Observations on breeding and dispersal by Capercaillie in Strathspey

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Capercaillie in Scotland have undergone a considerable decline in numbers and range contraction since the 1970s. The latest national survey in 2015/16 concluded that they remain at a critically low level of around 1,000 birds, with previous studies highlighting low breeding success as the proximate cause of decline. This study used radio-tagged females to assess the likely causes of poor breeding. Of the 12 possible breeding attempts followed, clutches were found for nine, six of which hatched, but only two (17%) successfully fledged young, giving an overall rate of 0.25 chicks reared per potential breeding attempt. Low productivity occurred due to 60% of first-year females not nesting and low chick survival, estimated at 8%. Over the same years, surveys in four local forests found 0.49 chicks per female (210 females found of which 24% were found with well-grown broods). Dispersal distances of six juvenile females ranged from 3.5 to 16.3 km highlighting the importance of conservation action across neighbouring forests at a landscape scale.

Introduction

The Capercaillie *Tetrao urogallus* has a world distribution covering northern Europe across to central Asia. The Scottish Capercaillie population was estimated to be only 1,114 birds (95% CL: 805–1,505) in winter 2015/16 (Wilkinson *et al.* 2018), similar to the previous survey in 2005/06 (1,285; 95% CL: 822–1,822) (Ewing *et al.* 2012), 49% less than estimated from survey in 1992/94 (2200, 95% CL: 1,500–3,200) (Catt *et al.* 1998) and more than an order of magnitude less than the guess of 20,000 birds in the 1970s. There has also been a 73% breeding range contraction between 1968–72 and 2008–11 (Balmer *et al.* 2013) and now an estimated 83% of the remaining birds are confined to Badenoch & Strathspey (Wilkinson *et al.* 2018).

The main proximate cause of the decline of Capercaillie in Scotland since 1970s has been low breeding success (Moss *et al.* 2000), accelerated by deaths due to collisions with deer fences (Catt *et al.* 1994, Baines & Summers 1997). Efforts to remove fences and effectively mark those that remained are likely to have helped survival (Baines & Andrew 2002), but predicted improvements in annual survival have not been measured. Measures to improve breeding success have been less successful and this remains low relative to previous estimates in the same forests (Moss & Oswald 1985, Baines *et al.* 2004, Baines *et al.* 2016), and elsewhere in the species' range (Moss *et al.* 2000, Jahren *et al.* 2016).

An analysis of breeding success from forests across Scotland between 1991 and 2009 (Baines *et al.* 2016) highlighted that females reared more chicks in years when hatch time in June was drier, and in forests with lower Pine Marten *Martes martes* and Carrion Crow *Corvus corone* indices. In addition, more females reared broods in years when Aprils were cooler. Densities of adult birds were also found to be lower in forests with higher Red Fox *Vulpes vulpes* indices. Although Capercaillie breeding success is negatively correlated with predator indices, more information is required to determine the stages of breeding that the birds are most vulnerable and which predators are most influential in determining breeding success. In this individual-based telemetry study, we monitored breeding attempts of six radio-tagged females, which were compared with forest-wide breeding measures collected over the same years and we also measured their dispersal distances to determine the required scale of conservation management.

Study methods

Annual surveys to estimate breeding success were undertaken with pointing dogs across four forests in Strathspey in August 2015–19 as part of a longer time series of counts (area covered = 11 to 37 km^2 per annum, Figure 1). When located by a dog, six female chicks approximately eight weeks old, were caught using a hand-held landing net, two in each of 2015, 2016 and 2017 and fitted with a 13 g VHF transmitter, with an expected battery life of 30 months. One female tagged in 2015 was monitored over three further breeding seasons, one tagged in 2016 for another two breeding seasons and the other for three breeding seasons and the two tagged in 2017 for two breeding seasons, giving a total of 12 possible breeding attempts over four years.

