Review of Management Prescriptions for Black Grouse *Tetrao tetrix* in Britain: An update and revision including monitoring

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Original report - ***A review of Management Prescriptions Advocated for Black Grouse*** **Tetrao tetrix** ***in the UK: An update and revision*** **by John Calladine, 20 December 2002.**

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Review of Management Prescriptions for Black Grouse *Tetrao tetrix* in Britain: An update and revision including monitoring

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1. Background and report structure

Formerly widespread in Britain, numbers of black grouse have declined and their range contracted throughout the 20th century (Baines & Hudson 1995, Gibbons *et al.* 1993, Sim *et al.* 2008). The species is a UK Biodiversity Action Plan priority species (UK Biodiversity Group 1999), with conservation effort reflecting this prioritisation. This takes the form of country specific agri-environment support, a number of nature reserves where the enhancement of black grouse populations is a major objective and regional recovery initiatives with dedicated project officers. Despite this, the decline continues across certain regions. The most recent population estimate suggests that were c.5000 lekking males in Britain in 2005, representing a 22 % decline since 1995/96, with this decline being most severe in southwest and southeast Scotland (49 % and 69 %, respectively) (Sim *et al.* 2008). The species remains of high conservation concern (Gregory *et al.* 2002, BTO 2008). This review summarises management prescriptions currently advocated to land managers and associated monitoring reported by conservation staff working closely with black grouse and identifies the levels of supporting evidence from published literature and current knowledge. It updates an earlier review (Calladine 2002).

The original review (Calladine 2002) collated details of the advice given to land owners and managers from RSPB (or RSPB affiliated) conservation staff that were actively advocating management for black grouse, or otherwise commenting on proposals that may affect the species. The information supplied was then summarised into a series of discrete prescriptions or themes where these were common to multiple prescriptions. Each prescription or theme was then reviewed by reference to relevant literature to accredit a realistic level of validation of observed or expected effectiveness for black grouse. The current update has: (i) expanded upon the details of advice given to land owners and managers by collating information from current practitioners (mostly from the RSPB) and (ii) revised the validation assessment for all prescriptions and themes in line with the scientific literature now available on black grouse. A tabular summary of the review is presented in Section 9. The remainder of this report explains the reasoning for the categorisations given within that table.

Contributing individuals and their remits are identified in the acknowledgements, including both those inputting to the original review and to this update.

2. A summary of management prescriptions, targeting strategies and monitoring advocated for black grouse.

The tables in section nine summarise actions currently advocated to conserve local populations of black grouse in the UK. Each action has been allocated to one of four categories according to the following criteria:

1. Backed up by published, peer-reviewed, studies.
2. Based on currently unpublished data or other non-reviewed publications.
3. Based on supportable anecdote and observation, or the logical interpretation of known biology.
4. Without any recognized foundation.

In some instances, more than one category is assigned to a particular action where it has been possible to separate the different aspects that have different levels of support. In all cases the reader is encouraged to refer to the relevant sections in the subsequent text for explanations of the categorisation.

It is emphasised that designation to a particular category depends on the current status of literature, thus inclusion into one of the 'lower' categories does not necessarily imply that the actions are certainly of no benefit to black grouse.

For the assessment of management prescriptions (Table 3), a second series of categories are also used. Thus, in addition to the source of the information, this table also records the reported effect of the prescription, as follows:

a) Beneficial population level or demographic (survival rates, breeding productivity) effect on black grouse following the application of this option
b) Response effect – birds recorded using the resources produced by the prescription, or studies show birds to be associated with or select the resource, or to respond in some way to the relevant factor (e.g. they are killed by predators or show a stress response to disturbance)
c) Resource effect – the prescription has delivered an increase in the extent and/or quality of the resource considered to be of benefit.

The lack of a symbol in the appropriate row of the table indicates that there is no evidence of any effect.

3. Monitoring of population density and breeding success

3.1 *Monitoring black grouse populations*

Monitoring can permit assessment of the distribution, status and, with due consideration, the effectiveness of implemented management. The most widespread method used to assess population density and distribution is counting the number of males at leks in spring (Gilbert *et al*. 1998). Black grouse males can display through most of the year, however numbers can vary. In the UK, peak numbers, and more critically the least variable numbers are present in the spring (early April to late May) and within two hours after dawn (Cayford & Walker 1991, Baines 1996a).

A proportion of birds will display alone and away from established lek arenas (Hancock *et al.* 1999, Höglund & Stohr 1997), so any counts should be clear as to whether they are solely counts of birds at established or known lek sites or include systematic searching of a clearly defined area. A series of counts of displaying males over a number of years all of which were undertaken during the periods of most consistent attendance at leks and are consistently recording either birds at leks only or, preferably combined with regular systematic searching of a defined area for all males, will provide a reliable index of population trends.

Further assessments of how lek counts and, perhaps more importantly, lek searching vary within-season and in relation to weather conditions could be of value. Assessment of hen density is less straightforward - with most workers using trained dogs to search out and flush birds. This normally leads to only restricted areas being searched and therefore numbers of birds can be low. Survival rates and periods of greatest mortality can differ between the sexes (Angelstam 1984, Hörnfeldt *et al.* 2001) and so there could be justifiable reasons for trying to measure population densities of both. Differences in the detecting efficiency by different dogs (with different experience), the effects of weather on dog efficiency, and the influence of dog-handler interactions, are unquantified but could represent important sources of variation in counts quantified (Warren & Baines 2011).

Although not reported by RSPB correspondents, an alternative method to using dogs, and one to which some quantification of efficiency has been attempted is the 'Finnish three-man chain' (Rajala 1974). This is essentially strip transects with 3 people walking 20 m apart and is used to monitor a range of wildlife in Finland. Within some habitats the 20 m distance recommended by this method maybe insufficient to flush hens (Baines *pers com*). Many correlative studies with habitat and predators use data thus collected. Evaluation during 'brood counts' in boreal Finland found that 61-64% of adult black grouse without young were found based on the proportions of radio-tagged birds located and only 1 from 11 broods (tagged hens with young) was not found. Although about 80% of combined adults and young were detected (Brittas & Karlbom 1990) this may be an overestimate, as radio tagged birds are often easily flushed.

If using monitoring to assess the effectiveness of prescriptive management implemented, the potential effects of uncontrollable influences should be considered. A significant influence on breeding productivity and potentially population densities of black grouse can be weather (Loneux *et al.* 1997, Loneux 2000, Summers *et al.* 2004), and therefore observed changes need not necessarily be caused by changes in management, or lack of them. An appropriate programme would include the monitoring of multiple sites including reference (or control) sites where management remains unchanged against which any trends can be compared. Alternatively, correlative evidence may be derived from an assessment of the extent of change in numbers against management type and intensity.

3.2 *Monitoring breeding success*

Assessments of breeding success have either been undertaken using dogs to search for broods or by following radio-tagged hens. Aside from the potential cost, there is perhaps no reason why the 'Finnish three-man chain' (see Section 3.1) also could not be used in Britain. There are likely to be differences in the estimates associated with the methodology used, and so comparisons between sites or across time should compare like with like. For example, hens fitted with radio transmitters (necklace mounted) had significantly reduced breeding success than for unmarked hens in a French study, the effect appeared greatest when hens were marked near to the time of laying (Caizergues & Ellison 1998).

Most breeding failures occur at the egg and early chick stages (Baines *et al.* 1996) and so sampling of broods when the chicks are over 3 weeks old, but before brood break-up, is expected to provide an accurate index of overall breeding success. Early sampling may overestimate breeding success while late sampling may find only incomplete broods or indeed the distinguishing of well-grown young females from hens may prove difficult in some conditions. The timing of breeding can vary even within its range in the UK (Baines *et al.* 1996), potentially between years, within the same area and between females of differing age. Consistency in timing of brood sampling between years and between reference and managed sites is recommended and will generally make comparison more valid. To reduce the possibility of bias introduced as a result of any variation between years in timing of breeding, the approximate chick ages could be assessed at the time of counts. Brood counts to estimate productivity are conducted from late July to mid/late August in most UK studies (Picozzi 1986, Baines 1996b, Calladine *et al*. 2002, Summers *et al*. 2004, Watson & Moss 2008), (RSPB staff recommend 21 July to 10 August, GWCT staff monitor until the end of August).

Measures of breeding success used include the ratio of the number of chicks per hen encountered, the number of chicks per brood encountered and the proportion of hens encountered that were attending a brood. Brood size alone is not necessarily a reliable indicator of relative success, with much, and in some instances all, variation associated with the proportion of hens retaining broods into the late chick-rearing stage (Baines *et al.* 1996, Calladine *et al.* 2002). Habitats, and therefore areas, used by hens with broods and those that have failed can differ (Starling-Westerberg 2001). Therefore, concentrating the search effort in areas known to be important for brood rearing could potentially over-estimate breeding success. Considering the restrictions on time available to do brood counts and the limited area that can be searched by dogs in any one day, there are probable conflicts between attaining a sufficient sample size of broods but minimising potential biases associated with that sampling strategy.

As with population trends, weather has a major influence on breeding success (Summers *et al.* 2004, Grant *et al.* 2009, RSPB unpubl. data). Accordingly monitoring to determine any influence of prescriptive management on breeding success will normally require multiple sites including references against which any changes can be compared. The importance of using the same methods across sites and years being compared cannot be overemphasised.

Summary

- *i)* *Monitoring numbers of displaying males can provide a reliable index of population trends but the timing of counts and a systematic approach to counting are needed.*
- *ii)* *Monitoring numbers of hens using dogs provides a less reliable index than that from displaying males but could be justified.*
- *iii)* *Brood counts using dogs, radio-telemetry and flushing by humans in strip transects can provide a reliable index of overall breeding success but the timing of sampling and the selection of areas sampled could introduce biases.*
- iv) *Determining the effectiveness of prescriptive management will normally require multiple study sites including references against which any changes can be compared.*
- v) *Comparisons should consider potential biases associated with methods used and must use the same methods across sites and years being compared.*
- vi) *The Finnish 3-man chain approach may be worth investigating in the UK as an alternative way of obtaining both adult density estimates and brood counts.*

4. Monitoring of some factors of importance in affecting black grouse demography

4.1 *Fence and other wire strikes*

Collisions with deer and livestock fences, telegraph wires and with the elevated cables associated with ski tows are a source of mortality amongst several grouse species, including black grouse (Miquet 1990, Baines & Summers 1997, Moss *et al*. 2000, Wolfe *et al.* 2007). For capercaillie in Scotland, mortality due to collisions with deer fences appears likely to have population level impacts at the national scale, whilst 'local-scale' effects on black grouse densities are suspected (Baines *et al*. 2000).

To effectively quantify collision rates requires regular searching of fence-lines and also under overhead cables and an assessment of removal rates of carcasses by scavenging animals (as in Baines & Summers 1997). Whilst much work has been undertaken to quantify deer fence collision rates, more work is required to assess and quantify the efficacy of some mitigation methods (Baines & Andrew 2003). Quantification of strikes with stock fences and overhead utility lines, and the determination of generic situations where problems are likely to occur are also required.

It is also likely that counts of corpses found along fence-lines provide a minimum estimate of mortality from this cause (even after accounting for corpse removal by scavengers). In studies of lesser prairie chickens in the southern United States, 84 of 719 radio-tagged birds were identified as having died as a consequence of a fence strike, representing 27% of all recovered carcasses (Wolfe *et al.* 2007). However, a proportion of these birds died some distance from the fence-lines, including injured birds that had returned to their nest or roost sites after the collision. Other birds were found to have had injuries caused by fence strikes just prior to predation events. It seems likely that this will also apply to collisions of black grouse with fences. Thus, 15 black grouse (12 cocks, 3 hens) corpses found in Dumfries & Galloway during the course of 'normal fieldwork activities' (as opposed to dedicated fence-line searches) between 1999 and 2001, were considered to be the result of fence strikes. This included two birds found on moorland well away from fences, for which collision with a fence was identified as the likely cause of death only after analysis at the Scottish Agricultural College (SAC) (John Adair unpubl. data). Work to establish the extent to which corpses resulting from fence strikes occur away from the actual fence-line would be of value to allow correction of counts made along fence-lines.

4.2 *Monitoring of grazing animals*

Grazing by wild animals (e.g. deer and rabbits) and domestic stock (e.g. sheep and cattle) are major influences on the quality of black grouse habitats (Section 7.2). Monitoring can be undertaken either by direct counting or dung counts to give an index of relative abundance. Even where reliable information for domestic stocking rates is available from farmers or factors, variation in local concentrations in all but the smallest of grazing units can be worth monitoring as the relative merits of different vegetation structures are beginning to be understood (Section 7.2).

