Raptor persecution in the Peak District National Park

Tim Melling, Mark Thomas, Mike Price and Staffan Roos

Tim Melling

188. A Northern Goshawk *Accipiter gentilis* displaying over woodland in the Dark Peak, February 2018.

Abstract The Peak District National Park is the southernmost area managed for driven Red Grouse *Lagopus lagopus* shooting in England. Grouse-moor management includes intensive moorland burning and predator control by gamekeepers. As in many areas with driven grouse shooting, there is evidence that raptors are persecuted by gamekeepers. Grouse-moor management is more intense in the northern part of the National Park, known as the Dark Peak, than elsewhere. We compared the number of confirmed raptor persecution events and the area of moorland burning (as a proxy for driven grouse shooting) in 10-km squares throughout the National Park. We also compared changes in the populations of two raptor species, Northern Goshawk *Accipiter gentilis* and Peregrine Falcon *Falco peregrinus*, between 1995 and 2015. The results show a strong association between confirmed raptor persecution incidents and the area of moorland burning. Populations of Goshawks and Peregrines have declined significantly in the Dark Peak over that period, whereas they have shown 5- and 20-fold increases respectively elsewhere in the National Park. Occupancy and breeding success rates are also significantly lower in the Dark Peak. Our results demonstrate strong associations between intensive grouse-moor management, persecution of raptors and negative population impacts on both Goshawk and Peregrine in the Dark Peak; and provide further support for proposals that driven grouse-moor management should be regulated.

Introduction

Large areas of the uplands in northern England and Scotland are managed for shooting of Red Grouse *Lagopus lagopus* (Douglas *et al.* 2013; Thompson *et al.* 2016). The management intensity differs between two styles of shooting: 'driven' and 'walked-up' shooting (Sotherton *et al.* 2009). Driven grouse shoots require high densities of grouse, so that a line of 20–50 'beaters' can drive the grouse towards a line of around 8–10 shooters standing in purpose-built 'grouse butts' waiting for the grouse to fly towards them (Sotherton *et al.* 2009). Walked-up shooting of grouse is traditionally associated with less intensive management of the land and the predator community, but brings in less income to the landowner and the wider rural economy (Sotherton *et al.* 2009).

To achieve the high densities of Red Grouse required for driven grouse shooting, landowners employ gamekeepers, often at densities up to one keeper per 10–15 km^2 (Sotherton *et al.* 2009; Douglas *et al.* 2013), who manage the land to promote fresh shoots of Heather *Calluna vulgaris*, the main food of Red Grouse (Hudson 1992; Watson & Moss 2008). They also legally control the numbers of several species of generalist predators that could eat Red Grouse, their eggs and chicks, notably Red Fox *Vulpes vulpes*, Weasel *Mustela nivalis*, Stoat *M. erminea* and Carrion *Corvus corone* and Hooded Crows *C. cornix*. But there is also ample evidence that illegal killing of predators, notably raptors and owls, is taking place on and near grouse moors managed for driven shooting (e.g. Etheridge *et al.* 1997, Green & Etheridge 1999, Smart *et al.* 2010, Amar *et al.* 2012, RSPB 2017, Whitfield & Fielding 2017). In the absence of such predators, the grouse occur at abnormally high densities, which makes them more prone to parasites and disease. Gamekeepers provide medicated grit to combat a nematode parasite *Trichostrongylus tenuis* that can cause strongylosis in grouse. Mountain Hares *Lepus timidus* are also killed on grouse moors because they can be vectors of the tick-borne disease louping ill, which causes high mortality in grouse and hares alike (Hudson 1992). However, a literature review by Harrison *et al.* (2010) showed that there is no compelling evidence to suggest that culling Mountain Hares might increase Red Grouse densities.

Tim Melling

189. The Dark Peak showing the Upper Derwent Valley with coniferous woods where Goshawks breed, plus the moors and high blanket bog plateau beyond. The rocks in the foreground are Millstone Grit and the stack on the right is known as the Salt Cellar; June 2015.

There is also evidence that grouse-moor management has intensified over the past 20–30 years: the numbers of gamekeepers employed, the area and frequency of burning and the amount of grouse medication used have all increased (Natural England 2009; Clutterbuck & Yallop 2010), and the most recent data show the continuing trend of intensification. First, on the grouse moors of the Peak District, between Manchester and Sheffield, the number of gamekeepers employed between 2001 and 2009 increased from 10 to 32 (Natural England 2009). Second, Hudson (1992) suggested that an economically viable driven grouse shoot needed a post-breeding density of 60 birds/km^2, but the *mean* July density on English grouse moors increased from c. 105 birds/km^2 in 2000 to 370 birds/km^2 in 2014 (Baines *et al.* 2015). Maintaining birds at such an unnaturally high density will have consequences on upland ecosystems. There are also concerns that hydrology, water quality in streams running into water reservoirs and carbon storage in peat-rich soils are negatively affected by the intensive land management associated with driven grouse shooting (Grant *et al.* 2013; Douglas *et al.* 2015; Thompson *et al.* 2016). Some people also argue that the upland scenery is negatively affected by the burning of Heather, which creates a patchwork of burnt, recovering and fully-grown Heather that is clearly visible from long distances. However, some stakeholders argue that this land management is important for rural economies (Sotherton *et al.* 2009).

The Peak District National Park is famous for its breathtaking scenery, with deep wooded valleys and bleak, rugged moors. It is the perfect place to enjoy some of the UK's most beautiful landscapes. Overall, this National Park attracts more than ten million visitors annually, and is an important driver of the regional rural economy (Swift 2008). It has the highest possible level of site protection for wildlife as it is part of the Peak District Moors Special Protection Area and Special Area of Conservation.

The northern part of the Peak District National Park is known as the 'Dark Peak', where the underlying limestone is capped by Millstone Grit, which means that in winter the soil is almost always saturated. Depressions on the high plateaus are filled with *Sphagnum* bogs and dark-coloured blanket peat that gave the area its name. On the slopes the peat is shallower and Heather and other dwarf shrubs predominate. Heather moorland managed mainly for driven grouse shooting is the dominant land use in the Dark Peak, which is notified as a SSSI. Increasingly, deep peat blanket bog has been burnt to encourage Heather growth and thus extend grouse shooting areas onto the high plateaus. There is also a spur of Millstone Grit moorland that extends down the south-east edge of the Peak District; known as the Eastern Peak District Moors SSSI, this comprises areas of conservation-managed moorland and much less intensive grouse management. The 'South West Peak' comprises two SSSIs: Goyt Valley and Leek Moors. This area holds a similar mix of habitats to the Dark Peak, but in a much more intimate mosaic, with smaller blocks of moorland fringed with rushy pastures, hedges, rivers, farmland and small areas managed for grouse shooting. The southern part of the National Park is known as the 'White Peak'. It is characterised by a geology dominated by limestone without a top layer of Millstone Grit, allowing rapid rainwater runoff. The soils lend themselves to sheep and cattle grazing, and there is an absence of moorland for grouse shooting. For simplicity, in this paper we refer to our study areas as the Dark Peak and White Peak, with the latter including the Eastern Moors and the South West Peak (fig. 1).