From April, females were triangulated every two or three days from forest tracks or roads. If locations were confined within a 100 m radius for three consecutive visits, the female was approached to determine if a clutch had been laid and its incubation had commenced. If the female flushed from the nest when approached, the clutch size was recorded. At that point, a trail camera was attached to a nearby tree, typically 5 m from the nest to reduce the risk of attracting predators (Summers *et al.* 2009). When the female was later located away from the nest location, the nest was approached to determine whether the clutch had hatched (small egg shell fragments found e.g. Green *et al.* 1987) or been unsuccessful (large egg shell fragments/eggs absent, confirmed by images from trail camera). Hatch date was assumed to be the mid-point between the date when it was last known that the female was incubating and the

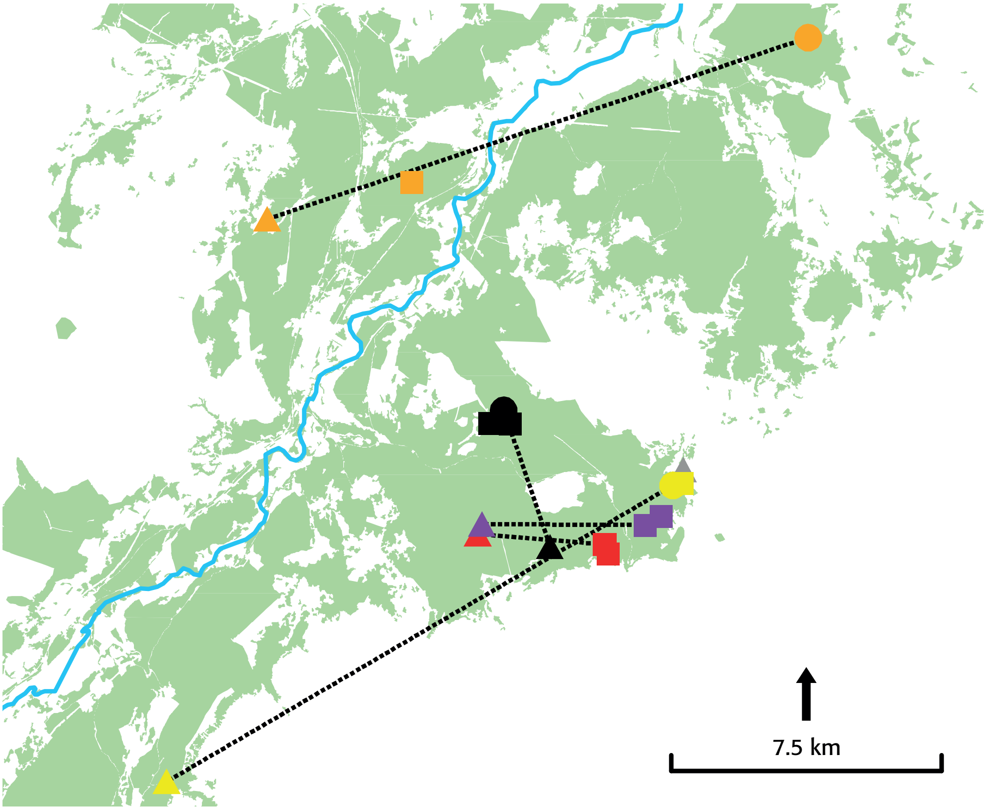


Figure 1. Radio-tagged female Capercaillie catch locations and subsequent breeding attempts (circle = bird location in May but no nest found; square = nest location), showing natal dispersal (▪▪▪▪▪▪▪▪▪). Individual females shown in different colours (black and grey were tagged in 2015, red and purple in 2016 and orange and yellow in 2017). The River Spey (blue line) and woodland cover (green) taken from the online National Forestry Inventory 2017.

date when it was known to have hatched. For clutches that hatched, first-egg laying date was calculated from the estimated hatch date minus 26 days incubation period, minus two days for each egg laid, assuming incubation started when the final egg was laid (Watson & Moss 2008). For clutches that were predated, the mid-point between the earliest date when the female was found at the nest location from triangulation and the previous check away from the nest location was recorded as the approximate start of incubation.

