BTO RESEARCH REPORT 715

Investigating wader breeding productivity in the East Cairngorms Moorland Partnership Area using collaborative methods

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Investigating wader breeding productivity in the East Cairngorms Moorland Partnership Area using collaborative methods

A report to the East Cairngorms Moorland Partnership

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BTO Research Report 715

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Cairngorms NATIONAL PARK
Pàirc Nàiseanta a' Mhonaidh Ruaidh

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EXECUTIVE SUMMARY

1. Breeding wader populations have declined significantly in recent decades in the UK. During this time, areas of moorland managed for grouse shooting and adjacent areas of rough pasture have been identified as persisting strongholds. A contributory cause to wader population declines is afforestation, and in the Cairngorms National Park (CNP) there is likely to be significant woodland expansion (with associated conservation gains for woodland biodiversity) in areas currently holding breeding waders. Land management planning in the CNP requires a balance between these and other competing objectives.

2. This project was carried out collaboratively with The East Cairngorms Moorland Partnership (ECMP), which comprises six estates (Mar Lodge, Mar, Invercauld, Balmoral, Glenavon and Glenlivet) and the Cairngorms National Park Authority. The over-arching purpose of the partnership is to demonstrate a clear contribution to the aims of the Cairngorms National Park, including priority species conservation through sustainable moorland management. These estates contain a mix of farmland, woodland, moorland and alpine habitat, with objectives including management for driven grouse shooting, deer stalking and woodland expansion. Predator control associated with management for grouse shooting is carried out across much of the partnership area.

3. The primary aim of the project was to investigate factors, including effects of woodland cover, affecting breeding productivity of wader species within the area covered by the East Cairngorms Moorland Partnership.

4. At the start of the 2018 breeding season a BTO staff member worked with estate staff (gamekeepers, rangers and ecologists) across the East Cairngorms Moorland Partnership area to train and encourage staff to monitor breeding waders using a variety of field methods. All project data were gathered by estate staff (and a wildlife volunteer group).

5. Estate staff returned breeding wader transect survey data from 16 sites within the ECMP area, carrying out two or three survey visits at each site. 156 likely wader territories were identified, with Lapwing *Vanellus vanellus* (48 apparent territories: AT), Oystercatcher *Haematopus ostralegus* (46 AT) and Curlew *Numenius arquata* (38 AT) the most frequently recorded species.

6. Estate staff located and monitored 107 nests using temperature data loggers; 72 Lapwing, 31 Oystercatcher, two Curlew and one each of Snipe *Gallinago gallinago* and Common Sandpiper *Actitis hypoleucos* nests were monitored. Hatching success of 42% for Lapwing and 58% for Oystercatcher across the study area was estimated using the Mayfield Method. 32 nests were also monitored with trail cameras with the following nest predators identified: Common Gull *Larus canus* (1 nest), Jackdaw *Corvus monedula* (1 nest), Stoat *Mustela erminea* (3 nests). Sheep *Ovis aries* were also recorded trampling one nest (1 nest).

7. A larger data set of monitored nests would be needed before making robust conclusions regarding factors affecting nest success. However, generalised linear models found that woodland cover within a 5 km radius around the nest was associated with higher hatching success. Possible reasons for this may be effective predator control ameliorating the negative effect of woodland, with pockets of predators persisting in more remote areas, and the influence of non-woodland nest predators such as Common Gull.

8. Monitoring of predator abundance and post-breeding flock counts was also attempted in the period immediately following the breeding season. More data are needed before an assessment can be made of the value of these methods, and possible improvements to these approaches are discussed in the report.

9. There is now significant capacity and enthusiasm for monitoring breeding waders on the participating estates. Continuing to monitor nests, ideally for at least two more years, will increase the robustness of findings and allow more detailed analyses to be carried out, possibly including analysis of the effects of different predator species. The wader transect surveys could also be expanded and continued, with a longer-term aim of generating trends for wader species within the ECMP.

10. The involvement of stakeholders in wader research projects helps to build a shared understanding across different stakeholder groups of the processes limiting breeding wader populations. Encouraging the shared ownership of research outputs on breeding waders makes it easier to reach consensus in decisions relating to management and monitoring.

1. INTRODUCTION

Scotland's breeding wader populations have declined markedly over recent years. According to the most recent BTO/JNCC/RSPB Breeding Bird Survey (Harris *et al.* 2018), the period between 1995 and 2016 saw Curlew decline by 61%, Lapwing by 57%, Oystercatcher by 38%, and Golden Plover *Pluvialis apricaria* by 23%. Common Snipe has also experienced severe declines since the 1970s (Siriwardena *et al.* 2000), although more recently the population has stabilised or increased in Scotland (Harris *et al.* 2018).

Drivers of population change on wader breeding grounds include agricultural intensification, afforestation by commercial conifer plantations, and increased numbers of generalist predators associated with these habitat changes (Galbraith 1988, Hancock & Avery 1998, Ottvall 2005, Smart *et al.* 2006, Eglington *et al.* 2010, Showler *et al.* 2010, Fletcher *et al.* 2010, van Dijk *et al.* 2015, Ainsworth *et al.* 2016, Franks *et al.* 2017). Lowland enclosed farmland has experienced the most severe declines (Baines 1990, O'Brien *et al.* 2002, Wilson *et al.* 2005, Shrubb 2007). In moorland areas where predator control is carried out for grouse moor management, waders have been found to breed at higher densities than in moorland without predator control (Tharme *et al.* 2001, Fletcher *et al.* 2010, Douglas *et al.* 2014, Franks *et al.* 2017). However, most declines are unlikely to be driven by a single factor, and in many cases predation pressure, habitat change and disturbance associated with agricultural activities will be acting synergistically to make conditions less suitable for breeding waders (Eglington *et al.* 2009, van der Wal & Palmer 2008, Calladine *et al.* 2014).

In light of these declines in the lowlands and the positive effect of predator control, upland areas of moorland and rough grassland where predator control is carried out are becoming increasingly important strongholds for breeding waders. In the East Cairngorms Moorland Partnership (ECMP) area (see Figure 1), predator control is carried out by all estates within the partnership, and there are also areas in the ECMP area where habitat is actively managed for breeding waders (for example the Quioch / Dee floodplain near Braemar, and farmland around Tomintoul: Cunningham *et al.* 2017). There are no published wader trends specific to the ECMP Area (although Francis 1997 and 2008 provide some context), but breeding wader declines in north-east Scotland are thought to be broadly in line with trends elsewhere in the UK (Francis & Cook 2011). However, it is likely that declines in north-east Scotland have been greater on improved lowland farmland, where habitat is less suitable and predator control less intensive or absent.

Breeding waders (especially Curlew) have become an increasing focus of conservation interest (Brown *et al.* 2015 for example). However, wader conservation is often in conflict with land management objectives related to afforestation. As well as providing habitat for woodland species and timber production, ecosystem services benefits of afforestation include flood management and carbon sequestration. The Scottish Government aims to increase woodland cover from 17% to 25%, an addition of some 650 000 ha over the 21st century (Scottish Government 2009, WEAG 2012), with a shorter-term objective to increase cover by 15 000 ha per year from 2024 (Scottish Government 2017). Because of the high agricultural value of lowland farmland (WEAG 2012) and the prohibitive cost of planting at higher altitudes, marginal upland areas are likely to be favoured for this expansion. In the east Cairngorms, such areas are likely to hold nationally significant numbers of Curlew, Lapwing, and Oystercatcher, with Redshank *Tringa totanus* and Snipe also present at lower densities (Balmer *et al.* 2013). Dunlin *Calidris alpina* and Golden Plover are most abundant at higher elevations which would be unsuitable for planting so would be less likely to be affected. However, in the longer-term, it is possible that the natural expansion of montane scrub at higher altitudes (Gilbert 2002) may have some impacts on these species.

In the ECMP Area, existing woodland also supports a declining population of Capercaillie *Tetrao urogallus* (Wilkinson et al. 2018) and other red- and amber-listed bird species (Common Redstart *Phoenicurus phoenicurus*, Spotted Flycatcher *Muscicapa striata*, Tree Pipit *Anthus trivialis*, Willow Warbler *Phylloscopus trochilus*, Wood Warbler *Phylloscopus sibilatrix* for example) which would likely benefit from woodland expansion. These conflicting conservation priorities make the east Cairngorms well suited to studies of the effect of habitat change for breeding waders.

Where woodland expansion does take place, the potential negative impacts on breeding waders can be divided into those resulting from direct habitat loss and potential 'edge effects', where densities of breeding waders in open habitat are reduced in proximity to woodland (Stroud *et al.* 1990, Hancock *et al.* 2009, Wilson *et al.* 2014). This may be caused by increased levels of nest predation in proximity to woodland reducing breeding success, or by waders avoiding areas near woodland where perceived predation risk is higher, or through a combination of both (Wilson *et al.* 2014). Douglas *et al.* (2014) looked at a range of sites (both with and without predator control) in northern England and southern Scotland and found that Curlew breeding success was negatively associated with woodland cover and positively associated with gamekeeper density (as a proxy for predator control). Understanding the extent to which 'edge effects' reduce wader breeding abundance and productivity in areas where effective predator control is carried out will be important in determining the possible effects of woodland expansion on waders in the east Cairngorms.

Despite the evidence for the importance of predator control in maintaining sustainable breeding wader populations, the public discourse around predator control and wider moorland management lacks nuance, and discourse between stakeholders is often adversarial (Thompson *et al.* 2016, Hodgson *et al.* 2018). In light of this, several recent initiatives have actively tried to reduce conflict between groups of stakeholders, while increasing understanding about wader population declines. The Understanding Predation project (Ainsworth *et al.* 2016) collected and reviewed information both from the scientific literature and stakeholders involved in land management. Much consensus was reached amongst participants on the need to work together to address the decline of breeding waders through a combination of habitat and predator management, with importance placed on the co-production of data amongst diverse groups of stakeholders to encourage shared understanding. Subsequently the 'Working for Waders' initiative (www.workingforwaders.com) has been providing further support to collaborative projects.

In 2017, the British Trust for Ornithology coordinated a pilot project using collaborative methods to survey waders, working with the Yorkshire Dales National Park Authority (YDNPA) and the Bolton Castle Estate in Wensleydale (Jarrett *et al.* 2017). The aim was to develop field methods for estate workers to monitor waders that: (a) were robust in providing useful information on breeding wader distribution, abundance and breeding success; and (b) could be used and applied effectively by gamekeepers and farmers. The approaches and lessons learnt from this Wensleydale project have been adapted and developed for use in the current project.

1.1. PROJECT AIMS

The specific aims of the current project were as follows:

- To contribute knowledge on the productivity and causes of nest failure of wader species breeding in the ECMP area through a collaborative project with the ECMP group of estates.
- To add to the growing body of evidence on factors which explain variation in wader breeding success, and consider the effect of landscape heterogeneity and woodland cover in driving population change. This evidence could inform management for breeding waders in different local contexts, and help to explain why wader populations remain stable in some areas but not in others.
- To add to knowledge of individual predatory species (and interactions between these) in wader breeding productivity.
- To use the findings of the pilot work to recommend longer-term approaches to monitoring wader productivity and numbers on the ECMP estates.

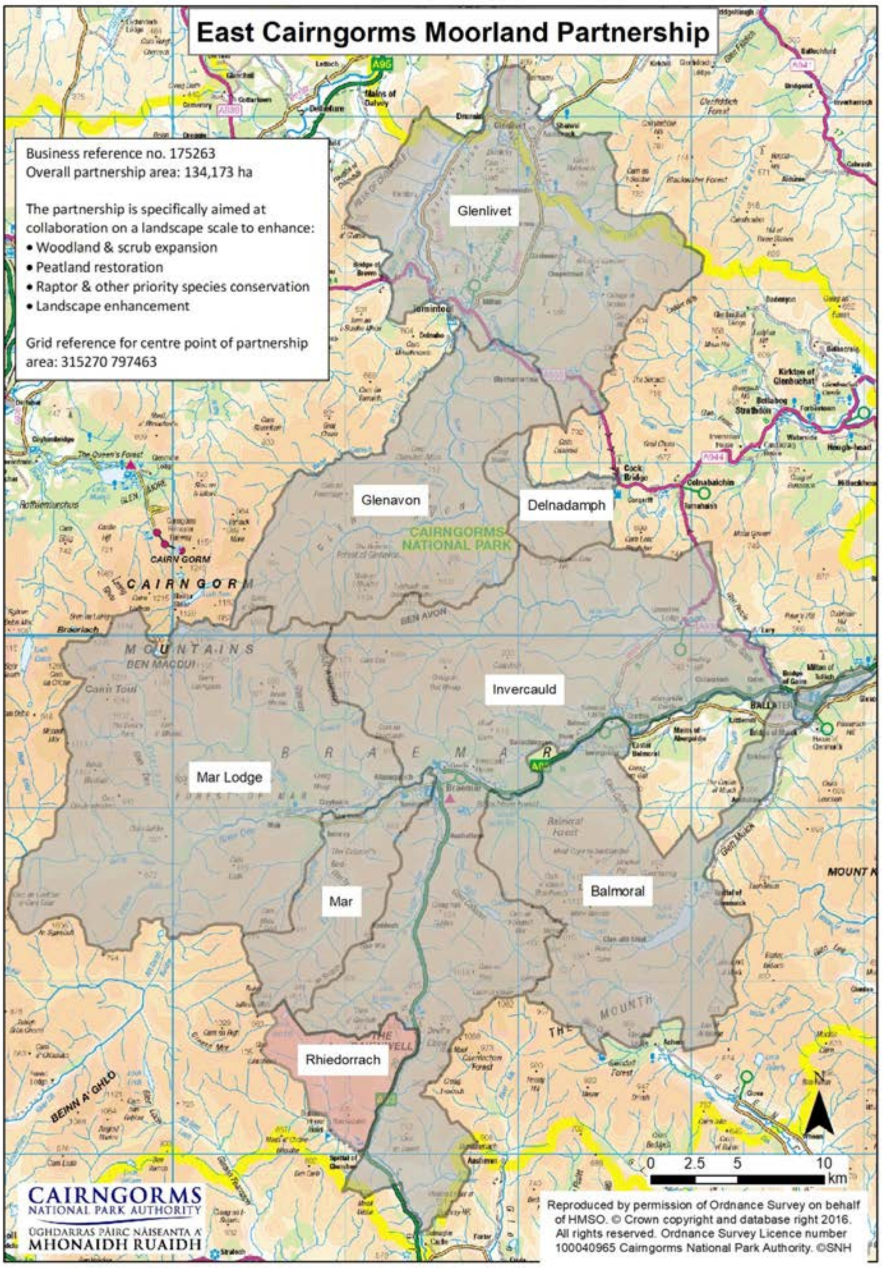
2. METHODS

A BTO staff member met with staff at each ECMP estate involved in the project in early April to discuss the proposed approach to wader nest monitoring, wader surveys, monitoring of mammalian predators, and the capacity for each estate to contribute to the project. Estate staff (gamekeepers, rangers and ecologists) were responsible for all the data gathering during the project, with the exception of additional nest monitoring data contributed by volunteers from the Tomintoul and Glenlivet Wildlife Group.

The four specific activities that estate staff agreed to carry out were:

- To monitor a sample of wader nests across the ECMP estates, using nest cameras and temperature loggers.
- To carry out systematic surveys of the numbers and behaviour of breeding waders at a selection of sites on each estate to provide context for the nest monitoring work.

Figure 1: The East Cairngorms Moorland Partnership Area (grey) showing the participating estates' boundaries. Part of Invercauld Estate was sold prior to the wader monitoring project commencing, and participated in 2018 as Rhiedorrach Estate (pink).



East Cairngorms Moorland Partnership

Business reference no. 175263
Overall partnership area: 134,173 ha

The partnership is specifically aimed at collaboration on a landscape scale to enhance:
- Woodland & scrub expansion
- Peatland restoration
- Raptor & other priority species conservation
- Landscape enhancement

Grid reference for centre point of partnership area: 315270 797463

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- To trial the counting of post-breeding flock ratios of juveniles to adults as a possible additional index of productivity at a broad, landscape scale.

- To deploy camera traps with baits to test a method for the collection of contextual information on predator abundance.

2.1. STUDY AREAS

Nest monitoring was carried out on all ECMP estates, while wader transect surveys were carried out on Invercauld – Rhiedorrach, Glenlivet, Glenavon, Mar, and Balmoral (Figure 1). Areas where wader surveys were carried out and where nests were monitored were largely selected by estate staff. This ensured that these activities took place in areas that were easily accessible – an important consideration given the size and relative remoteness of the estates involved. Participants were encouraged to select areas covering a range of different elevations, habitats, and distances from woodland. The mix of heather moorland managed for driven grouse shooting, rough grazing ('white ground') on the moorland fringe, and enclosed lowland fields within the ECMP area provide a broad suite of habitats suitable for breeding waders.