Until the 1990s, the Dark Peak was renowned for supporting healthy populations of two iconic raptor species: Northern Goshawk *Accipiter gentilis* and Peregrine Falcon *Falco peregrinus*. Both species have increased nationally in recent decades (Hayhow *et al.* 2017) but their fortunes differ between upland and lowland areas. For example, the most recent national survey of Peregrines showed that the number of lowland-breeding birds in the UK had increased between 2002 and 2014, particularly in England, whereas the number of upland breeding Peregrines had declined (Wilson *et al.* 2018). There is strong evidence that the intensive management required by driven Red

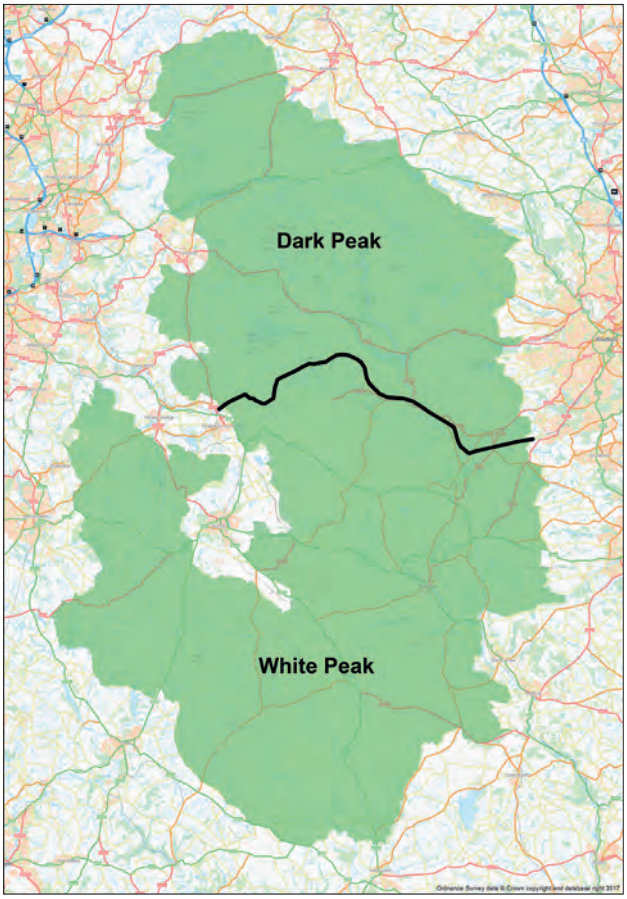

Fig. 1. The Peak District National Park showing the division between the Dark Peak and the White Peak used for this study. Data reproduced with the permission of RSPB. © Crown Copyright. Ordnance Survey licence number 100021787 (2018).

Grouse shooting is associated with the illegal killing of raptors. For example, Amar *et al.* (2012) showed that Peregrines breeding in English uplands with a high proportion of burnt heather moorland had lower breeding success than those breeding away from such burned areas. Similarly, other raptor species, such as Golden Eagle *Aquila chrysaetos*, Red Kite *Milvus milvus* and Hen Harrier *Circus cyaneus*, have also been shown to have lower breeding success, lower adult female survival, a higher proportion of subadult breeders and/or lower population density on or near driven grouse moors than in areas with other land uses (Etheridge *et al.* 1997; Green & Etheridge 1999; Whitfield *et al.* 2003; Smart *et al.* 2010; Sansom *et al.* 2016; Whitfield & Fielding 2017). All these variables suggest that illegal killing and nest destruction play an important role in determining the population density of these raptors in upland areas of Britain.

Given the variation in intensity of grouse-moor management in the different parts of the Peak District National Park, it is an ideal study area to examine whether illegal killing of raptors varies between areas of high-intensity grouse-moor management (the Dark Peak) and the rest of the National Park (the White Peak). Owing to the relatively short distances involved (for example, the most northerly Dark Peak Goshawk nest is only 50 km north of the most southerly White Peak nest), the breeding birds of both species can be regarded as being part of the same breeding population. This offers a prime opportunity to explore how intensive management for driven grouse shooting can affect breeding raptors.

While there is already strong evidence that Peregrine numbers and breeding success are negatively affected by intensive grouse-moor management (Amar *et al.* 2012; North East Scotland Raptor Study Group 2015; Wilson *et al.* 2018), there is only anecdotal evidence that Goshawks may be similarly affected. In this paper we examine the link between grouse-moor management, using the area of moorland burning as a surrogate for driven grouse shooting, and the number of confirmed cases of raptor persecution. We also report population trends and the breeding success of Goshawks and Peregrines in the Dark Peak and White Peak.

Peregrines in the Peak District National Park

The UK Peregrine population reached an all-time low in 1963, owing to a number of factors. From 1940 to 1946, the Destruction of Peregrine Falcons Order was in place, which encouraged the removal of Peregrines to safeguard homing pigeons returning with

Tim Melling

190. Female Peregrine Falcon *Falco peregrinus* in the South Pennine Moors, just to the north of the Peak District National Park, May 2014.

messages during the Second World War. This resulted in around 600 Peregrines being destroyed, plus a large number of nests (e.g. Ratcliffe 1993, Crick & Ratcliffe 1995). From the 1950s, the effects of the organochlorine insecticide DDT caused increased adult Peregrine mortality and a decline in breeding performance as a result of eggshell thinning (Newton 1979; Ratcliffe 1993). The population crash and this species' subsequent scarcity resulted in the remaining birds being targeted by falconers and egg-collectors (Ratcliffe 1993). Peregrines ceased breeding in the Peak District in 1954 or 1955. The banning of DDT and a campaign of nest protection has seen the national Peregrine population recover, with an estimated 1,505 pairs in the UK by 2014; the breeding population is now at an all-time high (Wilson *et al.* 2018).

The initial recolonisation of the Peak District National Park took place in the Upper Derwent Valley in 1981 and the first successful breeding was in 1984, due to a 24-hour nest-protection scheme. A slow increase in the Dark Peak breeding population took place up to the mid 2000s. However, the number of occupied territories masked a serious problem: there was a ready source of new breeding birds from nearby areas but breeding birds in the Dark Peak were rarely successful, as a result of suspected persecution (Wood & Hill 2013). At the same time, however, the White Peak population showed high levels of nesting success.

Goshawks in the Peak District National Park

In the UK, the Goshawk was once a widespread breeding bird but by 1889 it had become the first raptor to be persecuted to extinction (Newton 1979). Unofficial releases and escaped falconers' birds enabled Goshawks to recolonise, however, and they began breeding again in the 1960s (Batten *et al.* 1990). By 2008 there were an estimated 280–430 breeding pairs in the UK (Musgrove *et al.* 2013) and that increase has continued, with c. 437–616 breeding pairs in the UK in 2015 (Holling *et al.* 2017).

