The James Hutton Institute

Contract Report

Biodiversity impacts of game bird hunting and associated management practices in Europe and North America

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EXECUTIVE SUMMARY

1. Here we review and compare game bird hunting styles in Europe and North America and how these and their associated management impact non-target species and wider biodiversity.
2. Game birdshooting governance can be categorised into three main styles:
   - Landowner regulated. Hunting rights belong to the landowner and typically there is little or no state monitoring or regulation of harvest. This is the case in the UK and on privately owned land in much of Europe.
   - State regulated. Hunting rights usually belong to the landowner, though there may be some minimum land area restrictions. Hunting is by license or permit, harvest levels, for some species at least, are set by the state or a state agency, which may or may not be based on monitoring of game populations. This applies to much of the public land in Europe.
   - State owned. Game and hunting rights belong to the state (or are otherwise controlled by them). Hunting is regulated by licence, and there are usually bag limits imposed, which may or may not be based on monitoring of game populations. This is the governance style in North America, Hungary, Poland and Estonia.
3. Hunting styles can be broadly categorised in to:
   - Driven shooting. In certain areas driven shoots are popular, in particular in the UK, France and some areas of southern Europe, and in certain parts of North America (e.g. Bobwhite quail in Texas).
   - Walked up, or in the UK context 'rough', shooting. The majority of game bird hunting in Europe and North America is walked up shooting over dogs, or a similar practice.
4. Four broad categories of management for game bird shooting are described:
   - Habitat management for game birds is widespread and common throughout Europe and North America, but less so in Fenno-Scandinavia. There are a number of documented positive and negative impacts on non-game species. There is evidence that game bird habitat management may be beneficial to non-game species in agricultural habitats, but the evidence is less clear for non-agricultural habitats.
   - Species management via the provision of supplementary food and water are common practices that generally have positive impacts on other species, though there may be some increased risk of disease transfer and predation.
   - Predator control is a widespread practice in Europe and while prey densities usually respond positively to such control, the efficacy of predator control programmes is likely to vary according to population and ecological variables. Predator control is minimal in Fenno-Scandinavia, and uncommon in America. Both positive and negative effects on population dynamics of target species may be expected, and depend on the type and extent of control exerted. No studies up to now have shown negative effects of predator control on other prey species, but

available evidence for positive effects is limited. The control of some predators, particularly those of conservation importance (notably protected birds of prey), has detrimental effects on populations in some cases.

- Rear, release, and restocking tend to increase the harvestable population of target game species, but not necessarily the breeding populations. There are exceptions when restocking is accompanied by other management actions. However, releases can have important negative effects, through competition, habitat deterioration, and the loss of genetic diversity, particularly where releases are of a species outside of its native range. Yet there is limited information about the extent and significance of these processes in the wild.

5. Management practices implemented to maximise game bird yields can have positive or negative effects for non-game biodiversity. However, for the most part we have a very poor understanding of how game bird management practices impact on non-game biodiversity. While many game bird management practices in agricultural habitats, such as set-aside, conservation headlands and beetle banks, are beneficial for biodiversity, there has been no assessment of whether these practices are implemented more effectively or over a larger area in game than non-game areas. While there are examples where management for game bird shooting has clear positive effects of non-game bird biodiversity there are a number of hypothesised negative effects of game bird management for which evidence is not available or insufficient to draw conclusions.
    - More intensive 'driven' forms of hunting are associated with greater management intensity, in order to deliver the greater densities of game birds required. This generally results in greater impacts on biodiversity which can be either positive or negative. Driven shooting tends to dominate in countries or areas where land is under private ownership and where the right to shoot game birds and the number that can be shot rests with the owner.
    - In contrast, 'walked-up' forms of shooting are usually associated with lower management intensity, primarily due to the lower densities of game birds. Impacts on biodiversity (both positive and negative) tend to be less marked. Walked-up shooting tends to dominate in areas where land is common property or state owned and/or where authorities can regulate quotas.
6. Game bird management and its affects on habitats and other species are relatively well researched. However, the evidence in some cases remains equivocal and many questions still exist. Here we have identified 10 key 'knowledge gaps' relating to; governance, licensing, the potential affects of game bird medications on other wildlife, the potential impacts of intensely treated sheep flocks as 'tick mops', the effect of predator control on non-target species, raptor persecution, the impact of rear and released game birds on other wildlife, the prevalence of habitat management in game and non-game shooting areas, and the trade offs between game bird management and other land use options for delivery of ecosystem services.

7. More intensive forms of hunting such as ‘driven shooting’ are associated with greater management intensity focussed on increasing the densities of game birds. Such management is associated with greater impacts on biodiversity which can be positive for some species and negative for others. Less intensive ‘walked-up’ forms of shooting are associated with lower management intensity because lower densities of game birds are required. There is less evidence (positive or negative) for impacts on biodiversity in areas managed for this type of shooting. Driven shooting tends to occur where shooting and management rights belong to the private landowner. Although walked up is also practiced on land under private control, walked-up shooting tends to dominate in areas where the state has some control over shooting quotas, and/or where game is regarded as a common resource.

Introduction

Aims and scope

The aim of the present study is to review hunting styles in Europe and North America, and to compare these styles to those adopted in the UK in terms of: 1) types and intensity of habitat and/or species management, and 2) positive and negative impacts of such management on non-target species. The report is split into two sections; (i) Governance and management of game bird hunting, and (ii) Management practices associated with game bird hunting.

Approach

Game birds were defined as Galliform species only; water birds and other hunted species such as doves were excluded. In order to access the full range of literature and capture as much information as possible about game bird hunting over a wide geographic area, information was taken from peer-reviewed articles identified through Web of Science and Google Scholar searches, grey literature identified through Google searches, government department websites and through expert advice. Data on bag statistics were obtained from grey literature, or directly through the relevant government department or agency. Sections of the report were also fact-checked by academics and practitioners from relevant countries.

Section 1.

Governance and Management of Game Bird Hunting

Game bird hunting in the UK

Sport shooting in the UK is worth an estimated £1.6 billion to the national economy, and game bird hunting represents two thirds of all gun days provided (PACEC 2006). Game birds are classed as *res nullis* (nobody's property) with the right to hunt belonging to the landowner, though the rights may be sold or leased (Mustin, Newey & Slee 2010). Thus, the majority of shooting takes place on private land (FACE 2010d) and state regulation of hunting only determines which species may be hunted, the hunting seasons, and permitted hunting methods (FACE 2010d). Landowners set their own bag limits, and usually monitor the populations in order to do so (Newey & Smith 2010). Management and monitoring of game populations, which may include intensive habitat, predator and disease management, is undertaken by one or more gamekeepers who are employed by the landowner or manager, and sport shooting is estimated to generate 5,300 FTE (full-time equivalent) jobs (PACEC 2006).

The main game bird species are the native red grouse (*Lagopus lagopus scoticus*), and two introduced non-native species; the pheasant (*Phasianus colchicus*) and red-legged

partridge (*Alectoris rufa*) (see Table 1.1 for list of game species and indication of the numbers shot). Permitted hunting methods are shooting and falconry (FACE 2010d). Hunting is typically done either by "driven shooting" where a line of stationary guns shoots at birds which are driven towards them by a line of "beaters", or by "walked up shooting" where a line of guns walks through the habitat and shoots at birds which are flushed ahead of them. At the national scale the most common game bird shooting provided is driven lowland game, and the vast majority of game birds shot in the UK are pheasants and the 'rear and release' of pheasant and partridge is common with 35 million pheasants and 6.5 million red-legged partridge released for shooting each year in the UK (PACEC 2006; Bicknell *et al.* 2010). In Scotland driven red grouse shooting is the most popular and economically important game bird shooting, although there is growing demand for shooting over pointers in the UK, and this style of shooting is probably more akin to the hunting style most commonly practised in the Nordic countries, North America and much of the rest of Europe. Habitat and species management, and predator control are all carried out intensively for game bird hunting in the UK especially for "driven" shoots.

Nordic countries (Finland, Norway, Sweden, Denmark and Iceland)

In all of these countries the hunting rights belong to the landowner and may be leased, and on public land the rights belong to and are administered by the relevant government agency (FACE 2005; FACE 2008a; FACE 2010b; FACE 2010c; The Environment Agency of Iceland 2010).

On privately owned land in Sweden and Finland (approximately 50% and 65% of the land in total, respectively) there is no state regulation of hunting other than defining which species may be hunted, methods of killing and stipulating the hunting season. However, there are a variety of levels of control of hunting on public and state owned land. For example, Metsähallitus is a state-owned company in Finland, which administers hunting on public land. On smaller areas of land Metsähallitus usually leases the rights to a local hunting association, whereas on larger areas the hunting is regulated by licences sold to individual hunters, with regional quotas applied to the number of licences (FACE 2010b). However, in northern Finland local people have the legal right to hunt freely on state land within their home municipality, and so quotas are administered by balancing the allocation of non-local permit hunters with the number of local "free" hunters (Kurki & Putaala 2010). In northern Sweden, all hunters can purchase a daily hunting permit, but local hunters can purchase an annual permit and still hunt when the limit of hunter days for that area has been met (Hornell-Willebrand 2010). However, in general the Swedish system is self-regulating as there is not sufficient hunting pressure that over-exploitation is a current concern. The possibility of closing hunting areas is reserved by authorities, but very rarely needs to be implemented (Hornell-Willebrand 2010). In both Sweden and Finland, species quotas are set based on censuses conducted by volunteer hunters. Finnish game populations

are monitored every summer and winter under supervision of the Finnish Game and Fisheries Research Institute. Census results are used to plan hunting bags and make recommendations on the number of licenses sold (FACE 2010b). In Sweden, data on population status of game birds are compiled by the Swedish University of Agricultural Sciences and used to set quotas (Hornell-Willebrand 2010).

In Norway, hunting seasons for the different game species are laid down by the Directorate for Nature Management. However, landowners may shorten the season if desired. The local authorities issue quotas for the relevant species in their area, with the quota being distributed among landowners based on the size of their properties (FP7 HUNT 2010a). On private land there is no systematic, national game bird management.

In Iceland, on both public and private land there is no legal regulation of bag limits for ptarmigan (the only game bird species, Table 1.1) but hunters are requested to limit the number killed to their own use (Rafn Beck & Sigursteinsdottir 2010). However the 'request' has no legal basis and 'use' is not defined, though hunters are not permitted to sell ptarmigan. Public lands, where any Icelander with a valid hunting licence can hunt, can be prone to over hunting. To obtain a licence for small game from the Wildlife Management Institute it is necessary to specify where, when and how the hunting will take place (The Environment Agency of Iceland 2010). A report must also be submitted after the hunt.

There is a universal requirement in the Nordic countries to pass a mandatory hunting examination in order to obtain a hunting permit (FACE 2005; FACE 2008a; FACE 2010b; FACE 2010c; The Environment Agency of Iceland 2010). Game bird species in Norway, Sweden and Finland are black grouse (*Tetrao terix*), hazel grouse (*Bonasa bonasia*), capercaillie (*T. Urogallus*), pheasant, willow grouse (*Lagopus lagopus*) and ptarmigan (*L. Muta*) (Table 1.1). In Sweden and Finland wild, though mainly released, partridge and pheasants are also hunted, and in Denmark grey partridge (*Perdix perdix*) and released pheasant are the only game birds commonly hunted (Table 1.1). Typically shooting is done by walking over the habitat with a dog and flushing birds to shoot, which is a similar style to walked up shooting over pointers in the UK. However, other styles in the Nordic countries include "stalking" for capercaillie and black grouse. Another style is using Finnish Spitz dogs, a particular breed which locates a bird (usually a capercaillie or black grouse) and barks, at which point the hunter will approach and shoot the bird. Falconry is prohibited in the Nordic countries (FACE 2005; FACE 2008a; FACE 2010b). Vocal lures may be used in Sweden (FACE 2005). Habitat management is less common and certainly not intensive for game bird populations. Management in the Nordic countries focuses on monitoring game populations and sustainable harvesting (e.g. Willebrand & Hornell-Willebrand 2001; Hornell-Willebrand 2010; Kurki & Putaala 2010). Some provisioning of supplementary food is carried out, for pheasant and grey partridge, but some hunters avoid this practice as they believe it will attract predators

(Arroyo & Beja 2002). Predator control is also carried out but not usually intensively, and rear and release of pheasants is practised in some areas, although this tends to be seen more as a "corporate event" than as an activity for "hunters".

Southern Europe (Spain, Portugal and Italy)

In Spain, hunting rights belong to the landowner, though the game itself is '*res nullis*' (FP7 HUNT 2010b). However, the landowner may lease the hunting right to a hunting society or another person, and this happens frequently. Hunting estates (which cover ca. 70% of the surface (López-Ontiveros 1986)), need to have a 5-year Hunting Plan by law, where species hunted and maximum harvested annual numbers are specified (as well as management techniques to be implemented). Hunting societies or managers may implement self-imposed restrictions on the hunting pressure for game bird species on poor years, for example by reducing the number of hunting days, the number of animals harvested, and the number of hunting hours per day (Angulo & Villafuerte 2003). However these are apparently not based on quantitative evaluation of the shooting surplus, but on appreciations of the game keepers of population being unusually low. Numbers shot each year need to be declared to the regional government to compile annual statistics, although in many cases declared numbers are estimates and monitoring of birds shot within hunting estates is not very tight.

