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ORIGINAL ARTICLE

Pheasant release in Great Britain: long-term and large-scale changes in the survival of a managed bird

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Abstract
The release of artificially reared pheasants is a widespread practice in Great Britain, used to increase the number of birds available for hunting. We examined the spatial and temporal patterns of release and shooting between 1960 and 2014 using data from a self-selected sample of 1195 sites. We examined changes in the efficiency of release, the contribution of birds that were not released that year to the numbers shot, and the form of these relationships through time. An annual estimate of the efficiency by which releasing increased the numbers shot was 50% over the period 1960–1990 declining rapidly to 35% by 2005 and reducing more slowly thereafter. There was no obvious regional pattern to this relationship. It has been hypothesised that the efficiency of releasing is lower on sites that release higher densities of pheasants; this study does not support this hypothesis. Annual variation in the density of birds shot in the absence of releasing (1960–1990) was closely correlated with a measure of annual gamebird chick survival. After this date, the relationship was no longer significant, consistent with a decline in wild pheasant stocks and coinciding with the declines in other farmland birds. We highlight increased fox abundance, genetic and behavioural changes arising from the rearing process, and increased shooting in late winter as possible causes for the observed decline in releasing efficiency. We consider the general increase in rearing, habitat changes, increased disease or losses to protected predators as unlikely to have been important causes of the changes in releasing efficiency. Pheasant releasing results in increased numbers for shooting, but has not prevented the wide-scale decline of wild pheasant numbers.

Keywords Hunting · Release · Gamebird · Farmland

Introduction

The common pheasant (*Phasianus colchicus*) is currently the most numerous bird species hunted in Great Britain (Tapper 1992). It is a non-native species, introduced by the Normans or possibly the Romans (Lever 1977). Although it is a common breeding wild bird (Newson et al. 2008), in many areas, artificially reared birds are released to supplement autumn numbers for shooting during the winter (Hill and Robertson 1988a; Tapper 1992). This is a widespread activity, with estimates of over 35 million birds released annually in the UK (PACEC 2004). In Britain, the rearing and releasing process typically includes the collection of eggs from birds held captive or captured annually from the wild. These eggs are artificially incubated and the young birds typically raised to 6 weeks of age indoors. During July and August, these young birds are released into open-topped release pens, usually sited in areas of woodland, from where they are encouraged to spread into the surrounding habitat in advance of the shooting season.

A range of studies have described the survival and causes of loss of pheasants following release (Robertson 1988; Robertson and Dowell 1990; Brittas et al. 1992, Turner 2007), while studies of marked birds have documented the proportion of birds released that are subsequently shot (Bray 1967). However, these have typically been short-term case studies. The form of the relationship between the numbers released and shot has been the subject of debate. It has been

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suggested that the efficiency of pheasant releasing, measured as the effect on numbers shot, decreases as the density of birds released increases (Bicknell et al. 2010). Reports of the annual means, both of which have increased over time, indicate that the average number released in Britain has increased at a faster rate than the average number shot, with this effect becoming more pronounced in recent years as release numbers have increased (Tapper 1992; Aebischer and Baines 2008). If release efficiency does decrease with release density, then there may be a point where releasing further birds may be unlikely to lead to further increases in the numbers shot. However, beyond examination of annual means, the large-scale spatial and temporal patterns of releasing practice and efficiency remain largely unstudied.

Pheasant shooting, supplemented by releasing, is a significant source of income for many landowners (Martin 2011). Losses of birds to disease (Swarbrick 1985) or predation (Robertson 1988; Brittas et al. 1992) are minimised through management which can include supplementary feeding, the use of veterinary medicines to control diseases, together with the legal control of predators, primarily foxes (*Vulpes vulpes*). The widespread release of pheasants and this associated management also affect other species and habitats, both positively and negatively. An interest in pheasant shooting can promote woodland, hedgerow and other cover-crop planting by landowners, and their management in ways sympathetic to other species (Draycott et al. 2008, 2012). By contrast, high pheasant densities, particularly close to release points, may lead to altered habitats (Sage et al. 2005, 2009), invertebrate declines (Pressland 2009), disease spread (Tompkins et al. 2001) and altered farmland food webs (Bicknell et al. 2010). Pheasant release can also be a factor behind the illegal killing of protected predators such as birds of prey (RSPB 2009), although the significance of pheasant losses by protected predators remains controversial (Lees et al. 2013, Parrott 2015).