The Peak District National Park was one of the first parts of the UK to be recolonised, when a pair bred in the Upper Derwent Valley in 1966. The woodlands adjacent to the Dark Peak moorlands were clearly prime nesting territories: these were the ones colonised first and remained the stronghold for nearly three decades. By the late 1970s, the Peak District population had grown and

was nationally significant, constituting a third of the UK breeding population at that time, of around 60 pairs (Wood & Hill 2013). However, over the last 20 years, the Goshawk has been subjected to persecution in the Dark Peak, particularly from 2001, whereas in the White Peak this species has been thriving.

Methods

Raptor persecution in relation to grouse-moor management

We used two unique databases established by the RSPB to examine how the number of confirmed cases of persecution of any raptor species within the Peak District National Park was related to the area of moorland burning. Firstly, we summarised the number of confirmed persecution incidents involving any bird of prey species within each 10-km square in the Peak District National Park between 2000 and 2016 (RSPB 2017). These data also included confirmed persecution incidents involving owls and Common Ravens *Corvus corax*, since these species are also considered detrimental to grouse-moor interests. A confirmed incident is defined as one where the circumstances suggest that an illegal act has taken place. These incidents are of the highest evidential level and are accepted by the Police as indicating persecution. Information has been supplied by members of the public, specialist field-workers and RSPB staff. The persecution incidents in this analysis included cases of shooting, trapping, poisoning and nest destruction but excluded those relating to falconry and egg-collecting.

We also interrogated the RSPB's dataset of moorland burning, which used aerial photography to record the percentage cover of this activity at a 1-km square level (Douglas *et al.* 2015). The aerial photographs were taken mainly in 2005–07, and ground-truthing using a combination of local knowledge and site visits strongly suggested that these data could be used as a surrogate for driven grouse-moor management. If anything, the past ten years have seen an increase in the intensity of burning in the Dark Peak. Plate 192 shows that rotational burning on grouse moors is easy to identify using satellite imagery.

Abbey Vets, Barnsley

191. A Common Buzzard *Buteo buteo* found on a Dark Peak grouse moor in 2014 with a pole trap attached to its leg.

Raptor data

Peregrines and Goshawks both have traditional nesting territories and will usually nest in the same localised area year after year, even though individual birds may change. It is therefore possible to compare the success of individual territories over a long period. In this paper, we studied data collected over a period of two decades (1995–2015), which coincided with a period of intensification of grouse-moor management. We restricted the data on Goshawks and Peregrines to five-year intervals between 1995 and 2015, since the data were mostly not accessible in electronic format and had to be extracted from field notebooks. For the five study years (i.e. 1995, 2000, 2005, 2010 & 2015), we had data on occupancy and breeding success for 52 Goshawk and 43 Peregrine territories, all of which were located within the National Park. During the study period, new territories were established,

particularly in the White Peak, adding to the ongoing dataset. On average (± 1 standard error), 38 (± 6) Goshawk territories and 31 (± 5) Peregrine territories were checked per year by volunteer fieldworkers, who held the relevant Schedule 1 licences.

We used a Geographic Information System (ESRI 2011) to calculate the percentage of burned moorland within a radius of 1 km of all Goshawk and Peregrine nests in the National Park.

Population trends, territory occupancy and breeding success of Goshawks and Peregrines

We tested whether the population trends of Goshawks and Peregrines differed between the Dark Peak and the White Peak using a Generalised Linear Model (GLM), with the number of pairs in each year as the response variable. We used 'year' and 'region' (i.e. Dark Peak and White Peak) and the interaction between these variables as explanatory variables. We specified a Poisson error with a log link for this GLM. We tested whether territory occupancy by a breeding pair differed between the Dark Peak and the White Peak. We then tested whether there was a difference in breeding success (i.e. whether a pair produced at least one fledgling) between the two areas for all occupied territories. In these analyses, we also included the percentage of moorland burning within a 1-km radius of each nest, as well as the interaction between region (Dark Peak and White Peak) and percentage moorland burning as explanatory variables. We also specified territory identity as a random variable to account for the repeated nature of the data. We used a binomial Generalised Linear Mixed Model (GLMM) with a logit link for these tests.

Results

Raptor persecution in the Peak District National Park

The distribution of 1-km grid squares with presence of burned moorland was mainly confined to the Dark Peak (fig. 2). A visual inspection of fig. 2 also suggests that most confirmed raptor persecution incidents come from the Dark Peak and from squares with driven grouse-moor management. The highest number of confirmed incidents (24) came from SK19, a square with a number of grouse moors. Fig. 3 plots the relationship between confirmed raptor persecution

Esri, Source DigitalGlobe 2016

192. Part of the Dark Peak moorlands showing the characteristic patchwork pattern created by rotational moorland burning on intensively managed grouse moors; 5th June 2016.

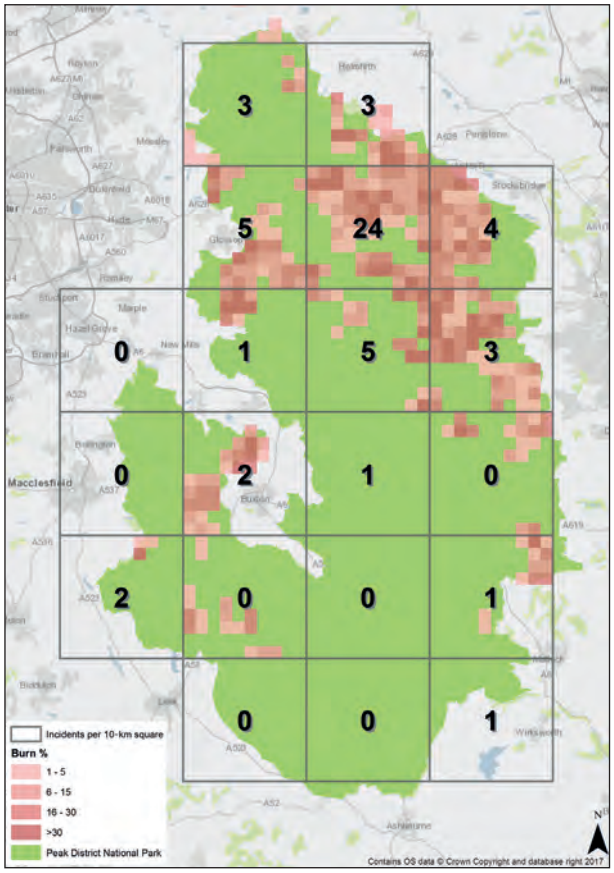

Fig. 2. The number of confirmed raptor persecution incidents within the 20 10-km grid squares that comprise the Peak District National Park. The 1-km grid squares with presence of burned moorland are also shown, in pink. We stress that presence of burned moorland within a 1-km grid square does not mean that the whole square was covered by this habitat, since even a 1% cover of moorland burning qualified as 'presence'.

incidents and the percentage of moorland burning by 10-km grid square. This reveals that within the 20 10-km squares covering the Peak District National Park, the number of confirmed raptor persecution incidents showed a significant positive association with the number of 1-km grid squares with presence of moorland burning (GLM, LR $\chi^2 = 86.08$, df = 1, $P < 0.0001$; fig. 3). This relationship explained 76% of the variation in the number of persecution incidents. Even without the outlier represented by SK19 (the square with 24 persecution incidents), the relationship is statistically significant ($P < 0.0001$).

