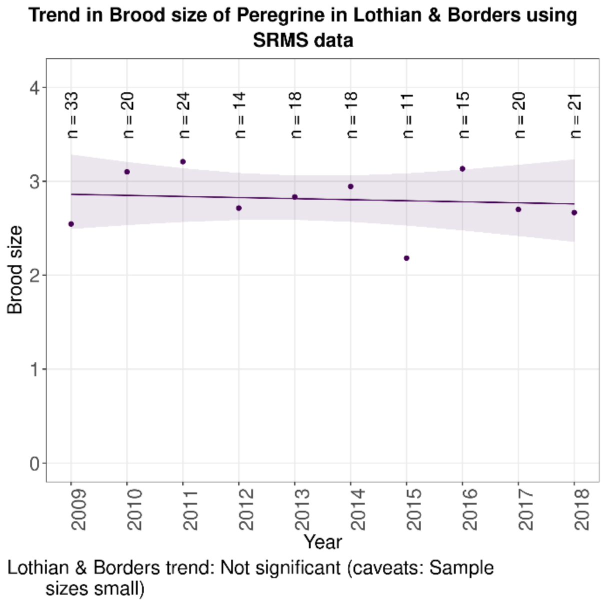
Dumfries & Galloway trend: Not significant (caveats: Sample sizes small)



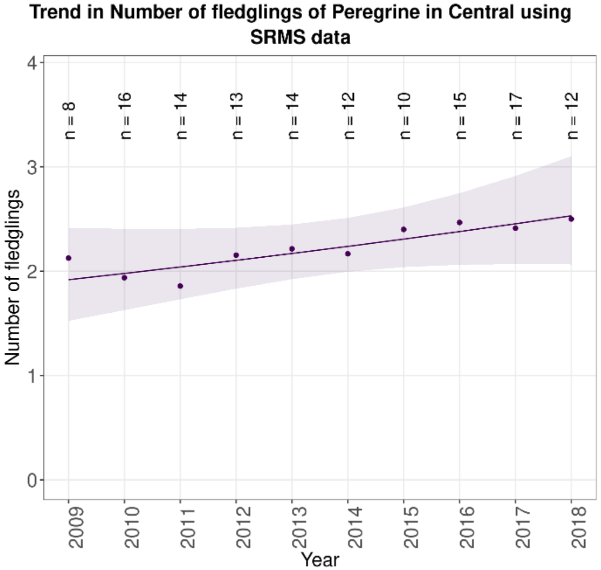
Lothian & Borders trend: Not significant

Trends in clutch size of Peregrine by SRMS region during 2009-2018.

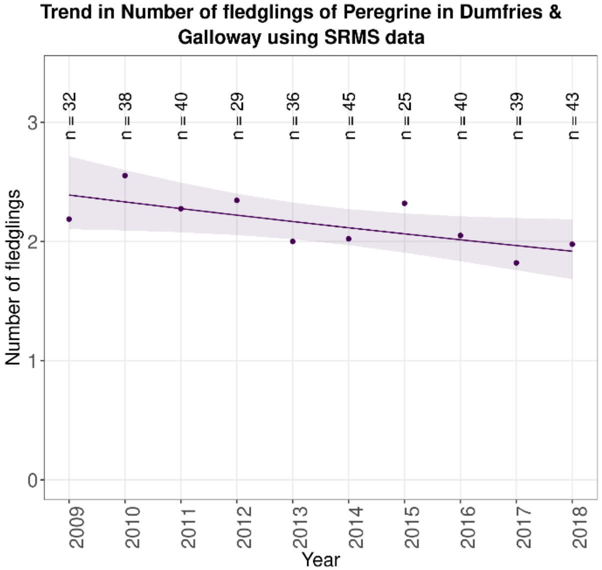




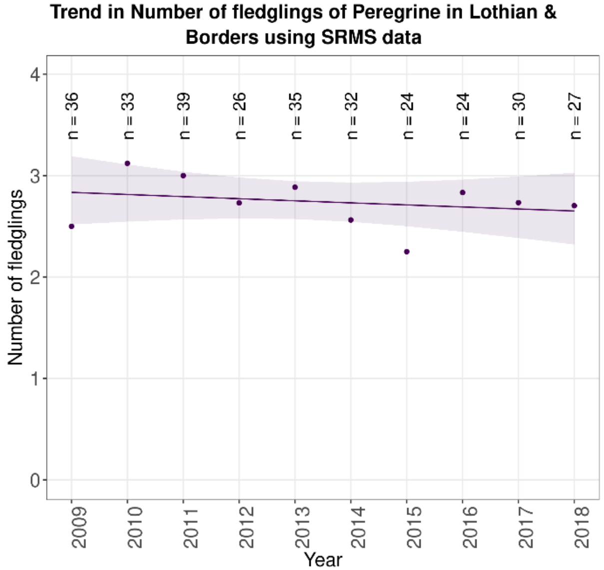
Trends in brood size of Peregrine by SRMS region during 2009-2018.



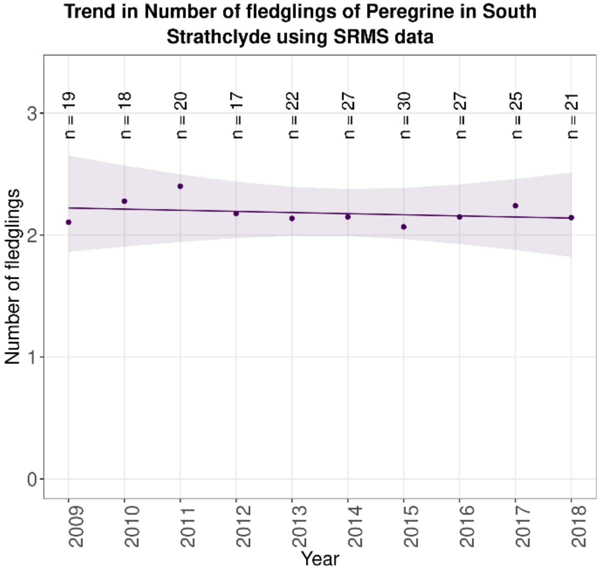
Central trend: Not significant (caveats: Sample sizes small)



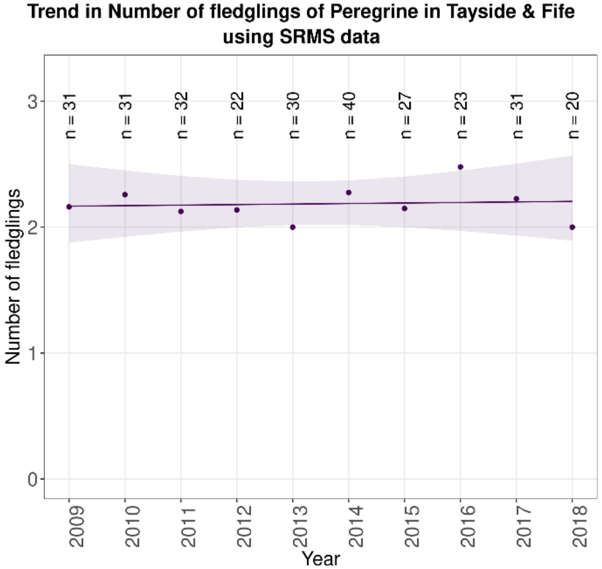
Dumfries & Galloway trend: Decrease



Lothian & Borders trend: Not significant

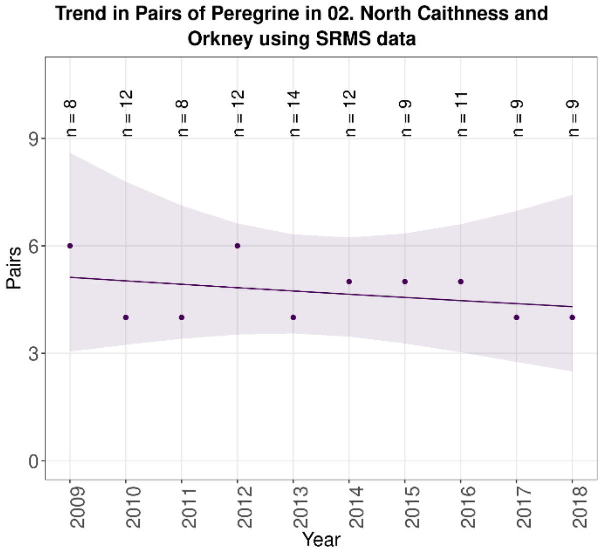


South Strathclyde trend: Not significant

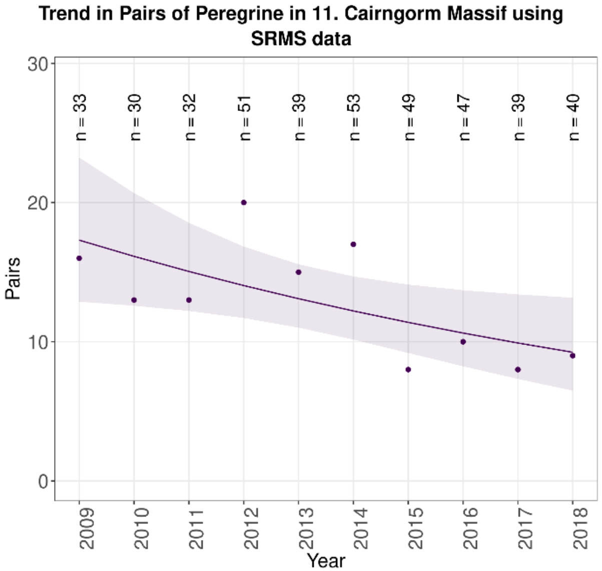


Tayside & Fife trend: Not significant

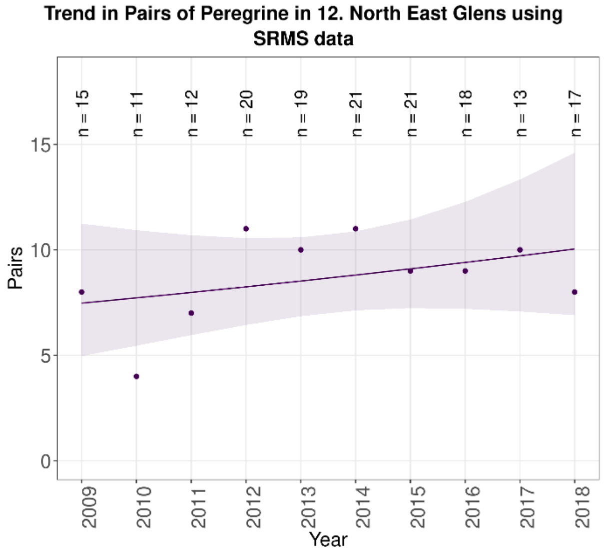
Trends in numbers of fledglings of Peregrine by SRMS region during 2009-2018.