In the UK, pheasants are a bird of small woodlands and farmed land (Robertson et al. 1993a, b), and many of the other birds associated with these habitats have undergone major population declines in recent decades (Newton 2004; Aebischer and Ewald 2012). These changes have been linked to agricultural intensification; with habitat loss and simplification, increased pesticide use and altered food webs, all contributing to the declines (Chamberlain et al. 2000, Newton 2017).

This paper examines the long-term changes in the relationship between the number of pheasants released and subsequently shot on shooting estates in Great Britain over the period 1960–2014. These data are used to examine changes in the efficiency of release, the contribution of birds that were not released that year to the numbers shot and the form of these relationships through time. These are used to test the hypothesis that the efficiency of pheasant releasing decreases as the density of birds released increases (Bicknell et al. 2010). Possible explanations for the temporal patterns observed are explored using data on annual grey partridge chick survival as a proxy for wild pheasant productivity and through an inferential discussion of the roles of other potential drivers including agricultural change, disease control, rearing and shooting methods and the role of predation.

The release of captive-reared animals is widely used to increase the numbers of pheasants and other species available for consumptive use (e.g. Gortázar et al. 2000, Jonsson et al. 2003, Oosterhout et al. 2005, Champagnon et al. 2013). It can also be a useful tool for the reintroduction of threatened species that have been lost from an area, and appropriate guidelines have been developed to support this (IUCN 1998). Releases have also been used to supplement extant populations with the aim of improving their conservation status (Garson et al. 1992, Hodder and Bullock 1997; Niewoonder et al. 1998, Seddon et al. 2007). The effects of the large-scale and long-term release of hand-reared birds on the status of the wild pheasant population can help assess this approach as a conservation tool.

Methods

The National Gamebag Census

Data on pheasant release and shooting were obtained from the Game & Wildlife Conservation Trust (GWCT)'s National Gamebag Census (NGC). This is a privately funded voluntary scheme that collects statistics on game species from over 600 sites annually (Tapper 1992). At the end of each shooting season, each participant completes a form detailing the numbers of each species shot, numbers released, shoot area and, in the case of upland shoots, moorland area. Although older records exist, the data have been collected systematically since 1960 (Aebischer and Baines 2008). Because participation is voluntary, it is not known to what extent the returns can be considered representative of sites with an interest in game shooting, or of the wider countryside. The data are maintained in confidence by GWCT, so the analysis used anonymised data from 1960 to 2014, where sites were identified only to broad regions within GB. We considered three areas, western, central and eastern Britain, based on the regions described in (Tapper 1992) (details included as supplementary material).

Criteria for inclusion of NGC data

To qualify for inclusion, a basic requirement was that in any given year, records needed to show that pheasants had been both released and shot. Initial inspection of the data identified a small number of sites reported as under 200 ha in size that produced anomalously high density estimates. These sites were excluded from the analysis, as were annual records involving fewer than five pheasants shot or released.

Sites contributed data for variable lengths of time. Consequently, the composition of the dataset changed over its lifetime, with the potential to introduce biases. To assess this, three sets of criteria were used to define which data should be included for analysis:

- Strict. All sites over 200 ha and contributing at least 7 years of data over a 30-year period ($n = 309$ in total, with 108–244 sites per year)
- Medium. All sites over 200 ha and contributing at least 7 years of data over a 15-year period ($n = 567$ in total, with 168–346 sites per year)
- Liberal. All sites over 200 ha and contributing at least 3 years of data over any period ($n = 1195$ in total, with 277–508 sites per year)

Subsequent analyses were repeated on each of these three datasets. However, there were few differences between the results, apart from those arising from the smaller sample sizes associated with the more stringent sampling. As a consequence, only results from the largest, liberal subset are presented in this paper.

Temporal data on gamebird chick survival

Annual variation in the autumn number of wild gamebirds on farmland, including both pheasants and grey partridges (*Perdix perdix*), demonstrates a strong association with rates of chick survival (Potts 1986; Hill and Robertson 1988a). This in turn is dependent on the effects of weather and agricultural practice on the availability of invertebrate chick-food insects (Green 1984, Hill 1985, Rands 1985). There is no systematic collection of data on pheasant chick survival rates on an annual basis in GB; however, national information on the rate of grey partridge chick survival is available via GWCT's Partridge Count Scheme (Aebischer and Baines 2008). The chicks of the two species share the same habitat, have similar diets and similar thermoregulatory requirements (Potts 1986; Hill and Robertson 1988a). The annual estimate of the grey partridge chick survival rate was therefore used as a proxy for wild pheasant productivity on an annual basis, likely to reflect temporal changes in environmental quality, weather and the effects of predation.

