# SNH's Scientific Advisory Committee Review of the SNH Licence for 'Strathbraan: removal of ravens'

## Purpose of review

The SNH Board requested its Scientific Advisory Committee (SAC) to review how the licence to remove ravens at Strathbraan in spring 2018 'fits with the wider work on adaptive action to save waders and to report on whether the methods agreed for this trial fit with the wider body of work underway'. All SAC members have contributed to, and have agreed, the wording of this review.

## Executive Summary

**Committee members supported the concept that further work on quantifying the impact of predators on wader populations is desirable, with a view to possible mitigation management. However, committee members were unanimous in the view that the existing trial methods, both as originally outlined in the licence application and as practiced in 2017, are completely inadequate and will fail to provide any meaningful scientific evidence for or against any effect of culling ravens on wader populations. Some advice is therefore offered on further work in this area of adaptive management.**

## The Committee's Review

The Committee met in Perth on Monday 28th May 2018 to undertake its review, which will be submitted to the Board.

**In attendance:** Professor Bob Furness (Chair), Dr Jackie Hyland (Board observer on the SAC), Professor Dan Haydon, Professor Neil Metcalfe, Dr Aileen Mill, Dr Ruth Mitchell and Professor Martin Price.

Apologies were received from Professor Jeremy Wilson, who provided the Committee with written comments on the papers prior to the meeting.

SNH staff attending: Lynne Clarke, Nick Halfhide, Dr Sarah Hutcheon, Dr Ben Ross, Sally Thomas and Professor Des Thompson

Conflicts of Interest: Dr Hyland and Professor Furness noted they are Board members.

## Background

In April 2018, SNH issued a licence for the control of northern ravens (*Corvus corax)* as part of the Strathbraan Community Collaboration study, Perthshire, to conserve wild birds, particularly curlew (*Numenius arquata),* lapwing *(Vanellus vanellus)* and Eurasian golden plover (*Pluvialis apricaria).* Control of ravens was proposed from March to mid-July 2018, (although the 2018 licence is valid until 31 December 2018), with the intention of licensing control over five years. The proposal was to remove around 40% of the estimated non-breeding raven population in order to test the effect of this on wader populations.

The study was described as an 'adaptive management approach' in keeping with the published *Understanding Predation Report* and work being taken forward under the collaborative programme 'Working for Waders' https://www.moorlandforum.org.uk/working-for-waders. Since the effectiveness of raven culling as a means to conserve waders is not known, the licence was issued for the purposes of *science, research or education.* Background information on relevant licensing functions in SNH is given here: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/licensing/species-licensing-z-guide/birds-and-licensing/birds-licences-control-predatory

The licence was issued to a local community group of land managers and conservationists to remove ravens as part of a project to test the extent to which this would support nesting waders. Background information and data were provided to the Committee.

**Terms of Reference**

In line with the Board's commission, the following Terms of Reference (ToR) were set and agreed, against which the Committee made its findings:

1. How the proposed trial fits within the existing knowledge-base around wader conservation and factors affecting wader populations;

2. The rationale for selecting ravens for removal, noting other drivers of change in wader populations;

3. The proposals and monitoring methods to inform the impacts of raven removal on wader numbers and productivity, and the baseline data and information informing this;

4. Consideration given to the impacts of removal on the raven population locally, and nationally;

5. How the information gathered can be used to best effect to inform future work on wader conservation through Working for Waders;

6. Whether, bearing in mind the community-led and adaptive nature of this proposal, there are any modifications that can be made to how the work is carried out in future in order to improve the value of any data collected, and the wider scientific impact of the work.

**The Committee agreed to report to the Board within one month of its meeting (by 28th June 2018).**

This report provides background information, comments from the Committee regarding the detail of the licence application and its consideration (drawn from papers provided and discussions with SNH staff at the meeting), and finally the formal findings under the six ToR headings.

**Background on Licensing**

SNH Licensing staff gave a short background presentation on licensing. This highlighted the information related to the Application (with supporting information provided by the Game and Wildlife Conservation Trust, GWCT), an additional statement from GWCT, and further data provided at the request of the Committee.