Grouse-moor management

The presence of land with signs of moorland burning within a radius of 1 km from nest sites differed significantly between the Dark Peak and the White Peak (Goshawk: $\chi^2 = 18.39$, df = 1, $P \leq 0.0001$;

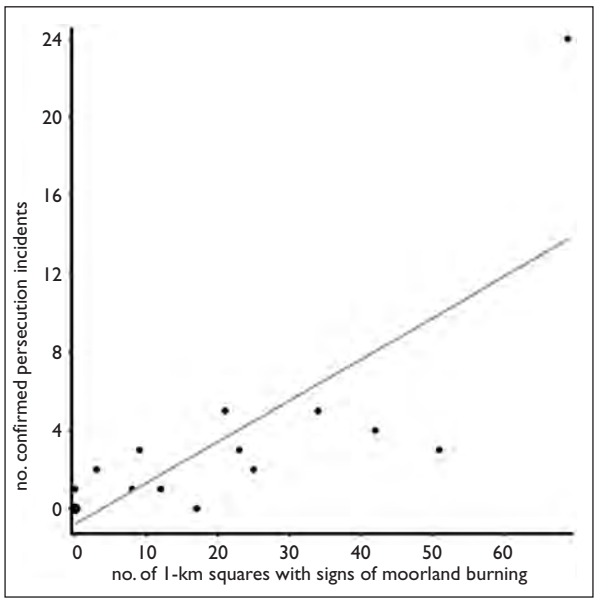

Fig. 3. The relationship between the number of confirmed raptor persecution incidents and the number of 1-km grid squares with signs of moorland burning in each of the 10-km grid squares covering the Peak District National Park. This relationship was tested using a Generalised Linear Model with Poisson errors and a log link, and the relationship was significant (GLM, LR $\chi^2 = 86.08$, df = 1, $P < 0.0001$). The line shows the best linear fit to the data. Six 10-km squares had no moorland burning and no raptor persecution events and they are shown by a single, slightly larger symbol. In addition, two 10-km squares had both 17 1-km grid squares with presence of moorland burning and no persecution events; these two grid squares are plotted using a regular-sized symbol. The square with 24 persecution incidents is SK19.

Peregrine: $\chi^2 = 7.14$, df = 1, P = 0.008). Despite the fact that Goshawks nest in woodland, 27 of 28 Goshawk territories (96%) in the Dark Peak had signs of moorland burning within 1 km of the nest. By comparison, only nine of 24 Goshawk territories (38%) in the White Peak had signs of moorland burning within 1 km of the nest. For Peregrines, which tend to nest on cliffs in open habitat, 12 of 21 territories (57%) in the Dark Peak showed signs of moorland burning within 1 km of the nest, compared with only three of 19 territories (16%) in the White Peak.

The percentage of land affected by moorland burning within a radius of 1 km from the nest differed significantly for both species between the Dark Peak and the White Peak. For Goshawk, there was significantly more moorland burning in the Dark Peak (mean ± SE, 8.80% ± 1.31) compared with the White Peak (2.60% ± 0.87; $t = 3.94$, df = 45.73, P = 0.0003). Similarly, for Peregrine, there was significantly more land with moorland burning in the Dark Peak (5.81% ± 1.57) compared with the White Peak (0.75% ± 0.58; $t = 3.01$, df = 25.43, P = 0.006).

Population trends of Goshawk and Peregrine

In the Dark Peak, the number of pairs of both Goshawk and Peregrine declined between 1995 and 2015, whereas in the White Peak the number of pairs of both species increased over the same period, by approximately 5- and 20-fold respectively. These differences in population trends in the two regions of the National Park were highly significant (Goshawk: LR $\chi^2 = 26.58$, df = 1, P < 0.0001; Peregrine: LR $\chi^2 = 21.22$, df = 1, P < 0.0001; fig. 4).

Territory occupancy

The probability that a checked Goshawk or Peregrine territory was occupied by a pair differed significantly between the Dark Peak and the White Peak, with occupancy rates being significantly higher in the latter (Goshawk: GLMM, $\chi^2 = 20.73$, df = 1, P ≤ 0.0001; Peregrine: GLMM, $\chi^2 = 18.37$, df = 1, P ≤ 0.0001; fig. 5). However, the probability of territory occupancy was not significantly related to the percentage of land with moorland burning within 1 km of the nest (Goshawk: LR $\chi^2 = 0.23$, df=1, P = 0.69; Peregrine: LR $\chi^2 = 1.58$, df = 1, P = 0.21).

Breeding success

The probability that a pair of Goshawks or Peregrines bred successfully (i.e. produced at least one fledgling) differed significantly between the Dark Peak and the White Peak (Goshawk: GLMM, $\chi^2 = 10.86$, df = 1, P = 0.001; Peregrine: $\chi^2 = 8.21$, df = 1, P = 0.004). Goshawks were roughly twice as likely to breed successfully in the White Peak

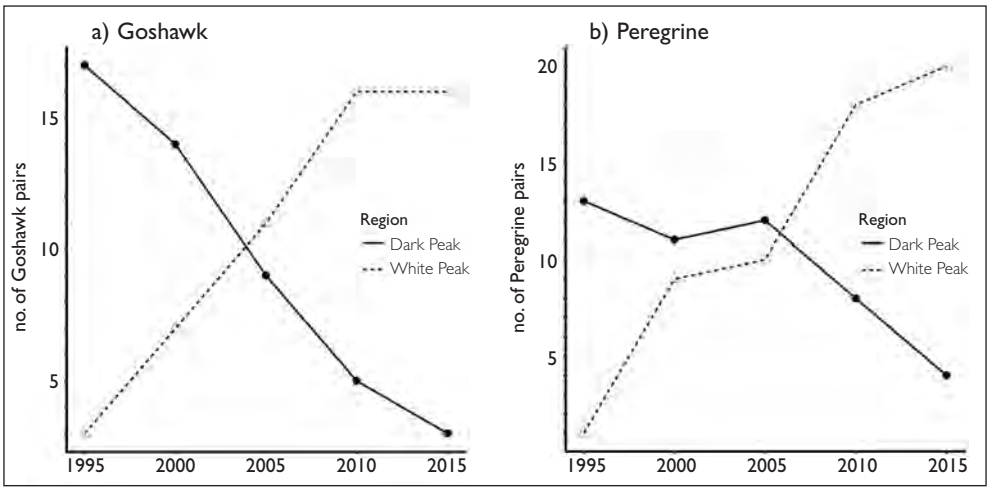

Fig. 4. The population trends of a) Northern Goshawk *Accipiter gentilis* and b) Peregrine Falcon *Falco peregrinus* in the Dark Peak and the White Peak. Differences in population trends in the two regions were highly significant: GLM, LR $\chi^2 \geq 21.22$, df = 1, P ≤ 0.0001.

