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The Scottish Raptor Monitoring Scheme: recent developments in good practice monitoring

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ABSTRACT

Capsule: The Scottish Raptor Monitoring Scheme (SRMS) has been operational for 15 years and provides many examples of how nationwide monitoring programmes for raptors and other scarce bird species could be developed.

Aims: To share experiences and approaches to the coordination of a nationwide raptor monitoring programme that other countries can use when embarking on their own monitoring programme for raptors or other scarce species.

Methods: We present seven current developments to enhance the SRMS, including: (i) profile raising, (ii) producing robust population trends, (iii) increasing monitoring of widespread species, (iv) expanding the volunteer network, (v) enhancing reporting on causes of breeding failure, (vi) developing an online data entry system and (vii) mobilizing data for conservation purposes.

Results: We present the first results on survey coverage and trends of raptor species in Scotland and highlight some of the challenges, including production of trends, data mobilization and lack of diverse income streams.

Conclusion: We recommend that new raptor monitoring programme should at the outset ensure that the aims of the monitoring programme are clearly defined and that agreement is reached regarding how data will be stored and shared. Consideration should be given to the potential uses of the data and the intended outputs from the programme, and the suitability of scheme design to meet the agreed objectives. A recording system that captures all required aspects of the data recording should be devised and implemented at an early stage.

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The Scottish Raptor Monitoring Scheme (hereafter SRMS or 'the Scheme') was established in 2002. An earlier review (Wernham *et al.* 2008) described the background, establishment and structure of the SRMS and discussed the challenges and experiences during the first four years. Here we aim to build on this earlier review to share our experience of a raptor monitoring scheme that has now been operating for 15 years and make recommendations to other countries or programmes looking to embark on their own monitoring programme of scarce birds.

Aims of the SRMS

A key role for the SRMS is to provide robust information on Scottish raptor populations, especially trends in numbers, range and productivity, and also to understand causes of population change and pressures on raptor populations. Trend information is critical to the assessment of a species' conservation status. With other information, population trends can help to develop an understanding of the causes of demographic change, thus identifying issues that can be addressed to make raptor conservation more effective.

The SRMS aims to produce population trends for species at three different scales: (i) local study area, (ii) regional (both SRMS regions (http://raptormonitoring.org/srms-regions) and the biogeographical zones used by the devolved Scottish Government and its agencies, i.e. Natural Heritage Zones (http://raptormonitoring.org/natural-heritage-zones) and (iii) national (for Scotland). Scottish data are also a critical (sometimes sole) input to UK conservation status assessments for some raptor species. Deriving robust national trends is dependent on having thorough regional trends, which in turn are

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dependent on having representative raptor monitoring coverage at a more local level.

Scottish raptor populations

The SRMS currently focuses primarily on annual monitoring of the abundance, distribution and breeding success of 19 species native to Scotland: 14 diurnal raptors, 4 owls and 1 corvid. Scotland holds the entire or majority of the UK populations of several raptor species. Table 1 provides the most recent estimates for the population size of these species in Scotland, the number of pairs monitored in 2015 and also an indication of the ability of the SRMS to be able to produce national and regional trends in both numbers and productivity from the data held by the Scheme.

Structure and operation of the SRMS

The SRMS partnership comprises statutory organizations (Scottish Natural Heritage, Forestry Commission Scotland, Forestry Enterprise Scotland and Joint Nature Conservation Committee), non-governmental organizations (British Trust for Ornithology, Rare Breeding Birds Panel and the Royal Society for the Protection of Birds) and volunteer-led organizations (Scottish Ornithologists' Club and the Scottish Raptor Study Group). With the exception of Forestry Commission Scotland and Forest Enterprise Scotland (which joined the SRMS in 2013 and 2017, respectively), all partners have been involved from the outset. Each of the nine partners is heavily involved in Scottish ornithology and/or conservation, and has expertise in rigorous scientific study of birds, and each brings its own perspectives and experience in raptor and wider monitoring to the Scheme.

The Scottish Raptor Monitoring Group consists of representatives from the nine partner organizations. This steering group meets 3–4 times a year to discuss and agree the work programme of the Scheme. The day-to-day running of the Scheme is undertaken by the Scottish Raptor Monitoring Coordinator, who is employed by the British Trust for Ornithology, a strictly impartial organization, on behalf of the partnership. The Scottish Raptor Monitoring Coordinator role was created in 2014 and is a full-time position to replace a part-time Raptor Monitoring Officer position, which existed until 2013.

SRMS methodology, data submission, curation and analysis

All our data contributors are encouraged to follow best practice guidance set out in Hardey *et al.* (2013). Annually, the SRMS now receives more than 6000 records of checked raptor home ranges, double the number of records received in the early years of the Scheme. This represents a tremendous amount of effort from SRMS contributors. Members of the Scottish Raptor Study Group, who undertake raptor monitoring fieldwork in a voluntary capacity, submit the vast majority of data to the SRMS, with further contributions from other Scheme partners and a small number of ecological consultancies.

Most SRMS data are submitted electronically, using a custom-designed Excel spreadsheet. The spreadsheet is currently the best means of ensuring that data are submitted in a consistent format. A single row is completed per home range annually and the information captured includes observer, site details and information regarding the current breeding season (e.g. visit dates, clutch size and number of fledglings). For many attributes, drop-down lists of options help ensure consistency.

Expertise in data curation and analysis is essential to being able to maximize data use. In the SRMS this expertise is primarily provided by the British Trust for Ornithology, which provides data curation, research and analytical support for the partnership. When data are received they are checked for errors and missing data and amended to produce a final, quality-assured dataset. This process ensures, for example, that observer, species, site names and codes and habitat information are reported in a standardized manner, consistent over time. Data are also checked for any duplication arising when data for the same home range occasionally reaches the SRMS via several routes. This 'data-cleaning' process is becoming increasingly automated, using bespoke programs developed in software such as SAS (SAS Institute Inc. 2014) and R (R Core Team 2015), which helps to minimize the amount of manual checking and updating needed.

Recent developments in the SRMS

An earlier review of the Scheme (Wernham *et al.* 2008) highlighted planned developments for the future, including: improving coverage; enhancing the value of the data that are collected; developing analysis and reporting; and ensuring the long-term success of the SRMS. Over the last three years, the Scottish Raptor Monitoring Group, which oversees the SRMS work programme, has been implementing developments to make the SRMS more modern and efficient. The Group aims to shift the focus of its work from purely cleaning and curating submitted data to making information products from the Scheme more available

Table 1. A list of the 19 raptor species that the SRMS covers summarizing the current state of monitoring and potential for trends production and the number of pairs monitored in 2015.

