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Summary review and synthesis: effects on habitats and wildlife of the release and management of pheasants and red-legged partridges on UK lowland shoots

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This review examines 128 items of primary and other literature to provide an insight into current knowledge of the effects of pheasant and red-legged partridge releasing and associated management for shooting on habitats and wildlife in the UK. It summarizes key findings and uses them to define sub-topic sections for which the effects are classified as positive, neutral or negative. This forms the basis of a numerical synthesis of effects and some overall conclusions.

Fifty-four directly related studies were identified, which defined 25 sub-topics or effects. A mix of positive, neutral and negative ecological consequences of releasing are described, for which the corresponding number of sub-topics approximately balance each other. Positive effects are usually a consequence of gamebird management activities, most negative effects are caused by the released birds themselves. The different spatial scales at which effects are likely to operate are identified, for example effects on generalist predators or of gamecrops occur at the landscape scale, while many habitat effects have a local impact.

Some local negative effects have relatively straightforward management solutions for example, by identifying and avoiding especially sensitive sites when locating release pens. The synthesis identifies seven negative effects associated with the increasing scale of releasing. Several positive effects are linked to economic considerations and are more likely to have greater impact at larger shoots. Pheasants released into woodland have more direct local effects than partridge releases on farmland.

The framework of sub-sections could be used as the basis for a more complex synthesis or weighted analysis for a particular set of ecological priorities. The review findings should be interpreted as representing a median type of shoot in terms of size and adherence to good practice over recent decades. They increase the awareness of potential conflicts, highlighting the need for best practice and what factors to consider for mitigation.

Keywords: *Alectoris rufa*, environmental impact, game crops, gamebird disease, *Phasianus colchicus*, pheasant, predator control, red-legged partridge, release density, releasing effects, supplementary feeding, woodland management

The release of pheasants *Phasianus colchicus* and red-legged partridges *Alectoris rufa* (hereafter partridge) is practised in woodlands and on farmland to support driven game shooting throughout England, lowland Wales and parts of lowland Scotland but especially southern England including the home counties and parts of the English midlands (Tapper 1992, Madden and Sage 2020). Small-scale releasing has been practiced since the 1800s, but the practice took off in the 1960s when wild bird (mainly grey partridge *Perdix*

perdix) populations declined and could no longer support shooting demand. Releasing has been increasing ever since (Robertson et al. 2017) and it is currently estimated that between 35 and 48 million pheasants and 7 and 14 million partridges are released in the UK, 85% of these in England (Aebischer 2019).

Pheasants are usually released into open-topped fenced pens in woodland and partridges into closed fenced pens with doors on farmland in mid to late summer for shooting in winter (GCT 1996). Birds are encouraged to disperse from the pen itself but shoots manage their releases to contain them on the shooting grounds. Radio-tracking studies at many sites indicate that typically 90–95% of released pheasants and partridges remain within 1 km or so of the release point and by the end of the shooting season on

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average 15% of the releases have survived (Turner 2007, Hesford 2012, Sage et al. 2018). Only a small proportion of released birds spread into the wider countryside in spring.

These released gamebirds have a range of effects on the lowland habitats they occupy and the associated wildlife. Many effects have been examined scientifically to some extent. Several authors have produced reviews of the literature on this (Madden and Sage 2020) but the group of references and the synthesis approach used here are new, providing concise information extracted from a comprehensive study of relevant published papers and non-peer reviewed or unpublished sources. Studies that investigated directly the ecological consequences of releasing are then used to undertake an unweighted synthesis of effects and to derive overall conclusions.

The effects of releases on lowland habitats can be separated into two main groups, namely management effects and the impacts of the released birds themselves primarily on semi-natural habitats. These two groups are reviewed, for woodlands and then for open habitats, in the first four sections of this report. The last two sections consider the two main groups of potential effects not related to habitat processes. Each section is split into sub-topics as defined by the evidence, and this is used to provide the basis for an overall synthesis of effects. The ethical, social and economic effects of releasing for shooting are beyond the scope of this review, which concentrates on identifying ecological effects.

Methods

The literature search is a subset of results from a rapid evidence assessment (REA, Collins et al. 2015) which is described in more detail in Madden and Sage (2020) and which used first, a keyword-based search of peer-reviewed papers. Keywords for Google Scholar were *Phasianus colchicus* or *Alectoris rufa* and Shoot. For Web of Science, ETHOS and NDLTD (UK and International PhDs) just *Phasianus colchicus* or *Alectoris rufa* were searched. Papers were restricted to post 1961 and Europe. Several thousand references were recovered which was reduced to around 200 in a rapid scan of titles and abstracts in accordance with Collins et al. (2015). We then undertook an extensive consultation of the grey literature via a request to other researchers in the field and with reference to a previously accumulated comprehensive database held by the GWCT.

Relevant references were then extracted following a full read of each, again following the REA protocol. If two references substantially overlap, only one is included. The review focused solely on the effects of released gamebirds and management associated with releasing. It excluded effects related specifically to shooting activities, such as welfare of shot birds, noise disturbance or lead deposition (see Pain et al. 2019 for a comprehensive review of lead shot effects). Specialist habitat management activities for enhancing wild game and wildlife populations such as conservation headlands in arable fields are also not included because they are not typical of release-based shoots.