It was reported that, across all licensing functions in Scotland, around 2,500 licences are issued each year, of which 300-400 are related to 'science, research and education' work, with a very small number of these issued for research. The Committee was informed that around 150-250 licences are issued to control ravens in Scotland (covering a proposed take of approximately 1,000 individual birds). To date, all of these licences, none of which were for scientific research, have been to prevent damage to agriculture (notably killing of lambs and attacks on sheep). It was noted that licences for controlling ravens causing agricultural damage can include the killing of breeding adults. The largest licence issued covers around 50 ravens at one location; most licences were for about 5-6 birds.

Matters related to public opinion are not taken into account in the licensing process (following Judicial Review of a Natural England licensing decision).

**The Strathbraan licence and discussion on details of the licence, with observations and initial findings from the Committee**

The Strathbraan licence was issued for 'science, research and education' purposes, although the original application was for 'conservation of wild birds'. One would expect very different proposals under these two different justifications, with a high degree of scientific rigour in design and evaluation in applications through the scientific route. In this context, it was noted that the Licensing Staff felt the level of scientific detail required in the licence application and for subsequent monitoring should be 'proportionate', and was not required to be at a high level of rigour. This lack of requirement for scientific rigour was queried by the committee, since the licence was being granted for the purposes of science, research and education – the point was made by the Committee that there was no value in conducting a study that generated no usable data. The Committee noted that Licensing staff clarified that there is an expectation that, when licences are issued, specifying management measures, data will be provided to enable SNH to learn from the implementation of these measures, with welfare principles followed to guide the impact of a management practice on wild birds.

The Committee discussed with staff what it was anticipated might be learnt from the Strathbraan licence issued, and noted that heavy emphasis was placed by Licensing Staff on the importance of the 'learning from management' as the 'education' component of the licensable purpose.

*Data management and survey design*

Data issues were discussed. The Committee noted that the GWCT assumed ownership of the collating of the data (the licence was issued to the Strathbraan Community). The Committee had been sent two sets of summary data assembled by the GWCT: the first set was preliminary, and the second was more recent and more complete.

The Committee noted that there was no 'control' area (in the sense of a scientific control rather than 'predator control' – i.e. a comparison area in which no intervention would take place) defined in the licence application, but subsequently a 'control' area is referenced. Staff commented that, during the assessment of the licence, SNH had to be reassured on the existence of a 'control' area. The 'control' area was not marked on maps provided to SNH or the Committee, and no details were provided on how similar the control and trial areas were in terms of habitat or other landscape features which could influence the nesting and brood rearing distribution of waders. The control area appeared to be the area for which a previous licence was requested but refused, was the area with the poorest baseline data, and was retrospectively designated as the 'control' area. For an adequate study, it would be necessary to study at least two areas that clearly included the same mix of habitats and initial densities of waders and ravens, and then *randomly* allocate one of these to be the area in which the intervention would take place (i.e. culling of ravens) while the other would be left as the 'control', to allow direct comparisons. The Committee noted that in the present case there was no such quantification of habitats or birds.

The data include observations from land managers, which were evidently unverified and not systematic (as detailed below). It was noted whilst the Strathbraan study is based on 'participatory observational work', there was no evidence of verification checks. Had this been a 'citizen science' project, there would have been a basis for comparing the field observations with a more robust baseline against which the observations could be judged, and used, with methods refined as appropriate.

In this context, the Committee noted that the work under 'Working for Waders' involves training on observation and survey techniques and field testing/validation of these (with the British Trust for Ornithology, BTO, evidently playing a prominent role in this). The Committee noted that it is especially challenging to obtain robust estimates of wader numbers (and productivity).

*Counts of wader numbers and productivity*

The transect survey methodology cited in the application was noted as standard, but the Committee identified that the methodology cited had not been followed. The Committee determined that the baseline data were flawed because the 'maximum count of birds' was reported and maximum counts will tend to increase with the number of repeats of the transect. It was noted that apparently about half of the transects were not walked the prescribed minimum of two times. Noting the small length and number of transects relative to the typical breeding densities of the birds, it was questioned whether sufficient numbers of waders were surveyed to give statistically meaningful comparisons between 'control' and trial areas.

The Committee noted from SNH staff that the GWCT designed the study, and had responsibility for the analysis. Specifically, GWCT trained field observers, quality assured the methods used and the data collected, and supported the data analysis. The Committee raised concerns that the GWCT had provided insufficiently detailed maps showing habitats available to, and used by, the three focal wader species, and raised concerns over the selection of locations and length of the transects, the frequency of counts made, and the putative establishment of the 'control' area. There appeared to be no attempt to match transect locations to habitat availability, or to standardise transects between trial and 'control' areas. In addition, the transects did not appear to be randomly placed, with most transects close to access points.