Grazing regimes required to achieve and maintain suitable vegetation structures will vary according to the existing vegetation condition, geographical location, geology, soil, aspect and exposure. Similarly, the response of vegetation to changes in grazing can be variable and will also depend on the degree and time-scale of any 'degradation' and also the type of grazing animals involved (Hill *et al.* 1992). The change in approach toward 'outcome options' within agri-environment schemes relies on detailed understanding of how grazing regimes can produce the desired vegetation composition and structure, rather than using fixed stocking regimes, which may produce different outcomes in different locations and situations. Accordingly the monitoring of grazing animals (density and seasonality) as well as vegetation composition and structure (Section 4.3) will be potentially informative as part of an appropriately designed programme for each particular site.

An alternative method for monitoring the impact of grazing on vegetation might be to assess the utilization rate of key plant species. Utilization rates (the percentage of current years growth that has been grazed) provides a more consistent comparison of the impact of grazing on vegetation between sites than livestock densities (Pakeman & Nolan 2009). Identifying the utilization rate that delivers appropriate grassland structure and composition for any particular site may be the most appropriate way to define appropriate grazing densities on that site.

4.3 *Monitoring of habitat and habitat changes*

Correlative studies have highlighted the importance of ground vegetation structure (and its influence by grazing, and potentially other processes such as burning) for population densities and breeding success of black grouse. In the British uplands, lower densities and breeding success can be associated with shorter swards maintained by higher densities of grazing animals (Baines 1991, Baines 1996b). An influence of changing the grazing regime has also been demonstrated with grazing reductions associated with increased numbers and higher breeding success, at least for the first few years following reduction (Calladine *et al.* 2002, Grant *et al.* 2009; see also 7.2 for potential spatial and temporal influences). Such an effect appears to occur widely in association with woodland plantings, where substantial reductions, or removal, of large herbivores is an initial part of the management change (e.g. at Loch Katrine in the Trossachs, Carrifran in Dumfries & Galloway, and at RSPB's Corrimony and Geltsdale reserves in the Scottish Highlands and North Pennines, respectively).

Similarly, black grouse abundance varies with changes in forest structure. Management and environmental changes creating open forests are associated with increased abundance, whilst forest canopy closure is associated with decreased abundance (Angelstam 2004, Grant & Dawson 2005, Pearce-Higgins *et al.* 2007). Such relationships with forest structure are likely to arise, in large part, via effects on the composition and structure of ground vegetation (7.1.1).

Smaller-scale woodland and forest managements are also widely advocated for black grouse, notably the planting of small stands of trees and shrubs within open landscapes (ideally within steep sided ravines) and edge restructuring of commercial plantations.

Studies examining effects of grazing and other management regimes have generally been opportunistic, in that managements were applied principally for reasons other than black grouse. Further monitoring of management changes and on a range of different vegetation structures (and grazing regimes) would prove useful in identifying whether there are 'optimal' grazing regimes and vegetation structures, or whether black grouse response is determined largely by changes in the growth rates and productivity of the field-layer, resulting from the management change. However, as with monitoring of black grouse, a number of methods are used to measure vegetation and other habitat variables, each with their own strengths and biases (e.g. Stewart *et al.* 2001) and so comparable methods should be used. Vegetation, and other habitat features (for example invertebrate availability) can take a number of years to develop and therefore annual monitoring is not always necessary. In some cases, measurements taken at two to five-year intervals may be sufficient (and not too resource intensive) to determine changes. Measures of tree and shrub occurrence and structure in relation to planting or management could prove useful as part of a programme to quantify any benefits to black grouse, as would measures of open habitat, tree density and canopy cover within forests.

4.4 *Monitoring of predators*

Predation is frequently the major proximate cause of mortality and breeding failure in black grouse, with fox, pine marten, stoat, peregrine, goshawk and crows all identified as significant predators (Angelstam 1984, Caizergues & Ellison 1997, Kauhala *et al.* 2000, Picozzi & Hepburn 1984, Warren & Baines 2002, Valkama *et al.* 2005, Park *et al.* 2008). Within Britain, raptors and foxes are probably the main predators of juveniles and adults throughout most of the range, although stoats are most important in the North Pennines, where there are intensive predator control regimes (Picozzi & Hepburn 1986, Cayford 1990, Baines *et al.* 2007). Foxes, mustelids and corvids are likely to be the main predators of clutches and chicks in Britain. The influence of predators can be complex, however (see 7.6).

Predation rates are not only influenced by predator type and abundance, but also by vegetation and habitat structure through interaction (Storaas *et al.* 1999, Thirgood *et al.* 2002) and by the abundance of alternative prey (Marcström *et al.* 1988). Therefore, where feasible, monitoring predation rates or the effects of predation is more useful than just predator abundance alone. However, this can be complex and resource intensive, and in many situations predation rates on juvenile and adult birds (likely to necessitate radio-tracking), as well as on nests and broods, have to be considered. Artificial clutches (containing wax eggs to enable predator identification) are sometimes used to assess predation rates (and differences in predation rates between locations or time periods) on real grouse nests but there are inherent problems and biases, and artificial clutches rarely mimic real clutches of the target species in this respect (Storaas 1988, Willebrand & Marcström 1988). However, studies on the effects of predator removal on black grouse (and capercaillie) productivity demonstrated that artificial clutches appeared to provide reliable measures of annual variation in crow and pine marten predation activity (Summers *et al.* 2004).

As there is evidence of intra-guild relations amongst predators (see 7.6), the monitoring of the full predator suite present in the area would prove more informative especially if a programme of predator removal is undertaken or proposed. However, this is rarely possible due to limitations on resources and the problems of obtaining reliable measures of the abundance of certain predators especially where there are moderate to high densities of predators, or where there is a significant amount of forestry. Also, in common with monitoring black grouse, there are several approaches. For example, indices of avian predators seen during timed counts or transects, counting of scats (with regular clearance), night time spot-lamping for foxes, tunnel 'traps' to record footprints of mustelids and the mapping of nests, dens and earths. Each of these will have associated biases and so the use of systematic and directly comparable assessments of predator indices is important where these are to be compared across sites and time periods.

When monitoring mammalian predators using scat counts, it is essential to ensure that scats are identified correctly. Recent studies suggest problems in distinguishing fox and pine marten scats reliably on the basis of morphology, so that DNA analysis may be required for this purpose in study areas where both species are present (Davison *et al.* 2002, Baines *et al.* 2011).

When monitoring predators, seasonal differences should also be considered; for example, nine out of 22 known causes of mortality in the North Pennines were attributed to peregrines, all outside the breeding season (Warren & Baines 2002). Within the same study areas and during the same period, the median count of all raptors was zero during spring and summer (Calladine *et al.* 2002). Accordingly, monitoring of predators or predation should not necessarily be restricted to the breeding season.

Summary

i) *The frequency of strikes on deer fences is now relatively well quantified, however, the monitoring of some mitigation methods is still required (7.4), as are assessments of the influence of strikes with stock fences and overhead utility lines, and the determination of generic situations where problems are likely to occur.*

ii) *Management of open ground and forest habitats can affect black grouse via changes to field-layer vegetation. The relative values of some grazing regimes and vegetation structures have been identified, but 'optimum' regimes and vegetation conditions have yet to be determined. Monitoring of grazing animals (densities and seasonality) in conjunction with vegetation and broader habitat monitoring is therefore potentially useful.*

iii) *Greater detail on effects of forest management and structure are required, whilst putative benefits of small-scale woodland planting and edge restructuring of commercial plantations need to be established.*

iv) *Monitoring predation rates would prove more informative than predator abundance alone, though it is rarely feasible to do more than monitor a limited number of predator species. The ability to monitor fox and pine marten (two of main mammalian predators of black grouse and their nests) abundance using scat counts is complicated by the fact that distinguishing their scats on the basis of morphology alone may be unreliable.*

5. Scale of management

Within the UK, black grouse are essentially sedentary (Toms 2002, but see Section 5.4) giving a distinct advantage that management within a particular area can be undertaken in order to satisfy the species' requirements throughout the year. There are, however, seasonal differences in habitat requirements that require a multi-scale approach. Although some studies, notably those using radio-telemetry, have given good indicators of overall home range (Section 5.1), survival and dispersal strategies (Section 5.4), most studies have not been sufficiently intensive to identify, or at least do not report, spatial concentration within a home range. Notable exceptions include brood studies (Section 5.2).

Much advice on black grouse management is predicated on the availability of habitat mosaics that include heath, grassland, mire and woodland. This general principle is well founded, with many studies examining habitat use (e.g. Picozzi 1986, Baines 1994, Brittas *et al.* 1987, Cayford 1990, Parr & Watson 1988, Starling-Westerberg 2001). The proportions of the different habitat components required within such mosaics, and their spatial distributions are known in many cases (e.g. Pearce-Higgins *et al.* 2007, Warren *et al.* 2011).

5.1 *Lek scale or Patch Scale*

Much of the currently advocated management is concentrated at the 'lek scale', thus aiming to provide a suitable diversity of habitats to support a viable population of black grouse through the year and centred on a known lek. Radio-telemetry studies suggest home ranges of adults (i.e. birds that have already recruited into the breeding population) in the UK of between 250 and 700 ha (Cayford *et al.* 1989, Picozzi & Hepburn 1984, Robel 1969). Furthermore, studies in NE Scotland found that c.50 % of 62 hens nested within 1 km of the lek on which they were caught (with maximum distance being almost 4 km), and similarly studies investigating effects of supplementary feeding black grouse in winter in Finland (Section 7.7) found that unfed hens nested on average 1.2 km from the mating lek (Picozzi 1986, Valkeajärvi & Ijäs 1994). Accordingly, the maintenance of an appropriate mosaic of habitats to support adult black grouse within a comparable area (for example by concentrating on the 1.5 km radius around target leks) is justified but the definitions of suitable mosaics require clarification. Reliable assessments of how habitat composition, and changes to this and to the spatial distribution of habitats, is related to black grouse population trends in the UK are therefore needed.

In Swedish boreal forests, the occurrence of leks and solo males is associated with extent of young forest or open bog (Angelstam 2004). Within 4 x 4 km squares, the combined extent of these habitats had to exceed 15 % or 22 % for there to be a 90 % probability of occupancy, by solo males (usually 1st years) or leks, respectively. The minimum patch size within which solo males or leks were found was 0.2 km^2 and 0.9 km^2, respectively, whilst the maximum recorded density was 5 lekking cocks per km^2. These findings provide some guidance on the extent of suitable habitat required to support black grouse leks, but they apply to core range with large, continuous, expanses of suitable habitat. It is likely that different dynamics/requirements on habitat patch size will be evident in peripheral, heavily fragmented, areas (Angelstam 2004).

5.2 *Brood scale*

The improvement or expansion of suitable brood-rearing areas is widely advocated. An assessment of the ecology of juvenile grouse of all species stresses the importance of early juvenile survival, suggesting that local scale management must focus on retaining, restoring or producing high quality brood habitat, in reasonable proximity to nesting habitat (Hannon & Martin, 2006). Hannon & Martin also propose that managing habitat to improve brood cover or hen body condition (thereby improving ability of hens to rear chicks) may offer long-term solutions to reducing predation rates on chicks. This may mean improving nutritional quality of food in both breeding and wintering areas.

Grazing reductions on grass-dominated moorland fringe areas in northern England were associated with higher breeding success (Calladine *et al.* 2002). However, summer hen densities (and therefore potential brood densities) showed the greatest rates of increase where grazing was restricted on the smaller areas of ground in that study (40 ha) and declines were recorded where that area exceeded about 100 ha.

Reported from radio-tracking studies in North England and Perthshire the home range of broods can be small (under 50 ha) (GWCT *unpublished* data, Starling 1990) and it follows that all requirements for chick-rearing should be on a similarly fine scale. However, some broods can be mobile and travel up to 400m in 6 hours (Cayford *et al.* 1989, Haysom 2001). Thus, there is potential for apparently larger home ranges especially in linear habitats such as forest rides. However, it might be expected that where larger home ranges for broods are necessitated, this may exert a negative effect on breeding success. In effect, it is likely to be the grain of the habitat that is important, for example in determining how far a chick will need to travel from a relatively tall sward of ground vegetation (insect-rich and affording cover from avian predators and some adverse weather) to shorter vegetation (offering opportunities to dry off after prolonged rain, or providing alternative food supplies).

