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Bespoke design of cage trap and patagial wing tag for the capture and study of Black Grouse *Lyrurus tetrix* at lek sites: assessment of effectiveness for future studies

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ABSTRACT
Given new avenues for Black Grouse *Lyrurus tetrix* telemetry, and translocations to previously occupied areas, we designed a new cage trap for use at leks that was safe, reliable, and easily transportable, and a custom black-and-white wing-tag that was visible in low light and under camera-trap infrared illumination. The trap was tested over 12 trap days in autumn/winter. Behaviour before and after trapping and marking was monitored with camera traps and then via daily spring watches. The trap was simple to set up and operate, with a quiet closure mechanism that did not typically flush other birds, allowing multiple catches per day. Birds were caught on three quarters of trap days and at a rate of 2.5 birds per hour set. Typically, birds behaved apparently normally around traps and after trapping and tagging, although with some indication of resource-guarding of bait. Lek counts between autumn and spring matched patterns reported from other local leks. Tags were identifiable using camera traps (including with infrared in pre-dawn low light) and via optics. This trapping method could be tested in the spring to assess its ability to catch females, and our approaches could be applied to future telemetry, translocation, behavioural or demographic studies.

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Lekking can be defined as a mating system in which several males display at an arena where females choose among males, and in which males provide no resources for females at the arena nor take any part in parental care (Payne 1984). Black Grouse *Lyrurus tetrix* is one of a small number of lekking bird species in Britain, alongside Western Capercaillie *Tetrao urogallus*, Ruff *Calidris pugnax*, and the reintroduced Great Bustard *Otis tarda* (Payne 1984). In Britain, Black Grouse lekking groups will generally perform year round, albeit with a peak of attendance and display in spring, particularly before and during the copulation period from the end of March to early May, and a lower peak in autumn after the moult (Baines 1996). One hypothesis suggests that males continue to display outside the mating season to maintain their hierarchical position and territorial ownership on the lek (Kruijt & Hogan 1967); autumn lek activity and territoriality is related to higher copulation success in the following spring (Rintamäki *et al* 1999).

Black Grouse are categorised by the International Union for the Conservation of Nature as of Least Concern across their global range, although their world population is decreasing (IUCN 2024). The species has declined historically across the majority of countries within its range across Europe and Asia (Storch 2000) and in the UK is on the national Red List (Stanbury *et al* 2021). There has been considerable research into Black Grouse ecology, population dynamics and habitat associations across much of their Eurasian range (e.g. *Hjeljord & Fry 1995*, Grant *et al* 2009, Borchtchevski & Kostin 2014, Zhang *et al* 2020, Canonne *et al* 2021, Tost *et al* 2022), yet there remains much research and practical conservation work to be done for the species. As a result of a deeper understanding of the nature of its decline and the underlying causes (e.g. Pearce-Higgins *et al* 2007, Ludwig *et al* 2009, Ciach 2015), there has in recent years been a drive for reintroduction or population reinforcement across several countries (Boon 2016, Warren *et al* 2017, Warren & Baines 2018, Høyvik Hilde *et al* 2024). Furthermore, satellite tags, which have become more affordable and also light enough to be fitted to Black Grouse (e.g. Boon

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2016, Tost *et al* 2020), have opened opportunities for more detailed studies of their movements.

Implementing telemetry and translocation programmes requires safe, reliable and effective trapping methods for Black Grouse. Their lekking behaviour, in which a large majority of the birds in an area, particularly the males, will reliably gather in predictable locations, offers an opportunity for trapping. Lek trapping is biased towards males, because females visit the lek typically to copulate and a large majority of them will copulat e only once per season (Lebigre *et al* 2007). Female presence at leks is relatively unpredictable and it could be considered a relatively sensitive place to trap them. Other trapping methods, such as using pointing dogs and drag nets in August when females are with mature broods, tend to be biased towards females. For example, in a radio-tag study in highland Perthshire, in August eight adult females were caught with 74 chicks, although frequently the female escaped (White *et al* 2013a). Since Black Grouse frequently roost in groups, the sample size of tagged females can be supplemented by tracking already tagged birds at night and using hand nets, spotlights and white noise to capture nearby non-tagged birds (White *et al* 2015); roost sites can also be located by watching roosting flights (Warren *et al* 2017).

Various approaches to trapping at leks have been widely used, including box or cage traps triggered by either the bird itself or a person. In our experience, methods for trapping at lek sites are rarely described in enough detail to replicate them or to compare their effectiveness. Caizergues & Ellison (2002) cited a paper that had described specifically the structure and function of the trap used, a 'lily pad' trap (Liscinsky & Bailey 1955). Some traditional Black Grouse specific trapping methods were illustrated and described by Bub (1991), although their effectiveness is not discussed in detail. Høyvik Hilde *et al* (2024) mention walk-through basket traps, Borecha *et al* (2017) drop traps triggered by nylon string, and Málková *et al* (2000) spring traps, whereas Marjakangas & Kiviniemi (2005) refer just to 'traps', Rintamäki *et al* (1995) to feeding traps and cannon-nets, and Lebigre *et al* (2013) to walk-in traps that are triggered manually or automatically when a bird enters. While some of these techniques may be familiar to Black Grouse specialists, there is likely a lot of useful and transferable trapping knowledge within such research groups that is not available to the wider research community.