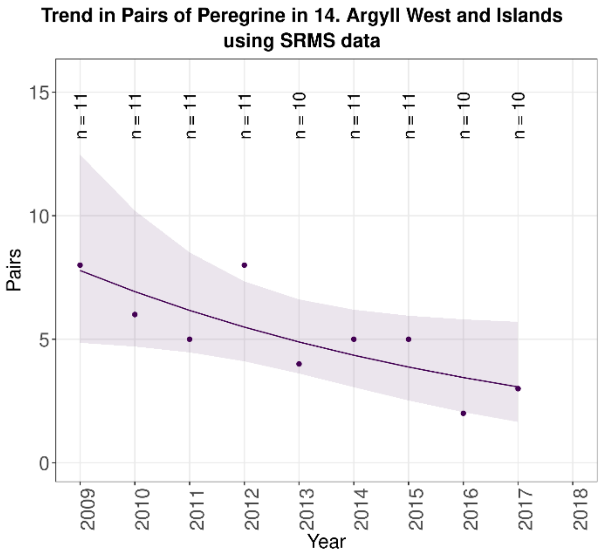
02. North Caithness and Orkney trend: Not significant (caveats: Sample sizes small)



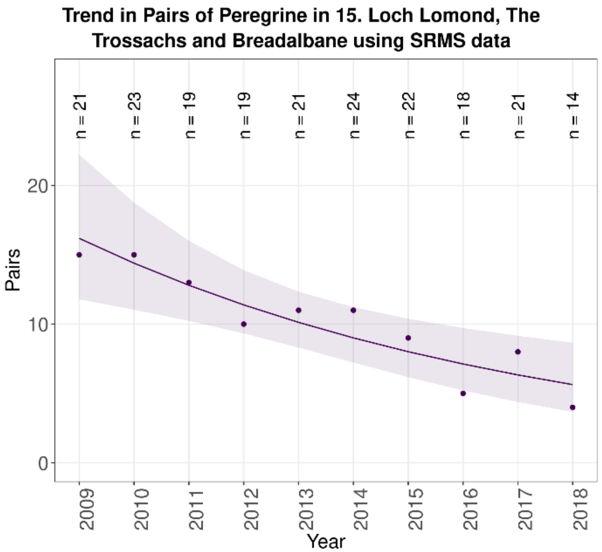
11. Cairngorm Massif trend: Decrease



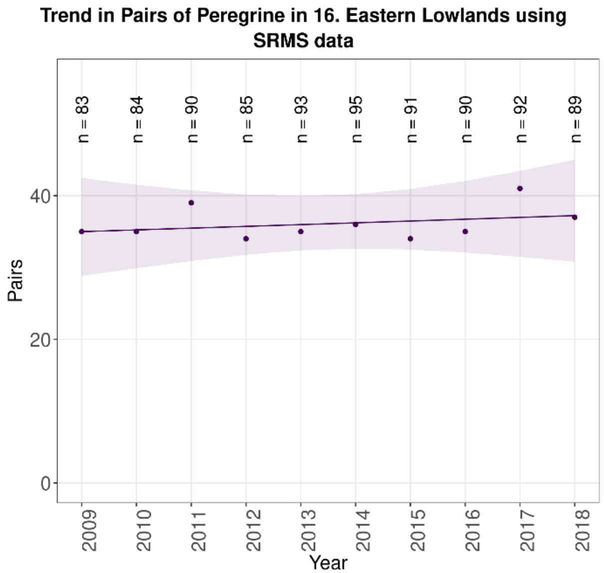
12. North East Glens trend: Not significant (caveats: Sample sizes small)



14. Argyll West and Islands trend: Decrease (caveats: Sample sizes small)

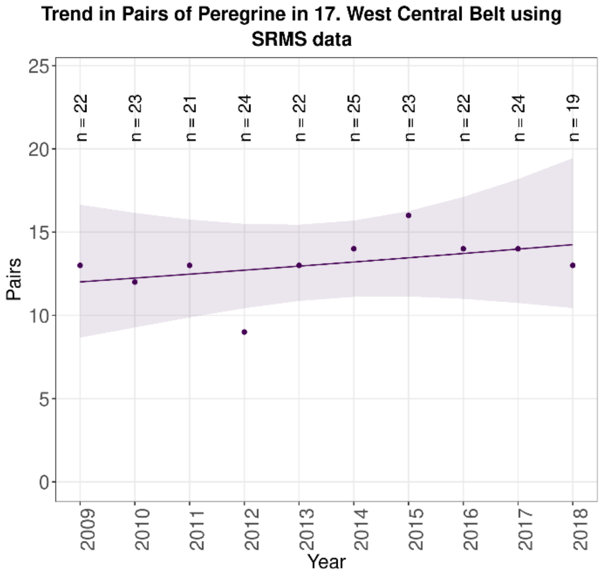


15. Loch Lomond, The Trossachs and Breadalbane trend: Decrease

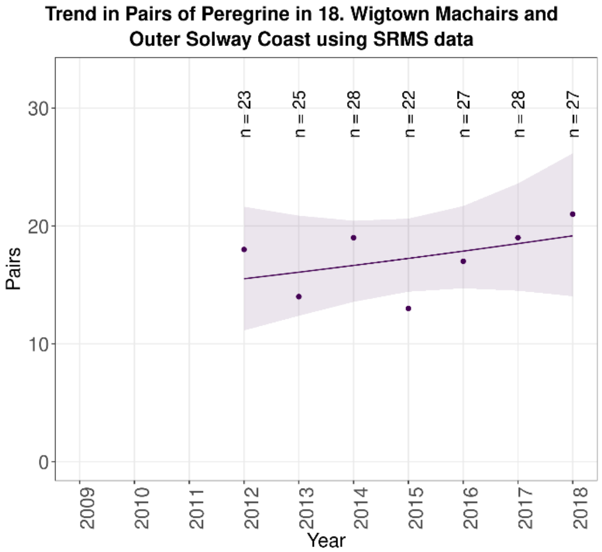


16. Eastern Lowlands trend: Not significant

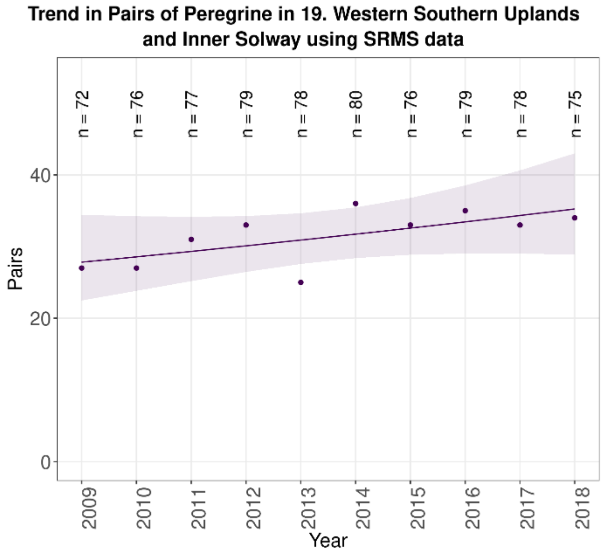
Trends in numbers of breeding pairs of Peregrine by NHZ region during 2009-2018.



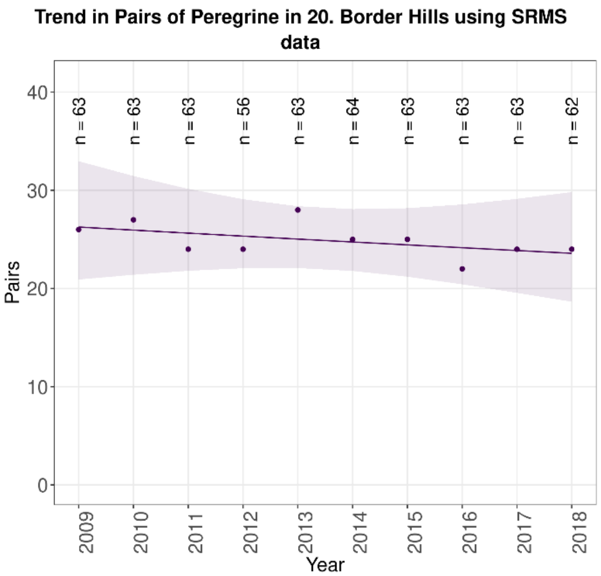
17. West Central Belt trend: Not significant



