

# Review of Potential Food in relation to the South Scotland Golden Eagle Reinforcement Project

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Haworth Conservation, Bendoran Cottage, Buessan, Mull, PA67 6DU

Paul F Haworth & Alan H Fielding

January 2017

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## 1. Background

Consultations with the general public were held across parts of Southern Scotland in late 2016 to provide detailed information on the nature, scope and timeframe for the golden eagle reinforcement project. Various issues came to light during the course of these consultations including questions relating to the likely distribution and abundance of potential prey thought to be present across those parts of South Scotland where the newly released golden eagles might settle and begin to breed.

This report provides a review of what is currently known about golden eagle diet in general and how this diet varies across those regions of Scotland where golden eagles breed. The current prey context in Scotland is outlined and information about likely prey requirements described. The distribution and abundance of known and potential prey species within South Scotland is set out using the most contemporary sources available. Measures for enhancing live prey are also discussed.

## 2. Golden Eagle Diet

The type of food consumed by golden eagles was outlined by Watson (2010) using information on more than 1,700 prey items collated from a detailed examination of more than 1,300 pellets collected from across Scotland.

Prey items comprised six major categories

- a. deer;
- b. sheep and goat;
- c. lagomorph (mountain hare and rabbit);
- d. other mammals (mainly voles, mustelids and foxes);
- e. grouse (red grouse and ptarmigan); and
- f. miscellaneous items (mainly birds such as fulmars, ducks crows, waders pipits, larks, thrushes plus a few reptiles and amphibians).

Using these data Watson (2010) recognised six types of eagle diet which he described in relation to nine ecological regions of Scotland which contain populations of breeding eagles. These nine regions are described below in section 3.

- Type A diet is lagomorphs (mainly rabbits), sheep and miscellaneous items (mainly fulmars) with a low proportion of deer. This diet was common in the Outer Hebrides and Skye (regions 1 and 2).
- Type B is lagomorphs (mainly mountain hares) and sheep. This diet was a feature of the Isle of Mull (Region 3).
- Type C diet comprises items from all six prey categories but with more deer consumed than anywhere else. This diet was a feature of the North, Northwest and West Central Highlands (Regions 4, 5 and 6).

- Type D diet is lagomorphs (mainly rabbits) and sheep. This diet was a feature of the Southwest Highlands (Region 7).
- Type E diet is grouse and lagomorphs (mainly mountain hare). This diet was feature of the East Highlands (Region 8).
- Type F diet comprised items from all six prey categories with rabbits and mountain hares in roughly equal proportions. However the miscellaneous category was predominant and included at least eight different bird families. This diet was a feature of Southwest Scotland (Region 9).

It is clear from Watson (2010) that golden eagles will utilise a wide variety of medium sized birds and mammals that are currently to be found in a wide range of habitats across upland Scotland. Watson's analysis clearly recognises that there is no such thing as a 'typical' diet for golden eagles across Scotland and that they change their diet according to local conditions.

Further work by Haworth *et al.* (2009) examined more than 2,000 prey remains collected from 90 golden eagle ranges located on Mull, Skye, Lewis, Harris and the Uists (Watson's regions 3, 2 and 1). Bird remains were mainly red grouse, fulmars, corvids and greylag geese, with mammals comprising mountain hares, rabbits, lambs and brown rats. The recorded variation in prey taken appeared to be a reflection of general prey availability. Also the high breeding productivity of some regions did not suggest a high degree of dietary specialisation (Whitfield *et al.*, 2009). Rather it seems that golden eagles are adaptable predators that can prosper in regions with a broad spectrum of prey whilst in other parts of Scotland plentiful grouse and lagomorphs result in good breeding productivity.

### 3. Ecological Regions

Watson (2010) made reference to nine ecological regions based upon their plant communities, the contemporary land use and management together with associated birds and mammals.

**Region 1: Outer Hebrides.** The vegetation here is largely wet heath and bog with substantial areas of machair grassland along the west coast. There are few conifer plantations. Red deer are widely distributed across the islands whilst sheep are predominantly kept by crofters on common grazings. Red grouse are widely but thinly distributed across bogs and mountains. Hares are absent from the Uists and Benbecula but present in small numbers in Lewis and North Harris. Rabbits are numerous in areas of machair. Seabirds are an important prey source for some coastal golden eagles.