For a trapping method to be used at leks that was safe, reliable and easily transportable, but also well documented and replicable by other researchers and bird ringers, we designed a novel cage trap. We tested it, in terms of catching rate, safety and impact on lekking behaviour and attendance, at a lek site in Perthshire. We also developed a custom-designed wing tag that would be usable in future studies of lek behaviour and demography.

Methods

The study took place on a lek in highland Perthshire at about 56.8°N, located amongst a rocky, deer-grazed, ombrotrophic wet heath mosaic approximating to M15 *Scirpus cespitosus – Erica tetralix* wet heath in the British National Vegetation Classification. It was chosen because the local population density of Black Grouse was known to be high, it supported multiple males, and it was out of view of any public paths or roads, being on an area of moorland used primarily for deer stalking. Habitats within the known home ranges of males and females from that lekking group include open moorland, mature commercial plantation, native pine plantation from the 1990s, and areas of birch woodland (White *et al* 2013a).

The lek had been part of a study of Black Grouse habitat use in 2009–13 (White *et al* 2013b, 2015), although birds had never to our knowledge been trapped there. The lek site itself had evidence of continuous usage: the vegetation is conspicuously shorter and greener than in its surroundings, suggesting prolonged nutrient input from droppings and the physical impact of regular use by birds for displaying as well as the feeding, resting and preening that occur between bouts of display. It is a relatively flat site, with the approximate lek centre about 50 m from a rough vehicle track that is used regularly by the gamekeeper.

Trap design

In 2014, an initial trap design was developed and tested but for several reasons we decided to design a new trap. To avoid any confusion, details of discarded designs are relegated to an Appendix. Based on this initial trap trial, CW developed a revised trap, based on the principles of traditional passerine cage traps, which was used in autumn and winter 2016/17 (Figure 1). The trap broadly consists of three components: three connected sheets of galvanised, welded, 1 × 1-cm wire mesh that easily fold flat, these forming the sides and roof, two flat reinforced mesh doors, and two aluminium door-guide frames, twice the height of the trap tunnel, which can also be easily disassembled. When

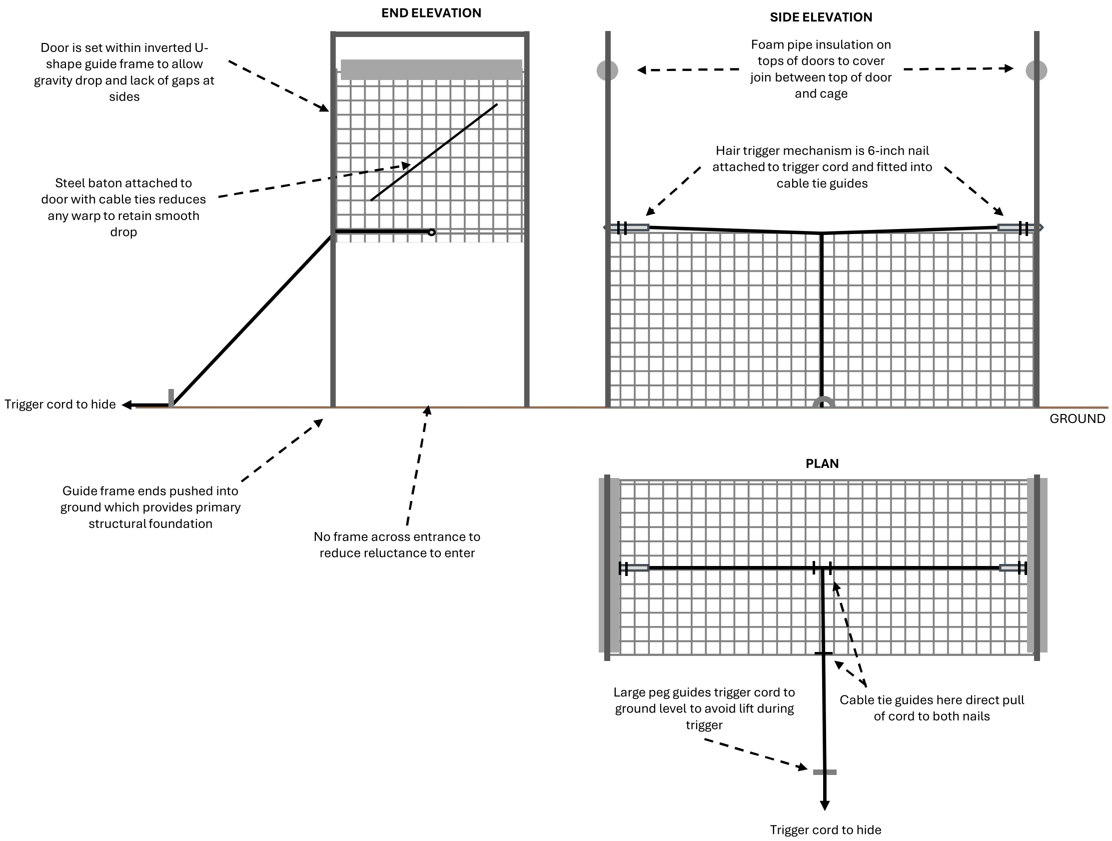

Figure 1. Schematic drawing of trap: the drawing is not to scale, but measurements of each section are provided in the text.

assembled and secured with cable ties or wire, the trap forms a tunnel shape with a square cross-section and with a profile deep enough that the body of a bird feeding on bait in the centre of the trap is sufficiently far from its closest door, and typically facing away from it.