18. Wigtown Machairs and Outer Solway Coast trend: Not significant

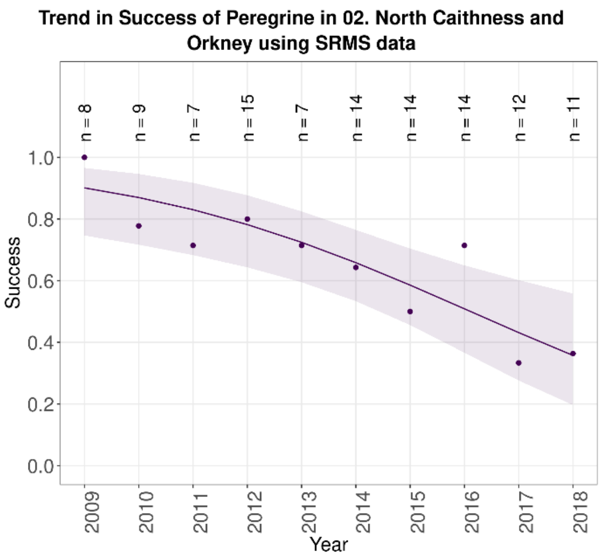


19. Western Southern Uplands and Inner Solway trend: Not significant

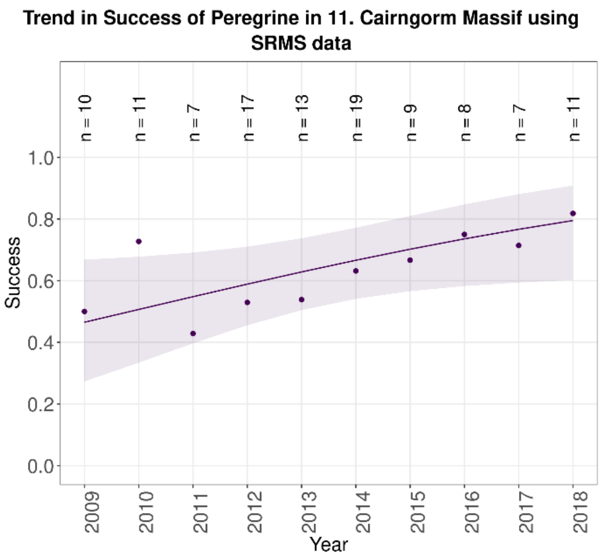


20. Border Hills trend: Not significant

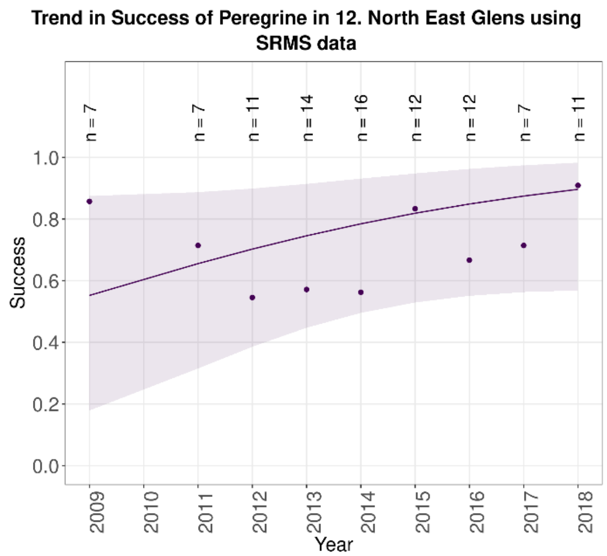
Trends in numbers of breeding pairs of Peregrine by NHZ region during 2009-2018.



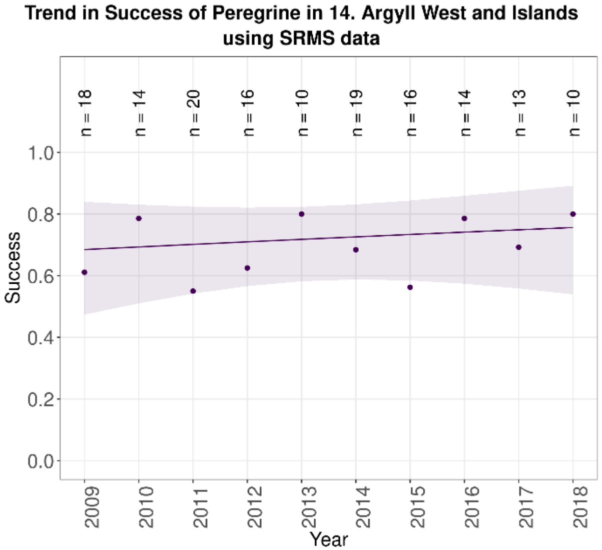
02. North Caithness and Orkney trend: Decrease (caveats: Sample sizes small)



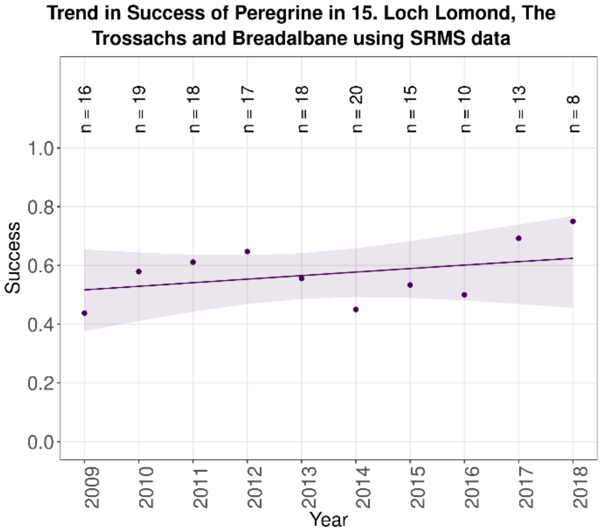
11. Cairngorm Massif trend: Non-linear (caveats: Sample sizes small)



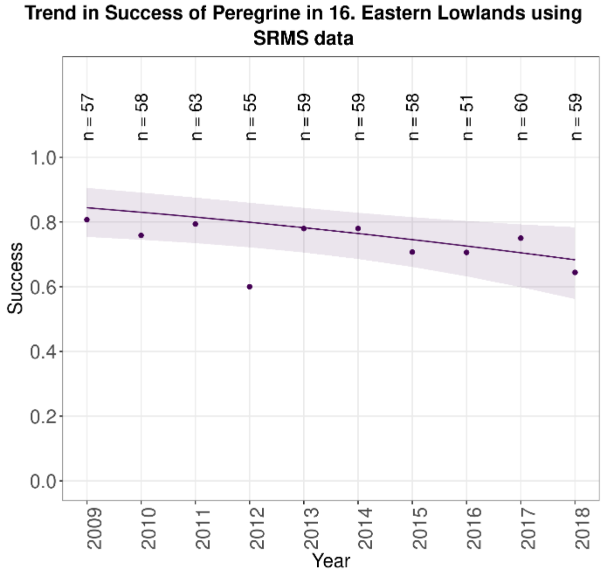
12. North East Glens trend: Not significant (caveats: Sample sizes small)



14. Argyll West and Islands trend: Not significant (caveats: Sample sizes small)



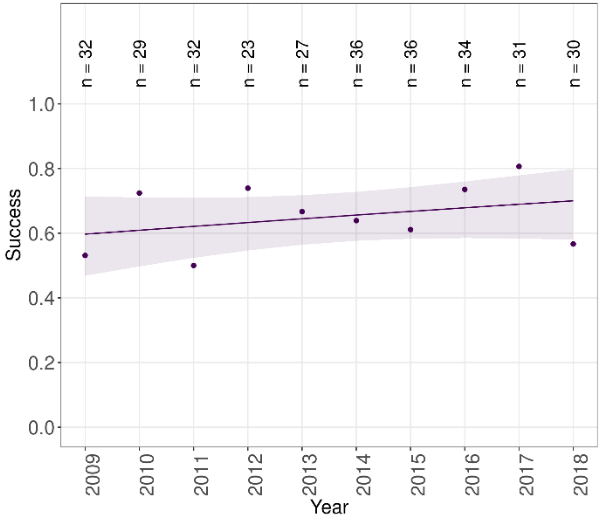
15. Loch Lomond, The Trossachs and Breadalbane trend: Not significant (caveats: Sample sizes small; No home range random effect)



16. Eastern Lowlands trend: Decrease

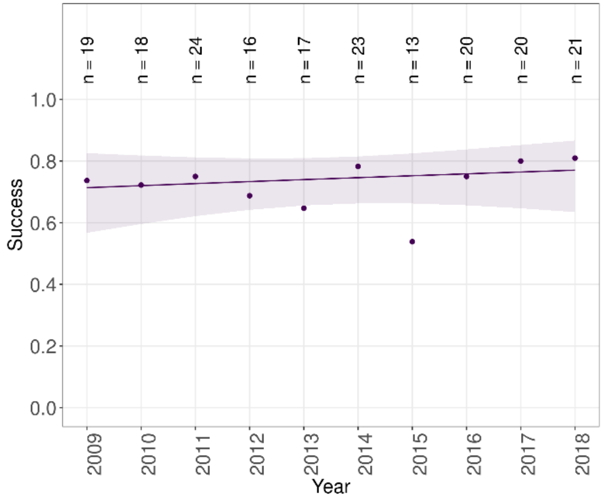
Trends in breeding success of Peregrine by NHZ region during 2009-2018.

Trend in Success of Peregrine in 17. West Central Belt using SRMS data



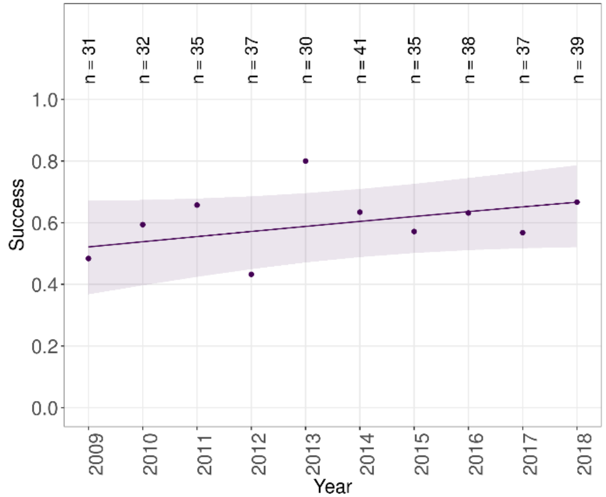
17. West Central Belt trend: Not significant

Trend in Success of Peregrine in 18. Wigtown Machairs and Outer Solway Coast using SRMS data



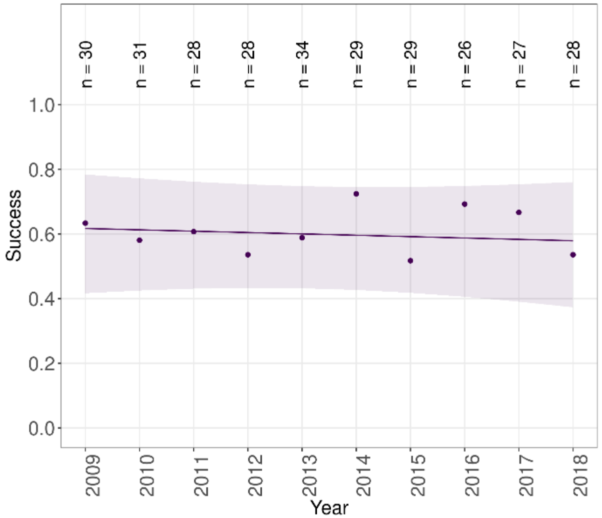
18. Wigtown Machairs and Outer Solway Coast trend: Not significant (caveats: Sample sizes small)

Trend in Success of Peregrine in 19. Western Southern Uplands and Inner Solway using SRMS data