Data analysis

Overall trends in the densities (numbers per km^2) of birds shot and released were calculated by generating an annual index using a generalised linear model (McCulloch 1997) with a Poisson error distribution and logarithmic link function, and with site and year as explanatory factors (ter Braak et al. 1994, Aebischer and Baines 2008). The dependent variables were numbers shot and released, analysed as densities by using the logarithm of site area as an offset in the model. Year coefficients were exponentiated to give an index on the arithmetic scale such that all index values were relative to 1960, which had a value of 1. Confidence intervals around the index values were obtained by bootstrapping at the site level: for each of 1999 bootstrap runs, sites equal in number to the original sample were selected at random with replacement and a new set of indices obtained (Efron and Tibshirani 1986). For each year, the 95% confidence limits were taken as the lower and upper 95th percentiles of the distribution of all 2000 index values.

To relate numbers shot to the number of birds released, we calculated the annual density of birds shot and released per km^2 per site. We then fitted mixed models to the density of shot birds with factors for year, density of birds released and the square of the density of birds released as fixed effects and site as a random effect. The model was then used to produce annual estimates of three parameters, the intercept, the regression parameter associated with release density and that associated with the quadratic term. Analysis was based on the untransformed densities of birds released and shot per km^2. While logarithmic transformation of both axes would have reduced the variance, we considered the parameters of the untransformed model to be more biologically meaningful, and we were interested in parameter estimation, not the optimisation of comparative statistics. Statistical significance was assessed using Wald statistics (W), calculated as the ratios of each parameter estimate to its standard error, compared to their empirical distributions obtained, as above, from 2000 runs comprising the original run and 1999 additional runs on datasets obtained by bootstrapping at the site level.

We considered the biological meaning of the three parameters as follows:

- The regression parameter associated with release density measured the efficiency of releasing, i.e. the average proportion of released birds that were shot that year across the sample of estates.
- The intercept measured the average density of birds shot that were not released in that year. These were considered to be a combination of wild-bred birds, the survivors of previous releases and immigrant birds from neighbouring releases.
- The regression parameter associated with the quadratic term served to test the linearity of the regression. If significant, it indicated that the efficiency of rearing varied between sites in relation to the density of birds released for a given year.

These three parameters and their associated standard errors were evaluated for each year. The calculations were repeated for each of the three levels of data inclusion and by region. All analyses were undertaken in R (R Core Team 2012) and GenStat 18th Edition statistical computer packages (Lawes Agricultural Trust 1995). Using grey partridge chick survival rate as a proxy for annual pheasant chick survival, we examined the strength of the correlation with the intercept, considering the data in rolling blocks of 15 years.

Results

Over the period 1960–2014, there was a maintained increase in both the density of pheasants released and shot by contributors to the NGC. Average release density increased by an average of 4.3% per year (Fig. 1) and was matched by an increase in the number shot of 2.1% per year (Fig. 2), although this rate appeared to slow from the early 1990s.

Modelling the relationship between the density of birds released and shot per site with year as a covariate identified a highly significant overall positive relationship between the densities released and shot ($W = 1806$; df = 1; $P < 0.001$). The slope of this relationship varied significantly between years ($W = 417.7$, df = 54, $P < 0.001$). The slope, considered to reflect the efficiency of releasing, was relatively constant at 0.5 over the period 1960 to the early 1990s. From then until 2005, there was a rapid decline from 0.5 to 0.35; after 2005, the reduction in efficiency was much slower (Fig. 3).