Species	Estimated Scottish population size	Number of pairs monitored in Scotland in 2015	Summary of current state of monitoring and potential for trend production
European Honey-buzzard *Pernis apivorus*	<10 pairs 2003–15 (Challis *et al.* 2016), but likely to be somewhat higher.	1	Monitoring coverage of this species is poor. Too few breeding pairs for formal trend analysis.
Red Kite *Milvus milvus*	A minimum of 273 pairs in 2015 (Challis *et al.* 2016), but likely to be somewhat higher.	245	Comprehensive monitoring of numbers and breeding parameters. Trends in both numbers and productivity are feasible at both regional and national scales.
White-tailed Eagle *Haliaeetus albicilla*	A minimum of 91 pairs in 2015 (Challis *et al.* 2016)	96	Comprehensive monitoring of numbers and breeding parameters. Trends in both numbers and productivity are feasible at both regional and national scales.
Eurasian Marsh Harrier *Circus aeruginosus*	<10 pairs 2003–15 (Challis *et al.* 2016)	6	Too few breeding pairs for formal trend analysis.
Hen Harrier *Circus cyaneus*	Wotton *et al.* (2018)	276	Widespread monitoring across Scotland of both numbers and productivity (in discrete study areas). Trend production limited pending further work on coverage and distribution. Trends likely to be possible for at least some regions and national trends may be possible.
Northern Goshawk *Accipiter gentilis*	Unknown. UK population of 437–616 pairs in 2015 (Holling *et al.* 2017)	146	Studies in three study areas only. Trends production limited by lack of detailed spatial information, lack of coverage information and some information only in summary form.
Eurasian Sparrowhawk *Accipiter nisus*	Unknown. UK population of 35 000 pairs in 2009 (Musgrove *et al.* 2013)	69	Historical trends potential from one rural and one urban area only (studies terminated in 2012 and 2016, respectively).
Common Buzzard *Buteo buteo*	Unknown. UK population of 57 000–77 000 pairs in 2009 (Musgrove *et al.* 2013)	440	Some high-quality studies for regional trend production but unlikely to be representative nationally.
Golden Eagle *Aquila chrysaetos*	508 territorial pairs in 2015 (Hayhow *et al.* 2017)	482	Widespread monitoring across Scotland of both numbers and productivity. Trend production limited pending further work on coverage and distribution. Trends likely to be possible for at least some regions and nationally.
Osprey *Pandion haliaetus*	216 pairs in 2015 (Challis *et al.* 2016)	212	Coverage and data quality likely to be good. Trend production limited by lack of grid-referencing and lack of coverage information. Trends likely to be possible for at least some regions and national trends may be possible.
Barn Owl *Tyto alba*	500–1000 pairs post 2004 (Shaw, 2007)	335	Trends in numbers and productivity likely to be possible from a number of study areas.
Tawny Owl *Strix aluco*	Unknown. UK population of 50 000 territorial pairs in 2015 (Musgrove *et al.* 2013)	165	Trends in numbers and productivity likely to be possible from a small number of study areas.
Long-eared Owl *Asio otus*	Unknown. UK population of 1800–6000 pairs in 2007–11 (Musgrove *et al.* 2013)	44	Monitoring too variable to produce any rigorous trends.
Short-eared Owl *Asio flammeus*	Unknown. UK population of 620–2180 pairs in 2007–11 (Musgrove *et al.* 2013)	78	Monitoring too variable to produce any rigorous trends.
Common Kestrel *Falco tinnunculus*	2750–5500 pairs in 2013 (Wilson *et al.* 2015)	145	Study in, and trend potential from, one area only. Data quality from this study will be high.
Merlin *Falco columbarius*	733 in 2008 (Ewing *et al.* 2011)	171	Widespread monitoring across Scotland of both numbers and productivity (in discrete study areas). Trend production limited pending further work on coverage and distribution. Trends likely to be possible for at least some regions and national trends may be possible.
Eurasian Hobby *Falco subbuteo*	Unknown. Great Britain population of 2800 pairs in 2009 (Musgrove *et al.* 2013)	0	Too few pairs breed for formal trend analysis.
Peregrine *Falco peregrinus*	516 pairs (479–575) in 2014 (Wilson *et al.* 2018)	264	Widespread monitoring across Scotland of both numbers and productivity. Trend production limited by lack of coverage information. Trends possible for at least some regions.
Northern Raven *Corvus corax*	Unknown. UK & Isle of Man population of 7400 pairs in 2009 (Musgrove *et al.* 2013)	366	Widespread monitoring across parts of Scotland of both numbers and productivity (in discrete study areas). Trend production limited pending further work on coverage and distribution. Trends likely to be possible for some regions and national trends should be possible in future.

for the benefit of raptor conservation and wider society. This will enable other rural activities, such as forestry, development and recreation, to take raptor conservation into consideration. Below we describe recent developments along with a discussion of the challenges the SRMS has faced in achieving them.

(a) Profile raising

The SRMS created its own, profile-raising website (http://raptormonitoring.org) in 2014. It has proved popular with users, with a high and stable number of visits annually (1637 in 2015, 1682 in 2016, 1895 in 2017 and 1088 to 31 May 2018). Additionally, from its inception in 2002, the SRMS has produced an annual report (http://raptormonitoring.org/annual-report) distributed to all scheme contributors, as well as to specific individuals within partner organizations and other target individuals within relevant conservation, policy and land management organizations. In 2016, the format of the annual report was enhanced with inclusion of articles on different aspects of SRMS work, using the new SRMS website to present useful supplementary information. In future, we anticipate that the website will be the principal mechanism through which SRMS data are reported to a wide range of stakeholders. The SRMS also issues an electronic newsletter 2–3 times a year, to keep its contributors and other interested individuals up to date with relevant activities (http://raptormonitoring.org/scottish-raptor).