The trap tunnel was 122 cm long and 65 cm in height and width. Mesh size was selected based on measurements of bill depth that we took from five males while using the older trap design, which ranged between 13.0 mm and 14.2 mm: the wire mesh is rigid and fine enough that, if barged by the bird, the bill could not pass through the mesh and allow individual wires to dig into the head . The total weight of the trap is about 10.1 kg, consisting of two doors at 1.03 kg each, three side/roof panels at 1.84 kg each and two aluminium guide frames at 1.25 kg each. For additional rigidity and to prevent any shearing movements, we placed two steel fencing pins, 1.2 m tall and 0.6 kg each, vertically each side of the trap (Figure 2a).

The doors fall vertically between the guides (Figure 2c). The aluminium door guide frames were U-shaped in cross section (2.5 × 2.5 cm) and the door fell between these guides, leaving sufficient room for a smooth fall, but the closed inset door then left no gap for a bird to escape (Figure 2c). The trigger mechanism for each door was a six-inch nail held between two cable-tie guides (Figure 2d). The cable-tie guides were tight enough to guide the nail but loose enough to allow motion. The door rested on the nail just next to the nail point. When the trigger cord was pulled, the door was no longer supported and fell vertically within the guide frame. The mechanism by which both doors were dropped simultaneously is shown in Figure 1.

The doors are relatively light , due to not having a fixed frame; the bottom edge was cut to have no protrusions, so in the unlikely event one falls on a bird it would not cause injury – although this never happened in more than 20 trapping events. To enter the trap the bird does not need to step over any part of the frame; in the earlier model, where the frame continued along the ground as a structural necessity (Appendix), we had noticed that this caused hesitancy. The trap needs to sit on relatively flat ground for the door mechanisms to work, but on a large lek site this should be achievable. In theory, gravity would close the doors fully even on a slight slope, due to the guide frames.

Figure 2. (a) A single trap in a set state; note trigger string running from top of trap diagonally down to left, and red rowan berries and rolled oats as bait. (b) Three traps set across the lek, angled to allow the watchers to see the position of a bird in the trap before triggering, with approximately life-size dummy male Black Grouse to the right. (c & d) details of the door guide frames and the trigger mechanism with the door in a set position.

The trigger mechanism was designed to be simple, consisting of nails fitted through cable-tie guides that hold the doors in a high position (Figure 2d). Cord from these nails feeds through cable-tie eyelets halfway along one side of the top of the trap and join to a single string. The cord then runs down at about 45° to run under a large peg on the ground (Figures 1 & 2a) and then along the ground under one or two large pegs in a straight line to a hide about 80 m away. The straight line is necessary to reduce friction. The aim of the additional pegs is to avoid the cord rising when it is pulled; this decreases both the response time, because the pull force is directed along the cord and not into raising it, and the risk of flushing birds on the lek that might otherwise see the cord rise up nearby. As discussed below, frequently during trapping birds remained on the lek even when a trap was triggered and had caught a bird, suggesting this was effective. When setting up in the dark, we were able to ensure straight lines of the trigger cords between trap and hide even across rough ground by fixing a small, coloured light to each trap and the trigger hide, removed before birds arrived, so we could walk directly towards the hide when unspooling the cord.

It was important that the person pulling the trigger could see how far into the trap a bird had moved, and ideally it would be close to and facing the centre to preclude the risk of being hit by a door, so we always placed our trigger hide so the watcher could view the trap in profile. A second person with a telescope typically acted as a back-up spotter in a higher hide about 120 m away, with communication via mobile phone call or text.

We observed the doors to fall simultaneously, at least to the limits of our perception. From a video recording of a door closure (see final video in playlist at tinyurl.com/bktrapping), we estimated the time from release to full closure to be 0.7 s. Some noise was generated by the falling doors, primarily when the pipe insulation (designed to create a seal at the top of the closed doors; Figure 1) caused the roof panel to vibrate briefly, though the doors fell directly onto soft peat and short heather. Even so, we frequently observed that nearby birds did not evidently take fright to the door closure, and trapped birds reacted calmly.

Although we did not specifically record instances of trigger failure, we cannot recall any with the final design (Figure 1), although it had happened with the discarded wooden trap (Appendix). Between trapping sessions the trap doors were secured fully open with several thick cable ties and the trapping cords were removed from the site. Traps had inconspicuous signage indicating they were part of a scientific study, and the gamekeeper monitored them for any potential interference, but none occurred.

Bait and lures

In initial trials we tried using commercially available Black Grouse decoy models (Figure 2b) and Black Grouse call lures. In addition, we placed rolled oats and rowan *Sorbus aucuparia* sprigs with berries attached – rowan being part of Black Grouse's natural diet (Málková *et al* 2000). Rowan berry sprigs were collected from some ornamental rowan trees in an urban setting which were superabundant with berries during our main autumn trapping period. In advance of winter trapping, we froze sprigs of rowan berries which defrosted during set-up and were eaten as normal. We noticed that the rowan berries were a very strong draw for birds to enter traps but that rolled oats were superfluous. We soon stopped using the sound lure also, and eventually the dummy birds, because males would attend the lek naturally on most trapping days. Rowan sprigs were replenished each trapping day, pre-dawn during set-up and at the end of each trapping session. Generally, all berries had been eaten when we returned, which was typically after one or two weeks.