With regard to wader productivity, it was noted that Vantage Point (VP) observations were one of the methods relied upon to assess wader productivity – this is novel, is not an established method for this purpose, and the Committee was not aware of scientific validation of the method. (VP observations will be species-biased, with golden plover chicks especially difficult to observe and count, will miss younger chicks, chicks in deeper vegetation, and/or more distant, and so out of sight, and will likely be biased towards detecting more mobile, fledged young, when one of the adult pair may be absent). Moreover, there was a mismatch between the areas over which adults were counted (through walking transects) and the areas in which chicks were counted (via VP observations), making it impossible to calculate the number of chicks per pair. The study had evidently not followed the Fletcher *et al.* (2010) methodology in assessing productivity (although GWCT stated that this had been done). There was no description of the VP methodology, and it appears that in many cases assessments of wader productivity were based on only single VP observations. It was also noted that the study was claiming to record numbers of 'fledged' young – which is not possible with a single count of chicks of unknown age. The Committee deemed these VP observations to be seriously flawed, to the extent that the study would be unable to determine either numbers of breeding pairs of waders or their productivity.

*Raven numbers and distribution, and selection of raven control areas*

Turning to ravens, the Committee found the estimates of densities and numbers provided to be flawed. The four hour VP observations made no allowances for repeat counting of the same individuals or proximity to nest sites (potentially resulting in multiple counting of some birds), seasonality of breeding season, and presence of non-breeding as opposed to breeding birds (which was crucial to determining where and when ravens should be removed).

The Committee was not presented with any quantitative evidence on numbers of nests/chicks of waders taken by predators, and the contribution of breeding and non-breeding ravens to this; the only evidence presented in the licence application were a few anecdotal observations of occasional predation events (which undoubtedly occur, but which may or may not have an impact on wader populations). In removing some ravens, no consideration was given to the possibility of compensatory predation (other predators moving in when ravens are removed) or fluctuating impacts by other predators varying in numbers from year to year and spatially; a well-designed study would have included monitoring of the numbers and impact of these other predators (such as foxes, crows, stoats, weasels etc).

In seasonal terms, the Committee noted that a better study design might have been to control ravens during the pre-wader/raven nesting season (possibly from late winter in the previous year), and that the licence was flawed in permitting raven control to occur through late summer, after wader breeding had been completed and so could no longer be influenced by any removals of ravens.

The Committee noted that there was uncertainty about the input of the Tayside Raptor Study Group to the study, although group members will have monitored breeding ravens on some of the Strathbraan area and so would have very useful data pertinent to the study, as would RSPB who have carried out local wader surveys in part of the area.

*Adaptive management*

The Committee noted it was not clear what was being ‘adaptively’ managed; the objectives stated were not defined with sufficient detail to be objectively measured. It was also not clear on what basis cull numbers might be changed in future years. Given the problems over raven counts, lack of detail on raven and other predator densities and distribution, and absence of data on other predators being controlled, the establishment of a ‘control’ area was deemed to be flawed in this instance.

The Committee noted that having issued the licence, SNH was aware that raven control was underway, with nine ravens shot to date.

Finally, the Committee noted that two other licences to control wild birds to protect waders in other parts of Scotland had been sought from SNH, and both were turned down on scientific grounds.

**Committee findings in relation to each of the six headings**

1. **How the proposed trial fits within the existing knowledge-base around wader conservation and factors affecting wader populations**

The Strathbraan Study trial does fit with the existing knowledge base. The literature (e.g., Amar *et al.,* 2010) encourages further research around the drivers of change in wader populations, such as was mooted for this trial.

The trial is set in the broader context of steep declines in the populations and breeding ranges of many wader species both in the UK and across Europe. Wader conservation is therefore unarguably a high conservation priority in Scotland – we have nationally and in some cases (curlew) globally important breeding populations, many of which are in decline. However, to guide both further research and decision-making, there is an extremely rich peer-reviewed scientific literature from the UK, Scandinavia and continental Europe which (i) documents population trends and their correlates, (ii) provides the underlying ecological basis for design of conservation measures, especially via agri-environment schemes, (iii) evaluates the effectiveness of the measures to support adaptive management, and (iv) considers impacts of wader nest and chick predation as a driver of declines and their interactions with habitat effects.