In Italy, the right to hunt is controlled by state licence, but wildlife and land management are at the discretion of the hunter (FACE 1995a). No further details were available for Italy.

In Portugal numbers of hunting days and the daily bag per hunter are controlled by government. Most hunting takes place on Associative Hunting Areas, which are managed by an association of hunters and open to its members and invited persons. There are also Tourist Hunting Areas, which are managed commercially by private companies, Municipal Hunting Areas, which are managed by a range of local, public or private organisations, and open to hunters on payment of an access fee, and National Hunting Areas which are managed by a government agency and are also open to hunters on payment of an access fee. Creation of new hunting areas is subject to government approval of an annual hunting plan detailing management, game species to be hunted and how populations will be monitored. For resident released game birds (red-legged partridge and pheasant) the annual hunting plans for each hunting area define the numbers of each species that can be shot each year. For migratory species, the hunting bag is controlled through limitation of the number of hunting days per week and by a daily limit of numbers of each species that may be shot per hunter. For all game birds the daily hunting bags are set annually by the government hunting agency (Arroyo & Beja 2002).

In Southern Europe, in order to obtain a hunting license there is usually a hunters' exam, though, for example, the exam is not compulsory in all of the Spain. Red-legged partridge and quail (*Coturnix coturnix*) are the main game bird species in Spain and Portugal (Table 1.1). In Spain, pigeons, doves and Turdus spp., and Eurasian Woodcock (*Scolopax rusticola*) in northern regions, are also important, and in some areas hunting partridges with a live decoy is also popular, but this practice is prohibited in other areas. In Spain and Portugal both driven and walked up shooting are popular, and habitat management, species management, predator control and rear and release are all common management practices (Table 1.1) (Arroyo & Beja 2002; FP7 HUNT 2010b). In Italy most game bird shooting is carried out as walked up shooting, and game species include quail, red-legged partridge, Barbary partridge (*Alectoris barbara*), pheasant, rock ptarmigan, black grouse and rock partridge (*A. graeca*) (Table 1.1) (FACE 1995a).

Central Europe (France, Germany, Austria, Belgium, The Netherlands, Luxembourg)

In central Europe hunting rights belong to the landowner and may be leased (FACE 2002; FACE 2003; FACE 2004b; FACE 2010a; FACE 2010e; Fědĕration Saint-Hubert des Chasseurs du Grand-Duchĕ du Luxembourg 2010). In some cases this is contingent upon meeting a minimum area requirement (FACE 2002; FACE 2003; FACE 2004b; FACE 2010e; Fědĕration Saint-Hubert des Chasseurs du Grand-Duchĕ du Luxembourg 2010). In Germany and Austria, for example, this has led to the formation of "Associative Hunting Territories", where neighbouring land owners pool their hunting rights in order to meet the minimum area requirement, which are then usually leased either to an individual or to a "hunting association"(FACE 2002; FACE 2003).

In both Austria and Germany hunting is regulated at the Federal State (*Länder*) level. However, in both countries black grouse and capercaillie can only be shot with official authorisation and in line with an approved shooting plan. Pheasant and partridge are the most important game bird species, though there is no systematic monitoring of these populations (except for grey partridge in Germany) and there do not seem to be official bag limits imposed for most species (Table 1.1) (FACE 2002; FACE 2003). There are however bag limits for some species, such as pheasant and grey partridge, which are regulated on a Federal State level (Wichmann 2010, pers. comm.).

In France, in association with owners, managers and users, the Departmental Federation of Hunters develops departmental game management plans. Most species, particularly upland species (hazel grouse, black grouse, capercaillie and ptarmigan), have bag limits imposed. Furthermore, where bag limits do not exist, all upland game bird hunting is regulated with limits placed on the number of days when hunting is allowed, season bag limits, closed areas, and by the protection of hens for black grouse and capercaillie. There is also a requirement that hunters declare the number of upland birds shot. However, there is no legal obligation to manage hunting bags of pheasant,

quail and red-legged partridge, though there is increasing voluntary implementation of hunting plans for grey partridge (FACE 2010a).

In the Flemish region of Belgium, regulation requires that hunting be based on written management plans, including management goals and actions. This is typically organised through hunters forming 'Game Management Units' (GMU). The GMU must have a work area of at least 1,000 ha and submit a five year game management plan to the Research Institute for Nature and Forest (INBO). INBO coordinates annual game bag statistics and spring-population estimates from the GMUs, as well as monitoring trends as part of these in order to evaluate the sustainability of current game management (INBO 2010).

In the Netherlands there are no bag limits imposed and approximately 30,000 hunting licences are issued each year. Commercial hunting is prohibited, and non-Dutch nationals can only hunt in the Netherlands by personal invitation. Game Management Units (WBE) are formed of hunters, farmers and landowners, and issue game management plans for the area they cover (at least 5,000ha) on which hunting takes place (FACE 2004b).

In all cases there is a mandatory hunters' exam in order to obtain a hunting permit (FACE 2002; FACE 2003; FACE 2004b; FACE 2010a; FACE 2010e; Fědĕration Saint-Hubert des Chasseurs du Grand-Duchĕ du Luxembourg 2010). Permissible game species vary within the region (Table 1.1) but released pheasant and red-legged partridge are popular. Black grouse and capercaillie are hunted in France, Germany and Austria where hunting of these species is more tightly regulated. Style of hunting depends on species, and includes driven, and walked up shooting, and falconry. The degree of management varies depending on the country and the species, but habitat management, predator control, species management, and rear and release are all carried out in central Europe. For example, the provision of grain and/or water is common for grey partridge, pheasant and red-legged partridge in France (Arroyo & Beja 2002).

Eastern Europe (Estonia, Hungary, Poland Czech Republic, Latvia, Bulgaria,)

In Estonia, Hungary and Poland hunting rights belong to the state, regardless of land ownership (FACE 1995b; FACE 2004a; Keskkonnaministeerium 2010). However, in the Czech Republic, Latvia and Bulgaria hunting rights belong to the landowner (Anon 2001; Anon 2002; FACE 2008b). The game species and an indication of the number shot for each country is presented in Table 1.1.

In Estonia the land is divided into hunting districts, which are hunted over by hunting organisations. The government has devolved the issuing of hunting certificates, to the Estonian Hunter's Society (Keskkonnaministeerium 2010).

In both Hungary and Poland hunting rights can be transferred to hunting clubs which can rent territories over varying periods, otherwise the land is available to be hunted over only by the authorities. In Poland approximately 91% of the land is rented to clubs, and about 83% in Hungary (FACE 1995b; FACE 2004a). In Hungary ten year game management plans are coordinated by the "Komitatsbehorden" within the Agricultural ministry, and their implementation is monitored by the hunting authorities (FACE 2004a). In Poland, as in other Eastern European countries, local government set annual bag limits, but long term hunting plans and bag limits (3-5 years) are set by the Regional Forest Directorates in co-operation with the Polish Hunting Association (Krogulec 2010, pers. comm.). Furthermore, hunting clubs must employ a gamekeeper, acting in an official capacity, on each territory(FACE 1995b).

In the Czech Republic hunting can take place on forestry and agricultural land, and rights are administered by the Ministry of Agriculture to "hunting areas". These are areas of at least 500ha, which may consist of land owned by one or more land owners, in the latter case forming a "hunting guild". A game management plan must be produced and is based on a state assessment of habitat quality, state controlled minimum and maximum spring game stocks, bag limits, and results of censuses which the owner(s) of the hunting rights are required to carry out at a set time annually. Both census and hunting data are submitted to the state (Anon 2001).

In Latvia, about half of the forests are state owned and normally the state grants hunting rights to hunter's collectives (clubs) or individuals. Use of private and municipal land for hunting varies, some are let for a fee, others are let without charge, and some are not used for hunting at all. Most farmland is privately owned and this may also be used for hunting. The hunting department of the State Forest Service (SFS) coordinates territorial units regarding supervision and control on hunting. The hunters' seasonal card serves as a permit for hunting small game and the SFS must be informed of all hunting events (FACE 2008b).

In Bulgaria the area over which hunting is permitted (the total area excluding natural reserves) is divided into "Hunting economic regions" regardless of boundaries and ownership. Each of these regions is subject to a hunting development plan, which is issued by the Minister of Agriculture and Forests, and covers the development of forests and hunting, grading of game habitats and game taxation. It is a requirement in Bulgaria that all hunters belong to a "Hunting company", consisting of at least 20 members. These are further grouped in to "Hunting associations" with companies from neighbouring regions. Hunting is by licence, issued by the state forestry or by the state game breeding station and must be renewed every calendar year. For each region there is also a hunting permission, which states the names of hunters licensed to hunt there,

the number of hunting licences available, the date and place of hunting, and the species and number of permitted game (Anon 2002).

In all eastern European countries there is a mandatory hunting exam in order to obtain a hunting licence (FACE 1995b; Anon 2001; Anon 2002; FACE 2004a; FACE 2008b; Keskkonnaministeerium 2010). Game bird species vary within the region (see table 1), however released pheasant and grey partridge are common to most countries. In Estonia, game bird hunting has been impacted by declines in black grouse and capercaillie, which were formerly popular game species (Keskkonnaministeerium 2010). Most hunting is walked up with dogs, but driven shoots and capercaillie stalking are also practised in some cases. Falconry is prohibited in Bulgaria but permissible else where, but may require state approval (FACE 1995b; Anon 2001; Anon 2002; FACE 2004a; FACE 2008b). Hunting guards are employed in the Czech Republic and Bulgaria to carry out predator control, control poaching and ensure that game management plans are followed (Anon 2001; Anon 2002). In Bulgaria there are laws preventing burning in stubble fields, hedges, strips along roads, areas with dry vegetation and vegetation in high mountain pastures, and preventing forestry operations near capercaillie lek sites during the breeding season (Anon 2002). There are also measures in place to prevent logging operations in old-growth pine forests to ensure the availability of woodland grouse breeding sites in Latvia (FACE 2008b). In the Czech Republic release of non-native species (pheasant and red-legged partridge) for hunting must be approved by the relevant state agency (Anon 2001).

North America (USA and Canada)

In USA and Canada game belongs to no one, and therefore hunting rights do not belong to the landowner and are considered to be held in trust by the state (Sharp & Wollscheid 2009). The hunting of game species is administered by licence on both private and public land, although due to rights of trespass, in most parts of North America private landowners can charge a fee to access their hunting grounds ("fee hunting") (Leal & Grewell 1999; Gutierrez 2010, pers. comm.). Hunting of non-migratory game birds is administered at the state or municipal level. Sate wildlife agencies set hunting seasons, determine daily and seasonal bag limits, decide how many licences for specific game species will be sold and set the licence fees (Leal & Grewell 1999). In the USA a number of schemes have been implemented, on a state by state basis (e.g. "Ranching for Wildlife" in Colorado), by which landowners are rewarded for certain management activities by modifying hunting regulations on their land (e.g. longer seasons, ranch-specific harvest limits) to allow them to capture more of the benefits of fee hunting (Leal & Grewell 1999). Bag statistics are collected by most states, but may be estimates based on the number of licences issued, and returns from a sample of hunters (e.g. wild game in Nebraska, (Lusk 2010, pers. comm.)), or may be an actual number based on mandatory checking of game (e.g. wild turkey in West Virginia (Wilson 2010, pers. comm.)) (Table 1.2). Game birds include quail, grouse, old world partridge, wild turkey and pheasant (Table 1.2).

Most hunting takes place alone or in very small groups, walking freely through the habitat with or without dogs (used to flush birds). Vocal lures may be used for some species, and driven shooting is rare and restricted to releases of reared birds on game reserves (Gutierrez 2010, pers. comm.). Habitat and species management are widely, though not ubiquitously, practised. For example, in Quebec, habitat management guidelines are available for some species, which are typically applied by landowners or managers to increase the quality of game habitats on small territories (Blanchett 2010, pers. comm.). In New York State, habitat management is conducted for game birds on public lands by the New York State Department of Environmental Conservation (Division of Fish, Wildlife, and Marine Resources; (Schiavone 2010, pers. comm.). However, approximately 85% of the land in New York is privately held, which limits the large scale impact of such management. There are, however, some programs which provide help for habitat management on private lands, but these are limited by a lack of staff and funding (Schiavone 2010, pers. comm.). In Ontario, management for most species is indirect as a result of land use and forest planning (Hubert 2010, pers. comm.). Rear and release is widespread but not common, for example, in Massachusetts, pheasants and some, bob white, quail are released (Massachusetts Division of Fisheries and Wildlife 2010, pers. comm.), while in British Columbia this practise is no longer in favour, though some hunting clubs or businesses are allowed to release captive-bred non-native game birds on private lands for hunting and dog training (Chutter 2010, pers. comm.). In Ontario, the small wild population of bobwhite quail are protected, but pen-reared birds can be released for immediate hunting on small put and take preserves which are not near remnant wild populations (Hubert 2010, pers. comm.). Predator control is not usually practised for the management of game bird populations.