(b) Producing robust trends

There is a long history of raptor monitoring in Scotland pre-dating SRMS. Many of the long-term studies now contributing records to the SRMS annually were not established with the aim of producing long-term trend information. Thus the SRMS has had to consider carefully how these data can be used to produce representative trends. High quality and accurate population trends can be generated from: (i) a comprehensive and consistent survey of an entire area of interest (i.e. the whole of Scotland, a whole region or a single study area) or (ii) a consistent sample of sub-areas that are together representative of a geographical area. When using SRMS data to generate such high-quality estimates of population trends, the territories and breeding attempts monitored must not be a biased sample, and sample areas surveyed need to be representative of the wider areas to be reported upon. In addition to reporting trends in breeding numbers, the SRMS aims to report trends in productivity parameters, including clutch size, hatching success, brood size, fledging success and number of fledglings produced per successful pair.

Provisional trends in breeding numbers and productivity have been published for many raptor species in Scotland based largely on SRMS data (Roos *et al.* 2015). These trends are considered provisional as the coverage and survey effort that went in to collecting the underlying monitoring data could not be thoroughly assessed ahead of trends production. A priority for SRMS is to build on the recommendations of Roos *et al.* (2015) and update these trends, with the aim of publishing them on the SRMS website when they are finalized.

In 2016, the SRMS was able to finalize robust national Scottish trends, as well as regional trends, for White-tailed Eagle *Haliaeetus albicilla*, covering the period from 1983 to 2015. Trends for White-tailed Eagle have been relatively straightforward to update because up until relatively recently the whole population received complete monitoring coverage and survey effort has been consistent between years. Table 2 shows the national trend in breeding numbers and various productivity parameters between 1983 and 2015. White-tailed Eagles have shown a linear increase in breeding numbers since the species was reintroduced to Scotland more than 30 years ago (Table 2 and Figure 1). Over the period 1985–2015 there has been a linear increase in the fledging success of White-tailed Eagle pairs in Scotland, with a mean (±se) probability of fledging of 0.61 ± 0.02 (Table 2 and Figure 2). The regional trends that have been produced (Table 3) show some interesting patterns. For example, the fledging success has increased significantly in Argyll between 1998 and 2015, with a particular strong increase up to 2006. Here, on average, 68 ± 3% (mean

Table 2. National population trends in the breeding White-tailed Eagle population between 1983 and 2015.

Parameter	Period	Years	Mean annual sample ± se	Type of trend	Mean ± se
Breeding pairs	1983–2015	33	NA*	Linear increase	27.4 ± 4.4
Laying pairs	1995–2015	21	38.3 ± 5.2	Linear increase	0.9 ± 0.0
Clutch size	1983–2015	33	20. 5 ± 2.9	Stable	1.5 ± 0.0
Hatching success	1995–2015	21	36.7 ± 4.6	Linear increase	0.7 ± 0.0
Brood size	1995–2015	21	24.0 ± 3.3	Stable	1.5 ± 0.0
Fledging success	1985–2015	31	24.6 ± 3.9	Linear increase	0.6 ± 0.0
Number of fledglings	1995–2015	21	20.8 ± 3.3	Stable	1.4 ± 0.0

*As there was comprehensive monitoring coverage throughout the period 1983–2015 the mean annual sample is effectively 100% (i.e. not a sample at all) as the whole population was monitored.

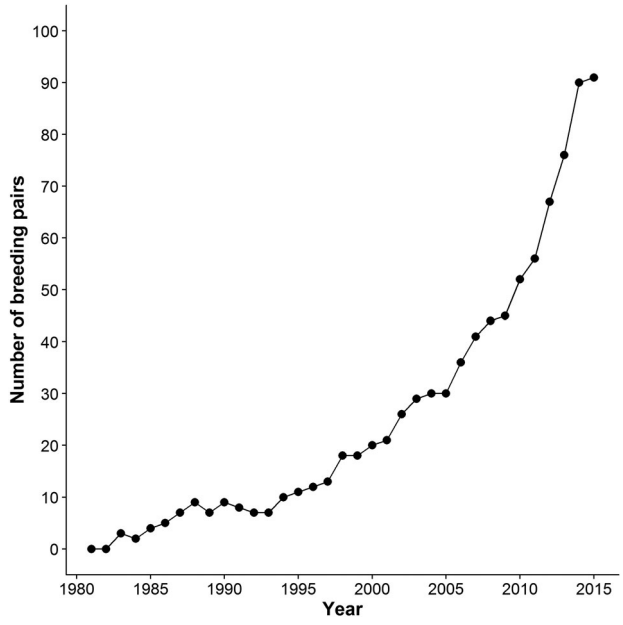


Figure 1. Trend in breeding numbers of White-tailed Eagle in Scotland between 1981 and 2015.

± se) of the pairs were successful (i.e. producing at least one fledgling; Figure 3). In contrast, in the Highlands there has been no significant change in fledging success between 1994 and 2015, with an average of 56 ± 3% of the pairs being successful (Figure 4). Further regional trends are available at http://raptormonitoring.org/srms-species/accipitriformes/white-tailed-eagle).

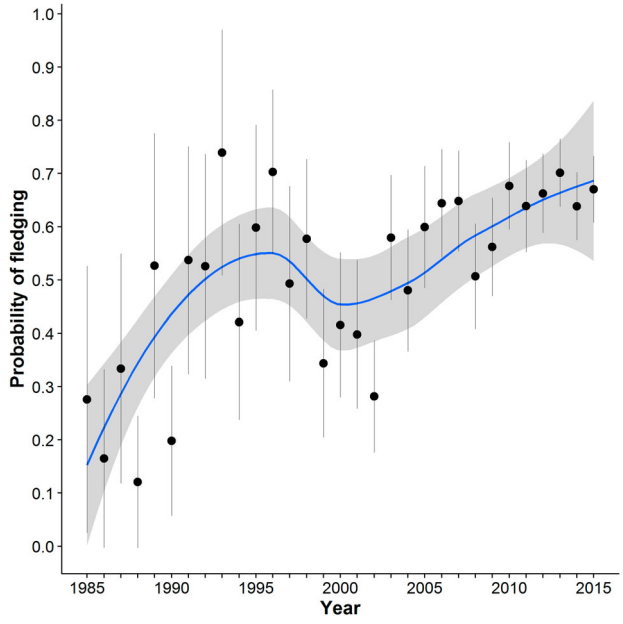


Figure 2. Trend in fledging success of White-tailed Eagle in Scotland between 1985 and 2015. The annual means are shown as black circles, with bars representing 1 standard error (se). The blue line shows the smoothed trend and associated se (grey area). The smooth trend should be used as a visual aid only.