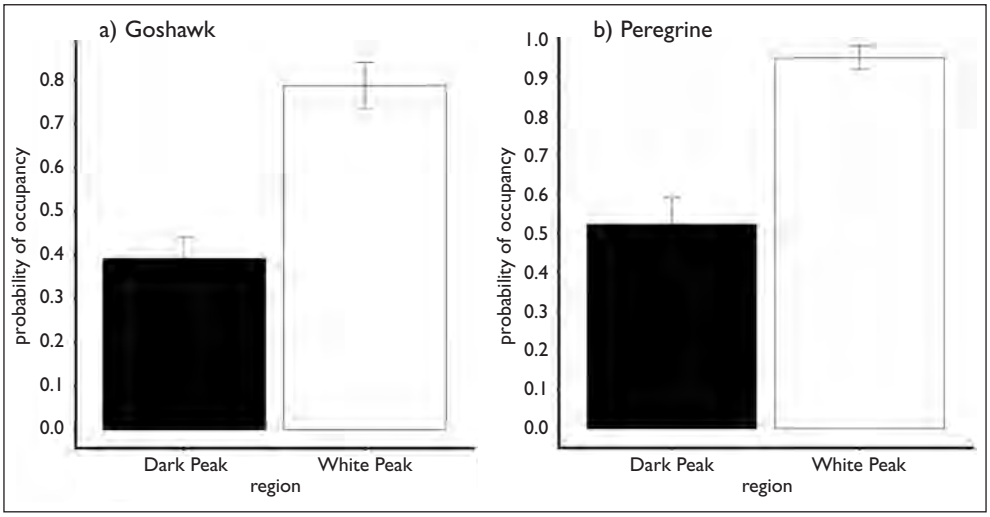

Fig. 5. The probability (±SE) that Goshawk (a) and Peregrine (b) territories checked by fieldworkers were occupied by a breeding pair between 1995 and 2015 in the Dark Peak and the White Peak.

compared with the Dark Peak (fig. 6a) and Peregrines were three times more likely to breed successfully in the White Peak (fig. 6b). However, the probability of a successful breeding outcome was not significantly related to the percentage of land with moorland burning within 1 km of the nest (Goshawk: $\chi^2 = 0.55$, df = 1, P = 0.46; Peregrine: $\chi^2 = 0.03$, df = 1, P = 0.86).

In figs. 7 & 8, the contrasting patterns of population trend and breeding success of both Goshawk and Peregrine are mapped together with moorland burn areas. The two maps for each species highlight the situation at the start (1995) and end (2015) of the study period within the National Park boundary, and show both breeding territories and outcome (red for failure, black for success). At the start of the study period, Goshawks were well represented in the Dark Peak, with multiple territories in woodland throughout the grouse-moor areas and some birds breeding successfully. By 2015, the Goshawk was almost absent as a breeding species in the Dark Peak (just two territorial pairs remained and both failed) whereas the White Peak population had increased and showed high levels of breeding success.

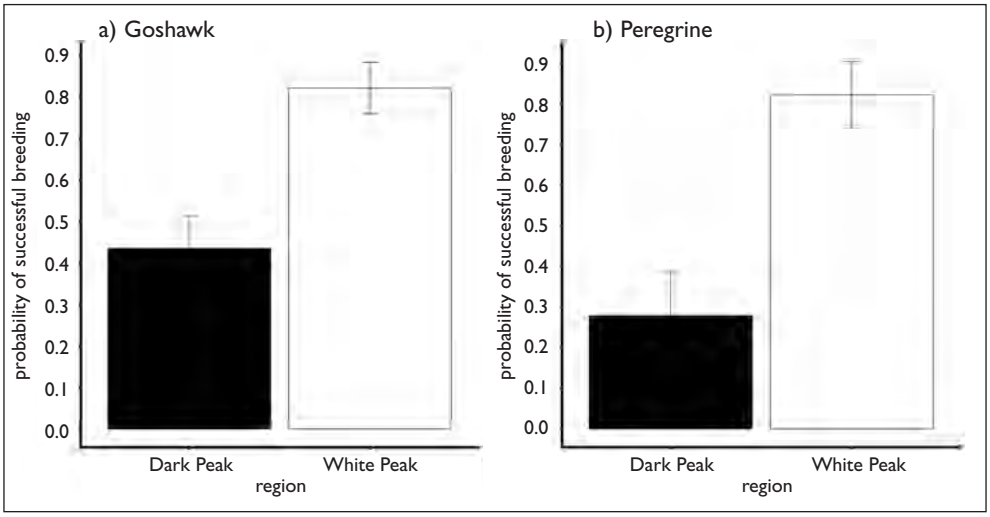

Fig. 6. The probability (±SE) that nests of a) Goshawk and b) Peregrine were successful (i.e. a pair produced at least one fledgling) between 1995 and 2015 in the Dark Peak and White Peak.

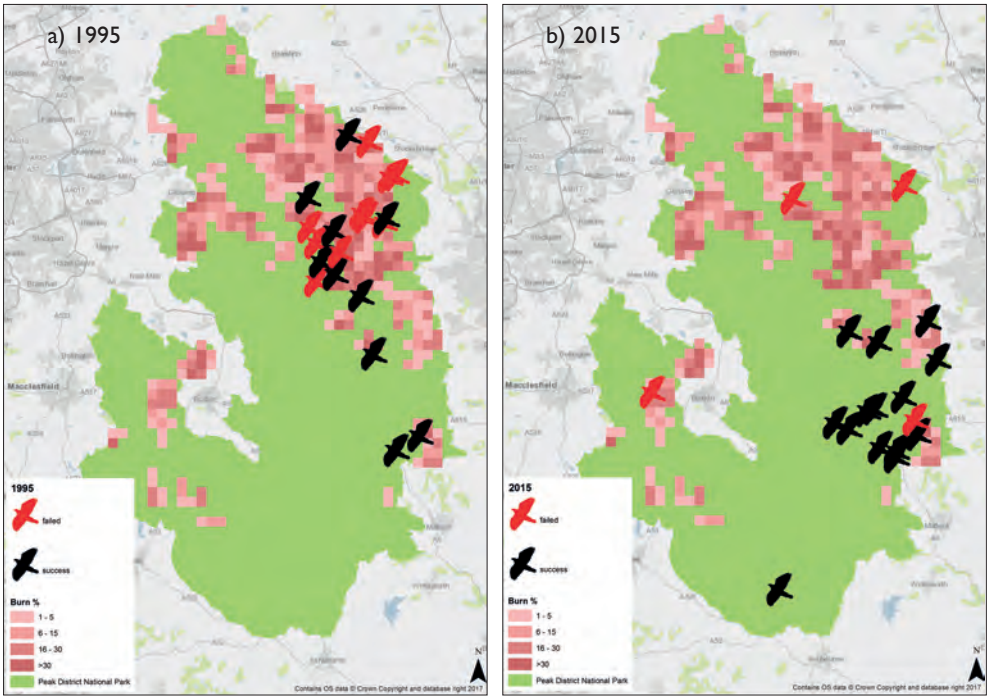

Fig. 7. The location and success of Peak District Goshawk nests in a) 1995 and b) 2015 mapped with percentage grouse-moor burn in each 1-km square.