Number of game birds shot

The data presented in Table 1.1 suggest that many more game birds are shot in the UK than any other country. However, a direct comparison between countries is not possible and any comparison needs to be approached with caution. The high number of game birds shot in the UK is mainly due to the shooting of rear and release pheasants. If these were removed then the inter-country difference would be much less. Similarly, Spain rears large numbers of red legged partridge. It would be interesting to compare densities of wild populations by country and another comparison of reared birds by country. However, we are not able to do this at this stage because a) bag data is missing from a number of species in different countries making comparisons invalid and b) it is not clear, from Spain for example, how many pheasants s are reared and released compared to the wild population. This highlights the need for a more systematic and uniform data recording protocol, at least at the EU level in order to make these comparisons.

Summary

Governance:

There are essentially three main styles of governance for game bird hunting in Europe and North America:

Landowner regulated: hunting rights belong to the landowner. No bag limits or monitoring of game populations, other than that done by the landowner/manager. This is the case in The UK and on privately owned land in much of Europe.

State regulated: hunting rights usually belong to the landowner, though there may be some land area restrictions. Bag limits are set by a state agency, at least for some species, and may or may not be based on monitoring of game populations. Hunting is regulated by some form of license or permit. This applies to much of the public land in Europe.

State owned: game and hunting rights belong to the state (or are otherwise controlled by them) and not to the landowner. Hunting is regulated by licence, and there are usually bag limits imposed, which may or may not be based on monitoring of game populations. This is the governance style in North America, Hungary, Poland and Estonia.

Hunting styles:

The majority of game bird hunting in Europe and North America is walked up shooting over dogs, or a version of this. In the UK, rough shooting is important but driven, and walked up, shooting for galliformes, (pheasant and grouse) is the dominant shooting style across the country although this also occurs in certain areas of France and Southern Europe and in certain parts of North America (e.g. Bobwhite quail in Texas). Falconry is permitted in the UK, North America, some parts Eastern, Central and Southern Europe. Vocal lures may be used in Sweden and North America, but are prohibited in many countries. Stalking of capercaillie and black grouse occurs in the Nordic countries and parts of central and Eastern Europe, and hunting with Finnish Spitz dogs is practised in Fennoscandia.

	Lowland											Upland					
Country	Common pheasant (*Phasianus colchicus*)	Other pheasant species†	Common quail (*Coturnix coturnix*)	Other quail species†	Guineafowl (*Numida meleagris*)	Red-legged partridge* (*Alectoris rufa*)	Grey partridge (*Perdix perdix*)	Wild turkey (*Meleagris gallopavo*)	Rock partridge (*Alectoris graeca*)	Chukar (*Alectoris chukar*)	Other partridge species†	Willow grouse (*Lagopus lagopus*)	Red grouse (*Lagopus lagopus scoticus*)	Hazel grouse (*Bonasa bonasia*)	Black grouse (*Tetrao terix*)	Capercaillie (*Tetrao urogallus*)	(Rock) ptarmigan (*Lagopus muta*)
United Kingdom	15000000	-	-	-	-	2600000	NA	-	-	-	-	-	400000	-	NA**	-	NA
Finland	50500	-	-	-	-	-	5900	-	-	-	-	4600††	-	59700	101100	21400	NA††
Norway	NA	-	-	-	-	-						217002		NA	21900	10500	95189
Sweden	52500	-	-	-	-	-	3300					63000		9200	25300	21500	19000
Denmark	707000	-	-	-	-	-	31000										
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85 000
Spain	252575	-	1123091	-	-	3381652	-	-	-	-	-	-	-	-	-	-	-
Portugal	NA	-	NA	NA	-	NA	-	-	-	-	-	-	-	-	-	-	-
Italy	NA	-	NA	NA	-	NA	-	-	NA	-	NA	-	-	-	NA	-	NA
France	NA	NA	NA	NA	-	NA	NA	-	NA	-	-	-	-	NA	NA	NA	NA
Germany	318821	-	-	-	-	-	12252	-	-	-	-	-	-	-	NA	NA	-
Austria	160900	-	NA	-	-	-	108000	-	-	-	-	-	-	160	1700	360	-
The Netherlands	75000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Belgium‡	130121	-	-	-	-	-	23406	-	-	-	-	-	-	-	-	-	-
Luxembourg	NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Czech Republic	NA	NA	-	-	NA	-	-	NA	NA	-	-	-	-	-	-	-	-
Latvia	NA	-	-	-	-	-	-	-	-	-	-	-	-	NA	NA	NA	-
Bulgaria	NA	-	NA	-	NA	-	NA	NA	NA	NA	-	-	-	-	-	NA	-
Estonia	NA	-	-	-	-	-	NA	-	-	-	-	-	-	-	NA	NA	-
Hungary	NA	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-
Poland	80700	-	-	-	-	-	16400	-	-	-	-	-	-	-	-	-	-

NA = bag data not available

*increasing numbers of red legged partridges are being released in the UK uplands for sport

**there is currently a voluntary ban in most areas of the UK, but this species remains legal quarry and small numbers are shot each year

† "other pheasant species" include Reeve's pheasant (Syrmaticus reevesii) and Silver pheasant (*Lophura nycthemera*); "other quail species" includes Japanese quail (*Coturnix japonica*), Bobwhite quail (*Colinus virginianus*) and California quail (*Colinus californica*); "other partridge species" includes Barbary partridge (*Alectoris Barbara*) and Black partridge (*Melanoperdix niger*)

††The figure for willow grouse includes ptarmigan

‡These data are for Flanders only

BAG DATA (WHERE SHOWN) ARE FROM ONE YEAR BETWEEN 1998 AND 2009 (DEPENDING ON AVAILABILITY)

Table 1.1: Lowland and upland game birds hunted in the UK and Europe. Figures are bag data for a single year between 1998 and 2010 (depending on availability). Blank spaces indicate no current season for that species in that country, NA indicates that bag data were unavailable at the time this report was produced.

Country	Common pheasant (*Phasianus colchicus*)	Bobwhite quail (*Colinus virginanus*)	California quail (*Callipepla californica*)	Gambels quail (*Callipepla gambelii*)	Scaled quail (*Callipepla squamata*)	Mountain quail (*Oreorgyz pictus*)	Montezuma quail (*Cyrtonyx montezumae*)	Ruffed grouse (*Bonasa umbellus*)	Blue grouse (*Dendragopus obscurus / fuliginosus*)	Spruce grouse (*Falcipennis canadensis*)	Sage grouse (*Centrocercus urophasianus*)	Sharp-tailed grouse (*Tympanuchus* phasianellus)	Greater prairie chicken (*Tympanuchus cupido*)	Lesser prairie chicken (*Tympanuchus pallidicinctus*)	Willow grouse (*Lagopus lagopus*)	White-tailed ptarmigan (*Lagopus leucura*)	(Rock) ptarmigan (*Lagopus muta*)	Chukar (*Alectoris chukar*)	Grey partridge (*Perdix perdix*)	Wild turkey (*Meleagris gallopavo*)
Alaska	-	-	-	-	-	-	-	NA	NA	NA	-	NA	-	-	NA	NA	NA	-	-	-
Alabama	-	138700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42400
California	540727	-	382130	43533	-	104765	-	8466[∂]	See ruffed grouse[∂]	-	47	-	-	-	-	-	-	149265	-	30864
Colorado	43330	3352	-	871	8955	-	-	-	15745	-	1197	286	NA	-	-	297	-	NA	-	NA
Florida	-	2147	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	785
Hawaii[¶¶]	NA	-	NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NA	-	NA
Idaho	91600	112100[‡‡]	See bobwhite[‡‡]	-	-	-	-	113400[‡]	-	-	4900	15900	-	-	-	-	-	46900	29100	5630
Illinois[∂∂]	64262	123933	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	31249
Indiana	NA	NA	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-	-	NA
Kansas	746000	485000	-	-	NA	-	-	-	-	-	-	-	5400	910	-	-	-	-	-	38014
Kentucky	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39271
Louisiana	-	39200[ΠΠ]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5600
Maine	NA	NA	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-	-	NA
Maryland	2944	3788	-	-	-	-	-	1319	-	-	-	-	-	-	-	-	-	-	-	4072
Michigan	NA	NA	-	-	-	-	-	NA	-	-	-	NA	-	-	-	-	-	-	-	44729
Mississippi	-	50044	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23377
Missouri	31260	191172	-	-	-	-	-	26[Ω]	-	-	-	-	-	-	-	-	-	-	-	56362
Minnesota	400000	-	-	-	-	-	-	358000	-	19000	-	10000	120	-	-	-	-	-	8000	14630
Nebraska**	299360	96700	-	-	-	-		-	-	-	-	22584[†]	See sharp-tailed grouse[†]	-	-	-	-	See grey partridge[††]	212[††]	NA
New Mexico	NA	NA	-	NA	NA	-	NA	-	NA	-	-	-	-	-	-	-	-	-	-	NA
New York	109447	NA	-	-	-	-	-	121663	-	-	-	-	-	-	-	-	-	-	-	33011
Oklahoma	115000	350000[ΩΩ]	-	-	See bobwhite[ΩΩ]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44750
Oregon	33720	-	38684	-	-	14258	-	63732	31910	-	784	-	-	-	-	-	-	57628	8921	5713
South Carolina[Δ]	9669	59470[ΔΔ]	-	-	-	-	-	558	-	-	-	-	-	-	-	-	-	5872	-	16924
South Dakota	NA	-	-	-	-	-	-	NA	-	-	NA	NA	NA	-	-	-	-	-	NA	NA
Tennessee		NA	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-	-	-
Texas	56789	584533	-	NA	145417	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37056
Utah	6760	-	35211[§§]	See California quail[§§]	-	-	-	19436	18239	-	702	254	-	-	-	21	-	27858	4376	2770
Vermont	NA	-	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-	-	6919
Washington	87024	90505[λλ]	See bobwhite[λλ]	-	-	See bobwhite[λλ]	-	101685[λ]	See ruffed grouse[λ]	See ruffed grouse[λ]	-	-	-	-	-	-	-	11279	3200	-
West Virginia	NA	NA	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-	-	10995
Wisconsin	241732	912	-	-	-	-	-	388849	-	-	-	27	-	-	-	-	-	-	91	60862
Alberta	18719	-	-	-	-	-	-	137961	388	12275	-	14899	-	-	10[Π]	See willow grouse[Π]	-	-	30187	NA
British Columbia	2698	-	1377	-	-	-	-	76471	22944	38531	-	1304	-	-	282*	See willow grouse*	See willow grouse*	1414[§]	See chukar[§]	357
Manitoba	-	-	-	-	-	-	-	NA	-	NA	-	NA	-	-	NA	-		-	NA	524
Newfoundland	-	-	-	-	-	-	-	26000	-	38000	-	-	-	-	41000	-	18000	-	-	-

and Labrador¶																				
Northwest Territories	-	-	-	-	-	-	-	NA	NA	NA	-	NA	-	-	NA	NA	NA	-	-	-
Nova Scotia	NA	-	-	-	-	-	-	NA	-	-	-	-	-	-	-	-	-	-	-	-
Nunavut	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NA	-	NA	-	-	-
Ontario	NA	NA	-	-	-	-	-	NA	-	NA	-	NA	-	-	NA	-	NA	-	NA	NA
Quebec	-	-	-	-	-	-	-	NA	-	NA	-	NA	-	-	NA	-	NA	-	NA	1332
Saskatachewan	NA	-	-	-	-	-	-	NA	-	NA	-	NA	-	-	NA	-	NA	-	NA	-
Yukon	-	-	-	-	-	-	-	NA	NA	NA	-	NA	-	-	NA	NA	NA	-	-	-

*this figure is for all three ptarmigan species
**these data do not include rear and release (47877 pheasant, 7037 chukar and 2049 bobwhite quail)
†most hunters are unable to accurately distinguish sharp-tailed grouse from greater prairie-chickens, so this figure is for both species. Based on wing collection surveys used to obtain harvest age-ratios, typically 75% of this number is sharp-tailed grouse, with the remaining 25% greater prairie chicken.
††this figure is for both grey and chukar partridges
‡this figure is for "forest grouse"
‡‡this figure is for bobwhite and California quail
§this figure is for chukar and grey partridge combined
§§this figure is for California and Gambel's quail combined
¶bag data are only available for the island portion of the province
¶¶other huntable game birds on some Hawaiian islands include green pheasant, kalij pheasant, grey francolin, black francolin, Erckels francolin, Japanese quail and chestnut-bellied sand grouse
Πthis figure is for "ptarmigan" which includes willow grouse and white tailed ptarmigan
ΠΠΠApproximately 94% of these are pen-reared
Δdata for ruffed grouse and bobwhite quail are from 2005, all other data are 2009-10. Pheasant and chukar are only hunted as pen reared birds.
ΔΔdoes not include pen reared birds, 160339 in 2009-10.
∂this figure is for both ruffed and blue grouse combined.
∂∂these figures do not include farm reared birds, for which data are not available
Ωseason was closed in 2010-11
ΩΩthis figure is for bobwhite and scaled quail combined
λthis figure is for "forest grouse" i.e. ruffed, blue and spruce grouse.
λλthis figure is for bobwhite, California and mountain quail combined

Table 1.2: Game birds hunted in a sample of states and provinces in North America. Figures are bag data for a single year between 2005 and 2010 (depending on availability). These are almost always estimated from random hunter surveys. The most notable exception is for wild turkey, for which most states require hunters to "check" hunted birds. Blank spaces indicate no current season for that species in that state or province, NA indicates that bag data were unavailable at the time this report was produced.