The main synthesis was based on references arising from studies that have investigated directly some aspect of a potential effect of releasing on habitats or wildlife. These

references were grouped as appropriate and defined the report sections and subsections to form the basis of the synthesis. They have a symbol attached (see below), distinguishing them from other references which provide context or used in discussion, or provide weak or less relevant evidence. Key findings have been extracted from the highlighted references which are provided in the Supplementary material Appendix 1, and then summarized with conclusions in the Results section for each subsection. The basic study type is indicated (in the Supplementary material Appendix 1) and the effects considered are categorized as positive, neutral or negative (indicated in square brackets in the Results for bold highlighted references only [+ve], [ntl] or [-ve]). This follows the approach used by Gallo and Pejchar (2016) in their review of the consequences for biodiversity conservation of improving habitat for game animals. Our categorization is always based on the broadest possible view of ecological effects, although for several effects this categorization might be regarded as debatable if viewed more narrowly. For example, evidence that the legal control of generalist predators for game is effective and can help other wildlife is categorized as positive here (see also Mustin et al. 2018), whereas a positive response of any predator species to gamebird release that might increase predation pressure on other wildlife and is therefore categorized as negative.

For each section, the categorization of highlighted references was summed to give an overall effect (OE, +ve, ntl or -ve) in the Results. The broad scale at which an effect operates was categorized as either local (part of a woodland or field), patch (the whole woodland or field) or landscape. These categorizations are presented at the beginning of each sub-section alongside the OE, and then combined into a summary diagram. At the beginning of most sections there is a note to provide context or background if necessary and comments at the end of sections might provide a footnote about findings or mention other studies that might contribute weak evidence.

For negative effects, if the size of releases or other density component (such as distance from release pen) was also reported as an effect, this was recorded for each sub-topic in the diagram. Positive effects that are economically dependent (i.e. expensive and hence more likely at larger shoots) and negative effects where the literature identifies a density component, i.e. larger releases worsen a negative effect, are also identified in the diagram. While no other type of weighting was applied here, it would be possible for a particular set of ecological priorities to use the sectional framework of the review as the basis for a weighted score analysis.

Results

Woodland management for pheasants

Woodland planting and retention for pheasants

+ve	ntl	-ve	OE	Landscape
2	0	0	+ve	

Two main studies document several positive effects on woodlands in areas with an interest in released pheasants compared to areas without. Firbank (1999) [+ve] found slightly

more and larger woods, but also an increase in woodland area over time, in game areas compared to non-game areas. Short (1994) [+ve] found farm holdings with a game interest had greater woodland cover and more new small woodlands. Another smaller survey reported that more landowners retained or planted small woodlands with pheasants in mind (Cobham Resource Consultants 1983).

Vegetation and breeding birds in lowland woodland interiors

+ve	ntl	-ve	OE	Patch
3	0	0	+ve	

Some of the techniques thought to improve woodlands for pheasants, e.g. coppicing, skylighting, shrubby edges and wide rides (GCT 1988, Robertson 1992, Robertson et al. 1993a, b), were often reported as being beneficial to other wildlife particularly birds (Fuller et al. 2005, Amar et al. 2006). Short (1994) [+ve] found that game woodlands were much more likely to manage rides, coppice trees and plant shrubs. Draycott et al. (2008a) [+ve] documented better canopy and ground flora structure but no differences in shrubs inside game managed broadleaf woods. There were more songbirds overall and warbler territories in particular in the pheasant woods. Sage (2018a) [+ve] found some differences in vegetative structure and more birds in game managed conifer plots. For conifer plantations in particular, less dense woods were probably selected for game management purposes and then improved/maintained through management for game.

Shrubs, butterflies and bees at wood edges

+ve	ntl	-ve	OE	Local
1	0	0	+ve	

Pheasants are birds of the woodland edge zone (Robertson et al. 1993a, b) and game managers tend to locate release pens and focus any management work in these areas. Woodburn and Sage (2005) [+ve] documented improved shrub cover and wood edge characteristics, more flowering shrubs and butterflies in the edge zone of pheasant woods.

Woodland rides in game woods

+ve	ntl	-ve	OE	Local
1	0	0	+ve	

Game managers use rides for access, to feed birds and provide sunning areas, and on some shoots as places to locate a line of guns (GCT 1988). In Capstick et al. (2019a) [+ve] rides were not longer but wider in game woods, were more likely to have an open canopy and experienced more disturbance by vehicles but less foot or horse erosion. There was less bare ground, more ruderal species and more shrub species in rides in game woods.

Songbird use of pheasant woods in winter

+ve	ntl	-ve	OE	Patch
1	0	0	+ve	

Released pheasants are fed in and around release sites in autumn and early winter following release. Alongside any woodland management, this might be expected to affect

overwintering birds. Hoodless et al. (2006) [+ve] found a greater abundance of birds and more species in winter game woods than non-game woods and linked these differences to woodland structure.