**Region 2: Inner Hebrides (north, Skye and the small isles).** The vegetation is mainly wet heath and bog with extensive richer grasslands on North Skye but little machair. Conifer plantations are extensive in parts of North West and South Skye. Red deer are few in number and sheep flocks are maintained by crofters on year round common grazings.

Red grouse and ptarmigan are scarce and mountain hares few in number. Rabbits are present in large numbers on lower ground near the coast. Seabirds such as fulmars are widespread along the west coast of Skye whilst seabird colonies on Rum and Canna are important sources of prey for golden eagles on these islands.

**Region 3: Inner Hebrides (south, Mull, Jura and Islay).** The vegetation on Mull is mainly wet heath with widespread grasslands. Conifer plantations are extensive. Red deer and sheep are numerous. Red grouse and ptarmigan are scarce but mountain hares are plentiful in most habitats down to sea level. Rabbits are present in a few locations near the coast. Sheep are largely absent from Jura but densities of red deer are very high. Introduced mountain hares still persist on Jura but are no longer present on Islay.

**Region 4: North Highlands.** The vegetation here is extensive blanket bog and wet heath on lower ground with moss heaths at higher altitudes. Conifer plantations are extensive in the east of the region. Red deer are widespread and numerous but sheep are present mainly at low densities. Moderate numbers of red grouse are present throughout with modest numbers of ptarmigan on the higher ground of the west. Mountain hares are thinly spread and rabbits are confined to the richer grasslands of the north coast.

**Region 5: Northwest Highlands.** The vegetation here is largely wet heath and blanket bog on lower ground with acidic grasslands at higher altitudes. There are few conifer plantations but scattered remnant pinewoods are present in the east of the region. Red deer are widespread and numerous but sheep are present mainly at low densities. Moderate numbers of red grouse are present throughout with large numbers of ptarmigan on the montane ground. Mountain hares are thinly spread in the west but common in the east of the region. Rabbits are confined to the west coast and some eastern glens.

**Region 6: West-central Highlands.** The vegetation here is largely wet heath and blanket bog on lower ground with moss heaths at higher altitudes. There are extensive conifer plantations in the southwest of the region. Red deer are widespread and numerous but sheep are present mainly at low to moderate densities. Red grouse are scarce throughout with larger numbers of ptarmigan on the montane ground. Mountain hares are largely absent. Rabbits are confined to the west coast and some eastern glens.

**Region 7: Southwest Highlands.** On the larger hills vegetation tends to mainly grassland with some wet heath. Areas of heather are to be found on some hills of moderate elevation. Conifer forests are very widespread and extensive. Red deer are numerous on both hill ground and within conifer forests. Sheep are widespread but declining in numbers. Red grouse are widespread at low densities with ptarmigan present on the highest ground. Mountain hares are thinly spread and rabbits occur on the lower ground.

**Region 8: East Highlands.** Heather moorland is the dominant vegetation at moderate altitudes with extensive montane heath on the higher ground. Pine woodlands are extensive in several large straths. Red deer are present at the highest densities in Scotland. Numbers of sheep are low. Red grouse are widespread and numerous.

Ptarmigan are abundant in the montane zone. Small numbers of capercaillie and black grouse are found in the pine forests and scrub woodland. Mountain hares are abundant on many hills with modest numbers of rabbits in some glens.

**Region 9: Southwest Scotland and the Borders.** The vegetation is a large scale mosaic of acid grassland, blanket bog, heather moorland and conifer plantations. Red deer are widespread, especially in conifer forests as are the much smaller roe deer. Red grouse are widespread and numerous on areas managed mainly for shooting. Sheep numbers remain high on the grassy hills. Mountain hares occur throughout the region with high numbers in some recent years. The lower ground supports an abundant population of rabbits.

