Full Title: Are farm-reared red-legged partridge releases increasing hunting pressure on wild breeding partridges in central Spain?

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Running head: Releases and hunting pressure on wild partridges.

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ABSTRACT

Wild red-legged partridge populations have experienced important declines in recent decades. With an aim to increase or maintain hunting quotas, releases of farm-reared red-legged partridges have concomitantly increased. However, the sustainability of this management practice is increasingly questioned. Farm-reared partridges suffer a high mortality rate immediately after release, and many released birds may be already dead before hunting take place. Therefore, it is possible that if hunters adjust harvest to the number of farm-reared released birds, this may lead to an overhunting of the wild breeding stocks. We investigated here whether autumn mortality by hunting of radio-tracked wild birds that bred in the previous summer differed between hunting estates that use or do not use releases as part of their management practices. Although our sample size was limited (32 radio-tagged birds monitored throughout the hunting season in four estates, with only one conducting releases), our results report novel data that support this cause for concern. We found hunting was the main cause of mortality and that the proportion of hunted partridges was much higher in the estate with releases of farm-reared birds than in the three estates that did not use releases. Therefore, the release of farm-reared partridges, instead of reducing hunting pressure on the wild stock through a potential dilution effect, may have an opposite effect. This should be confirmed with more spatial replicates, but raises serious concerns regarding the sustainability of wild partridge populations and their exploitation for hunting purposes in the future in estates that overhunt partridge populations.

Keywords: *Alectoris rufa*; game releases; hunting management; overhunting.

Introduction

Hunting is one of the human activities with longer tradition, practiced worldwide either for sport or subsistence, and with a marked environmental and socioeconomic importance. Recent decreases in some game species populations have promoted the application of management practices such as the release of farm-reared animals, which often are theoretically aimed to reinforce populations (Champagnon et al. 2012). However, the use of this management technique frequently affects only short-term harvest numbers (Sokos et al. 2008; Díaz-Fernández et al. 2012), and it has been indicated that the release of farm-reared animals has detrimental effects on wild populations through the spread of diseases or genetic pollution (Millán 2009; Barbanera et al. 2010; Champagnon et al. 2012).

The red-legged partridge is an important game bird of high socio-economic value throughout its native range and in introduced populations (e.g. UK). Wild red-legged partridge populations have recently suffered marked declines in most of the species´ range (BirdLife 2015). In Spain, the main stronghold of its native populations, red-legged partridge populations declined strongly at the end of the 20th century (Blanco-Aguiar 2007), while the release of farm-reared partridges increased and became more widespread since the 1990s (Blanco-Aguiar et al. 2008; Sánchez-García et al. 2009), which halted and even reversed the negative trend in national hunting bags (Sánchez-García et al. 2009). More recently (during the last 15 years), partridge populations have declined by ca. 33% (SEO/BirdLife 2013), while national hunting bags have been stable (ca. 3 million hunted partridge per year; MAGRAMA 2006, 2008, 2011), which could have also been sustained by releases (Blanco-Aguiar et al. 2012). Releases for hunting have been estimated to be around 3-4 millions of birds per year (Sánchez-García et al. 2009), although recent studies at regional level indicate that this information is likely to be underestimated (Caro et al. 2014).

The main stated objective of the releases is to benefit wild populations, whilst increasing or maintaining hunting quotas when population densities are low (Sokos et al. 2008). In other words, by releasing birds, the objective would be to either reinforce populations (because released birds would survive to contribute to the breeding stock), or to hunt mainly released birds, which would decrease the hunting pressure on wild stocks. However, farm-reared partridges have been shown to have very low survival rate when released in the wild (Gortazar et al. 2000; Gaudioso et al. 2011). Some studies on radio-tagged birds in Spain at the end of the last century indicated that 25-34 % of the released birds died during the first 72 hours post-release (Gortazar et al. 2000; Pérez et al. 2004). Even if rearing and release techniques may have improved ever since, most releases in Spain are carried out a few weeks before the hunting season starts, so many released birds may be already dead by the onset of the hunting season. Therefore, if hunters adjust harvest quotas to the number of farm-reared released birds, this may lead to an overhunting of the wild population (Keane et al. 2005; Díaz-Fernández et al. 2012; Viñuela et al. 2013).

