Instituto de Investigación en Recursos Cinegéticos

Relationships between red-legged partridge hunting management, red-legged partridge populations, and human populations

Relaciones entre la gestión cinegética de perdiz roja, las poblaciones de perdiz roja y las poblaciones humanas

Silvia Díaz Fernández

Tesis Doctoral

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RELACIONES ENTRE LA GESTIÓN CINEGÉTICA DE PERDIZ ROJA, LAS POBLACIONES DE PERDIZ ROJA Y LAS POBLACIONES HUMANAS

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SUMMARY / RESUMEN

The generalization of red-legged partridge hunting in Spain, the economic activity that this creates in some rural areas, the depletion of the species wild population during the last years and the controversy that some hunting management practices generate for biodiversity conservation, let us to think that there is space to improve the current sustainability of this activity. There are controversial management practices due to possible negative effects on partridge populations, on accompanying species, or on the hunting estate economy, which could not see optimized or at least compensated management costs. The goal of this thesis was to study implications that these practices have to red-legged partridge harvest, partridge abundance, or the estate economy, and on the other hand, to study how commercialization could be affecting estate hunting management. We saw that commercialization of red-legged partridge hunting implies greater intensity of management and more naturalized landscapes. However, we did not find (at least in the small segment of the market we studied) that the market is giving value to any of these parameters. The success of massive releases in intensive estates, following our microeconomic study, seems more led by the flexibility of this business model (almost unlimited offer, elasticity of the offer, and real options of expand and extent investments) and the no internalization of ecological costs. Due to the lack of these advantages, to the hunting that manages only wild populations it would be difficult to compete within the same market, at the same prices. However, while in intensive estates harvest depend completely on releases, in non-intensive estates releases are generally not effective to reinforce wild populations or to increase harvest, which in this case is more conditioned by pre-hunting wild densities. In addition, we found estates where partridge hunting is not profitable in spite of releasing farm-reared partridges in small quantities: in this case releases are justified neither by reasons of profitability. We also found evidence that non-intensive estates without releases, particularly in scenarios of medium and high prices, can be currently a profitable business, although their benefits can not be compared with those of intensive estates. On the other hand, we found current predator control useless to increase

partridge harvest or abundances in the estates when compared to habitat management or food/water supplementation; the effectiveness of food/water supplementation suggests problems with surrounding habitat and, required great expenses in the estates. It seems logical to compare these great investments with others directed to alternative habitat management. An economic and ecological optimization of management that redirect investments from useless management practices to others integrated with accompanying uses in the estate, or to get traceable hunts from the point of view of management, would help to increase sustainability of red-legged partridge hunting, that is to say, the net benefit that this activity generates for society. To this goal would also help to internalize in the estates ecological costs and benefits of management.

La generalización de la caza de perdiz roja en España, el movimiento económico que genera en algunas zonas rurales, la reducción de los efectivos poblacionales silvestres de la especie en los últimos años y la controversia que suscitan para la conservación de la biodiversidad algunas de las prácticas de gestión asociadas a la caza de perdiz roja, permiten pensar que actualmente hay margen para hacer más sostenible esta actividad. Hay prácticas de gestión controvertidas por sus posibles efectos negativos sobre las poblaciones de perdiz, sobre las especies acompañantes, o sobre la propia economía del coto, que podría no ver optimizados o ni siquiera compensados los costes de gestión. El objetivo de esta tesis ha sido estudiar las implicaciones que estas prácticas tienen para las capturas de perdiz roja, para la abundancia de perdiz o para la economía del coto; y por otro lado, estudiar cómo la comercialización puede afectar a la propia gestión en los cotos. Parece que la comercialización de la caza de perdiz roja está relacionada con más intensidad de gestión al tiempo que paisajes más naturalizados. Sin embargo, no encontramos (al menos en el pequeño segmento del mercado estudiado) que el mercado esté dando valor a ninguno de estos parámetros. El éxito de las sueltas masivas en los cotos intensivos, según nuestro estudio microeconómico, apunta más bien a la flexibilidad del modelo de negocio (oferta casi ilimitada, elasticidad de la oferta, y opciones reales de expansión o extensión de las inversiones) y a la no internalización de costes ecológicos. Por carecer de estas ventajas, a la comercialización de la caza que gestiona tan sólo poblaciones silvestres le resulta difícil competir en el mismo mercado, a los mismos precios. Por otro lado, mientras en los cotos intensivos la bolsa de caza depende completamente de las sueltas, en los cotos no intensivos las sueltas generalmente no son efectivas para reforzar las poblaciones silvestres o para aumentar la bolsa de caza, que en este caso está más condicionada por las densidades silvestres pre-caza. Además, encontramos fincas donde la caza de perdiz no es rentable a pesar de soltar perdices de granja en pequeñas cantidades: en este caso las sueltas ni siquiera son justificables por motivos de rentabilidad económica a corto plazo. También encontramos evidencia de que los cotos no intensivos sin sueltas, particularmente en escenarios de precios medios a altos, pueden ser actualmente negocios rentables, aunque sus beneficios no sean comparables con los de cotos intensivos. En lo que respecta a otras prácticas de gestión, hemos visto que el actual control de depredadores no es útil para aumentar la bolsa de caza de perdiz o su abundancia cuando se compara con la gestión del hábitat o la suplementación de comida/agua: y la suplementación, efectiva (lo que sugiere problemas del hábitat circundante), supone grandes costes en los cotos. Parece lógico comparar estos grandes costes con otros destinados a la gestión del hábitat. Como conclusión, una mayor optimización económica y ecológica de la gestión que redirija las inversiones hacia prácticas más útiles e integradas con el resto de usos en el coto, y a conseguir trazabilidad en las cacerías desde el punto de vista de la gestión, ayudaría a aumentar la sostenibilidad de la caza de perdiz roja, es decir, el beneficio neto que esta caza genera para la sociedad. A este objetivo también ayudaría la internalización de los costes y beneficios ecológicos de la gestión.

GENERAL INTRODUCTION

ECOLOGY AND ECONOMICS, BOTH NECESSARY TO UNDERSTAND THE EFFECTS OF MANAGEMENT ON NATURAL RENEWABLE RESOURCES

In general, the increase in a person's welfare (or well-being) is the change in the state of this person that goes from a less desired to a more desired state (state of health, happiness or safety), and the increase in human welfare of a population would be the sum of all those individual increases. We know that availability of natural resources constraints, in part, human welfare changes (Weiss 1992), and that renewable natural resources have the useful characteristic of, under certain uses (sustainable uses), being able to generate well-being without disappearing and, thus, without put at risk the well-being of the following generations. However, this sustainable use is not innate for humans, but it requires knowledge of the laws that lead the changes of the natural resources and the changes in human populations to prevent negative consequences of misuse; it also requires a group intention to prevent unsustainable uses, and moreover, requires using that knowledge to dynamically adapt the use to get this goal, in other words, it requires an explicit intention to increase the medium-term human well-being (Daly 1990, Weiss 1992, Hilborn et al. 1995, Balmford et al. 2002). In fact, a resource use usually arises from individual persons that look for maximizing their individual short-term well-being (the self-interest that already motivated participants in the economy in Smith 1776). This may be in conflict with long-term conservation of the exploited resource if this does not give back any benefit for the individual in the short-term (Lee 1993, Ludwig et al. 1993). In consequence, detailed knowledge of the effects of individual activities on their own benefits in the short term, on the general benefits in the medium term and on the conservation of the resource is necessary to successfully recommend changes to improve sustainability of uses, that is to say, to preserve the resource and generate human benefits with enough efficiency and equity to keep the use and avoid conflicts at the same time. This is simple: changes in the use will have to be implemented by individual users, so successful implementation will depend to some extent on the individual consequences for them (Ludwig et al. 1993).

Red-legged partridge hunting is an example of a natural resource use for which clues exist that is currently far from optimizing the human well-being that may generate. Red-legged partridge management has been traditionally practiced since long time ago, but it has been generalized along the last decades, coming to be applied in most of the territory where the species is present. At the same time, the consideration of the red-legged partridge hunting as economic activity that creates jobs in rural areas and monetary benefits to promoters has been favoured (Delibes 1992). Today, macroeconomic numbers usually emphasize the social and economic benefits this activity implies (Bernabéu 2002, Martínez et al. 2002). Moreover, this hunting generates leisure in rural areas for many people, whether it is commercially developed or not. However, recent decades have also been witness of the resource depletion (including the reduction in wild red-legged partridge population size and the anthropic modification of the genetic pool of the species in the field due to releases of farm-bred birds), of negative effects of partridge management on other wild species, or of big efforts on management with uncertain results. This fact alerts on the possible unsustainability of this current hunting system, and thus, of the unsustainability of the benefits that usually are attributed to this activity. Increasing demand of this game species over last decades is probably indicating that this activity keeps being beneficial for many people, in spite of its related problems. In consequence, there is space to improve the sustainability of this resource through deeper knowledge of the functioning of this hunting system while keeping the interest of individual users. This problem was taken as a case study of approaching the improving of a natural renewable resource use from an ecological and economic point of view simultaneously, to understand better the working of the system and prevent possible human consequences of the use modification. This PhD study different issues barely known of the red-legged partridge management and its possible effects, from both an ecological and an economic point of view. Below, the main issues needed to understand the problem of study, the approach and the structure of this dissertation are explained.

CASE STUDY: RED-LEGGED PARTRIDGE HUNTING

Red-legged partridge: Distribution, habitat, main ecological traits and population trends

The *Alectoris* partridges are the main gamebird species in Mediterranean countries (Aebischer 1997). Within this group, the red-legged partridge is, along with thrushes, the most numerically important gamebird species in Portugal and Spain. The red-legged partridge (*Alectoris rufa*, *Phasianidae*) is endemic from Southwest Europe, from the Iberian Peninsula and southern France to Northwest Italy, Elba and Corsica, although in the past the species reached naturally more northerly latitudes, probably up to southern Germany (Cramp and Simmons 1980, Calderón 1983, Baragaño and Otero 2001). The species has been successfully introduced in England and Atlantic Islands, re-introduced recently in northern France and released with little success in U.S.A., New Zealand and Central Europe (Baragaño and Otero 2001). However, most of its European population, estimated on 2200000-4500000 pairs in 2000, is located in Spain, where the highest abundances are located in the Central and South part of the country (Blanco-Aguiar et al. 2003).

Within its original range, it may be considered a highly adaptable species, inhabiting from semi-desertic steppes in southern Spain to open forests, and found from sea-level up to 1500 m in montane habitats (Cramp and Simmons 1980, Lucio and Purroy 1987). It is basically a bird of open areas, selecting those with a combination of vegetated lands for shelter and open ground for feeding. Optimal habitats, where maximum population densities are reached, seem to be diversified agricultural landscapes, particularly those including cereal fields and patches of low height shrubland, with typical Mediterranean climates characterised by low spring and summer precipitation (Lucio 1991, Lucio and Purroy 1987, 1992, Blanco-Aguiar et al. 2001). A similar positive role of diversified landscapes with cultivations, shrublands, and pasturelands has been detected in France (Garcia et al. 1983, Lartiges and Mallet 1983, Berger 1984, Gaudin and Ricci 1987, Reudet 1992).

A major limiting factor for this species seems to be the climate, as red-legged partridges are particularly common in dry Mediterranean areas with mild winters in France, becoming scarcer in areas with atlantic or continental climates (Geroudet 1955, Novoa 1984). Similarly, wild populations in United Kingdom are present only in the driest areas with milder temperatures of east England (Tapper 1999), and mean survival rates of British partridge chicks increase with high summer temperatures (Green 1984). On the other hand, in the typical Mediterranean areas inhabited by this species, summer droughts may also be a limiting factor, and it has been shown that the availability and spatial distribution of water points affect the distribution of red-legged partridges in Portugal (Borralho et al. 1998).

The species alternates territorial and social periods within its annual cycle. Pairs are formed between late January and March, starting the territorial period. Laying starts on average in mid April in our study area of southern Spain (Guzmán-García 2011). During May partridges can be incubating and first hatchings usually occur on late May, although this process may extend over two months. While parents are taking care of chicks, territoriality is relaxed (Ricci 1985). In August juveniles are usually the same size than adults and different coveys may clump together, creating bigger flocks in this more social period. Within these flocks, new pairs will be formed next spring (Duarte and Vargas 2002).

The species is characterised by high laying rate, an average of 15 eggs/pair in optimal areas (with the possibility of double clutches, one of them incubated by males, and a high likelihood of replacement clutches, Casas et al. 2009). It is also characterised by frequent egg and nest losses (Rands 1988, Yanes et al. 1998, Herranz 2000). Yearly survival rate without hunting mortality has been estimated at 44% in Buenestado et al. 2009, 50–70% in Office National de la Chasse 1986, and 71% in Ponce-Boutin et al. 2001. The high laying rates imply that populations may be stable or even increase despite high nest losses if survival rates are within the normal range. Wild red-legged partridge populations suffer strong year-to-year fluctuations, probably mainly due to climatic factors, and thus hunting pressure should be adapted to these variations, by establishing limits on bags or on the number of hunting days based on good estimates of game availability before hunting season, something that, unfortunately, at least in Spain, is not so common as it should be (Lucio 1998). This kind of limitation is the most common management practice in France and it has been shown that good management of hunting pressure is more important than other management practices (Pepin and Blayac 1990).

At least since XIX century, a decline in red-legged partridge numbers has been noted throughout the distribution range (Lucio and Purroy 1992, Rueda et al. 1992, Aesbischer and Potts 1994, Nadal et al. 1996, Aesbischer and Lucio 1997, Rocamora and Yeatman-Berthelot 1999). This decline has also been shown for Spain between the 1970s and the early 1990s (Blanco-Aguiar 2007), although last published data of annual surveys in Spain from 1998 to 2006 (Escandell 2006) show a stable tendency in population size for that period. However, since the 60s, probably concomitantly to reductions in wild population stocks, red-legged partridges exist also in industrial farms, where they have been bred and released into the wild increasingly, particularly since the 1990s (González-Redondo 2004). Those releases muddle the meaning of estimated population sizes by annual surveys or their implications to assess sustainability of populations. The species human use and management, in consequence, can not be divorced from ecological data to understand the state and tendencies of red-legged partridge populations (Blanco-Aguiar et al. 2012).

Red-legged partridge hunting: the way towards hunting management

In Spain, humans have traditionally taken advantage of the high productivity of this species through hunting, using shooting methods adapted to the annual cycle of the species and to its behavioural traits (Pérez y Pérez 1981). Nowadays, partridge hunting season in Spain starts in October and is closed in February-March, with slight variations between Autonomous Regions. Methods typically used for shooting partridges include: 1) driven shooting, where assistants beat the land to flush partridges and drive them towards a strategically arranged line of hunters; 2) walked-up shooting, where hunters (with or without dogs) shoot the birds as they encounter them (Buenestado et al. 2009); 3) decoy shooting, where a male partridge decoy is placed in a territory to attract wild partridges. Red-legged partridge hunting bags were declining at least since the 1970s, then stabilizing or even increasing during the 1990s, probably as a consequence of widespread releases (Delibes 1992). Recent data of red-legged partridge hunting bag in Spain is estimated by official game hunting statistics in more than 3 million partridges/year (Ministerio de Medio Ambiente y Medio Rural y Marino [MARM] 2006).

Today, there are ca. one million Spanish hunters (FACE 2005) and more than 70000 foreign hunters also come each year to Spain (Mulero 1991, Rengifo 2008). What they need to do to hunt in Spain is to buy a legal licence for hunting and to have permission for shooting in, at least, a specific hunting territory. In our country, game is "res nullius", but the hunting rights belong to either the government (in ca. 9% of the surface of Spain) or to private individuals or hunting associations, who may then lease or sell them. Most (around 390000 km^2, 68%) of Spain is thus divided in hunting estates, where hunting rights are managed privately (MARM 2006). Each one of them is bigger than 2.5 km^2 and generally much bigger than this (Ríos-Saldaña 2010). Then, given that most of the main red-legged partridge areas of Spain are private hunting estates (MARM 2006, Bernabéu 2002), hunters get the permission to hunt there through private contracts (implying monetary payments or not) with the temporal holder of the hunting rights in the estate.