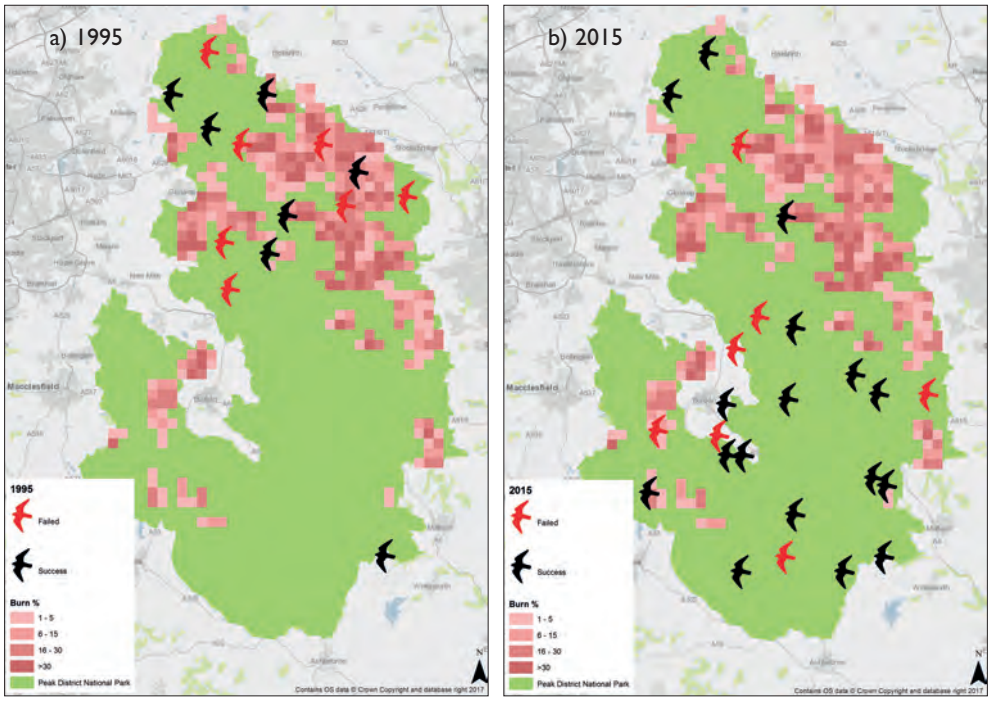

Fig. 8. The location and success of Peak District Peregrine nests in a) 1995 and b) 2015 mapped with percentage grouse-moor burn in each 1-km square.

For Peregrines, the maps again show breeding presence in grouse-moor areas of the Dark Peak at the beginning of the study but limited presence by the end. By 2015, the only successful Dark Peak Peregrine nests were on land managed by the National Trust or the RSPB, whereas the population in the White Peak had become well established and breeding success was high.

Discussion

At the beginning of this study, in the mid 1990s, the spectacle of several displaying Goshawks high over coniferous woodland adjacent to driven grouse moors in the northern part of the Peak District National Park was enjoyed by many birdwatchers, as was the successful reoccupation of traditional gritstone eyries by Peregrines. However, this situation changed dramatically over the following 20 years: Goshawks are now on the brink of extinction in the Dark Peak and Peregrines survive only at highly protected sites. Earlier reports published by the RSPB (RSPB 2006, 2007) documented the population crash in both species, and signposted the spread of systematic persecution throughout the Dark Peak. For Goshawks, this was most evident after 2001 on the eastern fringes of the Dark Peak, when foot and mouth disease access restrictions came into force. Based on a number of more recent incidents recorded by covert cameras, adult Goshawks were most probably shot on their nests, even at night. This would certainly explain the sudden disappearance of multiple adult birds from the population. By 2005, the spread of systematic persecution was evident in the stronghold of the Upper Derwent Valley, and the Goshawk population there had plummeted. For Peregrines, the population crash came after 2005, probably after the focus of persecution attention had moved on from Goshawks. Derbyshire has been the third-worst county for raptor persecution incidents in England in the annual RSPB *Birdcrime* report for the past five years with a high percentage of confirmed incidents in Derbyshire coming from the Dark Peak grouse moors (RSPB 2017).-

Both species have suffered various confirmed persecution incidents, including adults being shot, trapped, poisoned and their nests destroyed. A number of detailed Police and RSPB investigations saw two Dark Peak gamekeepers convicted for separate offences against Goshawks in the 2000s, while many more confirmed incidents have gone unpunished. In one successful investigation, the illegal use of a cage trap baited with a white domestic pigeon *Columba livia* was considered capable of removing the entire Goshawk population in the Upper Derwent Valley during the course of that winter (Ian Newton, in evidence hearing; plate 194). It is interesting to note that after this prosecution the number of active cage traps in the Dark Peak (purportedly used to legally control Carrion Crows) dropped significantly.

Tim Melling

193. A female Goshawk chick, approximately three weeks old, removed from a nest site in the Dark Peak briefly for ringing, in June 2016.

This paper demonstrates that the number of confirmed raptor persecution incidents per 10-km square is positively and significantly correlated with the number of 1-km squares with presence of moorland burning. In essence, more burning equates to a higher number of persecution incidents, with one particular 10-km square (SK19) showing very high levels of raptor perse-

cution (figs. 2 & 3). This square supports ten different driven grouse moors, the highest number in any square in the National Park.

We restricted this analysis to confirmed raptor persecution incidents, since this gave us the highest standards of evidence, but we also had information on a significant number of probable incidents, where the circumstances indicated that the most likely explanation was that an illegal act had occurred. These probable incidents showed a similar pattern to the confirmed incidents, in that most occurred in squares with moorland burning and the highest numbers were in SK19. Owing to the stringent nature of crime incident recording, reports of birds such as the Goshawk shown in plate 195, which are not uncommon, do not qualify as a confirmed incident.

Guy Shorrock/RSPB

194. Cage trap baited with a live white domestic pigeon *Columba livia*, Howden Moors, Derwent Valley, May 2010.

For both Goshawks and Peregrines there are fundamental differences in population trends between the Dark Peak and the rest of the National Park (fig. 4), and these contrasting fortunes are mirrored by the data on territory occupancy (fig. 5) and breeding success (fig. 6): Goshawk nests are twice as likely to succeed away from the Dark Peak and Peregrine nests three times more likely to succeed. Goshawks tend to nest in mature conifer woodland but hunt over moorland, so the prime territories for this species are in the vicinity of the moors. With so few breeding Goshawks now remaining in the Dark Peak, any surviving pairs will occupy the best territories, free from competition, but close to driven grouse moors and at increasing risk of persecution.