Section 2.

Management practices associated with game bird hunting

The following section examines the most common management activities for game bird hunting in Europe and North America, indicating the areas in which the practice is popular, and highlighting what is known about the biodiversity impacts of these practices. Regions in which management practices for game birds occur and their known positive and negative biodiversity impacts are summarised in Table 2.

Habitat management

Non-agricultural habitats

Habitat disturbance

In the UK, rotational burning (muirburn) of heather (*Calluna vulgaris*) is carried out in early spring and late autumn, to generate and maintain a mosaic of heather ages to provide optimal foraging, nesting habitat, and cover from predators is a common and widespread upland habitat management practice (Hudson & Newborn 1995; Grant *et al.* in prep). Muirburn is apparently beneficial to many waders (Haworth & Thompson 1990; Daniel 2010; Tharme et al 2001) but detrimental for the most important moorland passerine, the Meadow pipit *Anthus pratensis*, which is less abundant where burnt areas are common (Smith *et al.* 2001). Other studies comparing the distribution and/or abundance of bird species between moorland areas managed and unmanaged for grouse have shown that some species, including important waders, were most abundant in areas managed for grouse, whereas passerines were less abundant (Haworth & Thompson 1990; Tharme *et al.* 2001, although see Brown & Bainbridge 1995). However, separating the relative effect of habitat management versus other management practices was problematic. In a wider analysis, Thompson *et al*. (1997) found that in the Scottish Highlands, bird species were more widely distributed in areas with little or no grouse moor than in areas with much grouse moor, but in Southern Scotland, England and Wales the converse was true. They suggested that species richness and diversity would increase over upland areas in the absence of burning, if scrub and woodland developed in open mosaics, but the abundance of some moorland birds would be greatly reduced. Some studies have shown that plant species richness and diversity increase with rotational muirburn, however they have been geographically restricted, have not covered blanket bog habitats, and may not have been truly representative of grouse moor management in terms of burn severity and rotation length (Grant *et al.* in prep). There may be detrimental effects of muirburn on plant species of conservation importance such as juniper and sphagnum mosses, although evidence is generally lacking (Grant *et al.* in prep). Finally, rotational muirburn on dry dwarf shrub heath increases diversity and abundance of some invertebrate groups,

through increased structural diversity of the vegetation (Grant *et al.* in prep). However, this is dependent on the muirburn regime, and where the development of unmanaged heather stands is prevented invertebrate abundance and diversity may decrease, and some groups such as the lepidoptera may be particularly adversely affected (Grant *et al.* in prep).

Disturbing the habitat through burning, "disking" (mechanically opening up habitat patches) and herbicide application is a common practice in game bird management in North America, for maintaining a habitat mosaic, promoting the growth of food plants, and controlling brush and hardwoods (Holechek *et al.* 1982; Webb & Guthery 1983; Peoples *et al.* 1994; Welch *et al.* 2004). Prescribed burning may increase the abundance or diversity of non-game birds, however this may not be the case in the years immediately following burning treatment (Petersen & Best 1987; Reynolds & Krausman 1998). For example, Petersen and Best (1987) showed that prescribed burning of sagebrush to produce a habitat mosaic including open patches of forbs and bare ground increased the number of non-game bird species relative to unburned areas. Disking may be used to create a mosaic of successional stages in scrub habitat, for example to benefit bobwhite quail management, and may reduce the number of scrub dwelling non-game birds, but may be beneficial to other non-game species (Vega & Rappole 1994).

Grazing control

In the UK, grouse moor management includes manipulating sheep and deer numbers to change the grazing regime (Grant *et al.* in prep). Low levels of grazing benefit grouse moor management by maintaining the sward height and controlling invasion of trees, and thus benefit species that profit from these characteristics (Hudson (Hudson & Newborn 1995; Baines 1996). High levels of grazing remove beneficial plant species and affect heather cover detrimentally, but may be beneficial for maintaining high grass levels, and thus for the species dependent on grass areas (Redpath & Thirgood 1999b; Smith *et al.* 2001). In particular, high numbers of deer, in the absence of sheep, damage heather and reduce upland plant species diversity due to a dominance of coarse grass species {DeGabriel et al. 2011).

North American rangeland being managed for game birds will typically be under a rest-rotation, or deferred-rotation grazing system, to allow for reduced periods of disturbance during critical game bird life-cycle stages (Anderson & McCuistion 2008). Additionally, a light to moderate, and flexible stocking rate is typical (Anderson & McCuistion 2008). This type of grazing regime may be beneficial to passerines (Baker & Guthery 1990). The most adverse effects of rangeland grazing on non-game species result from heavy use of riparian areas, and a subsequent loss of food and cover, together with a general reduction in habitat diversity (Holechek *et al.* 1982). However, as these present adverse impacts for game birds too, in areas managed for game bird hunting temporary fencing of sections along streams may be used to enhance game bird habitat, and thus also benefit other

wildlife (Holechek *et al.* 1982). In Oregon this process has been shown to allow shrub and under-storey species establishment, which also stabilises stream banks and enhances fish populations (Holechek *et al.* 1982).

Forest management

Forest managers in Europe and North America may take account of game bird habitat suitability when managing forest habitats, though the management itself is not usually aimed at game bird hunting specifically. For example, in Finland, forest planners and managers are expected to be aware of the habitat requirements of forest grouse species, however forests are mainly private and so forest planning and management for game birds may be difficult at larger scales (Arroyo & Beja 2002). In France, forest management guidelines for capercaillie exist, and may be compulsory (Arroyo & Beja 2002), and in Bulgaria there are laws preventing forestry operations near capercaillie lek sites during the breeding season (Anon 2002). In Sweden, hazel grouse have been shown to be at higher densities in less intensively managed forest landscapes, and to be associated with un-thinned, older stands rich in deciduous trees and with a well-developed field layer (Åberg, Swenson & Angelstam 2003). In central Europe, historical forestry practices created new habitats for capercaillie, black grouse and hazel grouse (Klaus 1991). However, modern forestry practices such as clear cutting and the use of biocides and fertilisers are having detrimental effects (Klaus 1991). In North America, the maintenance of clearings is an accepted method for improving forest habitat for wild turkeys (Healy & Nenno 1983; Heffelfinger *et al.* 2000). Old logging roads may be converted to act as food plots for ruffed grouse by planting them to herbaceous cover such as orchard grass (*Dactylis glomerata*) or clover (*Trifolium spp.*), which has been shown to provide high invertebrate biomass (Hollifield & Dimmick 1995). This species also benefits from forest management which creates openings in the canopy to encourage herbaceous plant growth, such as prescribed fire or cutting (Jones *et al.* 2008). This may sometimes be used as a prescribed management tool specifically for ruffed grouse (Yahner 1984). Yahner (1984) found that abundance and species richness of non-game birds was higher in forest managed on a prescribed cutting rotation for ruffed grouse, than in unmanaged forest areas, and that species adapted to early successional habitats benefited most. Species for which such management practices may prove detrimental in the long-term include two neotropical migrants, the ovenbird (*Seiurus aurocapillus*) and the red-eyed vireo (*Vireo olivaceus*), which are both more sensitive to increased fragmentation resulting from clear-cutting (Yahner 1993).

Management practice	Practised in	Positive impacts	Negative impacts
Habitat – disturbance	• Important in the UK and North America	• Evidence of positive effects on waders in the UK and some passerines in North America • Muirburn may increase plant species richness • In dry heath, muirburn may increase the abundance and diversity of invertebrates	• Positive effects of habitat disturbances on non-game birds may not be apparent in the years immediately following treatment • Muirburn is detrimental to meadow pipt • Muirburn may be detrimental to juniper and sphagnum mosses, but evidence is lacking • If the development of unmanaged heather stands is prevented, then muirburn may decrease invertebrate abundance and diversity • Muirburn may have negative impacts on some lepidopterons • Disking of scrub habitats may be negative for non-game scrub-dwelling birds.
Habitat – grazing	• Important in the UK and North America	• Low levels of grazing associated with grouse moor management will benefit species which use heather moorland habitats, and may prevent the loss of important species to over-grazing. A high level of deer grazing, in the absence of sheep, reduces plant diversity. • North American rangeland passerines benefit from grazing regimes implemented for game bird management • Grazing exclosures in riparian areas help to stabilise stream banks and provide cover for non-game animals	• Low levels of grazing associated with grouse moor management are detrimental to grassland species
Habitat – forest management	• Important in central and eastern Europe, and particularly important in the Nordic countries and North America	• Abundance and species richness of non-game birds has been found to increase with a prescribed cutting rotation for ruffed grouse. Species adapted to early successional habitats benefit most.	• Long-term detrimental effects of clear-cutting are expected for species such as the ovenbird (*Seiurus aurocapillus*) and the red-eyed vireo (*Vireo olivaceus*), which are both more sensitive to increased fragmentation
Habitat – crop management	• UK, Europe and North America	• Planting of game crops is beneficial to other farmland species, in particular invertebrate abundance and passerine density may increase. • Restricted use of agro-chemicals around	

		crop edges (conservation headlands) is widely beneficial to farmland wildlife. There is strong evidence that reduced pesticide use increases the diversity or abundance of invertebrate, small mammals and birds. Pesticide free areas may also provide refugia for predatory and parasitoid arthropod species. However, there is no evidence that these practices are more common in game than non-game areas.	
Habitat – set aside, fallow and CRP	• UK, Europe and North America	• Set-asides sown with brood-rearing cover may provide refuge for rare arable wildflowers • Where game bird management of RSA involves natural regeneration with stubbles left over-winter, both game birds and other species should benefit in winter • CRP has been beneficial for non-game grassland songbirds However, again the extent to which ranches are enrolled in CRP to benefit game birds specifically is generally un-documented. (but see "CP33 – Habitat buffers for upland birds" which provides native herbaceous grasses and forbs for nesting and brood-rearing habitat for bobwhite quail, but also achieves wildlife habitat goals in agricultural systems as part of CRP)	• Overall botanical diversity is higher following natural regeneration rather than sowing to brood-rearing cover • The value of RSA for nesting and brood-rearing is more variable, because vegetation cover is frequently destroyed for cultivation in spring. Delaying RSA cutting for the benefit of game birds could be generally favourable for a number of invertebrates and rare arable wildflowers
Habitat - field margins and hedgerows	• UK, Europe and North America	• More hedgerows are planted on game estates, which may be valuable to other wildlife. However, the highest bird species richness and abundances are associated with tall and wide hedges with many trees, as opposed to typically short, narrow game hedges with few mature trees. • Herbaceous field margins benefit wildlife, particularly in intensive farmland, but may not be more common in game than non-game areas	
Habitat – farm woodlands	• UK	• Game bird management may support the	• Some evidence of marginally negative

		creation of new woodlands, and the preservation and management of old ones • There is some evidence of positive associations of woodland management for pheasants on butterflies and birds but it is limited and contradictory	effects on plants
Predator control	• UK and Europe, but not usually intensive in the Nordic countries • Rare in North America • Most intensive in UK and southern Europe	• Increased breeding success, density and diversity of waders • Increased breeding success and abundance of passerines	• Reduction in local abundance of predator species • Potential for meso-predator release • Illegal control of protected species
Rear and release	• UK, Europe and North America • Most important in UK and southern Europe • Banned in the Netherlands	• Potential consumption of non-native flora	• Habitat changes such as altered hedgerow structure, soil enrichment and browsing of native flora • Competition for invertebrate food resources during the breeding season • Genetic pollution through hybridisation with wild populations • Introduction or maintenance of parasites in wild populations
Species – parasite control	• UK and Europe • In the UK culling of mountain hare and use of sheep as "tick mops" are also common practices on grouse moors	• Medicating birds prior to, and after, release reduces the risk of disease transfer to wild game birds and passerines • Reduced tick prevalence as a result of "tick mops" may benefit other birds, such as waders	• Unknown population and conservation impacts of culling on mountain hare in the Scottish uplands • High numbers of sheep (as "tick mops") may have negative habitat effects
Species – food and water	• Provision of food in UK, Europe and North America • Water provision common in arid areas such as southern United States and southern Europe	• Provision of food and water for game birds is likely to benefit other species, but evidence is lacking	• Hypothesised increased risk of predation and disease transfer

Table 2: Regions in which management practices for game birds occur, and their known positive and negative biodiversity impacts.