The extent to which wader populations can be benefitted most effectively by habitat management, direct reduction of predation pressure via predator control or a synergistic combination of the two remains uncertain and may vary between locations and species. Tackling these questions has given rise to some experimental studies designed to very high standards of 'before-after-control-intervention' (BACI) design (e.g. Fletcher *et al*. 2010 and RSPB's current Curlew Trial Management Project) with replicated treatments and controls over multiple landscapes.

The control of predators (foxes, crows, stoats, weasels) can lead to increased breeding success and increased numbers of waders (Parr 1993; Bolton *et al.* 2007; Fletcher *et al.* 2010), although it does not always do so for all wader species (Parr 1993; Bolton *et al.* 2007, Bodey *et al*. 2011). Fletcher *et al.* (2010) reported a three-fold increase in breeding success of lapwing, golden plover and curlew when foxes, crows, stoats and weasels were subject to legal control. However, Amar *et al.* (2010) found no significant negative relationship between an increase in raven numbers and numbers of waders in uplands. Weak ($0.05<p<0.1$) negative relationships between raven abundance, and trends in curlew and lapwing numbers were thought to warrant further investigation (Amar *et al.* 2010). Raven abundance has increased further since that analysis. Calladine *et al.* (2017) showed that nest losses of waders were higher where predators were more numerous, but they found no clear relationship between local wader breeding success and trend in breeding numbers. They suggested that breeding numbers may be affected by many pressures in addition to nest predation.

In relatively long-lived birds, population trends are driven most strongly by variations in adult survival rather than by nest success, and may be affected by immigration and emigration (Amar *et al.* 2010). Therefore, it may be unrealistic to expect a clear relationship between local predation rates on eggs and chicks and population trends. Furthermore, curlew mostly start to breed when two years old (Forrester *et al.* 2007), so if any increase in productivity led to increases in breeding numbers, this would be with a lag of two years, so may be undetectable in a short-term trial.

The use of only anecdotal testimony on predation as a driver in the Strathbraan study is concerning from a scientific perspective, and the Committee noted that the undoubtedly valuable and experienced 'local knowledge' should nonetheless be underpinned with scientific knowledge, to support the approach of citizen science.

## 2. The rationale for selecting ravens for removal, noting other drivers of change in wader populations

The scientific rationale for selecting ravens for control at Strathbraan was absent: no evidence was provided that other known drivers of wader populations were not having an impact, and the design for raven control was flawed.

The peer-reviewed literature shows that the list of drivers of population change of waders, even in the UK, is diverse, interacting and species-specific. Key drivers to note include:

(i) agricultural change (especially grassland management – sowing & harvesting practices, fertiliser use, rolling, livestock densities, seasonality of grazing, and water table management – and arable crop management – timing of sowing, harvesting and field operations);

(ii) land-use change - notably the direct loss of moorland and marginal agricultural grassland habitats to dense conifer plantation which wader species (other than perhaps Woodcock) do not occupy, and the effect of windfarm developments (in some cases) in reducing breeding wader densities within their footprints;

(iii) climate change – through the impact of drying of soils on invertebrate prey availability, a relationship especially well studied for golden plover, and with growing evidence of the capacity for mitigation through peatland restoration;

(iv) elevated predation rates, a particular challenge for ground-nesting birds in contexts where land-use patterns (e.g. edge effects), land management (e.g. high levels of gamebird rear and release) and lack of apex predators combine to encourage high densities of generalist mesopredators, including corvids, foxes and mustelids (Roos *et al*. 2018).

Ravens are well known to be predators of eggs and chicks of waders (Amar *et al.* 2010) and some other ground-nesting birds. Byrkjedal (1987) found that 78% of golden plover clutches and 28% of chicks in Hardangervidda, Norway, were taken by predators, mostly by ravens, common gulls and foxes. Carle *et al.* (2017) reported that ravens were responsible for an 80% reduction in breeding productivity of pelagic cormorants at a colony in central California.

In the Strathbraan study area, foxes and crows have been reduced in numbers so that those major predators probably have low impacts on breeding waders. Therefore, it is possible that ravens represent a significant proportion of the residual predation impact in that area. Bodey et al. (2009) found that predation by ravens increased when crows and mustelids were controlled, and suggested that removal of mesopredators released ravens from competition. There are anecdotal observations of ravens searching for wader nests in the Strathbraan area, but the relative predation impact by each potential predator species remains unquantified. Some evidence suggests that breeding ravens may be more predatory than non-breeders (Amar *et al.* 2010), and that raven prey preferences are likely to show individual specialisation (Ratcliffe 1997; Carle *et al.* 2017). These features suggest that random culling of non-breeding ravens may be a relatively inefficient way of reducing predation on breeding waders.