In a previous study, Buenestado et al. (2009) found that hunting was the main cause of mortality in wild radio-tracked partridges during the hunting season in areas were farm-reared birds releases did not take place. However, to the best of our knowledge, there is no information available on hunting rates of breeding stocks (i.e. adult birds that bred during the previous breeding season) in hunting estates were farm-reared birds releases are used, or whether this differs between both types of hunting estates (using releases *vs*. no releases). Because released partridges are not marked (e.g. ringed), an alternative way to assess which part of the breeding stock is to rely on birds previously captured, marked (radio-tagged) and monitored during the breeding season prior to hunting. In this study, we address this issue for the first time, and assess whether mortality by hunting on wild breeding stocks differs between hunting estates that use or do not use releases as main management practice. For the purpose of this work, we monitored the fate of wild partridges that were captured and radio-tagged during the breeding season and were still alive at the beginning of the hunting season in four hunting estates in Central Spain. We tested the

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following alternative predictions, namely that releases of farm-reared partridges: 1) do not affect hunting mortality on breeding stocks; 2) reduce hunting mortality on breeding stocks, through a dilution effect; or 3) increase hunting mortality on breeding stocks, through increased overall hunting pressure, potentially leading to an overexploitation of the wild population.

Material and Methods

Our study was carried out in February-December during three years (2003-2005), on a 125 km² farmland area, dominated by a mosaic of crops, mainly cereal with interspersed patches of olive groves, vineyards and legume crops, whereas natural vegetation (short scrubland and pastureland) was scarce. It was located in Campo de Calatrava region (Central Spain, 38º 80´ N, 3º 80´ W, 610 m a.s.l., see Fig. S1), which included four small game hunting estates with similar habitat composition, but different hunting management practices (see Casas and Viñuela 2010 and Casas et al. 2013 for further details, Fig. S1). We interviewed game managers or hunting societies´ presidents of each estate for information about aims, hunting bags and releases in their estates. In three of these estates (estates A, C and D), hunting was mainly recreational, without releases of farm-reared partridges during the study period (in estate C, hunters occasionally released farm-reared partridges, but this management practice was not used during the years we captured and radio-tagged partridges on this game estate, according to the managers of that estate). In these estates, total harvest varied among years (Table 1). Hunting pressure (number of hunting days) was set based on qualitative assessments of partridge abundance during summer (Caro et al. 2015). The fourth estate (estate B) was privately managed for obtaining economic benefit. In this estate, releases of farm-reared partridges occurred every year, prior to the hunting season, and harvest quotas were similar in magnitude to releases (ca. 2000 birds/year, Table 1), although more detailed data were not provided by the manager.

We carried out censuses to estimate partridge abundance before the start of the hunting season (between August-September; Table 1) in all game estates and study years. Surveys were performed using a point count method (Bibby et al. 1992, Díaz-Fernández et al. 2013), and were driven during the three hours after sunrise and three hours before sunset, avoiding the middle part of the day when birds are less active and detectable. Observation points were distributed along tracks and separated between 500-750 m depending on visibility of the surrounding area. We calculated a partridge abundance index as the sum of recorded partridges at each observation point, divided by the number of observation points monitored in each estate (range 21-45, total 113 observation points). Given that there is only one estimate per estate and year, sample size was too small to do statistical comparisons of abundance between estates and years, but we use this information to describe general patterns.

Over the three study years, a total of one hundred fifteen partridges were captured in late winter/early spring (Table 1) using cage traps with adult red-legged partridges as a live decoy, which were also baited daily with wheat (Casas et al. 2009). Captured birds were ringed, sexed from plumage, biometry and ornaments (Sáenz de Buruaga et al. 2001), and a blood sample was taken from the brachial vein (0.5-1 ml). Birds were fitted with a necklace radio-transmitter equipped with a mortality sensor (10 g; Biotrack, Wareham, Dorset, UK), and released at the capture site (ca. 20 min). The sex of each bird was confirmed genetically (J.T. García and M. Calero-Riestra, *unpublished data*). Similarly, we used blood samples to detect chukar partridge (*A. chukar*) introgression using nine DNA diagnostic markers (8 nuclear microsatellite loci + 1 mitochondrial PCR-RFLP locus on a cytochrome b sequence), following the procedures described in Casas et al. (2012). We considered a bird as hybrid when at least one of the genetic markers showed introgression from chukar. Partridges were subsequently located by radio-tracking using AOR-AR8200 multiband receivers and three element YAGI antennas (Biotrack) at least twice every week from capture date to the end of the hunting season.

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For the main purpose of this work, which was to evaluate whether the probability of a wild breeding bird being hunted was affected by the release of farm-reared partridges or not in a given hunting estate, we only considered mortality during the hunting season (from early October to late December-early January). For our analyses, we excluded data from 2005, which was characterized by a marked spring drought that considerably reduced red-legged partridge productivity (see Casas et al. 2009) and led the hunting managers from estates A, C and D to decide not to hunt that year (Table 1). Three birds were also excluded from analyses because the signal was lost before the end of the hunting season (unknown fate). Thus, we finally used data collected over two hunting seasons on 32 adult red-legged partridges (15 females and 17 males, Table 1), which were still alive at the beginning of the hunting season. Red-legged partridge is a territorial, resident species, and pairs stay within their breeding territory throughout the year (Buenestado et al. 2008). During the hunting season we never observed a radio-tracked partridge moving from one estate to another or partridges captured in one estate hunted in a neighbouring game estate.