We were surprised not to find a significant correlation between the percentage of land with presence of moorland burning within 1 km of raptor nests and either occupancy rate or the probability of successful breeding. However, as the percentage of moorland burning was higher in the Dark Peak than in the White Peak (fig. 2) and the statistical models used included both 'region' (i.e. Dark Peak and White Peak) and percentage moorland burning, it is likely that most of the statistical variation on occupancy and breeding success was related to 'region'. In addition, we used data from every five years only and it is possible that if we had

Tim Melling

195. A Goshawk photographed in the Dark Peak in February 2018 showing what many birders refer to as a 'Maltese moult', but known locally in the Peak District as a 'Derwent moult'. This asymmetrical wing damage was most probably caused by a shotgun.

Tim Melling

196. A rare sight: an adult Goshawk flying over woodland adjacent to a grouse moor in the Dark Peak, February 2018.

had access to data for all years the results may have been different. Furthermore, the analyses regarding the probability of successful breeding contained few nests from the Dark Peak in the later years, making the analysis less powerful than if we had had a larger sample size. Finally, breeding success is governed not only by persecution but also by natural failures due to (for example) weather-related incidents and inexperienced birds. However, despite these relatively minor shortcomings in our data, our results suggest that Goshawks and Peregrines are significantly less likely to occupy breeding territories in the Dark Peak than in the White Peak; and that, if they do occupy a territory in the Dark Peak, they are less likely to breed successfully. The short distance between the Dark Peak and White Peak rules out climatological differences, while the high numbers of available prey items for both Goshawks and Peregrines on grouse moors (e.g. Tharme *et al.* 2001, Balmer *et al.* 2013) suggest that there is probably no food shortage for these raptors in the Dark Peak (Amar *et al.* 2012 reached a similar conclusion). When combined with the fact that we have shown that persecution data are significantly linked with moorland burning, then the only plausible explanation for our results is that Goshawks and Peregrines are routinely killed illegally and their nests destroyed in the Dark Peak, regardless of the percentage of burned moorland within 1 km of their nests.

This current situation explains why most Goshawks now encountered in the Dark Peak are immature birds, most likely from successful territories in the White Peak. In the White Peak, woodland areas farther from the moors were colonised only as the population expanded, and these sites are probably suboptimal from a Goshawk's perspective. Yet the breeding success of birds in these territories is still higher than in prime Dark Peak territories, which have been kept in check by recurrent persecution. This is the first time that an association has been demonstrated between grouse-moor burning, breeding failure and population decline for the Goshawk.

Peregrines feed primarily on high-flying birds such as pigeons, and so are not particularly associated with moorlands. However, when they nest on or near moorland areas, they can take gamebirds such as Red Grouse (Thirgood *et al.* 1998; Redpath & Thirgood 1999). To breed successfully, Peregrines need a secure nest ledge and the limestone quarries in the White Peak provide suitable ledges just as well as the gritstone crags in the Dark Peak. Our results show that, compared with Peregrines in the White Peak, those in the Dark Peak have lower territory occupancy and lower breeding success in the territories which are occupied. We have also shown that

there is a correlation between areas of moorland burning and confirmed incidents of persecution. Peregrines, which are noted for their long-term pair bonds and high site fidelity (Ratcliffe 1993), have an unusually high turnover in the Dark Peak. It is not uncommon for the adult birds observed occupying a territory in early spring suddenly to be replaced by immature birds, which then often disappear altogether. This turnover of birds would not be picked up in our persecution analysis unless a Peregrine was found that had been trapped, poisoned or shot, since birds that simply vanish are not recorded as confirmed persecution incidents. It is likely that sustained persecution is responsible for this abnormal turnover of birds within individual nesting territories and that the loss of territorial birds is one of the key reasons that nests fail. In contrast, the pair nesting on the RSPB's Peak District landholding in the Dark Peak sustained pair bonds typical of this species. In fact, only this pair and another on National Trust land have shown any success in recent years. Peregrines no longer breed on private grouse moors in the Dark Peak, despite suitable territories and an abundance of prey.

This paper provides strong evidence of what has been long suspected among birdwatchers and conservationists: that persecution associated with driven grouse shooting is limiting the populations of Goshawks and Peregrines in the Peak District National Park. In the Dark Peak, both species have lower occupancy levels, presumably because new territorial birds are removed early in the season, while those birds that do actually nest are two or three times more likely to fail. This would explain why the Dark Peak populations of Goshawks and Peregrines are declining when populations just a few kilometres away from the grouse moors are increasing.

Two initiatives that aimed to increase raptor populations in the Peak District have been tried and have failed. The first of these was the Peak Nestwatch Partnership, which started in 2000. More recently, the Peak District Bird of Prey Initiative (2011), led by the National Park Authority and consisting of partners from both the conservation and the shooting worlds, failed to reach any of its targets in each of its six years of existence. In short, self-regulation seems impossible, the persecution is intensive and the statutory bodies seem powerless.

Goshawks are now virtually extinct in the Dark Peak, and successful Peregrines occur only at highly protected sites on land managed by the National Trust or RSPB, yet on nearby land free from driven grouse shooting both species are thriving. Our results provide support for proposals that intensive grouse-moor management should be regulated; only then will it be possible for thousands of people to enjoy displaying birds of prey throughout this National Park.

Acknowledgments

We are indebted to the army of fieldworkers from the Peak District Raptor Monitoring Group and the South Peak Raptor Study Group who have contributed data. We also thank Matt Bruce (RSPB) for help with the data preparation and analysis, Paul Britten (RSPB) for production of the maps and David Douglas (RSPB) for allowing access to the moorland burning dataset. We also thank Roy Taylor (RSPB) for helpful comments and suggestions from the very beginning of this project and for inspiring us while coping with his own adversity. Mark Eaton (RSPB) and Mick Taylor for providing helpful comments during the drafting of the paper; and finally Roger Riddington and the anonymous referees who provided constructive criticism on an earlier draft of this paper.

References

Amar, A., Court, I. R., Davison, M., Downing, S., Grimshaw, T., Pickford, T., & Raw, D. 2012. Linking nest histories, remotely sensed land use data and wildlife crime records to explore the impact of grouse moor management on Peregrine Falcon populations. *Biol. Conserv.* 145: 86–94.

Baines, D., Newborn, D., Howarth, D., Fletcher, K., & Warren, P. 2015. Uplands monitoring in 2014. In: Shervington, L., & Swyer, J. (eds.), *Review of 2014*, pp. 42–45. The Game & Wildlife Conservation Trust, Fordingbridge.

Balmer, D., Gillings, S., Caffrey, B. J., Swann, R. L., Downie, I. S., & Fuller, R. J. 2013. *Bird Atlas 2007–11: the breeding and wintering birds of Britain and Ireland*. BTO Books, Thetford.

Batten, L. A., Bibby, C. J., Clement, P., Elliott, G. D., & Porter, R. F. 1990. *Red Data Birds in Britain*. Poyser, London.

Clutterbuck, B., & Yallop, A. R. 2010. Land management as a factor controlling dissolved organic carbon release from upland peat soils 2: changes in DOC productivity over four decades. *Sci. Total Environ.* 408: 6179–6191.