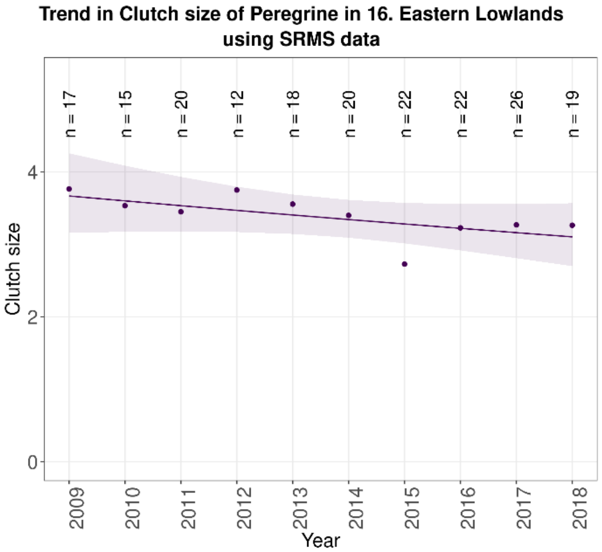
19. Western Southern Uplands and Inner Solway trend: Not significant

Trend in Success of Peregrine in 20. Border Hills using SRMS data

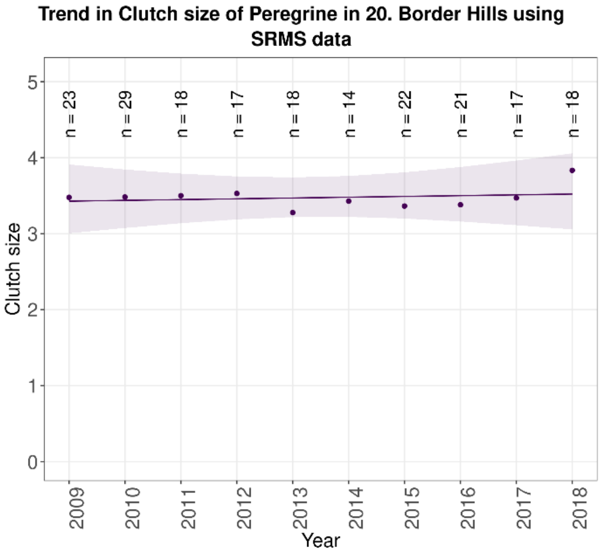


20. Border Hills trend: Not significant

Trends in breeding success of Peregrine by NHZ region during 2009-2018.

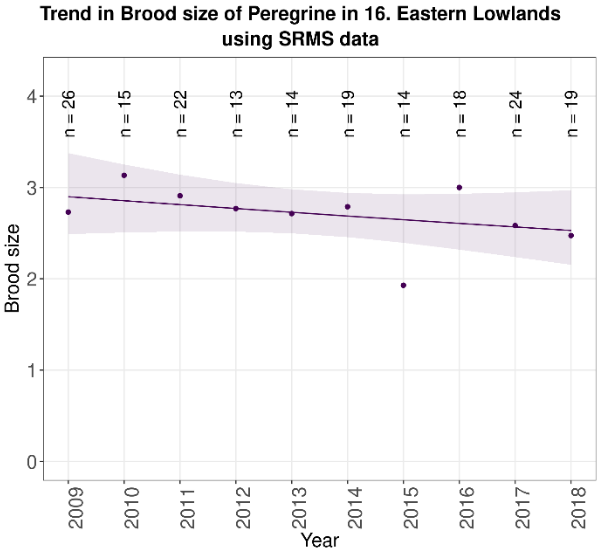


16. Eastern Lowlands trend: Not significant (caveats: Sample sizes small; No home range random effect)

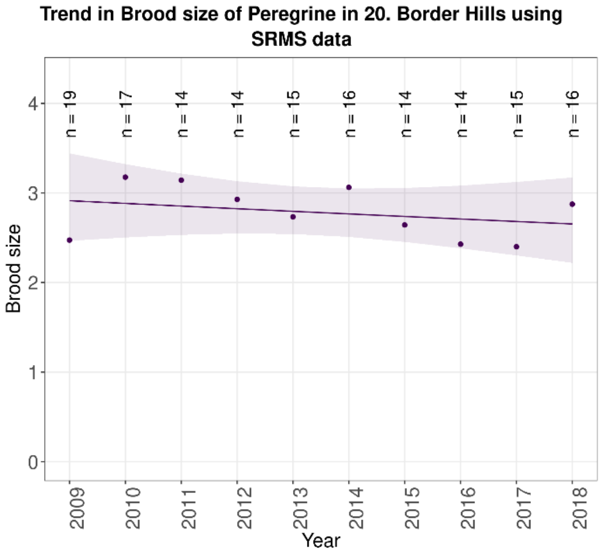


20. Border Hills trend: Not significant (caveats: Sample sizes small; No home range random effect)

Trends in clutch size of Peregrine by NHZ region during 2009-2018.

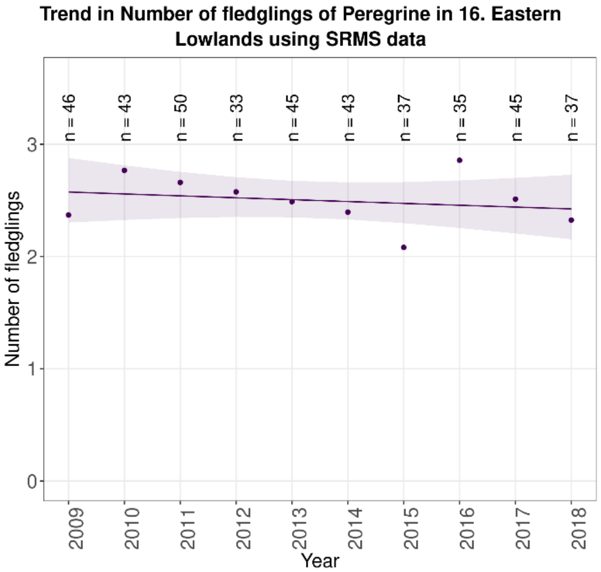


16. Eastern Lowlands trend: Not significant (caveats: Sample sizes small; No home range random effect)

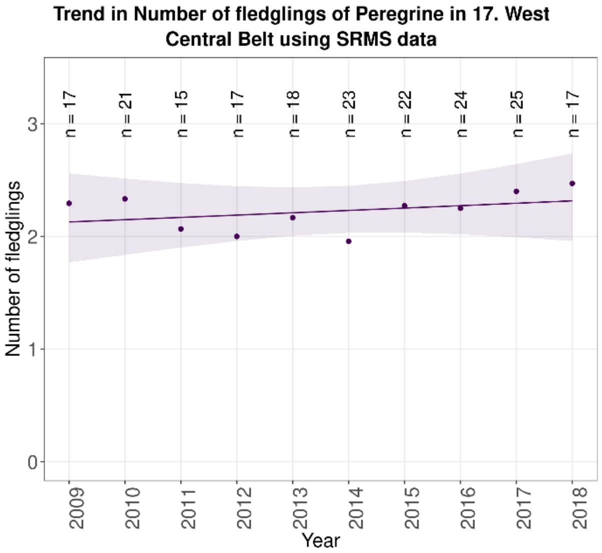


20. Border Hills trend: Not significant (caveats: Sample sizes small; No home range random effect)

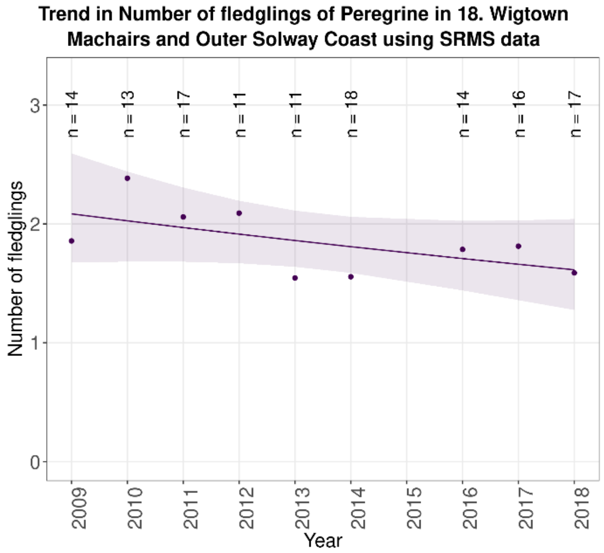
Trends in brood size of Peregrine by NHZ region during 2009-2018.



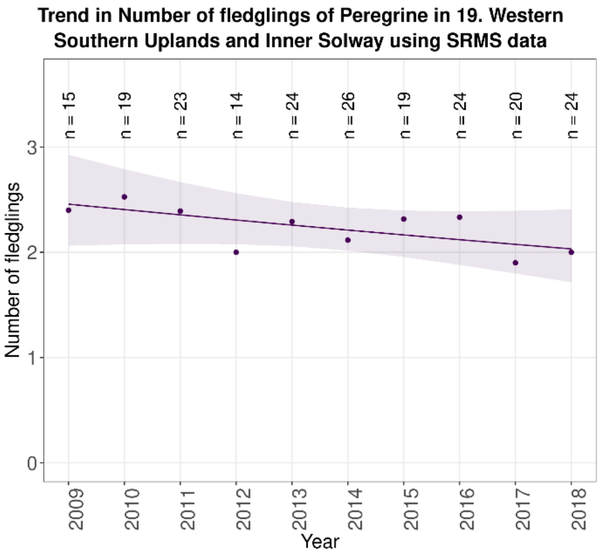
16. Eastern Lowlands trend: Not significant



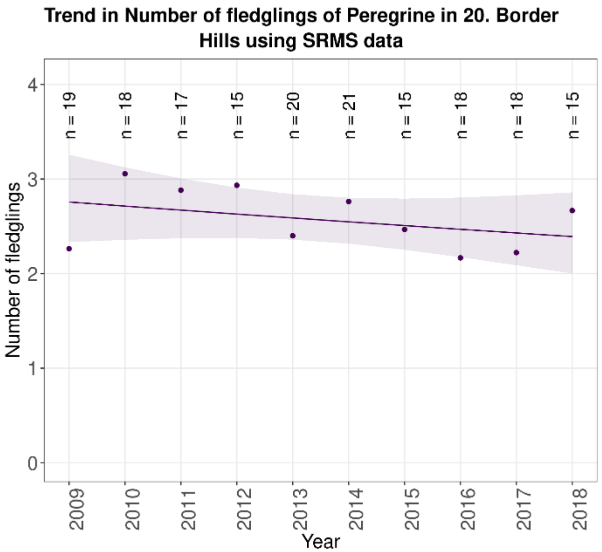
17. West Central Belt trend: Not significant (caveats: Sample sizes small; No home range random effect)



18. Wigtown Machairs and Outer Solway Coast trend: Not significant



19. Western Southern Uplands and Inner Solway trend: Not significant (caveats: No home range random effect)



20. Border Hills trend: Not significant (caveats: Sample sizes small; No home range random effect)

Trends in numbers of fledglings of Peregrine by NHZ region during 2009-2018.