It is important to recognise that the drivers of change may interact in complex and landscape-specific ways. A good example of this is the increasing evidence that upland forestry generates 'edge effects' in which densities of breeding waders are reduced by direct predation or 'landscape of fear' effects over distances of hundreds of metres over open ground adjacent to plantation edges. Correlative evidence of these effects is strong for curlew across the moorlands of northern England (Douglas *et al.* 2014) and southern Scotland, and for dunlin and golden plover in the Flow Country (Wilson *et al*. 2014).

The Committee noted the application ignored, and a letter from GWCT dismissed, the key paper by Amar *et al*. (2010) commenting that the data “may” be out of date and that “the report appears to many practitioners to underestimate the issue”. Neither of these are adequate reasons to dismiss the paper out of hand. Indeed, its conclusions now seem prescient, and provide sound advice in the context of this licence application:
“*This study therefore highlights the need to obtain robust evidence on the effects that protected predators have on their prey, prior to initiating lethal control, and may provide a framework for the types of analyses that should be undertaken to help decision makers decide on whether to issue control licences as future conflicts arise. If decisions are made without such information, resources could be targeting inappropriately away from the real cause of any prey decline, and could potentially and needlessly jeopardize the conservation status of the protected predator involved*.” (Amar *et al.* 2010).

At Strathbraan, the evidence that other drivers (e.g. habitats, land use, land management, other predators) were not influencing the wader population appeared anecdotal. Land management and habitat were described in the application as ‘optimal for waders’ without evidence to support this, and a conclusion that there are no further land management actions to be taken was reached without presenting any analysis of the extent, quality, and spatial targeting of agri-environment management for breeding waders in the landscape. This is despite the fact that in nearby Strathallan, Bell and Calladine (2017) found that a 25-year decline of breeding wader numbers was in large part attributable to agricultural management change.

The Committee felt that establishing the study as one examining raven control was premature given the absence of robust data on ravens as predators on wader nests/chicks in this area, an insufficient design for monitoring the impact of controlling ravens, and a lack of adequate consideration of other possible drivers of change in local wader populations.

### 3. The proposals and monitoring methods to inform the impacts of raven removal on wader numbers and productivity, and the baseline data and information informing this

There were major flaws in the baseline data, and the design and collection of the data for waders and ravens. Noting that there is just one year of baseline data, the basic design was inadequate at the outset. The Committee agreed that the data as presented cannot be used as a baseline, for assessing change and as a basis for the raven control ‘experiment’. The number of transects proposed was insufficient and their location poorly explained. The Committee noted that the confidence limits on wader counts were so large, due to the very small number of transects completed, that any impact of raven control would not be statistically detectable. A power analysis should have been undertaken to guide the level of sampling and design (cf. Fletcher *et al.*, 2010, used 71 transects). There is no quantification of habitats, nor matching of transects with habitat, nor random allocation of areas to ‘intervention’ versus ‘control’ treatments, all of which are needed to meet the minimum requirements of a robust experimental design.

Analysing these types of data is challenging and requires clear project management and sophisticated statistical approaches (as in Fletcher *et al.* (2010)). There appeared to be no explicit plan for data analysis and robust reporting, with some data for the 2017 season still to be collated a year after data collection. The Committee had concerns over the project management and lack of plans for appropriate data analysis.

Commenting in more detail, the Committee notes the design of the trial was that baseline data collected in 2017 would include wader counts from 'at least 8 sets of transects' with each transect 'walked a minimum of twice' with the final walk '*not earlier* than the third week of May' (quotes from Licence application). However, the licence application and licence imply that this will be from the trial area, and give no information on sampling effort in any control area. The transects are 2 km x 0.4 km, so each provides evidence of wader numbers over an area of 0.8 $km^2$. Typical densities of breeding curlew and golden plover in high quality habitat in Scotland are around 1 to 3 pairs per $km^2$ (Forrester *et al.* 2007). In addition to nesting at relatively low density, curlews and golden plovers tend to nest with the nearest neighbouring nest >500 m away (Fletcher *et al.* 2010).