However, owners of the hunting rights are not necessarily owners of the land where the hunting estate is placed, and thus hunting rights are not necessarily joined to the land property. A middleman between the hunter and the access to hunting rights not always existed. Its origin comes from an attempt of the Government to increase the net benefits from hunting for society. In general terms, from the first inhabitants of the Iberian Peninsula to the first half of the twentieth century hunting rights were not sold, but were always enjoyed by their owner: the right to hunt varied from free access to the ownership related to other privileges (e.g. aristocracy). The cost of hunting was basically the time and effort used to hunt and there were no middlemen between the resource and the final user, the hunter. The benefits of this hunting were considered enough high to, punctually along the history, try to introduce and acclimatize the species in areas where this did not exist previously. The overexploitation of wild populations was avoided, with more or less success, with laws directed to limit harvest or to limit access to hunt (González-Redondo 2004).

But in the Spanish 40s, the increase of inner and foreign demand of red-legged partridge hunting raised the risk of overexploitation of wild populations. Firstly to preserve the species as a source of incomes, then to preserve the species as biological richness itself covering the demand at the same time, the government used different methods to recover depleted populations or to repopulate areas where the species was not present: translocations of birds, artificial incubation of wild eggs to release the juveniles into the field, promoting farm-reared partridges production (González-Redondo 2004) and a more intense predator control (Ministerio de Agricultura 1953).

The high demand continued (the number of hunters was increasing from the 50s to 1985, when a steady decrease started) and new mechanisms to use red-legged partridge populations were considered. It was suggested that private initiative would be more effective to preserve or improve the production of partridge populations if private individuals with the right to manage populations in a territory would benefit directly from the right to hunt in this territory, for example, selling hunts (Martínez-Garrido 2009). This way demand would be covered, populations would be preserved and the value of the species would be materialized into economic benefits. This perspective was made true during the 70s, helped by a new hunting law (Ministerio de Agricultura 1970) that promoted considering red-legged partridge hunting as an economic activity and the private responsibility on the care of wild game populations in the hunting estates. Moreover, it promoted successfully an enlargement of the area where hunting was possible in Spain, to increase total hunting production (Martínez-Garrido 2009).

As said above, in terms of costs and benefits, the new hunting system scheme assumed that the participation of private managers would imply the preservation of the resource and a higher availability of partridges to be hunted due to an efficient use of labour and management. Thus, red-legged partridge hunting net benefits would increase for society. However, when private management activities fail in creating this real richness, management costs would be not compensated and would fall back on hunters, reducing the net benefit of red-legged partridge hunting for them. As the expected benefit of hunters (benefit considered in general terms, as human welfare) is the source of their activity (Smith 1776), reducing this would imply a stop in red-legged partridge hunting, stopping any benefit related to this. This is why to sustain the current benefits of red-legged partridge hunting, that is to say, to keep their general costs below their general benefits, the efficacy and efficiency of management activities are crucial. Sustainability of current red-legged partridge hunting depends on the efficiency of hunting management.

Red-legged partridge hunting: Current hunting management and uncertainties

In Spain, there are no precise spatial data-bases to know what, how and where hunting management practices are applied in private hunting areas. Therefore, hunting management in most of the hunting area in Spain can not be dynamically followed, at least not easily, neither can management be related to the changes on local game and non-game populations or with other land uses. With this state of information, related costs or benefits are also difficult to infer precisely. The sources of data of the current red-legged partridge management are each estate Hunting Technical Plan (mandatory legal document), each estate annual harvest report (mandatory legal document), hunting magazines and forums, and scientific studies focused usually on specific management practices within limited temporal and spatial ranges. The Hunting Technical Plan is a document specifying the planned management and harvest to be applied in an estate over usually 5 years, and the permission to hunt in the estate depends on the approval of this planning by the government. This planning is usually delivered on paper. The annual harvest report is delivered to the government by each estate at the end of each hunting season, but it is usually estimated rather than accurate, and detailed records do not exist in many of the estates. This report is expected to respect the legal harvest limits imposed at the start of the season. From these and the other sources cited above comes the knowledge on the current hunting management that today exists and is summarized below.

From the existing information, it arises that the most common management practices applied in Spain as elsewhere in Europe to increase small game populations are predator control (killing game species predators), habitat management (increase of the quantity or quality of habitats used by game species), species management (provision of supplementary food or water, or provision of medication to decrease parasites), and population supplementation through the release of captive-reared animals (Arroyo and Beja 2002, Virgós and Travaini 2005, Ríos-Saldaña 2010, Mustin et al. 2011). In the case of red-legged partridges, it has been suggested that some of these practices may be not effective to improve red-legged partridge populations, may be depleting wild partridge populations, may be negative to other wild animal populations, or may be being applied in an inefficient way, but detailed information is lacking for many of them, and a global evaluation is also lacking.

Predator control

Predator control is known to be effective to increase game numbers when performed intensively (eg. in UK, Tapper et al. 1996). However, the intrinsic constrains of real management situations may make predator control ineffective in certain cases (Arroyo and Beja 2002). Moreover, no studies have been done specifically in Spain where the network of predators (protected and unprotected) is rich and diverse, and their effect on prey populations little known (Valkama et al. 2005), even less than the effect of predator control.

In spite of the lack of evaluation of the effects this practice is having, it is highly widespread in the Iberian Peninsula (Virgós and Travaini 2005, Beja et al. 2009). In 2006 in Castilla La Mancha, 85.2% of the hunting estates asked for predator control, that centred in 5 generalist species, mostly foxes and corvids, followed by feral dogs and cats (Ríos-Saldaña 2010). Apart from the legal demands of this practice, illegal implementation exists, both in terms of targeted species (e.g. when protected predators are involved, Villafuerte et al. 1998), or in terms of methods (e.g. when poison is used, which may have collateral effects on protected predators, Rodríguez and Delibes 2004, Virgós and Travaini 2005).

All this makes predator control criticized in terms of biodiversity conservation due to concerns that widespread culling may be detrimental to predator populations (Etheridge et al. 1997, Villafuerte el al. 1998, Whitefield et al 2003, Valkama et al. 2005). In fact, it has caused reduction in geographic ranges of several endangered predators in the Iberian Peninsula (eg. Villafuerte et al. 1998, Rodríguez and Delibes 2004, Virgós and Travaini 2005). In contrast, it has also been proved that predator control may be positive for biodiversity (Reynolds and Tapper 1996, Fletcher et al. 2012). Even in the case of a neutral scenario for conservation, the efficiency of this practice to increase benefits from hunting should be considered because if proven inefficient this would imply just a transfer of benefits from hunters to employment for predator control.

Farm-reared partridge releases

Supplemental stocking with game farm birds is a practice aimed to maintaining or increasing partridge availability in the field. But experiences with farm-reared partridges have shown a general very low short-term survival of the birds released in the field (Pérez-Garrido 2008, Duarte et al. 2011). Leading to local and short-term increase availability to hunt with an affordable cost, a main criticism of this practice is the potential cost that releases are having on the sustainability of wild populations, and thus, in future availability (Dowell 1992). Studies point out overhunting of wild populations where farm partridges are released because farm and wild partridges are usually undistinguished during hunting, probable lesser fitness and survival of farm partridges in the wild (Casas et al. 2012), lesser reproductive success of farm partridges than wild ones (Potts 1989, Gortázar et al. 2000, Duarte et al. 2002, Sokos et al. 2008), diseases spread by farm partridges (Millán et al. 2004), and changes in populations genetic pool due to widespread incidence of introgressive hybridization with exotics or with domesticated relatives facilitated by supplemental stocking programs (Blanco-Aguiar et al. 2008, Barbanera et al. 2010) with disruptions of genetically distinct populations (Negro et al. 2001, Barbanera et al. 2010) and loss of important adaptative behavioural traits (Randi 2008).

The amount of farm partridges released annually is not exactly known because part of the production is not declared to avoid taxes (Garrido 2002) and because, at least at a local level, illegal releases are relatively widespread. Last available data recorded are for year 2006, when farm partridges produced and released legally were 1779200 and 1763915 respectively, 90% and 50% corresponding to the regions where this work was developed (MARM 2008). Releases increased exponentially from the sixties, achieving their maximum increase in the 80s and 90s (Garrido 2002). To compensate for the lack of exact data to estimate the amount of releases, indirect variables have been used (number or size of farms, farm advertisements, local studies in hunting estates, etc), obtaining always higher numbers than official records and a permanent increase from 1969 to 2003 (Delibes 1992, Garrido 2002, Martínez et al. 2002, Blanco-Aguiar et al. 2008). And all this happens in spite of the doubtful efficacy and suspected ecological or economic costs of this practice.

Food and water supplementation

Availability of water troughs influences red-legged partridge distribution (Borralho et al. 1998), but their effect on densities has not been tested, and we do not know scientific studies about the effects of food provisioning. In spite of the costs that the installation and maintenance of these artificial devices would imply and the questioned effects on this and other species (e.g. Guthery 2002a), water troughts and feeders are used in 70% and 60%, respectively, of the estates in Castilla La Mancha (Ríos-Saldaña 2010).

Habitat management

Habitats determine in a large extent the density, productivity and survival of a species in an area through their compatibility with the physical, behavioural and physiological adaptations of the species. In anthropic environments, habitats are the consequence of different land uses overlapped in the field and fast changes, to which some species may not adapt fast enough. This has happened with the advent of modern agrarian management systems, agricultural intensification and subsequent abandonment of marginal land during the last century (Chamberlain et al. 2000, Donald et al. 2001, Bota et al. 2005). Thus, it is not surprising that among the main factors negatively affecting red-legged partridge populations it has been repeatedly cited the changes induced by modern agriculture, such as disappearance of hedgerows, earlier harvesting dates, increased disturbance and nest destruction by agricultural machinery, pesticide use, abandonment of traditional set-asides, or increased shrub cover in abandoned rural areas (e.g., Lartiges and Mallet 1983, Ricci 1985, Lucio and Purroy 1992, Nadal 1992, Notario 1992, Aebischer and Potts 1994, Lucio et al. 1996, Nadal et al. 1996, Ramalho et al. 1996, Lucio 1998, Tapper 1999, Arroyo and Viñuela 2001). An adequate management of cultivations and shrubs is often cited as one of the main management practices to improve wild populations of this species (e.g., Lartiges and Mallet 1983, Gaudin and Ricci 1987, Pepin and Blayac 1990, Nadal 1992, Lucio 1998, Borralho et al. 2000), although in some cases it is not clear if these management may significantly increase population densities (García et al. 1983), and probably a combination of several management measures (habitat management, control of hunting pressure, predator control, and artificial supply of food and water) maintained over the years are necessary to keep high densities in the long-term (Borralho et al. 2000). However, it is not well known which, among the many changes induced by modern agriculture, may have a stronger negative impact on red-legged partridges (e.g. pesticides could be not so important in this case, Green et al. 1987), something critical to implement possible management plans making compatible the maintenance of wild huntable populations of partridge and profitable agricultural use. More recently, the density of *lindes* is proved to increase red-legged partridge breeding success (Casas and Viñuela 2010), and the highest densities have been found related to the heterogeneity of agricultural lands (Buenestado et al. 2008), while usual timing of agricultural practices is the cause of high mortalities on partridges. The conflict of uses told above makes sometimes difficult (depending on the property) to apply hunting management, and more difficult, that habitat management could be focused on hunting. Specific crops for hunting are an exception, which are declared in 60% of the estates in Castilla La Mancha.

Hunting pressure

Hunting pressure is crucial for game populations and biodiversity. In fact, many extinctions of wild populations have been attributed to excessive hunting pressure (Olson and James 1982, Lewin 1982, Duncan et al. 2002). In Spain, annual hunting licences in use are provincially recorded (e.g. more than 1.4 million licences were in use in 2006, MARM 2006). But it is not known how much time each hunter spends really hunting, and thus there is not a useful measure of hunting pressure to precisely study its biological or economic effects at local scales. This provincial data have been useful to study the evolution of hunting demand along time (Martínez-Garrido 2009) or to use an average provincial game bag (total number of partridges hunted divided by the number of licences) as index of partridge abundances to study demographic tendencies (Blanco-Aguiar 2007). However, due to the difficult to get records of red-legged partridge hunting pressure in individual hunting estates, studies of this variable in relation to other management, biological or economic variables at local scales are scarce.

Economics of red-legged partridge hunting: Current information and uncertainties

Economics of red-legged partridge hunting has been merely approached estimating the money that hunting moves at a national or regional level, in total or per activity sectors implied, and not considering the management unit (the hunting estate) as the unit of study. In 1985, gross income from hunting was estimated 401.5 million euros in Spain, from which 8% came from 22300 foreign hunters (Metra-Seis 1985). Otero (1995) estimated for 1991 an annual billing of direct hunting activity of more than 220 million euros only in Castilla La Mancha. However, all these numbers come from indirect data as number of estates, number of expended licences, estimations of the expenses of the average hunter, value of meat and estimations of other complementary incomes in hunting estates (Bernabéu 2002). Moreover, there is quite a lot agreement on the usual underestimation of economic resources that this activity moves due to its relation to black money, difficult to evaluate (Martínez et al. 2002).

On the other hand, Bernabéu (2002) estimated a total income in the hunting estates of Castilla La Mancha of more than 25 million euros, just from red-legged partridge hunting. However, Bernabéu was interested in the whole hunting system and thus studied total economic amounts for each sector involved; this is not enough to study economic consequences for hunting estates of their own management. To understand management consequences in game populations, in the economy of the estates and thus, in their sustainability and profitability, would be necessary economic information in relation to hunting management at estate level.

OBJECTIVES

The objective of this PhD was to study red-legged partridge hunting management in relation to biological and human traits in private hunting estates, and to know what of those traits are deepest related to management practices. This would help to understand current or possible future outcomes of this activity, reasons for current management or absence of management, and possible margins to improve effectively the social and individual benefits of red-legged partridge hunting. This goal crystallized in the particular objectives of the following chapters, explained below.

OUTLINE OF THIS DISSERTATION

This doctoral dissertation is structured into 6 chapters that cover different aspects and stages of the research (table 1).

Table 1. Objectives of this PhD.

OBJECTIVE	CHAPTER
Is the commercialization of red-legged partridge hunts related to the management practices applied in the hunting estates?	1
Have the amount of partridges released in a hunting estate a noticeable effect on annual harvest numbers?	2
What is the relationship between the intensity of management practices most currently applied in hunting estates (food and water	3
What economical consequences does the use of wild red-legged partridges versus farm-reared ones have in partridge hunting estates?	4
Are releases or the landscape affecting red-legged partridge hunts market value?	5

To study the relationship among management and commercialization, production and red-legged partridge wild populations, we centred our study in the area of Central Spain, where the highest abundances were recorded during the last decades, and where exists a deep tradition for the hunting of this species and the most widespread commercialization of this hunting within the country. The ecological, social and economic importance of the species in this area exemplifies best than anywhere the potential benefits and conflicts of this hunting and creates a good scenario to study their mechanisms. This importance also makes the study more valuable in terms of applied research due to the direct applicability of the results in the area. Once selected the general location, we tried that the specific study area was enough near to Ciudad Real to make as cheap as possible the field work. Following these spatial criteria, we finally got detailed information on management, physical, ecological and economical information of 60 hunting estates, covering a total land surface of 2099 km^2. Not all the variables studied along the different chapters were recorded for all the estates, and thus, the sample used varies from chapter to chapter depending on the data needed for each one.

First of all, we broadly described the red-legged partridge hunting management and habitat characteristics in hunting estates in relation to their profitability aims. We described physical and economic characteristics, game management and hunting methods, pressure and bags of hunting estates (chapter 1).

Due to the relationship between intensity of releases and profitability aims, and the problems that releases are creating in wild red-legged partridge populations, we wanted to explore the relationships between releases and harvest in the estates to look for clues of efficacy, and economic and ecological implications of releases (chapter 2). Thus, we studied if harvest was depending mainly on wild abundances or on releases, taking into account also the hunting pressure in the estate, in the 50 estates (intensive and non-intensive ones) for which we got all the information needed.

As a further step, and based in our result (chapter 2) that harvest in non-intensive estates are mainly depending on wild summer abundances and not on releases, we studied how the most costly and controversial management practices in these estates are related to abundances (chapter 3). We studied the supplementation with food and water, predator control and the number of partridges released, taking also into consideration characteristics considered important for wild game density as hunting intensity and habitat, in 38 non-intensive hunting estates.

Management selection may have economic implications in a hunting estate. When the main goal of the estate is the economic benefit, these implications may be taken into consideration to take decisions on management and these decisions will affect the profitability of the activity, which will affect again new decisions. Then, implementation and success of any management recommendations not only depend on their effect on the conservation of partridge populations or the harvest, but on the economic consequences at estate level of these recommendations.