In northern England, declines in summer hen densities were noted when the grain of an area of relatively tall, lightly grazed vegetation [perimeter (km)/area (km^2)] was less than about 4 (Calladine *et al.* 2002). Relatively fine-scale management of brood-rearing areas within the 'patch scale' approach appears to be appropriate, though more information on chick ecology and factors restricting chick movement is required.

5.3 *Winter home-range scale*

There is some suggestion that winter home ranges of full-grown birds can also be relatively small and sometimes distinct from areas used at other times of year with birds congregating on particularly favoured areas (Baines *et al.* 2002, Baines & Richardson 2007, Warren *et al*. 2009). This may simply reflect the restricted extent and occurrence of favoured winter habitats (e.g. patches of tall vegetation where grazing is restricted, vestigial areas of ericaceous vegetation or herb-rich meadows, and frequently wooded areas - Baines 1994, Baines *et al.* 2002, Starling-Westerberg 2001, Picozzi 1986), rather than being a consequence of social behaviour. However, this assumption requires further testing.

Hens occupying open, park-like, pine forest in Glen Tanar, northeast Scotland used small ranges (averaging c. 45 ha) throughout the whole year, and not only in winter (Picozzi 1986).

5.4 *Regional or metapopulation scale*

5.4.1 Habitat fragmentation

The prevention of habitat fragmentation and active de-fragmentation (e.g. connecting areas of semi-natural woodland remnants with heather re-generation) are widely advocated, whilst at the same time habitat mosaics are encouraged. These two statements appear contradictory and it is assumed that fragmentation actually refers to the scale of the range occupied by, or the distribution of, black grouse. Indeed, there are instances where the de-fragmentation of semi-natural habitats can lead to declines in birds of conservation concern that utilise low intensity agricultural areas (e.g. Lane *et al.* 2001, Law & Dickman 1998, Wolff *et al.* 2001). The same may also be true for black grouse, where populations depend upon agricultural process to create and maintain important habitats (e.g. brood and nest sites) (Calladine *et al.* 2002). In other situations, there is evidence of negative effects of large-scale habitat fragmentation on black grouse populations, such as in the extensive forests of Finland or the lowland heaths in northwest continental Europe (Kurki *et al.* 2000, Ludwig *et al.* 2009a, 2009b)).

Much of the confusion and apparent contradiction here presumably results from issues of scale and the need to consider both fine and coarse-grained habitat variation. Thus, the fragmentation of broad habitat-types that is potentially suitable for black grouse (e.g. moorland, rough grassland, open forest) by habitat which provide few resources for black grouse and in which they rarely occur (e.g. intensively managed farmland or closed canopy forest) is likely to result in the fragmentation of the species distribution and hence be detrimental.

In contrast, within habitat blocks that are potentially suitable for black grouse, creating variation in the habitat can provide substantial benefits (e.g. by creating areas of suitable chick-rearing habitat close to suitable nesting habitat, or by creating open areas of moorland or grassland within forests). However, consideration should also be given to the possibility that habitat-predator interactions may exist that could negate apparent benefits of such habitat variation.

5.4.2 Dispersal

Two studies using radio-telemetry, one in the Alps (Caizergues & Elllison 2002) and the other in northern England (Warren & Baines 2002) showed a marked contrast between the sexes in post-fledging dispersal. The majority of males remain close to, and the survivors ultimately recruit into, their natal leks. The majority of hens on the other hand disperse in their first winters and settle amongst other lekking groups (up to 20 km from their natal area in the English study and up to 30 km in the Alps). Such a high level of male philopatry to their natal area is also confirmed by genetic studies in Finland (Höglund *et al.* 1999, Segelbacher & Höglund 2000). Given that most hens leave their natal areas, the corollary is that the survival of a lek depends on immigration of hens from surrounding areas. Accordingly, the management of single or isolated lekking groups is unlikely to secure a population of black grouse. Effective management will only be achieved if connectivity between black grouse leks is maintained, so that wherever possible management is targeted at groups of leks. Knowledge of dispersal distances and barriers to dispersion assists management targeting at the landscape level.

Caizergues & Ellison (2002) suggest that the mean dispersal distance from natal to breeding sites for hens (4 km in the Alps, 9 km in the North Pennines) can be used to identify adequate distances to ensure connectivity between lekking groups. In the Alps, dispersal tended to be along valleys with high mountain ridges potentially acting as a barrier (Caizergues & Ellison 2002), whilst in the North Pennines there appeared to be no problem in crossing watersheds (Warren & Baines 2002). Potential physical barriers to dispersal in the UK may include some of the higher mountains and larger areas of open water (the latter especially for island or peninsular populations or extensive stands of commercial forest, e.g. Kielder). Observed population declines on peripheral areas of the distributional range in contrast to stability (at least) in the central areas of the range in Sweden, apparently regardless of land management (Angelstam *et al.* 2000), highlights the potential significance of distribution as well as population size.

The effect of current range fragmentation on the viability of populations of black grouse in the UK is unknown but good indications are derived from the rapid demise of the North Northumberland population when maturation of Kielder Forest reduced likely connectivity with counterparts in the North Pennines.

5.5 *Temporal scale*

Black grouse occupy transitional habitats, both spatially where different habitats are juxtaposed (a habitat mosaic) and also where habitats are in temporal transition (e.g. seral changes), specifically from open ground to scrub and/or forest (Seiskari 1962, Børset & Krafft 1973, Swenson & Angelstam 1993, Pearce-Higgins *et al*. 2007). Accordingly, black grouse should, in theory, be able to adapt to, and follow, successional stages in managed forests, colonising new open habitat patches, assuming that these are available within dispersal distance of existing leks and that the open areas are of adequate extent, with suitable field-layer development (Haysom 2001, Angelstam 2004).

Most prescribed management currently aims to deliver set objectives in terms of vegetation composition and structure. As yet, few monitoring programmes have been able to critically assess the effectiveness of such an approach in the longer term.

Some evidence (though not statistically significant) suggests that rates of increase in population density peaked in the early years of stock grazing reduction and then declined after 5-7 years (Calladine *et al.* 2002). Progressive declines in summer hen densities, following initial increases after grazing reduction, relative to neighbouring plots with no grazing reduction, have also been reported from Abernethy Forest and Creag Meagaidh. In some of these cases effects of grazing reduction may be confounded by other management, or environmental, changes (Grant *et al*. 2009).

Potential explanations for such an effect include development of dense and less diverse vegetative swards and associated reduction in invertebrate availability, and a decline in the availability of young, nutritious, plant material. Such increases in abundance followed by subsequent decline are widely reported following grazing exclusion for afforestation of moorland (e.g. Cayford 1993, Baines *et al.* 2000) and are widely attributed to canopy closure, which shades out the critical field-layer vegetation. However, other factors such as 'ageing' ground vegetation may also be involved. Further indications on the exact causes of this response may emerge from monitoring of black grouse around native woodland planting schemes (e.g. at Loch Katrine in the Trossachs, Carrifran in Dumfries & Galloway, and RSPB's Geltsdale reserve in the North Pennines). These schemes are often associated with increases in black grouse abundance following the initial reduction in grazing, and it will be informative to determine whether there are subsequent declines at such sites, given that many of these woodlands should retain a relatively open canopy.

Logical extrapolation of the birds' occupancy of transitional habitats suggests that mid- and long-term management may need to replicate transitional habitats through a planned programme of management changes (e.g. a variable grazing regime), rather than simply replacing one fixed regime with another. Clearly, a greater understanding of how improved conditions for black grouse can be maintained over the longer time scales involved in vegetation dynamics is required.

Summary

i) *Management of a mosaic of habitats within an area of 250 – 700 hectares, or a 1.5 km radius around leks, is based on the known home ranges of adult black grouse in the UK. Many of the key habitat components required by black grouse have been identified.*

ii) *Within the broader habitat mosaic, the finer scale management of chick rearing areas (to give a diversity of sward structures within an area of less than 100 ha) is justified on the currently available knowledge, but greater understanding of chick ecology is required.*

iii) *Post-juvenile dispersal of hens and observed changes in distribution show that prescriptive management should be targeted at a metapopulation level that ensures connectivity between lekking groups (perhaps a minimum of 4 – 10 km between leks). The potential effect of current range fragmentation in the UK needs to be determined.*

iv) *Extrapolation from the strong association of black grouse with transitional habitats, supported by some observation, suggests that variable management of field-layer vegetation, especially via grazing regime, may be needed to ensure long-term benefits of prescriptive management.*

6. Targeting management

To date, largely out of necessity, the management implemented for black grouse in Scotland has concentrated at sites where there has been sympathetic managers, sufficient funds to cover the costs of capital works or profits forgone for changes in management and sufficient manpower to complete or guide the application process for grants or schemes that may be available (e.g. Calladine 2001). Accordingly, the fine geographical targeting of management has been somewhat opportunistic. Where sufficient support and resources are available Biodiversity Action Plan partners have attempted to deliver positive management on a landscape scale (e.g. North England, Argyll and Stirling) (Hawkes *et al.* 2012, Warren *et al.* 2011).

In many parts of their UK range, the distribution of black grouse is well known. In some parts, recent trends are adequately known and so the targeting of advocated management to where it is most required and effective should be possible in many areas. The targeting or selection of the most appropriate management prescriptions will vary between sites and regions depending on the stages of the birds life cycle at which limiting factors are operating (e.g. breeding success or adult survival: Hughes *et al.* 1998, Blake *et al.* 2000). This does, however, require knowledge of local demography (see Section 3) and habitat requirements (see Section 4.3).

Summary

i) *Black grouse demography, and therefore limiting factors, can vary between sites and between regions.*
ii) *A more effective geographical targeting of prescriptive management should be possible for regions where black grouse distribution and recent population trends are known.*

7. Management prescriptions

This section aims to identify:

a) the types of management prescriptions that are, or have been, advocated by RSPB staff, or which they may have considered advocating,
b) whether the black grouse response has been monitored, and if so what conclusions can be drawn, and
c) any other general comments about the prescriptions.

Most current black grouse conservation initiatives aim to stabilise or increase extant populations (the efficacy of reintroduction or augmentation schemes are not considered in this review) and so it is assumed that these areas retain some habitats that are suitable for the birds. Prescriptive management must therefore necessitate a local approach that addresses factors that are limiting local black grouse populations (see Section 3).

7.1 Trees, shrubs and woodland

Woodland or scrub is often important to black grouse, providing sources of food and cover, and where conditions are suitable (e.g. open tree canopy and low grazing pressure) providing suitable field-layer vegetation. Black grouse distribution in Scotland appears to be closely associated to the presence of trees or woodland, with an estimated 26% of males attending leks within woodland (as defined by LCM2000 – Fuller *et al*. 2000), and over 75% attending leks that are within 200 m of any woodland, as determined from the 1995/96 national survey data on the location of lekking males (Hancock *et al.* 1999, RSPB, unpubl. data). A similar proportion of lekking males occur within, or close to, any woodland in Wales, but many fewer do so in northern England, where < 30 % of the British population is found (Sim *et al*. 2008, www.gwct.org.uk/about_us/news/2316.asp). The importance of woodland habitats is being assessed by a radio tracking study within the Tummel area of Perthshire. Although individual birds utilise woodland habitats, particularly new native; preliminary findings suggest that black grouse prefer open moorland (GWCT *unpublished data*). Across northern England black grouse are now restricted largely to the North Pennines, where grouse moor management is extensive. It is possible that the ability of black grouse to persist in this region, despite the scarcity of woodland, is linked to the intensive predator control regimes associated with these grouse moors. Although this population is heavily dependant upon heather moorland, it is believed that small pockets of woodland can provide an alternative food resource, enhance survival during winters with prolonged snow cover (Warren *et al. in press*).