Small mammals in pheasant woods

+ve	ntl	-ve	OE	Local
1	0	0	+ve	

In Davey (2008) [+ve] habitat variables explained most variance in numbers of small mammals caught in game woods but game management had a positive effect on two species, bank voles *Myodes glareolus* and wood mice *Apodemus sylvaticus*. The study found no evidence that pheasants preyed on small mammals. Grey squirrels *Sciurus carolinensis* are sometimes reported as being more common in woodlands with pheasant feeders. Draycott and Hoodless (2005) found no difference.

Impact of released pheasants on lowland woodland habitats

Ground flora effects in woodland-based pheasant release pens

+ve	ntl	-ve	OE	Local
0	0	3	-ve	

Pheasants are usually released into woodland-based, open-topped, fenced pens in late summer (GCT 1996) to protect the releases from foxes while they get used to roosting in trees. Sage et al. (2005a) [-ve] documented more bare ground, reduced low vegetation cover lower species diversity and lower percentage cover of shade-tolerant plants, more annual species especially where stocking density increased beyond 1000 pheasants per hectare of pen. Sage (2018a) [-ve] reported lower cover of herbaceous plants and ferns and lower fern diversity, inside release pens than outside in a group of large shoots. Capstick et al. (2019b) [-ve] looked at the recovery of sensitive woodland ground flora in disused release pens and found signs of recovery especially in long disused pens but this recovery was reduced where more birds had been released. The papers variously suggest several mechanisms that cause changes to ground floras where pheasants are released. Soil chemistry is one. Plants that are present in late summer/autumn may be damaged by pecking and trampling. Management of shrubs and trees in and around release pens can affect shade levels. Alsop and Goldberg (2018) documented a reduction in natural regeneration of tree and shrub species, more bare ground and a coarse and rank ground flora at one NNR site over several years, next to release and/or feed sites.

Soil effects in woodland-based pheasant release pens

+ve	ntl	-ve	OE	Local
0	0	2	-ve	

Sage et al. (2005a) [-ve] recorded elevated levels in soil potassium and phosphate in a small sample of pens compared to outside pens while pH and magnesium levels were not detectably different in this small sample. Capstick et al. (2019b) [-ve] found phosphate and potassium levels remained higher in most disused pens but soil chemistry

recovered slightly in older pens. At their NNR site, Alsop and Goldberg (2018) documented soil erosion, soil enrichment and associated concentrations of droppings where pheasants congregated.

Woodland ground invertebrates in pheasant release pens

+ve	ntl	-ve	OE	Local
0	1	2	-ve	

Pheasants are omnivorous and will take animal foods in the wild, generally insects, particularly when they are chicks (Beer 1988). In the rearing system the diet of young birds is usually grain-based with added protein. Adult birds, even wild ones, do not need a high-protein diet. In general, in her PhD, Pressland (2009) [ntl] found few differences in insect numbers in woodland plots with or without releasing and before or after releasing. Some insect groups were caught more frequently with releasing and some without. Faecal analysis indicated that pheasants sometimes ate invertebrates.

Neumann et al. (2015) [-ve] however found a more disturbance-tolerant flora, no overall difference in invertebrate abundance but a depleted community of larger ground beetles and more detritivores in the release pens. Hall (2020) [-ve] found that pen interior invertebrate biomass was lower, while slug counts were higher, in release pens compared to elsewhere. After release invertebrate numbers were sometimes lowered inside pens. Predation of, for example, beetles by pheasants and altered conditions (e.g. reduced shade due to tree canopy management in pens) are both likely to be relevant.

Direct impacts on butterflies

+ve	ntl	-ve	OE	Patch
0	1	0	ntl	

Corke (1989) suggested that fritillary butterflies might be less common in pheasant woods because of pheasant predation. Warren (1989) described how the ecology of fritillaries meant that they were at a low risk of predation, and that Corke's correlations were probably not causal. Clarke and Robertson (1993) [ntl] showed that pheasants did not eat fritillary larvae and that fritillary populations hadn't declined disproportionately in pheasant woods. Of 150 pheasant droppings collected from a site with pheasants and a high density of butterflies including marsh fritillary *Eurodryas aurinia*, two had unidentified caterpillar remains (Porter 1981).

Woodland bryophytes and lichens on trees

+ve	ntl	-ve	OE	Patch
0	0	1	-ve	

Lower-order epiphytic plants such as bryophytes (mosses and liverworts) and lichens are sensitive to damage through enrichment of the soil or atmosphere and remain common only in woodlands that are in relatively clean-air regions of the country (Mitchell et al. 2004).

Sage (2018a, b) [-ve] found reduced moss, lichen and liverwort diversity on tree trunks in woods with a release pen in an area of England notable for woodlands with good lower order plant floras. Increased nitrogen in the air was thought

to be responsible for these changes, partly because effects were detected outside pen areas, but reduced microclimate suitability through habitat management may be a factor.

Smith (2014) identified pheasant feeding and faeces as an additional pollution source, along with raised background levels of nitrogen and livestock farming that affected lichens at a site with a UK conservation designation. In Wales, Bosanquet (2018) identified relative degradation of the moss/lichen flora in part of another designated woodland enclosed by a pheasant release pen.