Extraction

To extract a bird from an occupied trap, the trap was approached rapidly from the hide. The extractor would lie on their belly, lift the door slightly and put a soft-rimmed net of black material into the cage and straight over the whole bird. The net was a similar diameter to the cage's width and the bird would tend to be at the opposite end of the cage to the extractor, so placement over the bird tended to be quick and no escape attempts or escapes past the extractor occurred. The extractor would then secure the door open with a small, pre-placed stick and crawl into the cage. The bird was then lifted out of the cage by handling the whole animal through the net material and transferred to a black bird bag. Birds were processed and released at a ringing station about 160 m from the lek.

Extraction was feasible from only one trap at a time; where additional traps contained birds, we covered them with very large, dark and thick sheets to calm the bird while another was extracted. Although we could not see the behaviour of the bird under the cover, we were not aware of sounds of it colliding with the trap.

Trapping trials

Trapping trials took place during October to March in 2016/17. The autumn/winter season was chosen because we knew a substantial proportion of males still attended the lek during this period (Baines 1996) and we wanted to test our methods outside the spring copulation period. Visits were made about every one or two weeks, depending on weather. Despite visits typically being at weekends, due to our availability, we never saw any members of the public. We always arrived several hours before sunrise, to allow time to replenish bait, set and test triggers, erect two hides, and prepare ringing and tagging materials. Traps were set and we were in our hides on average 65 minutes (14–91 minutes) before civil dawn, which is defined as when the sun is 6° below the horizon.

We set up three traps in a line across the lek (Figure 1b), side-on to the hide from which they were triggered. Trapping was carried out by two people but in theory one person could operate the traps and extract birds alone. The traps were designed to be readily movable, and our initial plan was to move them around to catch different males. We soon found, however, that although males do hold small territories on leks (Rintamäki *et al* 1995) there is a lot of general movement, particularly when birds first arrive or during lulls in display, when they feed or preen; because therefore a single trap placement could catch several different birds over the course of the trials, we left the traps in place for the whole trapping season.

As well as making qualitative assessment of the traps' effectiveness and function, we recorded operating hours, number of trap days and captures of new birds and retraps, to quantify trapping success.

Wing tagging

We were unable to find an existing standard for Black Grouse patagial wing-tag design. One previous attempt had used Darvic-type materials, which curled after application (N. Picozzi pers comm). Wing tags have been used for Black Grouse studies, but to our knowledge primarily on chicks or juveniles (see Marjakangas & Kiviniemi 2005, Borecha *et al* 2017). Thus, CW developed a custom specification of patagial tag for Black Grouse that was based on the well-established wing-tag design for raptors.

The tags needed to match the Black Grouse pied coloration, because that might be important in terms of display and mate choice, yet be readable by eye in low light and on monochrome camera-trap night-vision footage, which uses infrared illumination. While Rintamäki *et al* (2002) have shown that orange or red leg rings do not appear to impact lekking behaviour or copulation success of male Black Grouse, wing tags are more prominent during display. Easily readable, black-and-white tags presented a means to study behaviour and lekking activity of tagged males post-trapping and with traps *in situ* on the lek.

The patagial wing tags contained unique two-letter combinations (Figure 3). The required dimensions were broadly estimated from the raptor equivalents. Following distance–visibility tests on Black Grouse models, we specified tag dimensions of 40 × 40 mm, plus a fixing tab. This enabled the letters to be read at up to 300 m with a telescope. The material was light, flexible and UV-stable plastic-impregnated fabric, with integral printed digits. Details were set out in our licence submission to the British Trust for Ornithology's Special Methods Technical Panel. All ringing and trapping was carried out by qualified ringers holding BTO ringing permits with special-methods endorsements for wing-tagging.

Camera-trapping

A camera trap (Bushnell Trophy Cam HD) was placed on the lek, during the second period of trapping, to record behaviour of birds in and around the traps between and during trapping visits, before and after wing tagging, and to gather resighting data from wing-tagged birds and test the visibility of tags to camera traps as a potential future study approach. Camera traps have been trialled as a method for lek counts in other grouse species (Stenglein *et al* 2023) and their use also allowed us to see how Black Grouse reacted to camera traps and whether lekking behaviours were clearly visible on the recordings. Camera traps were set to record 20-second video clips initially, and then later to one minute. The lenses were positioned at c. 20 cm height and with different views, either close to a trap to record behaviour inside or further out to view areas both in and around the traps.