Agricultural habitats

The extent to which the following agricultural management practices are used primarily for game bird management is un-quantified. In many cases the practices may be no more prevalent in areas managed for game bird hunting than in agricultural areas not managed for that purpose. It is therefore important to bear in mind that while these practices have potential conservation benefits (outlined below), these benefits may not necessarily relate to game bird hunting only.

Crop management

Game crops have been grown extensively to provide cover and food for game birds during critical seasons of the year, particularly in winter and in the brood-rearing season (CTGREF 1975; Anon 1986; Reino, Borralho & Bugalho 2000). For example, in France, grey partridge management involves planting strips of maize and kale based cops in a mosaic, to ensure both summer and winter cover (Bro *et al.* 2004). While in the UK, kale, quinoa and cereals are planted as winters and summer cover crops for pheasant and red-legged partridge (Sage *et al.* 2005). However, Bro *et al.* (2004) report that due to increased predation risks at strip-field edges, and a general lack of response of partridge populations to this management scheme, this type of management may not be particularly effective for grey partridge. Management of wild turkey in North America calls for the planting of food plant plots, such as wheat, rye or oats, in areas where native plants or agricultural crops do not provide sufficient food (Litton & Harwell 1995). The planting of cover and food crops does seem to be beneficial for a range of farmland species, though only a few studies have analysed its effects in some detail (Dover 1988; Hinsley 1999; Stoate, Szczur & Aebischer 2003; Sage *et al.* 2005). For example, Sage *et al.* (2005) showed that winter and summer game crops held higher densities of songbirds than did adjacent arable crops. It is also expected that food crops will attract invertebrates during the spring and summer (e.g. Litton & Harwell 1995), which are a further source of food for game and non-game species alike. The value of crops to game birds is also expected to improve through under-sowing (mixing spring-sown cereals with grasses and clovers), with potential general benefits for biodiversity (Potts 1997). Some efforts have been made to restore under-sowing under agri-environment schemes, but it is apparently little used in game bird management.

The creation of conservation headlands, whereby the use of agro-chemicals is restricted around the crop edges during the breeding period, is probably the best example of a game bird management prescription (primarily implemented for grey partridge) that has widely beneficial implications for farmland wildlife (Sotherton, Boatman & Rands 1989; Sotherton 1991). Indeed, there is strong evidence that the reduction of pesticide applications needed to increase the food

supply for game bird chicks also increases diversity or abundance of invertebrates, birds and small mammals (Sotherton, Rands & Moreby 1985; Tew 1988; Sotherton, Boatman & Rands 1989; Hassall *et al.* 1992; Wilson 1994). These pesticide-free areas may also be valuable refugia for predatory arthropod, and parasitoid species (Chiverton & Sotherton 1991). Despite their value, however, conservation headlands may not be as widely used in game bird management as might be expected (Hinsley 1999) and the technique may be more commonly used in general wildlife conservation programmes, probably due to its progressive incorporation in agri-environment subsidy schemes (Anon 1995a; MAFF 1998; Chiverton 1999).

Another management practice, also designed as a grey partridge management tool, comprises the creation of "beetle banks" (raised ridges across the middle of an arable field planted with tussock-forming grasses). These are designed primarily to enhance populations of polyphagous invertebrate predators in arable field systems, to help control aphid pests in the adjacent crop (Chiverton 1989; Anon 1995b). Beetle banks seem to be beneficial to game birds (Thomas, Goulson & Holland 2001), though they have not been designed originally with this purpose. Beetle banks are apparently beneficial for farmland wildlife overall, primarily by providing suitable habitats for a range of species and reducing the use of pesticides in crop protection (Thomas, Wratten & Sotherton 1992; Sotherton 1995; Collins *et al.* 1997). Nevertheless, there is no evidence that beetle banks are used more extensively in areas managed for game birds than elsewhere, and thus the benefits of this technique cannot be ascribed solely to management for hunting (Hinsley 1999).

Finally, game bird management may include delaying crop harvesting to protect nests from destruction. Casas and Vinũela (2010) found that crop harvesting was the main cause of nest failure for red-legged partridge on a sample of game estates in central Spain. In North America, it has been demonstrated that hatching success of pheasant over a ten year period was lower in harvested than un-harvested hayfields (Warner & Ette 1989).

Field margins and hedgerows

Hedgerows are important for both game birds and farmland wildlife (Hinsley & Bellamy 2000; Maudsley 2000), and thus game management may have positive effects by contributing to the retention of hedges in game estates. Indeed, British landowners involved in hunting and shooting were shown to plant more new hedges than those who did not (MacDonald & Johnson 2000; Oldfield *et al.* 2003). However, game hedges may not be the most favourable to wildlife, as management for game bird shooting recommends relatively short and narrow hedges, with few mature trees (Rands & Sotherton 1987; Sotherton & Rands 1987;

Aebischer, Blake & Boatman 1994; Anon 1995b), whereas for instance the highest bird species richness and overall abundance is associated with tall and wide hedges, with many trees (Parish, Lakhanii & Sparks 1994; MacDonald & Johnson 1995; Sparks, Parish & Hinsley 1996). In any case, no single type of hedge is likely to benefit all species, and thus game hedges may still have positive net benefits if they contribute to increase hedge extent and diversity at the landscape scale (Hinsley *et al.* 1999).

Herbaceous field margins, or "linde" are beneficial to both game birds and wildlife in general, particularly in intensive farmland (Hooper 1987; Morris & Webb 1987; Vickery, Feber & Fuller 2009; Casas & Vinũela 2010). Management of herbaceous strips for game birds is targeted at reducing the negative impacts of farming operations such as pesticide spraying, while improving the use of the area for nesting birds and over-wintering of beneficial insects (Anon 1995b; Casas & Vinũela 2010). Game bird management thus has the potential to promote the conservation of such boundary structures and their associated biodiversity (Dennis & Fry 1992). Nevertheless, data is lacking on whether there are more herbaceous field margins in game than in non-game areas, and on the extent to which the management of these habitats for game bird management benefits other taxonomic groups (e.g., (Lagerlöf, Stark & Svensson 1992).

Set-aside, fallow and the Conservation Reserve Programme (CRP)

Since the late 1980s, the set-aside scheme of the European Common Agricultural Policy (CAP) has taken agricultural land out of production for periods of one (rotational set-aside; RSA) to several years (non-rotational set-aside; NRSA), introducing management challenges and opportunities for game birds (Sotherton *et al.* 1994; Peeters & Decamps 1998) and other wildlife (Berg & Part 1994; Tattersall *et al.* 1997; Buckingham *et al.* 1999). Set-asides may be comparable (depending on management) to the fallow fields characteristic of more extensive farmland, where portions of land are left fallow to recover soil fertility after a period of cultivation, creating a rotational farming mosaic that is important to farmland wildlife (Suarez, Naveso & De Juana 1997; Delgado & Moreira 2000).

Management of NRSA to the benefit of game birds may involve natural regeneration in the first year, and then sowing of non-harvestable seed mixtures to develop suitable vegetation for either winter or brood-rearing cover (Anonymous, 1996). Set-asides sown with brood-rearing cover may provide refuge for rare arable wildflowers, and may also be preferable where suppression of agricultural weeds is a priority (Sotherton 1998; Sotherton *et al.* 1998; Critchley & Fowbert 2000). However, NRSA may not be effective for plant conservation, as natural regeneration increases botanical diversity on NRSA, and habitats resembling permanent semi-natural grassland may develop in the long-term (Critchley & Fowbert 2000). Game bird management of RSA may involve

natural regeneration with stubbles left over-winter, thus providing winter feeding and holding cover, insects for chicks in summer and brood-rearing habitats (Anonymous 1996). RSA may therefore be beneficial for both game birds and other species in winter (Moreby & Aebischer 1992; Sotherton *et al.* 1994; Moreby & Sotherton 1995; Sotherton 1998; Sotherton *et al.* 1998; Buckingham *et al.* 1999). However, the value of RSA for nesting and brood-rearing is more variable, because vegetation cover is frequently lost due to cultivation in spring, precluding its use as nesting habitat (Sotherton *et al.* 1994). Delaying RSA cutting for the benefit of game birds could be generally favourable for a number of invertebrates and rare arable wildflowers (Sotherton 1998). A more complete evaluation of the effects of game set-asides would require more detailed information on their extent and characteristics on game and non-game areas, and how these may affect species with contrasting habitat requirements.

In the United States, the Conservation Reserve Program (CRP) was established in 1985, and amended by the 1996 Farm Bill to make continuous enrolment possible (Burger Jr. *et al.* 2006; Gray & Teels 2006). Under CRP around 13 million of acres of agricultural land have been planted to create permanent perennial grassland, and other agricultural conservation practices, such as; riparian buffers, wetland buffers, herbaceous filter strips, wetland restoration, shelter-belts, and shallow-water areas for wildlife have been implemented (Burger Jr. *et al.* 2006; Gray & Teels 2006). CRP has been found to be beneficial to game birds and non-game grassland songbirds (e.g. Svedarsky *et al.* 2000; Eggebo *et al.* 2003; Lupis, Messmer & Black 2006; Doxon & Carroll 2007) (reviewed in Ryan, Burger & Kurzejeskie 1998), though this effect is not ubiquitous and the extent to which ranches are enrolled in CRP to benefit game birds specifically is generally un-documented (e.g. Rodgers 1999; Greenfield *et al.* 2002). One example is the "CP33 – Habitat buffers for upland birds", which was jointly developed by the Southeast Quail Study Group (SEQSG) and nearly 30 conservation organisations, specifically to provide conservation borders and field buffers in crop production systems (Burger Jr. *et al.* 2006). Primarily intended to provide native herbaceous grasses and forbs for nesting and brood-rearing habitat for bobwhite quail, an economically important and declining game bird, also achieves wildlife habitat goals in agricultural systems as part of CRP (Burger Jr. *et al.* 2006).

Farmland woodland management

Small farmland woods provide critical habitat for game bird species such as pheasant, and thus game bird management may support the creation of new woodlands, and the preservation and management of old ones (Woodburn & Robertson 1990; Genovesi, Besa & Toso 1999). This was confirmed in the UK, where game estates were found to maintain the most established woodland, to have more new woodlands planted than areas without game bird management, and that game woodlands tend to be larger, older, and more likely to be

broadleaved, than non-game woodlands (Duckworth *et al.* 2003; Oldfield *et al.* 2003). However, these results may not be general, as another study recorded no marked structural differences between game and non-game woodlands, though the former contained a higher proportion of conifer trees (Hinsley *et al.* 1999).

Management of farmland woods for hunting may be beneficial for biodiversity (Robertson 1992), though information to support this view is still limited and contradictory. For instance, although Robertson (1992) documented positive associations of woodland management for pheasants on butterflies and birds, the effects reported by (Hinsley *et al.* 1999) were generally weak, being marginally positive for birds, marginally negative for plants and virtually nil for butterflies. Furthermore, Hinsley et al. (1999) suggested that sites managed for game had less variation in woodland characteristics than unmanaged sites, which may eventually reduce habitat diversity and make landscapes less likely to support a wide range of species with different habitat requirements. Clearly, there is a need to further investigate the consequences of game woodland management on biodiversity, at both the local and landscape scales.

Summary

Habitat management for game birds is widespread and common throughout Europe and North America. Some practices, such as habitat disturbance, planting of game crops and grazing control are specifically implemented to benefit game birds. However, there are a range of other management practices, such as forest management, set-asides and reduced pesticide use, which are beneficial to game birds, although evidence to suggest they are more common in game than non-game areas is lacking. There are a number of documented positive and negative impacts on non-game species, and particularly in agricultural habitats, it seems that game bird habitat management may be beneficial to non-game species.

Species management

The two main practices associated with species management of game birds are the control of disease and parasites, and the provision of supplementary food and water. These are largely ubiquitous practices throughout Europe and North America.

Control of diseases and parasites

Pheasants and partridges, the two most commonly released game birds, are prone to high levels of parasitic infection, and certainly released birds tend to have greater parasite infections than wild birds (Bicknell et al 2010). In the UK, anti-parasite drugs are used to treat captive reared game birds prior to their release, and are added to feeders around release sites (Bicknell *et al.* 2010). This is likely to benefit wild birds, compared to releases in the absence of such measures, as there is the potential to pass infections to wild populations.