Consequently, we wanted to know what main items take part in the economy of a red-legged partridge hunting estate, from the point of view of hunting management. And as long as the interest of restocking for hunting is usually defended in economic terms, we also looked for economic implications of the hunting based on farm-reared partridges face to wild birds (chapter 4). To do so, we used the information previously gathered for this PhD to define the main items necessary to take stock of red-legged partridge hunting in a generic estate. Then, we selected 3 intensive and 6 non-intensive hunting estates from our sample (3 of these last 6 with releases and 3 without releases) that had quite complete information to take stock for one year and thus, explore implications of both management approaches.

Finally, in a commercial activity offer and demand affect each other dynamically through the market price. In previous chapters, we studied hunting management and its implications for the resource and the promoter (offer side). In a further step, we wanted to know how the market is valuing some management decisions (chapter 5). To study this problem we explored a small segment of the national market. This segment was the hunts sold through advertisements in specialized magazines or on the internet.

We discuss jointly the results obtained, and sum up into some key conclusions.

Chapters 1 and 2 have been published in scientific journals, chapter 4 has been submitted, and chapters 3 and 5 will be in the near future. Therefore, chapters retain to some extent the structure of a scientific paper.

CHAPTER 1. HUNTING MANAGEMENT IN RELATION TO PROFITABILITY AIMS: RED-LEGGED PARTRIDGE HUNTING IN CENTRAL SPAIN

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ABSTRACT

Game management is widely implemented in Spain, affecting more than 70% of land cover. Management intensity may be linked to the financial aims of hunting estates, but no study of these aspects has been developed in Spain, where commercial hunting is common. Through interviews with game managers and field surveys, we quantified physical and economic traits, management techniques and hunting methods in a sample of 59 small game hunting estates located in south-central Spain (where Red-legged partridge hunting has the highest socio-economic importance in the country). We compared non-commercial estates (aimed for leisure, managed mainly by local hunting societies) and commercial estates (aimed at financial benefit); among the latter, we also assessed "intensive" estates (a special category of commercial estates licensed to release farm-reared partridges without temporal or numerical limits throughout the hunting season). Commercial estates had more intensive management, including more and larger partridge

releases, higher density of supplementary feeders and more intensive predator control. Thus, any positive or negative effects on biodiversity of these management techniques would be higher in commercial than in non-commercial estates. Commercial estates also retained more natural vegetation, which may help to enhance the landscape and biodiversity value of farmland in central Spain. On the other hand, differences in management and hunting styles were most marked between intensive and other type of estates (both commercial and non-commercial); this indicates that intensive estates are qualitatively different from other small game estates, both ecologically (hunting based on releases and driven shooting) and economically (higher inputs and outputs). It would be desirable to find ways to quantify the environmental or social costs and benefits of different management techniques, and integrate them in the economics of hunting estates.

INTRODUCTION

Hunting is an important socio-economic activity, practiced traditionally by many people over wide areas either for recreation or subsistence (Reboussin 1991, Rose 2001, Mileson 2009), and currently including an important economic dimension (Fontoura 1992, Bernabéu 2002, Chardonet et al. 2002, Rao et al. 2010). Additionally, hunting interacts with local biodiversity both through hunting activities and through game management practices, which are employed broad-scale, and therefore fulfils also an ecological function. Game management commonly implemented in Europe involves controversial practices, such as predator control or releasing captive-reared animals (e.g. Reynolds and Tapper 1996, Barbanera et al. 2010, Fletcher et al. 2010), as well as habitat management which can facilitate the preservation of natural ecosystems and improve the ecological value of anthropogenic ones (Tapper 1999, Robertson et al. 2001, Duckworth et al. 2003).

Game management intensity (and thus its effects on the environment) may vary with the economics of hunting estates (Sotherton et al. 2009). More intensive game management is sometimes linked to estates that aim to make financial profit from hunting (commercial estates), because game managers on these estates may try to boost the numbers of game species to increase income, and re-invest some of this income in management. Additionally, different forms of hunting may generate different financial profit for managers and lead to variation in management intensity. For instance, in Britain, driven red-grouse (*Lagopus lagopus scoticus*) shooting (where hunters remain in blinds while the grouse are driven by beaters walking towards them) leads to larger bags of grouse, has a higher market value and involves more intensive management than walked-up shooting (Thirgood et al. 2000).

In Spain, hunting is an important socioeconomic activity, with more than one million hunters (FACE 2005), and attracts more than 70000 foreign hunters each year (Mulero 1991, Rengifo 2008). Hunting regimes in Spain changed at the end of the 1960s, from mostly open access hunting to the current situation where approximately 75% of Spain (~350000 km^2) is divided into hunting estates managed privately, by hunter associations or individual managers (Grau 1973, López-Ontiveros 1986, MARM 2006). These private game estates may be managed with the objective of obtaining financial benefit from the hunting rights. Hunting currently constitutes a major income in some rural areas (Bernabéu 2002), and seems to be an expanding economic activity (Martínez-Garrido 2009). Small game hunting, particularly of rabbits (*Oryctolagus cunniculus*) and red-legged partridges (*Alectoris rufa*), is of particular relevance numerically and socio-economically (MARM 2006, Ríos-Saldaña 2010). However, populations of these two species have strongly decreased in recent decades (Blanco-Aguiar 2007, Delibes-Mateos et al. 2009). As a result, small game management is often and increasingly associated with the release of captive-reared animals, to maintain harvest following the decline in wild stock (Blanco-Aguiar et al. 2008, Delibes-Mateos et al. 2008a). Since early 1990s, some red-legged partridge commercial hunting estates may even ask for a special permit to release farm-reared birds without temporal or numerical limits throughout the hunting season (referred in Spanish law as "*cotos intensivos de caza*", i.e. "intensive hunting estates"). This variation in approach (from non-commercial to commercial hunting, and from wild to farm-reared stock) is probably linked to differences in game management or the most frequently used forms of hunting, but such information is scarce. However, knowledge about these issues may be useful to understand the extent to which game management practices support the commercial objectives of estates and the consequences that commercialization of hunting may have for the conservation of nature.

In this paper, we assess variation in characteristics, hunting styles or pressure, and game management between red-legged partridge hunting estates with different commercial objectives, as a basis to discuss the potential contribution of each type of hunting to the conservation of biodiversity and rural economies. We specifically focused on red-legged partridge hunting in central Spain, which is the main hunting area in this country (Ríos-Saldaña 2010).

METHODS

Data collection

We studied management and hunting practices on 59 small game hunting estates within central Spain, covering a total land surface of ca. 209000 ha (fig. 1). The main small game species in these estates was red-legged partridge. We selected estates representing the whole range of management intensity gradient. Data about different quantitative and qualitative aspects of every estate, characteristics and management were gathered through 'face to face' in-depth interviews with game managers, conducted between 2006 and 2009. In addition, field surveys were carried out in each estate to gather habitat data and estimates of partridge abundance. Data were recorded using point-count methods (Bibby et al. 1992), where observers drove along transects, stopping every 700-750 m (exact point depending on visibility of the surrounding area). On each point, partridge numbers and locations were recorded during 10 minutes. Surveys took place in summer (mid June to early August). We calculated a partridge abundance index as the sum of recorded partridges within 300 m at each observation point, divided by the number of observation points monitored in each estate. More details can be found in Díaz-Fernández et al. (2012). Additionally, habitat cover at each observation point was noted, and then averaged for each estate. Habitats described included agricultural land, the presence of natural vegetation, mainly scrubland and grasslands, which are known to add biodiversity value to farmland habitats in Mediterranean contexts (Olivero et al. 2011), or the presence of *dehesa* (sparse oak woodland with ground vegetation cultivated or used for livestock forage), which is also of conservation value (Halladay and Gilmour 1995, Blondel and Aronson 1999).

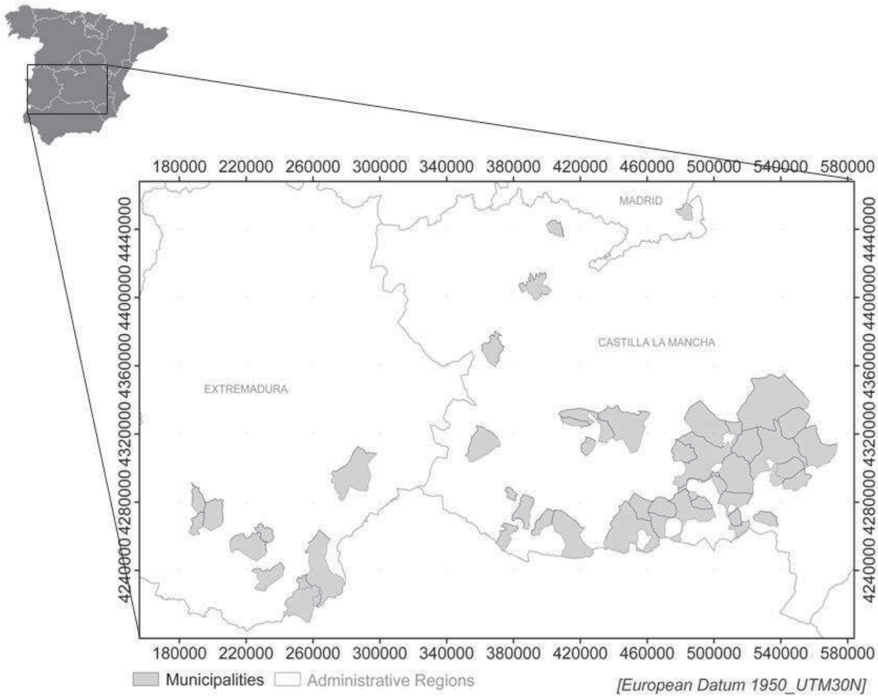

Figure 1. Municipalities (light grey) where the hunting estates studied are located and their situation in peninsular Spain (top left).

Variables analyzed were grouped into three main blocks. The first block included variables related to the *physical and economic characteristics* of the estate (table 1). Land surface of the estates, the main land uses to which the estate was devoted, and the percentage of the land that belonged to the owner of the hunting rights were obtained from the interviews, whereas habitat and partridge abundance were obtained from the field surveys. Additionally, we specifically asked the managers about their economic objectives in the hunting estates.

The second group included *game management variables* (table 2), obtained from interviews: partridges released per km^2, number of years prior to the survey in which releases were carried out, predator control, provision of supplementary feeding and water, and presence of game crops, the management techniques most commonly employed in the study area (Delibes-Mateos et al. 2008b, Ríos-Saldaña 2010). In addition, we collected information on the number of gamekeepers per estate, which we present also per km^2.

The third block included *variables concerning hunting methods, hunting pressure and hunting bags* (table 3), also obtained through interviews. Methods typically used for shooting partridges in central Spain include: 1) driven shooting, where assistants beat the land to flush partridges and drive them towards a strategically arranged line of hunters; 2) walked-up shooting, where hunters (with or without dogs) shoot the birds as they encounter them (Buenestado et al. 2009); 3) decoy shooting, where a male partridge decoy is placed in a territory to attract wild partridges. Partridge bags were expressed as the number of birds harvested on each estate during a hunting season, divided by the surface area of the estate. Annual hunting pressure was calculated as the number of hunters per day and km^2, multiplied by the number of hunting days in the hunting season.

Statistical analyses

The 59 hunting estates were categorized to three types:

a) Non-commercial estates (n = 14); this included estates identified legally as "social", and "private" ones where the stated aim was recreational hunting by a group of friends.

b) Commercial estates with restricted releases (n = 37); this included private estates where the stated aim was to obtain economic benefit from the hunting rights, but without an administrative permit for unrestricted releases.

c) Commercial estates with the "intensive" legal label, and no restriction on releases (n = 8).

For simplicity, we hereafter call these types "non-commercial" (a), "commercial-1" (b) and "commercial-2" (c).

We tested whether each of the variables mentioned above varied among the three types of estates using GLM for quantitative variables (log transformed, or arc-sine transformed in the case of habitat variables, to normalize the variables), and chi-square tests for proportions. Significant pair-wise differences among each pair of categories were evaluated through Tukey tests of LSMeans. Analyses were performed with SAS 9.2.

RESULTS

Physical and economic characteristics

Non-commercial estates were much larger than commercial estates, but less of the land was owned by those with the hunting rights (table 1). A very large proportion of estates of all types had other land uses, mainly agricultural, but the proportion of land covered by agricultural habitats was significantly smaller in commercial estates (mainly because of a lower proportion of permanent crops, i.e. olive trees and vineyards) and livestock was less common. In contrast, the proportion of non-productive land covered by natural vegetation (scrubland or uncultivated grasslands) was twice in commercial than non-commercial estates (table 1). *Dehesas* were most common in some commercial-1 estates, but overall differences were not significant among groups (table 1). No significant differences were found in summer partridge abundance between commercial and non-commercial estates (table 1), although highest densities were found in commercial-1 estates (fig. 2).

Table 1. Mean ± SD (sample size in brackets) values of the variables used to characterize physical and economic characteristics in small-game estates in central Spain, and results of tests for statistical differences among groups (GLM tests were used for continuous variables, Chi-square tests for proportions). Similar letters indicate categories that were not significantly different through Tukey LSMeans comparisons.

	Non commercial	**Commercial 1**	**Commercial 2**	F (* Chi^2)	P
Surface (km^2)	81.5 ± 77.9 (14) a	18.0 ± 25.0 (37) b	34.8 ± 15.9 (8) a	16.21	<.001
% of agricultural habitats	73.5 ± 25.3 (13) a	39.0 ± 24.7 (34) b	47.8 ± 33.4 (6) a	7.42	0.001
% of annual crops	44.6 ± 25.8 (13) a	32.6 ± 22.6 (34) a	32.4 ± 23.4 (6) a	1.12	0.33
% of permanent crops	28.8 ± 18.5 (13) a	6.5 ± 13.0 (34) b	15.3 ± 15.9 (6) a	14.1	<.001
% natural vegetation (grasslands or scrubland)	20.1 ± 21.0 (13) a	42.1 ± 21.8 (34) b	44.6 ± 27.9 (6) ab	4.78	0.01
% *dehesa*	1.3 ± 2.5 (13) a	11.1 ± 24.4 (34) a	3.4 ± 3.3 (6) a	1.31	0.28
% of the land that belonged to the owner of the hunting rights	20.4 ± 36 (13) a	68.7 ± 47 (23) b	45.6 ± 43 (8) ab	5.81	0.006
% of estates with agricultural use	92.9 (14)	88.9 (36)	87.5 (8)	0.22*	0.9
% of estates with livestock use	92.9 (14)	67.6 (37)	42.9 (7)	6.11*	0.05
% of estates with forestry use	23.1 (12)	10.8 (37)	16.7 (6)	1.23*	0.6
Partridge abundance (Partridges/observation point)	0.78 ± 0.79 (13) a	2.40 ± 3.50 (34) a	1.61 ± 1.19 (6) a	1.52	0.23

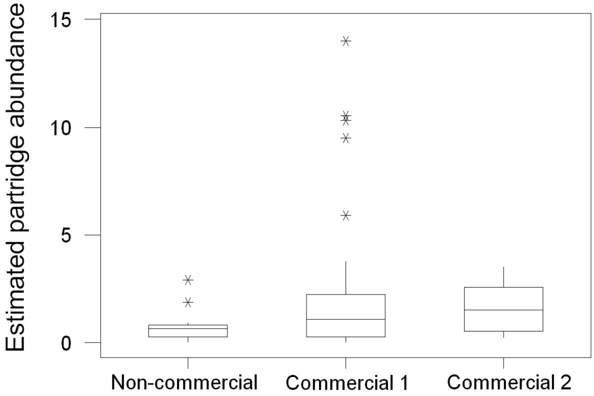

Figure 2. Boxplot of the estimates of summer partridge abundance.

Game management characteristics

The intensity of all management techniques increased significantly from non-commercial to commercial-1 to commercial-2 estates (table 2). As expected, this was particularly marked in terms of the frequency and intensity of partridge releases. The number of partridges released per km^2 was 10 times higher in commercial-1 than in non-commercial estates, and 1000 times higher in commercial-2 estates. Moreover, the frequency of releases also increased from non-commercial to commercial-1 to commercial-2 estates (where partridges were released every year). Similar significant gradients were found for the number of feeding and water points per km^2. Additionally, similar gradients but with less marked differences were found for the density and investment in gamekeepers, the number of red foxes (*Vulpes vulpes*) or magpies (*Pica pica*) killed, and the proportion of estates that used game crops as a management tool. Significant differences were mainly found between commercial-2 estates and the other two types, except for density of gamekeepers, where differences were found mainly between non-commercial and both types of commercial estates (table 2).

Table 2. Mean ± SD (sample size in brackets) values of the variables used to characterize management of small-game estates in central Spain, and results of tests for statistical differences among groups (GLM tests were used for continuous variables, Chi-square tests for proportions). Similar letters indicate categories that were not significantly different through Tukey LSMeans comparisons.