If the clutch hatched, the female was triangulated every week without flushing at night-time roosts and at day-time feeding locations. Three or more canes were placed vertically in the ground about 20 m from the female, as assessed by the strength and direction of the radio signal (Picozzi *et al.* 1999). Once the female was located using radio signals at night, a second observer used hand-held thermal imaging equipment (Pulsar Quantum XP50) to provide a more precise location. This reduced the area to be searched for chick faeces the following day. The number of chick faeces were counted (and weighed) to allow brood size estimation using the equation: number of chicks = 0.89 + 0.12 number of chick faeces as calculated for Black Grouse *Lyrurus tetrix* (Cayford *et al.* 1989). The roost and daytime locations were used to calculate brood home ranges using minimum convex polygons (ArcGIS v10.5, Kenward 2001). Observations of the tagged females were continued until either the breeding attempt had failed or until late July/August when the female was flushed with a pointing dog and a search conducted to locate any surviving flying chicks of approximately 7–9 weeks old.

Annual breeding success (chicks reared per female) of tagged females was compared with surveys of females and their broods using pointing dogs in four forests in 2016 and 2017 (area covered = 37 km^2) and one forest in 2018 and 2019 (area covered = 11 km^2). Data from all forest-years were combined to provide a mean young per female (and percentage of females with broods). Seven of the radio-tagged female breeding attempts overlapped with the areas used to calculate annual breeding success, four were within 3 km and one within 12 km of the boundaries (Figure 1).

Outside of the breeding period (i.e. from September to March), birds were located weekly by triangulation, but flushed at approximately only two-week intervals to provide accurate locations for subsequent habitat surveys (data not included here). These location data were used to identify periods of dispersive (i.e. longer) movements as opposed to short movements within the home range and to estimate dispersal distances. Dispersal was considered to have been completed when subsequent weekly locations were <500 m apart. Home ranges were calculated using minimum convex polygons from locations for the over-winter period and the breeding season for each female in each year. Autumn dispersal was quantified as the distance between the brood catch location and the centre of the over-winter home range. This was repeated for spring dispersal, measuring between the centre of the previous over-winter home range and subsequent breeding season home range. Natal dispersal was the distance from the catch location of the chicks to their first nest location, or the area they used in May if no nest was found (Moss *et al.* 2006).

Results

Breeding success

Of the 12 possible breeding attempts monitored, no evidence of breeding was found for three females, all in their first springs (Table 1). The average clutch size was 6.9 eggs (n = 9, range 5 to 9 eggs), with the estimated first-egg laying dates ranging from 23 April to 20 May (n = 6). Three clutches were predated by mammals. The camera near one nest captured images of a Pine Marten removing eggs (Plate 5). A second nest camera captured a blurred image of a medium-sized mammal (perhaps a Pine Marten) and the seven eggs were removed from this nest without triggering the camera again. Broken eggs from a third nest were examined by independent experts and deemed to have been predated by a mustelid, but marks on the egg-shells could not be distinguished between Pine Marten and Stoat *Mustela erminea*. There was no evidence that females laid replacement clutches.

Table 1. Details of breeding activity for five radio-tagged female Capercaillie (the sixth tagged female died before her first breeding season).

Age (years)	Year	ID	Laying date	Clutch size	No. chicks hatched	No. chicks fledged	Cause of failure
1	2016	15–1	no nesting attempt found				
	2017	16–1	2-May	7	7[a]	0	Chicks died 16–19 days old
	2017	16–2	<6-May	7	0	-	Clutch predation, probably by Pine Marten
	2018	17–1	no nesting attempt found				
	2018	17–2	no nesting attempt found				
2	2017	15–1	-	6	0	-	Clutch predation (mustelid-predated eggs were found when the female was flushed)
	2018	16–1	26-Apr	8	8	0	Chicks died at 0–9 days old
	2018	16–2	2-May	9	9	0	Chicks died at 0–9 days old
	2019	17–1	20-May	5	5	0	Chicks died at 4–11 days old
	2019	17–2	9-May	5	5	2	-
3	2018	15–1	29-Apr	7	6[b]	1	-
	2019	16–1	<25-Apr	8	0	-	Clutch predation by Pine Marten (Plate 5)

[a] all chicks hatched, one chick died in the nest.
[b] one egg found in nest after hatching with embryo partially developed, i.e. embryo death.