2.2. WADER TRANSECT SURVEYS

Prior to the breeding season, participating staff on all the estates were given guidance on carrying out wader surveys. It was confirmed in informal discussions on waders and a walk around the good wader ground on the estate (where possible) that they had sufficient knowledge of wader identification and behaviour to carry out effective surveys. During the previous project in the Yorkshire Dales National Park (Jarrett *et al.* 2017) keepers were encouraged to carry out wader surveys while checking traplines. However, in the east Cairngorms because the estates are much larger and small-mammal trapping is less spatially concentrated, most keepers did not have regular routes that they walked to check mammal traps. Consequently, none of the wader transect surveys carried out by estate staff during this project followed trapline routes. Participants were advised to choose a survey route of approximately 2–3km (but if longer or shorter routes were preferred this was not discouraged). Following site selection, estate staff were then provided with survey forms and maps (Appendix 3).

The methodology for estate staff carrying out wader surveys followed the approach set out for estate staff in Jarrett *et al.* (2017), with a target of three survey visits across the breeding season (Calladine *et al.* 2009). On each survey visit, the recorder followed their chosen route, which was marked onto the survey form. All waders seen and heard were recorded and mapped on each survey visit, with associated behavioural codes for 'displaying', 'calling', 'alarm calling' and 'aggressive encounter' to capture territorial evidence. On second and third visits, juveniles were recorded when encountered (the first visits were carried out before hatching). Flights were also mapped to help identify territory boundaries. During surveys some nests were opportunistically located and subsequently monitored, but surveys focussed on identifying territorial pairs.

Survey visit information was interpreted according to the rules described by Brown & Shepherd (1993). On an individual survey visit, where multiple individuals of the same species were present in an area and it was difficult to determine the number of breeding pairs they represented, individuals of all species were conservatively deemed to represent different pairs only if the distance between them was greater than 500 m. These distances broadly reflect the distances over which individuals may be observed to move (e.g. when mobbing intruders) during a single survey visit. When the three visits were complete, observations of pairs on different visits were considered to be separate only if at least 1000 m apart (Brown & Shepherd 1993). These distances reflect the distance that pairs, especially with young, might move between survey visits.

Where possible the surveys were carried out between 08:30 and 18:00 to avoid the periods when bird activity is more variable. All surveys were carried out in relatively calm and dry conditions. For all surveys, precipitation (none, drizzle, rain), wind (calm, breeze, windy), and visibility (clear, moderate, poor) were recorded. Adult alarm calling or the presence of juveniles on the third survey visits (or second visits where juveniles were encountered) were taken to indicate breeding success. Other observations associated with territory occupation, such as display behaviour, non-alarm calling or presence of pairs were not taken to indicate breeding success. An index of breeding productivity was calculated for those sites where three visits were carried out by dividing the number of alarm calling pairs (and pairs seen with juveniles) on the third survey visit by the maximum number of pairs recorded on any of the three survey visits.

An estimate of the percentage of habitat covered was also recorded across three categories: 'heather', 'tussocky grassland / white ground' and 'enclosed grazing'. The elevation of the centre-point of each transect was also obtained using a Digital Elevation Model (Pope 2017) on QGIS (version 3.2.1).

2.3. NEST MONITORING

At initial meetings with estate staff, advice was provided on methods for finding wader nests, including the relative difficulty of finding nests of the different species. Training on how to deploy temperature loggers and cameras was also provided. Each estate was also given standard recording forms to record information on monitored nests including recording grid references and time and date of deployment and recovery of the data logger (see Appendix 3).

The temperature loggers used were Thermochron ibuttons. Each logger was programmed to record temperature every 20 minutes, sealed in plastic and placed below the eggs within the nests. Each logger has space for 2,048 temperature records, meaning that approximately 28.5 days-worth of data can be stored on each logger. The loggers were programmed to overwrite earlier data to increase the likelihood of capturing the cessation of incubation, given that loggers would not be immediately deployed. All loggers were anchored by garden wire and screws into the soil at the base of the nests to reduce incidences of birds displacing loggers from nests. The relocation of loggers was facilitated by use of high-precision hand-held GPS units and, where necessary, a metal detector. Three copies of the software used to download the data from the temperature loggers were provided and used by a staff member at Balmoral estate, an ECMP Partnership employee, and a volunteer from the Glenlivet and Tomintoul Wildlife Group. Because the data loggers were programmed to overwrite, the prompt downloading of data from the loggers following the end of the incubation period was very important. The temperature traces downloaded from the loggers were used to identify the date and time when incubation ceased. The point of incubation ending was taken as when a clear diurnal cycle of temperature variation commenced.

Generalised Linear Models (GLMs; all statistical analyses used the statistical program R unless otherwise stated) were used to test for variables which affected the duration of incubation across the study area. We hypothesized that the recorded duration of incubation would be lower where a higher proportion of clutches were lost. In the model, incubation duration (in hours) was the dependent variable. Independent factors were: wader species (n = 5); habitat (n = 3); the start date of nest monitoring (annual Julian date as a continuous variable); whether the nests were monitored using cameras or not (n = 2) and a measure of woodland cover. The original models included the three interaction terms: (i) species * habitat; (ii) species * woodland cover; and (iii) habitat * woodland cover. The models used a normal distribution (this approach produced the most parsimonious models) and identity link function.

Wader species was included in the models to account for inter-specific differences in incubation period or predation rates. The habitat classes included were 'heather' (areas where *Calluna Vulgaris* was dominant) 'rough grassland / white ground' (areas where tussocky grassland was dominant) and 'enclosed / well-grazed' (where ground was fully enclosed and there were signs of livestock grazing). These were assessed using satellite images of the nest site grid reference subsequently. Because the measured incubation period might be influenced by the date at which the loggers were first placed in nests, monitoring start date was included in the models to account for such variation. Inclusion of whether or not nest cameras were deployed aimed to assess whether the marking of nests (with a visible camera) had a measurable influence on clutch survival.

Because we did not know the spatial scale at which woodland cover might influence predation risk, we ran multiple models with different 'woodland' variables in each model to test the effect of different woodland measures. The variables tested were i) the distance in metres from the location of the monitored nest (determined in the field using hand-held GPS) to the nearest mature tree using satellite images of the area surrounding the nest. This was a continuous variable. We also tested the proportion of total woodland cover within a ii) 300 m, iii) 1 km and iv) 5 km buffer of the nest location, and the proportion of only coniferous woodland cover within a v) 300 m, vi) 1 km, and vii) 5 km buffer of the nest location. These were also continuous variables. The National Forestry Inventory Scotland database (Scottish Government Spatial Data Infrastructure) was used to calculate these variables using QGIS (version 3.2.1).

2.4. EVIDENCE FOR CLUTCH PREDATORS AND HATCHING

Motion-triggered video cameras (Bushnell Trophycams), with night-vision capabilities, were placed overlooking 32 wader nests across the study areas (Table 2); 36 camera units were shared out amongst the participating estates, some of which were redeployed to different nests after being recovered from the first deployment. Images and video captured were used to specifically identify nest predators and to confirm successful hatching.

Using one or more of: (a) captured video images; (b) the examination of nest contents when retrieving temperature loggers; (c) the temperature pattern recorded by the temperature logger and (d) direct observations, the outcomes of monitored clutches were recorded as: (i) hatched; (ii) predated; (iii) lost to cultivation; (iv) otherwise failed; or (v) unknown. For each of the first four categories, the outcomes were defined as either confirmed or probable depending on the quality of evidence. Outcomes were classed as confirmed in cases where there was supporting video or direct observational evidence, or where any remaining nest contents provided irrefutable evidence of an outcome (e.g. remains of predated eggs or clear remains of egg membranes after hatching). Probable outcomes were classed as those where the evidence was less clear but still suggestive – normally this was interpretation of the temperature pattern at the ceasing of incubation. We used these data to calculate daily nest survival probabilities using an adjusted version of the Mayfield Method (Mayfield, 1975). The Mayfield Method formula is as follows:

> *Daily survival rate = exposure days a – failed nests b / exposure days a.*

a Exposure days is the number of days a nest is known to be active (between logger deployment and final outcome) and thus susceptible to predation. The hourly data from the data loggers were rounded up or down to half days for this calculation.

b Failed nests is a total of all failed nests. Because outcomes of some nests were only considered 'probable' rather than 'confirmed', we adjusted the failed nests value to include nests where outcomes were probable but not confirmed. Confirmed failed nests were given a weight of 1, where failure was likely but not confirmed, nests were given a weight of 0.75; where hatching was likely but not confirmed nests were given a weight of 0.25, and where hatching was confirmed these were given a weight of 0.

To generate a range within which the likely daily survival rate falls, we also calculated daily survival rates using two alternative approaches: a) where nest outcomes were probable but not confirmed, we made no adjustment for uncertainty and treated these nests as if outcomes were confirmed; and b) giving all nests where outcomes were probable but not confirmed a weight of 0.5, effectively treating outcomes as unknown.

2.5. TRIAL OF POST-BREEDING FLOCK COUNTS

To obtain an additional measure of breeding productivity within the study area, participants were asked to count and age any wader flocks that they encountered between late June and early August. Ageing of flocks in the post-breeding, migration and wintering period has been used for a variety of species (Rodway *et al.* 2015, Iverson *et al.* 2004 for example) to produce estimates of productivity that are less time intensive to obtain than carrying out surveys on the breeding grounds. Participating staff were provided with a guide for identifying newly fledged juveniles of the target species of the project. They were encouraged to collect these records in an 'ad-hoc' manner rather than record flocks in specific locations or specific times.

The form participating staff members were given for recording is in Appendix 3 to this report. Participants were asked to provide counts of juveniles, adults, unaged birds and total birds in the flock, as well as date/time, species and grid reference. This trial was intended to gather some initial data to see whether the approach was feasible and whether participants felt they were able to successfully identify juvenile waders.

2.6. TRIAL OF CAMERA TRAPPING FOR MAMMALIAN PREDATOR ABUNDANCE

The trail cameras used for nest monitoring (Bushnell Trophycams) were also used in July, following the breeding season, to trial an approach designed to generate an index of mammalian predator abundance at participating estates. Baits were used to increase the effectiveness of the camera trapping to reduce effective deployment time required (for consideration of deployment time see Si *et al.* 2014 and Ahumada *et al*. 2011). Using baits is also likely to better approximate predation risk than data collected from randomly distributed non-baited cameras. A fish-based long-life bait was used in the study which was kept inside a plastic bait cage (normally used in fishing), and fixed to the ground with a tent peg. The trail cameras were positioned overlooking the bait 2–3 m away. Participants were asked to leave the bait and camera at different locations around the estate at least 500 m apart, moving the bait and camera every three nights (methods informed by Wearn & Glover-Kapfer 2017). The recording form supplied to participants is in Appendix 3.

3. RESULTS

3.1. WADER TRANSECT SURVEYS

Estate staff carried out 16 wader survey transects across the project area, recording all wader species encountered: following analyses of surveys using the approach described in Section 3.2, across all 16 survey transects 156 apparent wader territories (ATs) were identified. The most numerous species recorded were Lapwing (48 ATs), Oystercatcher (46 ATs) and Curlew (38 ATs). First visits were carried out between the 18th April and the 8th May, second visits between the 9th and 25th May, and final visits between 11th and 26th June. Surveys were all at least two weeks apart at the same site (see Appendix 2 for survey dates). All surveys were carried out in dry weather with good visibility and low wind. Figures 2 provides an example of a transect route with likely territory centres for breeding waders identified using the rules for distinguishing separate territories from the Brown & Shepherd (1993) methodology described in Section 3.2. All wader transect survey maps are presented in the Appendix to this report (Appendix 1).

Data are summarised across all the sites in Table 1. An estimate of the number of successful territories based on third visit activity is shown in brackets for those transects (six) where three visits were completed. The sites surveyed were intended to cover a range of habitats and elevations of varying suitability for breeding waders, and the sites surveyed represent a small sample of the overall study area, so the data presented in Table 1 are not intended to facilitate comparison of overall wader numbers between the ECMP estates or with other areas.

Figure 2.: Example wader transect survey results, with the stars indicating the apparent territory centres for each species.

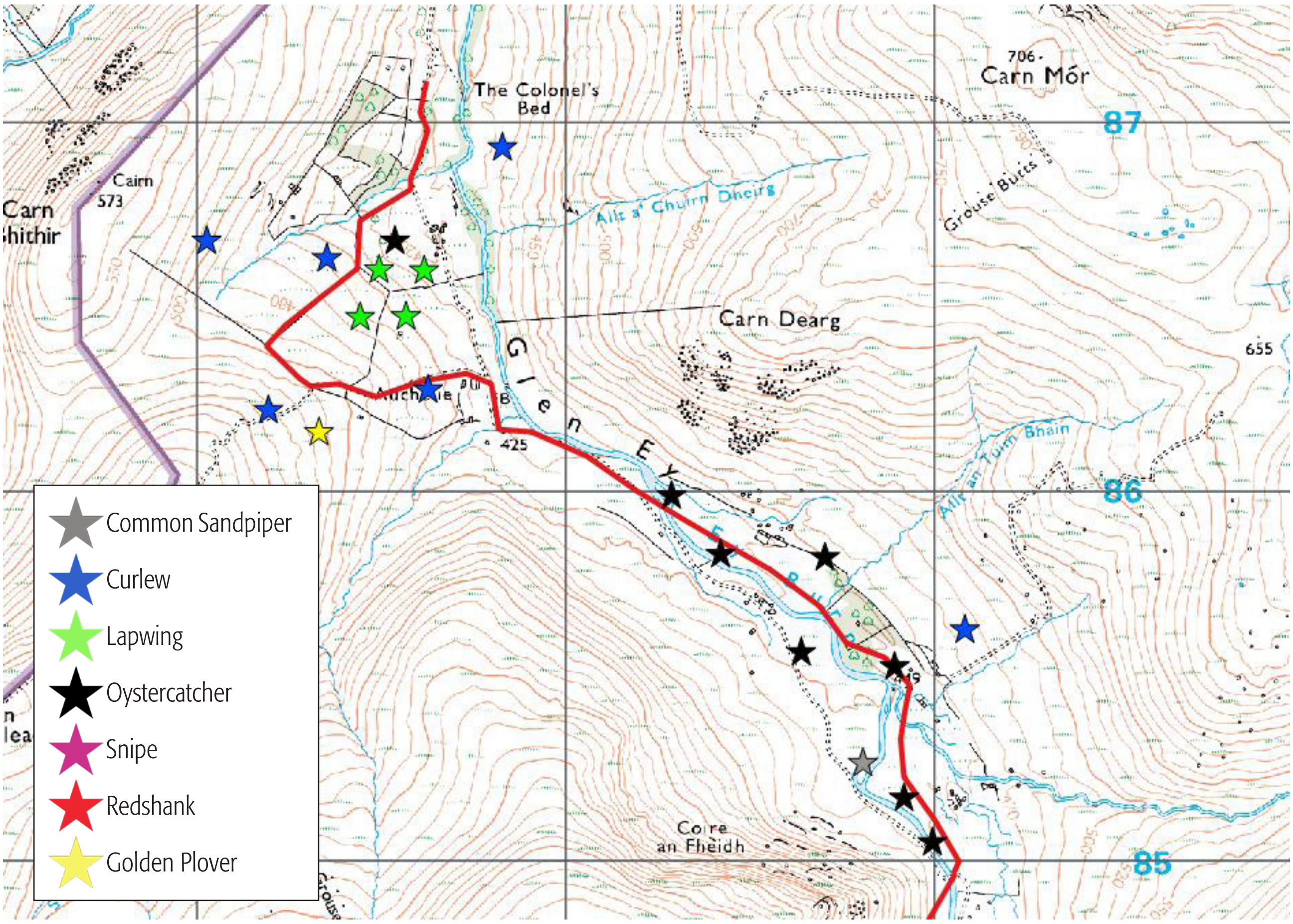


Table 1. Summary of data recorded from each of the wader transect surveys carried out by estate staff. Numbers are estimates of likely territorial pairs identified using the Brown & Shepherd (1993) methodology described in section 3.2. For survey sites where three visits were carried out, estimates of successful pairs based on third visit activity is shown in brackets.

	LENGTH OF TRANSECT	ELEVATION (MID-POINT)	HEATHER %	WHITE GROUND (%)	WELL-GRAZED (%)	COMMON SANDPIPER	CURLEW	GOLDEN PLOVER	LAPWING	OYSTERCATCHER	REDSHANK	SNIPE
Mar – Glen Eye (N)	3.6 km	445	20	80	0	1 (1)	6 (6)	1 (1)	4 (4)	8 (8)	0	0
Mar – Glen Eye (S)	2.5 km	475	20	80	0	5 (5)	0	0	3 (3)	4 (4)	0	0
Glenavon – Carn na t-Sleibhe	2.3 km	475	50	50	0	0	5 (5)	1 (0)	5 (5)	1 (0)	0	0
Glenavon – Blairnamarrow	3.2 km	455	50	50	0	0	1 (1)	1 (0)	1 (1)	0	0	0
Glenavon – Glen loin	2.2 km	480	60	10	30	1 (1)	1 (1)	0	0	3 (2)	0	0
Glenavon – Inchrory	1.4 km	460	30	10	60	0	2 (1)	0	4 (4)	3 (1)	0	0
Glenlivet – Inchnacape	2.4 km	395	0	30	70	0	3	0	5	2	1	0
Glenlivet – Tombreck	2.8 km	460	15	35	50	0	2	0	4	1	0	1
Glenlivet – Distillery	3.8 km	240	0	20	80	0	0	0	4	5	0	0
Glenlivet – Lagganvoulin	1.3 km	340	10	20	70	0	2	0	5	2	0	0
Rhieddorach – Carn Mor	3.0 km	840	80	20	0	0	0	7	0	0	0	0
Rheiddorach – Gleann Taitneach	5.8 km	385	20	65	15	0	6	0	0	6	0	0
Invercauld – Gleann Begg	4.1 km	370	10	80	10	1	8	0	8	9	1	0
Balmoral – Gelder Burn 1	2.3 km	370	50	0	50	1	1	0	2	1	0	0
Balmoral – Gelder Burn 2	2.3 km	335	75	0	25	0	1	0	2	0	0	1
Balmoral – Gelder Burn 3	2.3 km	320	10	40	50	1	0	0	1	1	0	0
TOTAL	–	–	–	–	–	**10**	**38**	**10**	**48**	**46**	**2**	**2**

3.2. NEST MONITORING

Participating staff located and monitored 107 wader nests, of which 75 were monitored solely with data loggers, and 32 were monitored with data loggers and nest cameras. The locations of monitored nests are shown in Figure 3 and Figure 4. The data logger was recovered (and an incubation period thus determined) for 92 of the monitored nests, enabling these to be included in the GLM analysis (described in Section 3.3). Nests were excluded from this analysis in situations where a) the data logger was not successfully recovered from the nest or b) the nest was abandoned following deployment of equipment (this happened on three occasions). Outcomes and causes of failure for all monitored wader nests are shown in Table 2, and the subset of nests monitored with a camera is shown in Table 3.