#### 4. Food for golden eagles: a Scottish context

Haworth *et al.* (2009) and Whitfield *et al.* (2009) demonstrated that, contrary to common perceptions, golden eagle productivity was not linked to diet specialisation. Instead it appears that it is food abundance that is important and diet specialisation is an inevitable consequence when a small number of prey items are super-abundant.

The Haworth *et al.* (2009) and Whitfield *et al.* (2009) studies concentrated on pairs in the Inner and Outer Hebrides and found that the failure of breeding attempts occurs most frequently during incubation or with small young. A small number fail with young at more than 6 weeks old or shortly after fledging. Late failure has been a feature of golden eagles breeding on the Uists in recent years and may be more widespread than previously thought. If late failure is more common then some of the estimates of golden eagle productivity may be optimistic since older chicks are usually assumed to have fledged.

There is relatively little information on the timing of nest failures. Payne and Watson (1983) recorded that 21 of 25 pairs (84%) in NE Scotland laid eggs in 1982, of these three nests failed to hatch young (85.7% of eggs hatched) and 15 nests fledged young (71.4% of eggs converted to fledged young). Lockie (1964) describes the death of two young eagles at six weeks which he ascribed to a shortage of food.

Corkhill's (1980) interpretation of the causes of breeding failure on Rum raises the need for caution when interpreting data from the 1950s and 1970s. He shows that five of 28 breeding failures (18%), between 1957 and 1978, were because eggs were not laid. A further nine (32%) were due to broken eggs and twelve (41%) resulted from addled eggs. Only two (7%) were a result of chick death. Corkhill (1980) provides evidence to suggest that these failures were not the result of a shortage of food. Rather, they arose as a result of contamination by toxic residues that derived from their seabird prey.

Similarly, Nygård and Gjershaug (2001) found relatively strong negative correlations between reproductive output and shell thickness and DDE concentration in eggs from ranges in western Norway (1973-1999). They suggest that their data indicates that the

golden eagle may be a particularly sensitive species to DDE and that the higher organochlorine content found in the eggs of coastal birds was caused by a diet that includes marine birds. Both of these studies build on the pioneering work of Ratcliffe (1960) who had noted that eggs of golden eagles were sometimes broken in the nest by incubating females during the 1950s and Lockie and Ratcliffe (1964) who demonstrated that reduced reproductive success in golden eagles, in the Scottish Highlands in the 1960s, was due to organochlorine compounds arising from the use of dieldrin in sheep dip.

Marquiss *et al.* (1985) examined the factors associated with a reduction in breeding in SW Scotland. Although they thought that afforestation was the principal cause they suggested that good breeding performance was associated with spring (pre-breeding) diet with the most productive pairs consuming more live prey (large birds) and less carrion. Although it was only based on a small sample, Pout (1998) suggested that adult golden eagles may have a diet that contains a significant proportion of carrion at the same time that they are feeding the young bird with live prey. However, he also thought that adult eagles favoured live prey over carrion during the pre-breeding period. Tjernberg (1981) suggested that, whether breeding occurs or not, is probably determined by prey abundance early in spring just before eggs are laid. Steenhof *et al.* (1997) also found that the percentage of pairs laying eggs was related positively to jackrabbit abundance and inversely related to winter severity.

In the more northern regions, e.g. Alaska and Scandinavia, there is evidence that breeding success is closely linked with the availability of live prey, primarily because major prey species often have marked abundance cycles that are much less clear in, or absent from, Scottish prey species. For example, Tjernberg (1981), working in northern Sweden (1975–1980) found that the proportion of golden eagle pairs with successful breeding (21%–85%) and the number of young produced per occupied territory (0.27–1.24) varied greatly between years. Productivity in the northern pairs was significantly correlated with the total hunting bag of small game species. However, this was not the case in more southerly pairs. The lack of a correlation was thought to be due to a good reproductive year (1977) when small game species were scarce. Tjernberg (1981) thinks that this may be explained by favourable weather conditions during the spring of 1977. Nystrom *et al.* (2006), also working in northern Sweden, examined the relationship between prey density fluctuations and golden eagle productivity. Even though the available prey diversity was low the pairs that they studied maintained a relatively broad food niche. Most of the main prey species (Microtine rodents, hare and Ptarmigan) had similar population fluctuations and the golden eagle breeding success was correlated with the annual density index of the most important prey category, the *Ptarmigan* species.