Preferences have been noted for a wide range of tree species, including birch, hawthorn, juniper, willow, larch, Scots pine and alder (e.g. Parr & Watson 1988, Ramanzin *et al.* 2000). These preferences are usually linked to foraging and to variation in the quality of food sources provided by different tree and shrub species to adult black grouse in the form of buds, twigs, catkins and fruits. Birch is the species for which preference is most frequently recorded, and the catkins (which are relatively nutritious) are often a major food source in late winter and early spring (Seiskari 1962, Hjelford *et al.* 1995, Grant & Dawson 2005). Larch has also been identified as important in spring (Cayford *et al.* 1989), with the buds being a relatively nutritious food source which could be important in determining the body condition of hens prior to egg laying (see Section 7.2.3 for the comparable importance of cotton grass). In some cases, preferences for particular tree species have been linked to the provision of cover or shelter (e.g. mountain pine in the Alps - Ellison & Magnani 1984) or to the associated field-layer (Brittas *et al.* 1987). In contrast to the preferences for particular species, any generic relative merits of locally native versus exotic species and of trees of local provenance are not substantiated by research.

The size of any woodland patch determines whether it has to support all or the majority of the requirements for a viable population of black grouse or is simply one of a mosaic of resources within a more open landscape. The division is arbitrary, but in the following sections, larger woodlands mostly refer to those in excess 200 hectares (often considerably more extensive) and smaller woods to those of less than 10 hectares (including small stands of shrubs). Between these will be many woodland stands that by themselves are unlikely to be sufficiently extensive to support black grouse (see Section 7.1) but could provide some of the features of larger woodland.

7.1.1 Larger woodlands (generally over 200 hectares)

This refers to management for trees in both natural-type woodland and commercial plantations. Woodland structure is of utmost importance in determining whether black grouse can be supported. Black grouse select young forest stands, typically 0 – 20 years old (Brittas & Willebrand 1991, Garson & Starling 1990, Haysom 2001, Swenson & Angelstam 1993, Angelstam 2004) or open woodlands where the tree density is typically between 5 – 200 stems per hectare, with a corresponding canopy cover that is often less than 20% (Beichle 1987, Ramanzin *et al.* 2000, McFarlane 2002). As described previously (4.3), changes in forest structure are an important determinant of trends in abundance within larger woodlands, with the creation of open woodlands associated with increases, and closure of the tree canopy associated with declines. For example, within a 700 km^2 study area in Perthshire, lek occurrence, lek size and changes in lek size were all correlated with forest structure, either positively with the extent of pre-thicket forest cover, or negatively with the extent of closed canopy forest (Pearce-Higgins *et al.* 2007). A 70 % decline in black grouse abundance was recorded in this study area between 1990 and 2002, with the maturation of commercial forestry plantations able to account for 58 - 78% of this decline. Preliminary analyses comparing changes in abundance on Scottish sites surveyed in both the 1995/96 and 2005 national surveys, suggest that canopy closure of such plantations cannot account for the decline across Scotland during this period (RSPB, unpubl. data). The extent to which the creation of greater amounts of open space within such commercial plantations can prevent declines as the forest matures and the canopy closes is unclear, but data from a small number of sites found that increasing open space from 7 – 21 % within a forest in Perthshire was insufficient (Baines *et al.* 2000).

Studies within forest or woodland habitats have found that nest and brood occurrence is associated with open canopies – generally of 30 – 40 % or more (Bernard 1981, Brittas *et al.* 1987). Essentially, the canopy structure has to be sufficiently sparse to permit the development of well-structured ground vegetation that includes ericaceous plants (Børset & Krafft 1973, Brittas *et al.* 1987, Cayford *et al.* 1989, Haysom 2001, Ramanzin *et al.* 2000, Magnani 1988, McFarlane 2002).

Within commercial plantations in Britain, black grouse rely on the young (< 12-20 year old) pre-thicket stands (Baines *et al.* 2000, Garson & Starling 1990, Haysom 2001, Pearce-Higgins *et al.* 2007). A comparable situation occurs with naturally regenerating forest blocks following clear felling (Brittas & Willebrand 1991, Swenson & Angelstam 1993, Angelstam 2004). Under natural circumstances such conditions would be established following fires and natural succession over mires (Swenson & Angelstam 1993). Second rotation crops following felling in commercial plantations in Argyll appeared to be occupied by a lek as readily as the first rotation of young trees. Patch size, the total amount of forest within the area, the proportion of pre-thicket stock and its level of fragmentation are all correlated with the probability of lek occurrence and the number of males in attendance (Haysom 2001). According to the findings of this study, to have a 20 % chance of hosting a lek, restocks had to be > 40 ha in area, and over 100 ha for a 100 % likelihood of lek occurrence (Haysom 2001). Interpreting these findings requires some caution as these figures were a single variable within a multivariate model.

As these findings indicate the scale of management is likely to be critical (see Section 5), but it is also likely that the availability and proximity of other open ground habitat is important and will influence the relationship between restock area and likelihood of occupation. Although the Argyll study acknowledged the potential complementing contribution of neighbouring, unplanted, open ground its influence was not accounted for. Furthermore, the Argyll study was undertaken in an area with a declining, low density, population, where c.30 % of leks comprised single lekking males, and relationships may differ where black grouse densities are higher and/or increasing. Lek isolation can be a critical factor in determining the number males in attendance over time, ensuring sufficient functional connectivity between lek sites is an important technique within forested environments. Further information on the dispersal capabilities of individual birds between suitable coups is required.

The spatial requirements of black grouse within young plantations or felling coups are currently unknown. Within forested areas the availability of other suitable habitats (e.g. open moorland) will probably have a bearing on the amount of woodland required to sustain a population. The findings from the Tummel forest project should provide further insight into their requirements within a mixed age commercial forest. Based on current limited knowledge, long term plans for extensive plantations should accommodate a continuity of large and well connected felling coups.

Following clearfelling and restocking of forest coups, the brash is usually left on site. Similarly, the practice of tree-thinning (frequently advocated as a method for delivering suitable black grouse habitat on sites where there is currently canopy closure) creates brash. If left on site, brash inhibits, or at least delays, the development of potentially important field-layer vegetation (Owen 2011). Conversely, brash can provide cover and protect ground vegetation from browsing. No studies on the efficacy of different treatment methods in affecting black grouse response have been undertaken.

Likewise, the effectiveness of denser stands of trees within larger woodlands as cover to avoid predation (see Section 7.6.3) has not been determined.

Whether working in native-type woodland, commercial plantations or on the moorland fringe, the principle appears to be the same, black grouse utilise trees - but that there can be too many of them. Of critical importance is the composition and structure of the ground flora where the adults mostly feed and chicks do so exclusively (see Section 7.2). Forestry prescriptions that will achieve some sufficiently open woodland include thinning (and even clear felling), planting sparse new woodland, restricting grazing (domestic stock and exclusion and culling of deer) to permit regeneration and conversely the introduction of grazing (or mechanical operations) to prevent thicket formation. Clearly woodland management is a classic example of where logical interpretation of the known requirements of black grouse (the management objective of open woodland), determines the management to be advocated or implemented. The findings of the Tummel forest project should provide further understanding into how black grouse utilise forested habitats in relation to suitable moorland.

7.1.2 Small woodland (generally under 10 hectares)

The planting of small woodlands in sheltered locations is advocated in predominantly open moorland-edge habitats. Evidence suggests that high mortality during winters with prolonged snow cover is associated with a lack of trees (Warren *et al* unpub). This study demonstrated that where woodland was scarce or absent, survival was low, following the prolonged snow cover in the winter of 2009/10 whereas numbers increased in some parts of Scotland over the same period. This fits with the known biology of black grouse, and specifically with their dependence upon trees for foraging during prolonged periods of deep snow cover, making field-layer plants unavailable (Pauli 1974, Picozzi & Hepburn 1984). There are also anecdotal reports of black grouse avoiding raptors by flying into small stands of trees. Although black grouse are reported as using remnant trees and isolated copses in open landscapes, they were not identified as important in two studies of habitat use in the north of England (Baines 1994, Starling-Westerberg 2001), though the design of the respective studies may not have been conducive to detecting this (particularly if the dependence on trees is only apparent in severe winters). Assuming there is a response by black grouse in using trees and small woodlands in otherwise open moorland fringe areas, any influence of such woodlands on population's remains to be assessed, although quantifying such effects may be difficult.

7.1.3 Edge restructuring

This is where the edges of plantations typically bordering moorland or within plantations along watercourses are thinned and/or include a high proportion of favoured species. Logical interpretation of the known ecology of black grouse suggests this would be useful where sufficient open ground or open woodland also occurs. Edge restructuring and its impact upon black grouse was assessed as part of a trial management project within two commercial forests (North and South Scotland); however, at the time of writing data is still being collected. Where this management has been undertaken on the external boundaries of plantations in Wales, Dumfries & Galloway, Perthshire and Highland Council area, at scales of 10 – 100 ha, anecdotal reports suggest increased use of such areas by black grouse. This can be an expensive form of management therefore it is probably more cost-effective to incorporate this into forest design at planting or restocking, not within a forest cycle. Anecdotal reports suggest external boundaries, especially where this borders other habitats used by black grouse (e.g. moorland or rough grazing) are more readily used than internal ones within a plantation. The relative benefits of edge restructuring (which per ha is an expensive practice) relative to more conventional forestry techniques (e.g. new native woodland planting) is unknown. Findings from the Scottish trial management project may offer further insight.

Summary

i) *Black grouse select young forest stands, typically 0 – 20 years old, or open woodlands where the tree density is typically between 5 – 200 stems per hectare, with a corresponding open canopy cover (ideally < 20 %). This canopy structure is sufficiently sparse to permit the development of well-structured ground vegetation that includes ericaceous plants.*

ii) *Tree species favoured by black grouse include birch, hawthorn, juniper, willow, larch, Scots pine and alder.*

iii) *Management prescriptions that will achieve sufficiently open woodland include:*
   - *thinning (even clear felling);*
   - *planting sparse new woodland;*
   - *restricting grazing (domestic stock and exclusion and culling of deer) to permit regeneration, and conversely*
   - *the introduction of grazing (or mechanical operations) to prevent thicket formation.*

iv) *Small planted woodlands and restructured edges of established ones are used by black grouse. High mortality was been demonstrated during winters with prolonged snow cover where trees are scarce or absent.*

7.2 Ground vegetation

A number of management prescriptions are currently being advocated specific to managing ground vegetation either on moorland and the moorland fringe or within woodland (including clearings and forest rides). This includes:

a) the maintenance of stands of tall heather,
b) the maintenance or creation of wet flushes,
c) reductions (sometimes seasonal) in wild and domestic grazing animals (sometimes to specific levels),
d) heather burning and conversely its avoidance,
e) the cutting and swiping of heather and rushes (sometimes to specified structures),
f) the spraying or mechanical control of bracken,
g) maintaining herb-rich meadows and pastures,
h) the blocking of moor grips and forest drains and
i) the restriction of foddering sites.

Studies of habitat use in both pastoral and forested landscapes identify the importance of ericaceous vegetation, blanket bog and other mires, semi-natural rough grassland (sheep-walk, allotment or intake), wet flushes (often dominated by rushes) and herb-rich meadows and pastures (e.g. Baines 1994, Børset & Krafft 1973, Cayford *et al.* 1989, Ramanzin *et al.* 2000, Starling-Westerberg 2001).

7.2.1 Nesting and brood-rearing habitats

Not surprisingly, for a ground nesting species reliant upon secretive behaviour to avoid nest predation, black grouse generally nest in tall, dense, vegetation providing abundant cover (Cayford *et al.* 1989, Picozzi 1986, Bernard 1981). Thus, vegetation around nests tends to be 40 - 55 cm tall, and nests are generally well concealed from above by the surrounding vegetation (Picozzi 1986, Storass & Wegge 1987, Parr & Watson 1988). Dwarf shrub dominated field-layers appear to provide the nesting habitat in most instances, but other tall, dense, ground vegetation is also used (e.g. dense grass tussocks (e.g. *Juncus effuses*) in alpine meadows - Bernard 1981).

A review of habitats used by black grouse broods indicates the importance of a diverse field-layer (containing bilberry, bog myrtle and eared willow) and flushes or other damp, tall, grassy habitats. For each of these two vegetation-types, eight of 16 studies reviewed indicated or demonstrated preferences for the vegetation-type (Grant & Dawson 2005). However, the studies considered in this review were limited to those undertaken in areas with substantial woodland or forest present (where bilberry field-layers may be more prevalent), whilst in many cases they did not distinguish the ages of broods for which habitat preference was assessed (which is important because black grouse chicks switch progressively from an invertebrate to plant-based diet after 2 - 3 weeks of age – Picozzi & Hepburn 1984, Wegge & Kastdalen 2008). Within Britain, studies of brood habitat selection generally show preferences for wet flush and/or tall grassy-type habitats (Picozzi 1986, Parr & Watson 1988, Baines *et al.* 1996, Starling-Westerberg 2001). A study of chicks of < c.2 weeks of age on sites across the Scottish Highlands showed brood locations to be positively associated with acid flush habitat and negatively with dry heath (RSPB, unpubl. data). When considered in terms of the cover of different plant taxa, these brood locations were associated with higher cotton grass (*Eriophorum* spp) and *Sphagnum* cover but lower heather cover. Studies specifically examining habitats of older broods show selection for drier areas, notably those with high bilberry cover, or where rushes and heather are present together (Parr & Watson 1988, McFarlane 2002).