The SRMS is now working on finalizing local study area trends, such as for Common Kestrel *Falco tinnunculus* (see http://raptormonitoring.org/srms-species/falconiformes/common-kestrel/ayrshire-study). This is particularly welcome, because the latest Breeding Bird Survey shows that Common Kestrels have declined by 69% between 1994 and 2015 in Scotland. To better understand the causes of the Kestrel population decline, enhanced monitoring coverage across broader areas of Scotland than are currently covered by the Breeding Bird Survey would be extremely beneficial.

At present, it is not possible to produce robust national or regional trends for other species since the extent to which currently collected data are representative cannot be assessed from the standard information that has been submitted to the Scheme each year to date. This is because the SRMS does not receive information about year-to-year changes in the timing, locations or overall effort of surveys by observers. The Scottish Raptor Monitoring Coordinator is now working in close collaboration with individual raptor workers to assess the feasibility of producing trends for their species and study areas. Talking to raptor workers about how their survey effort and coverage have varied over time, and between different areas, will allow us to take account of this variation in order to produce local trends that are scientifically robust. These local trends will, in turn, inform trends at wider scales. These discussions are also helping to inform decisions about future recording of survey coverage and effort, and how this could be built into the new online reporting system. In making these decisions, we recognize the difficulty of achieving an appropriate balance between the need for collecting robust information, and ensuring that recording and reporting this information does not become too onerous for raptor workers. Simple measures of survey effort (e.g. time spent in the field) are often difficult to compare between areas, species or observers, because of differences between species and habitats in the effort required to survey them, and differences between observers in their ability to survey raptors. However, it should be possible to use such simple measures to evaluate changes in effort in a single-species study area covered by the same observer(s) for the duration of the period being considered. On this basis, we can account for the effects of changes in survey effort over time within individual studies on the data that these studies collect and contribute to the SRMS.

(c) Increasing monitoring of widespread species

A recent review of SRMS data (Roos *et al.* 2015) demonstrated the potential to produce rigorous trends

Table 3. Summary of White-tailed Eagle regional population trends based on SRMS regions updated to 2015. For a map of SRMS regions please visit: http://raptormonitoring.org/srms-regions.

SRMS region	Parameter	Period	Years	Mean annual sample size	Type of trend	Mean ± se
Argyll	Breeding pairs	1998–2015	18	NA*	Linear increase	13.3 ± 1.9
	Clutch size	1998–2014	17	9.7 ± 1.1	Stable	1.6 ± 0.0
	Hatching success	2007–2015	9	17.6 ± 1.8	Stable	0.8 ± 0.0
	Brood size	2000–2015	16	9.9 ± 1.2	Stable	1.4 ± 0.4
	Fledging success	1998–2015	18	11.8 ± 1.7	Linear increase	0.7 ± 0.0
	No. fledglings	2005–2015	11	11.5 ± 1.4	Stable	1.3 ± 0.0
Highland	Breeding pairs	1987–2015	29	NA*	Linear increase	14.3 ± 1.8
	Clutch size	1990–2015	26	11.8 ± 1.3	Stable	1.4 ± 0.0
	Hatching success	1996–2015	20	17.1 ± 1.5	Stable	0.7 ± 0.0
	Brood size	1995–2015	21	10.2 ± 1.2	Stable	1.5 ± 0.0
	Fledging success	1994–2015	22	14.6 ± 1.5	Stable	0.6 ± 0.0
	No. fledglings	1998–2015	18	9.3 ± 1.0	Stable	1.4 ± 0.0
Lewis & Harris	Breeding pairs	2004–2015	12	NA*	Linear increase	9.4 ± 1.2
	Clutch size	2005–2015	11	8.6 ± 1.2	Stable	1.5 ± 0.1
	Hatching success	2006–2015	10	10.2 ± 1.4	Stable	0.6 ± 0.1
	Brood size	2005–2015	11	6.1 ± 0.9	Stable	1.6 ± 0.1
	Fledging success	2008–2015	8	9.3 ± 1.3	Linear increase	0.6 ± 0.1
	No. fledglings	2007–2015	9	5.6 ± 1.0	Stable	1.6 ± 0.1

*No annual sample was calculated, because we were not dealing with a sample of breeding pairs, as we had full knowledge of every pair. Therefore, we give the mean annual number of pairs in the column 'Mean ± se'.
**Sample size too small for meaningful trend production.

in breeding numbers and productivity for several Scottish raptor species, and identified those areas and species for which enhanced monitoring coverage would be beneficial. In general, scarcer species (e.g. those on the European Union Birds Directive Annex I) are surveyed more widely by Scottish Raptor Study Group members, whilst a number of more widespread species such as Common Kestrel, Eurasian Sparrowhawk *Accipiter nisus* and a number of owl species would benefit from enhanced monitoring. Scarcer raptor species have, understandably, attracted more attention

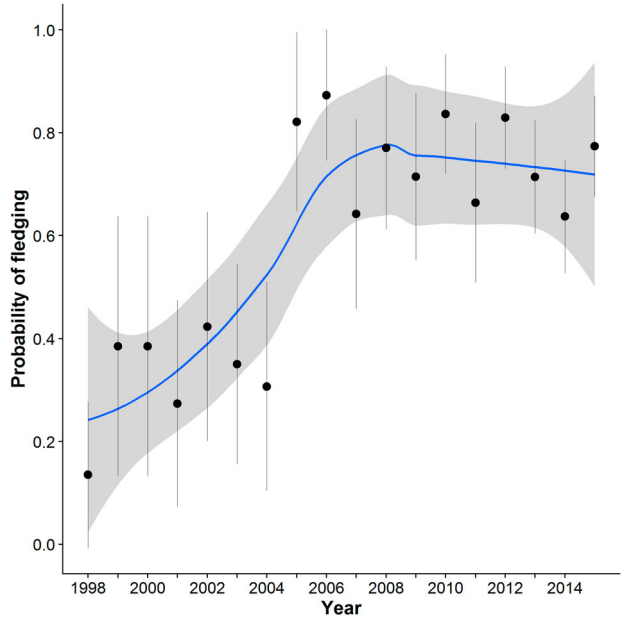


Figure 3. The proportion of White-tailed Eagle pairs in the Argyll SRMS regions breeding successfully (i.e. producing at least one fledging) between 1998 and 2015.