Statistical analyses

We used R 3.2.2 (R Core Team 2015) for statistical analyses. We tested if the probability of mortality (including all mortality causes) and of being hunted (excluding birds dead for other causes, n = 4, see results) during the hunting season was explained by the type of hunting estate (releasing vs non releasing partridges), sex, hybridization status and year using two general linear models (GLM) with binomial error distribution and logit link function. We included the variable “hybridization status” because it had been shown previously that occurrence of hybrid partridges is higher in game estates were farm-reared partridge took place (Casas et al. 2013), and hybrid partridges may have lower survival probability than non-hybrid birds (Casas et al. 2012). Initial models included all explanatory variables. Non-significant ($P > 0.05$) terms were removed sequentially using a backward stepwise procedure (type III results). All tests are two-tailed and data expressed as means ± SE. Given that sample size for comparisons relating to presence or absence of releasing is one hunting estate (B) versus

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three hunting estates, results could be skewed by estate-specific characteristics other than the release of farm-reared partridges. To explore this potential bias, we fitted models including as explanatory variable different hunting estate combinations (BCD *vs.* A, ABD *vs.* C and ABC *vs.* D).

Results

In general, partridge abundance was higher in 2003 than the other two study years, and higher in estate A than the other three, except in 2005 (Table 1). During the hunting season we found that the main mortality cause was hunting (73.3%; n = 11), followed by predation (20%; n = 3) and disease (6.7%; n = 1). Nine of thirty-five birds alive at the beginning of the 2003 and 2004 hunting seasons were hybrids. The percentage of hybrid partridges was highest in the game estate were farm-reared bird releases took place (hunting estate B: 45%, n = 9), followed by the two hunting estates adjacent to that one (hunting estate C and A: 40%, n = 5 and 23%, n = 13, respectively). We did not find hybrid birds in the eight partridges of hunting estate D, separate 9 km from estate B (Fig. S1). Probability of a tagged bird dying or being hunted did not differ significantly between sexes, hybridization status or years, but differed only between the hunting estate that released farm-reared partridges and the estates where releases did not take place (Table 2), but not for any other combinations of estates (Table S1). Mortality during the hunting season was much higher in the restocking estate (87.5 % ± 12.5) than in the non-restocking hunting estates (37.5 % ± 10.1). The probability of a tagged partridge being hunted was also higher (83.3 % ± 16.6) in the hunting estate with releases of farm-reared birds than in hunting estates where this hunting practice did not take place (31.8 % ± 10.2).

Discussion

Comentario [B1]: Verifica: en la tabla pone 35 para esos dos años, más 15 más en 2005

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Our results show that hunting was the main cause of mortality during the hunting season, as found previously in other study areas (Lucio 1998; Buenestado et al. 2009). Additionally, we found that the proportion of wild partridges dead during the hunting season differed between hunting estates that release or not farm-reared partridges. In the game estate releasing farm-reared partridges, the proportion of breeding birds hunted was higher than in the three hunting estates that did not use releases as a management tool. In the former, almost 85% of the wild-breeding birds alive at the beginning of the hunting season were shot. Thus, the release of farm-reared partridges, instead of reducing hunting pressure on the wild breeding stock, through a potential dilution effect, had an opposite effect and increased hunting mortality. Releases of farm-reared partridges may thus rather promote an overhunting of the wild stock, probably because the adjustment of harvest is made in relation to the number of released birds (Arroyo et al. 2012; Díaz-Fernández et al. 2012), whereas restocked partridges have a high mortality rate during the first days after their release (Gortazar et al. 2000; Gaudioso et al. 2011).

A careful adjustment between summer abundance and harvest is critical for the sustainable hunting of any quarry species, and around one third of the partridges available at the beginning of the hunting season is usually recommended as the maximum harvesting rate in order to maintain sustainable partridge populations in the long term (Potts 1986; Sáez de Buruaga 1991). However, it is known that most hunting estates in central Spain do only qualitative assessments of the abundance in summer (Caro et al. 2015). Indeed, in only one of the studied estates there seemed to be a strict adjustment between hunting pressure and abundance. Therefore, overhunting could also occur in game estates that do not release farm-reared partridges if there is not an adequate adjustment between availability and hunting yields. This could be the case of game estate C, because partridge abundance was higher in 2003 than in 2004, whereas hunting pressure had opposite trends (Table 1).