Most studies suggest broods use areas where field-layer vegetation is approximately 24 - 40 cm in height (Bernard 1981, Børset & Krafft 1973, McFarlane 2002, Baines *et al*. 1996), and select vegetation that is relatively tall (Parr & Watson 1988, Baines *et al*. 1996). However, the extensive studies undertaken on young broods from sites across the Scottish Highlands found that, on average, broods were found in areas where vegetation was c.40 – 58 cm tall (RSPB, unpubl. data).

7.2.2 Ericaceous vegetation

Studies of habitat use based on observation and radio-telemetry in open landscapes identify heather moorland (upland heath and blanket bog) as important for black grouse, especially so in the winter and also for a small number of individual hens through the year (Baines 1994, Starling-Westerberg 2001). In northern England, 95% of black grouse leks are associated with heather moorland managed for red grouse shooting (Warren & Baines 2004). Extensive areas of heather moorland alone, however, do not necessarily support black grouse (Garson & Starling 1990). A comparison of the broad distribution of black grouse with that of red grouse, for example from Gibbons *et al.* (1993), clearly shows that there are now many heather-dominated grouse moors from which black grouse are absent. In a study in Perthshire black grouse were most likely to occur where moorland comprised heather and grass mosaics (Pearce-Higgins *et al.* 2007).

As detailed above, in open and young woodland, broods have shown a preference for areas with ericaceous (including bilberry) ground flora (Baines *et al.* 1996, Børset & Krafft 1973, Haysom 2001, McFarlane 2002, Ramanzin *et al.* 2000) while a study of brood locations at Abernethy suggests older broods (c.6 – 8 weeks old) select for areas with a high cover of relatively tall bilberry and for an optimum cover (40 – 60 %) of heather between 25-35 cm in height (McFarlane 2002). Several other studies in wooded areas also find a relationship with bilberry and black grouse broods (e.g. Børset & Krafft 1973, Brittas *et al.* 1987). Although a similar relationship was not identified by studies in more open habitats, the shade tolerance of bilberry would tend to make it more abundant within woodland.

Regenerating heather following burning can be selected for feeding by adult black grouse (Ludwig *et al*. 2000), as it is by red grouse, with younger heather having more nutritious shoots than older heather (Savory 1978). Swiping or cutting has been used as an alternative to burning, particularly in forested areas, where fires may be deemed to pose an unacceptable risk. As with rotational muirburn, breaking up large patches of uniformly tall vegetation by swiping produces a more varied sward structure. Bilberry can respond readily to swiping (and burning) when it is present in a heather-dominated community, and field experiments at Abernethy Forest show increases in bilberry cover where cutting and burning have been undertaken (Hancock *et al*. 2011). Such an effect occurs over the short-term at least (up to at least 6 years after cutting/burning), although there is less certainty over the longer term effects. In addition hare's-tail cotton grass responds well and rapidly to swiping when undertaken in appropriate blanket bogs, wet heath or wet flushes (e.g. Gordon 2007). This accords with the documented effects of burning on blanket bogs or wet heaths (at least where purple moor-grass is not abundant), which leads to an initial dominance of hare's-tail cotton grass over heather that may persist for 11 – 15 years post burning (Currall 1981, Hobbs 1984).

Therefore, the judicious burning or cutting of heather to create structural mosaics (including the retention of tall heather) and to encourage the development of young and nutritious growth, or of other plant species of known importance to black grouse, may be supportable for black grouse where there is a heather-dominated field layer. However, whilst such management may be expected to benefit black grouse, clear evidence for benefits is lacking. Where such management has been undertaken in areas where RSPB have been involved in conducting or advocating management for black grouse, there are mixed views on whether it has benefited black grouse. For example, cutting and burning of heather are both undertaken at RSPB's Geltsdale reserve, but neither is deemed to have had effects on black grouse there. By contrast, anecdotal observations suggest possible positive effects of cutting at Abernethy and of rotational burning in Perthshire, with reports of increased numbers of birds using and feeding in the recently managed areas. Cutting and (to a lesser extent) burning patches of ericaceous vegetation was one of the main managements undertaken on sites targeted by the Welsh black grouse recovery project, which did produce a population level response in black grouse, at least on sites where predator control was in place (Grant *et al.* 2009, RSPB, unpubl. data). However, as described above, analyses were unable to determine which specific managements contributed to this response. Thus, effects of such management on habitat-use by black grouse have not been quantified, whilst there are no assessments of any population level effects.

The restoration of heather cover is advocated for black grouse as well as being a habitat of conservation importance and interest in its own right, with ambitious national targets for recovery. This can require the seasonal restriction of grazing or other reductions in grazing pressure (where vestigial ericaceous vegetation is present) or the (re-) seeding with heather.

Typically such action is aimed at semi-natural grassland on the moorland fringe, which in itself is an important component of the habitat requirements for black grouse (see 7.2.3), even if not deemed of such intrinsic interest. Findings from Perthshire show that lek occurrence is associated with a mix of grass dominated and heather dominated moor within an area of 0.5 – 1.5 km around leks (Pearce-Higgins *et al.* 2007), which provides guidance on the extent to which heather restoration may be required within an area of predominantly grass moor. In instances where there is abundant heather available nearby, such management could be detrimental if heather expansion is at the expense of more critical black grouse habitat. However, further quantification of how the spatial distribution of grass and heather moor affects black grouse is required.

7.2.3 Semi-natural grassland

Rough grazing - Rough grazing, typically *Agrostis, Nardus, Juncus squarrosus* and *Festuca* swards and *Deschampsia*, on the moorland fringe, locally referred to as sheepwalk, allotment, intake or white ground, is preferentially selected by breeding hens and moulting cocks, at least in some parts of the range (e.g. North Pennines - Baines 1994, Starling-Westerberg 2001). Within woodlands, some herb-rich grassy flushes can also be important brood rearing habitats (Baines *et al.* 1996, Haysom 2001), however the relative importance of grass and herb ground flora is even less quantified than for more open habitats. Correlative studies supported by grazing trials have demonstrated that relatively light grazed vegetation that includes grass swards exceeding 30cm high in summer is associated with improved breeding success and higher or increased population densities relative to more heavily grazed areas (Baines 1996b, Calladine *et al.* 2002). Although lower levels of grazing, in some instances supported by agri-environment schemes have shown some effect, these have not looked for nor identified any optimal regime or optimal vegetation structure. It must also be noted that the agri-environment schemes reported upon by Calladine *et al.* (2002) were principally aimed to restore heather cover, which if successful would change the mosaic composition and so have a potentially different effect on black grouse in the longer term.

There is also a need to investigate the relative merits of different grazing animals. For example, cattle may create a more diverse structure suitable for 'brood scale' management (see 7.2.1) compared to that created by grazing sheep, however there may be an associated increased risk of nest trampling. Similarly, mechanical cutting of grass/rush swards could potentially be justified to create sward diversity.

Meadows - Herb-rich meadows and pastures are used in autumn and winter by feeding (grazing) adults and can be used and selected for during chick-rearing (Bernard 1980, Baines 1994, Kolb 2000, Starling-Westerberg 2001). Despite a clear use of these resources where available, indicating their possible importance in some areas, black grouse do persist in other areas where traditional meadow management (low input and late cutting) is no longer practiced.

7.2.4 Grip/drain blocking

The effects of drainage on black grouse populations have received little attention. Direct effects include the drowning of chicks, while indirect effects might include changes in predation rates and/or changes in insect communities, and hence food availability for chicks (Ludwig *et al.* 2006, 2008). During studies of radio-tagged chicks in Wales, some died as a result of falling into deeper drains within conifer plantations, although this was a minor source of mortality only (RSPB, unpubl. data). Although no British studies have examined effects of drainage (or drain blocking) on black grouse, analyses have been undertaken on effects of drainage on black grouse productivity in Finland, where > 20 % of forested land had been drained by the end of the 1980s. These correlative analyses showed that annual black grouse productivity was negatively associated with drain density in south and central Finland, but not in northern Finland (where drainage is less prevalent), whilst there was a further negative effect of precipitation in May (which is the month prior to hatching) (Ludwig *et al.* 2008).

Cotton grass flowers are important food for hens in spring (Baines 1994, Starling-Westerberg 2001) and invertebrates are important food for chicks (Ponce 1992, Picozzi & Hepburn 1984, Starling-Westerberg 2001, Wegge & Kastdalen 2008). Broods can prefer wet flushes, often with cotton grass, bog myrtle, tall grasses or rushes (Parr & Watson 1988, Baines *et al.* 1996, Haysom 2001). Greatest abundance of invertebrates can be associated with wet flushes (Coulson & Butterfield 1985) and cotton grass and bog myrtle are typical plants of acid mires. Logical extrapolation suggests that the blocking of drainage channels to maintain or enhance the hydrological integrity of such features will benefit black grouse, although few studies have as yet been undertaken to determine the efficacy of this management in creating areas of wet vegetation. The availability of protein rich food sources (e.g. Cotton grass and larch buds) in spring may affect breeding success through improving hen body condition prior to egg-laying and incubation (Beeston *et al*. 2005). Body condition probably influences the amount of time black grouse incubate eggs with poorer conditioned birds spending more time away feeding (which could be positively related to detection by avian predators) and therefore less time incubating (possibly positively related to detection by mammalian predators) (Storaas & Wegge 1997).

7.2.5 Control of bracken, rushes and Molinia

The mechanical (cutting) and chemical (spraying and swiping) control of bracken, rushes and purple moor-grass is currently advocated where these are considered to be invasive and encroaching on other more valuable habitats. Conversely, the retention of bracken and rushes is also advocated. Some correspondents report bracken as providing cover for predator avoidance and for feeding areas. Bracken itself has not been documented in diet studies and is unlikely to neither be a food for black grouse nor harbour sufficient invertebrates for young; however stands of bracken can be the last remnant of ancient woodland and shelter some herb-rich ground flora which in turn would be potential food for adults and host invertebrates for chicks. Similarly rushes can provide structure to a sward of vegetation providing nesting habitat and are themselves food plants for some species of sawfly larvae in the uplands (Barker unpubl. data) that can be important chick food (Starling-Westerberg 2001). Clearly, decisions on whether to control these plants or not is a subjective one based on whether they are an invasive threat to other habitats or integral features of the habitat mosaic on which black grouse rely, and will thus vary from site to site according to the conditions and vegetation that are present.

Control of *Molinia* by swiping may not have the effects anticipated. *Molinia* can respond rapidly and so create a more uniform sward structure in many circumstances. It is recommended that there should be a presumption against swiping *Molinia*/*Calluna* mixes that have little or no *Eriophorum* present. A detailed site assessment should be undertaken at other sites with *Molinia* to assess the likely impact of swiping (Gordon 2007). Whether swiping of *Molinia* alone is beneficial at all is also unclear, swiping only being used in many areas where it can be followed up with cattle grazing. Varying the cutting height may produce a different response – this would be worth further investigation.

Another option to reduce the spread of *Molinia* is to use cattle for grazing. This is an option that is available through the English Agri-Environment scheme and is advocated by the Grazing Animals Project.

7.2.6 Foddering sites

On the basis of damage to vegetation (usually to heather), some advocate the moving or exclusion of foddering sites from moorland fringe areas. The impact of such local loss will perhaps rarely be an issue for black grouse. On the positive side, foddering sites could add to habitat and structural diversity and the short and trampled swards create potential lek sites but this is only likely to be beneficial in areas where there is a scarcity of short, open, vegetation. In the absence of hard quantitative data on requisite habitat mosaics, there will rarely be justification to exclude foddering sites on the basis of black grouse conservation alone. However, supplementary feeding is normally not permitted where grazing agreements within agri-environment schemes are held, and so where these are used to implement management, the issue should not arise.