for a number of reasons, including conservation concern (and the need for periodic national surveys), enthusiasm for finding and watching unusual birds, and the challenge of improving our knowledge of rare and elusive species. However, there is an increasing recognition that more information is needed about commoner raptor species too. Some of these more abundant raptors have declined significantly in recent years, for example the Common Kestrel, which in Scotland has declined by 69% between 1995 and 2015 according to the Breeding Bird Survey (Harris *et al.* 2017). Thus, the SRMS launched pilot work for a new initiative in 2016, called *Raptor Patch*. One of the aims of this initiative is to provide additional information for more widespread raptor species that can be used to generate trends. In the pilot year, *Raptor Patch* focused on the monitoring of four species: Common Buzzard *Buteo buteo*, Common Kestrel, Eurasian Sparrowhawk and Northern Raven *Corvus corax*. There are only a few long-term studies of these species in Scotland, so they are currently under-recorded in most areas, even in areas where other species are monitored (Figure 5). The SRMS has tried to make *Raptor Patch* appealing to birdwatchers and ornithologists not currently involved in raptor monitoring by providing training courses (see below) and to encourage individuals to monitor a defined geographic area (or 'patch') where they will ultimately become familiar with all breeding raptors present. Most patches are self-selected by the participant, in discussion with the Scottish Raptor Monitoring Coordinator. In each case, the aim is to delineate an area that is representative of the wider landscape, easy to access by the participant, and in which complete monitoring coverage can be achieved

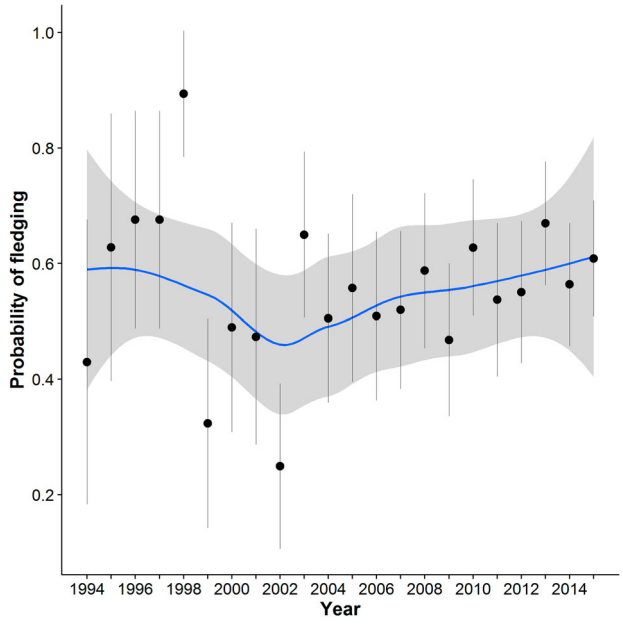
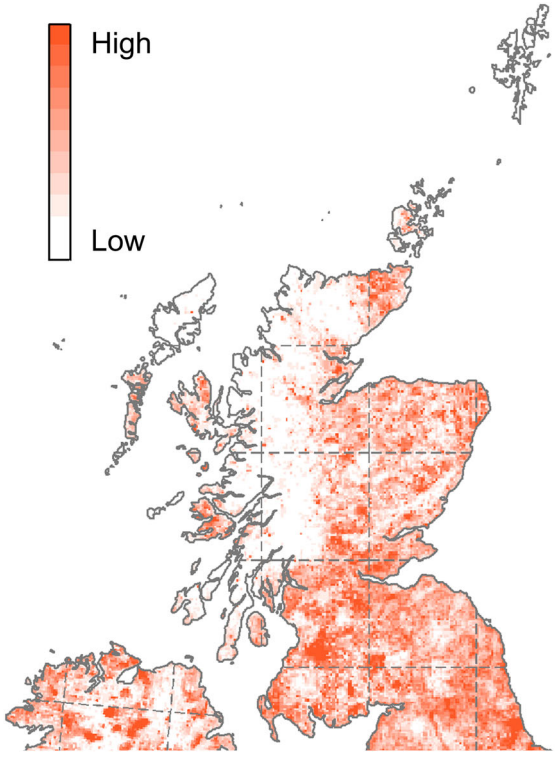


Figure 4. The proportion of White-tailed Eagle pairs in the Highland SRMS region breeding successfully (i.e. producing at least one fledging) between 1994 and 2015.

for at least one of the *Raptor Patch* species. Selected patches are typically around 4 km^2 in size but they can be larger, as long as appropriate complete coverage can be achieved. This area-based approach is similar to the model used by both the Estonian raptor monitoring programme (Nellis 2012) and the Finnish Raptor Grid (Saurola 2012). Our recommended patch size, while significantly smaller that the Finnish 10 km × 10 km grid squares, is more manageable for novice raptor workers to take on with the aim of achieving complete coverage, particularly when working alone. The other main difference between the Scottish model and those adopted in Estonia and Finland is the lack of stratified random sampling to select study areas. If this approach was adopted in Scotland, it is likely that participants would have to travel further to get to their study areas, which could discourage some volunteers from committing enough time and effort to take part.

As the SRMS is only just completing the second pilot year of this project, any long-term benefits are yet to be realized, but the Scottish Raptor Monitoring Group is hopeful that *Raptor Patch* will provide a valuable model for future development. The Scottish Raptor Monitoring Group will shortly review whether the model of self-selected patches and recommended patch size is appropriate for the information the SRMS seeks to generate and will consider what else can be done to train and support volunteers, including fostering greater team work. In addition to *Raptor Patch*, as further coverage and trends information is produced



SRMS Region	Pairs monitored
Argyll	8
Central	23
D & G	8
Highland	23
Lewis & Harris	0
Lothian & Borders	23
North-east	0
Orkney	18
Shetland	N/A
South Strathclyde	21
Tayside	27
Uist	4
TOTAL:	145

Figure 5. Relative abundance map for the Common Kestrel from the most recent, 2007–11 Atlas, with darker red showing higher densities (Balmer *et al.* 2013). The inserted table shows the number of pairs monitored in different SRMS regions of Scotland in 2015 (Challis *et al.* 2016; for locations of SRMS regions, see Figure 6). The low number of pairs monitored in most SRMS regions suggests that there is the need for enhanced coverage across Scotland. Map reproduced with permission of the British Trust for Ornithology.

from the SRMS, species-specific guidance for enhancing raptor monitoring coverage in Scotland will be developed, so that the monitoring effort of volunteers can be targeted most effectively into geographic areas or habitats that currently have low/no coverage.