Details of SRMS Regional trends for Peregrine.

Parameter	Region	First year of trend	Last year of trend	Number of years	Mean number of home ranges across years	Mean parameter value (and 95% confidence limits)	Trend during the period	Caveats	Estimated % annual change (and 95% confidence limits)
Pairs	Argyll	2009	2017	9	10.7	5.1 (3.6 to 6.7)	Decrease	Sample sizes small	-11.0 (-20.6 to -0.1)
	Central	2009	2018	10	19.7	12.6 (11.5 to 13.7)	Not significant	Sample sizes small	-0.4 (-6.3 to 5.9)
	Dumfries & Galloway	2009	2018	10	96.0	47.4 (44.7 to 50.1)	Not significant		0.7 (-2.4 to 3.9)
	Lothian & Borders	2009	2018	10	107.3	35.9 (33.9 to 37.9)	Not significant		-0.8 (-4.3 to 2.8)
	North East Scotland	2009	2018	9	19.4	7.3 (4.6 to 10.1)	Not significant		0.9 (-7.6 to 10.1)
	Orkney	2009	2018	10	10.4	4.7 (4.1 to 5.3)	Not significant	Sample sizes small	-1.9 (-11.2 to 8.4)
	South Strathclyde	2009	2018	10	32.8	13.7 (12.1 to 15.3)	Not significant		1.7 (-4.0 to 7.9)
	Tayside & Fife	2009	2018	10	76.8	36.8 (32.9 to 40.7)	Decrease		-4.1 (-7.5 to -0.6)
Success	Argyll	2009	2018	10	14.0	0.6 (0.5 to 0.7)	Not significant	Sample sizes small	1.9 (-2.1 to 5.8)
	Central	2009	2018	10	19.8	0.7 (0.6 to 0.7)	Not significant	Sample sizes small	2.0 (-1.1 to 5.0)
	Dumfries & Galloway	2009	2018	10	53.6	0.7 (0.7 to 0.7)	Not significant		0.5 (-1.1 to 2.0)
	Lothian & Borders	2009	2018	10	48.9	0.6 (0.6 to 0.7)	Decrease		-2.1 (-3.6 to -0.8)
	North East Scotland	2012	2018	7	23.0	0.7 (0.6 to 0.8)	Increase		8.3 (2.7 to 13.9)
	Orkney	2009	2018	10	11.1	0.6 (0.5 to 0.7)	Decrease	Sample sizes small	-2.4 (-4.2 to -0.9)
	South Strathclyde	2009	2018	10	36.1	0.6 (0.6 to 0.7)	Non-linear		Non-linear
Success	Tayside & Fife	2009	2018	10	43.7	0.7 (0.6 to 0.7)	Not significant		0.5 (-1.4 to 2.3)
Clutch size	Dumfries & Galloway	2009	2018	10	18.4	3.1 (3.0 to 3.2)	Not significant	Sample sizes small	0.5 (-2.3 to 3.4)
	Lothian & Borders	2009	2018	10	24.5	3.6 (3.5 to 3.7)	Not significant		-0.5 (-2.7 to 1.8)
Brood size	Dumfries & Galloway	2009	2018	10	17.1	2.7 (2.6 to 2.8)	Not significant	Sample sizes small	-0.5 (-3.5 to 2.6)
	Lothian & Borders	2009	2018	10	19.4	2.8 (2.7 to 2.9)	Not significant	Sample sizes small	-0.4 (-3.1 to 2.3)
Number of fledglings	Central	2009	2018	10	13.1	2.2 (2.1 to 2.4)	Not significant	Sample sizes small	3.1 (-1.0 to 7.4)

Parameter	Region	First year of trend	Last year of trend	Number of years	Mean number of home ranges across years	Mean parameter value (and 95% confidence limits)	Trend during the period	Caveats	Estimated % annual change (and 95% confidence limits)
	Dumfries & Galloway	2009	2018	10	36.7	2.1 (2.1 to 2.2)	Decrease		-2.4 (-4.7 to 0.0)
	Lothian & Borders	2009	2018	10	30.6	2.7 (2.6 to 2.9)	Not significant		-0.7 (-3.0 to 1.6)
	South Strathclyde	2009	2018	10	22.6	2.2 (2.1 to 2.3)	Not significant		-0.4 (-3.6 to 2.8)
	Tayside & Fife	2009	2018	10	28.7	2.2 (2.1 to 2.3)	Not significant		0.2 (-2.6 to 3.0)

Details of NHZ Regional trends for Peregrine.

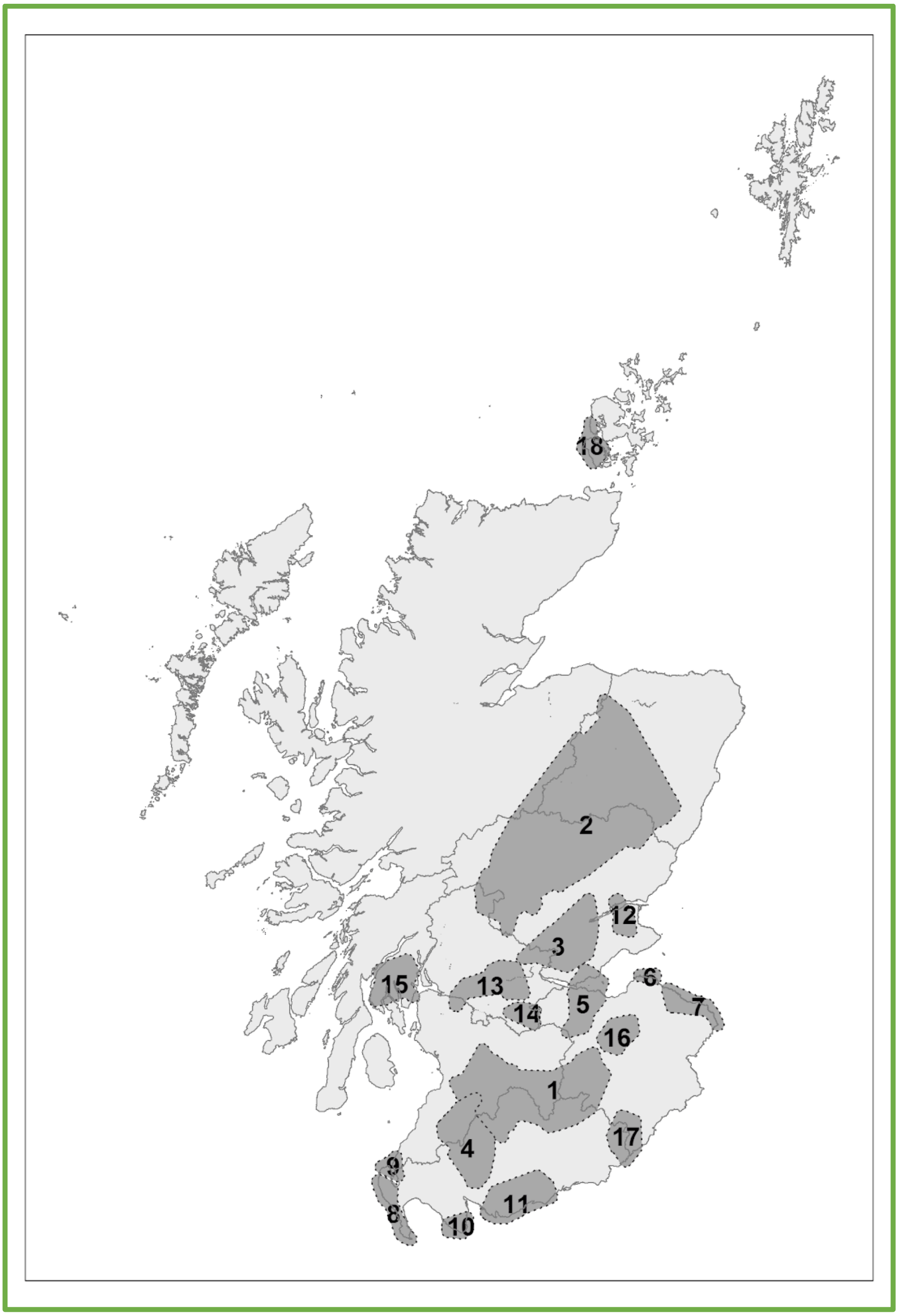
Parameter	Region	First year of trend	Last year of trend	Number of years	Mean number of home ranges across years	Mean parameter value (and 95% confidence limits)	Trend during the period	Caveats	Estimated % annual change (and 95% confidence limits)
Pairs	02. North Caithness and Orkney	2009	2018	10	10.4	4.7 (4.1 to 5.3)	Not significant	Sample sizes small	-1.9 (-11.2 to 8.4)
	11. Cairngorm Massif	2009	2018	10	41.3	12.9 (10.0 to 15.8)	Decrease		-6.7 (-12.2 to -0.9)
	12. North East Glens	2009	2018	10	16.7	8.7 (7.2 to 10.2)	Not significant	Sample sizes small	3.3 (-4.0 to 11.2)
	14. Argyll West and Islands	2009	2017	9	10.667	5.1 (3.6 to 6.7)	Decrease	Sample sizes small	-11.0 (-20.6 to -0.1)
	15. Loch Lomond, The Trossachs and Breadalbane	2009	2018	10	20.2	10.1 (7.4 to 12.8)	Decrease		-11.1 (-17.1 to -4.6)
	16. Eastern Lowlands	2009	2018	10	89.2	36.1 (34.5 to 37.7)	Not significant		0.7 (-2.9 to 4.4)
	17. West Central Belt	2009	2018	10	22.5	13.1 (11.8 to 14.4)	Not significant		1.9 (-4.0 to 8.2)
	18. Wigtown Machairs and Outer Solway Coast	2012	2018	7	25.714	17.3 (14.6 to 19.9)	Not significant		3.6 (-5.3 to 13.2)
	19. Western Southern Uplands and Inner Solway	2009	2018	10	77	31.4 (28.7 to 34.1)	Not significant		2.7 (-1.2 to 6.7)
	20. Border Hills	2009	2018	10	62.3	24.9 (23.7 to 26.1)	Not significant		-1.2 (-5.4 to 3.2)
Success	02. North Caithness and Orkney	2009	2018	10	11.1	0.6 (0.5 to 0.7)	Decrease	Sample sizes small	-2.4 (-4.2 to -0.9)
	11. Cairngorm Massif	2009	2018	10	11.2	0.6 (0.5 to 0.7)	Non-linear	Sample sizes small	Non-linear
	12. North East Glens	2009	2018	9	10.778	0.7 (0.6 to 0.8)	Not significant	Sample sizes small	5.4 (-1.6 to 12.2)
	14. Argyll West and Islands	2009	2018	10	15	0.7 (0.6 to 0.7)	Not significant	Sample sizes small	0.9 (-2.6 to 4.1)