The intercept, considered to reflect the density of birds shot that were not released in that year, also varied significantly between years ($W = 400.2$, df = 54, $P < 0.001$). The intercept estimates suggested a figure of around 30 non-released birds shot per km^2 in the early 1960s, declining steadily to around 10 birds per km^2 by the early 1990s, with a subsequent increase to around 20 birds per km^2 by 2005, a density that has remained fairly constant since that date (Fig. 4). Using grey partridge chick survival rate as a proxy for annual pheasant chick survival, we examined the strength of the correlation with the intercept in rolling blocks of 15 years (Fig. 5), For years in the range 1960–1990, chick survival rate had a strong positive influence on the number of birds shot that were not released in that year. The inclusion of years after 1990 was associated with a large decline in the strength of this correlation, suggesting chick survival rate was no longer a significant factor influencing this value. For more recent data runs, the values have recovered to some extent, but not to the levels seen before the 1990s.

Testing for the presence of a quadratic function between the densities of pheasants released and shot found significant differences between years ($W = 115.6$, df = 54, $P < 0.001$), but only three effects significant at $P < 0.05$ in any of the 55 years when testing each year separately. That is as close as it is possible to get to the theoretical 2.75 expected when testing at this level of significance. We therefore consider there to be no significant effect of release density on the efficiency of releasing. Thus, in any 1 year, wherever it fell within the period 1960–2014, the relationship between the densities released and shot was best explained by a simple linear relationship with no evidence of a reduction in return rate on sites releasing higher densities of birds.

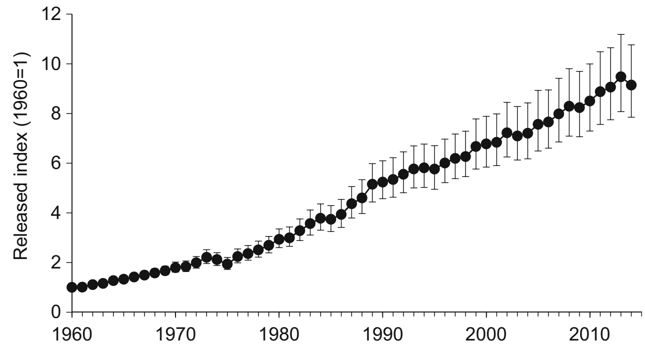

Fig. 1 Changes in the numbers of pheasants released on contributing NGC sites in Great Britain 1961–2014 (± s.e.). This is presented as an index with 1960 set to one

Splitting the data into three regions to examine geographical differences and modelling each regional dataset separately resulted in models that were too unstable to allow bootstrapping and the calculation of statistical significance. However, the estimated slopes are presented in Fig. 6. Although there was considerable variation in return rate between regions in the 1960s and 1970s, the declines appeared to occur with a high degree of synchrony in the different regions and to follow a similar path. We consider that there was no credible evidence for regional differences in the timing or extent of the declines in the efficiency of releasing.

Discussion

The release of artificially reared animals is widely used to increase the local abundance of harvested species (Robertson and Dowell 1990; Gortázar et al. 2000; Jonsson et al. 2003, Champagnon et al. 2013). As might be expected, we found a

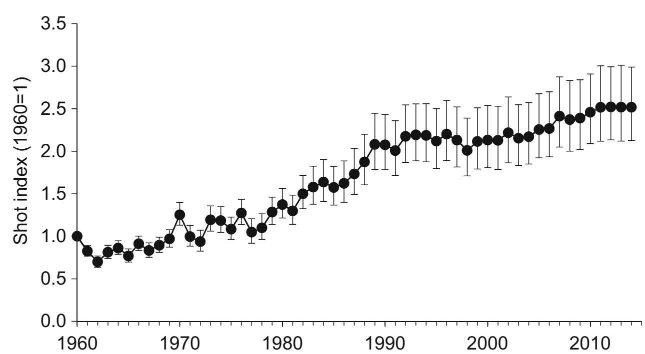

Fig. 2 Changes in the numbers of pheasants shot on contributing NGC sites in Great Britain 1961–2014 (± s.e.). This is presented as an index with 1960 set to one