McIntyre (2002) showed that, in the Denali National Park in Alaska, occupancy rates were independent of prey cycles but laying rates were lowest when spring prey populations were at their lowest. However, the success of pairs that laid eggs was not influenced by spring prey abundance.

Lockie (1964) thought that in the relatively poor regions of Wester Ross, there was annual variation in the amount of live prey and carrion and that in “good years” the combination of live prey and carrion would be sufficient to allow reproductive success for the golden eagle. Brown (1969) came to a similar conclusion in that he suggested the supply of food “appears rather scarce in Sutherland compared with the Eastern Highlands” but that the difference changed between years. He identified 1967 as a year in which there seemed to be very little live prey with a possible ten fold reduction compared with the period 1958-1960. However, he thought that it was unlikely that there was less than 5,000 kg of carrion per territory, a figure that would allow birds to continue their occupation despite the scarcity of live prey.

The parish sheep statistics data gathered by Haworth *et al.* (2009) showed that a substantial decline in numbers is well now under way, at least in many parts of the Hebrides and probably elsewhere in the west of Scotland although the declines may be less in SW Scotland. There were no obvious effects of this change in sheep density and perhaps none should be expected over such a short timescale. It is also worth bearing in mind that sheep numbers are only now declining below the stocking levels of the early 1980s. Hewson (1984) suggested that golden eagles (and foxes) killed lambs when they were 1-5 days old, with golden eagles taking lambs up to 6 kg. At that time the main threat to lambs was during the first ten days of May. Watson (1997) gives a median laying date of the 25 March and an incubation period of approximately seven weeks. This means that young eagles would not hatch until about May 13, after the period that Hewson quotes as the most likely period for predation on lambs. Superficially it is difficult to reconcile these dates since there is clear evidence that lambs are present in some nests with young eagles. However, some of these lambs or parts of lambs may well have been scavenged as carrion.

Lockie and Stephen (1959) suggested that eagles began to increase on Lewis in about 1946. This coincided with the period when mountain hares, grouse and some rabbits (on the hills) began to decline. They quote a keeper on the Morsgail Estate who suggests that hares began to disappear in 1946-47 from areas where they had once been common. Although the reasons for these declines are unknown they suggest that it may have been associated with an increase in the number of sheep. If their suggestion is true an increase in these prey species may be expected as the number of sheep decline. However, their observation also suggests that a decline in the golden eagle population is also possible. Watson (1997) thought that a reduction in sheep numbers, such as that now underway, should lead to a reduction in eagle density in the west but this could be compensated for by a long term increase in productivity.

Lockie writing in 1964 said that it was clear “from the writings of sportsmen” that wildlife, in NW Scotland, was much more abundant in the early 19<sup>th</sup> century. However, Lockie (1964) also notes that, despite the decrease in live prey, there were more foxes and golden eagles than previously. Lockie quotes Darling (1955) to suggest that the reduction in live prey arose as a consequence of increasing sheep density combined

with excessive burning that has destroyed much of the cover needed by many of the prey species. Lockie (1964) thought that eagles would be more likely to take larger lambs, outside of their preferred prey size-range, when live prey and carrion were scarce. Watson (1997, p 141) suggested that the tendency for golden eagles in the United States to lay larger clutches was due to the better food supply and that there is evidence that clutch sizes have declined in Scotland since the middle of the nineteenth century. Such a decline is consistent with the types of habitat degradation described by Lockie (1964) and others.

## 5. Food Requirements

There has been discussion and speculation previously as to how much prey is required for an eagle range to be productive. McGahan (1967) working in south-central Montana, recorded that one pair of eagles brought an estimated 490 g of edible food mass per eagle per day to a nest during a 39-day period. Over a 100-day period this means that each eagle took an estimated 40-49 individual food items to the nest, with lagomorphs being the most important species (white-tailed jackrabbits *Lepus townsendii* and cottontails *Sylvilagus audubonii* and *S. nuttallii*).