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Overexploitation reduces wild breeding stocks for the following breeding seasons, jeopardising a sustainable use of this game bird (Lucio 1998); when releases form part of the management style, this may lead in turn to increase the frequency and intensity of releases from year to year to maintain hunting (Díaz-Fernández et al. 2012), thus increasing the negative effects on wild stocks. Additionally, we did not find differences in the probability of being hunted between hybrid and "pure" birds, which could be due hybrids and "pure" partridges are being hunted proportionally. Therefore, the higher occurrence of hybrid partridges in restocking game estates (Blanco-Aguiar et al. 2008; Casas et al. 2013), and the lower survival probability of hybrid partridges outside the hunting season (Casas et al. 2012), could also reduce resilience of these populations.

Conclusions

Most studies up to now suggest that releasing farm-reared red-legged partridges is a relatively unsuccessful tool to recover wild populations (Gortazar et al. 2000; Pérez et al. 2004; Sokos et al. 2008), whereas habitat management is considered the main management tool for the maintenance of sustainable wild populations (Casas and Viñuela 2010; Delibes-Mateos et al. 2012; Viñuela et al. 2013). Releases of farm-reared partridges can bring the introduction of new diseases and parasites (Villanúa et al. 2008; Millán 2009; Díaz-Sánchez et al. 2012) or genetic introgression due the release of hybrids between red-legged and chukar partridges (Blanco-aguiar et al. 2008; Barbanera et al. 2010; Casas et al. 2012). Our study also indicates that it can also lead to overhunting of wild stocks, which can further contribute to the decline of partridge populations, especially in low-density populations (Blanco-Aguiar 2007). Although, our results should be confirmed with more spatial replicates (in more estates using releases as a main management tool), they nevertheless raise further concerns regarding an overhunting of wild stocks. This study also supports previous recommendations that this management technique should be regulated and limited temporally and spatially (Viñuela et al. 2013). Galliforms are very sensitive to overexploitation, and an increase in hunting pressure has contributed to increase

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the proportion of threatened Galliformes species (Keane et al. 2005). Recently, a polarisation among hunting managers in relation to their views towards releases has been reported, but most managers expressed at least some negative views and concerns about this practice (Delibes-Mateos et al. 2015). Therefore, there is an urgent need to further monitor the extent and consequences of this management practice; for this, it seems necessary to apply methods to determinate the number of farm-reared partridges hunted, allowing hunting managers to know the proportion of released and wild breeding stock they are harvesting. Ringing these farmed birds could be an easy and cheap method to evaluate the success of farm-reared bird releases, allowing hunting managers that use this management tool to adjust quotas along the hunting season.

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Tables

Table 1. Characteristics of the studied hunting estates between 2003-2005 and sample sizes for the study. Number of individuals captured and radio-tagged in late winter-early spring (Cap) and number of these alive at the beginning of the following hunting season (in brackets), abundance before the beginning of the hunting season (Ab, number of birds/observation point), and approximate number of hunted (Hunt) and released (Re) partridges, according to the game estate managers, in each of the four study game estates. Numbers in brackets under "Hunt" refer to the estimated number of birds hunted per hectare on each game estate each year (i.e. hunting pressure).

		2003				2004				2005			
Game Estate	**Surface (ha)**	**Cap**	**Ab**	**Hunt**	**Re**	**Cap**	**Ab**	**Hunt**	**Re**	**Cap**	**Ab**	**Hunt**	**Re**
A	3145	10(9)	14.2	1600 (0.51)	0	16(4)	9.7	980 (0.31)	0	16(6)	4.4	0	0
B	1484	20(8)	7.0	2000 (1.35)	2000	15(1)	3.0	2000 (1.35)	2000	-	2.7	2000 (1.35)	2000
C	1009	9(5)	5.7	170 (0.17)	0	-	2.0	300 (0.30)	0	-	4.1	0	0
D	548	-	-	-	0	13(8)	6.0	300 (0.55)	0	16(9)	9.7	0	0

Table 2. Results of GLMs explaining the probability of dying during the hunting season or of being hunted (i.e. excluding birds dead for other causes, n=4) between hunting estates that do not release farm-reared partridges (hunting estates A, C and D) and where this management practice takes place (hunting estate B). Significant results are highlighted in bold.

	Dead partridges (n = 32)			Hunted partridges (n = 28)		
Variables	χ^2	df	P	χ^2	df	P
Sex	0.87	1	0.35	0.44	1	0.50
Hybridization	0.98	1	0.32	2.59	1	0.11
Year	0.61	1	0.43	1.46	1	0.23
Type of hunting estate	**6.58**	**1**	**0.01**	**5.31**	**1**	**0.02**