However, many parasites are restricted to a relatively narrow range of hosts and so game birds, such as grey partridge, might be those most likely to benefit from medication (Bicknell *et al.* 2010). However, passerines are commonly infected by *Salmonella*, and may be infected through interactions with game birds at feeders (Bicknell *et al.* 2010), and so would also potentially benefit from medication programs. It is important to note that the extent to which birds are medicated prior to release is unregulated and therefore will vary between estates, and that dispersal away from release areas may mean that birds are no longer medicated despite the provision of treated feed hoppers around release sites (Bicknell *et al.* 2010). The potential affects of such medications on other inverts has not been investigated.

Red grouse management in the UK uplands also includes the provision of medicated grit to treat infections of *Trichostrongylus tenuis* (Hudson 1992) and direct dosing with anthelmintic drugs. There seems to be no literature covering the potential impacts of such medication on non-target species and this topic warrants research. Red grouse are also prone to louping ill (LIV), a tick borne virus which has a number of mammalian hosts including sheep (*Ovis aries*). Although mountain hare (*Lepus timidus*) do not show clinical symptoms, they are hosts for ticks, and tick to tick transmission of LIV can occur when they are co-feeding on the same individual (Jones *et al.* 1997; Laurenson *et al.* 2003). Culling of mountain hares in the Scottish uplands, to protect red grouse from LIV, is increasingly common, although there is a lack of reliable evidence that such culls reduce the prevalence of ticks, or LIV or increase red grouse densities (Harrison *et al.* 2010). There is growing conservation concern as the population response of hares to culling is not well understood (Harrison *et al.* 2010). The management of LIV in red grouse also involves the use of sheep as "tick mops". This practise involves putting sheep out on the hill, and then treating them with an acaracide every six weeks to kill ticks or prevent them from feeding. Reducing tick prevalence may benefit other birds which are prone to high tick burdens, such as waders (Grant *et al.* 1999; Newborn *et al.* 2009), however direct evidence is again lacking. There may be biodiversity impacts of increased sheep numbers (see grazing control) and of the intensive use of acaricide which may exceed recommended use when used with 'sheep mops' and is an area that would benefit from research.

Provision of supplementary food and water

The provision of grain, particularly over winter, is a common management practice throughout Europe and in North America, particularly in agricultural habitats. For example, released pheasants in the UK are typically provisioned from release until the end of the shooting season, to maintain body condition and retain birds in shooting areas (Draycott *et al.* 2005). It is assumed that such

provisioning has positive impacts on other granivorous species, however hard evidence is lacking (Arroyo & Beja 2002). There is also a suggestion that concentrating birds around feeders might increase the risk of disease transfer and predation (Arroyo & Beja 2002), supplementary feeding of woodland grouse was stopped in Fennoscandinavia in response to concerns that supplementary feeding increased predation, although this differs from the UK situation where supplementary feeding is targeted at released pheasants and red-legged partridge, rather than with the wild stocks of woodland grouse of Fennoscandinavia. In North America grain is sometimes used as bait near to roads, to facilitate harvests (Haines *et al.* 2004).

Provision of supplemental water is also common in arid parts of Europe and North America (e.g. Arroyo & Beja 2002; Krausman, Rosenstock & Cain 2006; Casas & Vinũela 2010; Gaudioso Lacasa *et al.* 2010). While there is some evidence concerning the impacts on non-game species there is certainly evidence that a wide range of non-game species use provided water, and particularly that some bat and bird species benefit from man-made water sources (Krausman, Rosenstock & Cain 2006), though use by non-game species may be lower than use by target game (Gaudioso Lacasa *et al.* 2010). Furthermore, it appears that they do not present a high risk of predation (Krausman *et al.* 2006), particularly when fenced (Gaudioso Lacasa *et al.* 2010). There may be some risk of entrapment in certain types of water development, and also the ability of some species to use developments may be impaired by their design (Krausman, Rosenstock & Cain 2006).

Summary

Provision of supplementary food and water are common practices in game bird management. They are likely to have positive impacts on other species, though there may be some increased risk of disease transfer and predation. There is a general lack of evidence available to assess these impacts at present.

Predator control

Predator control is a traditional practice in game bird management across Europe, and targets a large variety of predators (Arroyo & Beja 2002). This practice is particularly common in relation to the management of important socio-economic game birds such as partridges, pheasants and red grouse. For example, in rural areas of Spain magpie (*Pica pica*) control is commonly used as a management tool in small game hunting estates (Díaz-Ruiz *et al.* 2010). In the UK, corvids, mustelids and foxes are commonly killed, although there is lots of spatial variation. Estates which are predominantly relying on released birds, and not on a breeding population, are less likely to operate consistent predator control outside the shooting season (Bicknell *et al.* 2010). With the exception of managed red grouse moors, predator control is rarely carried out specifically for

upland species, such as black grouse, capercaillie or rock ptarmigan (Arroyo & Beja 2002).

Predator control is rarely applied for game bird populations in North America. North American predator management tends to focus on managing habitat to minimise predation risk, for example, removing dens and perches, improving cover, increasing the size and density of habitat patches and reducing patch isolation (Jiménez & Conover 2001). There is, however, a growing interest among some hunters and game managers in applying direct predator control (e.g. (Burger 2001; Rollins & Carroll 2001). Rollins and Carroll (2001) suggest an "Integrated Pest Management" (IPM) approach, a concept which was developed in relation to the strategic control of crop pests. IPM advocates that non-lethal (i.e. habitat management) approaches are applied as a first defence, and lethal approaches (i.e. predator control) are applied "surgically" to reduce costs and minimise risks to non-target species. There remains, however, concern as to how economically and practically viable it is to effectively control predators over the large areas over which game is managed compared with management of habitats to minimise predation risk (e.g. The Nature Conservancy 1999; Heffelfinger *et al.* 2000; Riley & Schulz 2001; Leopold & Chamberlain 2002). Additionally, public support is not in favour of broad scale predator control purely to increase populations for hunting (Messmer *et al.* 1999; Riley & Schulz 2001). This latter point makes sense in the context of governance of hunting in North America, i.e. wildlife is held in trust by the state for the people. Indeed in all cases, predator control can be considered to be a contentious subject. Some conservationist groups have expressed ethical and biological arguments against the killing of predators (e.g. Messmer *et al.* 1999; Leopold & Chamberlain 2002). Also, predator control has been considered as a factor destabilising predator guilds, and thus being detrimental for conservation (Moral Castro 1999). Illegal predator control affects the abundance and distribution of legally protected species, such as birds of prey (e.g. Etheridge, Summers & Green 1997; Villafuerte, Viñuela & Blanco 1998b; Whitfield et al 2008; Fielding et al 2011) representing an important problem for several predator species (Mañosa 2002).

Effects on game birds

Hunters consider that predator control is essential to maintain numbers of some game bird species, for conservation purposes and even to maintain healthy ecosystems (Reynolds, Angelstam & Redpath 1988; Suárez, Yanes & Herranz 1993; Reynolds & Tapper 1996; Tapper 1999). Previous reviews of experimental predator control studies showed that predator control often increases the breeding success of small game, and thus the size of the autumn (harvestable) population, although it is less clear whether it affects breeding density (Reynolds, Angelstam & Redpath 1988; Newton 1993; Stahl & Migot 1993; Côté

& Sutherland 1997). However, the results of an eight year experiment on upland moorland in Britain demonstrated that legal predator control of foxes and crows increased both breeding success and subsequent breeding densities of red grouse (Fletcher *et al.* 2010). Tapper (1996) also demonstrated increased breeding success, autumn density and subsequent breeding density of grey partridge during a six year experiment reducing foxes, carrion crows and magpies during the partridge nesting period. Salo *et al.* (2010) conducted a worldwide meta-analysis of field experiments where densities of terrestrial vertebrate predators were controlled, and responses of terrestrial vertebrate prey were monitored. They concluded that predation does limit prey populations, and prey densities usually change substantially after predator management. They suggested that control of introduced vertebrate predators can be used to manage wildlife. However, they note that care should be taken in managing native predators, because control of top predators may cause mesopredator release. Salo *et al.* (2010) further conclude that the most important factor in the efficacy of predator control, is the efficiency of predator management. Indeed, the efficacy of predator control depends on many variables. The strongest effects of predator removal have been found in areas where habitat is degraded and thus vulnerability of the prey is high (Chesness, Nelson & Longley 1968; Stahl & Migot 1993; Sovada, Anthony & Batt 2001). The intensity of culling and the diversity of predators culled also influence the efficacy of predator control (Parker 1984; Greenwood 1986; Stahl & Migot 1993; Norrdahl & Korpimaki 1995; Côté & Sutherland 1997). Furthermore, there is also evidence that the removal of non-native predators has more effect than the removal of native predators, though this may be mostly being driven by red fox (Salo *et al.* 2010). However, Baker *et al.* (2006b) found that while pheasant comprised the largest avian portion of fox diet in a sampled farm in southern Britain, birds constituted only 11% of fox diet over all. Furthermore, they concluded that while this might represent between 34 and 81% of spring pheasant biomass, annual losses to predation appear to be fully compensated by immigration of birds from neighbouring farms. Additionally, predator control exerted in declining game bird populations may be ineffective (Parr 1993; Côté & Sutherland 1997), and there is also some evidence that cyclic prey species show a decreased response to predator management over time, whereas non-cyclic prey show an increased response (Salo *et al.* 2010). The effect of predator removal may only be found in certain years when food supply for the game is poor, or alternative prey for the predators are scarce (Parker 1984; Marcstrom, Kenward & Engren 1988; Baines 1991; Kauhala, Helle & Helle 2000). Finally, the area over which control is exerted is also important. For example, Frey et al (2003) showed that predator removal in the Intermountain West area of the USA might not increase pheasant populations when applied only to small areas, but might be more successful in larger areas.

Effects on non-game species

Predator control could potentially have a positive effect on other species, if those species are also limited by predation. In their meta-analyses, Côté & Sutherland (1997) did not find any heterogeneity in the effect of predator control between game and non-game species, suggesting that the positive effects of predator control on breeding success affect other, non-game, species. Ground nesting birds might be expected to benefit from the control of mammalian and avian predators and several studies have shown the control of predators, particularly foxes and crows, to have positive impacts on breeding success, densities and diversity of waders in the UK (Parr 1993; Tharme *et al.* 2001; Daniel 2010; Fletcher *et al.* 2010). Capercaillie, which are of conservation concern in the UK, also benefit from predator, particularly crow, control (Baines, Moss & Dugan 2004; Summers *et al.* 2004). There is also some evidence from the UK that passerine breeding success and/or abundance can increase when predators, particularly corvids, are controlled (Stoate & Szczur 2001; Stoate 2005; Stoate 2007; Stoate, White & Szczur 2008; White *et al.* 2008; Stoate, White & Szczur 2009). Furthermore, Suarez *et al.* (1993) found that passerine nests in a nature reserve in Spain suffered higher mortality rates due to predation (mainly by foxes and dogs) than in a close-by area where these predators were controlled for hunting interests. They suggested that lack of predator control in the reserve had resulted in an unsustainable predation rate for passerines. However, Newson *et al.* 2010, found little evidence for any impact of avian predation on songbird species, suggesting broad scale population impacts on passerine species are far from universal. In some cases, where estates are relying predominantly on rear and release shooting, rather than breeding game bird populations, predator control might stop after the shooting season, and therefore the cessation of predator control will coincide with the breeding season for other birds (Bicknell *et al.* 2010).

While there may be a number of positive effects of predator control, there are also potentially both direct and indirect negative effects on non-game species. One obvious example is the effects on predators themselves. For example, while Stoate & Szczur (2001) found that hatching success of some songbirds increased as a result of corvid removal, due to predator control, carrion crow and magpie did not breed on the game estate. Where predator control methods are non-selective there is also the potential for negative impacts on non-target predator species. For example, Virgos and Travaini (2005) found that, in central Spain, carnivore species richness was significantly lower in areas managed for small-game hunting than in areas where other land uses predominated. In addition, the control appeared to have least effect on the main target species, red fox (*Vulpes vulpes*). Messmer *et al.* (1999) reported that US public support for predator control is higher when it is applied "surgically", rather than broadly. Taken

together this suggests that reconciling carnivore conservation and game bird management requires selective predator control techniques.

Predator control may also have an indirect impact on other species by altering the structure of the predator guild. Removal of top predators may produce a release in numbers of meso-predators (e.g. Ritchie & Johnson 2009; Salo *et al.* 2010). Mesopredator suppression by apex predators is both a common and widespread phenomenon which has been shown to impact prey populations, and acts either through direct mortality, or changes in behaviour due to stress and predator avoidance behaviour (Ritchie & Johnson 2009). For example, the removal of foxes in some areas may produce an increase of rodent numbers, which in itself may a have high impact on nest predation. The re-introduction of apex predators to reduce the impacts of meso-predators has even been suggested, for example coyotes and red foxes in North America (Jiménez & Conover 2001). However, predator control may be positive for biodiversity if the unmanaged structure of the predator guild is biased towards mesopredators, and these are the ones culled for hunting purposes. For example, Travaini *et al.* (1997) observed that the diversity and evenness of a carnivore community decreased over 6 years in an area without fox culling, as compared with an area managed for rabbit and partridge, where continuous culling of foxes was carried out, including illegal control methods such as poison or snares.