Figure 3. Location of monitored nests in the south of project area.

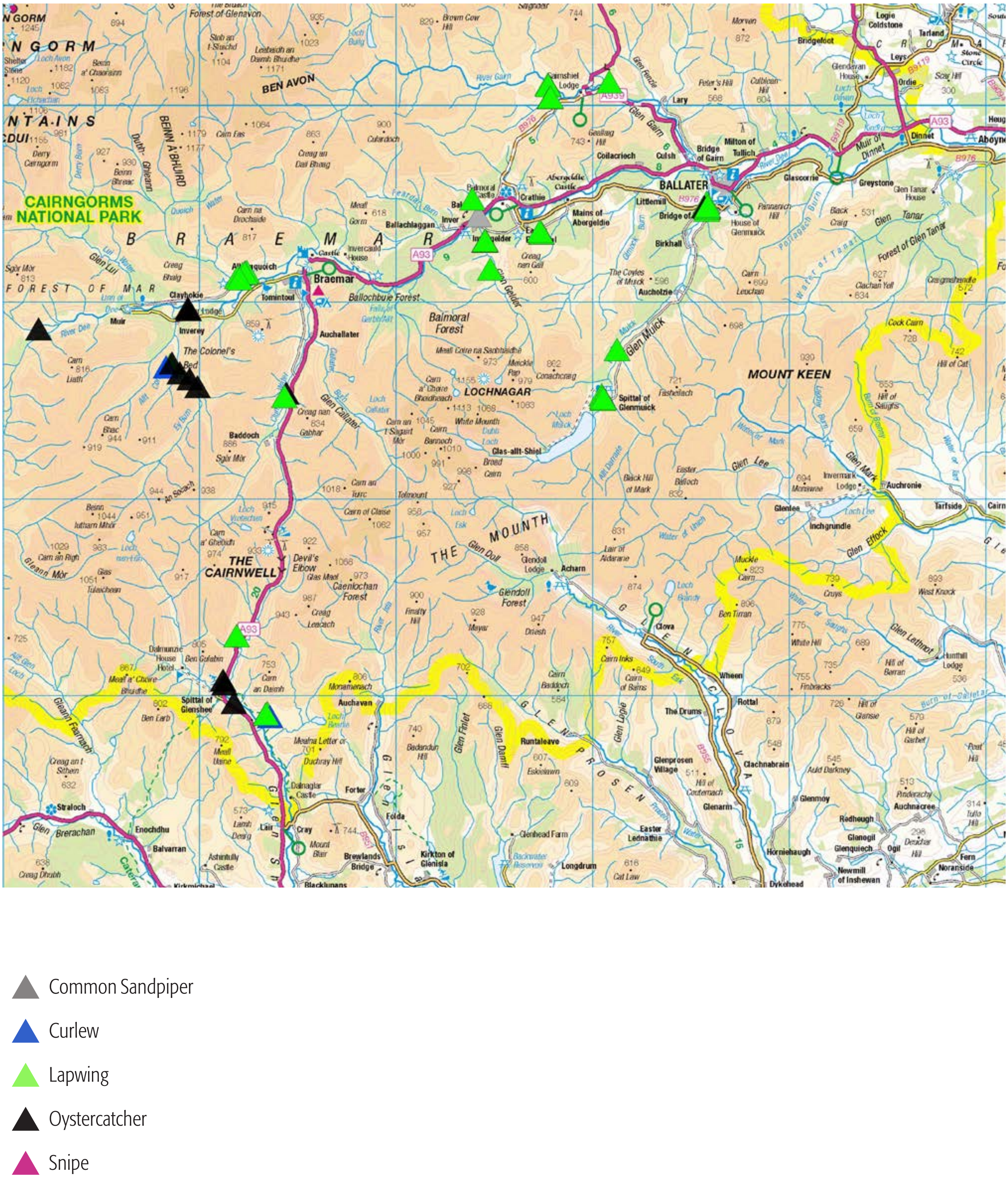
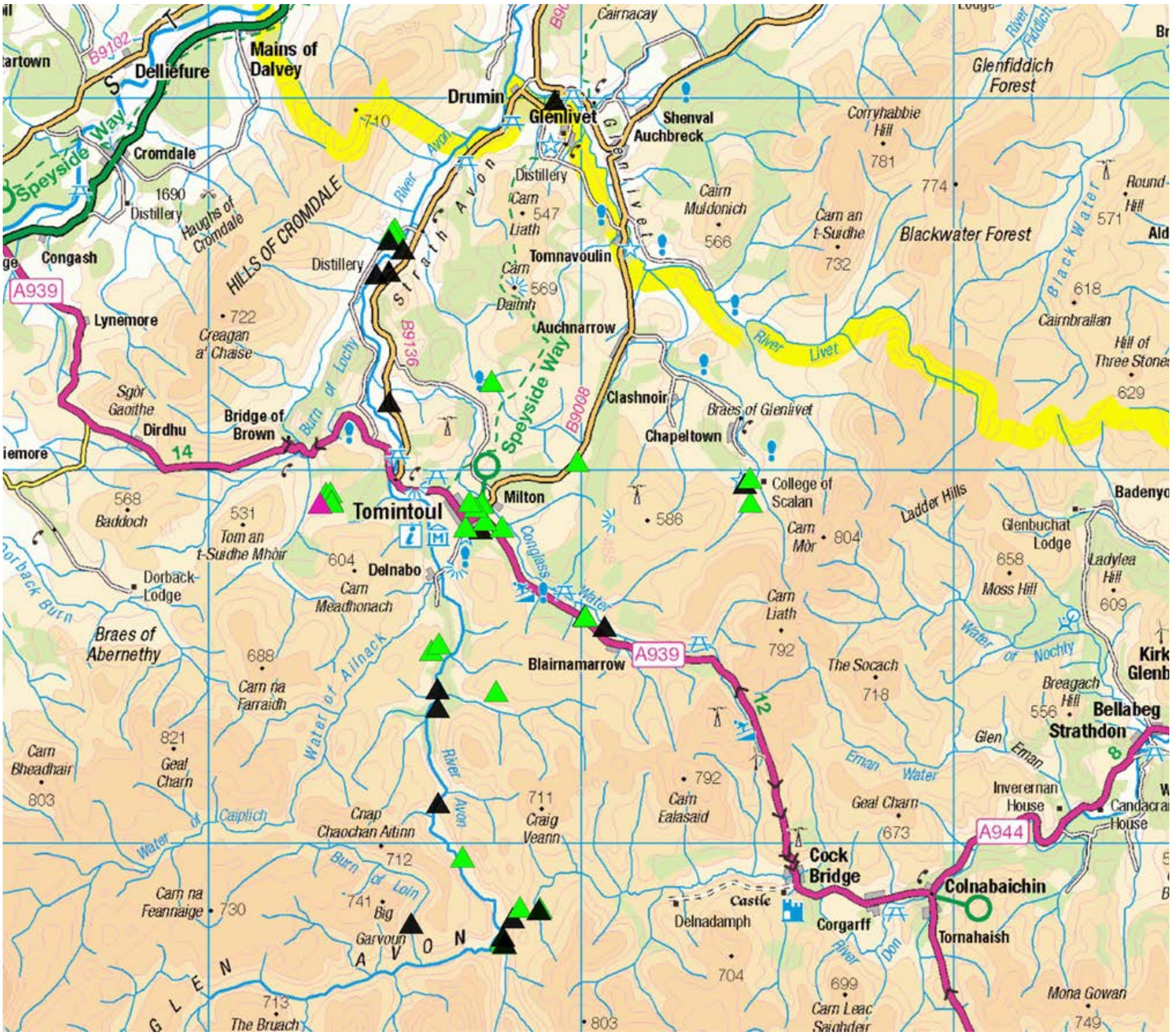


Figure 4. Locations of monitored nests in the north of the project area.



▲ Common Sandpiper

▲ Curlew

▲ Lapwing

▲ Oystercatcher

▲ Snipe

Table 2. Nest outcomes from all wader nests monitored. Cases where outcome was confirmed through video or other irrefutable evidence (see Section 3.2) are shown in brackets in the 'hatched' and 'failed' columns.

	OUTCOME				CAUSES OF FAILURE							
SPECIES	Total	Hatched	Failed	Unknown	Unattributed failure (diurnal)*	Unattributed failure (nocturnal)	Abandoned	Sheep	Agricultural operations**	Jackdaw	Common Gull	Stoat
Lapwing	72	33 (9)	29 (14)	10	16	3	3	1	3	0	1	2
Oystercatcher	31	23 (8)	8 (3)	0	2	3	0	0	1	1	0	1
Snipe	1	1 (1)	0	0	0	0	0	0	0	0	0	0
Common Sandpiper	1	1 (0)	0	0	0	0	0	0	0	0	0	0
Curlew	2	1 (0)	0	1	0	0	0	0	0	0	0	0
TOTAL	**107**	**59 (18)**	**37 (17)**	**11**	**18**	**6**	**3**	**1**	**4**	**1**	**1**	**3**

* Nocturnal is defined as being between the hours of 10pm and 4am. Nocturnal nest failures are usually assumed to be caused by mammalian predators (Macdonald & Bolton 2008), while diurnal nest failure is less easily attributable, with mammalian predation still possible, avian nest predation possible, and other causes of failure including livestock trampling / predation, and disturbance or abandonment related to human activities also possible.

** For the four nests which were assumed lost to agricultural operations the data logger was not recovered and the incubation period was unknown.

Table 3. Outcomes for the subset of nests (32) monitored with trail cameras and data loggers.

	OUTCOME				CAUSE OF FAILURE					
SPECIES	Total	Success	Failed	Unknown*	Abandoned	Stoat	Jackdaw	Common Gull	Unknown	Sheep trampling
Lapwing	17	10	6	1	2	2	0	1	1	1
Oystercatcher	13	10	3	0	0	1	1	0	0	0
Snipe	1	1	0	0	0	0	0	0	0	0
Common Sandpiper	1	0	0	1	0	0	0	0	0	0
TOTAL	**32**	**21**	**9**	**2**	**2**	**3**	**1**	**1**	**1**	**1**

*For these nests the camera memory card was full or the camera disturbed by livestock before hatching / failure was recorded. For some additional nests in the 'success' or 'failed' column, outcomes were confirmed by the data.

Nest failure was attributed to agricultural activities where a field was furrowed, ploughed or rolled and the nest was destroyed – in all four cases the data logger wasn't recovered from these nests. Of the 15 nests for which an incubation period was not determined, the data logger was not recovered due to difficulty re-finding the nest in nine cases (including those nests lost to agricultural activity), for three nests the data logger was recovered but the data were downloaded too late to ascertain the nest outcome, and for three nests the birds did not return to the nest following deployment of the data logger.

The results from the GLMs are shown in Table 4, with different models run for each woodland variable tested. Significant variables in (some or all of) the models were date, habitat and species, and the woodland cover variables were significant in some models with clutch survival increasing with increased conifer and woodland cover within 5 km of the nest, and with conifer coverage within 1km of the nest. The models which included woodland or conifer cover within 300 m of the nest and distance to mature tree explained less variation (assessed using AIC value, Akaike 1973) in incubation period than the 1 km and 5 km models. Incubation periods were significantly longer in heather than in enclosed fields (in the 1 km and 5 km models), and in the 5 km woodland cover models incubation was also significantly longer on 'white ground.'

3.3. DAILY SURVIVAL PROBABILITY

The adjusted version of the Mayfield method (Mayfield 1975) was used to calculate daily nest survival rates across all the nests monitored – the probability that the nest will survive from one day to the next. Assuming a hatching period for Oystercatcher of 25.5 days (24–27 days; Ferguson-Lees *et al.* 2011) and for Lapwing 26.5 days (26–27 days; Ferguson-Lees *et al.* 2011), the likelihood of nesting success is shown in Table 5. For both species, additional Mayfield Method calculations were carried out as described in Section 3.4, to provide the range of possible values within which the correct hatching success figure was likely to fall to account for uncertainty in nest outcomes. Curlew, Common Sandpiper and Snipe are excluded because data were only recovered from one nest for each of these species.

3.4. POST-BREEDING FLOCK COUNTS

Data received from participating staff that carried out post-breeding flock counts are presented in Table 6. The counts were only carried out on Balmoral and Mar Lodge Estate. A worked example with the data from the Quoich floodplain (on Mar Lodge) is presented to give a ratio of juveniles to adults gathered from six counts between the 17/6/18 and the 3/7/18. The proportion of juveniles amongst all aged birds recorded in these counts was 24%. Daily nest survival of all wader species on the Quoich Floodplain was 0.944 (n=8). Six counts were also carried out on an area of the Balmoral Estate where the proportion of juveniles counted was 28%, and daily nest survival was 0.986 (n=11).

Table 4. Model outputs for fixed effects from GLMs that examine associations between explanatory variables with the length of incubation period (a proxy for nest success). A different model was run for each different woodland variable tested, outputs from the seven different models are shown here. Woodland 300 m (for example) represents the proportion of land cover within a 300 m radius of the nest location which was woodland. In each of the seven models, the woodland variable tested is the column heading. All variables which were tested in the original model are shown, and those variables which were statistically significant (P < 0.05) or marginally non-significant (0.05 < P > 0.10) are shown in bold text. The lower the AIC value (Akaike 1973) for each model, the more effective the model is at explaining variation in the incubation period.

	WOODLAND VARIABLE TESTED IN MODEL						
	DISTANCE TO MATURE TREE	WOODLAND 300 m	WOODLAND 1 km	WOODLAND 5 km	CONIFER 300 m	CONIFER 1 km	CONIFER 5 km
Explanatory variable	Est (P)	Est (P)	Est (P)	Est (P)	Est (P)	Est (P)	Est (P)
Intercept (L, enclosed grassland, no camera)	73494	**106020 (0.07)**	83502	**86659 (0.10)**	93620.41	80087	**91933 (0.08)**
Species Oystercatcher	78.05	75.84	92.20	**99.72 (0.09)**	78.00	100.67	**105.83 (0.07)**
Species Common Sandpiper	139.65	142.05	91.24	128.57	159.85	82.67	116.57
Species Curlew	0.73	22.54	40.06	1.28	12.08	48.70	8.128
Species Snipe	1.49	22.97	16.67	-0.92	18.16	8.86	0.469
Date	-4.15	**-5.99 (0.07)**	-4.72	**-4.90 (0.10)**	**-5.28 (0.10)**	-4.53	**-5.198 (0.08)**
Camera	37.71	26.69	26.47	34.76	32.47	25.25	35.76
Habitat Heather	109.39	104.32	**148.87 (0.09)**	**167.74 (0.06)**	104.10	**171.38 (0.04)**	**173.86 (0.05)**
Habitat White ground	50.86	39.38	75.36	**101.88 (0.09)**	35.20	79.08	**105.48 (0.07)**
Woodland variable (see column heading)*	-0.03	0.0007	0.000087	**0.0000058 (0.05)**	0.00089	**0.00016 (0.06)**	**0.0000095 (0.02)**
AIC	**1238.1**	**1236.9**	**1235.7**	**1234.3**	**1237.9**	**1230.1**	**1232.9**

Table 5. Daily survival and likelihood of hatching success. The ranges shown in brackets represent values calculated using alternative Mayfield Method approaches. Treating 'probable' outcomes as 'confirmed' gives the higher hatching success estimate, and treating 'probable' outcomes as 'unknown' gives the lower hatching success estimate.

SPECIES	ESTIMATED LIKELIHOOD OF HATCHING SUCCESS	DAILY SURVIVAL PROPERTY
Lapwing	42% (37–47%)	0.968 (0.963–0.972)
Oystercatcher	58% (51–66%)	0.979 (0.974–0.984)

Table 6 Example of Post-breeding flock count data from the Quoich floodplain.