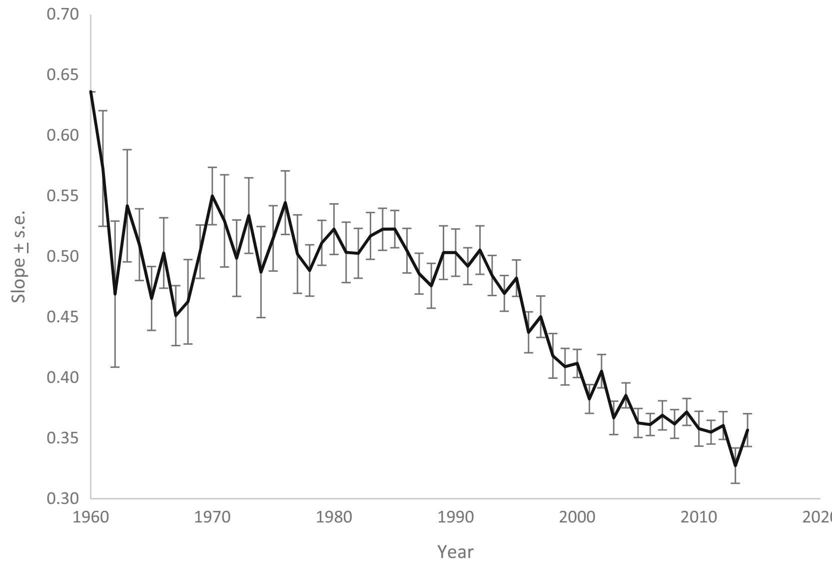

Fig. 3 Temporal changes in the efficiency of releasing. Annual estimates of the slope (± s.e.) of the relationship between the numbers of pheasants released and shot per unit area on contributing NGC sites in Great Britain 1960–2014

strong relationship between the density of birds released and the density shot across all years. Over the period 1960–1990, the release of every 100 pheasants on a site was associated with an increase in the numbers shot of around 50 birds, an efficiency of releasing of 50%. We found a subsequent decline in this efficiency, falling from 50 to 35% over the period 1990–2005, with much less change thereafter. The timing and extent of this decline did not appear to demonstrate any obvious regional pattern. Within years, we found no evidence for a curvilinear relationship between the densities released and shot; hence, the efficiency of release on a site in a particular year did not appear to be influenced by the density of birds released.

Bicknell et al. (2010) examined the average annual numbers of pheasants reared and shot per year in the UK. They concluded that these provided evidence that the efficiency of releasing declined as release densities increased. They suggested that increasing the density of birds released on a site would therefore have a progressively smaller effect on the density shot, and that there would come a point where further releasing would have no additional effect on the numbers shot. Our data do not support these conclusions, as we found that the efficiency of releasing was affected by year, but not by the density of birds released within a year. While release densities have increased over time, and a decline in the efficiency of release was observed between 1990 and 2005, this decline was seen equally on sites releasing both high and low densities of birds. In addition, the efficiency of releasing within a year was not affected by the density of birds released. The apparent decline in the efficiency of releasing seen over time is therefore not the result of increasing pheasant densities, as these changes have been common across sites regardless of the

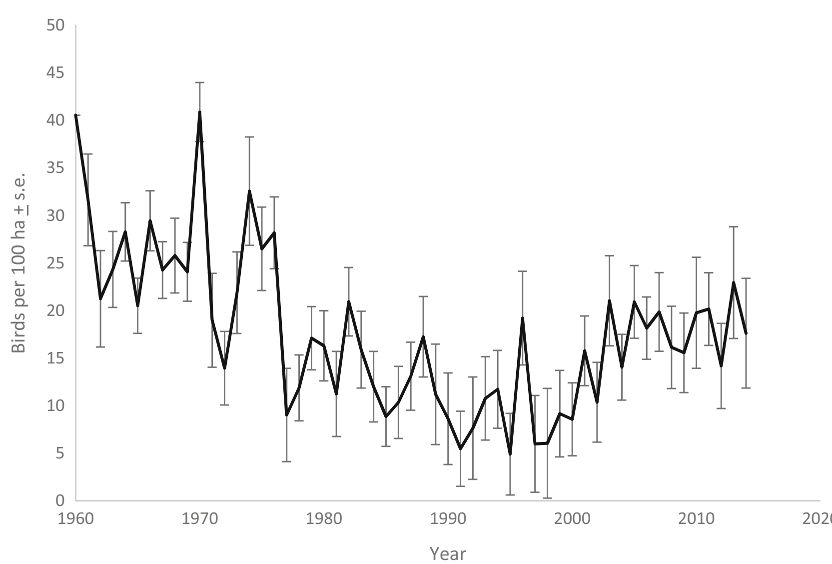

Fig. 4 Temporal changes in the density of pheasants shot in the absence of releasing. Annual changes in the intercept (± s.e.) of the relationship between the numbers of pheasants released and shot per unit area on contributing NGC sites in Great Britain 1960–2014

Fig. 5 The correlation between the annual intercept of the number of pheasants released and shot per unit area and the annual chick survival rate of the grey partridge over a rolling 15-year period. The grey partridge chick survival rate was used as a proxy for wild pheasant chick survival in that year

densities of birds released. Nevertheless, the efficiency of releasing has clearly declined through time, particularly over the period 1990–2005.