Management for released gamebirds on farmland habitats

Hedgerows and other edge habitats on farmland

+ve	ntl	-ve	OE	Landscape
2	0	0	+ve	

Hedgerows are widely used by game managers to link woodland pheasant releasing areas to holding cover, usually game crops, to facilitate shooting (GCT 1988). Firbank (1999) [+ve] found more hedges and more common hedgerow birds and butterflies on game areas than on non-game areas. Draycott et al. (2012) [+ve] showed that game estates had more hedgerow and more grass margins or uncultivated strips alongside them per square kilometre than farms with no releasing.

There are a range of other field-edge habitat management practices undertaken by wild pheasant and partridge shoots in some parts of the country (Tapper 1999). These include brood-rearing crops, conservation headlands, nesting cover and beetle banks. It is however uncommon for release-based shoots to use these unless they have a particular interest in wild birds (Ewald et al. 2010).

Songbirds using game crops planted on farmland

+ve	ntl	-ve	OE	Landscape
6	0	0	+ve	

Winter seed-bearing crops of various kinds are widely planted on farmland on released game estates to provide feed areas and to hold pheasants and partridge as part of a shoot (GCT 1994). Ewald (2004) estimated 80% of all shoots planted these game crops covering 3% of their arable area. Several studies have documented greatly increased overwintering bird numbers in game crops such as kale, quinoa and cereal game crops compared to other fields on the same or nearby farms (Sage et al. 2005b [+ve], Parish and Sotherton 2004 [+ve], Stoate et al. 2003 [+ve], Henderson et al. 2004 [+ve]). At some sites the seed resource declined later in the winter especially in smaller plots (Henderson et al. 2004 [+ve], Sage et al. 2005b [+ve]). Parish and Sotherton (2008) [+ve] found that game-crop plots in grassland landscapes had more birds in winter than similar game crops in arable areas. In a grassland landscape, where game crops can be the only or dominant seed bearing crop, Sage (2018a) [+ve] found more breeding resident birds in the surrounding hedgerows in the spring.

Winter and summer game crops are planted in relatively small plots and hence concentrate birds. Nevertheless these patches of game crops lead to substantial increases in the

abundance of wintering and breeding songbirds not only in those plots but in adjacent land, especially where there is little arable cropping.

Supplementary feeding of gamebirds

+ve	ntl	-ve	OE	Landscape
3	0	0	+ve	

Providing supplementary food for released gamebirds through feeders is practised on most release-based shoots. Sanchez-Garcia et al. (2015) [+ve] documented a wide range of farmland birds and mammals using gamebird feeders including species in decline. Several species increased or declined more slowly alongside experimental feed plots (Siriwardena et al. 2007, 2008) [+ve]. The studies suggest that game estates that maintain feed points following shooting (as required by the Code of Good Shooting Practice produced by UK shooting organisations) can improve over-winter survival and breeding numbers of seed-eating farmland birds. At 54 red-legged partridge hunting estates in Spain the abundance of granivorous species black-bellied sandgrouse *Pterocles orientalis* and pin-tailed sandgrouse *Pterocles alchata* increased significantly with the density of partridge feeders (Estrada et al. 2015) [+ve]. Game management including (but not exclusively) feeding was associated with higher abundance of raptors and ground-nesting birds on partridge shoots in Portugal (Caro et al. 2015).

Impacts of released gamebirds on open habitats

Impacts of released pheasants on hedgerows

+ve	ntl	-ve	OE	Local
0	1	1	-ve	

Pheasants are often encouraged to make daily movements along hedgerows between releasing woods and holding cover to facilitate driven shooting back to the home wood and partridges will occupy hedges if they are released nearby. Bare ground was increased and ground flora and shrubbiness diminished inside hedges close to release pens and alongside game crops (Sage et al. 2009) [-ve]. These stretches of hedges also had fewer songbirds. In another study Draycott et al. (2012) [ntl] looked for but did not find a reduction in woody structure of hedges near to release sites.

Gamebirds and grassland invertebrates

+ve	ntl	-ve	OE	Patch
0	2	0	ntl	

Released partridges are usually driven between game crop patches on farmland to facilitate shooting. This means that the potential for damaging semi-natural habitats was reduced compared to pheasants. Partridges can however be released into or alongside more sensitive grassland habitats. Callegari (2006) [ntl] found that although the gamebirds were eating some invertebrates on several chalk grassland sites (based on faecal sample analysis), mainly following release in autumn, they did not have a measurable impact on overall spring invertebrate densities, or on numbers of Adonis blue *Polyommatus bellargus* butterfly, which were studied in particular detail Callegari et al. (2014) [ntl].

Comparing isotope signatures, Jensen et al. (2012) found that released pheasants ate fewer or no insects compared to wild pheasants.