Summary

- *i) Black grouse select tall, dense, ground vegetation for nesting. Where available tall dwarf shrub vegetation is usually used. Young black grouse broods that are still largely dependent on invertebrate foods select wet flush or wet grassy type habitats, although bilberry may also be important in woodland situations, whilst older broods appear to select drier habitats, including those with high bilberry cover. Broods often appear to select relatively tall vegetation.*
- *ii) Ericaceous vegetation (notably bilberry and heather) is an essential component of a habitat mosaic for black grouse, though extensive heather moorland alone is unlikely to support them.*

iii) *Semi-natural grassland, in terms of rough upland pasture on the moorland fringe or grass-herb flushes on the woodland floor is demonstrated as important for black grouse especially for broods. Traditionally managed hay meadows, where they persist within the range of black grouse appear important.*

iv) *The structure of ground vegetation, both in terms of height and diversity, has a demonstrable effect on black grouse population densities and breeding success. This is influenced by grazing, cutting or, in the case of heather also by burning. Broods select areas, and greater breeding success has been recorded, where sward height exceeds 25 – 30 cm in places. Burning and cutting of heather may contribute to the encouragement of nutritious vegetation for black grouse and the development of a diverse sward structure but the effects at a population level have not been assessed.*

v) *Evidence from Finland indicates possible negative effects of large-scale drainage on black grouse breeding productivity. Mires and wet flushes are important food sources in spring and during brood rearing. Where drains threaten their integrity, blocking is likely to be beneficial.*

vi) *Control of bracken, rushes and Molinia may be of benefit where they are invasive of other habitats essential to black grouse.*

vii) *Bracken is unlikely to neither be a food for black grouse nor harbour sufficient invertebrates for young, but stands of bracken can be the last remnant of ancient woodland and shelter some herb-rich ground flora, which in turn would be potential food for adults and host invertebrates for chicks.*

viii) *Rushes can provide structure to a sward and are food plants for some species of sawfly larvae in the uplands that can be important chick food.*

ix) *Damage to vegetation at foddering sites from moorland fringe areas will rarely be an issue for black grouse.*

7.3 Disturbance

Restricting human disturbance to leks sites and during the breeding season is widely advocated, whilst local concentrations of birds can gather in some favoured areas in winter (Baines *et al.* 2002, Baines & Richardson 2007, Warren et al 2009) with the implication that disturbance could also be an issue outside the breeding season and away from leks. Human disturbance is also cited as a major factor causing black grouse to fly into overhead cables (Miquet 1990).

The most detailed work on disturbance has been undertaken in the Alps, in relation to large-scale ski developments and also the increased free-ranging, off-piste, winter sports activities (Arlettaz *et al.* 2007, Patthey *et al.* 2008, Braunisch *et al.* 2011). In the Alps disturbance appeared to lead to shifts in winter-feeding and display areas away from intensively used skiing areas to less disturbed sites with concurrent declines in numbers (Miquet 1986, Zeitler 2000). Experimental studies show that disturbance of birds from their winter snow burrows leads to an increase in levels of stress hormones and that levels of these hormones are higher in birds inhabiting areas of high snow-sports activities (Arlettaz *et al*. 2007). Such effects could have consequences to survival rates or subsequent reproductive success, through associated increased energetic costs or risks of predation, although whether this is the case remains untested. In terms of population level effects, ski infrastructures were associated with a mean reduction of 36 % in the abundance of lekking males (after accounting for associated habitat effects), whilst reductions in black grouse winter abundance are also associated with winter sports activities (Patthey *et al*. 2008, Braunisch *et al.* 2011). Recommendations to minimise these effects combine increasing vegetation patchiness along the ski runs (i.e. a mosaic of grassy shrubland with scattered trees), and establishing wintering preserves where human access is banned, or strictly limited.

Studies of disturbance effects on black grouse in Britain are limited to work undertaken in the North Pennines, where the response of radio-tagged birds to three disturbance levels (i.e. none, flushed once per fortnight, flushed twice per week) was monitored. Increased disturbance resulted in increased flushing distance, particularly in winter and spring, but there was no link between disturbance levels and productivity or survival rates in the study (Baines & Richardson 2007).

Other than recreational disturbance, other potential forms of major disturbance to black grouse in Britain are likely to include windfarms construction and operation and forestry operations, and such activities could potentially have greater impacts than recreational disturbance.

- Various measures intent on reducing the impact of human disturbance have been recommended and undertaken throughout the UK e.g. the retention of mature trees to screen breeding habitat adjacent to well-used footpaths.
- The inclusion of disturbance avoidance guidance on information boards.
- Waymarked trails, lek viewing schemes and restricting dogs to leads.

7.4 Fences and Wires

Strikes with fences and overhead wires can be an issue for black grouse. Anecdotal reports also suggest rabbit netting as a source of chick morality. The frequency of collisions by woodland grouse are reported for deer fences (Baines & Summers 1997, Moss *et al.* 2000, Baines & Andrew 2003) and for elevated cables associated with ski tows (Miquet 1990). With respect to deer fences in the Scottish Highlands, it has been shown that that the associated mortality of capercaillie is likely to have an affect at the UK population level (Moss *et al.* 2000). Initial trials in Tayside, comparing trends at six black grouse lek sites where all deer fences within a 1 km radius of the lek were marked (see below regarding efficacy of marking) with those at six leks where fences were not marked, provided some suggestion that mortality from fence collisions may have a population level effect, at least at the local scale, although these findings were inconclusive (Baines *et al.* 2000). Variations in collision rates could partly be explained by lek size in vicinity of fences, although other features regarding the location of the fence also affected whether birds were likely to impact.

Although several methods of fence marking are advocated, only the effectiveness of broad bands of orange plastic netting on deer fences protecting woodlands in reducing strikes appears to have been quantitatively assessed for black grouse. Black grouse collision rates with fences in the Scottish Highlands found that marking fences with orange netting significantly reduced collision rates by 91% (95% CL 67–98%; P<0.001) (Baines & Andrew 2003). The fences chosen for this study had previously recorded high collision rates for woodland grouse (mean of 1.3 black grouse collisions km^{-1} $year^{-1}$).

Livestock fences (and overhead cables) also cause mortality through collisions. Studies in northern England (an area with few or no deer fences) found that four of 148 (i.e. 10 %) radio-tagged full grown black grouse died from collisions with fences or overhead cables (Baines *et al*. 2007). Perhaps surprisingly, a similar proportion of radio-tagged birds in a study area in the Scottish Highlands (where deer fences are common) were reported as having died from collisions with deer fences (i.e. three from 28; 12 %) (Baines *et al.* 2007). In northern England all new livestock fences in black grouse areas are fitted with bird flight diverters funded through agri-environment schemes. Anecdotal evidence suggests that the fitting of flight diverters on stock fences is effective but actual influence on black grouse populations remains untested.

Currently, there are four deer fence marking methods listed by Forestry Commission in their fence marking best practice guidance note (FC 2006), which have been used in a trial project at several sites across Scotland. The trial focussed on assessing the technicalities and durability of the various marking methods. However, on one 13km section there was an eight-fold decrease in combined collisions of red grouse, capercaillie and black grouse following marking with these methods.

- Orange plastic netting: Guaranteed for 8 years and have thicker strands and joints. The full width of the net should only be used within forests. For exposed sites, one strip of 300mm should be placed at the top of the fence, but its recommended two parallel widths should be attached. At less exposed sites, 600mm widths should be used. Netting should be attached to fence wires by highly UV stabilised plastic cable ties. Used at Glen Finglas between 1998-2000, during which there was a coincident increase in lekking numbers, but there were also numerous other management prescriptions occurring at this time (including stock removal) so it is impossible to say how much (if any) of this increase was use to fence-marking with orange netting.
- Droppers: Chestnut, Larch or Red Cedar is recommended for longest life but softwood can be treated to extend life. Split into rough triangular sections of 100mm approximately. Sawn specifications run from 30 x 12, up to 40 x 15mm. Individual pieces attached vertically at spacing of 150mm near lek sites and 300mm elsewhere. The use of angled droppers of 1.2m placed at 150mm and 300mm, provide better visibility at less wind loading areas near to lek sites and elsewhere respectively. To prevent slipping, pieces should be hooked or woven into the fence. Since 2006, droppers have been used at RSPB's Inversnaid reserve. Within this period, no strikes have been

recorded, while there has been an increase of usage and sightings of black grouse in the area, with one male seen lekking.

- 9 m paling: Two lengths of timber are available, 0.9-1.0m timber used within two sets of twisted wires and 1.2-1.8m timber used within three sets of twisted wires. Rolls are fixed to an existing fence. To be used vertically with pales with 150mm spacing near leks and 300mm spacing elsewhere. No wires should remain above the paling.
- Bamboo canes – Use is still experimental and should only be used as a last resort very high exposure sites using 1.2m lengths diagonally attached. Provides only a limited visual area, only about 25% of other fence marking methods. If used, a length of 1.2m is recommended for deer fences and 0.75m on stock fences. Bamboo should be spaced at 300mm near leks and 600mm spacing elsewhere and fixed diagonally between 35-40 degrees from vertical to the upper part of the fence

Since 2006, FC has updated their fence marking guidance for black grouse and capercaillie. Further details on the specifications, including diagrams, can be found in this updated guidance (Trout and Kortland 2012). The advice largely focuses upon the four marking techniques listed above. The revised note recognises that the choice of techniques requires consideration of the visibility of the marking material to capercaillie and black grouse, the ability of the material to cope with wind exposure, and the costs of the material and installation. As such, specific recommendations on best practice marking techniques, for any given site, are listed. Other marking techniques are mentioned within the guidance; however, these remain to be adequately tested:

- Metal plates: Used on stock fences at Geltsdale reserve and other sites in the North Pennines, although no information is available regarding their effectiveness.
- ABSTabs: Used at Creag Meagaidh in the late 1990s. Again, no information is available on their effectiveness.

Summary

i) *Human disturbance may be an issue and is not necessarily restricted to disturbance at leks or during the breeding season However, evidence for effects at the population level arise from situations where recreational activity levels (and associated infrastructures) are likely to be greater than in most situations in the British uplands .*

ii) *The effectiveness of mitigation to reduce fence strikes is restricted to some marking of deer fences, although an influence at the population level has not been demonstrated.*

7.5 Lek site clearance

The clearance of lek sites to maintain them as open areas with relative short vegetation is advocated especially within commercial conifer plantations. Any contribution that such management has to the maintenance of black grouse populations has not been demonstrated.

7.6 Predation

To control predation, two general principals are currently advocated, one involves the removal of predators, and the other manipulates conditions that are expected to reduce the risk of predation or increase predator avoidance opportunities for black grouse.

7.6.1 Predator removal

Evidence for the impacts of predation on black grouse populations comes from a wide range of studies. Within Britain, studies involving the removal of crows and foxes at Abernethy Forest demonstrated that black grouse productivity was highest in those years with low June rainfall and low crow predation activity (Summers *et al*. 2004). In years with high June rainfall productivity was low irrespective of crow abundance and predation activity, so that crow predation reduced productivity during years with low June rainfall only. Although this study also attempted to manipulate fox abundance, their numbers appeared to be unaffected by culling (Summers *et al*. 2004). Black grouse population change at Abernethy (as indexed by counts of lekking males) was strongly related to the previous year's breeding productivity (Grant *et al.* 2009), indicating population level impacts of predation. Studies in Wales demonstrated that habitat management measures (e.g. cutting heather and thinning forests) had detectable effects on productivity and population trends only at those sites with predator control in place (RSPB, unpubl. data). Sites with predator control in place had lower crow and fox abundance, whilst predator control also appeared to offset the negative effects of wet June weather on productivity. Other studies examining associations between black grouse abundance and game keeping or the intensity of grouse moor management have failed to detect effects (Baines 1996b, Tharme *et al.* 2001).

Elsewhere, studies have demonstrated impacts of predation on black grouse productivity and/or abundance, particularly in Fennoscandia. Correlative studies across different sites in Finland, found associations between grouse (black, willow and hazel grouse and capercaillie) breeding productivity and predator (red fox and pine marten) abundance but not between predator indices and grouse density (Kauhala & Helle 2002, Kurki *et al.* 1997). Brood sizes of all grouse (black, hazel, willow and capercaillie) showed an increase within experimental plots where predators were removed relative to decreases where predators were protected. However, again, there was no measurable effect on grouse density, although the trend for black grouse was in the expected direction but not significant, and the sample size was inevitably smaller (Kauhala *et al.* 2000). In these trials, breeding productivity decreased during a year with few voles, which is expected because (in the absence of predator removal) black grouse productivity is often linked to vole cycles at these high latitudes, with predators switching to alternative prey when voles are scarce (Angelstam *et al.* 1984, Marcström *et al.* 1988).