Of the six clutches that hatched, only one of 41 eggs laid remained unhatched, with a partially developed embryo found inside, i.e. 100% fertility (96% hatching). A newly-hatched chick was also found dead in a nest. Brood size at hatching averaged 6.5 chicks (n = 6, range 5 to 9). Four hatched broods did not fledge any chicks: two had chicks that all died before the first check at nine days old, one brood was lost when all chicks were 4–11 days old and one when they were 15–19 days old. This latter brood was found roosting on three occasions, but only 1–3 chick faeces (total weight 0.2 to 0.9 g) were found on each check.

Although six chicks left the nest cup this suggested that only one chick was alive by the first roost visit at six days old. The successful brood reared in 2018 by a three-year old female, fledged one chick. Roost locations were found 7, 15 and 21 days after hatching, with three to four chick faeces (1.1 to 2.2 g) recorded on each visit. This low number of chick faeces also suggests that only one chick was present by seven days after hatching. The brood reared in 2019 by a two-year old

Plate 5. A trail camera image of Pine Marten carrying an egg from a Capercaillie nest, Strathspey, May 2019. © *Game & Wildlife Conservation Trust*

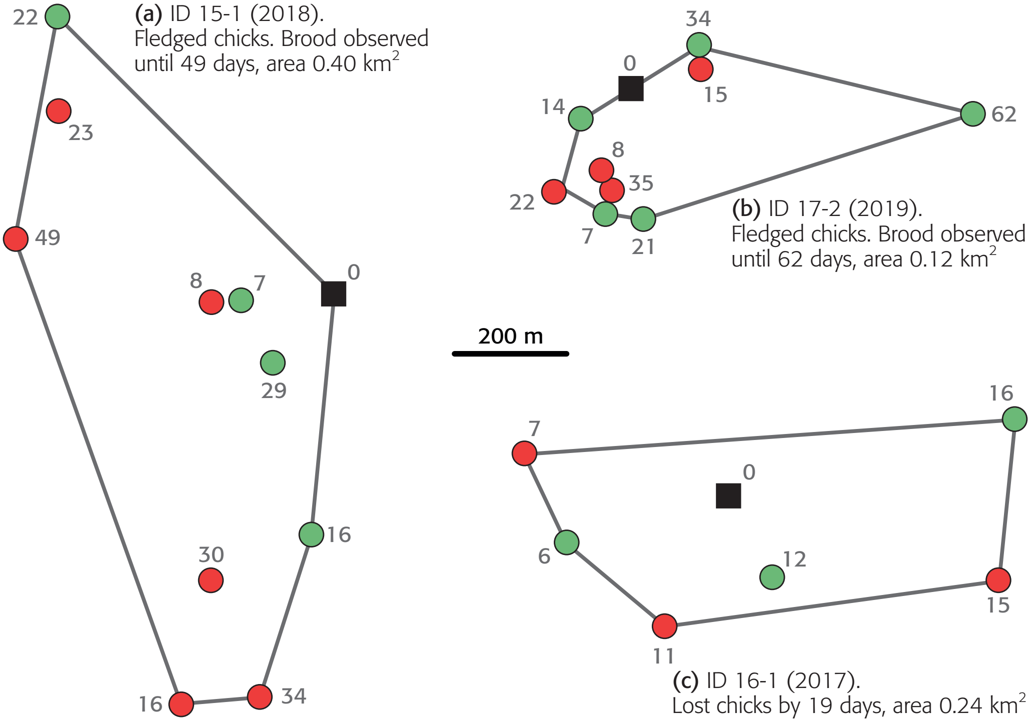
female, fledged two chicks. Roost locations were found at 7, 14, 21 and 34 days after hatching. Ten chick faeces (5.1 g) were found on the first roost visit suggesting that only two chicks were alive by seven days old. Subsequent visits recorded 22 to 27 chick faeces (9.2 to 33.5 g), with two chicks seen next to the roosting hen with the thermal imaging equipment when 34 days old. Mean chick survival from hatching to last flush at 7–9 weeks old was estimated to be 8%.