Direct impact on reptiles

+ve	ntl	-ve	OE	Patch
0	0	1	-ve	

The Amphibian and Reptile Conservation Trust (ARC) suggests that all six British reptile species could be vulnerable to predation by, in particular, pheasants. Blanke and Fearnley (2015) cite earlier work that list a range of predators of sand lizards *Lacerta agilis* including pheasant. The ecology of the six reptiles suggests that adults and juveniles can be exposed to released pheasants in autumn and spring (Beebee and Griffiths 2000).

There are however no peer reviewed studies. Dimond et al. (2013) found no reptile fragments in pheasant droppings collected from an area known to contain reptiles. In his MSc, Berthon (2014) [-ve] found that juvenile penned pheasants preferentially pecked at reptile shaped plastic objects and recorded no reptiles under refugia in three pheasant releasing woods and a small number of reptiles in refugia in three non-release woods. There is little scientific evidence of an effect of released pheasants on reptiles but anecdotal reports and the ecology and behavior of some species suggest that they are vulnerable.

Red-legged partridge releasing and over-shooting wild partridges

+ve	ntl	-ve	OE	Landscape
0	1	1	-ve	

Watson et al. (2007) [-ve] found that releasing red-legged partridges where wild grey partridges occur can lead to unsustainable losses to shooting of the grey population even if greys are off the quarry list. It had been demonstrated that losses can be minimised by using a warning system on shoot days (Aebischer and Ewald 2010) [ntl]. In Spain at a sample of four sites Casas et al. (2016) found that where partridges were released, a greater number of wild ones were shot, suggesting releasing could cause over shooting of wild stocks.

Indirect impacts of releasing – shared parasites, disease and genes

Endo parasites of pheasants and partridges

+ve	ntl	-ve	OE	Landscape
0	2	3	-ve	

Released gamebirds are prone to infection by endo-parasitic worms in the rearing system and post release, the commonest being *Heterakis gallinarum*, *Capillaria* spp. and *Syngamus trachea* (Clapham 1961, Draycott et al. 2000, Gethings et al. 2015).

Some of these worms may also be found in other birds (Clapham 1957). Gethings et al. (2016a, b) [-ve] suggested that pheasants and carrion crows can share *Syngamus trachea* or gapeworm infections and both can be negatively affected. Bandelj et al. (2015) found syngamus in a small but significant proportion of omnivorous primarily migratory bird

species. Holand et al. (2015) found that house sparrows produce fewer eggs if infected with *S. trachea*.

Millan et al. (2004) found that most reared and wild partridges had different species of helminths suggesting they may not share them. Villanúa et al. (2008) [–ve] found a greater number and variety of parasites in partridges on releasing sites than wild ones and suggested that the release of farm-reared partridges poses a risk of exposing other wild bird populations to parasites that are normally only found in the rearing system.

A model was developed that suggested that pheasants carrying *H. gallinarum* could compete with grey partridges via the parasite alone (Tompkins et al. 2000, 2001 [–ve], Tompkins et al. 2002). Sage et al. (2002) [ntl] provided evidence from a more substantial laboratory study that disputed this and despite the increase in releasing, 12 000 post-mortem reports found that the rate of infection of wild grey partridges by *H. gallinarum* fell by 90% since 1951 (Potts 2009).

There is little information on whether parasite control treatment for releases, which is undertaken using anthelmintic-treated grain or water in pheasant feeders inside release pens, has any positive or negative effect on other wildlife (Mustin et al. 2018). Other animals especially birds are known to use pheasant and partridge feeders.

Pheasants, ticks and Borrelia

+ve	ntl	–ve	OE	Landscape
0	0	2	–ve	

Lyme disease in humans, caused by the bacteria *Borrelia* spp. is acquired through tick bites, predominantly *Ixodes ricinus*. *Borrelia* bacteria are maintained in an enzootic tick-wildlife cycle, infecting small mammals and ground-feeding birds. The importance of the different factors on the incidence of *Borrelia*-infected ticks and the effect of these ticks on wildlife is unknown (Ostfeld et al. 2018).

Hoodless et al. (1998) [–ve] confirmed a high abundance of ticks on previously released pheasants particularly males and at a level comparable with small mammals, while Kurtenbach et al. (1998) [–ve] showed that these pheasants can pass the spirochetes back to ticks. While there are other wildlife species that carry ticks but don't transmit *Borrelia*, this identified released pheasants for the first time as a potential vector of *Borrelia*.

Woods managed for pheasants tend to have more shrubs and ground cover than other woods and these otherwise normally beneficial woodland conservation practices may promote ticks and tick–host interactions (Ehrmann et al. 2018). Whether there are particular tick–host communities involving pheasants that might increase the prevalence of *Borrelia* requires investigation.

Diseases of gamebirds and wildlife

+ve	ntl	–ve	OE	Landscape
0	1	3	–ve	

The occurrence of diseases in gamebirds on a particular site depends on factors such as the source of the gamebirds, contact with other wildlife, stocking density, management of the birds during rearing and weather conditions. Respiratory

diseases, in particular the pathogen *Mycoplasma gallisepticum* (MG) (Welchman et al. 2002) occurs in released game, has been detected in several other wild bird species and there is at least the opportunity for transmission between them (Pennycoot et al. 2005) [–ve].