The pheasant is a common wild bird breeding in Britain (Newson et al. 2008), but the NGC cannot differentiate between wild and released birds in the records of numbers shot. The intercept of the relationship between the numbers of birds released and shot per unit area provides an annual estimate of the number of birds expected to have been shot on sites where no birds were released. This is likely to be a combination of wild birds, survivors from previous releases and immigrants from neighbouring releases.

Over the period 1960–1990, the intercept density was positively correlated with the grey partridge chick survival rate for that year, used as a proxy for the wild pheasant chick survival rate. For these years, it seems likely that that annual variation in the intercept density was associated with variation in autumn wild bird abundance and predominantly measured the contribution of wild birds to the bag, although this density fell from around 30 to 10 birds shot per km^2. After 1990, the intercept value gradually began to increase, but it was no longer significantly correlated with the chick survival rate, suggesting that the role of reared birds surviving from the previous year or, less likely, immigrants from neighbouring releases assumed a greater importance.

The decline in the efficiency of pheasant releasing for shooting, which took place between 1990 and 2005, appeared to apply equally to sites releasing high and low densities of birds, with no apparent regional pattern in the timing or extent of the decline. It was also unlikely to be an artefact caused by the changing composition of the NGC through time, as the same pattern emerged under three different sampling scenarios. The onset of this decline appeared to coincide with the point at which wild birds ceased to make a meaningful

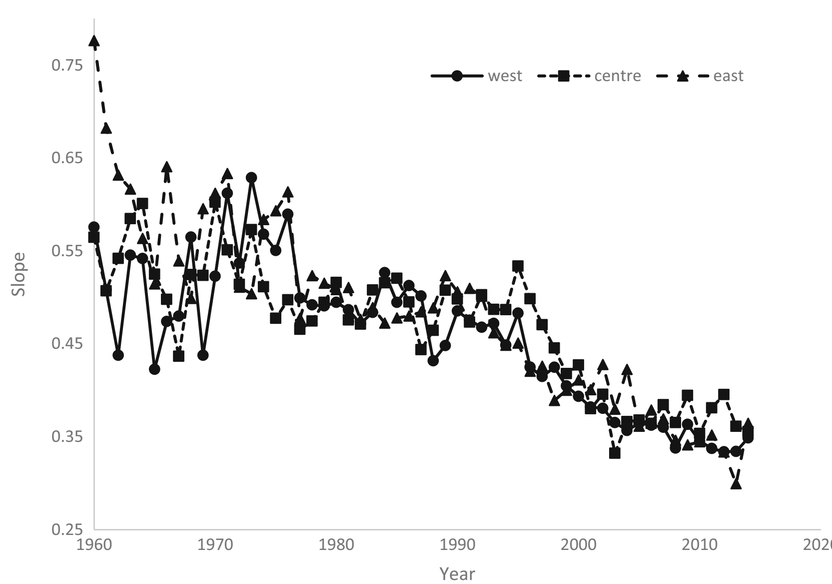

Fig. 6 Regional estimates of the efficiency of pheasant releasing per year. Estimates are presented separately for western, central and eastern Britain. The efficiency of releasing was estimated from the slope of the regression between the density of birds released and shot per year

contribution to the numbers shot. It is worth considering the range of factors that may have contributed to this decline, its timing and the absence of a regional pattern. These might include changes to the farmed habitat, disease, together with the risk of predation by species which can be legally managed such as foxes or those which are protected by law, such as birds of prey. It is also worth considering management changes in releasing and shooting practice. However, such a post-hoc analysis can only be inferential and cannot demonstrate cause and effect in what may well be a multi-factorial situation.