(d) Expanding the Scottish raptor volunteer network

The age profile of the existing SRMS contributors is skewed towards older age-groups. To ensure the valuable long-term studies carried out by existing Scottish Raptor Study Group members are maintained, and to have opportunity to enhance monitoring coverage in future, it is important to recruit new and younger raptor workers.

One of the ways that the SRMS is trying to involve more people in raptor monitoring is through the new initiative *Raptor Patch* (see above). Apart from increasing monitoring of widespread raptors, the project aims to: (i) complement the training/mentoring already being carried out by the Scottish Raptor Study Group; (ii) stimulate new volunteers through giving them the skills and confidence to start their way up the 'volunteering progression ladder' and (iii) provide a source of competent and committed volunteers to feed through to the Scottish Raptor Study Group for further mentoring and encouragement to take up long-term studies.

In March 2016 and March 2017, the SRMS ran two *Raptor Patch* training days with support from existing Scottish Raptor Study Group members with expertise in the four focal species. These events were attended by nearly 50 participants in total, and take up of raptor patches following these training events has been very encouraging. In addition to the training provided at these events, SRMS has made guidance and training materials available via the SRMS website (http://raptormonitoring.org/getting-involved/raptor-patch) and created an online forum for *Raptor Patch* volunteers to keep in touch with each other and ask questions of more experienced raptor workers.

(e) Enhancing reporting on causes of breeding failure

Every year a proportion of raptor breeding attempts will fail (Newton 1979). The SRMS database allows exploration of temporal and spatial patterns in breeding success and causes of failure.

In Scotland, the deliberate illegal killing of raptors is of significant concern to SRMS partners and other stakeholders, and such killing has been shown to constrain several raptor populations. A recent review of the movements and fates of Golden Eagles *Aquila chrysaetos* satellite tagged during 2004–16 highlights illegal persecution as a major factor in artificially restricting the Golden Eagle population in Scotland (Whitfield & Fielding 2017), supporting the earlier findings of a Conservation Framework for Golden Eagle (Whitfield *et al.* 2008). Similarly, a Conservation Framework for Hen Harrier *Circus cyaneus* presented strong evidence that illegal persecution was causing the failure of a majority of breeding attempts in five biogeographic regions of Scotland, leading to reduced occupancy and/or fewer successful nests (Fielding *et al.* 2011). Recent studies have shown that illegal killing is the major factor limiting population growth of Red Kites *Milvus milvus* in north Scotland (Smart *et al.* 2010, Sansom *et al.* 2016). There is, therefore, particular interest in improving understanding of information about human causes of failure held in the SRMS database, and enabling these data to be used by SRMS partner organizations and others (such as the UK National Wildlife Crime Unit) to help to combat wildlife crime.

While SRMS has always encouraged the collection of cause of failure information, most of this was not captured in a standardized way. With advice from the UK National Wildlife Crime Unit, a standardized coding system is now used to summarize breeding outcomes. All records held by the SRMS have now been retrospectively coded to manually assign a cause of failure to every record of a failed breeding attempt held in the database, along with any supporting evidence for the cause of failure (in both cases dependent on the original supply of relevant information). Figure 6 shows an example of geographic patterns in Hen Harrier breeding outcomes in a single year from SRMS information. The new coding system will be available in the new online recording system being developed (see (f) below) so that in future cause of failure information will be recorded in a standardized and strictly objective manner from the outset.

(f) Developing an online data entry system

While the custom-designed Excel spreadsheet has served the SRMS well for the last 15 years, many volunteers find it cumbersome to use. Moreover, it does not allow the collection of all the information that the Scottish Raptor Monitoring Group now recognizes would be useful, such as coverage and survey effort information (to allow production of statistically robust population trends) and visit-by-visit information (to allow better understanding of rates and timing of breeding failures).