Monitoring of behaviour after trapping, and during peak lekking period

As a follow-up to assess the effectiveness of wing tagging and the extent to which lek activity appeared normal after trapping, and with the cages still on site, the lek was monitored from a hide on five days per week, typically from Wednesday to Sunday, for one month. This work doubled as a pilot study to assess whether the wing-tagging design would allow detailed study of

Figure 3. Patagial wing-tag detail: (a) after fitting; (b) tag position on the free-moving bird and visible in daylight and (c) by infrared illumination in low light on camera-trap recordings.

behaviour and space use of individual Black Grouse at leks. The seasonal timing was somewhat arbitrary, relying on availability of one of us (ARM) to do daily watches. Thus, due to other commitments earlier in the spring, it took place from 24 May to 24 June 2017. Visits were made for four hours from about 03:00, starting well before dawn and, from our previous experience, before the first lek arrivals.

Each day, maximum attendance was recorded, as well as the identity of any tagged birds. Time of first arrival was noted and behavioural observations made. The hide was placed 70 m from the closest trap, by a small fenced enclosure, and kept in place between daily visits. Observations were made with binoculars and a telescope. In addition, we mapped activity on the lek site by creating an arbitrary grid over the lek. The coordinates of the three traps were recorded and nine low-key but visible wooden pegs were placed in three rows across the main area of the lek so that the location of birds could be estimated to the nearest metre. Due to the foreshortening effect of a relatively low viewing angle, these were placed four metres apart across the field of view and seven metres apart in the observer's line of sight.

Scan sampling was conducted every five minutes and the identity, behaviour and estimated coordinates of each tagged individual on the lek were recorded. Additionally, territorial behaviours of Black Grouse during watches, with identity and location, were recorded *ad libitum*; territorial behaviours were defined as erect display posture, fighting, flutter-jumping, horizontal display posture, chasing and crowing-hiss displays (Kruijt & Hogan 1967).

We do not provide detailed results from these observations here but rather examples to demonstrate that the trapping and wing-tagging approach allows intensive observation of known individuals on a lek. For three wing-tagged birds observed on between five and nine days, including seven days when at least two of them were present, we plotted their kernel density utilisation distributions using the 'adehabitatHR' package (Calenge 2006, RStudio Team 2020). Two other wing-tagged birds attended during this period but not frequently enough to plot their spatial distributions. Kernel density estimation is a technique to plot animal home ranges based on coordinates, used commonly at larger scales (Fleming *et al* 2015, Thornton *et al* 2021). We calculated a 50% kernel, this being an estimate of the smallest area in which an individual was located during half of its time on the lek, to represent their core area. We mapped these core areas and overlaid the locations of all territorial behaviours recorded for each bird.

Comparison of lek attendance to leks in wider area

We wanted to assess whether the pattern of attendance at the study lek appeared to be normal, given our trapping and wing-tagging activity there and the continuous presence of traps. To do so, we combined maximum attendance counts made during trapping in autumn/winter 2016/17 with formal counts carried out in late April and early May 2017 for the Perthshire Black Grouse Study Group, and with our daily observations in May and June 2017.

Lek attendance varies through the annual cycle so, as a benchmark, we compared the patterns of maximum counts at our study lek to the pattern seen by Baines (1996), who gathered weekly lek counts at eleven leks in the same region for every week over one year. To allow a comparison, we took the mean monthly proportion of displaying male Black Grouse at dawn from that study extracted, with reasonable precision, from Figure 3 in his paper (Baines 1996). We scaled those data to ours by setting the maximum monthly mean proportion (0.63 in April; Baines 1996) equal to the maximum count at our lek (nine males) and scaling other months accordingly; for example, Baines (1996) reported a mean proportion of 0.23 males displaying in June, so we scaled our data by applying the factor 0.23/0.63 to our nine males, giving 3.3 males as the expected value for that month. We plotted our monthly count data alongside the scaled data from Baines (1996) and compared them visually.

Results

Trapping success rates and retrapping

From 12 trap days we had nine (75%) that were successful, with at least one bird trapped. We caught 0.92 individuals per trap day, with in total six newly trapped birds and five retrapped from the earlier exercise using discarded trap designs (see Appendix). Initially we focused mostly on whether the trapping system would work, but later we became interested in the ratio of effort to trapping. Over ten trap days where we recorded the length of time traps were live before catching, once we were in our hides and waiting to trap, we trapped 1.4 new birds per hour, or 2.5 birds per hour including retraps. The quickest time between birds arriving on the lek and a bird being trapped was nine minutes. During trapping, birds arrived on average four minutes before civil dawn, arrivals ranging between 26 minutes before and 14 minutes after. Frequently they would arrive before being visible by eye, but could be heard calling and could sometimes be heard flying in over the hides.

The rate of retrapping for the second trapping period was lower than it might otherwise have been, because in later visits we deliberately tried not to retrap birds that we could see were already tagged. At least some birds became 'trap-happy' and perceived the lure of the bait as a greater driver than fear of trapping. We do not have sufficient data to test this, however, as we did not record instances where tagged birds entered traps and we chose not to trigger the trap. This was also evident from footage of wing-tagged birds feeding within traps between visits, recorded by our camera trap.

On some occasions we were able to trap multiple birds on the same day, at the same extraction time, or even in the same trap. On one occasion we were able to trap birds in each of the three traps before emerging for extraction and on another we caught two birds in the same trap. Trapping in multiple cages was possible because birds frequently did not flush when the doors came down nearby. The most individuals caught in one day was six, of which four were retraps and two were new birds. On at least two occasions when we had performed an extraction, which would flush birds from the lek as we approached, the lekking group returned following our resetting of traps and returning to the hides, although we did not record how soon.