In Norway, indices from hunting bags showed temporal correlations at a range of geographic scales between red fox and black grouse abundance following dramatic declines in the fox numbers due to the advent of sarcoptic mange, though the same study found a positive relationship between pine marten and black grouse abundances (Smedshaug *et al.* 1999). Similarly, in Sweden black grouse abundance increased as fox numbers declined dramatically due to sarcoptic mange, with subsequent declines in black grouse following recovery of the fox population (Lindström *et al.* 1994). These temporal correlations are arguably more compelling than spatial ones, however they still do not define cause and effect, but some experimental studies are more definitive. Thus, the experimental removal of red foxes and pine martens from two islands in the Baltic (with switched treatments) resulted in improved breeding success (both brood size and the proportion of hens successfully rearing young) and a subsequent increase in the number of lekking male black grouse (Marcström *et al.* 1988).

Clearly there is sufficient evidence to demonstrate that predator removal can benefit black grouse, in some situations at least. However, any predator removal programme must also consider potential intra-guild relationships amongst predators, and risks of compensatory predation. In Norway, Smedshaugh *et al.* (1999), report a negative correlation between the abundances of red fox and pine marten. Also in Norway, crow removal during a period of relatively high breeding success and population increase by black grouse, possibly reduced nest losses, but chick mortality did not decline and compensatory predation by stoats was suspected (Parker 1984). Some circumstantial reports from England and Wales where corvids and foxes have been removed suggest predation by mustelids may increase. The management objectives of a predator removal programme should also be considered, that is whether the aim is just to increase the survival chances of black grouse in an area or if the land manager, in addition, seeks a harvestable surplus.

7.6.2 Diversionary feeding

The deliberate feeding of predators to divert their attentions away from breeding black grouse has been reported, although not widely. In Scandinavia, breeding failure by black grouse due to predation can be low in years when alternative prey, for example voles or mountain hare are abundant (Angelstam *et al.* 1984, Marcström *et al.* 1988). However, when mountain hare numbers were low, nest predation on black grouse, principally by foxes, was high (Angelstam *et al.* 1984) and increased numbers of predators following summers with high vole numbers possibly led to higher winter predation of black grouse (Marcström *et al.* 1988). The artificial provision of alternative prey could therefore reduce predation on black grouse in the short term, although the longer term effects are unknown.

7.6.3 Habitat manipulation

Within the UK it has been speculated that black grouse are able to persist in relatively open habitats (notably the North Pennines) because predators are intensively controlled (Baines 1996b). In areas such as Wales and Galloway, where predators are more abundant, black grouse tend to be more closely associated with forestry blocks (Hughes *et al.* 1998); however, open moorland still remains a key habitat within both regions. The planting of small stands of trees and shrubs, or allowing scrub regeneration, on moorland fringe areas and similarly, denser stands of trees within open woodland, may provide cover for predator avoidance in such areas. The effectiveness of such management remains untested.

Within more extensive forested landscapes, increased fragmentation with agricultural land has been associated with reduced breeding success by black grouse (Kurki & Lindén 1995, Kurki *et al.* 2000) and increased numbers of generalist predators within such areas (Kurki *et al.* 1998) implies predation rates may be higher. Ludwig *et al.* (2008) report that predation rates increased in Finland in areas where drainage levels are highest. This may also be a measure of the likelihood of agricultural land, and/or grassland sustaining higher densities of generalist predators.

The issue of maintaining a diversity of habitats that can support black grouse but at the same time does not encourage an abundance of generalist predators is clearly complex. Although some habitat changes appear to have benefited black grouse, for example grazing reductions on the moorland fringe (Calladine *et al.* 2002), the increased sward height may also lead to increased numbers of rodents as potential prey that support higher predator numbers (Klaus 1991).

Approaches to reducing predation impacts that are based upon habitat manipulation (and/or diversionary feeding) may become increasingly important in the future, because of the resources required for effective predator removal in regions with little or no game management, and because of the potential importance of predation impacts from protected species (e.g. pine marten and raptors). As stated previously (4.4), raptors are often important predators of black grouse and some Fennoscandian studies and in Wales suggest that goshawks in particular could limit populations in some instances (Bowker *et al.* 2007, Tornberg *et al.* 2005, Widen 1987). Such effects have not yet been demonstrated in Britain (Park *et al.* 2008); however, high raptor densities can be a key limiting factor for red grouse populations (Thirgood *et al.* 2000).

Summary

i) *Evidence from Britain and Fennoscandia demonstrates that predation can limit black grouse populations and that predator removal can be important in enabling population recovery. The influence of predators can be complex with intra-guild relationships amongst predators potentially confounding some control efforts where this is restricted to one or a small number of predatory species.*

ii) *Habitat composition and structure can influence predation but again the influences are complex. Testing and developing approaches to reducing predator impacts that are based upon habitat t manipulation may become increasingly important in the future.*

7.7 Arable plots, supplementary feeding and grit

Old literature and anecdotes widely report black grouse feeding on cereals and especially stooked oats following harvest. Patches of arable crops were grown on nearly every farm, even hill farms, in the late 19th century, often as fodder for horses. These were particularly exploited by black grouse at the time and it has been suggested that the loss of these arable areas may have contributed to the decline in black grouse from many farmed areas (Shrubb 2003). However, arable is now largely absent from areas where black grouse persist so it may equally be assumed that grain is not an essential requirement, although its local reintroduction is being advocated in order to provide alternative food sources for the birds.

Some trial plots in Strathspey were quickly utilised by black grouse (Cosgrove & McKnight 2001) and similar is reported from the North Pennines and Wales (N. Mason & P Lindley *pers. comm.*) and also in Germany (Ludwig *et al.* 2000). In Finland, artificial winter feeding with oats has been widely practised since the late 1960s, as part of game management. In one study, survival and breeding success of fed females were compared with those of unfed birds. Fed females appeared to show some benefits of feeding, laying larger eggs and, although there were no differences in the overall numbers of chicks per hen in August, there was some indication (not statistically significant) that the proportion of hens with nest and brood losses was lower in the fed sample than in the unfed sample (Valkeajärvi & Ijäs 1994). However, fed hens had lower survival rates than unfed hens, largely as a result of predation by goshawks from May to end of August (31 % of fed hens predated compared to 9 % of unfed hens). This difference in predation was attributed to the feeding site attracting both black grouse and goshawks (Valkeajärvi & Ijäs 1994). In a second Finnish study, no effects of feeding with oats were detected on weight gain or on subsequent breeding success of fed birds, but sample size was small (Marjakangas & Aspegren 1991).

Clearly there is a functional response by black grouse to the provision of grain, however a strong positive influence at the population level has not been demonstrated, whilst there is evidence that negative effects can arise through the attraction of predators. With this in mind, careful consideration has to be given to selection of any feeding sites, whilst monitoring of predator abundance and predation is recommended. Issues such as the type and diversity of grain and seeds made available also need investigating.

The provision of gizzard grit, to help grind fibrous vegetation prior to digestion and medicated grit with the additional benefit to control infestation with the parasitic nematode *Trichostrongylus tenuis* is locally advocated. A functional response by taking grit is reported from Wales, but effects on individuals or at the population level have not been investigated. The provision of grit may have some benefits in areas where natural supplies (including forest tracks) cannot be found.

Although improved breeding success in red grouse has been associated with the provision of medicated grit (Newborn & Foster 2002), that species occurs at much higher densities than black grouse and so may be more prone to parasitic infection. Black grouse historically have been reported to succumb to disease outbreaks. In northern England post mortems have found the presence *Trichostrongylus tenuis*, but usually at lower levels than seen in red grouse. There have however been deaths which exhibit typical signs of strongylosis. Sub lethal effects of these parasites are not known, which could impact on breeding productivity through poor maternal condition. Currently the effects of medicated grit on black grouse survival and breeding productivity have not been quantified.

7.8 Shooting and other game

Some correspondents advocate a shooting ban on black grouse whilst others use a potential harvestable surplus as an incentive to some to implement prescriptive management. As management for black grouse can conflict with other commercially viable sporting interests (for example deer that can lead to overgrazing, red grouse that can lead to heather management and restoration at the expense of other habitats, potential disease transmission and increased risk of accidental shooting), the exclusion of black grouse from the quarry list is not necessarily beneficial. However, over-shooting may well have contributed to some declines but is not conclusively documented in the UK.

Effects of hunting will depend upon the current status of the hunted population, as well as the hunting levels that occur. Thus, one study in the French Alps found shooting rates were likely to have a major influence on populations (Caizergues & Ellison 1997), whilst others have found that preferential targeting of cocks has been associated with distorted sex ratios (Bocca 1987, Ellison *et al.* 1988). Conversely, a study in Switzerland found no discernible effect of hunting pressure on black grouse abundance, although hunting pressure in the study area was relatively low and considered unlikely to represent additive mortality (Patthey *et al.* 2008). In Finland shooting in excess of 10% (both sexes) of local populations resulted in declines (Linden & Sorova 1992).

In northern England, a voluntary moratorium on the shooting of black grouse is proving effective, helping to meet Species Action Plan targets of increasing numbers and range expansion (Warren *et al.* 2011). While black grouse remain on the quarry list, local voluntary shooting bans are widely advocated including the recommendation for financial penalties for accidental shooting, for example during driven red grouse shoots (Warren *et al.* 2011).

A related issue is the incursion of released game (typically pheasants, red-legged partridge and mallard) into black grouse areas. Potential risks raised include the increased incidence of accidental shooting and the potential transmission of diseases to the wild birds. Although the parasites *Histomonas meleagridis* and coccidiosis have been isolated in black grouse (Davis 2000), the extent of infection, their origins and potential symptoms are unknown. Many parasites are known to be species specific and therefore unlikely to affect black grouse. The potential risks clearly need further investigation. Avoiding release of captive-reared game within existing black grouse populations could also help to reduce accidental shooting, whilst it is also possible that large-scale releases of captive-reared game will increase predator numbers and cause increased competition for resources. Conversely, through creating game keeper jobs and thereby heightening predator control, game release can also benefit black grouse.

Summary

i) *Black grouse readily take grain and grit, however a clear positive effect of supplementary feeding has not been demonstrated (although the main studies to date have been in Finland), whilst there is a risk of increases in predators around feeding sites.*

ii) *Overshooting will obviously affect populations of black grouse and their viability; however it has not been conclusively documented in Britain. Further work is required to determine what levels of shooting are sustainable.*

iii) *The potential impacts (and benefits) on black grouse associated with the release of captive-reared game require attention.*

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9. Tables summarising actions currently advocated conserving local populations of black grouse in the UK.

Table 1 New items not included within the original review (Calladine 2002)

ACTION	CATEGORY	Reference section in text	Summary of comments in text
Spring hen counts with dogs	1	3.1	Probably less reliable than lek counts.
Finnish 3 man chain	1	3.1, 3.2	Not used in UK – in Finland supported through evaluation with radio-tagged birds.
Radio-tagged females	1	3.2	Radio tagging can provide an assessment of breeding success and adult survival.
Create and maintain (extensive) areas of young, open, wood and forest	1a	6.7.1	Unclear on extent to which creation of young, open, woodland is confounded with grazing reduction/exclusion in causing response, but several studies (and many examples) show positive response to young woodland.
Reduction of grazing	1a 3c	7.2.2	Some studies and numerous examples indicate positive response (in terms of abundance) to reductions in grazing, although some evidence also suggests (in absence of other management) this may be a temporary effect lasting c.5 – 7 years, after which populations may decline again. Evidence also for effect on chick productivity for 5-6 years.
Large-scale human activities involving infra-structure developments	1a	7.3	Major developments can create a negative population effect (e.g. Alpine ski resort); however, the occurrence of similar effects in Britain is unclear.