Illegal predator control

In the UK there are a number of conflicts between the management of economically important game birds, and the conservation of legally protected raptors (reviewed in Park *et al.* 2008). Perhaps the most widely reported conflict is that between red grouse management and hen harrier conservation (e.g. Thirgood *et al.* 2000b; Redpath *et al.* 2004; Thirgood & Redpath 2008). High densities of hen harrier can limit grouse populations at low density and reduce shooting bags (Redpath & Thirgood 1997; Redpath & Thirgood 1999a; Thirgood *et al.* 2000a; Thirgood *et al.* 2000c). Hen harrier have been legally protected in the UK since 1954, however some illegal persecution continues which limits the breeding population in some areas (Etheridge, Summers & Green 1997; Anderson *et al.* 2009; Fielding *et al.* 2011). A similar situation exists for golden eagles in Scotland (Whitfield et al, 2008). Other conflicts in the UK arise between conservation of peregrine, goshawk, buzzard and sparrow hawk in relation to red grouse, pheasant and grey partridge management respectively (reviewed in Park *et al.* 2008) and illegal persecution of a range of bird of prey species shows little signs of declining despite significant investment over the past 20 years (RSPB 2009). There is also a documented conflict between hen harrier conservation and grey partridge management in France (reviewed in Bro, Arroyo & Migot 2006).

In a recent review, Valkama *et al.* (2005) highlighted that in Europe gyrfalcon, goshawk and golden eagle have high proportions of game birds in their diets, and that harriers, buzzards, peregrines and Bonelli's and booted eagles are locally important predators, however the extent to which any of these species negatively impact game populations is unknown. There are at least three systems in which raptor predation is believed to affect cycles in prey population dynamics: goshawks and forest grouse in northern Finland, common buzzard and forest grouse in western Finland, and gyrfalcon and ptarmigan in Iceland (Valkama *et al.* 2005). However, hunters in Fennoscandinavia appear accepting of this and there is little persecution although there is some translocation of buzzards away from pheasant release sites in Sweden (Thirgood, Woodroffe & Rabinowitz 2005). The reason for the differences in attitude between Scandinavia and the UK are unclear and likely the result of many interacting factors. However, in Scandinavia most game bird shooting is carried out on common ground where game birds are a shared resource and there are no clear rights of ownership or responsibility for sustainable management, nor incentive for hunters to invest in game management (Newey, Dahl & Kurki 2010). In the UK on the other hand land and hunting rights are often privately owned creating a situation where there is more personal incentive for owners to invest in management practices (habitat, disease and predator control) to increase game bird densities, if they will personally reap the rewards in terms of income as well as practising a style of hunting that is in demand from a section of the shooting community. This can encourage significant private investment and long-term interest in sustaining higher game bird population and therefore bag (Newey & Smith, 2010). There is evidence from Portugal that raptor abundance varies inversely with game keeper density within game estates, suggesting potential interference; however, with the exception of common kestrel, there was no evidence that numbers of raptors were lower on game estates than elsewhere, because the higher densities of game in game states had a positive influence on the abundance of their predators (Beja *et al.* 2009). There is also evidence that the number of illegal poisonings of Spanish imperial eagle in relation to small game management has increased (González *et al.* 2007), and that it has caused reduction in the range of several endangered predators in the Iberian Peninsula (e.g. Villafuerte, Viñuela & Blanco 1998a; Rodríguez & Delibes 2004). While there is evidence that predation by raptors influences populations of grouse and pheasant in North America, the lack of evidence of the efficacy of predator control, together with public concerns regarding the practise mean that raptor persecution is not a common issue (Valkama *et al.* 2005).

A number of methods to reduce the conflicts between raptor persecution and game bird management have been suggested, including habitat management, diversionary feeding, translocations and control under a quota system (e.g. Redpath *et al.* 2004; Valkama *et al.* 2005). Diversionary feeding has been shown

to be effective at reducing hen harrier predation on red grouse chicks, at least under some circumstances, reducing predation by up to 86% (Redpath, Thirgood & Leckie 2001) although further trials are required.

Summary

Direct predator control is a widespread practice in Europe, and prey densities usually respond to such control. Widespread and common intensive predator control appears to be primarily associated with driven shooting of rear and released game birds, and red grouse management in England and Scotland. The efficacy of predator control programmes is likely to vary according to population and ecological variables. To maximise efficiency, predator control has to be carried out in combination with habitat manipulation, and/or has to be very intensive, culling all potential predators, over large areas, and particularly in years or conditions when the impact of predation is likely to be greatest. This, along with lack of public acceptance, is in part why predator control is not common in North America. The effect of predator control on prey species other than game birds is little studied. Both positive and negative effects may be expected, and the relative importance of both would depend on the type and extent of control exerted. No studies up to now have shown negative effects of predator control on other species, but available information for positive effects is inconclusive. The (illegal) control of predators of conservation importance has important detrimental effects on some species in some areas.

Rear and release

Approximately 35 million pheasants and 6.5 million red-legged partridge are released in the UK each year, which equates to approximately 41,000 tonnes of pheasant, and 3,200 tonnes of red-legged partridge, biomass (Baker *et al.* 2006a; PACEC 2006). In the UK the practice is largely un-regulated, and the species' are exempt from regulation relating to the release of non-native species (Bicknell *et al.* 2010). Pheasant releases are widely and evenly distributed throughout lowland Britain, and are largely absent from the uplands (Bicknell *et al.* 2010). Pheasant shooting bags have been declining in the UK since 1990, despite continued increases in release density, and this may be related to losses to predation, disease and other mortality, or to changes in habitat either increasing dispersal or making birds more difficult to flush (Bicknell *et al.* 2010). The breeding population was estimated as 1.8 – 1.9 million females in 2006, and has continued to increase (Bicknell *et al.* 2010). Red-legged partridge is preferred over the native grey partridge for rear and release in the UK, and the distribution of partridge releases compared to pheasant releases is more restricted, and the numbers involved are smaller (Bicknell *et al.* 2010). Relatively recently, increasing numbers of red-legged partridges are being released on upland moorland fringe, to in part compensate for declining red grouse bags (Bicknell *et al.* 2010). The introduction of game birds into hunting grounds is a widespread

and growing practice in the rest of Western Europe, though remains rare in Fennoscandia (though it may be locally popular, e.g. pheasants in southern Sweden) and has been banned in the Netherlands (e.g. Brittas *et al.* 1992; Tapper 1999; Arroyo & Beja 2002; de Bruijn 2010, pers. comm.).

The introduction of game birds is particularly common in farmland habitats, where tens of million hand-reared pheasants and partridges are released each year (Arroyo & Beja 2002). The birds are frequently released just before the shooting season, with the aim of achieving hunting yields higher than that possible from wild stocks. In other cases, the objective is to restock depleted or declining local breeding populations, thus assisting in their sustainable harvest. However, long term survival of released birds may be lower due to, for example, altered behaviour in relation to wild predators and generally high predation rates (e.g. Brittas *et al.* 1992; Alonso *et al.* 2005). No releases occur for upland game bird species (but note partridge releases in the UK uplands), except for conservation purposes. Ecological effects of introducing hand-reared birds into hunting areas may result primarily from demographic interactions with the native breeding populations, introduction of exotic species and genetic pollution, and spread of diseases and parasites. However, there may also be some habitat effects. For example, Bicknell et al (2010) reported that in the UK high densities of game birds impact the ground flora in release pens. Furthermore, released birds may cause soil enrichment, and may affect hedge structure and species richness, and woodland ground flora, for example by browsing protected species such as bluebells (Bicknell *et al.* 2010). Changes in hedge structure might impact on birds including yellowhammer which nest in the lower portion of hedgerows, and could subsequently reduce productivity (Bicknell *et al.* 2010). Furthermore, released pheasants which subsequently breed may act as competition for invertebrate food resources for other breeding birds (Bicknell *et al.* 2010). This may become more important in the future as game organisations work to increase game bird breeding numbers (Bicknell *et al.* 2010). A study in North America concluded that the habitat effects of introducing chukar partridge appeared to be mostly benign, and that they may even have a positive effect on plant diversity by consuming non-native plants and showing a limited propensity for subsequent seed dispersal (Larsen *et al.* 2007).

Effects on wild stocks

Detailed quantitative assessments of the effects of releases and restocking on the demography of wild game bird stocks are generally lacking. The contribution of hand-reared birds to the breeding population may be small, because they have much lower rates of survival and breeding success than their wild counterparts (Hill & Robertson 1988; Robertson & Dowell 1990; Putaala & Hissa 1998). This is related to the poor behavioural, morphological and physiological capacity of hand-reared birds to live in the wild, rendering them extremely susceptible to

starvation and predation (Brittas *et al.* 1992; Paganin & Meneguz 1992; Putaala *et al.* 1997; Liukkonen-Anttila, Putaala & Hissa 1999; Millán, Gortazar & Villafuerte 2001; Alonso *et al.* 2005). Therefore, although releases and restocking operations usually result in the short-term increases of population densities necessary to sustain high shooting pressure, it is far from clear whether they actually enhance the wild stocks.

In England, releases of chukar (or hybrids with red-legged partridge) into areas with red-legged partridges was associated with crashes in the wild stocks (although note these 'wild' birds must have been the progeny of previously released birds), whereas releases of grey and pure red-legged partridges had no obvious detrimental effects on the wild populations (Robertson & Dowell 1990). Robertson & Hill (1992) showed that as the number of pheasants released increases, the productivity of the breeding population steadily declined to reach a lower equilibrium point than that attained in the absence of released birds. Hand-rearing and release thus seems to become self-perpetuating: after the release of birds the productivity declines as does the incentive for wild bird management; this in turn leads to an increased reliance on rear and released birds if the bags are to be maintained. These results are in line with studies documenting that due to poor survival and reproduction output, restocking operations may have little value in attempts to boost populations of grey (Putaala & Hissa 1998) and red-legged partridges (Gortázar & Villafuerte 2000). However, the joint use of restocking together with habitat management and predator control, may be useful in some circumstances to increase depleted game bird populations (Carvalho *et al.* 1998).

Introductions and genetic pollution

In Europe, introductions of exotic game birds for shooting have been carried out for a long time, resulting in the establishment of feral populations of North American and Asian species, as well as of Palaearctic species outside their natural ranges (Hagemeijer & Blair 1997). Releases of non-indigenous game birds may cause artificial mixing of formerly isolated genetic populations, which might reflect adaptations to local environmental conditions (Kark *et al.* 1999). By breaking genetic isolation, releases may cause the contamination of local genetic stocks, genetic erosion, or the introduction and spread of locally maladaptive traits (Hodder & Bullock 1997). For instance, it was suggested that hybridisation between native European and released Japanese quails (Derégnaucourt, Guyomarc'h & Spanò 2005; Chazara *et al.* 2010), may be leading in France to widespread genetic pollution resulting in the loss of migratory behaviour (Derégnaucourt, Guyomarc'h & Spanò 2005). However, a study in Catalonia (Spain) found no evidence that the number of hybrid common x Japanese quail

had increased between there first detection in 1990, and 2006 (Puigcerver, Vinyoles & Rodríguez-Teijeiro 2007).

Undesirable genetic effects of game bird releases may be prevented to some extent by the survival and poor breeding of the released hand-reared birds. One possible explanation for this pattern is the reduced viability or even sterility of the hybrid female offspring of two different subspecies (Liukkonen-Anttila 2001). However, there is evidence that red-legged partridge have hybridised with chukar throughout the entirety of it's range (Barilani *et al.* 2007; Blanco-Aguiar *et al.* 2008; Barbanera *et al.* 2010), and that wild rock partridge are also carrying chukar genes (Barilani *et al.* 2007). It is suggested that such genetic pollution results from the release of hybrids with chukar for shooting purposes (Barilani *et al.* 2007), and certainly this is a more recent phenomenon as chukar genes do not occur in museum specimens of red-legged partridge (Blanco-Aguiar *et al.* 2008; Barbanera *et al.* 2010). Furthermore, the negative genetic consequences may be high where the wild stocks are small and the number of birds released is great, in which case it is likely that appreciable numbers of released birds can enter the breeding population. The problem is illustrated by the decline and eventual extinction of pure forms of the Italian subspecies of the grey partridge (*Perdix p. italica*), largely attributed to the intensive release of hand-reared grey partridges associated with overshooting and habitat degradation (Matteucci & Toso 1986). This suggests that loss of local genetic diversity may be widespread, for it is when the local stocks are small or declining that releases and restocking are most frequently undertaken.