Parameter	Region	First year of trend	Last year of trend	Number of years	Mean number of home ranges across years	Mean parameter value (and 95% confidence limits)	Trend during the period	Caveats	Estimated % annual change (and 95% confidence limits)
	15. Loch Lomond, The Trossachs and Breadalbane	2009	2018	10	15.4	0.6 (0.5 to 0.6)	Not significant	Sample sizes small; No home range random effect	1.2 (-1.8 to 4.2)
	16. Eastern Lowlands	2009	2018	10	57.9	0.7 (0.7 to 0.8)	Decrease		-1.3 (-2.4 to -0.2)
	17. West Central Belt	2009	2018	10	31	0.6 (0.6 to 0.7)	Not significant		1.2 (-0.9 to 3.3)
	18. Wigtown Machairs and Outer Solway Coast	2009	2018	10	19.1	0.7 (0.7 to 0.8)	Not significant	Sample sizes small	0.7 (-1.7 to 3.0)
	19. Western Southern Uplands and Inner Solway	2009	2018	10	35.5	0.6 (0.5 to 0.7)	Not significant		1.7 (-0.6 to 3.9)
	20. Border Hills	2009	2018	10	29	0.6 (0.5 to 0.7)	Not significant		-0.4 (-2.9 to 2.0)
Clutch size	16. Eastern Lowlands	2009	2018	10	19.1	3.4 (3.2 to 3.5)	Not significant	Sample sizes small; No home range random effect	-1.8 (-4.5 to 0.8)
	20. Border Hills	2009	2018	10	19.7	3.5 (3.4 to 3.6)	Not significant	Sample sizes small; No home range random effect	0.3 (-2.2 to 2.9)
Brood size	16. Eastern Lowlands	2009	2018	10	18.4	2.7 (2.6 to 2.8)	Not significant	Sample sizes small; No home range random effect	-1.5 (-4.3 to 1.4)
	20. Border Hills	2009	2018	10	15.4	2.8 (2.7 to 2.9)	Not significant	Sample sizes small; No home range random effect	-1.0 (-4.2 to 2.2)
Number of fledglings	16. Eastern Lowlands	2009	2018	10	41.4	2.5 (2.4 to 2.6)	Not significant		-0.7 (-2.7 to 1.5)
	17. West Central Belt	2009	2018	10	19.9	2.2 (2.1 to 2.3)	Not significant	Sample sizes small; No home range random effect	0.9 (-2.3 to 4.3)
	18. Wigtown Machairs and Outer Solway	2009	2018	9	14.556	1.8 (1.7 to 2.0)	Not significant		-2.8 (-6.8 to 1.3)

Parameter	Region	First year of trend	Last year of trend	Number of years	Mean number of home ranges across years	Mean parameter value (and 95% confidence limits)	Trend during the period	Caveats	Estimated % annual change (and 95% confidence limits)
	Coast								
	19. Western Southern Uplands and Inner Solway	2009	2018	10	20.8	2.2 (2.1 to 2.3)	Not significant	No home range random effect	-2.1 (-5.2 to 1.1)
	20. Border Hills	2009	2018	10	17.6	2.6 (2.4 to 2.7)	Not significant	Sample sizes small; No home range random effect	-1.6 (-4.7 to 1.7)

Number of Peregrine home range checks for occupancy reported to the SRMS during 2009-2018, in each of the 12 SRMS Regions, with approximate proportion of estimated population monitored. At the bottom of the table, row A is the mean number of home range checks over the most recent five years. Row B gives the estimated proportion of the national population in each region, based on Bird Atlas Timed Tetrad Visit (TTV) data. The depth of red shading indicates the relative importance of each region for this species. If survey effort was spread evenly across the whole population, the ratio of A:B would not vary much between regions.

Year	ARGYLL	CENTRAL SCOTLAND	DUMFRIES & GALLOWAY	HIGHLAND	LEWIS & HARRIS	LOTHIAN & BORDERS	NORTH EAST SCOTLAND	ORKNEY	SHETLAND	SOUTH STRATHCLYDE	TAYSIDE & FIFE	UIST	Total
2009	27	33	116	23	1	132	15	20	0	58	101	8	534
2010	30	38	109	31	5	133	0	28	0	63	101	2	540
2011	30	37	111	21	3	134	1	12	0	67	113	5	534
2012	33	41	108	23	0	122	64	30	0	66	104	5	596
2013	35	34	111	31	1	141	76	33	0	68	98	5	633
2014	68	59	119	121	4	142	165	38	76	86	188	6	1072
2015	34	41	109	18	0	140	85	28	14	77	117	4	667
2016	40	38	115	20	3	138	99	35	11	78	103	4	684
2017	33	44	117	54	5	142	20	32	20	80	107	6	660
2018	19	28	112	88	2	143	86	29	20	75	99	4	705
A: Mean home range checks	**38.8**	**42.0**	**114.4**	**60.2**	**2.8**	**141.0**	**91.0**	**32.4**	**28.2**	**79.2**	**122.8**	**4.8**	**757.6**
B: Proportion of estimated Scottish population	18	3	14	17	0	11	17	3	0	4	9	1	100



Areas corresponding to the clusters of home ranges from which sufficient data were reported to attempt to derive population trends for Peregrine between 2009 and 2018**.**

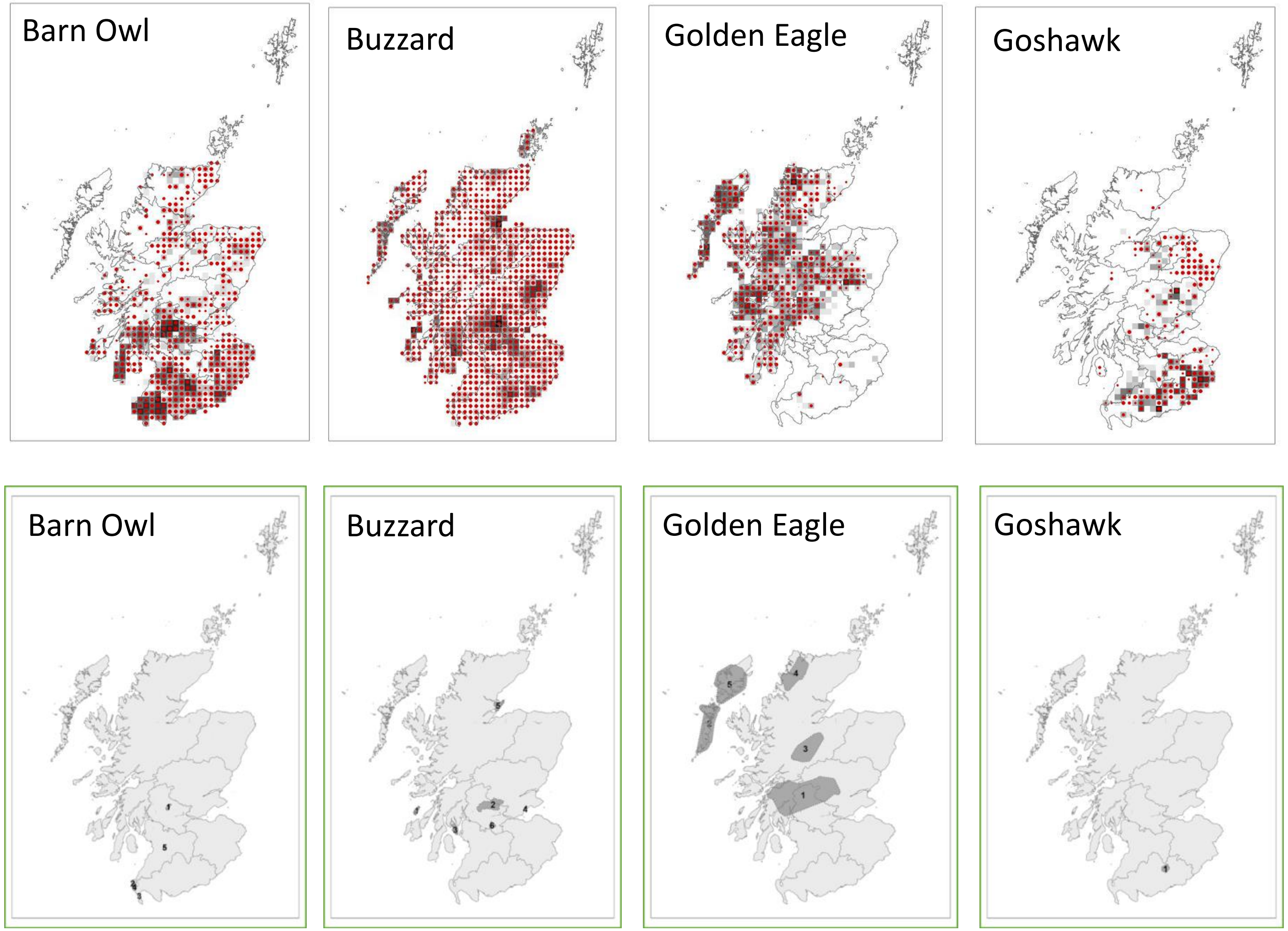
6 Assessment of monitoring gaps – SRMS enhancement needs

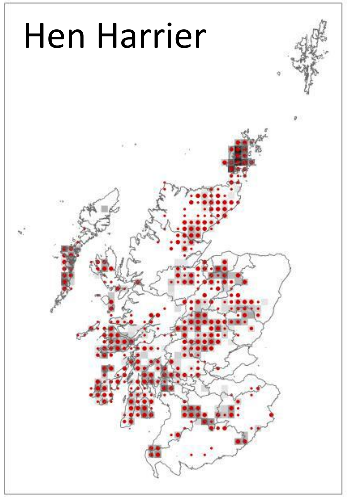
6.1 Monitoring gaps for individual species