Behavioural responses to cage traps and camera traps

Camera-trap clips of Black Grouse in and around traps are available in a playlist at tinyurl.com/bktrapping. From the footage, Black Grouse appear to be very tolerant of the cage traps. Clips of males displaying, interacting including chasing, and feeding both on the bait in the traps and on the natural vegetation show typical lek behaviours, despite the presence of traps. We noticed that birds frequently did not fly off when nearby traps were triggered; in Figure 4, taken moments after trapping, a bird is in a closed trap and normal display is continuing, both inside and outside the trap.

The footage shows that birds remained very calm when caught in the traps and tended to either pace around or in occasional cases continue to feed, not seeming to notice that the door had closed initially and not interrupting their feeding. When we left our hides for extraction, the trapped bird would display an anti-predator response and try to flee but the small mesh of the trap panels meant that no injuries were

Figure 4. Display behaviour by a bird caught in a trap, and others outside. The doors of the traps closed quickly, and frequently the trapping event did not flush non-trapped birds from the lek.

detected, although one bird received a small graze above the bill. To minimise stress for the birds, we would coordinate leaving our hides via mobile telephone and approach the traps and extract from them swiftly.

Attendance and activity on lek post trapping and tagging

After wing-tagging, and while the traps were still *in situ*, we observed a range of normal behaviours, including resting, vigilance, displaying, calling and chasing (tinyurl.com/bktrapping). Tagged and untagged males displayed together with no apparent difference in behaviour between them. In some cases, there appeared to be resource guarding of the traps or bait, although this may simply have been because the traps were in an existing territory which was being defended as normal. We occasionally observed birds landing on the traps or droppings on the trap roofs. Birds continued to visit the lek when there was lying snow.

During the intensive watches in 2017, males attended the lek on every one of 16 days of observation between 25 May and 16 June, but then on none of four days during 17–22 June . For the three wing-tagged males that attended most regularly we were able to see that they had individually different core areas on the lek, perhaps representing approximate territories (Figure 5). Territorial activity appeared to be concentrated into these core areas.

During the 2016/17 study period, attendance approximately followed the patterns expected from Baines (1996), being lower in autumn, peaking in April/May and then falling sharply from May to June (Figure 6). As well as peak numbers falling during our May/June period of daily observation, first arrival also became progressively later relative to civil dawn, potentially indicating reduced motivation to attend the lek towards the end of the peak lekking period (Figure 7).

Resighting of tagged birds

We found wing tags readable by eye, in most cases, using telescopes from the hides and via camera traps on the lek. In occasional cases, the wing tags were partially obscured by wing feathering; for example, it can be seen in one camera-trap video (tinyurl.com/bktrapping) that tag AK is legible but on the other wing-tagged bird the second letter, following 'A', is not visible. The beat keeper reported being able to see wing tags with the naked eye, though not read them accurately without optics, among groups of birds feeding away from the lek.

One of the key benefits of their black-and-white design was that tags were legible using camera traps under infrared as well as in visible light. Randler & Kalb (2018) showed that for duck-sized birds, such as Black Grouse, the detection probability of passive infrared detectors of a range of camera traps falls to about 50% at 3 m. We found a similar pattern in that the closest bird in shot when a camera trap triggered was estimated to be a metre or less from the lens 87% of the time, although this result might have been

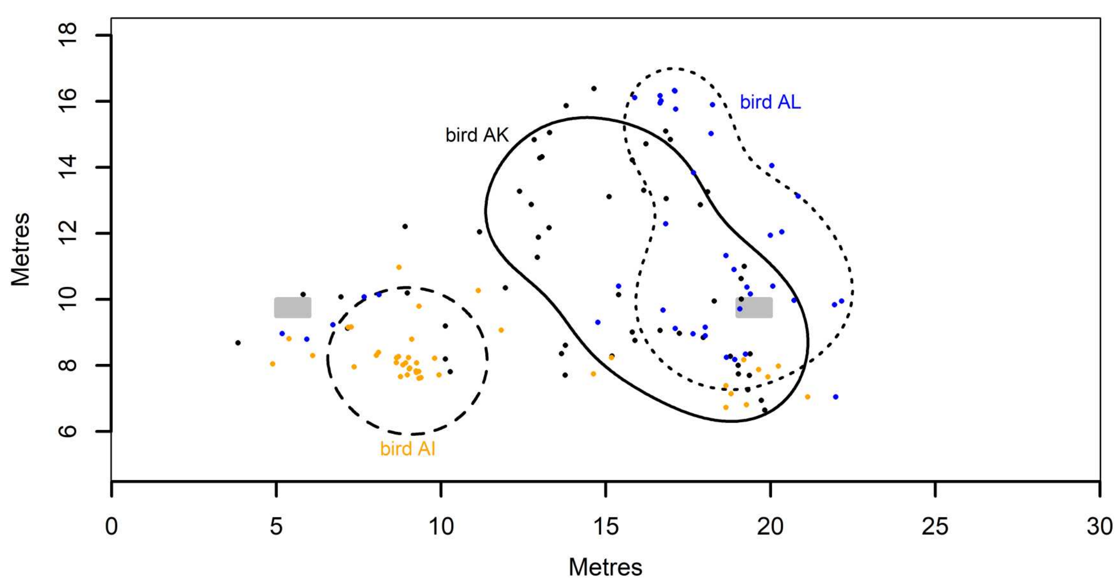

Figure 5. A map of activity of three wing-tagged male Black Grouse at lek observed from a hide: coordinates are arbitrary and represent a simple grid. Points represent locations where territorial display or interaction was recorded, with each bird plotted in a different colour. Boundaries show 50% fixed kernels for each individual, based on all locations including non-territorial activity such as loafing and feeding. The grey boxes represent two of the three traps, the third being off the map.