Naturally occurring pheasants are associated with farmed habitats. The local abundance of pheasants is closely linked to the availability of boundaries between dense cover, such as shrub rich woodland, and farmland, with arable crops attracting higher pheasant numbers than grassland (Robertson et al. 1993a, b). This species preferentially nests in tall grassy cover close to farmland (Robertson 1996). Pheasant chick survival is linked to insect food availability within agricultural crops (Hill 1985) and can be increased by manipulating the use of pesticides (Sotherton et al. 1993). Many farmland birds in the UK have undergone major population declines associated with the intensification of agricultural practice. The period 1970–88 saw the most agricultural intensification in the UK, characterised by increases in the area of oilseed rape and autumn-sown cereals, as well as in the use of pesticides and inorganic fertilisers, while spring-sown cereals, bare fallow and root crops all declined (Shrubb 2003). The timing of agricultural and farmland bird population change are broadly matching but with a time lag in the response of birds. The most accurately measured agricultural variables for the period 1974–91 matched the changes in farmland birds more closely (Chamberlain et al. 2000) and this period also saw the greatest decline in the wild grey partridge (Aebischer and Ewald 2010). The decline in the intercept density of pheasants shot described here also matches this temporal pattern, suggesting that the wild pheasant population may also have declined in the same way as those of many other farmland birds and the grey partridge. However, this explanation is not a good fit with the decline in the efficiency of releasing, which appears well after the main period of agricultural intensification and the period of decline of the other farmland birds.

During the rearing process, gamebirds are vulnerable to a range of diseases and parasites, often closely linked to those experienced by the poultry industry (Potts 2009). Protozoal infections such as histomoniasis and trichomoniasis can cause particular losses (Ruff 1999) and have been widely controlled through the use of veterinary medicines, in particular dimetridazole (Boxall et al. 2004). A major change in disease management in pheasants has been the use and then removal of this compound to control protozoan infections. The use of this product in food-producing species was banned throughout the EU in 1995. In 2001, the European Commission also withdrew its authorisation as a zootechnical feed additive. In the UK, products containing dimetridazole for game rearing ceased being manufactured in 2002, although remaining stocks could still be legally sold and administered until 2005. With its withdrawal, no effective replacement has been available and the control of protozoa has increasingly relied on improved husbandry. Thus use of this product to control protozoan diseases in reared pheasants would be expected to have declined between 2002 and 2005, with consequent increased risks of losses. Given that the withdrawal of this veterinary medicine took place towards the end of the period of declining efficiency of releasing, it is unlikely to have explained the initial period of decline since 1990 when the drug was still widely available. At most, an increased risk from protozoan infections may have contributed only to the latter stages of the decline in the return rate.

Artificially reared pheasants are naïve, lacking parental influence or experience of life in the wild when they are first released. They can be particularly vulnerable to predators, and losses primarily to foxes are the main cause of mortality between release and the beginning of the shooting season (Robertson 1988, Turner 2007). Reynolds and Aebischer (1991) also found gamebirds, likely to be mainly pheasants, to feature in 19% of fox droppings collected in rural England. The density of foxes culled on sites contributing to the NGC has trebled over the period 1960–2014 (Aebischer et al. 2011) while Wright et al. (2014) suggest a decline since 1996. This NGC observation could be explained by increases in either fox abundance or gamekeeper effort. However, it is considered unlikely that gamekeeper effort has increased over this period as the emphasis on wild game management has declined and the methods available for fox control have been restricted. An increase in fox predation could have contributed to the decline in released pheasant survival, although a lack of spatial and temporal information on changing fox abundance and contradictory information from different surveys limits our ability to explore this possibility further.

Young pheasants are also taken by protected birds of prey, although losses to these predators are generally considered small compared to losses from other causes. The review by Parrott (2015) reported losses of young released pheasants to birds of prey to be less than 1% of the total number released on 90% of properties, but with losses of over 5% and up to 10% reported on a small proportion of sites. Any impact of birds of prey may have changed through time, for example following large increases in the range and numbers of the buzzard (*Buteo buteo*) in the UK since the early 1990s (Clements 2000). If buzzard predation were a significant additional cause of mortality for released pheasants, then it might be predicted that the efficiency of releasing would change in relation to their pattern of spread. In this case, a decrease might be expected to have spread from west to east, with this change most pronounced since 1990 when the buzzard increase was most evident. While the onset of the decline in the early 1990s coincides with the increase in the range of the buzzard, we found no evidence to support a regional pattern of declining pheasant return rates from west to east. Also, the reported losses of released pheasants to protected birds of prey appear small compared to the observed 15% drop in the efficiency of pheasant release. Consequently, we consider it unlikely that the large-scale decline in pheasant return rates described here can be explained by increased buzzard numbers, although the effects on individual sites may vary (Parrott 2015).