	DATE	SPECIES	JUVENILE	ADULT	UNAGED	TOTAL FLOCK
	17/06	Oystercatcher	3	6	0	9
	22/06	Curlew	2	1	0	3
	01/07	Lapwing	0	3	0	3
	01/07	Oystercatcher	0	13	2	15
	01/07	Oystercatcher	2	4	0	6
	03/07	Curlew	2	2	0	4
AREA SUMMARY	–	–	9	29	2	40

3.5. MAMMALIAN PREDATOR ABUNDANCE

Cameras were deployed with bait for mammals for 77 nights recording in 21 different locations on Invercauld, Rheidorrach, Glenlivet, Mar, Balmoral and Mar Lodge. One instance of Stoat and one instance of Common Rat *Rattus norvegicus* approaching the baits were recorded. More data are needed to understand the effect of mammalian predator abundance on spatial variation in hatching success, or the distribution of predator species, in relation to habitats and topography.

4. DISCUSSION

The objectives of this initial year of the project were to investigate factors affecting wader nest productivity within the ECMP area, and to gather contextual information on wader abundance and predator species. The success of the project was dependent on participation by estate staff; in general, the estates engaged very well with the project and the data generated were of a quality and quantity which allowed initial investigation of the project objectives. We would recommend, based on the success of the initial year, that there would be considerable benefit to continuing data collection in future years. The results of the wader transect survey methodology are discussed in Section 4.1 and the nest monitoring with cameras and data loggers in Section 4.2. The post-breeding flock counts are discussed in Section 4.3, and the predator monitoring in Section 4.4. More general conclusions regarding wader monitoring within the East Cairngorms Moorland Partnership and the Cairngorms National Park are presented in Section 4.5.

4.1. WADER TRANSECT SURVEYS

All participants were enthusiastic about carrying out wader transect surveys and demonstrated the ability to identify and record the necessary species and behaviours. Transect surveys revealed high densities of the target species in suitable habitats. While for some of the lowland ECMP areas around Tomintoul (for example) there has been relatively good coverage from existing wader projects (e.g. Cunningham *et al.* 2017), from some other survey sites covered there was little existing wader data. Information on wader abundance at these sites will help to inform land management planning within the ECMP area.

For six of the 16 transects, three survey visits were carried out, enabling an index of breeding success to be generated based on behaviour on the third survey visit. In future years it will be important to stress the importance of completing three visits to allow this index to be generated across all surveyed transects. The index of success indicated from the wader transect surveys is higher than that indicated by the nest monitoring – this will partly be explained by the propensity of pairs to re-lay when they fail at the egg stage, meaning that pairs can still be active, and breed successfully, despite earlier nest failure. However, the sample of transects for which a third visit was completed is relatively small, and more work is needed to understand how to better calibrate productivity measures obtained from different methods. Using third visit territorial behaviour as a metric of productivity can result in over-counting in areas of rough grassland fringing moorland, because moorland breeding birds are likely to bring chicks into rough grassland areas fringing moorland which may provide better feeding opportunities (Grant *et al.* 2000).

Training and encouraging estate staff to carry out wader surveys is a cost-effective means of improving knowledge on breeding waders in upland areas (Jarrett et al. 2017) where coverage from traditional survey volunteers is limited (for example from the BTO/JNCC/RSPB Breeding Bird Survey, Harris *et al.* 2018). The wader transect survey data will improve knowledge of wader populations within the ECMP area, and could potentially evolve into an effective long-term monitoring tool. A realistic objective would be to provide long-term support for the continuation and expansion of the estate staff transect surveys, with a process put in place to collate and report on data gathered. This could, over time, be used to deliver effective breeding wader trend data within the ECMP area (or the extent of the CNP if there were enthusiasm to extend the approach), possibly complementing data from the Breeding Bird Survey. If this were to be an objective, it would be important to consider the representativeness of survey sites. In this initial year participants selected sites known to hold breeding waders, and so were not gathering nil (or very low) counts from sites from which waders are absent or present in very low numbers. If within the ECMP area the suite of sites covered was broadly representative of the range of wader habitats across elevations, topographies and types of land management, this would enable modelling of the relative abundance of waders species. In the Yorkshire Dales, Bradter *et al.* (2013) produced predictive maps of Curlew distribution and relative abundance, using data from a sample of 61 transects. It is unlikely to be realistic, at least in the short-term, to attempt to gather enough data for modelling of the higher altitude species such as Golden Plover, Dunlin and Dotterel *Charadrius morinellus*, because this would require a very large effort in terms of coverage of the more remote higher ground.

Because of the relatively small sample of sites covered in this initial year, and the fact that we don't have information on the representativeness of surveyed sites, we haven't used the wader transect data to generate wader density estimates for the ECMP area, or made comparisons to other upland areas. However, as discussed above, this could be an aim in future years.

4.2. NEST MONITORING

The nest monitoring aspect of the project was very successful, with participants enjoying the challenge of nest finding and being enthusiastic about the outputs in terms of identifying causes of nest failure and measuring nest productivity. Given that nest predation rates are often the most significant factor influencing wader breeding productivity (Macdonald & Bolton 2008, Douglas *et al.* 2014), identifying nest predator species is important for informing management for breeding waders. However, a large sample of monitored nests is needed before robust conclusions could be made about associations between the relative importance of different nest predators, so we would recommend that nest monitoring be continued for two more years (or more).

The estimate of Lapwing hatching success for the first year of this project (42%) is higher than the equivalent figure for Lapwing in Wensleydale in 2017 of 35% (Jarrett *et al.* 2017), and within the range of 30-60% typically reported for studies of Lapwing from lowland grassland sites (Berg *et al.* 2003, Seymour *et al.* 2003, Bolton *et al.* 2007), although there is less comparable data from upland areas, and also less comparable data for Oystercatcher. Both Lapwing and Oystercatcher nest failure rates have been increasing across the UK (Figure 5, Massimino *et al.* 2017), with daily nest survival of monitored nests currently at similar rates (0.97 – 0.98) to that found in this project. However predation and survival rates at the same site can vary widely between years, with Teunissen *et al.* (2008) reporting variation in annual predation rates of between 8% and 51% (significant inter-annual variation can also be seen in Figure 5). The inter-annual variation in hatching success provides additional justification for collecting more years of nest monitoring data before making conclusions on hatching success.

In the analysis of factors affecting nest productivity we did not detect a negative effect of woodland cover on the length of incubation period, despite various studies having linked woodland cover and habitat fragmentation with reduced wader breeding success (Douglas *et al.* 2014, Bertholdt *et al.* 2017) and reduced abundances of breeding waders (Hancock *et al.* 2009, Wilson *et al.* 2014, Franks *et al*. 2017). Indeed at the 5 km scale, for both coniferous and broad-leaved woodland, we found significant effects of woodland cover being correlated with longer incubation periods. It should be stressed that the data set is relatively small and more data would be needed before drawing robust conclusions, but assuming that this is a genuine effect, there may be various factors involved. Within the ECMP area, predator control was carried out on all estates involved in the project (Table 7). Douglas *et al.* (2014), whose study included both keepered and un-keepered sites, found that increased gamekeeper density (as a proxy for predator control) ameliorates the negative effect of woodland cover on breeding productivity. If in the East Cairngorms Moorland Partnership area predator control was more intensive in areas within 5 km of woodland, and less intensive in more remote areas of moorland, the findings here would not be contradictory with Douglas *et al.* (2014). This is probably feasible in the east Cairngorms, where the participating estates are very large, and there are expansive open areas of moorland where predator control is less intensive due to the constraints.

An avoidance effect, where waders choose to nest further away from habitats and landscape features they associate with higher predation risk has been found previously (e.g. Stroud *et al.* 1990, Wilson *et al.* 2014

Figure 5.: Lapwing and Oystercatcher nest failure rates (taken from Massimino *et al.* 2017).

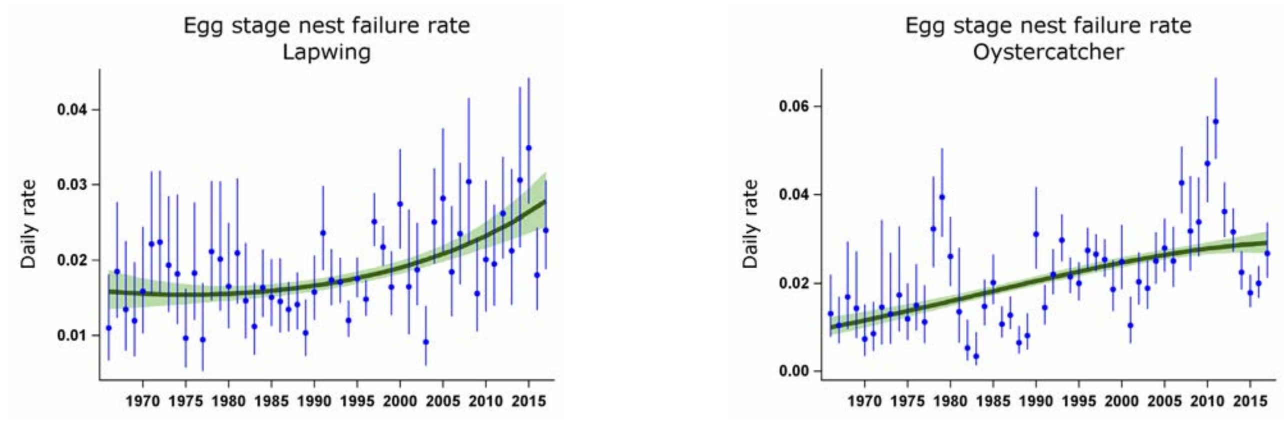


Table 7. Indicative summary of predator control effort across estates involved in the project.

ESTATE	AREA (ha)	AREA COVERED BY MOORLAND (ha)	NUMBER OF GAMEKEEPERS	SPECIES CONTROLLED
Balmoral	17,289	4,065	10	Foxes, mustelids, crows
Glenavon	17,028	11,579	6	Foxes, mustelids, crows
Glenlivet	20,819	9,674	6	Foxes, mustelids, crows
Invercauld	43,772	16,454	16	Foxes, mustelids, crows
Mar	6,142	1,366	2	Foxes, mustelids, crows
Mar Lodge	29,373	8,602	5	Foxes

and Bertholdt *et al.* 2017), and this may also reduce actual predation risk on wader nests in proximity to woodland. An investigation of the spatial distribution of wader territories within the study area in relation to woodland would allow this to be investigated. At larger distances from woodland cover, reduced predation associated with woodland predators may also be offset by increased predation pressure from Common Gull colonies, which are relatively common within the study area, often in remote glens some distance from any woodland. Common Gulls were recorded predating one Lapwing nest which was in an area with very little woodland (nearest mature tree 918 m away). In general, more years nest monitoring data are needed to further investigate the relationship between woodland cover and breeding productivity and generate robust conclusions.

We also found shorter incubation periods in improved grassland sites (indicating lower hatching success) than in rough grassland and heather sites. This may be a consequence of the effect of agricultural activities (such as rolling / harrowing) or higher densities of sheep in improved grassland sites resulting in higher levels of nest trampling and disturbance (Hart *et al.* 2002, Sabatier *et al.* 2010, Pakanen *et al.* 2011, Sharps *et al.* 2017) and also potentially nest predation by livestock (Pennington 1992, Nack & Ribic 2005, Jarrett *et al.* 2017).

4.2.1. PRACTICAL CHALLENGES

Data loggers were programmed to over-write earlier temperature data after 28 days (as discussed in the methods section). In situations where this resulted in the data relating to the end of incubation (hatching or nest failure) being over-written, it was impossible to determine whether or not nests hatched successfully. These nests typically had to be excluded from analysis, but this could lead to bias. Because the end of the incubation period tends to be earlier for predated nests than where hatching occurs, data from predated nests are more likely to be over-written. In this project, data from three nests were not downloaded in time. Because these nests were excluded from the analysis, this may have introduced a small bias into the data analysed.

An additional issue can arise for loggers deployed at early-failing nests, which is that these may be harder to re-find due to growth of surrounding vegetation over the course of the season. This means that nests from which the logger was not re-found were possibly more likely to have been predated than those for which logger data are included in analyses. There were nine nests for which the loggers were not re-found. Together with the possible bias arising from over-written data described above, actual failure rates may have been slightly higher than estimated in this report. To improve the interpretation of nest monitoring data, we will ask participants to record nest contents (shell fragments present/absent, size of fragments) when recovering data loggers and/or cameras, because hatching, mammalian predation or avian predation can also be estimated from nest remains (Green *et al.* 1987).

Cameras were distributed between estates at the start of the project when it wasn't known how much resource the estate would be able to commit to nest finding. As such, some cameras were not used during the project with 36 cameras available for the project to use and 29 nests monitored with cameras.

While most studies on wader nest predation have not reported negative effects of monitoring nests on nest survival (MacDonald & Bolton 2008, Calladine *et al.* 2017), and methods for nest monitoring are well established, it is difficult to rule out the possibility of negative effects of monitoring because of the difficulty in obtaining or producing effective control data. In this project, following the set-up of nest monitoring equipment, out of the 107 nests monitored, three Lapwing nests were abandoned.

4.3. POST-BREEDING FLOCK COUNTS

Gathering accurate data on wader fledging success to complement data on hatching success is critical to gaining a better understanding of spatial variation in wader breeding productivity. Post-breeding flock counts could be a means of gathering data on breeding productivity relatively cost-effectively, although more trialling of the approach is necessary to establish effectiveness.

Uptake of the post-breeding flock counts was lower than we had hoped. It was reported by project participants that birds left the study area very soon after the breeding season as a result of the hot, dry conditions from June through to August making foraging conditions in upland areas poor for waders. In July most participating estates were increasingly busy due to preparations for the grouse shooting season, in addition to other monitoring and engagement activities. The data that were gathered were insufficient to make any assessment on the extent to which the post-breeding flock counts were correlated with productivity data from other measures. Additionally, because a significant proportion of Lapwing broods are typically aggregated into post-breeding flocks at the time of third survey visits (late June) it may be more appropriate to encourage surveyors to count and age flocks of Lapwing when carrying out third survey visits. We will consider these options and discuss in advance with participants to agree on a suitable approach in future, which may also involve providing additional support at this time of year.

4.4. PREDATOR ABUNDANCE

A better understanding of what drives variation in predator abundance in different landscapes, how predators use the landscape, and how predation pressure can be ameliorated have long been identified as key to enabling effective conservation of breeding wader populations (Evans 2004, MacDonald & Bolton 2008). Many recent studies have investigated nest predation at lowland grassland sites (Seymour *et al.* 2003, Bolton et al. 2007, Eglington *et al.* 2009, Laidlaw *et al.* 2015, 2017, Mason *et al.* 2017), but fewer have focussed on upland areas. A notable exception is the work by Fletcher *et al.* (2010), who experimentally deployed legal predator control at a range of upland sites and monitored the effect on wader productivity.

A repeatable, low-cost mammalian predator abundance survey would be an effective means of informing the identification of areas where measures to improve habitat conditions or reduce predation pressure for breeding waders would deliver the greatest return in terms of increased productivity. In the absence of this contextual data on the abundance of mammalian predators, attempts to improve breeding wader numbers through management of habitat may be less likely to succeed (Calladine *et al.* 2014). While more detailed approaches to mammalian predator monitoring have involved deploying tracking tunnels for mustelids (King & Edgar 1977) or fox scat monitoring transects (Webbon *et al.* 2004), it would be unrealistic to ask estate staff to carry out these activities. Baited camera trapping is likely a realistic compromise that deserves further attention and development. Data on predator abundance gathered from areas such as the ECMP, where predator control is carried out relatively intensively, could then be used to inform management objectives for breeding waders in other areas.

During this project there was relatively restricted uptake of camera trapping for mammals amongst participating estates, partly because of a delay in receiving the bait cages from the supplier. We asked participants to carry out mammal surveys in July in the immediate post-breeding period, when estates were also busy in preparation for the grouse shooting season or with other monitoring and engagement activities. The timing of any future camera-trapping initiatives should be discussed in advance in order to maximise their ability to take part. While more information on the seasonality of mammalian predator abundance, movement and behaviour in upland landscapes would be useful, it is likely that mammal monitoring will be of most relevance to breeding productivity if the work is carried out as close to the breeding season as possible. However, baits should not be used on breeding grounds during the wader breeding season because of the possibility that this would affect the probability of nests being predated. Additionally, further consideration should be given to the type of bait used, and the sampling method, in terms of the spatial distribution of sampling points and the period of deployment at each point.

It is also possible to use the extent of muirburn, or Red Grouse *Lagopus lagopus scotic*a abundance (associated with driven grouse shooting) as a proxy for predator control measures. Such measures can reveal large-scale patterns in the effects of predators and predator control (see Franks *et al.* 2017), but these are unlikely to be at a fine enough resolution to inform site management. Information about the number of predators controlled by gamekeepers could be very valuable for future analysis in the ECMP area, but would not necessarily be comparable between sites where the intensity of predator control and density of predators vary: a relatively small number of predators controlled could be a result of either effective control of predator numbers, or low trapping effort. More generally, the effectiveness of predator control in reducing predation pressure will vary between landscapes, and additionally the abundance of predatory species which are not on the general licence will not be reflected in bag data. For example, some parts of the ECMP area are likely to support relatively high densities of Pine Martens *Martes martes*, while in other areas of the ECMP they are thought to be almost absent (pers. comm with estate staff). Little is known about the potential impact of Pine Marten recolonisation on breeding waders, or the ways in which recovering Pine Marten populations might interact with other generalist predators.