	Non commercial	**Commercial 1**	**Commercial 2**	F (* Chi^2)	P
Partridges released per km^2	1.6 ± 6. 0 (14) a	15.6 ± 34.1 (37) b	2142.1 ± 1972.2 (8) c	40.70	<.001
Number of years (considering the last 9 years prior to the survey) in which releases were employed	0.7 ± 2.4 (14) a	2.1 ± 3.3 (37) a	9.0 ± 0.0 (8) b	18.98	<.001
Density of gamekeepers (gamekeeper/km^2)	0.01 ± 0.01 (14) a	0.14 ± 0.17 (37) b	0.11 ± 0.07 (8) b	4.25	0.01
Investment in gamekeepers (k€)	12.8 ± 14.2 (12) a	19.3 ± 43.6 (33) b	74.1 ± 57.9 (8) c	6.37	0.003
Foxes killed/km^2	0.78 ± 0.8 (13) a	1.64 ± 4.3 (34) a	2.69 ± 2.3 (8) b	3.02	0.056
Magpies killed/km^2	11.4 ± 31.1 (13) a	15.9 ± 18.3 (33) b	17.0 ± 15.3 (8) b	3.96	0.02
Supplementary feeders/km^2	0.05 ± 0.16 (14) a	5.3 ± 5.6 (36) b	29.6 ± 35.6 (8) c	21.73	<.001
Supplementary water points/km^2	0.47 ± 0.9 (14) a	6.4 ± 10.7 (34) b	11.7 ± 11.8 (8) c	14.30	<.001
% of estates with crops for game species	28.6 (14)	54.1 (37)	62.5 (8)	3.3*	0.15

Table 3. Mean ± SD (sample size in brackets) values of the variables used to characterize hunting in small-game estates in central Spain, and results of tests for statistical differences among groups (GLM tests were used for continuous variables, Chi-square tests for proportions). Similar letters indicate categories that were not significantly different through Tukey LSMeans comparisons.

	Non commercial	**Commercial 1**	**Commercial 2**	F (* Chi^2)	P
% of estates offering only driven shooting	14.3 (14)	13.5 (37)	12.5 (8)	0.014*	0.9
% of estates offering driven and walked-up shooting	7.1 (14)	16.2 (37)	87.5 (8)	21.2*	<.001
% of estates offering only walked-up shooting, or walked-up shooting and hunting with decoy	78.6 (14)	70.3 (37)	0.0 (8)	15.8*	<.001
Driven shooting days/year	0.7 ± 1.5 (14) a	1.5 ± 3.6 (33) a	50.6 ± 32.3 (8) b	57.08	<.001
Walked-up shooting days/year	8.78 ± 5.26 (14) a	9.43 ± 8.49 (32) a	13.14 ± 14.8 (8) a	0.16	0.84
Decoy shooting days/year	7.61 ± 11.22 (14) a,b	3.06 ± 6.08 (32) b	16.7 ± 15.8 (8) a	4.17	0.02
Number of hunters/km^2 and day	1.23 ± 0.22 (14) a	1.25 ± 0.14 (34) a	0.26 ± 0.30 (8) b	6.56	0.003
Annual hunting pressure (Hunters/km2/yr)	18.6 ± 19.0 (14) a	16.8 ± 14.5 (34) a	16.8 ± 9.8 (8) a	0.76	0.47
Partridges harvested/km^2	18.2 ± 9.9 (13) a	39.0 ± 33.8 (33) a	1270.1 ± 990.0 (8) b	46.90	<.001
% of partridges harvested in driven shooting	16.7 ± 38.9 (12) a	23.7 ± 41.4 (30) a	95.4 ± 5.6 (6) b	9.78	<.001

Hunting methods, pressure and hunting bags

There were also major differences in relation to the methods of hunting used in each estate type (table 3). A large majority of non-commercial and commercial-1 estates did not carry driven shooting at all, whereas this was the most common method in commercial-2 estates. The amount of decoy shooting offered was also significantly larger in commercial-2 estates, but was also important in non-commercial ones. The density of hunters was significantly lower in commercial-2 estates but, because the number of hunting days per year was also much higher there, annual hunting pressure was very similar among the three types of estates. Annual harvest was 30-70 times larger in commercial-2 estates, where driven shooting was more common. Annual harvest was twice as large in commercial-1 as in non-commercial estates, although this was not statistically significant (table 3).

DISCUSSION

Our study demonstrates that there are differences in the physical characteristics, management practices and style of hunting offered between estates managed for commercial and non-commercial reasons: commercial estates are associated with a greater proportion of natural habitats and more intensive management, and are able to offer greater numbers of birds to be shot, although differences for the latter when excluding estates with no restrictions for captive-reared bird releases were not significant. Additionally, differences in management between commercial and non-commercial estates were much less marked when excluding these “intensive” estates, which are thus markedly different from the other estates. We discuss these results below.

Commercial vs. non-commercial estates

Game bird shooting can be a primary source of income, as occurs with grouse shooting in some areas of the uplands in the UK (Sotherton et al. 2009). In contrast, in our study area more than 85% of even the most intensive estates had agriculture too, which indicates that hunting there is generally a complementary activity to other land uses (Martínez et al. 2002).

In general, game management was more intensive in commercial than in non-commercial small game estates, and this was true for most variables even when excluding intensive estates. The management variables that were more frequently employed in commercial estates as compared to non-commercial estates were predator control, partridge releases, supplementary feeders and water points. Commercial estates also employed more gamekeepers per unit surface. These differences are not surprising, as all these management techniques represent a high economic investment for managers (both in infrastructure, salaries, or direct expenses as food or captive-reared birds) and are less likely to occur in those estates that do not produce economic profit. These results suggest that any positive or negative effects on biodiversity of these management techniques would be higher in commercial than not-commercial estates. It is increasingly accepted that farm-reared partridge releases damage biodiversity conservation: supplemental stocking practices may threaten the integrity of the wild partridge population gene pool (Blanco-Aguiar et al. 2008, Barbanera et al. 2010) or may pose a risk to wild populations by introducing parasites (Villanúa et al. 2008), which can threaten other species of conservation concern such as the little bustard (*Tetrax tetrax*; Villanúa et al. 2007). Predator control is a source of social conflict when illegally implemented, and has caused a reduction in the geographic range of several endangered predators (e.g. Villafuerte et al. 1998, Rodríguez and Delibes 2004, Virgós and Travaini 2005), but it may have positive effects on other species (Fletcher et al. 2010). Supplementary food or water provided for partridges may have also positive effects on other species (authors unpublished data), although this has been scantly studied.

Additionally, our results indicate that areas managed for commercial hunting have more scrubland or uncultivated grasslands compared to non-commercial estates, where most of the area was occupied by farmland. Scrubland and uncultivated grasslands are positively associated with higher natural value of farmland in Mediterranean Spain (Olivero et al. 2011). In addition, game crops, which are known to increase biodiversity in farmland (Parish and Sotherton 2004), were more common in commercial estates. Hunting has been claimed to be associated with the retention of natural habitats (Otero 2000, Robertson et al. 2001, Duckworth et al. 2003). Our data do not allow us to ascertain whether hunting activities have directly contributed to the retention of natural habitats in small game estates in Spain. However, our results indicate that managing for commercial hunting may have advantages over non-commercial estates in terms of farmland habitat quality. Moreover, land property and hunting rights were more often tied in commercial than in non-commercial estates. In the latter, land ownership was highly fragmented, often not including the owner of the hunting rights, and management decisions about land use including hunting resources are often made by different persons there. In contrast, the owner of the hunting rights in commercial estates was also often the landowner, which suggests that retention of natural habitats in private hunting lands might be a consequence of game management instead of just a reflection of where commercial estates are located, but more research is needed to confirm this.

The more intensive management in commercial estates, however, did not necessarily lead to higher abundance of wild stocks or higher annual harvest, and hunting pressure was similar between non-commercial and commercial estates. Annual harvest was significantly higher in intensive estates, which reflects the markedly higher investment in releases (table 2, and see Díaz-Fernández et al. 2012). The fact that summer abundance in intensive estates was similar than in other estates despite the much higher level of released partridges also must reflect the extremely high mortality of released birds (Gortázar et al. 2000, Alonso et al. 2005). Non-intensive commercial estates tended to have higher annual harvest and summer partridge abundances (the highest densities were observed in those types of estates) than non-commercial ones, but differences were not statistically significant, probably due to the high variance of both variables. Further studies should investigate the relationship between abundance and harvest quotas, to assess the sustainability of wild partridge populations under the different management regimes.

In summary, our results suggest that non-commercial hunting, due to fewer releases, could contribute to the conservation of the genetic pool of wild partridge populations in Spain. However, commercial hunting was also associated with more natural vegetation within the farmland matrix, suggesting positive relationships between hunting commercialization and biodiversity. Furthermore, commercial estates generate more jobs than non-commercial estates, and could thus have social benefits in rural communities (Bernabéu 2002, Caro et al. 2011). It is now urgent to determine the cost-efficiency of management techniques to identify management to promote the optimal combination of social, economic and conservation benefits of hunting.

Intensive vs non-intensive estates

Administratively labelled « *intensive* » estates were indeed more intensive in their management than other commercial estates. Most striking differences related to both the frequency and number of partridge releases, but intensive estates also invested proportionally more in the use of supplementary feeders and water points, as well as in growing crops devoted to game cover. This is not surprising because 1) supplementary food and water are considered necessary to improve the short-term survival in inexperienced recently released partridges (Gortázar et al. 2000); 2) feeders and watering points create "attraction points" to retain released partridges linked to the estate, reducing dispersal, and are also useful as medication points to control diseases associated with farm-reared partridges (Villanúa et al. 2008). The high densities of captive-reared released birds in intensive estates probably attract carnivores, which are a primary cause of death in recently released partridges (Alonso et al. 2005), which may explain why more foxes were killed on intensive estates than on the other two types of estates (either because there are more foxes, or because higher effort is made to control this mortality factor for released birds). The higher level of magpie control in intensive units is however surprising, as these corvids are usually killed because they prey on partridge eggs (Díaz-Ruiz et al. 2010), and consequently do not present a risk for released birds. This suggests that there is a culture of controlling any potential predator as an index of perceived good management that may be not necessarily linked to increasing profitability (authors unpublished data).

Intensive estates were also different from others in relation to hunting styles. Driven shooting was the main method of hunting partridges there, but secondary on the other two types of estates. It has been suggested that driven shooting is more harmful for wild partridge populations than walked-up shooting (Buenestado et al. 2009) because this form of hunting may be associated with higher disturbance, although the evidence for this is lacking. Intensive estates also offered a much higher number of decoy shooting days than the other estates. Hunting with decoys is controversial because it may interfere with breeding. It would be necessary to know whether birds hunted with decoys in intensive estates are potential breeders or captive-reared released birds, and thus the potential impact of this hunting method on wild populations.

The number of birds harvested was notably higher in intensive estates, suggesting that income generated on these estates is higher. Driven grouse shooting in Britain is estimated to generate roughly 10 times the revenue of walked-up shooting (Sotherton et al. 2009), although it is offset to some extent by the cost of employing higher number of gamekeepers and the associated management carried out. Expenditure in intensive estates in central Spain was also much higher than in non-intensive estates for the same reasons. What is now needed is to compare the cost-revenue ratio and the variation in these measures among non-intensive and intensive units.

At present, there are still very few intensive game estates in central Spain (3%; Ríos-Saldaña 2010), but their economic and social impact could be very high, at least judging from hunting bags or jobs created, and their numbers could thus increase as a way to contribute to rural development. However, our results suggest that this industrialization of hunting is linked to a marked increase in the use of controversial management practices and could lead to conflicts over land management in these areas.

Increasingly, there is pressure to develop incentives and support schemes that promote management practices that provide effective conservation and social benefits and enhance employment and economic growth. In order to inform such policies more work is needed to quantify the externalities (environmental or social costs and benefits) of different management techniques, and to integrate them in the economics of hunting estates (Hennart 1986). For example, hunting estates with conservation and social benefits (e.g. those promoting employment and financial benefits, but associated with environmental benefits through preservations of wild stocks and/or natural habitats) could benefit from tax relief or be eligible for financial support through and accreditation scheme were they demonstrate their social, economic and environmental sustainability. Further studies (including socio-economic ones) should be implemented to determine the feasibility and acceptability of such schemes, and thus their efficiency in promoting conservation-friendly hunting and game management.

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CHAPTER 2. HARVEST OF RED-LEGGED PARTRIDGE IN CENTRAL SPAIN

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ABSTRACT

A basic rule to attain sustainable use of harvested resources is to adjust take to availability. Populations of red-legged partridges in Spain have decreased in recent decades, and releases of farm-bred partridges to improve short-term availability are increasingly common. We used questionnaires and bird surveys to assess whether harvest was related to availability of wild partridges or intensity of farm-bred partridge releases. We studied 50 hunting estates, including 6 administratively labeled as intensive (with few numerical and temporal restrictions to releases). In addition, we considered hunting pressure (number of hunters × hunting days / km^2) and habitat as explanatory variables in the analyses. In intensive estates, annual harvest was exclusively related to release intensity, indicating that in these estates hunting is detached from natural resources and approaches an industrial activity based on external inputs. In non-intensive estates, harvest was affected by wild stock availability, walked-up shooting pressure, and habitat (greater harvest in estates with more Mediterranean shrubland). In these estates, releases did not increase annual harvest, and can be considered an inefficient practice. Additionally, the relationship between abundance estimates and harvest disappeared in estates

with low partridge abundance estimates, suggesting possibilities for overharvesting in a large proportion of estates. Increasing the abundance of wild red-legged partridge through techniques like habitat management, and improving the adjustment of harvest to availability, may be a good strategy to increase long-term harvest in non-intensive estates. Additionally, Government and managers must create ways to segregate and label the estates where only wild red-legged partridges are managed from those where releases are used, to reduce ecological costs of management decisions.

INTRODUCTION

Adequate management of natural resources requires a balance between the needs of the public and the long-term maintenance of those resources. A basic rule to attain sustainable use of harvested resources is to adjust take to availability. Simulation techniques like management strategy evaluations (MSE; Punt and Donovan 2007) have shown how decreasing the uncertainty in estimates of fish population size enables a better adjustment between take and availability, contributing to increased yield stability and profitability (Holland 2010). This may be valid also for other systems like hunting, where dynamically adjusting extraction to availability increases the sustainability of wild game populations (Guthery 2002b, Hunter and Runge 2004).

A common objective of managers is usually to maintain or increase current harvest. Increasing availability of the resource to increase harvest can be achieved by improving natural conditions for population productivity and survival. However, in recent times managed systems are increasingly relying on the use of external inputs (Jackson et al. 2009) rather than on maintaining naturally renewable resources. In the case of harvested animal populations, an example of this is the artificial increase of resource availability through (re)stocking, an increasingly used management technique that may entail environmental costs (Laikre et al. 2010).

The red-legged partridge (*Alectoris rufa*) is a farmland game bird from southwest Europe with most of its global population located in Spain (Blanco-Aguiar et al. 2003). In addition to being a primary prey source for many Iberian predators (Calderón 1977, Herranz 2000, Duarte and Vargas 2001), this species comprises 23% of all the small game animals harvested in Spain, a proportion only surpassed by the European wild rabbit (*Oryctolagus cunniculus*). Indeed, 62% of the money paid directly for small game corresponds to both of these species (MARM 2006). Despite its ecological and economic importance, wild populations of red-legged partridge have declined sharply since the 1970s for reasons associated with changes in agricultural practices and overhunting (Aebischer and Potts 1994, Aebischer and Lucio 1997, Rocamora and Yeatman-Berthelot 1999, Blanco-Aguiar 2007, Casas and Viñuela 2010). Annual harvest in Spain decreased from approximately 3.5–4 million partridges in the 1970s and 1980s to 2–2.5 million in the early 1990s (Blanco-Aguiar 2007). Interestingly, annual harvest from the 2000s increased again to the current level of 3.3–3.5 million partridges (MARM 2010), probably because of widespread releases of farm-bred partridges (Blanco-Aguiar et al. 2012).