Table 2 Updated categories for items highlighted within the original review (Calladine 2002)

ACTION	ORGINAL CATEGORY	NEW CATEGORY	Reference section in text	Summary of the comments from the text
Plant, thin and/or graze to promote understory development	1	1b 3a	7.1,7.2	Most applicable to larger woodlands. Typical prescriptions include thinning of commercial plantations, controlling deer.
Manage for a mosaic of ericaceous, mire, flush and grassland	1 (mosaic components) 3 (mosaic components)	1a (mosaic components) 1a (mosaic components)	6,7.2	Applies to open moorland, sparse woodland, forestry clearings and pre-thicket forestry. The proportional composition of the mosaic required has been defined within Perthshire and the north Pennines.
Block moor grips and avoid deep and long forest drains	3	2a (chick drowning) 3c (food provision)	7.2.4	Hydrologic integrity of mires and flushes may enhance food abundance for adults in spring and chicks. Long, deep drains may be a physical hazard to chicks.
Predator removal/culling	1 (in Fennoscandia) 3 (in UK)	1a	7.6.1	Intra-guild relationships amongst predators should be considered.
Grain Provision	1(use) 4(effect)	1b	7.7	Includes managing arable plots and putting out grain. Possible risk of feeding sites attracting predators, leading to negative effects on black

Category 1. Backed up by published, peer viewed, studies 2. Based on currently unpublished data or other non-reviewed publications 3) Based on supportable anecdote and observation, or the logical interpretation of known biology. 4) Without any recognised foundation

Table 3. Methods used to monitor/evaluate black grouse and factors affecting black grouse populations.

ACTION	CATEGORY*	Reference section in text	Summary of comments from text
Monitoring of population density and breeding success		3	A systematic and constant approach is required when comparing across sites and years (to assess effectiveness of management)
Monitoring of Black Grouse Populations			
Lek counts	1	3.1	Most frequently used method in UK.
Spring hen counts with dogs	1	3.1	Probably less reliable than lek counts.
Finnish 3 man chain	1	3.1	Not used in UK – in Finland supported through evaluation with radio tagged birds.
Monitoring Breeding Success			
Brood counts with dogs	1	3.2	Most frequently used method in UK.
Radio tagged females	1	3.2	
Finnish 3 man chain	1	3.2	Not used in UK – in Finland supported through evaluation with radio-tagged birds.
Monitoring of factors of importance in affecting black grouse demography		4	
Fence and other wire strikes	1 (deer fences) 3 (stock fences)	4.1	Collisions with deer fences have been quantified and the effectiveness of some mitigation measures is known. .
Monitoring of Grazing animals: *Direct counts* *Dung counts Utilisation rates*	1	4.2	To complement habitat/vegetation monitoring where part of management trials.

Category 1. Backed up by published, peer viewed, studies 2. Based on currently unpublished data or other non-reviewed publications 3) Based on supportable anecdote and observation, or the logical interpretation of known biology. 4) Without any recognised foundation

Monitoring of habitat and habitat changes	1	4.3	Monitoring vegetation change can provide an assessment of habitat suitability and management success.
Monitoring of Predators and predation rates: *Mortality of radio tagged adult hens* *Count active crow nests* *Count active fox dens* *Transect counts of avian predators* *Count scats (foxes and pine martens)* *Tunnel 'traps' to record mustelid footprints* *Lamping for foxes*	1	4.4	Actual predation rates can be quantified through radio tracking adult birds and identifying the cause of mortality. Although monitoring individual birds can be more useful (but more resource expensive) an alternative would be to monitor predator abundance (ideally beyond the breeding season). Although desirable, monitoring the full suite of predators would in many instances prove impractical. Any monitoring should be systematic, and where comparisons across sites and years are needed, methodology must be comparable. Recent studies show that morphological identification may be inadequate to reliably distinguish fox and marten scats. Current alternative techniques (DNA) may be prohibitively expensive where monitoring is over large areas and/or long timescales (hence involving large numbers of scats).

Table 4. Understanding the scale at which management needs to be delivered.

ACTION	CATEGORY*	Reference section in text	Summary of comments from the text
Scale of management		5	
Lek or patch scale (250-700ha)	1 (adult range) 3 (habitat mosaic)	5.1	Quantification of habitat mosaics is required
Brood scale (<100ha)	1	5.2	Requires more information on chick movements between and within brood sites.
Winter home-range scale	1	5.3	Based on observations and radio tracking studies winter home ranges can be small.
Regional or metapopulation scale	1or 2	5.4	Based on dispersal strategies and supported by genetic studies – suggests that connectivity between leks is important.
Temporal scale (a planned variable management regime	1	5.5	Black grouse occupy transitional habitats which often requiring long term/continued management to sustain.
Targeting management Existing lek sites Known brood rearing areas Potential brood-rearing areas	2	6	The distribution and recent population trends are adequately known in some areas which would permit targeting of resources for black grouse.

Category 1. Backed up by published, peer viewed, studies 2. Based on currently unpublished data or other non-reviewed publications 3) Based on supportable anecdote and observation, or the logical interpretation of known biology. 4) Without any recognised foundation

Table 5. Management prescriptions.

ACTION	CATEGORY*	Reference section in text	Summary of comments from text
Trees, shrubs and woodland			
Create and maintain (extensive) areas of young, open, wood and forest	1a	6, 7.1	Unclear on extent to which creation of young, open, woodland is confounded with grazing reduction/exclusion in causing response, but several studies (and many examples) show positive response to young woodland. The placement of new native woodlands requires careful consideration, especially within important moorland breeding habitats.
Manage for trees that are known food sources for black grouse.	1b	7.1	Birch, hawthorn, rowan, willow, larch, Scots pine, alder, juniper.
Manage for native trees species of local provenance.	4c	7.1	This may satisfy other conservation objectives, but no evidence that it is important for black grouse.
Plant, thin and/or graze to promote understorey development.	1b 3a	7.1, 7.2	Most applicable to larger woodlands. Typical prescriptions include thinning of commercial plantations, controlling deer.
Permit occasional grazing to prevent extensive thicket formation.	3c	7.1.1, 7.6.3	Some thickets *may* assist predator avoidance.
Retain mature seeding broadleaves.	3c	7.1	As a food source, but benefits may be negated if form extensive closed canopy.

Category 1. Backed up by published, peer reviewed studies 2. Based on currently unpublished data or other non-reviewed publications 3) Based on supportable anecdote and observation, or logical interpretation of know biology. 4) Without any recognised foundation. A) Beneficial population or demographic effect on black grouse b) Response effect – birds seen using the resources produced by the prescription c) Resource effect – the prescription has delivered an increase in the extent of the resource.
Refer to section 2 for more detailed information about the categories

Restrict natural regeneration on mire and some heath.	3c	5, 7.1, 7.2.1	Only if encroachment on other habitats will be detrimental.
Plant or permit natural regeneration to extend or establish woods (including 'tree-line' effects).	3b	5, 7.1	Requires an assessment of current local availability before advocating.
Incorporate clearings and avoid straight lines.	2a (large clearings) 4 (small clearings)	5, 7.1.1	Black grouse utilise suitable woodland plantations (e.g. clear fell, low density pre thicket stands) Broods generally utilise open canopy habitats.
Remove trees close to leks and chick rearing areas.	4	7.5, 7.2	Potentially provides suitable habitat where plantation abut other open habitats used by black grouse.
Create low-density feathered edges on outer boundaries of commercial plantations alongside moorland habitats.	3b	7.1.3	Potentially beneficial; however, demographic responses have not been quantified.
Create low-density feathered edges on internal boundaries (rides, water courses) of commercial plantations.	4b	7.1.1, 7.1.3	
Ground vegetation			
Manage for a mosaic of ericaceous, mire, flush and grassland.	1a	5, 7.2	Applies to open moorland, sparse woodland, forestry clearings and pre-thicket forestry. The proportional composition of the mosaic required has been defined within Perthshire and the north Pennines.

Manage for ericaceous vegetation:	1b	7.2.1, 7.2.2	Typical prescriptions can include stock and deer reductions especially in winter to encourage ericaceous cover and the extensive felling and thinning of trees to permit the development of ericaceous ground vegetation.
Rotational burning of heather	3b	7.2.2	Perhaps supportable where there is a heather dominated field layer, or (subject to other conservation objectives and requirements – e.g. avoiding burning on blanket bogs) on wet heath or bog where there is an aim to increase cotton grass cover.
Rotational cutting of heather	3c	7.2.2	Perhaps supportable where there is a heather dominated field layer.
Manage for semi-natural grassland:	1b	7.2.1, 7.2.3	Typical prescriptions include stock and deer reductions to encourage sward growth.
Grass moor/rough grazing	1a	7.2.1, 7.2.3	Important brood rearing habitat where modest levels of grazing permits development of sward structure.
Hay meadow (and similar herb-rich flushes)	1a	7.2.3	Important feeding and brood-rearing habitat in parts of range. Prescriptions include 'traditional' late cutting and low inputs for meadows and light grazing for flushes (to maintain floral diversity).
Maintain structural mosaic of ground vegetation that includes some tall swards (25-30cm+) and shorter vegetation.	1a (importance of sward diversity) 3a (importance of structural diversity)	6.2, 7.2	Extensive areas (>100 ha) of tall swards *may* limit brood habitat (6.2, 6.5); however, optimal compositions are unknown. Typical prescriptions include differential grazing, cutting and heather burning. Initial reductions in grazing (domestic stock, deer and rabbits) may be required.

<u>Reduction in grazing</u>	1a	7.2.3	Some studies indicate a positive population response (in terms of abundance) to grazing reductions (in absence of other management); however, this may be a temporary effect lasting c.5 – 7 years. .
Block moor grips and avoid deep and long forest drains.	3c	7.2.4	Hydrologic integrity of mires and flushes may enhance food abundance for adults in spring and chicks. Long, deep drains may also support higher plant and invertebrate diversity; however these can pose a physical hazard to chicks.
Control bracken, rushes and Molinia (mechanical or chemical).	4	7.2.5	Only where encroachment onto other habitats is deemed an issue.
Exclude foddering sites from sensitive habitats.	3b	7.2.6	There may be some influence only if these are so extensive as to affect the availability of heather to black grouse.
Disturbance			
Restrict human disturbance during the breeding season.	3b	7.3	Disturbed birds are more likely to flush greater distances; however, there appears to be no detectable impact upon fecundity.
Restrict human disturbance at leks and winter feeding areas.	3b (at leks) 1b (winter feeding)	7.3	Black grouse may be susceptible to increased recreational disturbance at winter feeding areas whilst anecdotal evidence suggests that lek disturbance could be an issue.
Large-scale human activities involving infra-structure developments	1a	7.3	Major developments can create a negative population effect (e.g. Alpine ski resort); however, the occurrence of similar effects in Brit is unclear.

Fences and wires			
Remove or mark deer fences	1b (the problem deer fences) 2b (fence marking)	7.4	A range of marking methods is advocated including chestnut paling on deer fences and fitting flight diverters on utility cables and stock fences. The only mitigation for which quantification of effectiveness has been tested is for orange plastic netting on deer fences.
Remove or mark stock fences.	3b (the problem stock fences)	7.4	Anecdotal evidence suggests that the fitting of flight diverters on stock fences is effective but actual influence on black grouse populations remains untested
Mark overhead wires where black grouse collisions occur (leks, key feeding areas etc).	3 (mitigation using flight diverters)	7.4	Anecdotal evidence suggests that the fitting of flight diverters is effective but actual influence on black grouse populations remains untested
Avoid rabbit netting	3	7.4	May restrict movement of chicks.
Clearance			
Lek site clearance	3	7.5	Maintaining open lek sites with relative short vegetation is advocated especially within commercial conifer plantations. The benefits of this approach are unknown.
Predation			
Predator removal/culling	1a	7.6.1	Relationships between predators should be considered (i.e. does simply removing one or a few species increase the abundance of another predator).
Diversionary feeding	4	7.6.2	Supplementary feeding may provide a useful tool for reducing the number of chicks taken by hen harrier (*Circus cyaneus*). This is based upon experimental trials assessing red grouse. Longer term effects of supplementary feeding are unknown.

Habitat manipulation	3	7.6.3	Maintaining thickets may create cover against predators. Trade offs between woodland cover and predator abundance remains untested.
Arable plots, supplementary food and grit			
Grain provision	1b	7.7	Includes managing arable plots and putting out grain. Possible risk of feeding sites attracting predators, leading to negative effects on black grouse survival (Finland).
Grit	4	7.7	Black grouse taking grit has been reported. The use of medicated grit can reduce the intestinal parasitic worms shared with red grouse.
Shooting and other game			
Shooting restriction	3	7.8	Most estates impose shooting bans.
Avoid release of captive-reared game	4	7.8	Disease transmission may be an issue but could form an effective form of supplementary feeding. Additional game may attract predators; however, heightened keeper presence may neutralise any increase.

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