4.5. CONCLUSION

The participating ECMP estates contributed significant resources to the project, and following the investment in training, support and engagement with staff across the 2018 breeding season there is the skill and potential to continue gathering breeding wader data in the ECMP area in future years. Data gathered during the project were of a quality that can be used to further understanding of breeding waders in upland areas. The ongoing resource required to support continued data gathering is likely to decrease over time as capacity for monitoring and understanding of methods increases on the ECMP estates. With more wader transect data gathered in future years, options for producing more detailed analyses – such as annual wader trends or spatial models of wader density – will increase. Similarly, with more nests monitored each year the statistical power afforded to investigate factors affecting breeding productivity at a finer scale will also increase.

The landscape-scale habitat change expected in some parts of the CNP (see www.cairngormsconnect.org.uk, for example), presents both an opportunity to improve our understanding of how resilient wader populations are in the face of such changes, and also the imperative to establish long-term conservation strategies for breeding waders which are compatible with competing land management objectives. Applying similar methods in other parts of the CNP where predator control is less intensive, both in the deer forests of the south-west and the more wooded areas of Speyside, could significantly increase our understanding of factors affecting breeding waders. This would improve our understanding of how wader populations are influenced by both predator control and habitat management within the wider Cairngorms area, and provide comparative data to the ECMP area. Given that initial results reported here suggest that increasing woodland cover may not be associated with decreased hatching success where predator control is carried out, we would also stress the importance of gathering further data to improve our understanding of the spatial determinants of predator abundance and distribution.

It is important to ensure that support for engagement with estate staff is sustained and that resources are in place to capitalise on the enthusiasm and interest generated by this initial year. It is also important that, in the longer term, infrastructure is put in place to effectively analyse and report on data being gathered by estate staff. Significant numbers of estates in the Yorkshire Dales National Park are also now carrying out wader transect surveys following a pilot project in 2017 (Jarrett *et al.* 2017), and there may be synergies to be gained from pooling resources and data between upland areas. Collaboration with groups carrying out wader research and monitoring in other upland areas of the UK has the potential to significantly increase our understanding of how different land management approaches affect wader populations in upland landscapes, and also to highlight the importance of these areas for breeding waders in a national context.

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7. APPENDICES

APPENDIX 1: WADER TRANSECT SURVEY RESULTS. ON FIGURES 6–21, SURVEY ROUTE IS MARKED WITH A RED LINE, AND APPARENT TERRITORY CENTRES ARE INDICATED WITH STARS.

Figure 6. Balmoral Estate: Gelder Burn 1

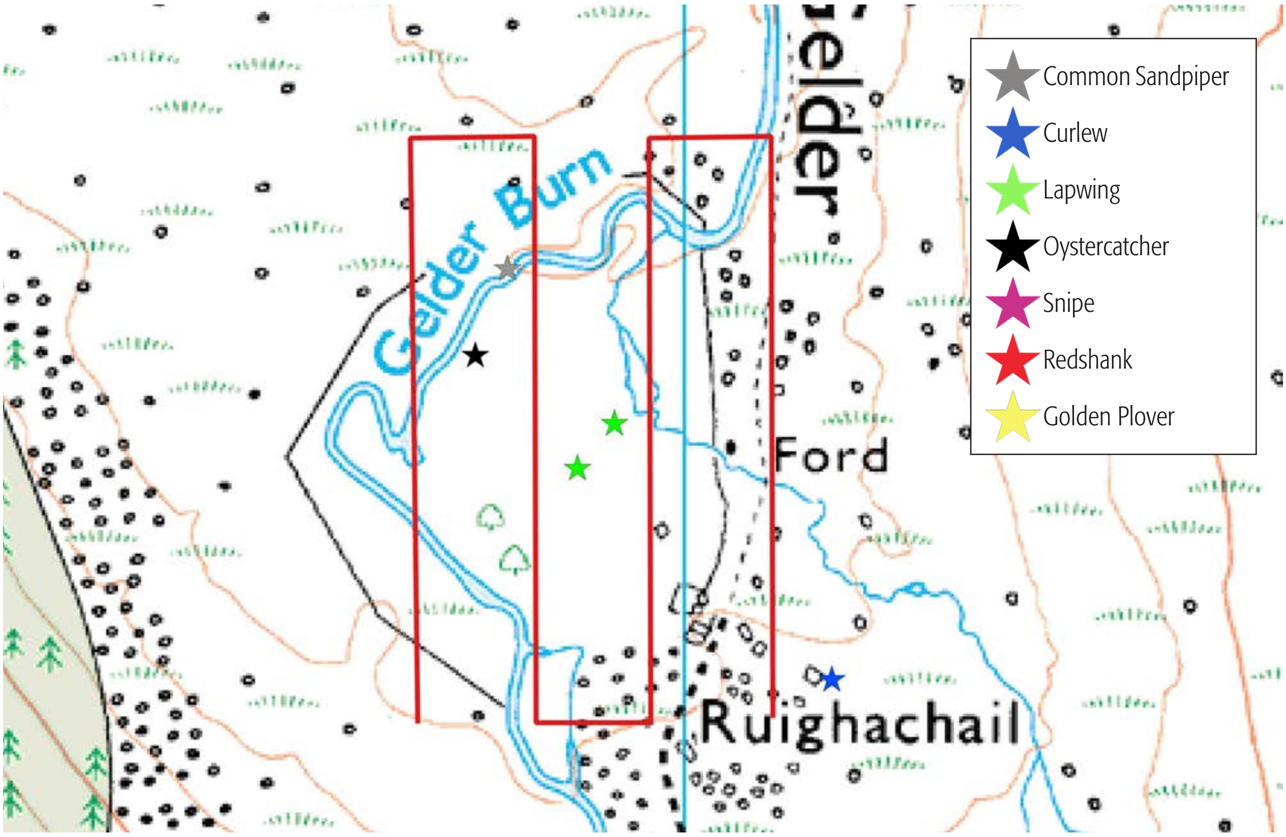


Figure 7. Balmoral Estate: Gelder Burn 2

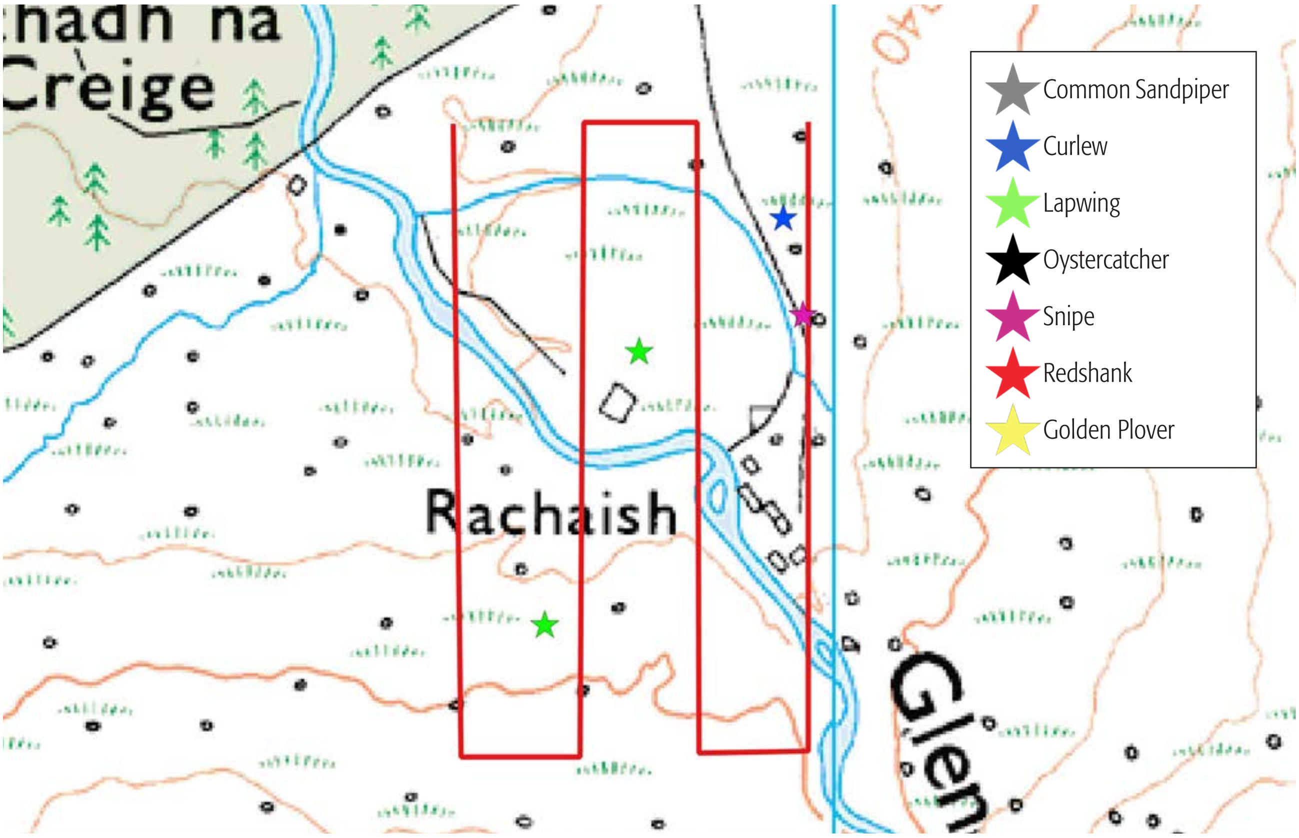


Figure 8. Balmoral Estate: Gelder Burn 3

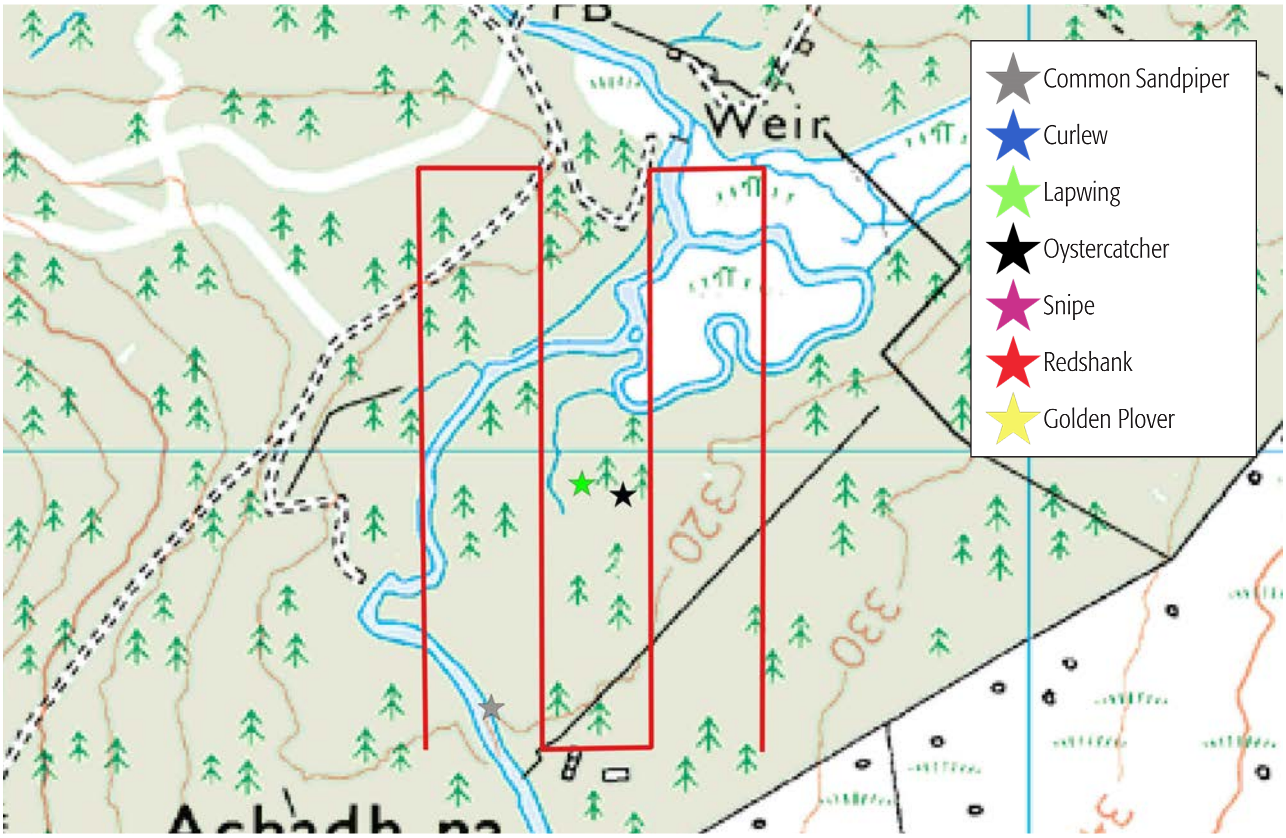


Figure 9. Mar Estate: Glen Eye (North)

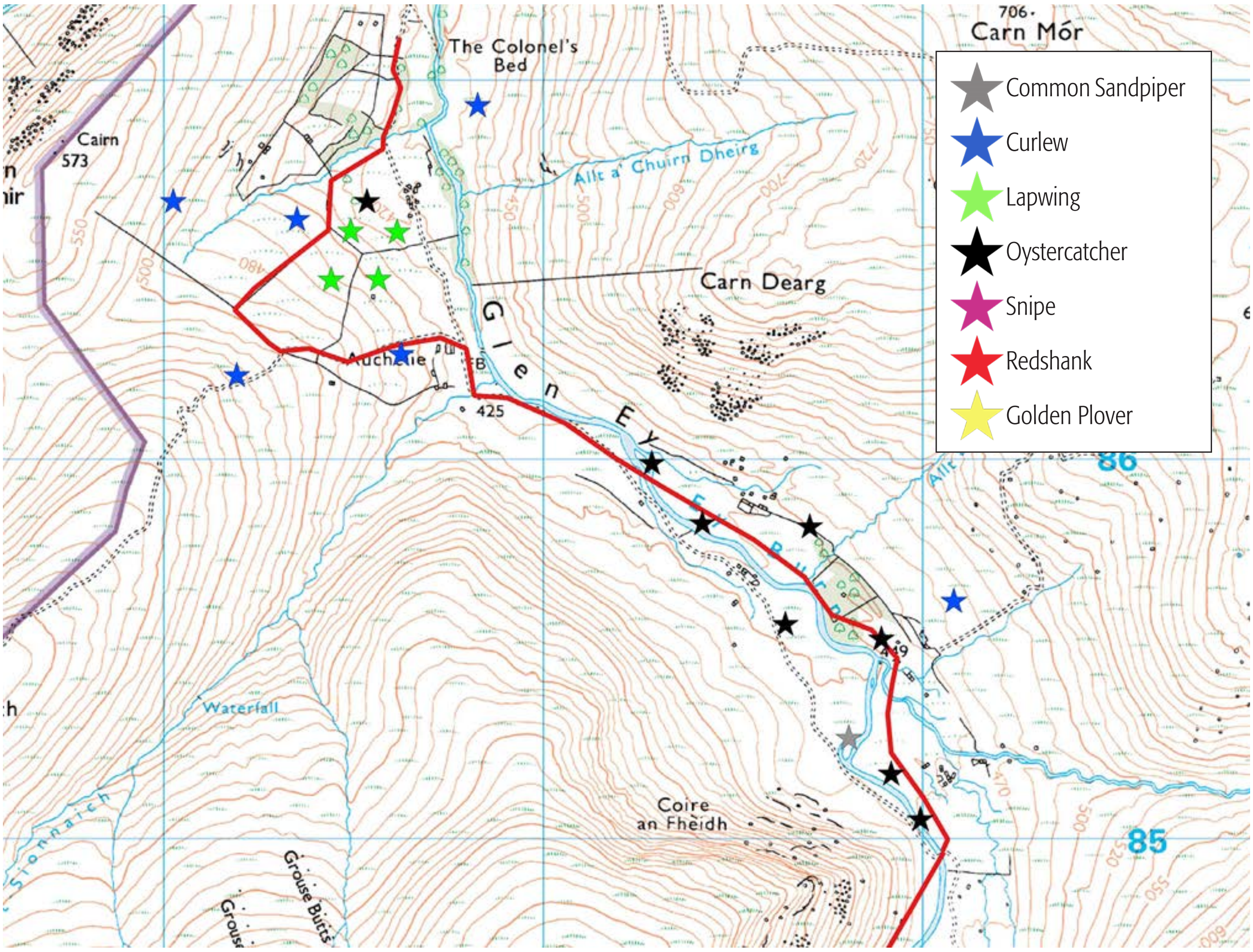


Figure 10. Mar Estate: Glen Eye (South)