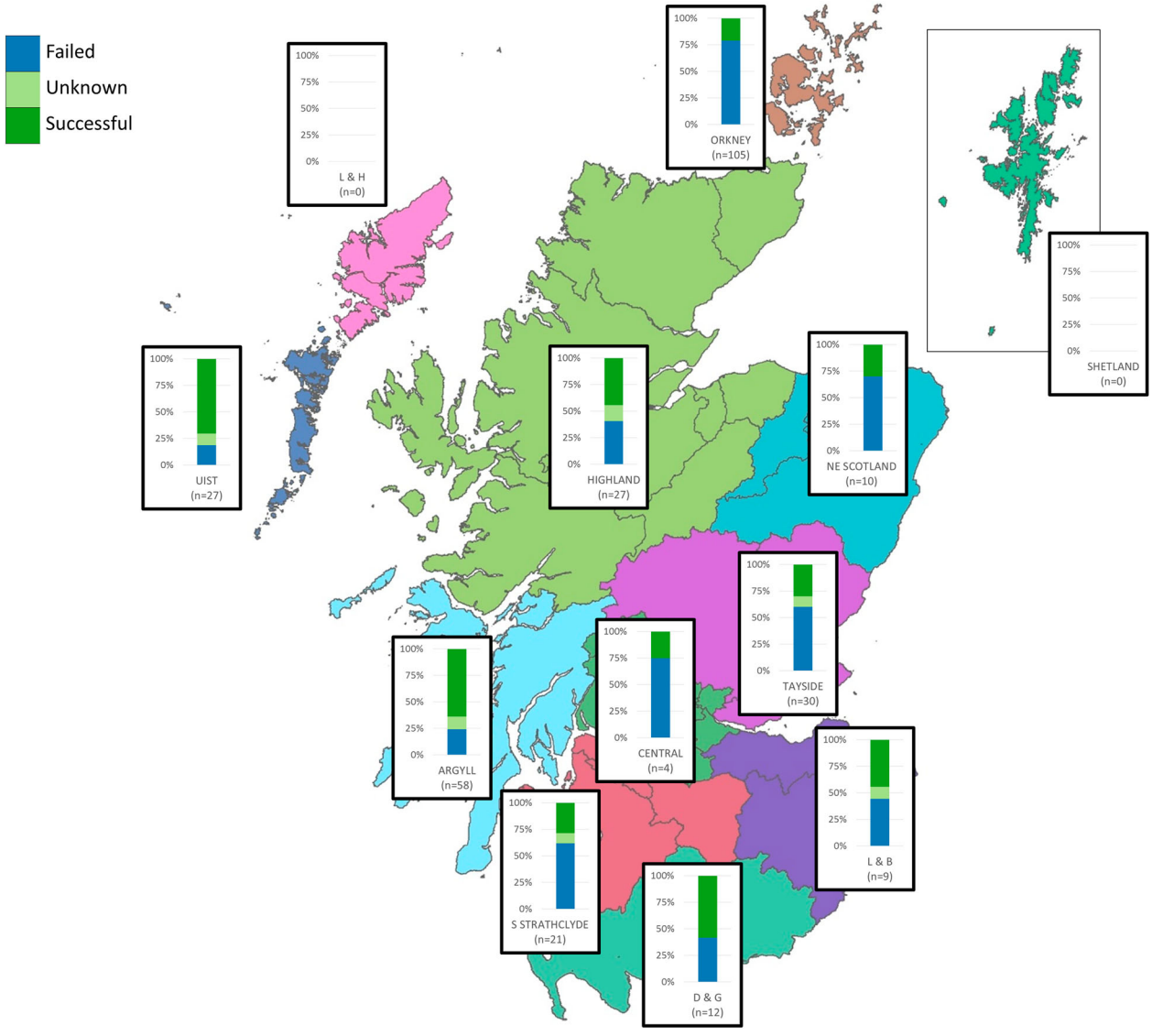


Figure 6. Proportion of breeding pairs of Hen Harrier that were successful, failed or the outcome was unknown in each SRMS regions of Scotland in 2015. D&G = Dumfries & Galloway, L&H = Lewis & Harris and L&B = Lothian & Borders.

From 2018, the SRMS will be implementing an online data entry system, similar to those now used by other biological recording schemes. The SRMS is capitalizing on work that is being undertaken by the British Trust for Ornithology to improve ringing and Nest Record Scheme (Crick *et al.* 2003) data submission. This will greatly assist in providing most of the infrastructure that will be required to support entry, collation and storage of SRMS data and information.

The future online system will make data submission and handling easier and more efficient, and will enable raptor workers to visualize and share their own data with others. From the point of view of the raptor worker, the enhanced capability within the software to link the SRMS with the Ringing Scheme for Britain and Ireland as well as the Nest Record Scheme (the latter two schemes organized by the British Trust for Ornithology) should be advantageous and welcomed. Raptor workers will be able to submit ringing details, including re-sightings of marked birds and dead recoveries, via the online SRMS portal, which will save them time and make all reporting available using only one system. Another major advantage will be that fields will be prepopulated with existing information/data and volunteers will only need to update the relevant data (e.g. clutch size and fledgling numbers) each year. There will also be a mapping interface that will allow users to pinpoint sightings and nest sites on a map from which grid references will be automatically generated, which should minimize spatial errors that can occur when grid references are entered manually. The new system will allow standardized, annual

reporting of survey coverage and effort to SRMS for the first time, making production of high-quality trend information more efficient. This system will also allow SRMS to report more robustly on causes of failure. The online data entry system is designed to more readily distinguish failures where the cause is actually *known* from where it has been *assumed*. Raptor fieldworkers will select from a pre-defined list of causes of failure and evidence types, helping to ensure that these data are comparable between areas and years (Appendix 1).

The structure of the online data entry system will encourage visit-based data collection, which the existing SRMS spreadsheet does not readily accommodate. There are scientific advantages to recording nesting progress at each visit, rather than with summary information across the season. Of particular relevance to monitoring patterns of breeding success, visit-based recording enables calculation of failure rates in a standard manner using Mayfield estimates (Mayfield 1961, 1975). While many SRMS participants currently record the outcome of attempts, the probability of observing a failure is dependent on the length of period of nest observation. This means that failure is more likely to be recorded for nesting attempts monitored from an early stage than for those found nearer to fledging. The accuracy of information about stage of failure is also dependent on visit dates, with long periods between visits leading to greater uncertainty about failure stage. Only by recording the stage at which nests are found, and when subsequently visited, can these sources of bias and uncertainty be taken into account. This will enable greater confidence in comparisons involving failure rates, guarding against the possibility that conclusions are confounded by methodological differences.

For data requests for conservation use (such as informing responses to planning and development casework), use of the online system will mean that data can be mobilized very quickly. Once a majority of observers are using the new system, this will make the SRMS more efficient, freeing up resources for other SRMS work (e.g. population trend analyses) and ensuring that SRMS data are used as effectively as possible to assist raptor conservation.

(g) Mobilizing data for conservation purposes

All raptor species in Scotland are legally protected through the Wildlife and Countryside Act 1981 and Nature Conservation (Scotland) Act 2004. Through the Environmental Information (Scotland) Regulations 2004, every Scottish public authority has a duty to make environmental information available on request. The nest site locations of many raptor species are considered sensitive environmental information and the legislation means that detailed nest site locations are not readily released publicly. Scottish Natural Heritage, the statutory conservation agency in Scotland, maintains a Sensitive Species List which shows the species that are considered sensitive together with the appropriate resolution at which any records should be released to the public (Appendix 2).

The Scottish Raptor Monitoring Group aspires to facilitate access by conservation professionals (particularly within SRMS partner organizations) to the detailed data in order to increase their use for a wide range of conservation purposes. Any requests to access SRMS data are currently considered on a case-by-case basis, requiring consultation with all SRMS partners, as well as with individual data contributors. Mobilizing data efficiently and effectively for conservation purposes is one of the Scheme's greatest challenges, hampered because agreed detailed protocols for data sharing and use were not in place from the outset.

The Scottish Raptor Monitoring Group is developing a *Data Sharing and Use Policy* that will govern how SRMS data may (and may not) be shared, accessed and used by different audiences. This policy will also address how the SRMS will share the data it holds with the public via the National Biodiversity Network Atlas Scotland (https://scotland.nbnatlas.org/) at appropriate resolutions. Progress with this work is necessarily slow as the Scottish Raptor Monitoring Group are liaising closely with all Scheme contributors to ensure that a range of sensitivities (e.g. concern that liaison with data collectors would be circumvented) are given due consideration in policy development.

Current and future challenges

The SRMS relies on substantial annual funding from Scottish Natural Heritage, which is funded by the Scottish Government. With public spending cuts continuing, Scottish Natural Heritage's budget is likely to reduce further providing a major challenge for the SRMS in future. The SRMS has been made more affordable through substantial in-kind contributions and funding from its other partners.