Intestinal disease is commonly associated with bacterial infections, e.g. *Salmonella* and *Escherichia coli*. These are usually associated with younger birds in the rearing system where they are unlikely to spread to wild birds. Díaz-Sánchez et al. (2012b) [–ve] provided evidence that farm-reared partridges in Spain can act as carriers of these enteropathogens following release and suggests there was a potential risk of transmission to natural populations. There was some evidence that releasing gamebirds treated with antibiotics has the potential to disseminate resistant bacterial strains among wild birds (Díaz-Sánchez et al. 2012a) [–ve]. Gamebirds were unlikely to significantly spread the notifiable diseases avian influenza and Newcastle disease because they are subject to an eradication policy (Bertran et al. 2014) [ntl]. An important respiratory disease in poultry which has also been found in reared and wild gamebirds is infectious bronchitis (IB) (Cavanagh et al. 2002, Welchman et al. 2002). There is therefore the potential for IB to be transmitted from released to wild gamebirds (Curland et al. 2018).

Red-legged partridge and chukar hybridisation

+ve	ntl	–ve	OE	Landscape
0	1	0	ntl	

In the 1960s game farmers began rearing an *Alectoris rufa* and *A. chukar* cross (Blanco-Aguilar et al. 2008). However these hybrids were breeding with genetically pure wild *A. rufa* throughout its natural range and where it had been introduced (Casas et al. 2012) [ntl]. This has resulted in the virtual loss of the native *A. rufa* genome (Barbanera et al. 2010), or at least one of its three subspecies *A. r. rufa* (Madge and McGowan 2002) including no pure *A. rufa* in the UK (Barbanera et al. 2015).

The release of *A. chukar* or its hybrids was banned in 1992 and with no pure *A. rufa* in the UK the release of partridges no longer has an effect on the genetic integrity of wild birds. So while the damage has been done the mechanism has been resolved hence [ntl].

Releasing and predators

The effect of predator control

+ve	ntl	–ve	OE	Landscape
3	1	0	+ve	

There is a wide literature on the impact of predators or of predator control on gamebirds and other birds. A synthesis and analysis by Roos et al. (2018) provided good evidence that for three of the four main groups of birds (seabirds, gamebirds, waders) numbers are limited by predators. In an experimental predator control sub-sample, there was evidence of this for passerines as well. The paper concluded that predator management aimed at foxes *Vulpes vulpes* and corvids simultaneously is more likely to be effective. It is not however clear that release-based shoots undertake effective predator control.

In their review Mustin et al. (2018) concluded that predator control associated with game management did have a positive effect on some other wildlife but few papers considered directly released game. Porteus et al. (2019) [+ve] documented culling effort and the fox population at 22 game managed estates, many of which released pheasants. At all 22 the fox population was suppressed successfully to on average about half of the estimated carrying capacity. There was also an indication that the effectiveness of fox control was reduced compared to other sites at some of the larger releasing shoots. Heydon and Reynolds (2000) and Heydon et al. (2000) [ntl] however found no reduction in foxes in a released gamebird region of England but did find a reduction in a wild gamebird region.

Releasing shoots that undertook high level predator control in the spring had improved survival of breeding adult pheasants (Sage et al. 2018) [+ve] and improved nest survival (Draycott et al. 2008b) compared to shoots that did not, suggesting other ground nesting birds might benefit. In Spain little bustard *Tetrax tetrax* declined in most parts of a Spanish province except for areas that had large release-based shoots that undertook predator control and habitat management (Cabodevilla et al. 2020) [+ve]. White et al. (2014) found that the type of predator control practiced on releasing estates was less effective at improving breeding success in hedgerow nesting songbirds than that on wild estates. In summary there is a mixture of evidence that suggests that at least some release-based shoots undertake effective predator control around release sites. In these circumstances the papers that Roos et al. (2018) reviews indicate that other wildlife can benefit.

The impact of releases on predators

+ve	ntl	-ve	OE	Landscape
0	1	6	-ve	

In theory generalist predators (e.g. foxes, corvids, raptors) will respond to increased prey numerically (i.e. increase in number) and functionally (switch to eating more pheasants) (Solomon 1949, Robertson and Dowell 1990). On average around 60% of pheasants released for shooting at seven sites in the UK died of causes other than being shot and most of these were predated or scavenged (Sage et al. 2018). Roos et al. (2018) found that the overall density of foxes in the UK was higher than in eight other European countries (but not Italy and Spain) and that crow density was higher than in most other European countries. Bicknell et al. (2010) and others discuss the idea that predators, responding to releases, remain on site and switch to other prey when numbers of released birds decline in the spring. This is a reasonable hypothesis but there is no evidence to support or refute it. Here we look at the information available relating to the idea that predators may respond to releasing gamebirds.