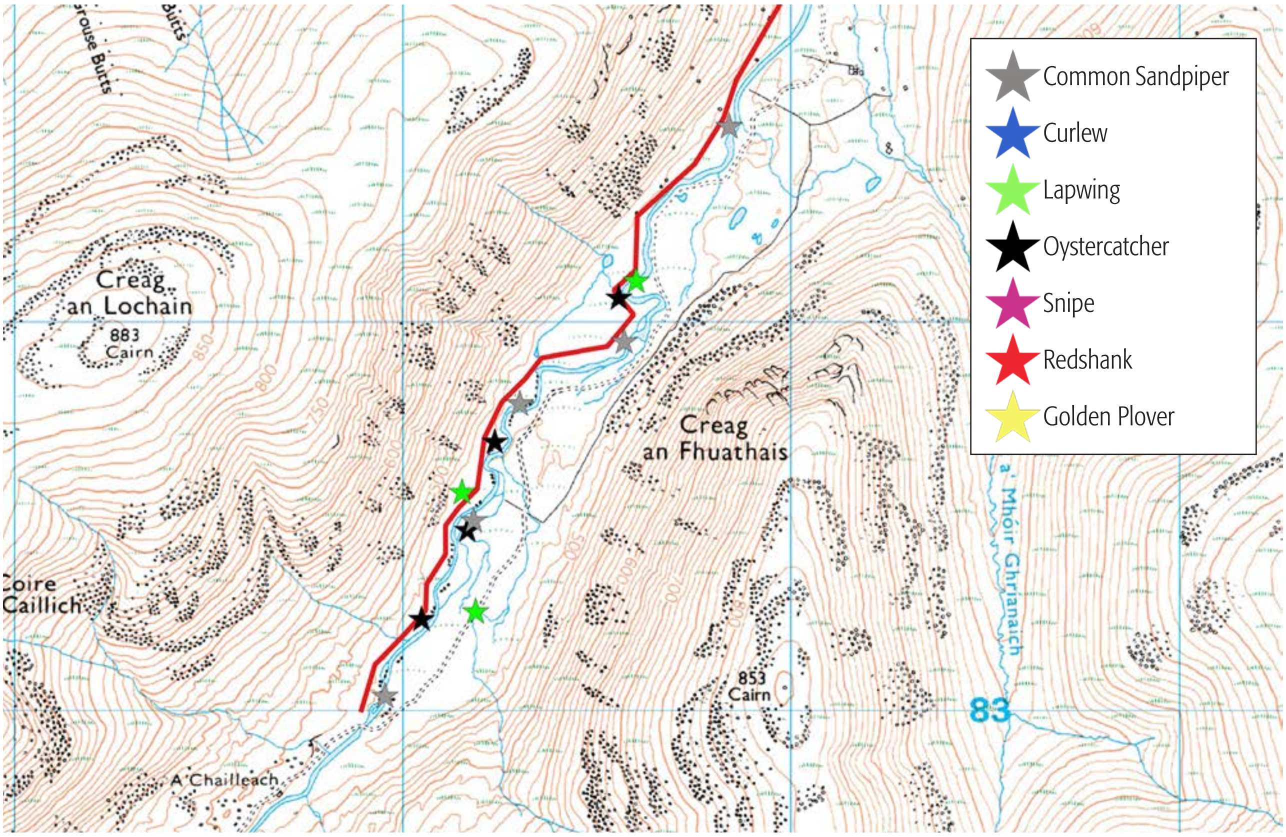


Figure 11. Glenavon: Carn na t-Sleibhe

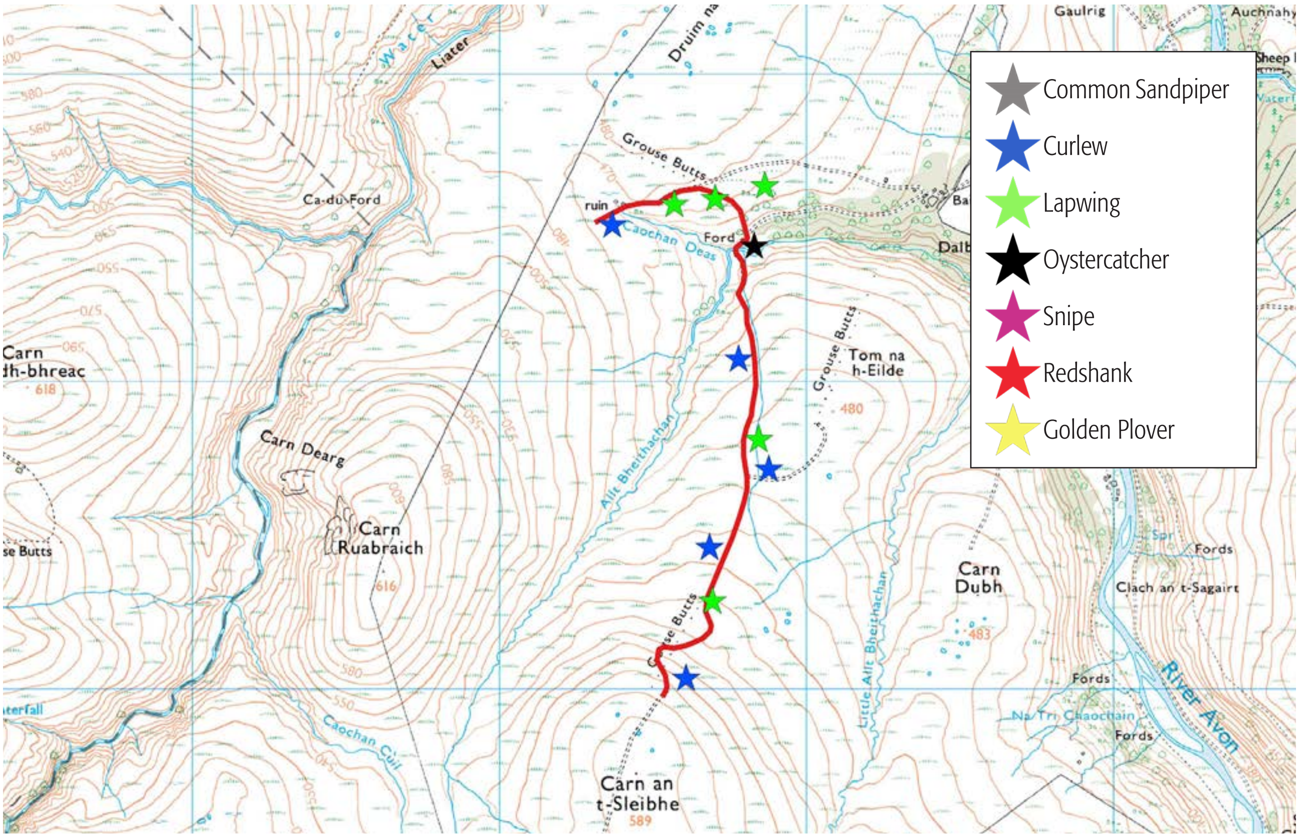


Figure 12. Glenavon: Blairnamarrow

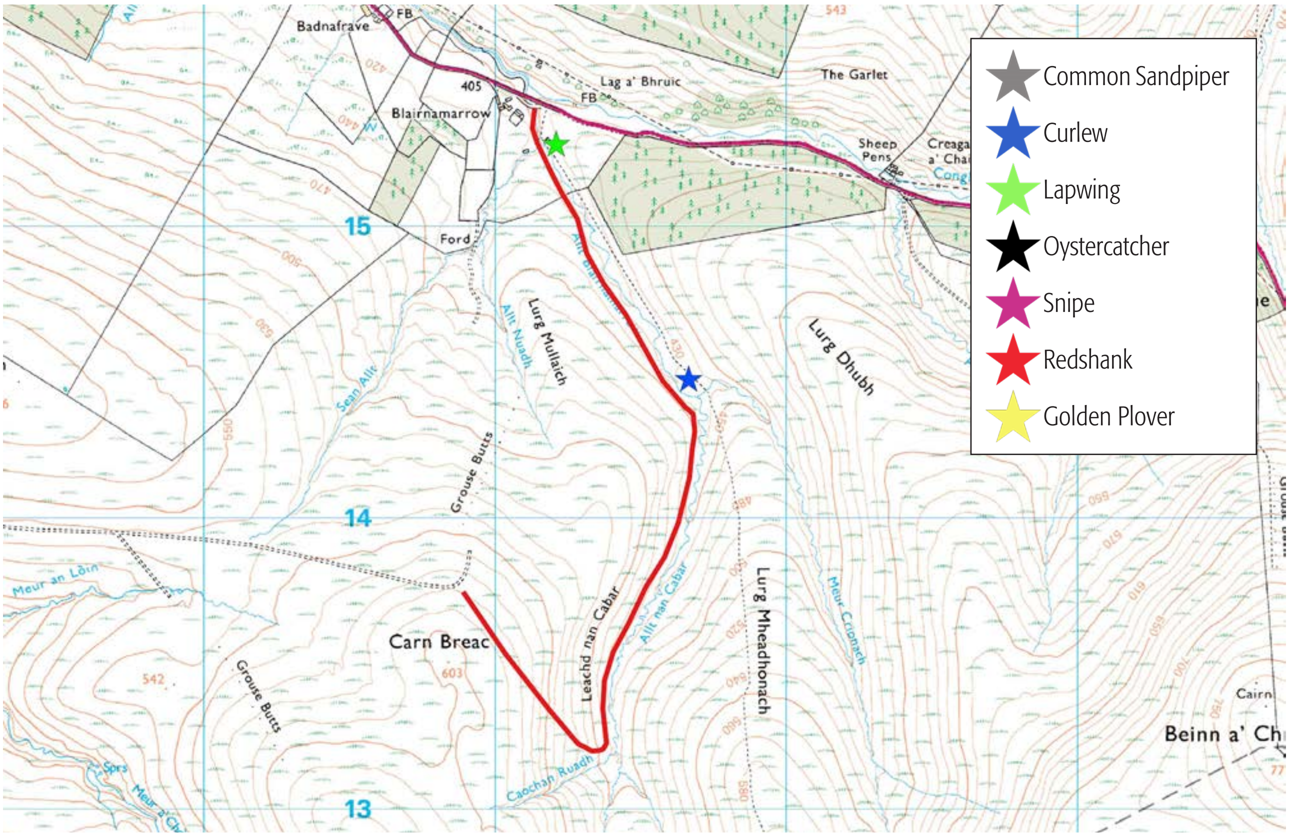


Figure 13. Glenavon: Glen Loin

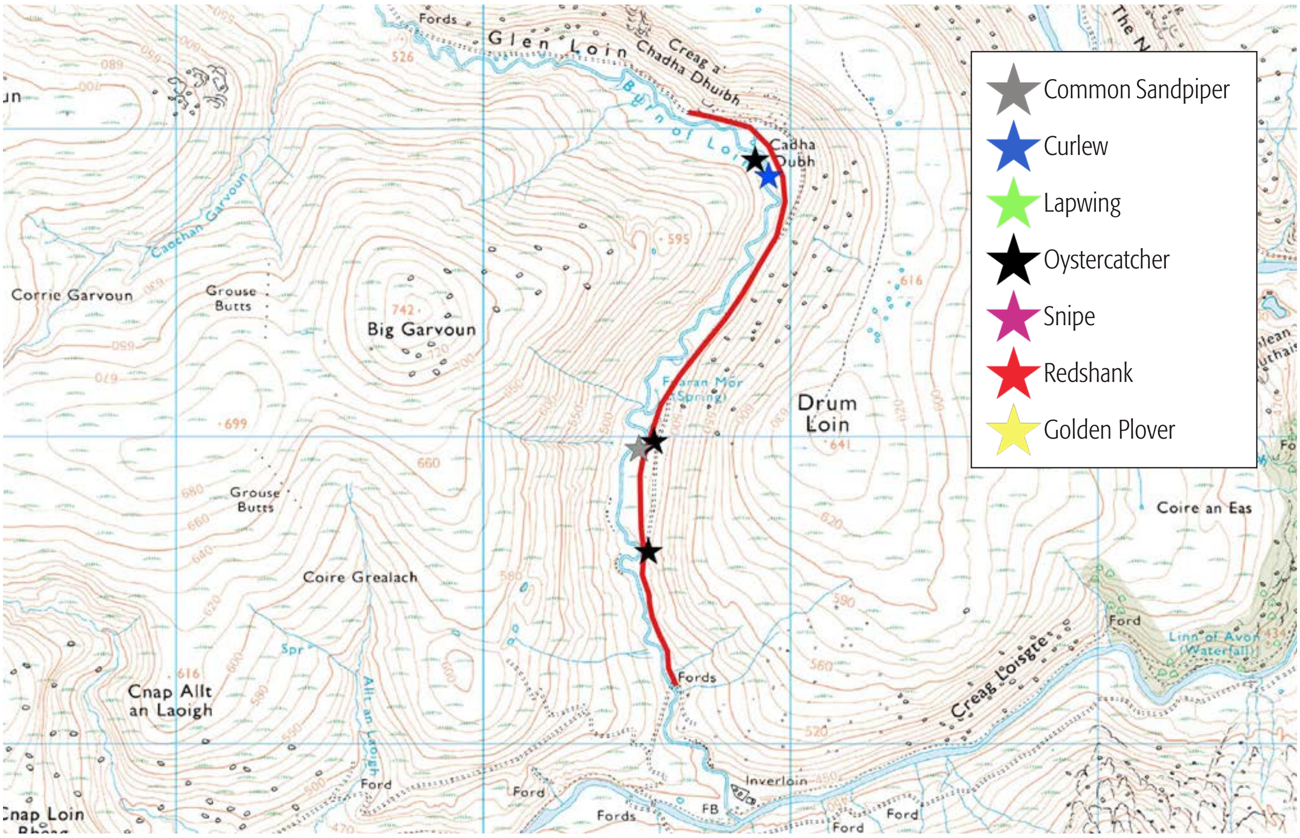


Figure 14. Glenavon: Inchrory

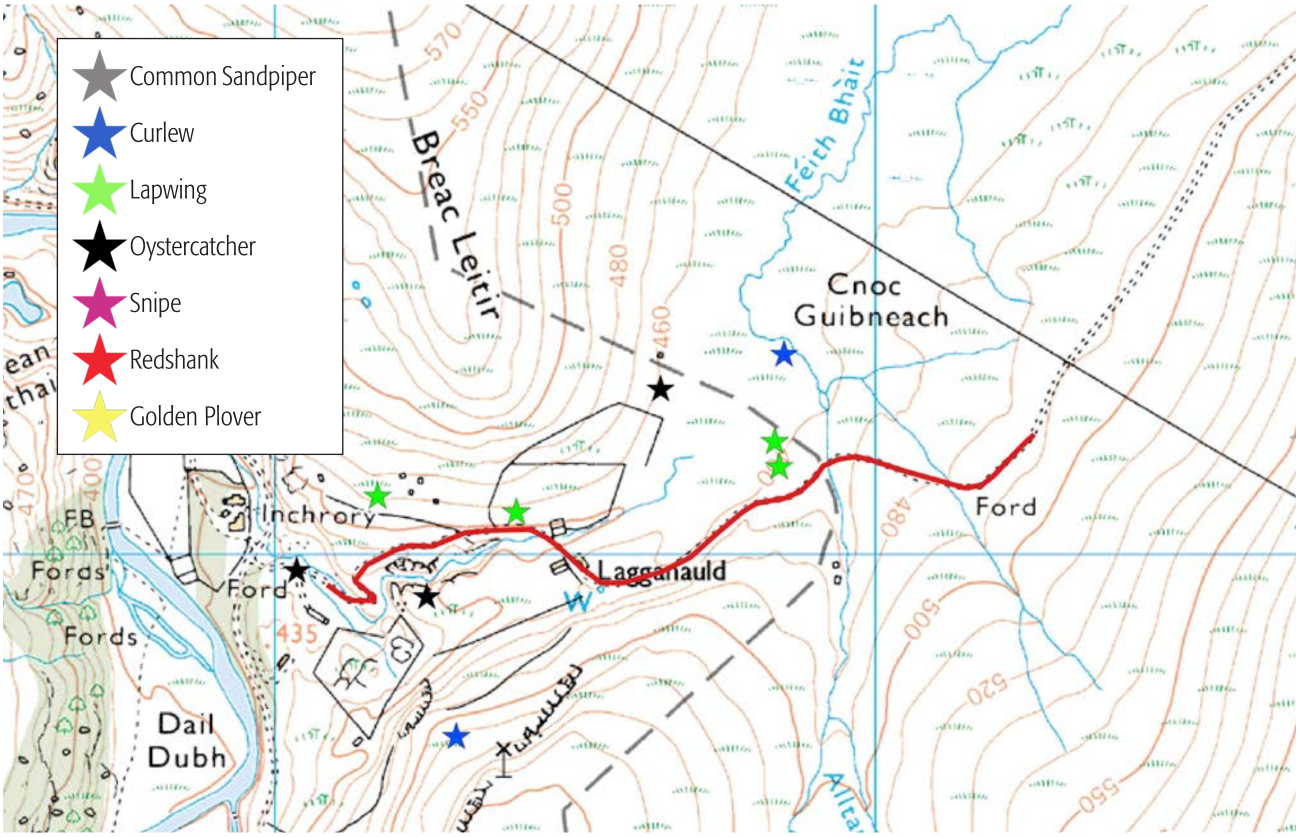


Figure 15. Glenlivet: Inchnacape

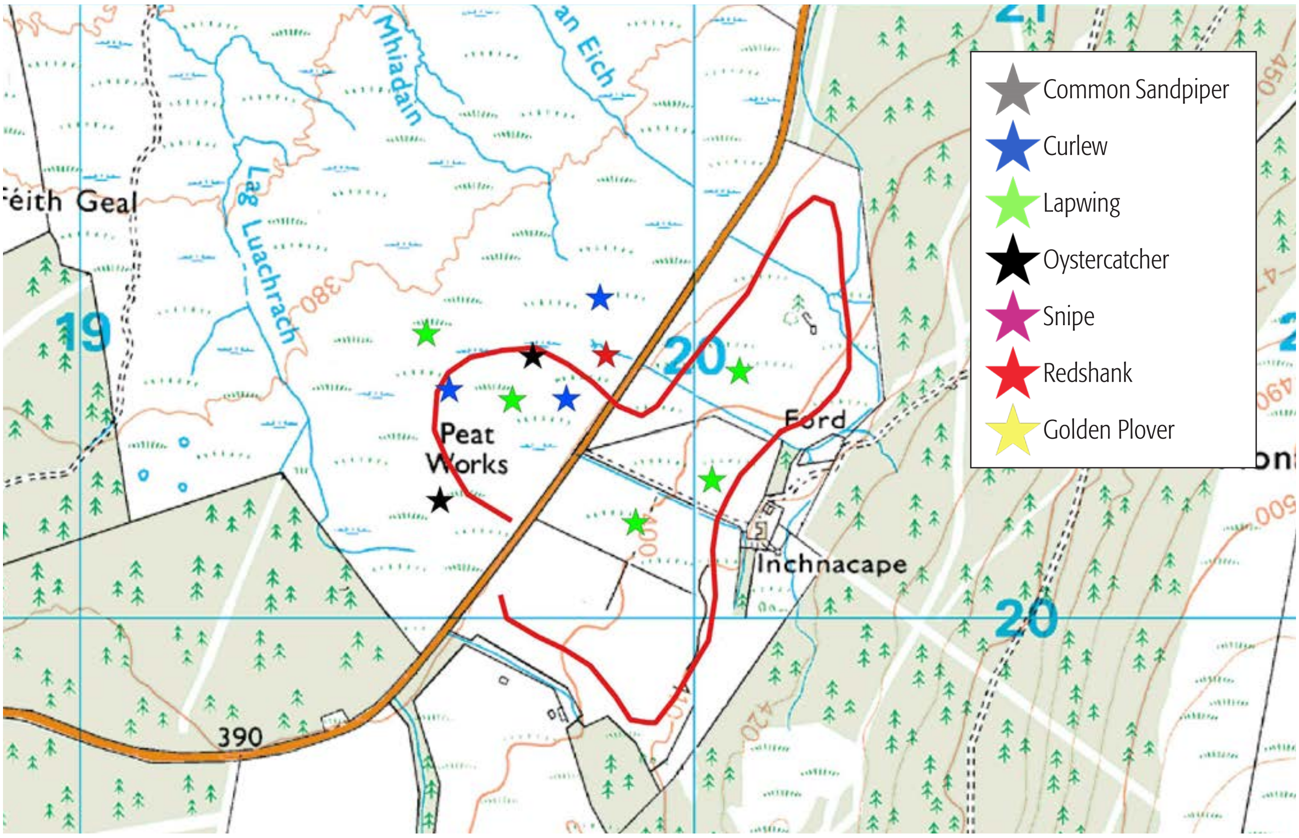


Figure 16. Glenlivet: Tombreck

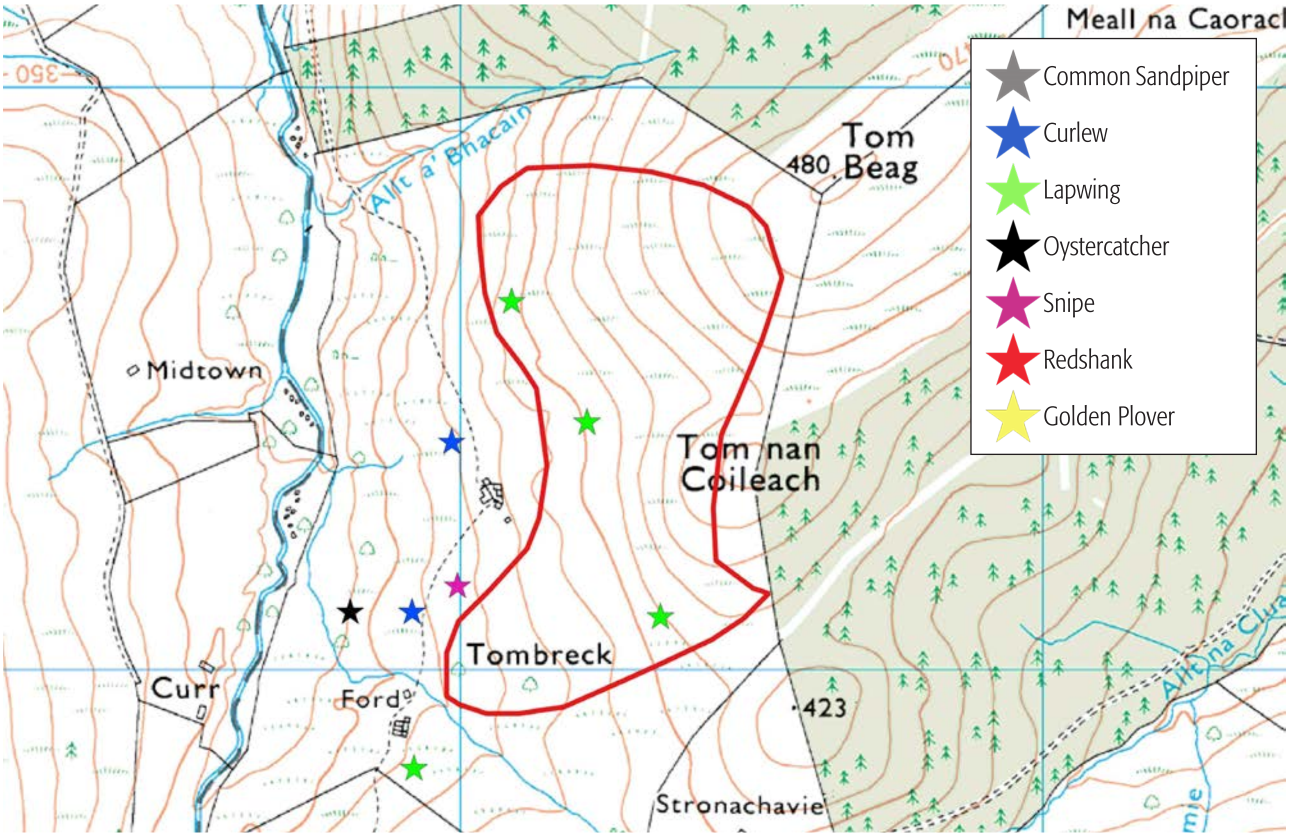


Figure 17. Glenlivet: Distillery

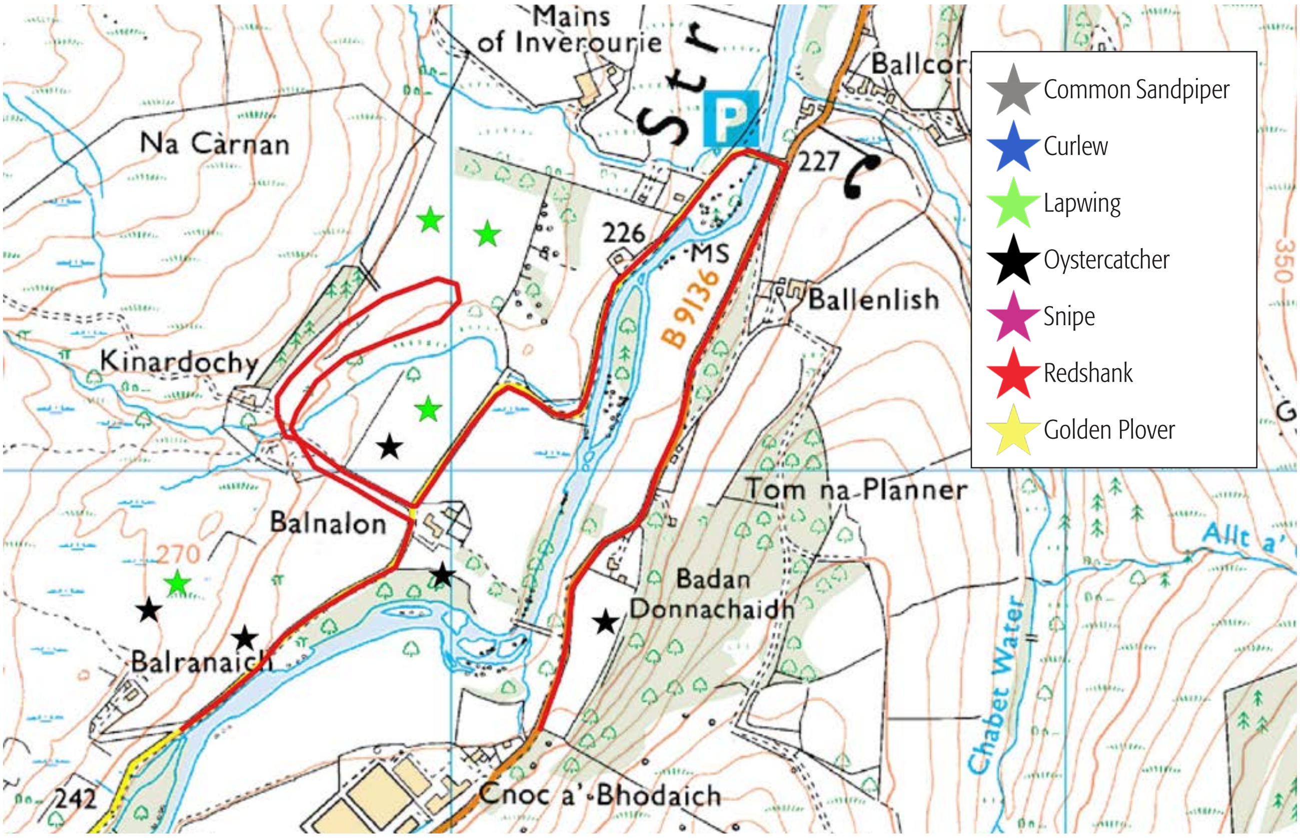


Figure 18. Glenlivet: Lagganvoulin

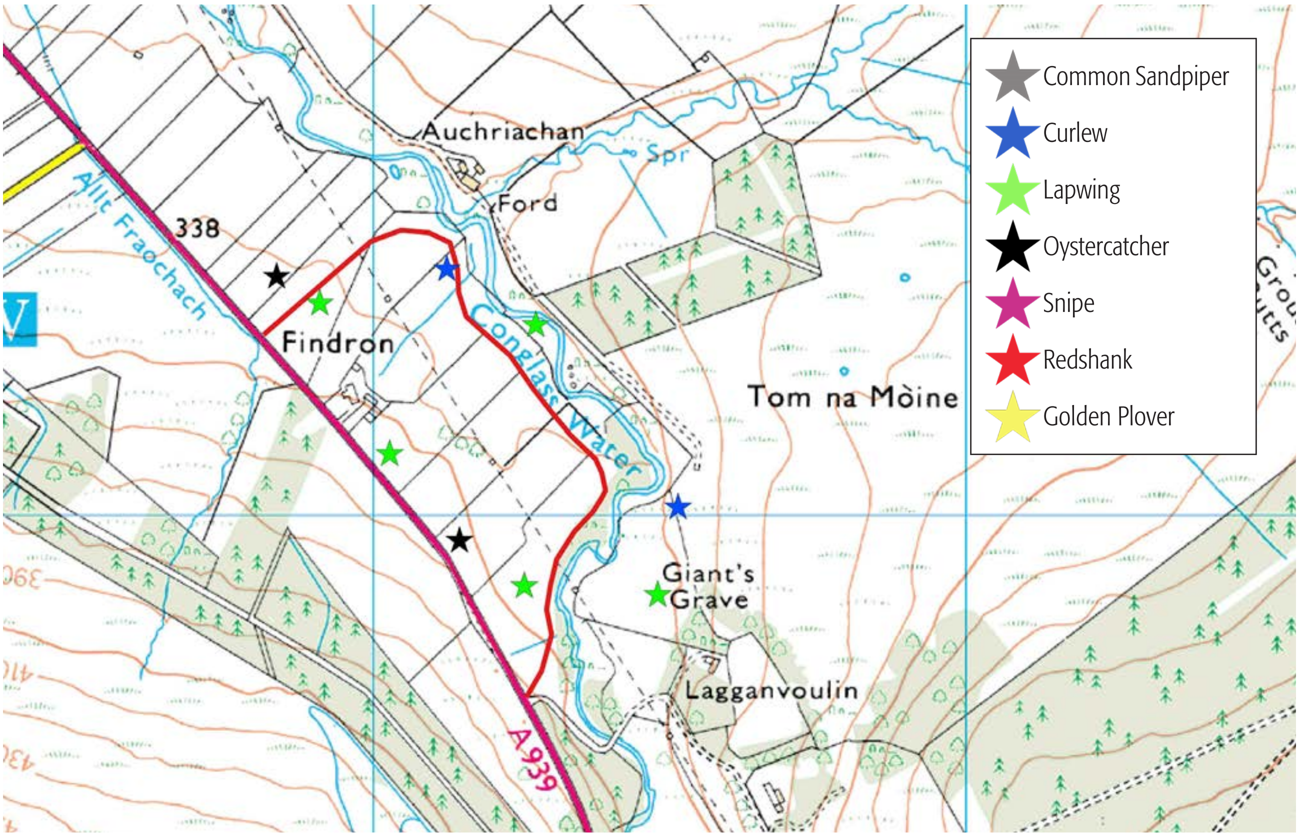


Figure 19. Ivercauld – Rhiedorrach: Carn Mor

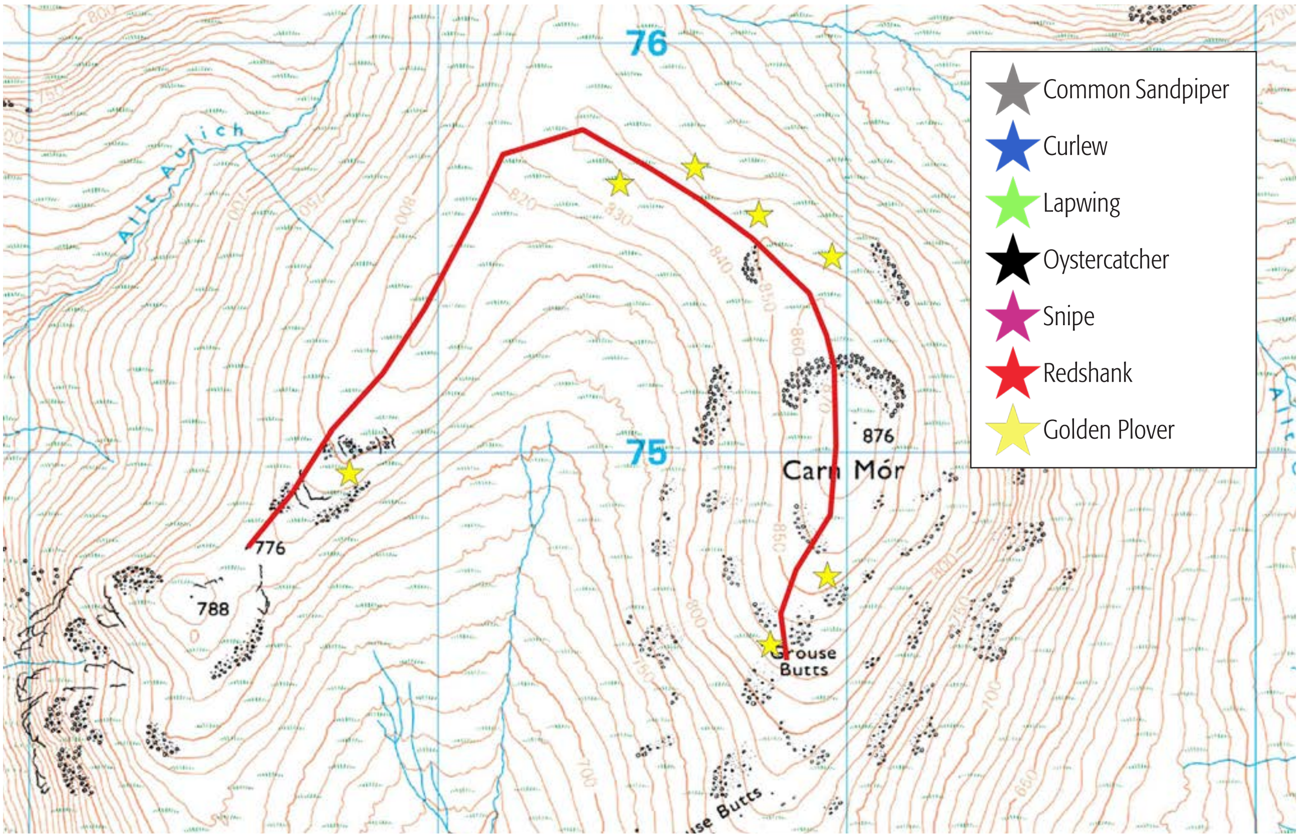


Figure 20. Invercauld: Gleann Beag

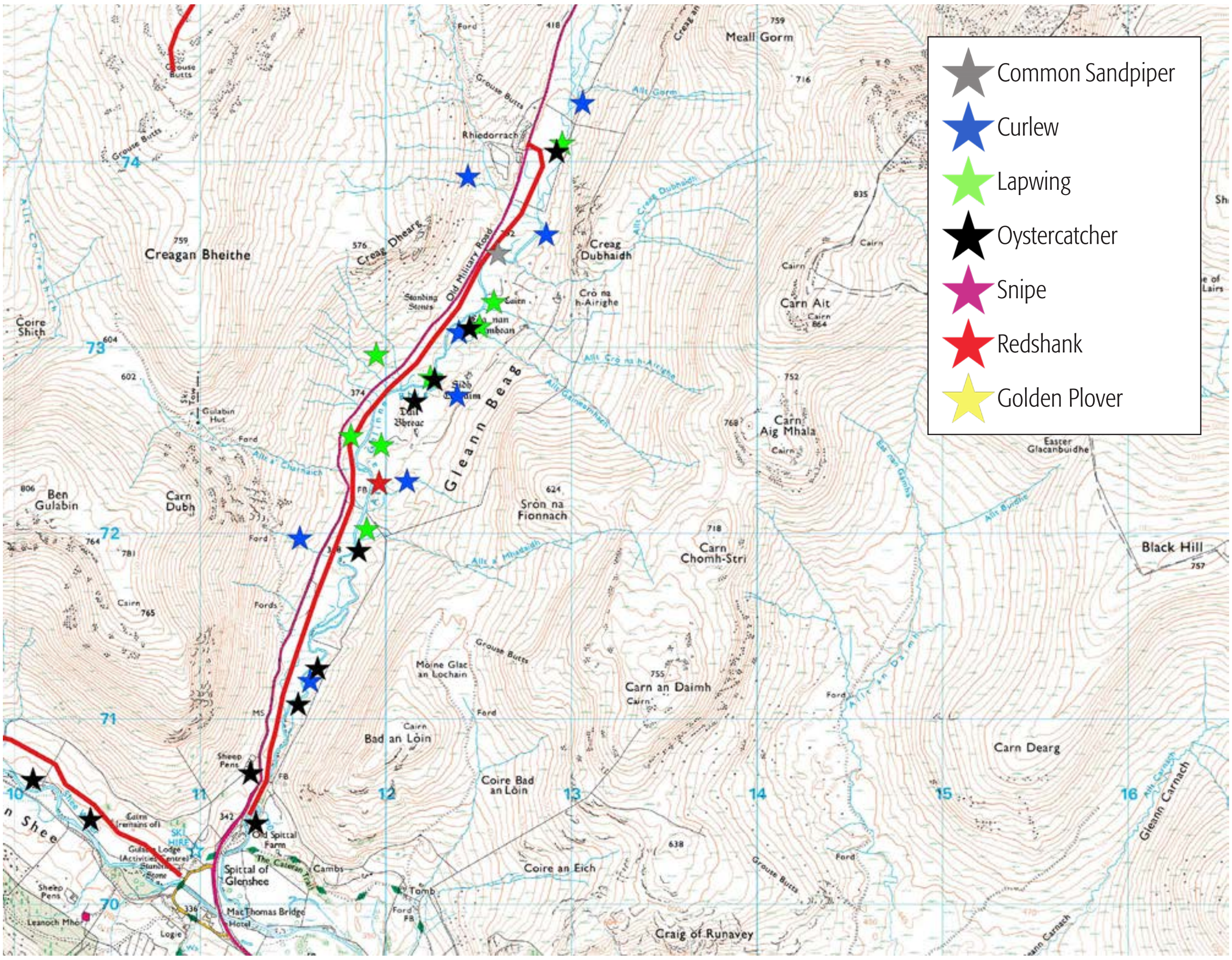
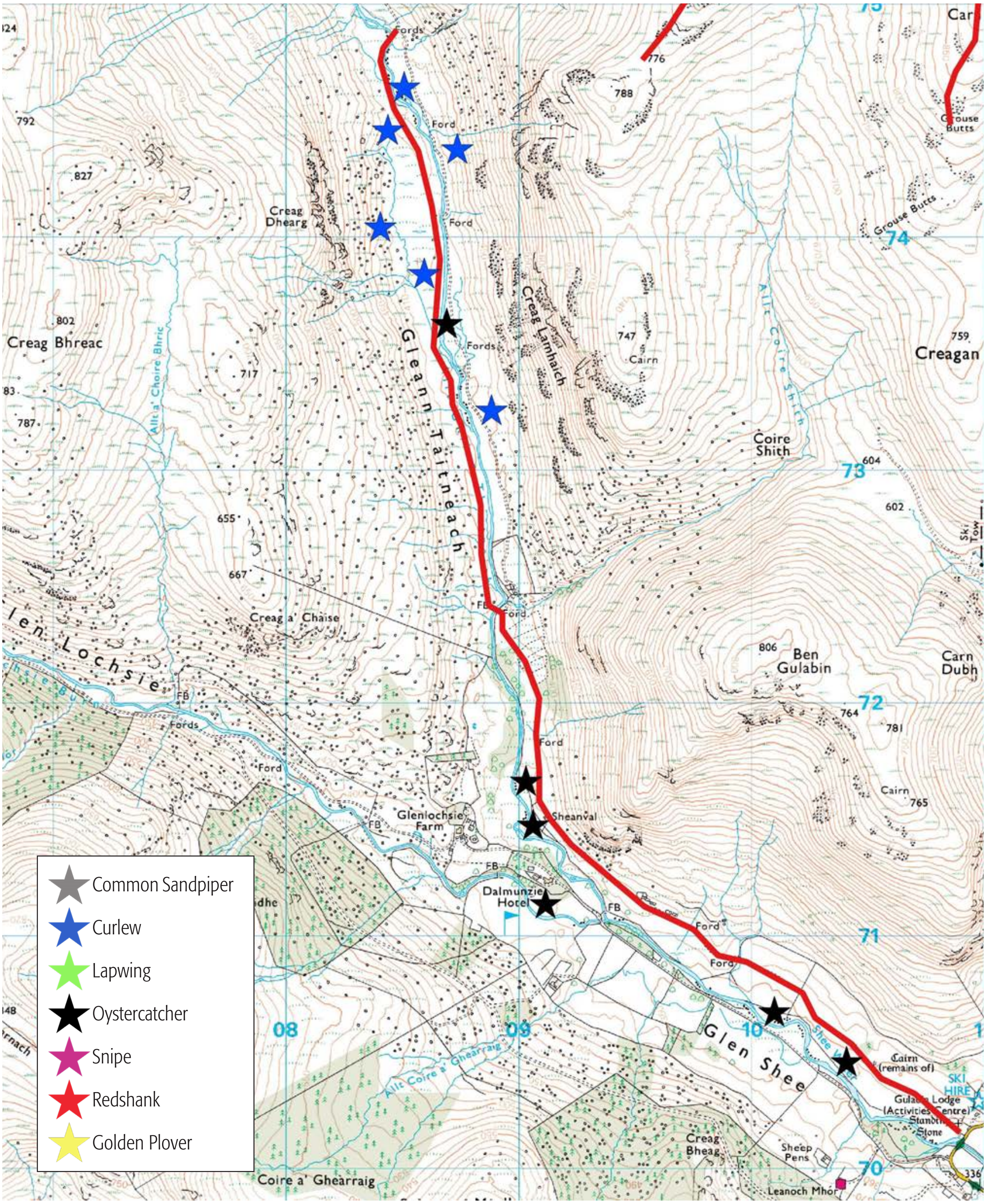


Figure 21. Invercauld – Rhiedorrach: Gleann Taitneach



APPENDIX 2. VISIT DATES FOR WADER TRANSECT SURVEYS.

Table 8. Visit dates for wader transect surveys

ESTATE	SITE	VISIT 1	VISIT 2	VISIT 3
Mar	Glen Eye S	08/05	25/05	11/06
Mar	Glen Eye N	08/05	25/05	11/06
Rhiedorrach	Glen Taitneach	07/05		18/06
Rhiedorrach	Càrn Mòr		09/05	
Invercauld	Gleann Beag (Glen Shee)	07/05		18/06
Glenlivet	Kinardochy	26/04		12/06
Glenlivet	Lagganvoulin	18/04	22/05	
Glenlivet	Scalan*	20/04		
Glenlivet	Inchnacape	20/04	15/05	
Glenlivet	Tombreck	26/04		12/06
Balmoral	Gelder Burn 1	04/05		19/06
Balmoral	Gelder Burn 2	04/05		19/06
Balmoral	Gelder Burn 3	04/05		19/06
Glenavon	Blairnamarrow	22/04	23/05	14/06
Glenavon	Glen Loin	20/04	21/05	20/06
Glenavon	Inchrory	20/04	23/05	14/06
Glenavon	Carn na t-Sleibhe	20/04	18/05	26/06

*No map is provided for Scalan because only one survey visit was carried out.

Wader Survey Instructions

Aim to carry out three surveys spaced out across the breeding season, one approx. mid-April, second approx. mid-May and a third mid-late June (don't worry if you miss one of these visits, the data will still be valuable). If you have time for an extra survey in June this would be useful in estimating breeding success – in this case do one survey in early June and one in late June.

Choose a day with good weather and aim to do the survey between 08:30 and 18:00.

When walking your route, record all waders that you see or hear – try and take roughly the same amount of time to do the survey each time, and try to only stop to record birds. Walk the same route on each visit.

The waders recorded are likely to be Curlew, Lapwing, Oystercatcher, Redshank, Golden Plover, Snipe, Ringed Plover, Common Sandpiper and Dunlin.

Use the codes below to record the wader species and their activity onto your map. Record the route you take at least once over the season.

On the June visit(s) pay particular attention to bird's behaviour – recording the presence or absence of agitated alarm calling adults accurately is the helps us to estimate breeding success - record any juvenile birds seen too as shown below.

Species codes:

CU – Curlew
DN – Dunlin
GP – Golden Plover
L. – Lapwing
OC – Oystercatcher
RK – Redshank
SN – Snipe
CS – Common Sandpiper

Activity symbols & codes to be marked on map at appropriate location:
(Where Lapwing and Snipe are doing display flights, record this with a circle like a singing bird)

CU	Curlew (on ground)	– $\underline{\text{CU}}$ →	Calling CU fly over
$\underline{\text{CU}}$	Calling Curlew	$\underline{\text{2CU}}$ →	Two Curlew, call and fly off
$\underline{\underline{\text{CU}}}$	Repeatedly calling (agitated) Curlew	CUjuv	Juvenile Curlew
$\textcircled{\text{CU}}$	Singing Curlew	$\textcircled{\text{CU – CU}}$	Aggressive / territorial encounter between 2 Curlew

Mark the route you walked with a dashed line and an arrow to indicate the direction - - - - - >- - - - -