Recommendations

For any countries or programmes considering setting up their own monitoring programme, we make the following recommendations:

(1) The aims of the monitoring programme should be clearly defined. Consideration should be given to

which species are to be monitored and the methodology raptor workers should be adopting to ensure that results can be readily compared both temporally and spatially.

(2) Ensure that an ongoing assessment of monitoring coverage is built into the structure of the programme from the outset. This includes assessing completeness of coverage for all species at a national and sub-national level. Emphasis should also be placed on area-based approaches to achieving complete and consistent coverage of discrete areas representative of the wider landscape, i.e. akin to the SRMS's new *Raptor Patch* approach (see (c) above). Any changes in survey coverage and survey effort should be documented systematically every year, through processes specifically designed to capture this information (see (f) above).

(3) Ensure that consideration is given to the age profile of volunteers and to ensure that succession planning is in place to ensure that long-term monitoring of the taxon of interest is secured well into the future.

(4) A recording system which captures all aspects of the data recording (ideally an online data entry system) should be devised from the outset. Ideally such a system should be useable in an offline capacity, so that information can be inputted away from an internet connection (for example in remote field locations using a mobile phone), with subsequent upload.

(5) Ensure that at the outset, agreement is reached regarding data storage and potential uses of data held – especially in the context of relevant legislative constraints.

(6) Avoid becoming dependent on a single source of funding. Diversification of funding streams is important to reduce financial risks. Running a monitoring programme, such as the SRMS is expensive, but careful set up of protocols for data capture, sharing and, therefore, automated analyses can help to reduce the overall costs. In-kind contributions (e.g. promotional presentations at conferences, training days for new raptor workers and trend analyses) should be maximized wherever possible.

(7) Regular communication from the Scheme organizer to data contributors is important. Communication channels such as an annual report, newsletters and acknowledgements of data submissions are important to keep data contributors content and motivated.

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Appendixes

Appendix 1. Pre-defined lists of causes of failure & supporting evidence which users of the new SRMS online data entry system will be able to select from in the future.

Type of cause	Cause
Disease	Disease
Food supply	Extrinsic (outside factor)
	Intrinsic (due to parents)
	Unknown
Human	Burning
	Poisoning
	Shooting
	Disturbance induced abandonment:
	Deliberate
	Fieldwork
	Forestry
	Other works (house building, road repair, etc.)
	Quarry or mining operations
	Walkers, climbers, other recreation
	Other disturbance
	Nest contents destroyed
	Nest contents removed
Intrinsic	Breeder old, infertile or in poor condition
	Cannibalism or self-destruct
	Infertile eggs
	Young breeder
	Avian predation
Other animal	Conspecific competitor
	Fulmar
	Mammalian predation
	Nest competitor
	Nest trampling
	Other intra-guild
	Unknown/other predator
	Cold (including snow)
Weather	Heat
	Nest flooded
	Rain (non-flood)
	Unknown
	Weather (other)
	Wind/falling object
	Unknown
Unknown	

Supporting evidence provided by observer
Observed cause of failure directly as it happened
Trampled nest or surrounding vegetation
Human signs in or around nest
Predator signs in or around nest
Remains of predated eggs/young
Failure captured by camera
Burnt out nest
Burning near nest
Nest fallen from ledge or tree
Nest destroyed in rock or snow fall
Nest flooded
Recent adverse weather
Evidence of inadequate food supply
Confirmed poisoned adult or young
Confirmed poison bait observed near nest
Other evidence of poison bait near nest
Confirmed shot adult or young
Observed or heard shooting near nest
Dead adult
Injured adult
Death or injury of parent(s) confirmed
Human activity observed near nest
Negative response to fieldwork observed or suspected
Low provisioning rate observed before failure
Poor chick development observed
Lab or vet diagnosis
Other
None

Appendix 2. This is an extract for raptors from Scottish Natural Heritage's Sensitive Species List. The term 'Sensitive' refers to species that are vulnerable to persecution or over-exploitation. To safeguard them from deliberate harm known locations of such species should only be made public at an imprecise resolution. This list is subject to ongoing review and revision according to conservation status and expert advice.

Species	Which part of the life cycle is sensitive?	What sort of data is sensitive?	Where is it sensitive?	At what scale is it sensitive?	What is the justification Vulnerability	Threat
European Honey-buzzard *Pernis apivorus*		General location of breeding sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Rare breeder 20+	Egg collecting & disturbance
White-tailed Eagle *Haliaeetus albicilla*	Breeding and regular roosting sites	General location of breeding and roost sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Rare breeder 55	Egg collecting & illegal killing/persecution
Red Kite *Milvus milvus*	Breeding and regular roosting sites	Specific location of nest and roost sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Rare breeder ?150	Egg collecting & illegal killing/persecution
Eurasian Marsh Harrier *Circus aeruginosus*	Breeding only	Any breeding site away from Tay Estuary	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Rare breeder 3–8	Egg collecting & disturbance
Hen Harrier *Circus cyaneus*	Breeding and regular roosting sites	Specific location of nest sites or regular non-breeding roosts	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Uncommon breeder 633	Egg collecting & illegal killing/persecution
Northern Goshawk *Accipiter gentilis*	Breeding only	Specific location of nest sites or regular non-breeding roosts	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Rare breeder 130+	Egg collecting & illegal killing/persecution
Golden Eagle *Aquila chrysaetos*	Breeding only	Specific location of nest sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Uncommon breeder 420+	Egg collecting & illegal killing/persecution
Osprey *Pandion haliaetus*	Breeding only	Specific location of nest sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	uncommon breeder 200	Egg collecting & illegal killing
Merlin *Falco columbarius*	Breeding only	Specific location of nest sites	Throughout Scotland	Below 4 km^2 (2 × 2 km)	Uncommon breeder 800	Egg collecting
Eurasian Hobby *Falco subbuteo*	Breeding only	General location of breeding sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Extremely rare breeder <5	Egg collecting & disturbance
Peregrine *Falco peregrinus*	Breeding only	Specific location of nest sites	Throughout Scotland	Below 100 km^2 (10 × 10 km)	Uncommon breeder 600	Egg collecting & illegal killing/persecution
Short-eared Owl *Asio flammeus*	Breeding only	Specific location of nest sites	Throughout Scotland	Below 4 km^2 (2 × 2 km)	Uncommon breeder 125–1250	Egg collecting & illegal killing