Brown and Watson (1964) estimated that a pair of eagles needed 174 kg of live prey and carrion per year. Brown (1969) expanded on this by suggesting that another 54 kg was required if an average of 0.8 young per year were reared plus an additional 43 kg for sub-adult birds using the territory intermittently. Takeuchi *et al* (2006) had a larger figure for the young bird. Using video recordings at nests they showed that there was temporal change in prey selection during nestling periods, but with similarities in later deliveries of snakes and in total prey weights (83.7–89.9 kg) delivered to successfully fledged broods. This is closer to the figure that can be extrapolated from Collopy (1984) who gives a mean delivery of 1.42 kg per day (approximately 100 kg). However, these are delivery and not consumption figures so a lower figure is presumably adequate.

Collopy (1984) quotes a much lower figure of 0.885 kg per day given by Lockhart. Even after making allowances for the assumed 0.8 fledging, the adjusted figure for Brown and Watson (1964) remains lower at 67.5 kg. Similarly, Fevold and Craighead (1958) arrived at a larger figure for adult birds. They fed captive golden eagles mainly venison during autumn and winter. Extrapolating from their figures gives annual requirements of 112 kg (female) and 96 kg (male) or 208 kg for a pair. If the average range areas per pair quoted by Brown and Watson (1964) are used (4613 ha – 7273 ha) their food requirement estimates equate to only 0.06 and 0.04 kg prey ha<sup>-1</sup> year<sup>-1</sup>. Even if Brown and Watson had made a large underestimate it seems unlikely that such small quantities are not reached, even in the most degraded habitats.

Indeed, using more conservative estimates the requirement is still less than 8 kg per km<sup>2</sup> per year. Brown and Watson (1964) recognized this and noted that the average food potential in all areas is greatly in excess of the requirements. However, they also recognize that live prey may be relatively scarce in some western areas and that this is

offset by the amounts of carrion. Their statement that “*large differences in food potential between areas do not correspond with differences in eagle density*” was later refined by Watson *et al.* (1992) who showed a correlation between eagle density and carrion abundance.

There is limited evidence from Mull that, at least for some ranges, the removal of sheep has had little measurable impact on golden eagle productivity. At one range sheep and deer were removed in 1995 to facilitate large scale landscape regeneration. This pair has continued to breed successfully averaging approximately 1 chick per year from 1997 onwards. In the past ten years sheep have been reduced to very low numbers across three other ranges in central Mull without adverse effects on productivity. At another range in north Mull extensive afforestation by broadleaf native woodland of a large part of the range ten years ago coincided with the pair laying eggs for only the second time in almost thirty years and then breeding successfully in most years since.

The relationship between breeding productivity and land management is complex. In general however deer are most likely to exert an indirect influence on prey abundance and availability through grazing pressure either on their own or most frequently in combination with sheep and burning. Unfortunately neither sheep statistics nor deer counts correspond to golden eagle range boundaries making it difficult to assess accurately the impacts of varying levels of grazing upon breeding productivity. Differing levels of grazing intensity are likely to impact differentially on the various key groups of potential prey, particularly hares and rabbits, and this in itself will vary from region to region.

## 6. Potential Food in South Scotland

In region nine, Southwest Scotland and the Borders, Watson (2010) noted that some 60 % of golden eagle diet was mammals with deer, sheep and goats, hares and rabbits by far the most important items accounting for more than 50% of the total. Rats, mice, voles, foxes, weasels and badgers comprised approximately 9% of the total number of identified items. Birds accounted for just less than 40% of all the identified items and in terms of avian prey grouse and pheasants comprised almost 16% of recorded items with a further 9% pigeons and crows. An additional 4% were waders, 3% ducks and geese and almost 5% pipits and thrushes.