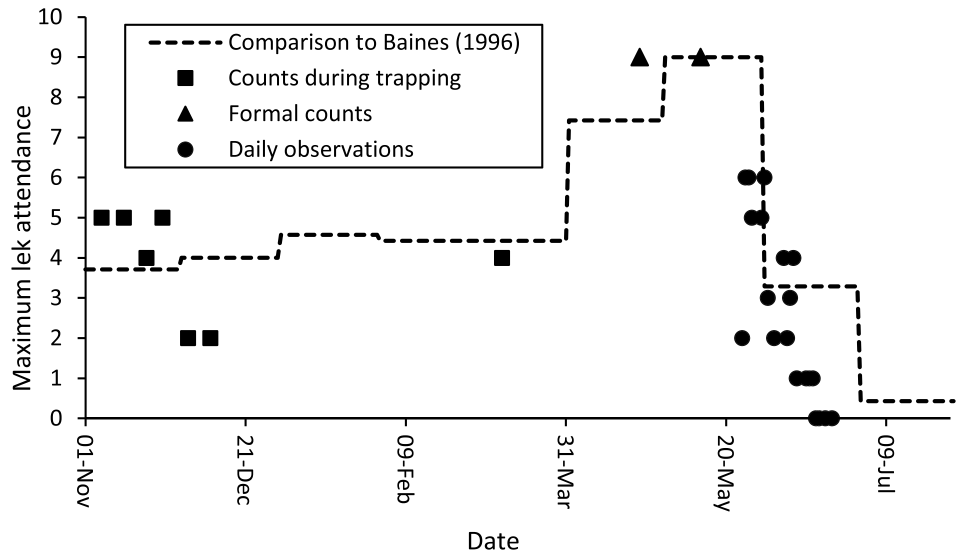

Figure 6. All daily maximum counts of males at the study lek in 2016/17 from trapping days, formal counts made by the Perthshire Black Grouse Study Group, and our daily observations from a hide. The traps were present on the lek throughout and there were a number of wing-tagged birds in the lekking group. The line represents the mean monthly proportion of displaying male Black Grouse at dawn across several leks in the same region from Baines (1996), scaled to our maximum count of nine males.

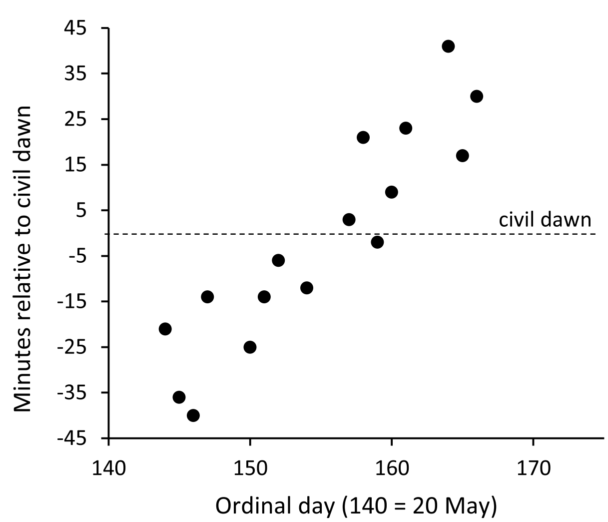

Figure 7. Time of arrival of first males at the lek from observations during 25 May to 22 June 2017 while traps were *in situ* on the lek and following ten days of trapping in the preceding autumn and winter: negative minutes indicate arrival before civil dawn.

biased by placing the camera trap relatively close to baited traps.

Discussion

We set out to design an effective but also easily transportable, simple and safe trap for Black Grouse on leks. This was achieved through two iterations of the trap and we demonstrated that it was successful on most days of operation and could retrap birds as well as catch new ones. We have not found any comparable data from other studies on trapping success at lek sites with which to compare our trapping rates, although there might be some studies that we have missed .

Some studies have reported cannon netting as their main trapping approach (e.g. Rintamäki *et al* 1995), a method which has the potential for large catches per fire. But cannon netting involves a loud and potentially disturbing explosion and raises health and safety considerations; it requires a high level of qualification among practitioners, as well as large operating teams on any firing attempt, and therefore are not always practical. Where cannon nets are being considered, the potential for more damaging disturbance due to noise impact would have to be taken into account.

The use of cage traps readily facilitates trapping where small teams are undertaking multiple site visits. Cage traps represent an alternative, logistically simpler and sustainable method for many researchers. In addition, if a study required catching only a small proportion of birds from a series of leks, for example a telemetry study, or in order to minimise translocation risks to a source population (IUCN 2013), then cage traps offer the facility to achieve this reliably in one or a few sessions. Our success rate of catching on 75% of days and at a rate of 2.5 birds per hour per trap set seems to represent an efficient use of resources.