In the second half of the twentieth century, the number of hunters in Spain doubled and the philosophy underpinning hunting activities changed from self sufficiency or simple family entertainment to a profitable business (Martínez et al. 2002, Martínez-Garrido 2009). Concurrent with its population decline and rising economic interest, the use of farm-bred birds to supplement wild populations of red-legged partridges started in the late 1970s and has exponentially increased ever since (Angulo 2003, González-Redondo 2004, Blanco-Aguiar et al. 2008, Ríos-Saldaña 2010). The amount of farm-bred partridges released annually is not precisely known, but estimations move between 3 and 6 million (Delibes 1992, Pérez y Pérez 1992, Garrido 2002, Martínez et al. 2002, González-Redondo et al. 2010), a figure comparable to the current annual harvest (MARM 2010). Generally, if hunting estates release farm-bred partridges, they have to do so within restrictions on timing (no later than 2 weeks prior to the start of the hunting season in Oct) and numbers. However, regulations have been recently approved (e.g., Dirección

General de Conservación del Medio Natural 1993, Consejería de Agricultura y Medio Ambiente 1996) allowing certain estates (administratively labeled as intensive) to have much fewer legal restrictions in relation to number or timing of farm-bred partridge releases. In these types of estates, large numbers of partridges (>2,000/km^2 on average) are released annually, and throughout the whole hunting season (Ríos-Saldaña 2010, authors unpublished data). Intensive estates are relatively scarce (3% of all hunting estates in 2006; MARM 2006, Ríos-Saldaña 2010), but there is an increasing demand for this label.

Releases of farm-bred birds as a management tool is highly controversial among hunters, managers, and conservationists, both in Spain (Martínez et al. 2002, Gortázar et al. 2006) and elsewhere (Leopold 1944). In the case of partridges, this is because of perceived (and increasingly documented) negative effects of releases on wild red-legged partridge populations due to disease spread, changes in population genetic pool, reduction in fitness, or overhunting (Blanco-Aguiar et al. 2008, Sokos et al. 2008, Villanúa et al. 2008, Barbanera et al. 2010, Casas et al. 2012). Thus, releases could positively affect harvest by temporarily increasing partridge availability, but negative effects through reducing the survival of wild stock partridges could also be expected (Gortázar et al. 2000, Gortázar et al. 2006). Understanding the factors affecting harvest and the relationship between releases and harvest is essential to optimizing management and to assessing if the use of farm-bred partridges is having positive effects that may compensate its costs (either monetary for individual managers or ecological for the environment).

We explored the relationship between harvest and partridge availability (from wild and released birds), to evaluate whether releases have a noticeable effect on annual harvest numbers. We discussed the importance of assessing the effectiveness of management techniques to assist managers in avoiding any negative ecological effects.

STUDY AREA

We worked in central Spain, one of the main regions for small-game hunting in Spain (Ríos-Saldaña 2010). Hunting is allowed in 89% of central Spain (Ríos-Saldaña 2010), and hunting estates are either managed by the government (13%) or privately (87%), the latter by either individuals or hunting societies. If managed privately, they may be commercial venues (the purpose of the estate is to sell hunting days to hunting customers). In any case, land management decisions are often made separately from game management decisions, as the land itself rarely belongs to the owner of the hunting rights.

We studied 50 hunting estates (all of them managed privately; fig. 1). The total area of studied estates (1,945.87 km^2) covered 22% of the municipalities in the study area. Hunting estate area ranged from 2 km^2 to 280 km^2. Most were relatively small; 22% were ≤5 km^2, 40% had an area between 5 km^2 and 30 km^2, and only 6% were ≥100 km^2. Only 6 of the 50 studied estates (amounting to 12% of the sample) were intensive. Intensive estates were those legally labelled as such, which allowed them to have few numerical and temporal restrictions on releases of farm-bred birds, whereas supplementation of artificially-raised birds in non-intensive estates, if it happened, was usually more limited. As intensive estates represented only 3% of all estates available in the area, our sample was positively biased towards intensive estates.

METHODS

To determine if harvest was related to the availability of farm-bred birds or to wild population densities, we also took into account variables of hunting pressure and habitat, because they may potentially affect this relationship. Harvest may be associated with hunting pressure, as the longer the time people are allowed to hunt in a given estate, the larger the harvest, assuming a constant intention to hunt (Palmer et al. 2002). Additionally, habitat variability between estates may have an effect on harvest irrespective of game availability or hunting pressure (e.g., by reducing the area where hunting is possible or the visibility of birds). Thus, we considered partridge abundance, release intensity, hunting pressure, and habitat simultaneously in our analyses.

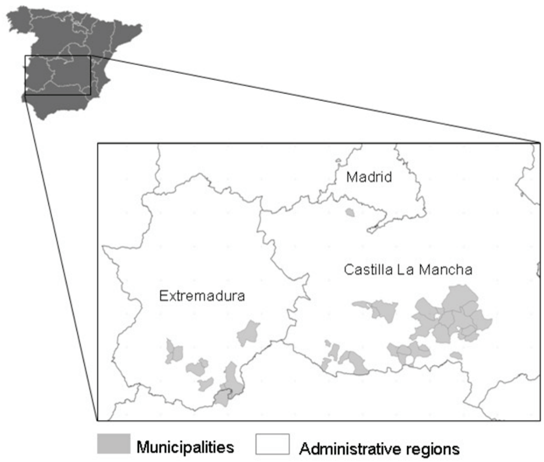

Figure 1. Municipalities (light grey) where we studied Harvest of red-legged partridge from 2005–2009 within hunting estates and their situation in peninsular Spain (top left).

Management and Hunting Data

We interviewed managers from each study estate. Through the interviews, we obtained data on area, red-legged partridge annual harvest, farm-bred partridge annual releases, hunting pressure, and possession of an intensive hunting estate license. We calculated mean partridge harvest (harvest) as the total annual harvest in the estate divided by its area (in km^2). Interviews were conducted on August 2005 (22 interviews), March 2008 (1), June 2008 (5), September 2008 (3), February 2009 (1), March 2009 (3), April 2009 (10), May 2009 (4), and February 2010 (1). When information for several years existed, we used the harvest during the game season previous to the interview, which was usually the year prior to the field survey (see below). We assumed that between-estate variability in harvest was greater than among-year variability for a given estate, and thus that our data from just 1 game season characterized the level of annual harvest for each estate. We checked this last assumption for 21 estates for which we had information on harvest for different number of years (mean ± SD = 6.71 ± 3.74 years) and obtained a repeatability value (Lessells and Boag 1987) of 0.99, showing that harvest adequately represented harvest variability among estates.

We calculated partridges released as the number of farm-bred partridges released the year prior to the interview in each estate divided by its area (in km^2). We checked again if this variable was representative of estate release intensity for an average year with data for 47 estates (mean ± SD = 10.55 ± 2.54 years), and obtained a repeatability value of 0.87. We also categorized each estate as intensive or non-intensive, according to whether they had the administrative category or not (variable: intensive).

We calculated hunting pressure as the product of mean number of hunters per day by the number of hunting days in the estate during the hunting season, divided by the estate area. Three main hunting methods are used in central Spain: 1) walked-up shooting, where hunters go walking alone or in small groups, with or without dogs, and shoot the game species they find along the walk; 2) driven shooting, where partridges are driven towards concealed and stationary hunters by teams of beaters; and 3) hunting with decoy, where the hunter remains hidden and shoots the wild partridges when they approach the decoy (occurring only between Jan and Mar). Walked-up shooting was the prevalent method in non-intensive estates; 86% of 44 non-intensive estates offered this method, whereas only 19% offered driven shooting days (see also table 1). In contrast, 100% of intensive estates offered driven shooting, and 96% of all harvest occurred through driven shooting. Hunting with decoy was less common in general than the other 2 methods (Buenestado et al. 2009), and did not occur at all in 55% of our non-intensive and 34% of our intensive estates. Given that the different hunting methods may have a completely different ratio between time spent hunting and success, we measured hunting pressure separately for each hunting method.

Partridge Abundance Data

We calculated a summer partridge abundance index using point count transects (Ralph and Scott 1981, Bibby et al. 1992) in each of the 50 hunting estates. Point count transects are widely used for bird population monitoring in Europe and North America, and they are considered particularly useful for red-legged partridge when the objective is a large-scale census (Onrubia 1998). Observers drove along transects, stopping every 700–750 m (exact point depending on visibility of the surrounding area). The number of points assessed in each estate was 69.6 ± 64.1 (range: 4–425 points), depending on estate area. We aimed to sample transects covering the whole of the estate or, when they were too big, a representative area of the estate stratifying by habitat. On each point, we recorded partridge numbers and locations for 10 minutes. Observations took place in early morning (from sunrise to approx. 3 hr later) and in the evenings (last 3–4 hr of sunlight), avoiding the hottest central hours when activity was lowest. We also suspended observations during rain or when conditions were too windy. We estimated distances from partridges to observer using intervals of 50 m.

We selected survey dates to coincide with the time when most of the cereal had been harvested (in order to maximize partridge visibility), but before farm-bred partridge releases occurred (or at least before they were widespread). In non-intensive estates, releases usually took place as near as possible to the opening of the hunting season (i.e., in or after Aug). We surveyed 22 estates from 16 June to 31 July in 2006, 9 estates from 17 July to 13 August in 2008, and 19 of them from 16 June to 12 August in 2009. Furthermore, we checked with game managers or gamekeepers that partridges had not been released before the census whenever possible. Thus, we have reasonable confidence that our census must reflect abundance of wild partridges, including any possible survivors of releases from the previous hunting season. Available scientific information indicates that overwinter survival of released partridges is low (Gortázar et al. 2002, Alonso et al. 2005, Gaudioso et al. 2011, Casas et al. 2012).

We calculated a partridge abundance index as the sum of recorded partridges within a radius of 300 m at each observation point, divided by the number of observation points monitored in each estate. We did not specifically evaluate detection probability, and therefore we did not calculate population density (Bibby et al. 1992). However, this method provided comparable data between areas of relative abundance estimates. We used a 300-m radius for the index because 1) taking into account distance between observation points, a greater than 300-m radius would not confidently avoid counting the same animal twice; and 2) using much smaller radii, we had a much greater proportion of points with zero observations, which could potentially increase the error. In any case, we found strong correlations between estimates for each hunting estate calculated using each of 3 possible radii (300 m, 250 m, or 200 m); *r* coefficients ranged between 0.996 and 0.999 for 2×2 correlations of the 3 different estimates for each estate ($n = 50$).

Habitat Data

We recorded the estimated percentage of each habitat type within a radius of 100 m at each observation point, during the bird surveys at each hunting estate. We defined 7 habitat categories (table 1) with functional and management meaning for red-legged partridge: 1) arable farmland (mostly cultivated with winter cereal or left in annual fallow and usually ploughed during summer or fall), 2) vineyards, 3) tree crops (mainly olive groves, secondarily almond trees, occasionally fig trees), 4) uncultivated grasslands (including fallow land >1 yr old and uncultivated areas covered by low herbaceous vegetation), 5) Mediterranean shrubland (mainly medium-height Mediterranean shrubs, most often *Cistus* sp., *Halimium* sp., *Retama sphaerocarpa*, *Rosmarinus officinalis*, with a strong component of *Quercus coccifera* and Holm oak [*Quercus ilex*], the latter sometimes achieving full tree height), 6) woodland (pine or eucalyptus plantations, secondarily poplars), and 7) dehesa (areas of sparse oak woodland, which may be cultivated or grazed underneath). A few estates contained sparse juniper (*Juniperus phoenicea*) trees, with either pasture or crops underneath. We categorized this as dehesa because it had the same structure. Other reported habitats (riparian vegetation or country houses) occurred only marginally. For analyses, we lumped arable land, vineyards, and tree crops as farmland to further simplify habitat variables and as trends in preliminary analyses were similar for the 3 variables.

Statistical Analysis

We tested the relationship of harvest with explanatory variables (partridge abundance index, release intensity, hunting pressure, and habitat) with general linear mixed models with a normal error of the response variable and an identity link. The model included census year as a random variable, to control for the potential effect of year on the estimation of abundance. First, we considered the whole data set, included the binomial variable called intensive as an additional explanatory variable, and constructed models with different combinations of our explanatory variables. Then, considering the large difference between intensive and non-intensive estates in both release intensity and harvest (see Results), we repeated the analysis separately for both groups of estates to study the effect within smaller ranges of release intensity. When analyzing data from intensive estates, we used general linear models (as all censuses but 1 were completed in a single year), and only considered relevant combinations of up to 2 explanatory variables because of the small sample size (6 estates). We considered as best models those with smaller corrected Akaike´s Information Criterion (AIC_c; Burnham and Anderson 2002, Bolker et al. 2008). Specifically, we considered within the set of best models those with up to 3 AIC_c difference with regard to the lowest. We calculated Akaike weights for all models initially considered, and used them to estimate the relative importance of each variable summing the Akaike weights across the set of best models where that variable occurred (Burnham and Anderson 2002). We further used the set of best models to obtain model averaged parameter estimates, and standard errors for the variables. We carried out analyses with the glm, lme, dredge and model.average R functions (R Development Core Team 2009). We checked the goodness of fit of the set of best models with the adjusted R-squared of the linear regression between predicted and observed values of each model, and with a Shapiro-Wilk (S-W) test of normality for residuals. Finally, although we built the set of best models as explained above, we pointed out the variables possibly included as uninformative parameters following Arnold (2010), that is to say, variables appearing as one additional parameter of models with lesser AIC_c within the group of best models.

RESULTS

For intensive estates, numbers of birds released was 200 times larger than for non-intensive estates, but the partridge abundance index was similar (table 1). Harvest was 46 times larger in intensive estates (table 1). Hunting was mainly through driven shooting in intensive estates, and through walked-up shooting in non-intensive estates. Decoy shooting pressure was low in both types of estates (table 1).

Table 1. Average (± SD) values for red-legged partridge management and hunting variables in our sample taken in central Spain, 2005–2009, calculated for non-intensive and intensive estates separately.

	Non-intensive	Intensive
Partridges released (number/km^2)	13.49 ± 31.78	2,672.91 ± 2,022.94
Driven shooting pressure (hunters/season/km^2)	0.01 ± 0.03	0.12 ± 0.09
Walked-up shooting pressure (hunters/season/km^2)	0.13 ± 0.12	0.03 ± 0.03
Decoy shooting pressure (hunters/season/km^2)	0.03 ± 0.08	0.04 ± 0.03
Partridge abundance index (number/observation point)	1.96 ± 3.18	1.61 ± 1.19
Harvest (number/km^2)	33.12 ± 34.06	1,535.15 ± 1,015.09
Farmland (%)	47 ± 31	47 ± 33
Mediterranean shrubland (%)	24 ± 25	38 ± 29
Dehesa (%)	5 ± 10	3 ± 3
Woodland (%)	9 ± 24	3 ± 6
Grasslands (%)	11 ± 15	7 ± 5

When we considered all estates together, the best models explaining variation in harvest (table 2) included 4 habitat variables (woodland, grassland, Mediterranean shrubland and farmland) and 5 management variables: driven shooting pressure, walked-up shooting pressure, abundance index, release intensity, and possession of the intensive label. Harvest increased with driven and walked-up shooting pressure, as well as with wild and farm-bred availability, and was greater in intensive than in non-intensive estates. It was also greater in estates with greater proportions of Mediterranean shrubland and farmland, and lesser in estates with more woodland and grassland (table 3). However, grassland and farmland appeared as one additional parameter of the top-ranking model (table 2), meaning that they probably were uninformative variables, which was also supported by the small relative importance calculated for them (table 3). The relationship between observed and predicted harvest was strong in all the models (R^2=0.99, table 2; S-W $P \geq 0.225$).

For non-intensive estates, the best models with informative parameters explaining variation in harvest included 2 management variables, partridge abundance index and walked-up shooting pressure (table 2), both positively related to harvest (table 3), and 3 habitat variables (table 2), Mediterranean shrubland positively related to harvest and farmland and dehesa negatively related (table 3). Mediterranean shrubland was the habitat variable with greatest relative importance (table 3). All the other management and habitat variables studied (driven shooting pressure, decoy hunting pressure, partridges released, woodland and grassland) were included in some of the best models, but they were probably uninformative parameters, because they appeared as one additional parameter of models with lesser AIC_c. The relationship between observed and predicted harvest gave an adjusted *R*-squared between 0.59 and 0.66 (table 2; S-W $P \geq 0.013$). The relationship between abundance estimates and harvest in non-intensive estates, although significant, was very scattered, particularly among estates with lesser abundances of birds (fig. 3). The relationship relied on a small number of game estates with high summer bird densities. If we removed from the analyses the 5 estates with summer abundance indices ≥5, the relationship disappeared, and the only variables affecting harvest in these estates were walk-up shooting pressure and Mediterranean shrubland habitat.