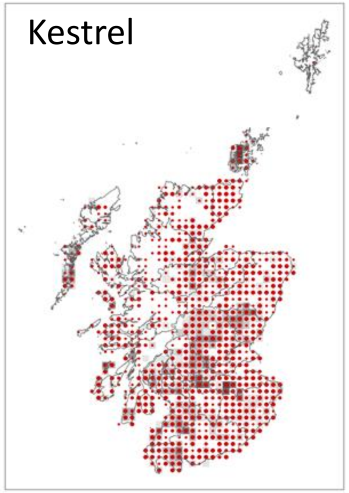
In this section we ask the following question for each species: **To improve existing monitoring efforts in Scotland towards production of rigorous national trends in numbers and productivity, what changes would be most useful to fill gaps in knowledge and work towards robust national trends, if we were able to initiate new studies, re-focus effort or enhance monitoring approaches?**

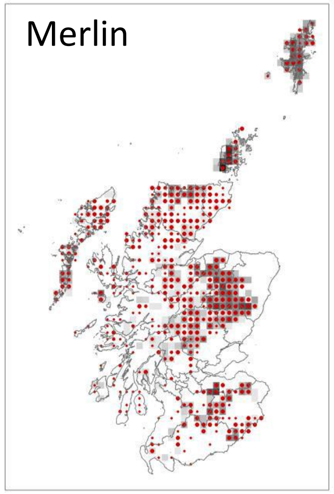
Gaps in coverage have been assessed with reference to the maps in Figure 4. For each of the 14 species, these show, firstly, the known breeding distribution in Scotland (from Bird Atlas 2007-11 data) and the distribution of all SRMS records submitted to the Scheme during the most recent part of the trend period (2014-2018) and, secondly, the 'clusters' or areas of consistent coverage that were identified and could be used to produce rigorous trends. Through comparison of the two maps for each species, we have highlighted the main areas of Scotland which would benefit from improved consistent annual monitoring coverage in order to move towards representative national trends in future. The main geographical areas requiring improved coverage are outlined in Table 2, along with any other enhancements to monitoring approaches that would benefit the trends for the individual species.

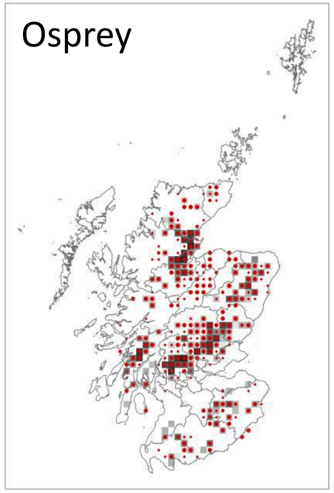
Figure 4 Maps used to assess gaps in monitoring covering for 14 Scottish Raptor Monitoring Scheme species: (a) known breeding distribution of the species taken from Bird Atlas 2007-11 (red dots, with size of dot positively related to probability of breeding) and records reported to SRMS during 2014-2018 (grey squares, darker shade indicating more records); and (b) 'clusters' of consistent coverage across years identified for each species (from which rigorous trends could be derived).

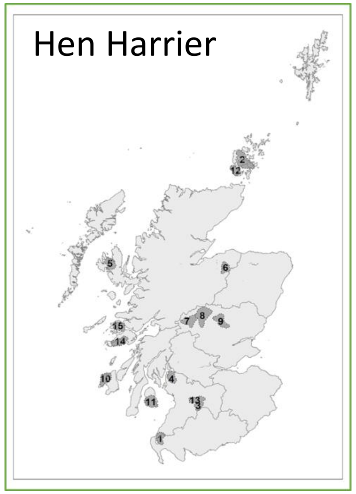



Hen Harrier

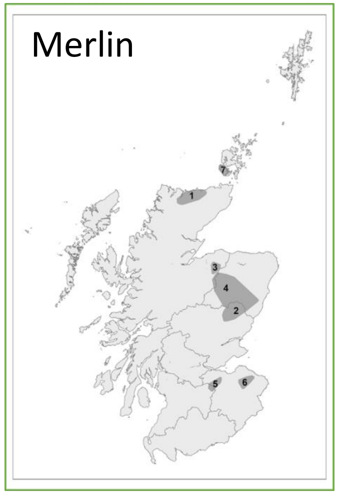

Kestrel

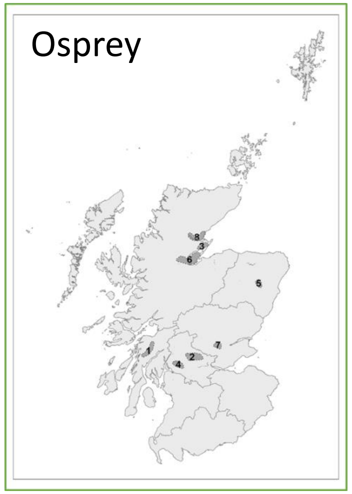

Merlin


Osprey

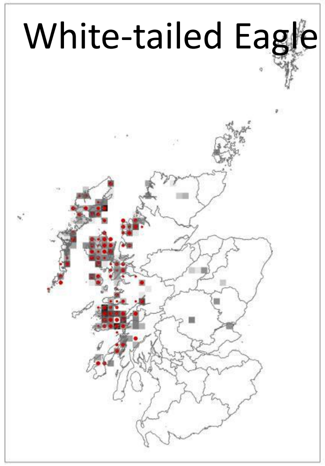

Hen Harrier

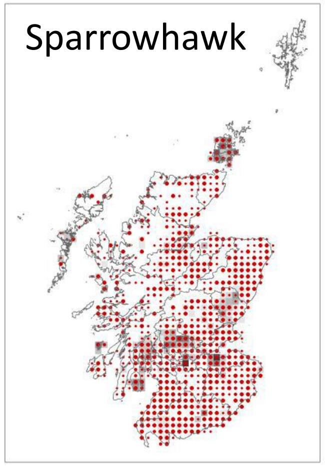

Kestrel

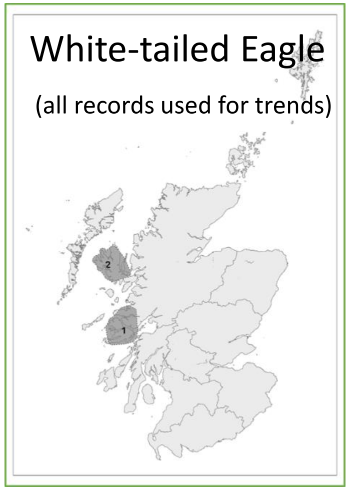

Merlin


Osprey


Peregrine
Raven
Red Kite
Tawny Owl
Peregrine
Raven
Red Kite
Tawny Owl







Sparrowhawk

(no clusters available)

Table 2. Current monitoring gaps for Scottish Raptor Monitoring Scheme species (with reference to maps in Figure 4). Column 2 indicates the number of SRMS regions for which a trend in breeding pairs could be derived / the number of SRMS regions in which the species breeds regularly (to provide a simple measure of the extent to which coverage is representative of the Scottish population currently).

Species	**SRMS regions with trends in numbers**	**Geographical gaps**	**Any specific parameter gaps**	**Other gaps/suggestions**
Species with trends				
Barn Owl	3/8	Needs additional study areas from all parts of the range except SW Scotland.	As for geographical.	Needs updated guidance on how to approach nest box studies rigorously.
Buzzard	3/12	A low proportion of the Scottish range is represented; in particular, would benefit from data from south of the Central Belt and from Angus/NE, where abundances are high. Large parts of the Highlands and islands are also not adequately represented. BBS trend available. *Raptor Patch* has a role to play.	No productivity data from the North East, and few from the south-west, the west Highlands, and north and west Tayside.	Patch-based monitoring essential for this species because of fluidity of territories.
Golden Eagle	4/10	Lewis & Harris and NE Scotland are the major gaps in coverage, along with Argyll and some other islands with abundant populations (Skye, Mull).	Productivity data required from NE Scotland.	Some important monitoring data are not currently shared with the SRMS.
Goshawk	1/7	Needs additional study areas from most parts of the range.	As for geographical.	Some important monitoring data are not currently shared with the SRMS.
Hen Harrier	6/11	Gaps in coverage exist in Caithness and East Sutherland, NE Scotland and the Uists in particular.		Patch-based monitoring essential for this species because of fluidity of territories.
Kestrel	1/11	Needs additional study areas from most parts of the range. *Raptor Patch* has a role to play.	Poor representation over much of the Highlands, North East Scotland and also much of Lothian & Borders.	Needs updated guidance on how to approach nest box studies rigorously.
Merlin	5/12	Needs additional coverage from northern Scotland, Lewis and Uists.	Productivity data biased towards eastern areas (more required from Highland and Lewis).	Patch-based monitoring essential for this species because of fluidity of territories. Data from Shetland now available for future use.

Osprey	5/8	Needs additional coverage south of the Central Belt (and to monitor range expansion), and in the heart of the Scottish range (including Speyside).	As for geographical.	Some important monitoring data are not currently shared with the SRMS.
Peregrine	8/12	Coverage of Highland Region and Central Lowlands (including urban areas) are major gaps in the national trend information.	Information on brood size at fledging should be obtainable from more regions.	
Raven	6/12	Coverage biased towards southern Scotland. More coverage of Highland, the north and the islands required. *Raptor Patch* has a role to play.	More productivity data required from the north and west of the range (except Uist).	Data from Shetland now available for future use.
Red Kite	5/8	The main additional coverage needs relate to regions into which the species is expanding its breeding range. *Raptor Patch* could play a role in future.	Productivity data may not be representative of younger breeders in areas of range expansion.	Future monitoring needs to be appropriate for an expanding population.
Sparrowhawk	0/14	Needs additional study areas from all parts of the range. *Raptor Patch* has a role to play.	Trend only available for one NHZ (Central Scotland – Eastern Lowlands).	
Tawny Owl	2/8	Needs additional study areas from most parts of the range. *Raptor Patch* could play a role in future.	Productivity data is lacking from much of the Scottish (e.g. almost no data from eastern areas, the southwest, and most of Highland).	Needs updated guidance on how to approach nest box studies rigorously
White-tailed Eagle	4/7 + only species with national trend	Coverage currently adequate to produce a national trend in numbers but in future additional coverage will be needed to take account of breeding range expansion.	Productivity data may not be representative of younger breeders in areas of range expansion.	Future monitoring needs to be appropriate for an expanding population.
Species without any trends				
Hobby	Scarce breeder in Scotland. Not abundant enough yet for long-term trends (though probably more widespread than reported currently). Rare Breeding Birds Panel collate records.			
Honey Buzzard	Secretive breeder. Now the subject of detailed surveys but data not currently shared with SRMS.			
Little Owl	Scarce breeder in Scotland. Not abundant enough yet for long-term trends. Rare Breeding Birds Panel collate records.			
Long-eared Owl	Need for updated guidance for rigorous patch-based monitoring (breeding numbers very hard to assess).			
Marsh Harrier	Scarce breeder in Scotland. Not abundant enough yet for long-term trends. Rare Breeding Birds Panel collate records.			
Short-eared Owl	Need for updated guidance for rigorous patch-based monitoring (breeding numbers very hard to assess).			