Since the 1960s, game rearing interests have adopted methods from the commercial poultry industry. These have included indoor rearing methods, mechanical incubators, the use of veterinary medicines and the increasing centralisation of production in a smaller number of larger units (Martin 2011). These changes, which influence the rearing of young birds up to 6 weeks of age, have led to reduced costs and increased volumes of reared pheasants being produced for release. At approximately 6 weeks of age, young reared pheasants are released into open-topped fenced pens in woodland, from where they are encouraged to gradually disperse into the surrounding habitat. The genetic composition and behavioural characteristics of the reared pheasant are likely to have been affected by these changes. Before the 1990s, it seems that wild pheasants still made an important contribution to the total numbers of shot, as seen by the relationship with chick survival rates. Many estates reared their own birds during this period based on stock that had survived the shooting season. After this date, there was an increasing shift to the centralised rearing of pheasants at a smaller number of sites, often relying on captive breeding stock rather than birds caught annually from the wild. The 1990s also saw increasing concerns from hunters that the typical reared pheasant was becoming increasingly large and docile; hunters responded by bringing in new pheasant strains, particularly small types considered to have more wild characteristics (Robertson et al. 1993c). Changing rearing and shooting practice may also have affected the behaviour of the birds. Madden and Whiteside (2014) provided evidence that unselective shooting meant that shy pheasants better survived a hunting season. More recent studies have shown that changes to the diet and conditions under which birds are reared can also have direct consequences for their post-release survival (Whiteside et al. 2015, 2016), offering the prospect of benefits through improved husbandry.

The methods of pheasant shooting have remained largely unchanged over this period, with the shooting season running from 1 Oct to 1 Feb each winter. However, the increased density of birds being released is considered to have led to more days of shooting, with these days spread more evenly throughout the 4-month season than was the case in the past. One consequence is that there is now more emphasis on maintaining high released pheasant densities on the ground into January, giving birds longer to experience predation and other causes of loss than when most shooting was concentrated earlier in the season. This may partly explain the apparent decline in release efficiency, as released birds are now spending longer in the wild than previously. Information to document this last cause could be extracted from daily hunting records, which are not collected by the NGC.

Overall, this inferential review suggests three factors as likely to be most closely associated with the observed decline in the efficiency of releasing. The fox is known to be the main cause of loss of released pheasants and fox numbers appear to have increased over the period of study, although temporal and spatial information on this trend is lacking. Pheasant rearing practice has also changed, with a shift to centralised rearing practices based on captive breeding stocks coinciding with the main period of decline. Lastly, shooting practice has extended the volume of shooting that now takes place in the latter stages of the hunting season, increasing the time released birds are exposed to other causes of loss.

Other factors cannot be ruled out, but the evidence of increased losses to disease or protected birds of prey are either of insufficient magnitude or are not thought likely to have occurred at the time of the largest changes in the efficiency of releasing. Changes in the farmed habitat are likely to have been the major cause of the inferred decline in wild pheasant numbers, coinciding with similar declines in other farmland birds, but occurred too early to have been the main cause of the changes in releasing efficiency described here.

The release of captive-reared animals can be a useful tool for the reintroduction of threatened species that have been lost from an area (IUCN 1998). However, releases have also been used to supplement extant populations with the aim of improving their conservation status (Garson et al. 1992, Hodder and Bullock 1997; Niewoonder et al. 1998, Seddon et al. 2007). The long history, wide distribution and intensity of pheasant releasing in the UK is probably unique as an example of artificially supplementing a naturally occurring terrestrial wildlife population. Despite the release of tens of millions of reared birds per year, the evidence from this study is that the wild pheasant population in GB probably underwent a decline similar to that of many other farmland birds. Reared birds are not a simple addition to the resident population; they are known to have reduced survival and breeding success compared to birds reared naturally by a parent (Hill and Robertson 1988a, b), while the increase in shooting pressure associated with releases may result in the overshooting of any wild stock (Robertson and Dowell 1990). Nevertheless, it is likely that continued releases have maintained pheasants in areas where the habitat is no longer suitable to sustain a naturally occurring wild population. Overall, the extensive release of pheasants in the UK has not prevented the decline, nor improved the sustainability of the wild population.

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