The surveys using pointing dogs showed that Capercaillie breeding success during 2016–19 was on average 0.49 (range: 0.22 to 0.86) young per female and 24% of females had broods (range: 14 to 40%). The equivalent values from the tagged females were within this range, with 0.25 young per female and 17% of females having broods (Table 2).

Table 2. Comparison of measures of Capercaillie breeding success in August from forest-wide surveys and tagged females in the same years (2016–19).

Method	Number females	Number broods	% females with broods	Number chicks fledged	Young per female
Forest-wide surveys	210	51	24%	103	0.49
Tagged females	12	2	17%	3	0.25

The two broods from which chicks successfully fledged had a home range of 0.40 km^2 (0 to 49 days old, n = 11 locations) and 0.12 km^2 (0 to 62 days old n = 10, Figure 2). The brood which was followed until 16 days old (no chicks were detected at 19 days) covered a home range of 0.24 km^2 (n = 7), which was greater than the home ranges for the first 20 days of the successful hens (ID 15–1 = 0.12 km^2 (n = 5), ID 17–2 = 0.02 km^2 (n = 5)).


(a) ID 15-1 (2018).
Fledged chicks. Brood observed until 49 days, area 0.40 km^2

(b) ID 17-2 (2019).
Fledged chicks. Brood observed until 62 days, area 0.12 km^2

(c) ID 16-1 (2017).
Lost chicks by 19 days, area 0.24 km^2

Figure 2. Nest and brood locations and home ranges of three Capercaillie broods, Strathspey, 2017–19. Key: black square = nest location; red = day location; green = night roost location. The number of days since hatching are shown and minimum convex polygon for each brood is drawn (grey lines).

Table 3. The dispersal distance and timing (mid-point) of six female Capercaillie in their first year of life.

ID	Year tagged	Distance in km (mid-point date) Autumn movement	Spring movement	Natal dispersal
15–1	2015	2.7 (29.9.2015)	1.7 (5.4.2016)	4.5
15–2	2015	3.1 (8.10.2015)	died before completed	-
16–1	2016	0 (-)	4.2 (8.4.2017)	3.5
16–2	2016	4.9 (25.10.2016)	0 (-)	4.2
17–1	2017	2.5 (30.9.2017)	18.8 (not available)	16.3
17–2	2017	1.8 (14.9.2017)	14.3 (5.5.2018)	15.8

Dispersal

All six females had dispersal movements within their first year, four in both autumn and spring, one in autumn only and one in spring only (Table 3). Spring movements were three-times further (median: 9.3 km, range: 1.7 to 18.8 km) than autumn (range: 2.6 km, 0 to 4.9 km). Median natal dispersal was 4.5 km (range: 3.5 to 16.3 km).

After first-year dispersal, four females used similar summer and winter home ranges in following years. However, one female nested in her second breeding season 11.7 km from the centre of her home range in the previous year, with the movement taking place between 30 April and 7 May.

Discussion

Three of five females (60%) appeared not to breed in their first springs, which is similar to the 46% of 13 females not recorded breeding in their first springs in north-east Scotland (Moss *et al.* 2006). As the tagged females were only approached once incubation had commenced, it cannot however be ruled out that breeding had been attempted and that undetected clutches may have failed during laying or initial stages of incubation. All females bred in their second and third springs.