Cairngorms wader surveys	**Site:**
Observer name:	**Date (dd/mm/yyyy):**
Start time (24-hr):	**End time (24-hr):**
Cloud: ☐ Mainly clear (0-33%) ☐ Partly cloudy (33-66%) ☐ Mainly cloudy (66-100%)	**Rain:** ☐ None ☐ Drizzle ☐ Showers
Wind: ☐ Calm ☐ Light ☐ Breezy	**Visibility:** ☐ Good ☐ Moderate ☐ Poor
Habitat: ___% Heather (☐ Recent burns) ___% Tussocky white ground ___% Well grazed (only record once – rough estimate of total % of each habitat type on route)	**Notes:**

Mark route taken on the map (turn over) in a different colour. Mark waders on the map at the location you first encounter them:

Singing/displaying: $\textcircled{\text{CU}}$

Alarm calling: $\underline{\underline{\text{CU}}}$

Pair: ⚥CU

Flock: 7CU

Juveniles: CU$_{\text{juv}}$

CU=Curlew L=Lapwing RK=Redshank GP=Golden Plover SN=Snipe OC=Oystercatcher RP=Ringed Plover CS= Common Sandpiper

Post-breeding flock counts

Recording the number of juveniles and adults within flocks of waders at the end of the breeding season may be a relatively quick and simple way to gather information on wader breeding productivity. This is a relatively new approach to monitoring breeding productivity so any feedback you have on this method will be useful.

The species targeted will be **Lapwing, Curlew, Redshank, Oystercatcher and Golden Plover**. Refer to the simple identification guide for juvenile waders provided for key tips to identify juveniles of each species. For the purposes of these counts a 'juvenile' is a fledged bird capable of flight. Chicks that are judged to be not capable of flight should not be recorded as juveniles, but a note made in the last column of the recording form (with an estimate of chick age).

Any group of three or more juveniles/adults should be considered a 'flock'. Try to avoid including pairs which are still breeding. Where you see a group of three or more birds but no juveniles are present, it is important to still make a flock count record.

Initially these counts will be of most value in areas where you (or someone else) have also been carrying out wader surveys, so we can investigate how closely the productivity data from the wader surveys correlates with data generated from post-breeding flock counts.

It won't be necessary to follow the same route as the wader survey or try to systematically count every bird in the area. Counting and ageing flocks within the site from distance with binoculars/scope is likely to be the best approach. Opportunistically recording flocks seen while carrying out other work (or during grouse counts etc) is fine.

For each species, the ideal time to carry out post-breeding flock counts is likely to be approximately 7 to 10 weeks after the first hatched chicks are seen of that species:

- For Lapwing, if first chicks are usually first seen around the 1st of May, this would indicate post-breeding flock counts for Lapwing from the 19th June to the 10th July.

- For Curlew, if first chicks are usually seen around the 20th May, this would indicate post-breeding flock counts for Curlew from 8th July to the 29th July.

If surveys are timed for Lapwing and Curlew, the other waders (Oystercatcher, Redshank, Golden Plover) will also be suitably covered.

On the recording form, complete a separate line for each different flock count, and a separate line for each different species when counting multiple species on the same visit.

Any feedback / comments on these methods will be useful.
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Post-breeding flock records

Observer……………………………………………………………

Estate / contact details……………………………………

Date	Species	Location - grid ref (preferred) or description	Juvenile count	Adult count	Unaged count	Total flock count	Notes (pre-fledged chicks etc)