For the future, SRMG will need to use the information in this table to make decisions about priorities for enhancing SRMS data collection. We will need to come to agreement on (a) the current relative quality of national and regional trends for each species and (b) which species and geographical areas are of highest priority in terms of addressing current gaps. Some enhancements might require species-specific plans, while others (such as increasing patch-based monitoring in certain regions) could benefit a broader range of species trends and be a cost-effective means of delivering more information from across Scotland. There is also a need to consider (and integrate, where appropriate, into analyses or reporting) raptor monitoring information collected by other schemes outside of the SRMS.

6.2 Monitoring gaps that apply to more than one species

Figure 5 compares the raptor species richness of monitoring effort from data submitted to the SRMS in recent years (2017-2019) with raptor species richness from Bird Atlas 2007-11 data (Balmer *et al.* 2013). This comparison highlights some extensive overall gaps in SRMS monitoring coverage (or in submission of monitoring data), principally across large parts of north and west Scotland, some of the islands and within some of the larger urban areas.

(a) 2017-2019 SRMS records species richness **(b) 2007-11 Bird Atlas raptor species richness**

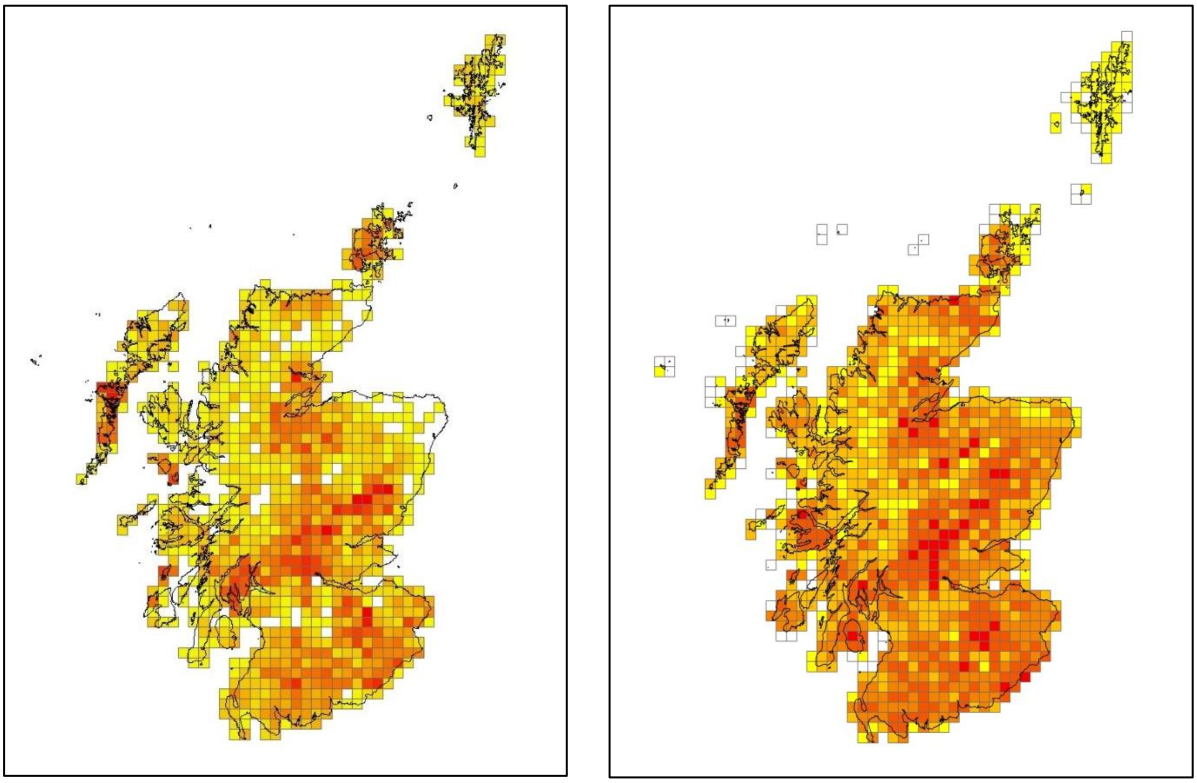


Figure 5: Scottish Raptor Monitoring Scheme coverage across Scotland in relation to species richness from Bird Atlas 2007-11 data. Fig. 5a shows the number of SRMS species for which occupancy (or absence) was recorded for each 10km square during the years 2017-2019 combined (based on records for which data suppliers have granted permission for their use in line with the SRMS Data Sharing & Use Policy). The maximum number of species checked for occupancy in a single square between 2017 and 2019 was 12 (from a total of 20 SRMS species). White squares indicate no monitoring records. Note that this figure masks variation in coverage at finer geographic scales, and work is ongoing to improve knowledge of coverage. Fig. 5b shows raptor species richness (the number of raptor species recorded) in each 10km square during Bird Atlas 2007-11 breeding season surveys for comparison.

As Figure 6 shows, these broader-scale gaps in monitoring coverage are not unexpected given the low human population densities in these areas (to provide a pool of people from which to source raptor monitoring volunteers). In fact, SRMS monitoring coverage is impressive across large areas where human population density is low (such as the southern and central highlands). However, some of the areas where coverage is sparse for many raptor species may require consideration of novel monitoring approaches (see Section 7.2).

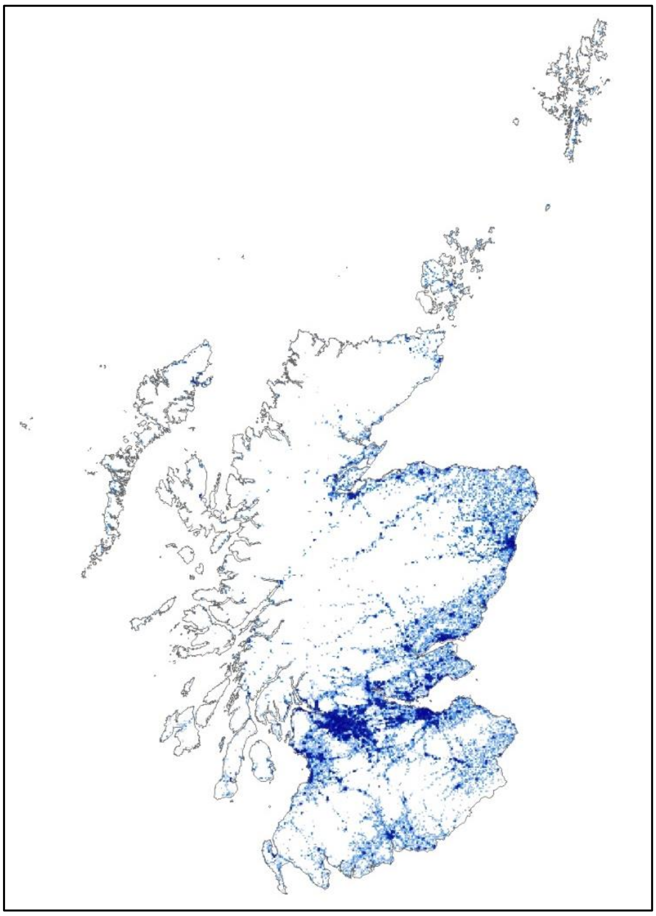


Figure 6: Relative human population densities across Scotland from National Census data (Reis *et al.* 2017).

6.3 Progress on SRMS enhancements recommended by Roos et al. (2013)

Table 3. Recommended enhancements to SRMS data curation to improve efficiency, cost effectiveness and biological value (following on from the previous review of SRMS data by Roos *et al.* 2013.)

Shortfall identified Roos et al. (2013)	**Explanation of importance Roos et al. (2013)**	**Actions for improvement /progress in 2013 Roos et al. (2013)**	**Current situation (2022)**
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**	**Full records (one record per breeding attempt) now submitted by most observers.** **SRMS Online will further improve this, with visit-by-visit data submission.**
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**	**Most records now supplied with grid references of at least 1-km resolution.**

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 AGREED TO DO THIS**	**SRMS Online recording platform now available and ensures that all essential information is collected in a standardised format suitable for efficient and effective analysis.**
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 AGREED TO DO THIS**	**SRMS Online recording platform now available and ensures that all essential information is collected in a standardised format suitable for efficient and effective analysis.**
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 AGREED TO DO THIS**	**SRMS Online recording platform now available and ensures that all essential information is collected in a standardised format suitable for efficient and effective analysis.**

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 AGREED TO DO THIS**	**SRMS Online recording platform now available and ensures that all essential information is collected in a standardised format suitable for efficient and effective analysis.**
Overall inadequacy of MS Ex	*el 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 AGREED TO DO THIS**	**SRMS Online recording platform now available and ensures that all essential information is collected in a standardised format suitable for efficient and effective analysis.**
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 AGREED TO DO THIS**	**SRMS Online recording platform now available and ensures that all essential information is collected in a standardised format suitable for efficient and effective analysis.**

7 Options for enhancement of monitoring coverage [SECTION FOR DEVELOPMENT AND DISCUSSION WITH SRMG]

7.1 Individual species enhancement (with reference to the table in section 6.1)

7.2 Geographical gaps / multi-species options

7.3 Role of patch-based monitoring (including the *Raptor Patch* initiative) – why this is so important for the production of rigorous trends. How a combination of SRSG patch-based work plus Raptor Patch could enhance this.

7.4 Enhancement of productivity parameter information - clutch size and brood size may be less of a focus because we might not wish to encourage more people to disturb raptors to record them (except perhaps for species where they be obtained easily – e.g. nest-box species). Brood size at fledging and breeding success should be higher priority to record widely and could be enhanced further – important to know all breeding attempts that are monitored to get rigorous and comparable samples of breeding success.

8 Role of SRMS data in providing the outputs from national surveys (population estimates and change measures) [SECTION FOR DEVELOPMENT AND DISCUSSION WITH SRMS]

- To include the work already carried out for Merlin to support decisions around a future national survey, and considerations for other species previously the subject of SCARABBS surveys
- To assess the extent to which current SRMS monitoring coverage could be expanded to replace or better support national surveys in future

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