Table 2. Models (with $\Delta AIC_c \leq 3$) explaining variation in red-legged partridge harvest in central Spain for a) all estates, b) non-intensive estates, and c) intensive estates. We provide number of parameters (*K*), second-order Akaike's Information Criterion (AIC_c), difference in AIC_c relative to the best model (Δ), Akaike weight (w_i), log likelihood (logLik), and adjusted *R*-squared of the linear regression between predicted and observed values (R^2). F = farmland, MS = Mediterranean shrubland, D = dehesa, W = woodland, G = grasslands, Ab = partridge abundance index, R = partridges released, I = having intensive license, WSP = walked-up shooting pressure, PDS = driven shooting pressure, PHD = hunting with decoy pressure.

F	MS	D	W	G	Ab	R	I	WSP	PDS	PHD	K	AIC_c	Δ	w_i	logLik	R^2
a) All estates																
	x		x		x	x	x	x	x		10	533.0	0.00	0.20	−242.6	0.99
	x				x	x	x	x	x		9	534.9	1.85	0.08	−242.9	0.99
	x				x	x	x		x		8	534.9	1.93	0.08	−249.3	0.99
	x		x	x	x	x	x	x	x		11	535.1	2.13	0.07	−242.4	0.99
x	x		x		x	x	x	x	x		11	535.8	2.76	0.05	−242.6	0.99
			x		x	x	x	x	x		9	536.0	2.97	0.04	−242.6	0.99
b) Non-intesive estates																
	x				x			x			6	402.5	0.00	0.09	−189.9	0.62
	x			x	x			x			7	403.8	1.22	0.05	−189.9	0.62
x		x			x			x			7	404.0	1.41	0.05	−187.6	0.66
	x				x						5	404.2	1.68	0.04	−189.9	0.62
	x	x			x			x			7	404.3	1.73	0.04	−188.3	0.66
x		x			x						6	404.4	1.83	0.04	−193.7	0.63
	x		x		x			x			7	404.5	1.97	0.03	−190.9	0.62
	x				x			x	x		7	404.7	2.16	0.03	−183.8	0.62
	x			x	x						6	404.9	2.34	0.03	−195.8	0.59
	x				x			x		x	7	405.0	2.46	0.03	−185.1	0.62
	x				x	x		x			7	405.1	2.51	0.03	−191.1	0.61
	x	x			x						6	405.1	2.55	0.03	−194.3	0.62
x	x				x			x			7	405.2	2.68	0.02	−189.9	0.62
x		x	x		x			x			8	405.5	2.96	0.02	−188.6	0.66
c) Intensive estates																
						x					3	95.0	0.00	1.00	−35.79	0.97

[a]Thirty one other competing models all had Δ >3.00 and w_i <0.001.

When looking at intensive estates separately, the best model explaining variation in harvest included only 1 variable: partridges released (table 2, 3). We found a linear relationship between releases and harvest in these estates, which indicated that approximately 45% of released partridges were harvested (fig. 2, table 3). The relationship between observed and predicted harvest was strong (R^2=0.97, table 2).

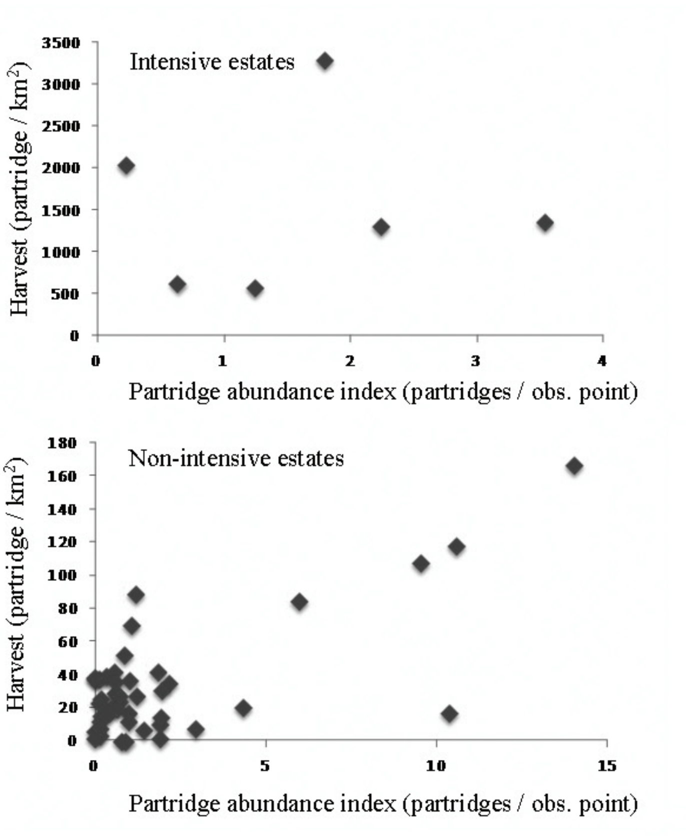

Figure 2. Relationship between red-legged partridge harvest and releases for intensive estates (above) and excluding intensive estates (below) in central Spain, 2005–2009.

Table 3. Model averaged parameter estimates (β) and standard errors (SE), and relative variable importance (calculated as the sum of AIC weights for models containing the parameter) for the variables included in the best models explaining red-legged partridge harvest in central Spain, 2005–2009 (i.e., those with Akaike's Information Criterion differences [ΔAIC_c] ≤3).

	β	SE	Relative variable importance
All estates			
Intercept	−23.743	14.616	
Abundance index	8.998	2.391	0.52
Intensive license	164.982	34.397	0.52
Driven shooting pressure	782.421	193.251	0.52
Partridges released	0.476	0.011	0.52
Mediterranean shrubland	0.604	0.274	0.48
Walked-up shooting pressure	138.387	64.477	0.44
Woodland	−3.266	1.609	0.36
Grassland	−0.453	0.459	0.07
Farmland	0.162	0.241	0.05
Non–intensive			
Intercept	9.714	14.487	
Abundance index	7.668	1.145	0.53
Mediterranean shrubland	0.359	0.142	0.42
Walked-up shooting pressure	57.296	29.246	0.39
Dehesa	−0.296	0.186	0.18
Farmland	−0.242	0.191	0.13
Grassland	0.303	0.239	0.08
Woodland	−0.854	0.882	0.05
Driven shooting pressure	90.149	115.791	0.03
Decoy hunting pressure	−23.864	41.212	0.03
Partridges released	0.056	0.10348	0.03
Intensive			
Intercept	211.15	130.25	
Partridges released	0.4953	0.040	1.00

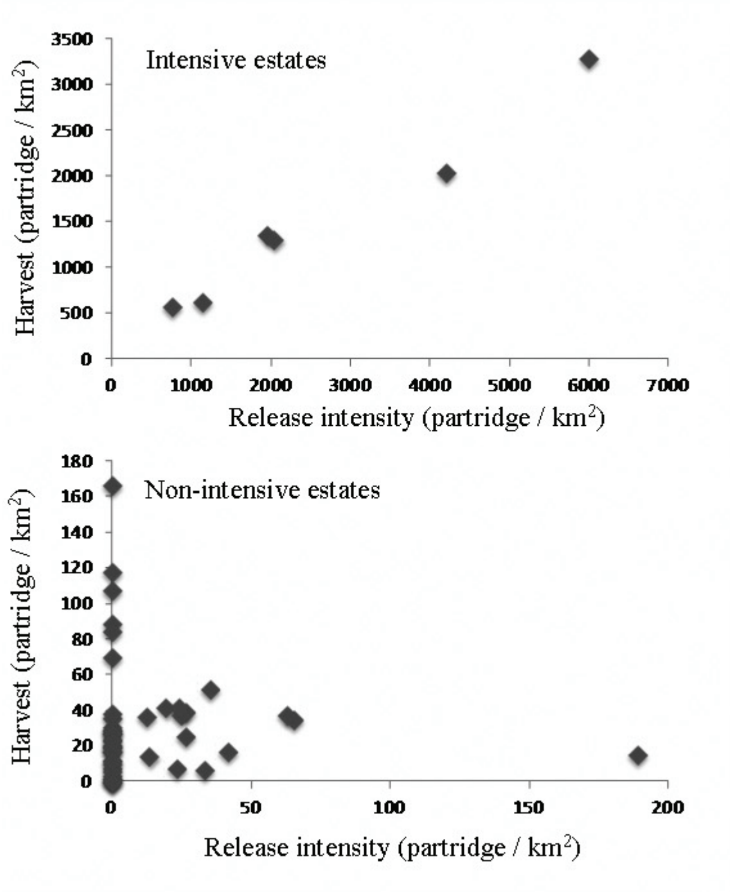

Figure 3. Relationship between red-legged partridge harvest and summer abundance for intensive estates (above) and excluding intensive estates (below) in central Spain, 2005–2006.

DISCUSSION

Our study indicates that, in central Spain, variation between estates in red-legged partridge harvest was related to both partridge availability and hunting pressure, but with marked differences between intensive and non-intensive estates. In intensive estates, harvest was linearly dependent exclusively on release intensity. In non-intensive estates, harvest increased mainly with wild partridge densities and walked-up shooting hunting pressure, and releases only had a minor effect in one of the 14 best models. The main effect of habitat was an increase of harvest with increasing abundance of Mediterranean shrubland.

Harvest in Intensive Estates

In intensive hunting estates, harvest was exclusively and linearly related to the number of partridges released; frequency of releases is probably adjusted by managers to short-term harvest demand, and the numbers of partridges released is adjusted to the number of hunters. This would explain the absence of effects of hunting pressure on harvest. On intensive estates, releases are usually allowed over a longer period of the year than in non-intensive estates. According to the coefficient in the model, the mean return on harvest of partridges released is around 45%, although partridge summer densities are not greater than in non-intensive estates, suggesting a loss of more than half of the released birds both before and after the shoots. This is concurrent with the high mortality of released partridges reported in other studies (Gortázar et al. 2000, Alonso et al. 2005).

In intensive estates, we found no relationship between harvest and summer partridge abundance, confirming that in these estates hunting is detached from in situ natural resource management and is approaching an industrial activity based on external inputs. From an ecological and managerial point of view, commercial activities based on natural populations or on farm-bred animals have entirely different objectives and natural resource sustainability. Rules to avoid dangers of large quantities of animals establishing in free-ranging populations or disease transmission to native wildlife should be adopted (e.g., The Wildlife Society 2012). Also an administrative separation of estates employing each type of management, not only legally (as happens now with the legal label) but also potentially in terms of taxes or commercial eco-labels would be relevant, as it would reward managers that preserve multifunctional estates by maintaining healthy wild populations whilst allowing them to compete in the market. This separation was also recommended in the conclusions from the review of Sokos et al. (2008).

Harvest in Non-Intensive Estates

Harvest in non-intensive estates was positively related to summer partridge abundance, but the relationship relied on those few estates with greatest summer densities. In estates with moderate or low summer abundance indices, we did not find any relationship between harvest and wild partridge abundance estimates. We cannot discard that our abundance index was not sensitive enough to clearly distinguish among low abundances, and thus some noise in the relationship may come from the abundance index itself. Also, partridge releases may have been unreported by managers during the interviews in some of those 5 estates with high summer bird densities. Selling farm-bred partridges as if they were wild partridges may be a highly profitable business that, obviously, must be based on hiding release activity to the public. The increasing likelihood of this fraudulent activity when releases are more widespread has been previously mentioned (Delibes 1992). Our results show that the relationship between harvest and availability was not strong with low abundances, which was also found by Cattadori et al. (2003) studying red grouse (*Lagopus lagopus scoticus*) harvest. This suggests that either estimation of abundance made by managers in certain estates is poor, or that other criteria are used to determine harvest. For example, harvest in some partridge estates may be determined by the willingness of hunters to hunt even if populations are low, so hunting pressure may be greater than expected from wild stock abundance. This may be relevant whenever hunters lease an estate for a short time and they do not intend to renew the lease in subsequent years so the concern about long-term sustainability of hunting in that estate is low or non-existent. This also occurs when land owners or game managers do not establish any regulatory or monitoring framework for hunting pressure for the hunters hiring the hunting rights, as happened on some of the estates in our sample. Overall, underharvesting to guarantee survival of populations, and particularly overharvesting to maximize short-term yield could be happening in a proportion of the estates. Given that overharvesting is particularly dangerous for population sustainability, particular care should be taken to minimize this risk.

Harvest in non-intensive estates was positively related to walked-up shooting pressure, which suggests that estates with more hunters or more frequent hunts may overall hunt more than it should be appropriate for availability (Watson et al. 2007). It has already been suggested that at the national level an increase in the number of hunting licences (and thus hunting pressure) in the 1970s was a main factor leading to the decline in red-legged partridges at that time (Blanco-Aguiar et al. 2003). Similarly, hunting pressure has been found to be negatively associated with European wild rabbit population trends in northeastern Spain (Williams et al. 2007). Managers should look for a balance between the monetary or social benefits of increasing shooting pressure in non-intensive estates, and the effect in partridge population abundance, which also may have negative monetary and social consequences.

Furthermore, in non-intensive estates, supplementing partridges in relatively small numbers (studied range: 12–189 partridges/km^2) had no noticeable effect on harvest. Releases in non-intensive estates may be being used to attract hunters to estates with low density populations, but this management action seems to be inefficient. The high percentage of rapid losses of released partridges when using traditional management (Gortázar et al. 2000) probably prevents any marked increase in availability when releases are performed in small numbers. Release methodologies and wild densities differ in non-intensive estates, which could increase the variability in the relative effect of releases. Considering this general lack of effect on harvest, we were surprised that small-scale releases are frequently and increasingly used in these estates. For example, 38% of non-intensive estates in our study region declared to release partridges (Ríos-Saldaña 2010). This raises the question of the relative benefits and costs of this management technique, and for whom the releases benefit. If releases are used only to maintain hunting activities in estates with low populations of partridges, our results suggest that this action is not cost effective (e.g., Musil 2004) and should be avoided on an economical basis.

Alternatively, they may be carried out to help the recovery of wild populations, but this needs careful management of releases and many failures have been recorded (Leopold 1944, Potts 1986). Releases in non-intensive estates as a tool for population reinforcement should only be allowed if the strategy also includes stopping hunts in the estate until the desired abundance is attained.

Finally, we found a relationship between habitat and harvest, which tended to be greater as the area covered by Mediterranean shrubland in the estate increased. Red-legged partridges tend to use shrubland more frequently during fall and winter (Lucio and Purroy 1987, Lucio 1991), and our results may be reflecting this seasonal pattern of habitat selection. In contrast, increasing percentages of area covered by dehesa, farmland, or woodland negatively affected harvest. Dehesa and farmland are open habitats where partridges may probably escape walking hunters more easily, whereas woodland is a habitat generally avoided by partridges (Blanco-Aguiar et al. 2003).

Our results show that partridge harvest in non-intensive estates with low abundance is mainly related to hunting pressure possibly creating a mismatch between harvest and availability in our study area. Increasing the abundance of wild red-legged partridge through techniques like habitat management (which has been suggested as an effective measure; Casas and Viñuela 2010), and improving the adjustment of harvest to availability like Lucio (1998) already recommended, is advised for partridge managers. Overall, our results lead to the questions of what is the future viability and sustainability of partridge hunting and if we may be depleting our natural capital (Costanza et al. 1997, Daily 1997, Woodworth 2006). Inaccurate or unavailable information about spatial distribution and numbers of released birds, wild contingents, harvest numbers, and the general benefit of this management technique at a large scale does not help to answer these questions. Similarly, not including environmental costs in management may be promoting a lack of environmental efficacy and environmentally expensive management.

MANAGEMENT IMPLICATIONS

The common practice of releasing small numbers of farm-bred partridges had little impact on annual harvest, and thus this practice is not an effective tool to sustain traditional hunting. Together with described negative effects on wild red-legged partridge populations, we predict that their use would have a negative effect on harvests of wild birds, leading to increased dependence on releases. On the other hand, massive releases in small areas are effective at increasing annual harvest, and they have a locally high social and economical effect in the short term. Government and managers need to carefully select where to locate intensive estates, and to create ways to label and segregate the estates where only wild red-legged partridges are managed from those where releases are used. This would allow hunters to use restocking as additional criteria to select their preferred estates (currently, trustworthy guarantee to do so does not exist), and would reduce ecological costs of management decisions. Moreover, we strongly encourage authorities in charge of game preservation and game managers to improve game information recording systems, hunting laws, and management techniques, for the sake of future exploitation of a unique game resource that may be currently globally endangered.

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CHAPTER 3. EFFECT OF GAME MANAGEMENT ON WILD RED-LEGGED PARTRIDGE ABUNDANCE

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[This chapter has not yet been published]

ABSTRACT

1. The reduction of game and fish species has derived increasing investment on management practices. Hunting and fishing managers use several game management tools to maximize harvest. Managers need to know the impact that management of fisheries or hunting estates has on wild populations. This issue is especially interesting to improve both management and biodiversity conservation.