The design of the baseline data collection thus appears to lack the statistical power required to detect before-after changes in breeding numbers of waders because the surveys were proposed to be from such small sample areas. However, even the very limited targets set were not achieved in 2017. Only seven transects were carried out within the licence area, and only three of those achieved the minimum specified two visits. This raises a methodological problem because the transect data presented are the maximum count of waders; where transects are walked more often, the maximum is likely to be higher, so the estimate is affected by survey effort which is inconsistent across sites.

The 2017 data found highly variable numbers in different transects within the licence area. For example, for lapwing the six sites reported 0, 2, 6, 21, 31, and 33 birds (maximum counts). These give a mean of 15.5 per site, standard deviation 14.76, standard error 6.02, with a 95% confidence interval for the mean from 3.5 to 27.5 birds. Given this huge uncertainty in estimates of the mean, there would need to be an astonishingly large change in numbers for any statistically significant difference to be seen in mean numbers of lapwings. We conclude that the design is inadequate to expect to be able to assess change in breeding numbers between the baseline and raven-control years from the transect data. We were not given access to wader transect count data from the control area, but that appears to be from an even smaller sample size.

Productivity data were obtained from transects, from VP areas, and from general observations. It is unclear how these mixed sources of data have provided quantitative estimates of productivity. According to GWCT (Summary of wader count data in Strathbraan area 2017), this followed methods in Fletcher *et al.* (2010). However, that paper followed breeding success by making weekly visits and derived fledging success per pair if 'the presence of chicks was recorded for a minimum of three weeks'. The Strathbraan estimates appear to derive from single visits, which implies that data regarding numbers of pairs will be highly uncertain and it will not be possible to measure fledging success; the best that could be achieved is a ratio of chicks present to adults present, which may or may not correlate with breeding success. The 2017 baseline data presented to SNH indicate that productivity estimates are of 'chicks fledged'. It is unclear how that is possible. Curlew mostly lay in early May, hatch in early June and fledge in July (Forrester *et al.* 2007). Replacement clutches can be even later. Hence in order to assess fledging success, fieldwork should continue into July. According to the licence application, wader monitoring was carried out only from April to early June, with productivity estimates made in late May or early June. That could not assess fledging success, nor assess hatching success of most late clutches of curlews.

According to GWCT (letter of 27 April 2018), the design of the wader monitoring at Strathbraan was a Before-After-Control-Impact (BACI) design. However, no control area is defined in the licence application or in the issued licence. The 2017 data presented to SNH include data from a control area, described as 'outside licence area' but not shown on a map. Seven transects were walked outside the licence area in 2017, but only two of those had the specified minimum of two visits. We have not seen numbers of birds recorded in the ‘control’ transects. The fact that there is only one year of ‘Before’ data is severely limiting to any analysis because it makes it impossible to assess year to year variation, and the small sample size results in low statistical power.

The design of the trial with regard to timing of raven cull seems inappropriate. The licence appears to allow culling of ravens from 4 April 2018 to 31 December 2018. If this is the case, it is unclear how culling of ravens after the completion of wader counts (i.e. after early June 2018) will be relevant to understanding predation impact on waders, since any predation impact will only be assessed up until early June. Culling ravens after early June 2018 will, therefore, have no relevance to wader monitoring in 2018. It would be a better design to ensure that all raven control took place before the start of wader monitoring in that same year.

The lack of any monitoring of other species of nest predator makes it difficult to attribute variations in wader breeding success to predation by ravens, as much of the variation in predation rate may be due to variation in abundances of other predators rather than just ravens (Fletcher *et al.* 2010).

## 4. Consideration given to the impacts of removal on the raven population locally, and nationally

The Committee concluded the actions under the license should have no impact nationally, but potentially could have local impacts, but that these are difficult to determine given the nature of the raven control planned/undertaken.

Population modelling presented in Wilson *et al*. (in press) indicates that the proposed removal of nonbreeding ravens would be sustainable at the national level but possibly not within the study area in Strathbraan (uncertainty being due to lack of site-specific demographic data from the study area, and on rates of immigration from neighbouring areas where raven numbers were not being controlled). The licence application suggested that it was under consideration to expand the removal area in future years as the trial developed. However, the Committee considered that the planned intensity of culling in the Strathbraan removal area could not be extended to a wider area without a likely impact on raven populations.