*put an asterisk next to a count if it's an estimate. If there are birds within the flock that you aren't able to positively identify as adult or juvenile, put these in the 'unaged' column.

Mammal monitoring

Location

i) All camera trap monitoring points should be in open habitat which is broadly suitable for waders. A selection of points on heather moorland, rough grassland, enclosed grassland, and points close to and far away from forestry/woodland should be selected.

ii) Different camera trap monitoring points should be at least 500m apart.

iii) Either record grid ref of camera trap monitoring point or mark location on a map where it was deployed (and provide copy of map).

iv) Do not select points deliberately near to known sites (dens, setts etc) for particular mammal species.

v) Do not select points on or near to well-used tracks.

Deployment

i) The bait should be inside the bait cage and fixed to the ground with a tent peg (or similar). Once a bait cage is used with a particular bait, do not change the bait.

ii) Camera switched on with same settings as for nest monitoring, approx. 3m from bait.

iii) Aim to deploy the camera between 10am and 2pm (deploying at approx same time will mean mammals have equal chance to detect bait at each monitoring point).

iv) The mustelid lure bait is long-life and should work for up to 5 weeks in the field.

v) Avoid placing camera facing areas of long vegetation – to avoid camera being triggered by vegetation blowing in wind.

Collection

i) Leave the bait + camera out for **three nights**, then collect at any time the next day.

ii) Check the status of the memory card to see if it needs to be replaced or can be deployed again before the memory card is likely to fill up.

Recording

i) Record all omnivorous/carnivorous mammals caught on the camera (exclude herbivores) and any gulls/corvids/raptors. Where a species is caught on camera again, it is not necessary to record it.

ii) Record bait type as either ‘mustelid lure’, ‘mustelid lure + aniseed oil’, ‘dog food’, ‘dog food +aniseed oil’.

Date + time deployed	**Date + time collected**	**Grid ref**	**Camera no.**	**Type of Bait**	**How many times bait used? (1st, 2nd 3rd etc)**	**Species 1 (species, date and time)**	**Species 2 (species, date and time)**	**Species 3 (species, date and time)**	**Species 4 (species, date and time)**

Images: Liz Cutting / Hugh Insley / Nigel Clark. Cover image: Liz Cutting

Investigating wader breeding productivity in the East Cairngorms Moorland Partnership Area using collaborative methods

Breeding wader populations have declined significantly in recent decades in the UK. During this time, areas of moorland managed for grouse shooting and adjacent areas of rough pasture have been identified as persisting strongholds. A contributory cause to wader population declines is afforestation, and in the Cairngorms National Park (CNP) there is likely to be significant woodland expansion (with associated conservation gains for woodland biodiversity) in areas currently holding breeding waders. Land management planning in the CNP requires a balance between these and other competing objectives.

This project was carried out collaboratively with The East Cairngorms Moorland Partnership, which comprises six estates (Mar Lodge, Mar, Invercauld, Balmoral, Glenavon and Glenlivet) and the Cairngorms National Park Authority. The primary aim of the project was to investigate factors, including effects of woodland cover, affecting breeding productivity of wader species within the area covered by the East Cairngorms Moorland Partnership.

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Looking out for birds