2. We used questionnaires and field bird surveys in 48 hunting estates to assess whether summer red-legged partridge *Alectoris rufa* productivity and abundance were related to the intensity of management tools (provision of supplementary food and water, predator control and releases of farm-bred partridges), harvest intensity and habitat in central Spain. We hypothesized that partridge abundance would be higher where management practices were applied more intensively.

3. Productivity was explained by habitat (Mediterranean scrub and vineyard), year and management practices (density of supplementary food and water points, magpies control and partridges released). Density of feeders and water points had a positive relationship with productivity, while the density of partridges released and magpies controlled were negative.

4. Post-breeding red-legged partridge abundance was related with habitat, year and management variables (all management variables that for productivity), although management variables were more important than habitat in explaining variability in abundance. Harvest intensity was negatively related to partridge abundance, and had a high relative importance. The others management variables had the same type of relationship with abundance as with productivity, except for magpie control that was positive.

5. *Synthesis and applications*. Our study suggests management practices have a stronger effect than habitat in explaining post-breeding abundances, which suggests that its application is beneficial. However, this effect varied among management tools, as some had the desired effect (an increase in partridge abundance), whereas others were not and can be thus considered inefficient, so their use should be reconsidered from both ecological and economical points of view. Management efforts focused on farm-reared partridges releases are encouraged to examine the economic benefits, because they are not contributing to increase wild partridge abundance in hunting estates.

INTRODUCTION

The collapse of commercial fisheries and large-scale population declines of other harvested species are particular cases within current biodiversity crisis, that should be dealt within a common conceptual framework integrating both, ecological and social information (Milner-Gulland et al. 2010, Schluter et al. 2012). Combining sound ecological knowledge of the harvested species, as well as a proper assessment of the effect of human actions to manage stocks is essential to develop an adequate "management technology", that could optimize long-term exploitation of the harvested resource (Guthery 2002b). Otherwise, incorrect management programs may lead to resource depletion or extinction (Bunnefeld et al. 2011).

Hunting is practiced in many regions throughout the world either for recreation or for subsistence, and it also currently has an important economic dimension in many areas, sometimes contributing importantly to rural economies (Bennett and Robinson 2000, Grado et al. 2001). In order to allow sustainable use of game, over-exploitation needs to be avoided. Thus, a critical management tool to maintain maximum sustainable harvest on wild game populations is to adaptively adjust harvest through the monitoring of game populations and the establishment of maximum hunting quotas in relation to their abundance (Hudson 1992, Guthery 2002c). However, technical tools to get robust adaptive decision making are scarcely developed or applied (Bunnefeld et al. 2011), or management programs may not be properly based on sound scientific grounds (Guthery 2002b). In fact, many wild game populations have suffered severe declines in recent decades (e.g. Sauer et al. 2008), mainly through a combination of environmental factors (such as agriculture intensification or climate change) and overexploitation, but also with a possible but little known contribution of incorrect management (Bunnefeld et al. 2011). In fact, current hunting systems have been increasingly altered and sometimes completely replaced by more "artificial" models based on intensive management. Management focused on increasing or maintaining post-breeding game populations is carried out in many areas, particularly when economic interests are strong (Thirgood et al. 2000, Sahlsten et al. 2010, Arroyo et al. 2012). The most common management practices applied in Europe to increase small game populations are predator control, habitat management (increase of the quantity or quality of habitats used by game species), species management (provision of supplementary food or water, or provision of medication to decrease parasites), or population supplementation through the release of captive-reared animals (Arroyo and Beja 2002, Champagnon et al. 2009).

Some of these hunting management practices are controversial, and may lead to conflicts between stakeholder groups. For example, predator control has a strong negative connotation for many non-hunters (Messmer et al. 1999, authors unpublished data) and has been associated in cases to detrimental effects to protected predator populations (Valkama et al. 2005 and references therein), although when legally and properly applied it also may help to population recovery of target and non-target protected species (Fletcher et al. 2010). Similarly, the widespread use of restocking to increase small game bags or recreational fisheries stocks has been criticized among some hunters and managers as well as scientists, because of their negative effects on both wild game or fish stocks (Gortázar et al. 2006, Van Poorten et al. 2011).

On the other hand, these techniques are frequently considered by hunters and hunting managers as necessary to maintain hunting, or at least to maintain economic profitability of this activity, and several studies have shown that game management is usually related to higher abundances of target game species (Borralho et al. 2000, Duckworth et al. 2003, Beja et al. 2009). Additionally, in the current context of accelerated rates of biodiversity loss, improving sustainability of hunting activities is crucial not only to avoid negative environmental impacts, but also to maximize their high potential for ecosystem conservation. Hunting activities may be positive for biodiversity through the maintenance of valuable habitats (Thirgood et al. 2000, Duckworth et al. 2003), which may happen more frequently when economic profit is made from those activities (Sotherton et al. 2009, Arroyo et al. 2012). Assessment of the relative effect of different management tools, both on the target game species and associated wildlife, would help in cost-benefit analyses of different management scenarios to reduce controversies and, ultimately, be able to develop optimal management decisions for game, biodiversity and society at large.

In Spain, the red-legged partridge (*Alectoris rufa* L.) is one of the most important small game species numerically and economically (MARM 2006, Ríos-Saldaña 2010). Its importance as a source of economic activity has even grown in recent decades as part of the general Spanish hunting "boom” (Martínez-Garrido 2009), despite its well recorded, large-scale and deep population decline from the late 1970 (Blanco-Aguiar 2007). Hunting estates have been increasingly managed with costly and specialized techniques (Arroyo et al. 2012). Red-legged partridges are generally more abundant in areas of extensive farmland with high density of edges and a mixture of natural vegetation (Lucio and Purroy 1992, Vargas et al. 2006). Availability of water points influences red-legged partridge distribution (Borralho et al. 1998), but their effect on densities has not been tested, and there exist few studies about the effects of supplementary food provisioning (Millán et al. 2003), a very commonly used tool (Ríos-Saldaña 2010, Arroyo et al. 2012). Predator control, also widely used, is known to be effective to increase game numbers when performed intensively (eg. in UK, Tapper et al. 1996, Fletcher et al. 2010), although no studies have been done specifically in Spain where the network of predators (protected and unprotected) is rich and diverse, and their effect on prey populations scarcely known (Valkama et al. 2005). Finally, negative effects of restocking on wild red-legged partridge populations such as disease spread, changes in population genetic pool or overhunting, have been found (Blanco-Aguiar 2007, Blanco-Aguiar et al. 2008, Villanúa et al. 2008), whereas the effectiveness of small-scale releases to increase hunting yields has been questioned (Díaz-Fernández et al. 2012).

The intense use and demand of red-legged partridge in Spain (González-Redondo 2004), and the large geographical spread in management aimed to raise the harvestable stock (Arroyo et al. 2012), makes it critical to assess the efficacy and consequences of the management activities to discuss the best management options to maximise long-term economic profitability and secure conservation of the game species and hunting activity, while minimising the use of techniques that may be harmful for other species or promoting those favouring ecosystem conservation.

We studied the relationship between post-breeding partridge abundance and the intensity of various management tools currently applied in hunting estates (food and water supplementation, predator control and restocking), whilst also taking into account two other variables that are known to affect game densities (habitat and harvest levels). We hypothesized that partridge abundance would be higher where management practices were applied more intensively, but we were particularly interested in knowing which were more or less effective on increasing abundance, if applied simultaneously. We discuss our results in terms of their application to improve sustainable exploitation and conservation of a socio-economically important game species with declining wild populations, as the red-legged partridge.

MATERIALS AND METHODS

We studied 48 hunting estates located in Central Spain, in latitudes ranging from 37.98N to 40.33N and longitudes from 6.48W to 2.11W, ED 1950 (see Díaz-Fernández et al. 2012, for a Figure). Game management in these estates was mainly aimed to red-legged partridge hunting. The dominant open landscapes of these estates were characterized by different proportions of cultivated land, areas of sparse oak woodland which may be cultivated or grazed underneath (called "*dehesa*"), and natural vegetation (from grassland to woodland). Estate size ranged from 2 to 280 km^2 (mean ± SD = 36.79 ± 54.70; sum of all estates 1765.95 km^2).

We selected privately managed hunting estates, which are the great majority in the region (87%, MARM 2006), either with commercial or non-commercial goals, but excluding intensive estates (those with license to release farm-bred partridges without numerical limits throughout the hunting season), because management in those estates is qualitatively different from that in other types of estates, and harvest there depends directly on the number of partridges released but not on wild red-legged partridge populations (Arroyo et al. 2012, Díaz-Fernández et al. 2012). Studied estates varied largely in the intensity of management performed (as seen in the large standard deviations of means in table 1, see also Arroyo et al. 2012).

Partridge abundance data

We estimated partridge abundance from field observations in each hunting estate, using a point count method (Bibby et al. 1992). Observers drove along transects distributed throughout the whole of the estate or, when they were too big, a representative area of the estate stratifying by habitat. Every 700-750 m (exact point depending on visibility of the surrounding area) observers stopped and on each point, partridge numbers and locations were recorded during 10 minutes, using binoculars. Observations took place on early morning (from sunrise to ca. 3 hours later) and in the evenings (3-4 last hours of the day), avoiding the hottest central hours when partridge activity is lowest. Observations were also suspended in case of rain or too windy conditions. Distances from partridges to observer were estimated using intervals of 50 m. The number of points in each estate was 55.53 ± 69.43 (range: 4-420, depending on estate size).

Table 1. Variables analyzed in this study and observed values in the studied estates (mean ± standard deviation; minimum and maximum values)

Variable	Mean±SD	Min.	Max.
Summer red-legged partridge abundance (partridges/survey point)	1.24±2.30	0.00	14.00
Arable land (%)	34.71±24.22	0.00	93.02
Vineyards (%)	5.26±9.03	0.00	36.77
Tree crops (%)	8.82±13.10	0.00	41.93
Mediterranean scrub (%)	20.47±23.88	0.00	88.84
Dehesa (%)	13.82±27.96	0.00	100.00
Uncultivated grasslands (%)	12.87±15.03	0.00	66.66
Woodland (%)	1.21+4.42	0.00	26.12
Estate scale Shannon index	0.47±0.23	0.00	0.82
Point scale Simpson index	0.69±0.13	0.49	1.00
Feeders (feeders/km^2)	3.57±5.41	0.00	25.00
Big water points (big water points/km^2)	0.88±2.83	0.00	16.52
Small water points (small water points/km^2)	3.63±5.17	0.00	25.00
Foxes controlled (foxes controlled/yr/km^2)	1.46±4.04	0.00	25.13
Magpies controlled (magpies controlled/yr/km^2)	11.54±17.70	0.00	86.21
Partridges released (partridges/km^2)	14.54±33.57	0.00	188.68
Harvest intensity	0.00±19.16	-30.43	61.23

We calculated a summer partridge abundance index (hereafter partridge abundance) as the sum of recorded partridges within a radius of 300 m at each observation point, divided by the number of observation points monitored in each estate. Additionally, we calculated for each estate the ratio of young to adult partridges observed (hereafter productivity), when information about partridge age was available (n = 37 estates, in which the proportion of observations of non-aged partridges was lower than 25%).

Field work was carried out from mid June to early August, during the red-legged partridge chick rearing period (Casas et al. 2009). Specific survey dates of each estate were selected to coincide with the time when most of the cereal had been harvested, in order to maximize visibility, but before farm-bred partridge releases occurred (if they happened at all). In non-intensive estates, releases usually take place as close as possible to the hunting season, i.e., from August to September. From the sample of 48 estates, we excluded from analyses data from 4 of those as we had strong suspicions of possible summer releases not reported in the inquiries (high summer abundance with very low productivity, Fig 1; and contradictory data between spring and summer abundance estimates, authors unpubl. data; see also Díaz-Fernández et al. 2012). Surveys were carried out from June 16th to July 31st in 2006 (n = 25) and from June 16th to August 12th in 2009 (n = 19).

Habitat data

We recorded habitat data during bird surveys as the percentage of each habitat type within a radius of 100 m at each observation point. We considered the following habitat variables, defined with functional and management meaning for red-legged partridge (Buenestado et al. 2008, Casas and Viñuela 2010): arable land (mostly cultivated with winter cereal or left in annual fallow, usually ploughed during summer; secondarily other annual crops), vineyards, tree crops (mainly olive groves, secondarily almond trees, occasionally fig trees), uncultivated grasslands (including old fallow land and uncultivated areas covered by low herbaceous vegetation), Mediterrenean scrubland (mainly medium-height mediterranean scrubs, most often *Cistus* sp., *Halimium* sp., *Retama sphaerocarpa*, *Rosmarinus officinalis*, with a strong component of *Quercus coccifera* and Holm oak *Quercus ilex,* the latter sometimes achieving full tree height), woodland (pine or eucalyptus plantations, secondarily poplars), or *dehesa* (see before). In a few estates there were sparse juniper *Juniper phoeniceus* trees, with either pasture or crops underneath. We lumped this with *dehesa* because of having the same landscape structure. Other reported habitats (riparian vegetation, country houses, etc) occurred only marginally. We also calculated habitat Shannon diversity index for each estate from the mean percentage for every habitat category in the estate, and Simpson diversity index (Simpson 1949) as the average Simpson index calculated for each observation point separately. Simpson index is equivalent to the probability that two randomly selected points correspond to the same habitat (maximum diversity if index is cero, minimum if index is one), and was an indicator of spatial variability in habitat availability.

Management and hunting data

We collected management data through face-to-face questionnaires with game managers. For each estate, we obtained data on estate size, number of feeders (devices with grain or commercial feed to be consumed by partridges, refilled always during spring and summer, sometimes also in winter), number of artificial water points (see below), number of foxes and magpies annually controlled (the two most important predators legally controlled in the area), number of farm-bred partridges annually released and red-legged partridge annual harvest (i.e. number killed in the estate). These data usually corresponded to the hunting season previous to the measure of summer abundances. All variables were expressed per estate surface for analyses.

Artificial water points were of two types: small and large. Small water points, which contain less than 500 l, are water tanks maintaining a constant water level in an external small dish. Large water points are shallow artificial ponds containing more than 500 l of water and covering up more than 100 m^2. We found that the number of small water points and the number of feeders were highly correlated in the estates (Pearson = 0.87, table 2), as they are usually placed together. Thus, one of them retains information for both, and we only used the density of artificial feeders in subsequent analyses.

Table 2. Spearman correlation coefficients among the management variables considered in this work

	Feeders	Big w.	Small w.	Fox.	Magpies control.	Partridges released	Harvest i.
Feeders	1.000	0.162	0.873	0.007	0.622	0.608	0.178
Big water points	0.162	1.000	0.295	0.233	0.080	-0.247	0.042
Small water points	0.873	0.295	1.000	0.138	0.714	0.588	0.076
Foxes controlled	0.007	0.233	0.138	1.000	-0.140	0.039	0.319
Magpies controlled	0.622	0.080	0.714	-0.140	1.000	0.495	0.092
Partridges released	0.608	-0.247	0.588	0.039	0.495	1.000	0.042
Harvest intensity	0.178	0.042	0.076	0.319	0.092	0.042	1.000

We also obtained an estimate of hunting intensity as the residuals of the linear general model with number of partridges harvested as response variable and partridge abundance as explanatory variable. Our values for number of partridges harvested corresponded to the hunting season previous to the field survey. Between-estate variability in harvest was higher than among-year variability for a given estate, and thus our data characterized correctly annual harvest for each estate (Díaz-Fernández et al. 2012).

We lacked data on harvest (and thus hunting intensity) for four of the estates (two of which also lacked information on fox and magpie numbers killed). Two further estates also lacked information on the number of magpies killed. Given that comparisons of AIC between different models are only possible if the same sample is used in all models (Burhnam and Anderson 2002), we also eliminated these data from GLM analyses. We also carried out analyses with the full (n = 44) sample, replacing missing values for average values for the whole sample. Variables included in the selected models were similar with both sets of data, so we present results for the smaller (more conservative and robust) data set.

Statistical analysis

Analyses were carried out with R 2.13 (R Development Core Team 2011).