In the early 1990s there were several attempts to quantify the diet of the Galloway pairs in the face of declining productivity. Rollie *et al.* (1994) reported on prey found in the Dumfries and Galloway nests B and D between 1983 and 1993. Although they have some important caveats about the robustness of the data, they were able to identify some general trends. Firstly, lagomorphs appear to have been the most important prey item during the nestling period, forming 41% of all items, by number, recorded at pair `B', and 53% of those at pair `D' including a total of 39% of rabbits. Red grouse appeared to be more important for pair `B', forming 26% of recorded prey items, compared with 14% for pair `D'. Other non-passerine birds (including duck, gulls, waders, pigeon and

pheasant) accounted for roughly similar proportions of recorded prey items at each site, namely 16% (pair `B') and 17% (pair `D'). There were few records from nest C but the three records were all birds: one greater black-backed gull, one unspecified gull and one black grouse. Shaw (1994) reported on an analysis of pellets from the three extant ranges (B, C & D) using information from pellets collected between August 1992 and October 1993. Lagomorphs were the most important component in the pellets for all three pairs at all times of year, contributing between 37%-65% of the recorded items. When they could be separated, rabbits were the majority for pairs B & D while, in range C, hares were the majority item. Other species identified included deer, goat *Capra aegagrus hircus*, sheep, 'other' mammal, grouse and 'other' birds.

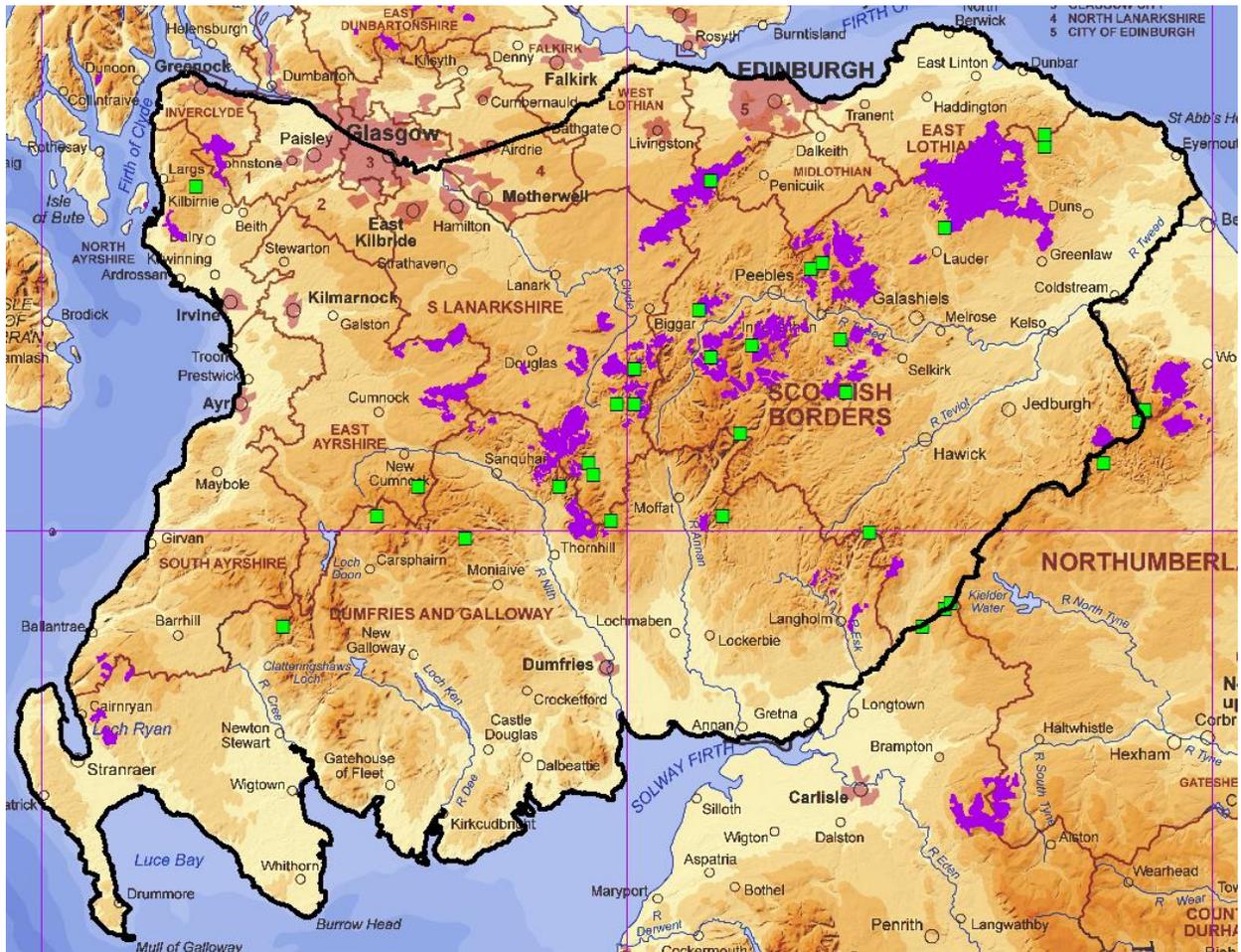
There are very few red deer in the Borders and in upland areas of Dumfries and Galloway they are mainly associated with the Galloway Forest Park. Sika deer and fallow deer are present in Dumfries and Galloway. However, roe deer are numerous throughout the south of Scotland. Hares are present on many grouse moors whilst rabbits are patchily distributed in the more grassy moorland edges.