Robertson (1986) [-ve] found many more fox droppings near to a pheasant release pen and following the release of pheasants. Radio tagged goshawks *Accipiter gentilis* at a pheasant release site in Sweden were at a higher density, had smaller ranges and were heavier than Goshawks elsewhere (Kenward et al. 1981) [-ve]. While buzzards *Buteo buteo* have increased in the UK alongside pheasant releasing

in recent decades suggesting a link, Kenward et al. (2001) [ntl] thought other factors were more likely to be responsible. Swan (2017) [-ve] however found buzzards breeding at greater density in areas with more pheasants and rabbits. Pringle et al. (2019) [-ve] found weak spatial correlations between released gamebirds and some raptor species in long term datasets. Using surveys, Beja et al. (2009) [-ve] reported more foxes on game estates than elsewhere in Portugal. On five UK estates, measures of fox abundance appeared to be positively correlated to the number of released gamebirds (Porteus 2015) [-ve].

Releasing and illegal killing of raptors

+ve	ntl	-ve	OE	Landscape
0	0	3	-ve	

In questionnaire surveys of release managers, Lloyd (1976) and then Harradine et al. (1997) both reported tawny owl *Strix aluco*, sparrowhawk *Accipiter nisus* and buzzard as the main problem species at release sites. In a review FERA (2012) concluded that losses of released pheasant poults to raptor predation was <1% at >90% sites. Swan (2017) found support for the idea that there are some buzzards that specialise in taking pheasant poults. Some studies report little direct predation by raptors of releases (Turner 2007, Lees et al. 2013). While Kenward (1977) and Kenward et al. (2001) suggest that only goshawk presents a serious threat to releases in Britain there remains a perceived problem of some other raptors impacting recently released pheasants (Kenward et al. 2001, Lees et al. 2013, Parrott 2015).

Kenward et al. (2001) [-ve] is the main source of evidence of buzzards being killed in association with releasing with several radio-tagged individuals found shot or poisoned near pheasant release pens. Similarly (but now over 40 years ago) Marquiss and Newton (1982) [-ve] documented illegal killing of ringed goshawk in Britain at or near to pheasant release pens. In Portugal, kestrel *Falco tinnunculus* were found to be less common on game estates and the abundance of most raptors varied inversely with gamekeeper density Beja et al. (2009) [-ve]. RSPB (2019 and previous years) [-ve] has occasionally reported raptor killing alongside releasing in the UK.

In their recent review, Mustin et al. (2018) reported only one paper relating to raptors and released game (Beja et al. 2009) while five concerned raptors and grouse moors. A Europe-wide review (Arroyo and Beja 2002, Manosa 2002) concluded that illegal killing of raptors was less common in association with releasing than with other forms of game management and that it had declined across Europe.

Conclusions

This review focused on ecological effects directly attributable to releasing pheasants and partridges and draws from 128 scientific literature sources. Many have not been peer-reviewed but have a considerable contribution to make where primary sources are few. The 54 directly relevant sources define 25 distinct sub-topic sections or effects and form the basis of the synthesis summarized in Fig. 1. For practical reasons, most studies contributing to this review have not had an