Three of the nine clutches (33%) were likely predated by Pine Martens, which approximates to the 39% of clutches predated by Pine Martens at nearby Abernethy Forest (Summers *et al.* 2009). Only two of 12 breeding attempts by the radio-tagged females were successful, with chicks being reared, confirming the low rate of breeding success in Scottish forests (Moss *et al.* 2000, Baines *et al.* 2016). The average of 0.25 young per hen recorded from radio-tagged hens was lower than the average of forest-wide estimate from surveys using pointing dogs in the same years (mean 0.49, range 0.22 to 0.86 young per hen). Whilst reproductive success declined but has now stabilized at low levels in most European regions (Jahren *et al.* 2016), reproductive output in Scotland is thought to still be declining (Baines *et al.* 2016). Levels of breeding success in this study were below the 0.6 chicks reared per female per annum required rate to offset the mortality of full-grown birds estimated by Moss *et al.* (2000).

By tagging females, we provided insights into causes of breeding failure, principally predation of clutches by martens and low chick survival, estimated to be only 8% across the six broods that hatched. A weakness of the study was that it was not possible to determine the causes of low chick survival. Previous studies have identified inclement post-hatch weather (Moss 1986, Baines *et al.* 2004) and predation, again perhaps involving a Pine Marten (Fletcher *et al.* 2015, Baines *et al.* 2016) as being important. A further factor, that of parasite-induced impacts on chicks, especially by Sheep Tick *Ixodes ricinus,* which has increased in abundance and distribution in recent decades on moorland (Kirby *et al.* 2002), including those in the vicinity of our study forests, has yet to be adequately considered. Studies of ticks and ground-nesting birds in northern Scotland and wider have shown significant impacts on chick survival in both Red Grouse *Lagopus lagopus scotica* (Baines & Taylor 2016) and Golden Plover *Pluvialis apricaria* (Douglas *et al.* 2019). Tick parasitization of Capercaillie chicks commonly occurs in at least one of the study forests (R. Moss unpublished data), may be having similar impacts, and is considered a priority subject for further research. Invertebrate availability, especially preferred lepidoptera larvae feeding on Blaeberry *Vaccinium myrtillus,* may also influence chick survival (Picozzi *et al.* 1999, Wegge & Kastdalen 2008). Fitting radio tags to chicks thereby enabling carcass recovery (e.g. Mason *et al.* 2018), would be an option to improve our understanding of the factors known to limit chick survival, especially in the first two to three weeks after hatching when most chicks died in this study. The balance between the importance of these data to Capercaillie conservation relative to the associated disturbance related impact would need to be considered when planning further studies.

Females had a median natal dispersal distance of 5 km (range: 4 to 16 km), half that recorded on Deeside (median 11 km, range 1 to 30 km, n = 13 Moss *et al.* 2006). These dispersal distances within the core of the Scottish Capercaillie range clearly show that appropriate management to increase breeding success needs to be deployed at a landscape scale across adjacent forest boundaries. Data from this and other studies suggest this should include means of reducing the impacts of Pine Martens and crows to increase clutch survival and possibly that of chicks too. Deployment of methods to reduce possible tick-related impacts on chicks, may also be necessary once much needed research has been completed on this topic. Without management interventions to increase breeding success, it is likely that the already threatened Scottish Capercaillie will continue to decline.

Acknowledgment

This work was funded by Scottish Natural Heritage, Scottish Forestry (formerly Forestry Commission Scotland), Forestry and Land Scotland (formerly Forest Enterprise Scotland), Cairngorm National Park Authority and Game & Wildlife Conservation Trust. The work was undertaken under SNH and BTO licenses with assistance from Nick Hesford, Mike Richardson and Phillip Warren. We thank the forest owners and estate staff for access and assistance with night visits. We are grateful to Rob Raynor and Robert Moss for examining egg remains and an anonymous reviewer for helpful suggestions to improve the text.

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Revised ms accepted November 2019