Sanitary problems

The spread of pathogens is a potential problem in any species translocation program (Viggers, Lindenmayer & Spratt 1993), but it may be particularly serious in the case of hand-reared game birds, due to the artificial environment of aviaries and the high stocking densities (Beer 1988; Pennycott & Duncan 1999; Pennycott 2000). Furthermore there is some evidence that the excretion of parasite transmission stages increases in pheasants following release (Villanúa *et al.* 2006). Introduction of infectious diseases and parasites in the breeding population may then increase mortality or reduce fecundity of the wild birds (Hudson, Dobson & Newborn 1992).

Sanitary problems are also possible where releases are responsible for maintaining high densities of game birds in the wild. For example, evidence from Spain shows that parasite prevalence and diversity is higher on estates where farm-reared birds are released (Villanúa *et al.* 2008). However, Villanua *et al.* (2008) also found that there was a limited potential for introduced parasites to establish in wild populations in the absence of continued releases. In the

lowlands of the UK, pheasant populations are artificially maintained at high densities through increasing numbers of released birds (Tapper 1999; Bicknell *et al.* 2010). In this case, pheasants may act as a reservoir host for the caecal worm *Heterakis gallinarum*, infection with which is detrimental to grey partridge, but more significantly so to the pheasant (Tompkins, Dickson & Hudson 1999; Tompkins, Greenman & Hudson 2001; Bicknell *et al.* 2010). Seemingly, *H. gallinarum* cannot persist within partridge populations without the presence of alternative host species and infection from pheasants largely determine the worm burdens of partridges in the wild (Tompkins, Draycott & Hudson 2000), eventually causing the exclusion of grey partridges when pheasants are present (Tompkins *et al.* 2000). These findings, however, are disputed by Sage *et al.* (2002) who failed to detect clinical effects of *H. gallinarum* on grey partridges.

Pheasants may also be important in maintaining the transmission of Lyme disease, as they are competent reservoir hosts for the Lyme disease spirochaete, *Borrelia burdorferi* s.l., and carry large infestations of the vector ticks, *Ixodes ricinus* (Hoodless *et al.* 1998; Kurtenbach *et al.* 1998; Bicknell *et al.* 2010). It is not known whether this affects other wildlife populations, but Lyme disease does affect humans. Pheasants selectively infect nymphs feeding on them with a genospecies of spirochete (*B. garinii*) that causes neuroborreliosis in humans but is not maintained by mammalian hosts, and filter the genospecies *B. burgdorferi* maintained by mammals out of the system. This ensures a high infection prevalence only in adult questing ticks, which are more conspicuous and less numerous than nymphs.

Summary

Rear, releases and restocking tend to increase the harvestable population of target game species, but not necessarily the breeding populations. There are exceptions when restocking is accompanied by other management actions. On the other hand, releases may have important negative effects, through the loss of genetic diversity and the introduction of diseases and parasites. Yet there is limited information about the extent and significance of these processes in the wild. The main way in which releases are likely to affect non-game species seems to be through potential habitat modification where release densities are high, such as in the lowlands of the UK.

Other impacts

Other possible biodiversity impacts not covered by the rest of this report include accidental by-catch, for example of grey partridge during a red-legged partridge shoot (Watson *et al.* 2007), lead poisoning from ingestion of ammunition (Butler *et al.* 2005; Ferrandis *et al.* 2008; Kreager *et al.* 2008; Knott et al 2010) and disturbance (Sastre *et al.* 2009).

Knowledge Gaps

Despite a wealth of research on the impacts of game bird management on game bird and non-target species we have identified 10 main areas that would benefit from further research:

1. Land ownership and the legal framework regulating land and hunting rights interact with national, regional and local government, and local culture to form a hunting tradition or model of governance. How governance drives and interacts with wildlife management and biodiversity remain poorly documented.
2. Large areas of land are managed for, or affected by, management for game birds. The ecological, economic and social trade-offs between managing for increased game-birds and other competing land-use objectives that focus on other ecosystem goods and benefits are not well understood
3. The use of medicated water and food is wide spread in most countries where rear and release is practiced. Additionally, the specific management of intestinal parasites in wild red grouse occurs in the UK. The potential influence of these medications on non-target species is largely unknown.
4. The use of sheep flocks intensively treated with acaricide as part of tick control strategies appears to be growing in the UK uplands. The potential affect of these acaricides on the sheep and non-target species, which may used more intensively in tick control programmes than in conventional sheep husbandry, is little understood.
5. Grazing by large herbivores has been implicated in the decline of heather-dominated moorlands in the British uplands. The impact of changes in grazing pressure on habitat condition and biodiversity due to the shift towards sheep flocks as tick mops rather than for lamb production has not been quantified.
6. While there is some evidence that predator control has positive effects on the harvestable population of game birds and some non-target bird species, the evidence for positive effects on the breeding population of other non-target species is equivocal and further studies are needed to disentangle the proximate and non-proximate drivers of population change and to identify the limiting and regulating factors determining population dynamics.
7. Persecution of raptors is an issue across much of Europe. There is a need for research into the novel methods for resolving this conflict and mitigating these effects. This includes understanding social and cultural factors that drive and maintain this conflict to understand the barriers that hinder successful resolution.

8. Rear and release of game birds for shooting is wide spread and popular in some areas of continental Europe and particularly in the UK. While there is evidence that associated habitat management may be beneficial to non-target species there is evidence that released birds can have a negative effect on other species and habitats, the biodiversity impacts of rear and release at a landscape level remains poorly understood and represents a priority area for future research.
9. While habitat management associated with rear and release of game birds can have clear benefits on non-target species and habitats it is unclear if these habitat improvements are more common in shooting areas than in non-shooting areas. Assessing the range and distribution of habitat management actions such as beetle banks and field headlands between shooting and non-shooting areas would be informative in assessing the wider biodiversity benefit of habitat management for rear and release of game birds.
10. A key difference between the UK shooting tradition and the majority of other national models examined in this report is that in the UK there is no legal requirement to take a hunting or shooting test before as a prerequisite for shooting game. How this influences the efficacy and ethics of shooting and animal welfare, and the perception of shooting is unknown. Similarly, the barriers to implementing such competency testing in the UK are not well understood.

Conclusions

Game birds are widely managed to improve or maintain hunting yields, by manipulating those factors considered limiting for their populations. In some cases this management is intensive, in order to maintain the high numbers of birds required for "driven shooting", a practice which is common in the UK, central and southern Europe (Table 3). In the Nordic countries and North America, game bird hunting and management is typically less intensive, though locally intensive management occurs (Table 3). The main game bird species hunted and associated management practices vary locally, nationally and internationally, there are however some management practices which are common to many, or all scales, including; improvement of breeding and feeding habitats, the control of natural predators, the direct provisioning of food and water, and the release of farm-reared game birds to increase harvest (Table 4). These practices are widespread and implemented at large scales, and may have a significant impact on biodiversity at the levels of genes, species and ecosystems.

We identified three types of governance linked to game bird management; landowner regulated, state regulated, and state owned (Table 3). Under

landowner regulated governance, which represents the UK system, game are essentially a private resource to which the land owner largely controls access, these exclusive rights are thought to make it worthwhile for owners to make considerable investments in management of predators, habitats and disease aimed at maximising bird densities. This is usually associated with driven shooting where revenue is high due to the high rates charged for each brace shot and the large numbers that can be shot. Under *state regulated* governance while hunting rights reside with the landowner hunting is regulated, to some extent, by the state who, or whose agents, set harvest limits which may or may not be informed by monitoring of populations and/or harvest data. State regulation seems to discourage intensive private management of game populations and habitats. Under *state owned* governance, as found in North America, Hungary, Poland and Estonia, the right to hunt resides with the state and hunting is regulated by license, and there are usually harvest limits set, which may or may not be informed by monitoring.

Hunting styles can be broadly categorised as 'driven' or 'walked up' shooting. Driven shooting, popular in the UK and some areas of central and southern Europe, requires high densities of game birds and is associated with intensive management through rear and release of game birds, particularly pheasant and red-legged partridge (although in the UK red grouse are an important exception), predator control, habitat management, and in some areas provision of supplementary food, water and possibly medication (Table 4). High intensity management has the greatest potential to impact on other species and wider biodiversity. In agricultural landscapes, which are subject to intense management there is evidence that game management can have a positive effect on other species, though whether these practises are more common in game managed areas or not remains to be identified. In more natural landscapes however the affects of game management are less clear, with some positive and negative impacts documented, though the legal and illegal management of predators clearly impacts on the predator themselves and wider predator and prey assemblages and predator control remains the most controversial aspect of game bird management. Walked up shooting on the other hand, requires much lower game bird densities and consequently less, or in some cases effectively no, direct species or habitat management. Walked up shooting represent the dominant hunting style in Fenno-Scandinavia and North America, but is also popular over much of continental Europe (Table 3). While the less intensive management tends to cause fewer potential threats to non-target species, the fact that walked up shooting is more often carried out on common lands raises issues over potential over harvest and sustainability.

Habitat management for game birds is widespread and common throughout Europe and North America. Some practices, such as habitat disturbance, planting of game crops and grazing control are specifically implemented to benefit game birds and there are a number of documented positive and negative impacts on non-game species, particularly in agricultural habitats. However evidence to suggest they are more common in game than non-game areas is lacking. A lack of evidence also makes it difficult to assess the overall benefits of supplementary feeding and provision of water which are common practices in some lowland and rear and release game bird management systems, as while they likely positive impacts on other species, there may be some increased risk of disease transfer and predation.

Predator control is particularly common in Europe in relation to the management of important socio-economic game birds such as partridges, pheasants and red grouse. Predator control is rarely applied for game bird populations in North America. Unsurprisingly, predator control can be very successful at reducing predator numbers and may also have an indirect impact on other species by altering the structure of the predator guild and non-game bird prey communities. The effect of predator control on species other than game birds remains however little studied. Both positive and negative effects may be expected, and the relative importance of both would depend on the type and extent of control exerted. No studies up to now have shown negative effects of predator control on other species, but available information for positive effects is inconclusive. The (illegal) control of predators of conservation importance has detrimental effects in some areas and species.

Rear and releases of game birds tends to increase the harvestable population of target game species, but not necessarily the breeding populations. Releases may have important negative effects, through the loss of genetic diversity and the introduction of diseases and parasites. Yet there is limited information about the extent and significance of these processes in the wild. The main way in which releases are likely to affect non-game species seems to be through potential habitat modification, competition, genetic contamination where release densities are high, such as in the lowlands of the UK.

Governance / Style / Management	UK		Nordic	S. Europe	E. Europe	C. Europe	USA
	U	L					
Management							
State monitored and regulated			X				
State regulated				X		X	
State owned					X		X
Style							
Driven	X	X		X	X	X	X
Walked up	X	X	X	X	X	X	X
Stalking						X	
Management							
Management of harvest levels	X	X	X	X	X	X	X
Habitat management	X	X		X	?	X	X
Predator control	X	X		X	?	X	
Rear and release	X	X		X	X	X	X

Table 3. Summary of the different game bird shooting governance, style and management identified in this report. UK – United Kingdom, Nordic – the Nordic countries; Norway, Sweden and Finland, S. Europe – Southern Europe; Spain, Portugal and Italy, E. Europe – Eastern Europe; Estonia, Hungry, Poland, Czech Republic, Latvia and Bulgaria, C. Europe – Central Europe; France, Germany, Austria, Belgium, The Netherlands, and Luxemburg, USA – North America. U – Upland, L – Lowland. X - this activity is believed to be carried out in this region as part of game bird management. ? - this activity is carried out, but it is unclear if it is explicitly part of game bird management, in this region as part of game bird management.

Management practice	UK		Nordic	S. Europe	E. Europe	C. Europe	USA
	U	L					
Grazing control	X			X	?	?	X
Burning (habitat mosaic)	X				?	?	?
Scrub control (burning, herbicides, swiping/disking)	X	?			?	?	X
Game crops (food and/or cover)	?	X	?	X	X	X	X
Set-asides		X		?	?	X	?
Field margins		X		X	?	X	?
Hedgerows		X			?	?	?
Woodland management		X			X	X	X
Food and/or water provision		X	?	X	?	?	?
Predator control	X	X	X	X	X	X	
Rear and release	?	X	X	X	X	X	?

Table 4. Summary of the different game bird management practises identified in this report and where they are carried out. UK – United Kingdom, Nordic – the Nordic countries; Norway, Sweden and Finland, S. Europe – Southern Europe; Spain, Portugal and Italy, E. Europe – Eastern Europe; Estonia, Hungry, Poland, Czech Republic, Latvia and Bulgaria, C. Europe – Central Europe; France, Germany, Austria, Belgium, The Netherlands, and Luxemburg, USA – North America. U – Upland, L – Lowland. X - this activity is believed to be carried out in this region as part of game bird management. ? - this activity is carried out, but it is unclear if it is explicitly part of game bird management, in this region as part of game bird management

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