The most up to date and comprehensive account of the distribution and abundance of potential avian prey for golden eagles in South Scotland is the BTO Bird Atlas 2007-11 (Balmer et al 2013). Examination of the mapped Atlas data shows that:

- Geese and ducks, pink-footed geese (pages 168-169) are widespread and abundant in winter. Greylag geese (172-173), Canada geese (174-175), teal (196-197), mallard (198-199) and goosander (230-231) are all widespread and abundant in both breeding and winter seasons.
- Medium sized game birds including red grouse (234-235), black grouse (238-239), red-legged partridge (242-243) and pheasant (248-249) are abundant and widespread throughout the year.
- Waders are also widespread and abundant throughout the year and include oystercatcher (336-337), golden plover (348-349), snipe (366-367), woodcock (368-369) and curlew (376-377). Common sandpipers are widespread and abundant during the breeding season.
- Rock doves/feral pigeons (434-435) and woodpigeons (438-439) are widespread and abundant in both breeding and winter seasons.
- Corvids are numerous and widespread and include jackdaw (482-483), rook (484-485), carrion crow (486-487) and raven (490-491).
- Thrushes are also widespread and abundant throughout the year and include blackbird (566-567), song thrush (570-571) and mistle thrush (574-575). In addition large numbers of fieldfares (568-569) and redwings (572-573) are present throughout the winter period.

An integral part of this review has been a detailed GIS based appraisal of the extent and distribution of moorland managed for red grouse. This habitat potentially supports high numbers of red grouse and mountain hares, species likely to form important elements of golden eagle diet in the context of south Scotland. This work has recorded the distribution of 91 individual blocks of moorland managed for red grouse. These 91 blocks cover a total area of 746 km<sup>2</sup> (range 0.16-204 km<sup>2</sup> with a mean of 8.3 km<sup>2</sup>) are shown in Fig. 1.

Figure 1. Distribution of managed grouse moor (digitised from 2016 Landsat 8 images). Also shown are the historic golden eagle place names from Evans *et al.* (2012). Contains Ordnance Survey data © Crown copyright and database right 2010



## 7. Potential management measures to enhance food availability.

Taking account of the numbers and distribution of potential prey items described above it seems clear the south of Scotland as a region possesses a sufficient prey base to sustain a breeding population of golden eagles of 12-16 pairs. Although the potential base is not as plentiful as parts of the east highlands the diversity and abundance of

many birds and mammals is greater than several areas in the west and North West of Scotland.

Within Scotland as whole there are several high density golden eagle regions with low productivity and little prey so one issue for the South Scotland reinforcement programme may be one of local prey management once birds begin to settle and distribution is known. Detailed examination of land use and land management, for example, forest felling and restructuring, variation of grazing regimes and establishment of native woodland can be undertaken within each new range to promote the enhancement of live prey to increase productivity if such a course of action is deemed to be appropriate.

It should be borne in mind that at the scale of Scotland only one in approximately every three golden eagle nest produces a chick in any given year. Therefore in the South of Scotland only 3-4 chicks might be expected to fledge each year once the reinforced breeding population reaches say 12 pairs.

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