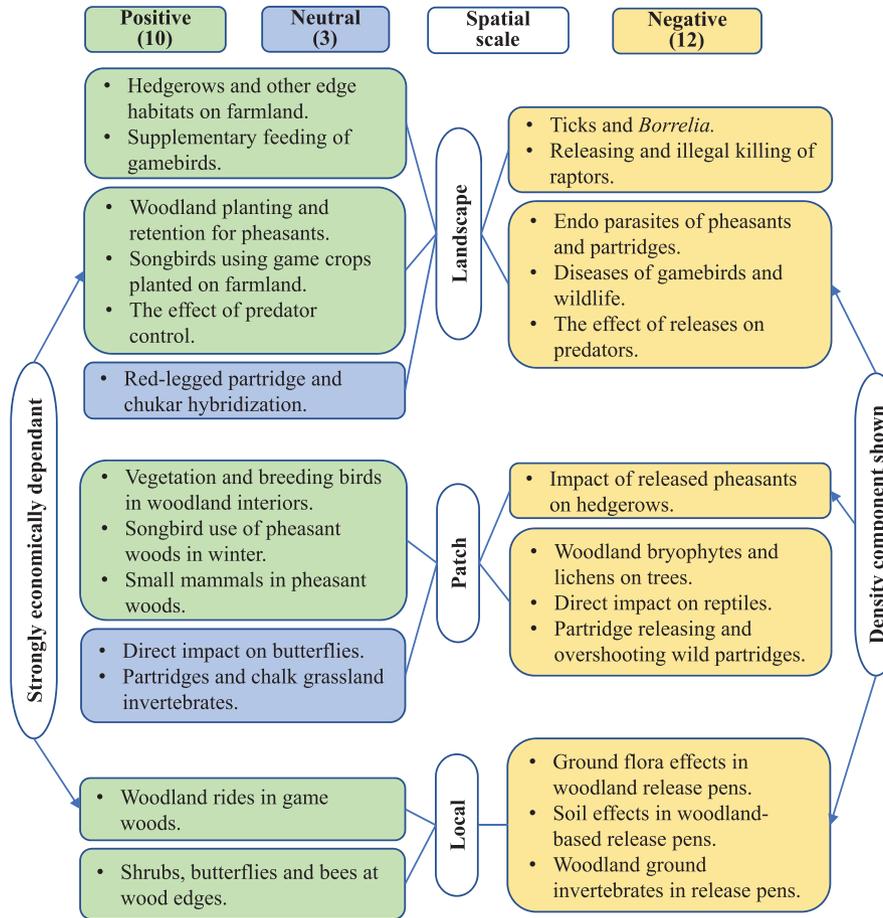


Figure 1. Twenty-five ecological consequences of gamebird releasing for shooting as identified by this review and synthesis. There are 10 potentially positive, three neutral and 12 potentially negative effects that occur at one of three spatial scales as indicated. Positive effects that are dependent on economics (i.e. can be expensive) are also indicated and there are seven negative effects where there is evidence that they are reduced or eliminated when fewer birds are released. Economically dependent positives are more likely to be found at larger releases but as size goes up some of the negative density related consequences may become more apparent. There is scope for some local or patch related negatives to be avoided by identifying sensitive sites.

experimental component relying instead on the selection of suitable sites for data collection. This means bias is always possible and it is not always clear what caused an effect as indicated in subsection comments.

Positively classified effects of releasing are usually a consequence of gamebird management activities, and negative effects are usually caused by the released birds themselves (Fig. 1). Nine management effects (see Woodland management for pheasants and Management for released gamebirds on farmland habitats) are classified as positive, seven of the direct effects caused by the released birds, mainly pheasants, on habitats and other wildlife are negative and two neutral. Three effects of shared parasites and disease are negative and one neutral, and for predator issues there is one positive and two negative effects.

Some of the negative effects are spatially confined, usually at the release site or feed point while others, in particular disease issues and the effect of releasing on generalist predators, may occur at a landscape scale. Most of the positive effects of management for releases occur at the scale of a whole woodland or across an estate or farm. Overall, there are five positive and five negative effects that potentially act at a landscape scale and four and six respectively at a local scale

(Fig. 1). There is evidence that some positive management activities such as game crop plantings or predator control are more effectively implemented at larger releases. Because pheasants are usually released into a more sensitive habitat type they have more negative effects than partridge releasing.

Some negative effects have relatively straightforward management solutions summarized in Fig. 1. The synthesis indicates that, working within the normal range of releases accessed by the majority of studies (a few hundred birds to a few thousand in any one pen), most (seven) negative effects increase with higher densities of birds at release sites. There is also scope for shoots to reduce or eliminate local or patch related negative effects by identifying sensitive sites and avoiding conflicts with for example reptile colonies or woodland areas with valuable ground floras. The illegal killing of raptors is a landscape scale negative effect that should and could be eliminated with no detriment to game management interests.

While the review synthesis not does attempt to qualitatively assess the relative importance of each topic by ranking or weighting them, the framework of sub-sections could be used as the basis for an analysis that weights the synthesis more in one or other direction, taking account of a particular

set of ecological priorities. Similarly a more complex synthesis could incorporate non-ecological effects or consequences of releasing such as welfare, social and economic issues.

The field-based studies were undertaken at many hundreds of different release-based shoots over several decades. The findings of the review should be interpreted as representing a median type of shoot in terms of size and adherence to good practice over that period, during which releasing numbers have steadily increased. By identifying damaging activities and practices the work done so far has increased the awareness of potential conflicts, the need for good practice and the tools to employ it. The overall balance of effects today and in the future will depend on the extent to which shoots engage with this. Increasing adherence to recommended stocking limits of pheasant releases in woodland pens, improving the process of identifying and avoiding individual sites that are especially sensitive to releases, and the cessation of illegal raptor killing are three straightforward ways of improving this balance.

There are significant knowledge gaps throughout the range of broad topics covered in this review. Some of the data on the benefits of woodland management, woodland planting and retention is out of date and the numbers of gamebirds released has increased in the meantime. More generally it would be useful to look carefully at the link between the scale of modern releasing and land management practices undertaken for the benefit of released game such as woodland management, field edge management, game crop planting, supplementary feeding and predator control.

Some of the direct impacts of releasing require further investigation. There is for example a small amount of anecdotal evidence and an inconclusive study that suggest that certain reptile species could be vulnerable to released pheasants. The impact of released gamebirds on invertebrates also needs further clarification with two studies showing an effect in woodland release pens but several studies finding little effect outside those areas.

There is only patchy knowledge on the potential of releases to introduce diseases and parasites to wildlife. Transmission of certain enteropathogens or parasites such as *Syngamus trachea* need further study. There is also the need to understand the role, if any, of pheasants in relation to *Borrelia*.

It is not clear how predators respond to the release of gamebirds at and around the release site. There is evidence that game managers suppress foxes but it may be relatively ineffective at some sites. Whether predators attracted to release sites go on to cause problems for other wildlife, for example ground nesting waders, is not known. A study of this would need to tease out the contribution of pheasant releases in the context of the other modern land management practices, including many agricultural related practices, other anthropogenic food sources and disturbance, all of which will also influence predators.

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Supplementary material (available online as Appendix wlb-00766 at <www.wildlifebiology.org/appendix/wlb-00766>). Appendix 1.