Since the local SRSG members probably monitor breeding ravens in Strathbraan, it would seem appropriate to also include that group’s data in any evaluation of the impact of culling on breeding numbers of ravens in the area. The Committee felt it important to examine the SRSG data to provide an independent assessment.

The Committee noted that it is not known if the area is a ‘source’ or ‘sink’ for ravens. It is very difficult to distinguish between non-breeding and breeding birds. The control of ravens is likely to impact more on juvenile birds, but could also include breeding birds, especially when using traps (so that flock size is unknown) and later in the year when breeding birds are not tied to nest sites.

## 5. How the information gathered can be used to best effect to inform future work on wader conservation through Working for Waders

The Committee felt the information gathered, as presented, would not meet the intended purpose. Following the advice of Amar *et al.* (2010), the appropriate next step to follow up the local testimony in this instance would be to make a detailed and rigorous observational study of the wader populations, at the individual species level, to properly quantify local trends and nest success, the extent of raven predation, and whether this predation is having population effects additive to those of other impacts on the breeding wader population. Strathbraan may be a suitable landscape for such a study. The outcome of such a study would be a reasonable basis for assessing any future licence application to cull ravens in the interests of wader conservation.

The Committee noted the importance of bringing parties together to plan and implement such work, as espoused by Working for Waders, but this had not happened here.

More appropriate field methods include use of cameras to identify predators visiting wader nests, as deployed successfully by Carle *et al.* (2017) and by Calladine *et al.* (2017).

6. **Whether, bearing in mind the community-led and adaptive nature of this proposal, there are any modifications that can be made to how the work is carried out in future in order to improve the value of any data collected, and the wider scientific impact of the work**

The Committee notes many points above, which are essential to include to ensure that the work provides meaningful evidence for or against any effect of culling ravens on wader populations. Given the flawed baseline data and experiment design, the Committee suggests that, if continued, the trial should be completely redesigned rather than the current trial being modified. Importantly, there is no evidence of key and relevant stakeholders being brought together for discussion, preparation and agreement of proposals. It would be desirable to bring together key and relevant stakeholders for discussion, preparation and agreement of proposals, for example the local Raptor Study Group who have important local knowledge and data sets.

A formal adaptive management framework would be suitable for a project of this type, where future cull levels are based on monitoring of a clearly defined objective. The existing trial methods, both as originally outlined in the licence application and as practiced in 2017, are inadequate and will fail to provide scientifically meaningful evidence for or against any effect of culling ravens on wader populations. A more robust project management is required to ensure that data collection meets the minimum levels specified in the project, and to ensure that data are stored in a quality-assured database.

For the transect counts to provide scientifically robust data with enough statistical power to test the hypothesis that wader numbers increase where ravens are removed, the existing data collected in 2017 from Strathbraan and the wider literature on breeding waders suggest that there would need to be somewhere around 30 x 2 km transects within the trial area and 30 x 2 km transects in the control area. These transects need to be positioned so that they cover the same representation of habitats and land management regimes in trial and control areas – and these habitats / land management regimes should be recorded for each transect each year. To obtain statistically meaningful data on fledging success of waders, the transects should be walked weekly from early April to July, mapping locations of breeding waders and their behaviour as described by Fletcher *et al.* (2010). Data on fledging success would be more appropriate than data on breeding numbers, as breeding numbers may vary from year to year for many reasons. Predation is likely to be more readily quantified through study of breeding success. Monitoring of indices of other likely major predator populations would also be desirable as context. The committee noted that monitoring on this scale would be labour intensive and time consuming.

Alternative approaches for establishing the impact of predation on waders might be considered. Cameras might be set up to identify nest predation events (Calladine *et al.*

2017) and recorded images or video could be analysed by citizen science volunteers. Data loggers that record temperature (and hence the presence of an incubating bird) can be used to monitor when nest losses occur, which discriminates between mammal predation (predominantly at night), bird predation (predominantly during the day), and successful hatching, and these can be used in conjunction with cameras to quantify hatching success and causes of egg loss (Calladine *et al.* 2017). Such work might ideally be carried out most cost-effectively by a PhD student funded as a SNH studentship or a NERC CASE studentship.

It is SAC's view that the raven monitoring should be modified as described above. In particular, the survey should avoid the potential for double counting of ravens, recording the number of ravens seen at any one time. The raven VPs should cover the same area monitored for the wader transects, take account of the location of raven nest sites, seasonality of breeding season, and presence of non-breeding as opposed to breeding birds.

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