Crick, H. Q. P., & Ratcliffe, D. A. 1995. The Peregrine *Falco peregrinus* breeding population of the United Kingdom in 1991. *Bird Study* 42: 1–19.

Douglas, D. J. T., Bellamy, P. E., Stephen, L. S., Pearce-Higgins, J. W., Wilson, J. D., & Grant, M. C. 2013. Upland land use predicts population decline in a

globally near-threatened wader. *J. Appl. Ecol.* 51: 194–203.
—, *et al.* 2015. Vegetation burning for game management in the UK uplands is increasing and overlaps spatially with soil carbon and protected areas. *Biol. Conserv.* 191: 243–250.
ESRI. 2011. ArcGIS Desktop. Environmental Systems Research Institute, 10.1. Redlands, California.
Etheridge, B., Summers, R. W., & Green, R. E. 1997. The effects of illegal killing and destruction of nests by humans on the population dynamics of the Hen Harrier *Circus cyaneus* in Scotland. *J. Appl. Ecol.* 34: 1081–1105.
Grant, M. C., Mallord, J. W., Stephen, L., & Thompson, P. S. 2013. *The Costs and Benefits of Grouse Moor Management to Biodiversity and Aspects of the Wider Environment: a review*. RSPB Research Report No. 43, Sandy.
Green, R. E., & Etheridge, B. 1999. Breeding success of the Hen Harrier *Circus cyaneus* in relation to the distribution of grouse moors and the Red Fox *Vulpes vulpes*. *J. Appl. Ecol.* 36: 472–483.
Harrison, A., Newey, S., Gilbert, L., Haydon, D. T., & Thirgood, S. 2010. Culling wildlife hosts to control disease: Mountain Hares, Red Grouse and louping ill virus. *J. Appl. Ecol.* 47: 926–930.
Hayhow, D. B., *et al.* 2017. *The State of the UK's Birds 2016*. RSPB, BTO, WWT, DAERA, JNCC, NE, NRW and SNH, Sandy.
Holling, M., & the Rare Breeding Birds Panel. 2017. Rare breeding birds in the United Kingdom in 2015. *Brit. Birds* 110: 706–754.
Hudson, P. J. 1992. *Grouse in Space and Time*. Game Conservancy, Fordingbridge.
Musgrove, A., *et al.* 2013. Population estimates of birds in Great Britain and the United Kingdom. *Brit. Birds* 106: 64–100.
Natural England. 2009. *Mapping Values: the vital nature of our uplands – an atlas linking environment and people (NE209)*. Natural England, Peterborough.
Newton, I. 1979. *Population Ecology of Raptors*. Poyser, Berkhamsted.
North East Scotland Raptor Study Group. 2015. Peregrines in North-east Scotland in 2014 – further decline in the uplands. *Scottish Birds* 35: 202–206.
Ratcliffe, D. A. 1993. *The Peregrine Falcon*. 2nd edn. Poyser, London.
Redpath, S. M., & Thirgood, S. J. 1999. Numerical and functional responses in generalist predators: Hen Harriers and Peregrines on Scottish grouse moors. *J. Anim. Ecol.* 68: 879–892.
RSPB. 2006. *Peak Malpractice: what's happening to wildlife in the Peak District National Park?* RSPB, Sandy.
— 2007. *Peak Malpractice Update 2007*. RSPB, Sandy.
— 2017. *Birdcrime 2016: a focus on raptor persecution in the UK*. RSPB, Sandy.
Sansom, A., Evans, R., & Roos, S. 2016. Population and future range modelling of reintroduced Scottish White-tailed Eagles (*Haliaeetus albicilla*). Scottish Natural Heritage Commissioned Report No. 898. SNH, Edinburgh.
Smart, J., Amar, A., Sim, I. M. W., Etheridge, B., Cameron, D., Christie, G., & Wilson, J. D. 2010. Illegal killing slows population recovery of a re-introduced raptor of high conservation concern – the Red Kite *Milvus milvus*. *Biol. Conserv.* 143: 1278–1286.
Sotherton, N., Tapper, S., & Smith, A. 2009. Hen Harriers and Red Grouse: economic aspects of Red Grouse shooting and the implications for moorland conservation. *J. Appl. Ecol.* 46: 955–960.
Swift, J. 2008. Contribution of the Peak District National Park to the economy of the East Midlands. SQW Consulting.
Tharme, A. P., Green, R. E., Baines, D., Bainbridge, I. P., & O'Brien, M. 2001. The effect of management for Red Grouse shooting on the population density of breeding birds on heather-dominated moorland. *J. Appl. Ecol.* 38: 439–457.
Thirgood, S. J., Redpath, S. M., Hudson, P. J., & Donnelly, E. 1998. Estimating the cause and rate of mortality in Red Grouse *Lagopus lagopus scoticus*. *Wildlife Biology* 4: 65–71.
Thompson, P. S., Douglas, D. J. T., Hoccom, D., Knott, J., Roos, S., & Wilson, J. D. 2016. Environmental impacts of high-output driven shooting of Red Grouse *Lagopus lagopus scotica*. *Ibis* 158: 446–452.
Watson, A., & Moss, R. 2008. *Grouse*. HarperCollins, London.
Whitfield, D. P., & Fielding, A. H. 2017. Analyses of the fates of satellite tracked Golden Eagles in Scotland. Scottish Natural Heritage Commissioned Report No. 982. SNH, Edinburgh.
—, McLeod, D. R. A., Watson, J., Fielding, A. H., & Haworth, P. F. 2003. The association of grouse moor in Scotland with the illegal use of poisons to control predators. *Biol. Conserv.* 114: 157–163.
Wilson, M. W., *et al.* 2018. The breeding population of Peregrine Falcon *Falco peregrinus* in the United Kingdom, Isle of Man and Channel Islands in 2014. *Bird Study* 65 doi.org/10.1080/00063657.2017.1421610
Wood, D., & Hill, R. (eds.). 2013. *Breeding Birds of the Sheffield Area*. Sheffield Bird Study Group, Sheffield.

Tim Melling (correspondence author), RSPB Denby Dale Office, Westleigh Mews, Wakefield Road, Denby Dale, Huddersfield HD8 8QD; e-mail tim.melling@rspb.org.uk

Mark Thomas, RSPB, The Lodge, Sandy, Bedfordshire SG19 2DL

Mike Price, Peak District Raptor Monitoring Group

Staffan Roos, RSPB Centre for Conservation Science, 2 Lochside View, Edinburgh EH12 9DH

Tim Melling is a Senior Conservation Officer at the RSPB with over 30 years of experience dealing with urgent conservation issues. He works mainly on site and species conservation in the north of England. **Mark Thomas** is a Principal Specialist within the RSPB Investigations team, investigating raptor persecution and protecting rare breeding birds. **Mike Price** is an independent raptor fieldworker, working on various raptor projects across the UK. **Staffan Roos** is a Senior Conservation Scientist at the Centre for Conservation Science at the RSPB. He works mainly on raptors, conflict resolution and upland ecology.