We demonstrated the success of our trap outside the peak spring lekking period in which copulation occurs.

If operated in April and May, the trap could potentially catch more birds more quickly, since lekking activity is highest then (Baines 1996), and also trap females, which mostly attend the lek only in this period (Lebigre *et al* 2007). This would need to be tested with field trials, however. We did demonstrate that behaviours and pattern of activity did not seem out of the ordinary in the presence of traps, and following the fitting of wing tags, both during and after the trapping phases, and that lek attendance peaked as expected during the spring period. Although we found that the black grouse appeared to habituate to the presence and operation of our cages, when they detected the presence of humans they defaulted to predator responses. We infer that human disturbance of leks would still be a pressure on Black Grouse populations. There was some evidence of resource guarding of bait on the lek, but this needs further investigation since it could be confounded with normal territorial behaviour.

While we focused on a lek site, the trap could also be successful on feeding or roosting grounds, particularly when using rowan berries to attract birds into traps. This would need to be tested, however; the birds' drive to visit the lekking ground, evolved via sexual selection (Alatalo *et al* 1992), will not be present in feeding areas and birds there might be more wary of traps. If the aim is to catch males only, for studies of lek behaviour or for translocation, then we have demonstrated this can be achieved effectively outside the copulation period. Catching females on a lek during the copulation period might be feasible, subject to ethical review and careful consideration of impacts; otherwise a translocation project could potentially catch adult females, and juvenile of both sexes, by using pointer dogs in August (e.g. White *et al* 2013a), and then adult males at lek sites in August/September, when lek attendance starts to increase after the July hiatus (Baines 1996).

Our design of wing tag had two aims: to help us assess the effectiveness of the trap by observing behaviour of trapped and released birds, and as a proof of concept for a wing tag that matches Black Grouse coloration and is highly visible via direct observation in low light and under infrared illumination in camera traps. It should be noted that the blue structural feather coloration showing as a blue sheen on Black Grouse males is important in mate attraction (Siitari *et al* 2007); given that the patagial tags do not cover the contour feathers of the neck, bib, mantle and back, where the sheen is most prominent, they are not expected to impact its visibility to females. Males with wing tags returned readily to the lek, continued their territorial and display behaviour and were still attracted to bait in traps. Although we did not attempt to compare male territories before and after tagging, tagged males held central positions on the lek suggesting tagging had not caused any displacement. Camera traps have been suggested as a tool for lek monitoring in other grouse species (Stenglein *et al* 2023) and our study shows that Black Grouse tolerate these camera traps on leks very well. They gave a unique insight into the behaviour of individual birds and interaction between birds and the traps. Combined with wing tags that are clearly identifiable both in daylight and infrared illumination, this offers opportunities for future studies of lekking behaviour and dynamics.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix: Discarded designs and methods

Figure A. Prototype trap design used in autumn 2014, including drift fences designed to guide birds into the trap from different parts of the lek. Dummy birds give an idea of scale relative to a male Black Grouse.

An original trap design was adapted from drawings shared by E. Strauß-Lebenslauf of the University of Veterinary Medicine, Hanover, that had been effective in Germany. We initially developed a wooden prototype and tested it in autumn 2014. This original trap had doors that closed by dropping on hinges from inside out, and the system had a series of drift fences, which were temporary chicken-wire fences about 40–50 cm high, designed to guide birds into the traps (Figure A).

Although trapping success was good, with birds being caught on seven of ten trapping days, we found a few limitations to our design. For example, the door system meant that the bird had to be right in the centre of the trap before we could trigger it. The wooden frames warped in the climatic conditions of upland Scotland and the trapping mechanism could therefore be unreliable, sometimes not triggering, or with only one door shutting. We were concerned that the chicken wire used on the trap sides and top could potentially damage birds that tried to flee while being approached for extraction. We also found, contrary to expectation, that the drift fences did not generally guide birds into the trap; they were fiddly to set up on each trapping day and could not be left on the lek between trappings because they restricted free movement by foot across the lek. In addition, we observed some evidence of birds using drift fences as territorial boundaries, with birds displaying to each other across the drift fence while pacing back and forth along a section of fence.

We also undertook *ad hoc* trials of two further trapping methods, which again we subsequently discounted.

1) A baited horizontal drop net was installed on four vertical posts just off the lek in an area we had observed some males crossing on foot, with a manual string release mechanism. This did succeed in trapping a single bird but overall proved to be impractical. Although males and a female were attracted to the bait, any movement in the net as a result of air movement resulted in trap avoidance. Since still days at altitude are rare, it proved to be an inefficient

catcher. The structure and release mechanism were also subject to failure and was complex to set up and reinstall as a temporary structure.

2) A standard whoosh net proved a relatively effective trapping method, with birds having been attracted to the safe firing zone with rowan berries. However, only one pull per trapping session was possible as the whole lekking group would flee in response to the noise and movement of the discharging net. The risk of not catching in any session was assessed as greater than was apparent with the cage traps. In addition, extracting birds from whoosh net entanglement was observed to be both lengthy and intrusive.