Factors affecting variation in abundance were analysed using Generalized Linear Models (GLM). We fitted response variables (density or productivity) to a Gaussian distribution. We checked for normality of residuals of the final models. We performed all possible combinations of independent variables with the function dredge (library MuMIn) and selected the models with delta AICc < 2. We present model-averaged parameter estimates for the variables included in those models, as well as their relative weights (Burnham and Anderson 2002). Finally, although we built the set of best models as explained above, we pointed out the variables possibly included as uninformative parameters following Arnold (2010), that is to say, variables appearing as one additional parameter of models with lesser AICc within the group of best models.

We wanted to evaluate which management variables explain summer red-legged partridge abundance while removing the expected effect of habitat quality. Since we could not include all potential habitat and management variables in a single model (due to small sample size), we first tested for habitat, and evaluated which habitat variables (arable land, its quadratic term, vineyard, olive trees, Mediterranean scrub, dehesa, woodland or grassland availability in the estate, as well as Simpson´s and Shannon habitat diversity estimates) best explained variations in abundance. We included the quadratic term of arable land based on prior information about habitat needs for the species (i.e., areas of arable land but mixed with other habitats; Lucio and Purroy 1992, Fortuna 2002, Buenestado et al. 2008, Duarte 2012), so we expected a bell-shaped relationship with this variable. The best models (those with delta AICc < 2) included arable land and its quadratic term, Mediterranean scrub, vineyards and year (see results). These variables were subsequently included in all other analyses, whereas other habitat variables were excluded.

We carried out two sets of tests. An initial exploration of data showed that abundance was positively correlated with productivity (see results). Thus, we tested the effect of management variables, the selected habitat variables, and year on productivity (using a data set of n = 28 estates for which information on both productivity and all management variables existed). Second, we evaluated the effect of management variables, the selected habitat variables and year on abundance (using a data set with n=38 estates for which information on all management variables existed). We assumed that all variables affecting abundance that were not included in the model explaining productivity were variables mostly affecting density of breeders.

In all models, we included the variable "number of count points divided by estate area" as a weight, to control for the potential effect of bird census intensity on the abundance estimate.

RESULTS

Summer red-legged partridge abundance was linearly and positively related to productivity in our sample of hunting estates (n = 33), with productivity explaining 66% of the variance in summer abundance (figure 1).

The best habitat variables explaining variations in partridge abundance were arable land, its quadratic term, and Mediterranean scrub (table 3, fig. 2), although the quadratic term of arable land appeared as one additional parameter of a better model in the ranking (table 3) meaning that it was probably an uninformative parameter to explain partridge summer abundance. Abundance increased with both arable land and Mediterranean scrub. Vineyards were included in the final model, but its parameter estimate included cero (table 4).

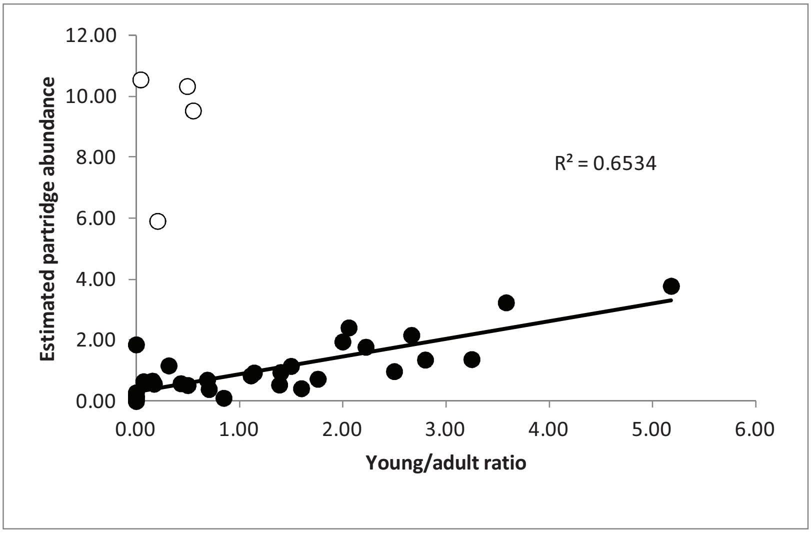

Figure 1: Relationship between summer red-legged partridge abundance (total partridges observed within 300 m / number of count points) and productivity (ratio young/adult). In white, data from the four estates eliminated from analyses (see methods). Also presented is the regression line and r^2 of the relationship for considered estates.

The best models explaining variations in partridge productivity included two habitat variables (Mediterranean scrub and vineyards), year (with higher productivity observed the second than the first study year), and several management variables: the density of feeders, big water points, magpie control intensity and intensity of release of farm-reared birds (table 3). Density of feeders and big water points had a positive relationship with productivity, while the density of partridges released or magpies controlled were negative (table 4). Of all of these variables, feeders, releases and year were the ones with higher relative importance (table 4).

Table 3. GLM models (those models with delta AICc < 2) explaining variation in partridge summer abundance or productivity. K = number of parameters, AICw = Akaike weight, a = arable land, a2 = arable land squared, ms = Mediterranean scrub, vy = vineyards, f = feeders, w = water points, r = releases, hi = harvest intensity, mg = magpie control intensity, yr = year.

	K	AICc	Δ AICc	AICw
Abundance in relation to habitat and year (n=38)				
(null)	2	148.23	0.00	0.257
ms	3	148.75	0.52	0.199
a+ms	4	149.59	1.36	0.130
a2+ms	4	149.90	1.67	0.112
a	3	150.04	1.81	0.104
a+ms+yr	5	150.12	1.89	0.100
vy	3	150.15	1.92	0.098
Productivity in relation to habitat, year and management (n=28)				
f+r	4	96.2	0.00	0.110
yr	3	96.4	0.17	0.102
f+r+yr	5	96.6	0.42	0.089
mg+yr	4	96.9	0.68	0.079
(null)	2	97.0	0.75	0.076
f+r+mg+yr	6	97.0	0.81	0.074
f	3	97.0	0.84	0.073
w+f+ms	5	97.3	1.13	0.063
f+mg+yr	5	97.6	1.42	0.054
f+yr	4	97.8	1.55	0.051
w+f+r	5	97.8	1.58	0.050
r+yr	4	97.9	1.70	0.047
w+f	4	98.0	1.75	0.046
f+r+mg	5	98.0	1.84	0.044
vy	3	98.1	1.92	0.042
Abundance in relation to year, habitat and management (n=38)				
w+f+hi+ms+r+vy	8	119.74	0.00	0.250
w+f+r+ms+r+mg+vy	9	120.10	0.36	0.208
w+f+r+ms+r+mg+vy+a+yr	11	121.21	1.47	0.120
a+w+f+hi+ms+r+vy	9	121.32	1.58	0.113
f+r+ms+r+mg+vy+a+yr	10	121.45	1.71	0.106
a+w+f+hi+ms+vy+yr	9	121.46	1.72	0.105
w+f+hi+ms+vy	7	121.61	1.88	0.098

Table 4. Model-averaged estimates (parameter estimate and standard error) of the direction and magnitude of each effect size, and relative variable importance (RVI) calculated as sum of Akaike weights across all the models in the set where that variable occurred

Variables	Parameter estimates ± SE	RVI
Abundance in relation to habitat and year (n=38)		
Arable	0.014 ± 0.013	0.33
Arable^2	0.017 ± 0.015	0.11
Mediterrenean scrub	0.017 ± 0.011	0.54
Vineyards	-0.023 ± 0.036	0.10
Year (2009)	0.910 ± 0.649	0.10
Productivity in relation to habitat, management and year (n=28)		
Feeders	0.065 ± 0.036	0.65
Water points	0.222 ± 0.160	0.16
Releases	-0.010 ± 0.006	0.41
Magpies controlled	-0.012 ± 0.009	0.25
Year (2009)	-1.131 ± 0.653	0.50
Mediterranean scrub	0.018 ± 0.010	0.06
Vineyards	-0.037 ± 0.033	0.04
Abundance in relation to habitat, management and year (n=38)		
Arable	0.014± 0.008	0.34
Mediterrenean scrub	0.035 ± 0.08	1.00
Vineyards	0.074 ± 0.027	1.00
Year (2009)	0.764 ± 0.446	0.33
Feeders	0.107 ± 0.030	1.00
Water points	0.516 ± 0.075	1.00
Releases	-0.009 ± 0.004	0.80
Magpies controlled	0.012 ± 0.007	0.43
Harvest intensity	-0.024 ± 0.008	1.00

The best models explaining variations in summer partridge abundance included three habitat variables (arable, Mediterranean scrub and vineyards), year, and five management variables: those explaining partridge productivity, and also harvest intensity (table 3). The latter variable was negatively related to partridge abundance, and had a high relative importance (table 4). Feeders, water points and releases had all the same type of relationship with abundance as with productivity, and had also high relative importance (table 4). In contrast, the relationship between magpie control had a positive, not negative relationship with summer abundance, but with a relatively low importance (table 4).

DISCUSSION

Our study suggests management practices and habitat have a strong effect in explaining post-breeding abundances, while productivity was related mainly with management tools and annual variations, which suggests mostly that hunting management application is beneficial. However, this effect varied among management tools and the availability of each type of habitats. Provision of supplementary food and water, Mediterranean scrubs and vineyards positively, and harvest intensity and gamebird releases negatively were most important for abundance. Whereas related with productivity, positively feeders, and negatively year, releases and magpie control were the most important. These results allow building an open decision framework for managers, which could be applied under multiple objectives of economic, biodiversity conservation, recreation or preservation of cultures of rural areas through wild game sustainability.

Habitat-related factors are considered crucial to determine the distribution and density of the populations of most species (Cody 1985). At broader scale, red-legged partridge were more abundant in provinces where arable land was the main land use (Vargas et al. 2006, Blanco-Aguiar 2007). However, at a smaller scale, highest abundances were found in those estates with arable land mixed with Mediterranean scrub, particularly in those with large proportions of both of those habitats (Lucio and Purroy 1992, Fortuna 2002). About other habitat variables, only vineyards entered the models, with contradictory and relative effects on abundance and productivity (table 4). It has been shown that vineyards can be a poor breeding habitat (Casas and Viñuela 2010), but vineyards could also potentially provide critical protective cover during summer after cereal harvesting (authors unpublished data). Additionally, it is possible that some characteristics of farmland management not included here, have important influence on partridge productivity (Gortázar et al. 2002, Villanúa 2007). For example, Casas and Viñuela (2010) found that field edges in agricultural landscapes or the timing of cereal harvest were crucial for successful breeding. Similarly, Vargas et al. (2011) found a high spatial association between broods sizes and field edge density and natural vegetation. Our sample size was not large enough to test for interactions between habitat and other management variables, but it could be envisioned that the effect of food supplementation is larger in those habitats with lower availability of natural food, or that the effect of predator control is only noticeable in degraded farmland habitats, where protective habitat is scarcer (Blanco-Aguiar et al. 2003). Further studies should clarify the role of vineyards and consider the inclusion of other agricultural management variables, which may improve the value of habitat models in explaining variations in partridge abundance.

Previous studies have highlighted the strong influence of climatic conditions on red-legged partridge productivity (Lucio 1990, Villanúa 2007, Casas et al. 2009), mainly through effects in clutch size and chick survival (Lucio 1990, Casas et al. 2009), thus anual variations on productivity seem to be related with weather conditions. Abundance at the end of the breeding period depends on the product of abundance of breeding birds and average productivity. In many galliformes with large brood sizes summer (post-breeding) abundance depends largely on chick production (Cattadori and Hudson 1999, Panek 2005). This appeared to be the case also in our study (fig. 1), since red-legged partridge, where double-nesting may be common (each pair attending two nests, one by the male and one by the female; Casas et al. 2009).

As stated before, we found that densities of feeders and water points have a high importance on summer red-legged partridge abundance and productivity. The provision of food and water has been frequently suggested for gamebirds population improvement (Pépin and Blayac 1990, Guthery 2002a) and is commonly used (Ríos-Saldaña 2010), however its efficacy has been scarcely tested (Gaudioso et al. 2010, but see Borralho et al. 1998). In fact, it has also been suggested that food and water supplementation could be unnecessary or even have negative consequences (Guthery and Koerth 1992, Guthery 2002a), because feeders and water points could enhance disease transmission through higher contact between individuals (Millán et al. 2004, Vicente et al. 2007), and could also enhance attraction of predators and poachers (DeStefano et al. 2000). Our results are thus the first supporting a positive relationship between food supplementation and red-legged partridge abundance and productivity, suggests therefore that food is limiting in our managed areas. In other gamebirds, food supplementation has been found to improve body condition or productivity during the breeding season (Draycott et al. 2002, 2005), although not clutch size or breeding success (Hoodless et al. 1999). Nevertheless, on a metanalysis of studies on bobwhite *Colinus virginianus* showed also contradictory results of the effect of food supplementation, which could be indicative of different natural food availability in the different studies (Guthery 2002a). As stated above, if this was the case we should expect interactions between habitat and the influence of feeder density, which would be interesting to test in future studies. Alternatively, and since the density of feeders was correlated to the density of water points, the effect of feeders could be indicating the beneficial effect of water provision, which is also indicated in the positive effect of provision of water points.

Positive effects of water availability on survival or population dynamics have been found in other Mediterranean galliformes (Degen 1985). Red-legged partridges use water points usually during summer, especially under harsh climatic conditions (Gaudioso et al. 2010), and spatial distribution in summer is influenced by presence of water troughs (Borralho et al. 1998). Water could be especially important for chicks due the high requirements during growth. An alternative explanation to the positive relationship between provision of water troughs and density could thus be that partridges find other important resources around water points, such green vegetation, insects or cover. One way or other, our results support that water supplementation in Mediterranean habitats is a beneficial management tool for red-legged partridges, despite this species being well adapted to scarcity of water.

Partridge summer abundance decreased with increasing numbers of farm-reared partridges released. It may be argued that more partridges are released where summer densities are low, but in any case, what is clear from our results is that releases are not effectively increasing summer abundances. It may also be argued that the main goal of releases is just to increase partridge bags in the short term and not to increase summer abundances, and thus effectiveness may not be measured in terms of summer abundances. However, Díaz-Fernández et al. (2012) showed that releases in low densities are not effective to increase harvest either. Both findings lead to the conclusion that farm-partridge releases in small densities are at best ineffective to increase red-legged partridge hunting bags in the short (annual) or medium term in private hunting estates in Central Spain, as has been previously suggested (Gortázar et al. 2000). Otherwise, other studies suggest that releases are indeed negatively affecting the viability of wild populations, through increasing the likelihood of overhunting of wild populations (Keane et al. 2005), spreading parasites or diseases (Blanco-Aguiar 2007, Villanúa et al. 2008) or through the modification of the gene pool through the presence of breeding hybrids between *A. rufa* and *A. chukar* in wild populations, due to lack of genetic control of released birds (Blanco-Aguiar et al. 2008).

Finally, it was interesting that we did not find an important effect of predator control intensity on partridge abundance, only magpie control have a relative low importance and smaller as compared with other factors (such as food availability). This agrees with the concerns of Arroyo and Beja (2002) about the lack of effect that predator control could have in real-life management situations, contrasted to the effectiveness of very intensive control found in experimental situations (Tapper et al. 1996, Fletcher et al. 2010). An alternative explanation is that predator control effectiveness interacts with other variables, such as habitat type. One of the limitations of our study (which, in any case, reflects also the limitations of the managers themselves) is that we did not evaluate predator abundance, and hence it is not possible to evaluate the effectiveness of predator control on reducing predator abundance in each of the studied estates, which may explain the observed results. Similarly, Villanúa (2007) did not find a relationship between predator abundance (red fox) and predation frequency or an effect on summer partridge abundance. On the other hand, we found positive relationships between the intensity of fox control and the abundance of another farmland bird, the Little Bustard *Tetrax tetrax* (authors, companion paper), which suggests that our measured variable has indeed a biological meaning (i.e., that higher levels of predator control are indeed associated to lower predator numbers). Considering the widespread use of predator control in Central Spain (85.2 % of small game estates in Castilla-La Mancha, Ríos-Saldaña 2010), its low effectiveness for partridges and its possible negative effects for protected predators (Valkama et al. 2005 and references therein), a cost-benefit evaluation may help to optimize hunting management benefits in relation to this management tool. Further studies should concentrate in these important issues.

MANAGEMENT IMPLICATIONS

Overall, our results support previous work by Borralho et al. (2000), who found a marked effect of game management on partridge abundance, although in that case they did not differentiate among management techniques. Although the effect was much less important than other management techniques, our results also indicated that hunting intensity may have an effect on summer partridge abundance. The relationship between hunting intensity and abundance was negative: in other words, overhunting is associated with lower densities, which is not surprising. At a larger scale, an increase in hunting pressure has also been found to have a significant effect on the population decline observed in Spain since 1970 (Blanco-Aguiar 2007). This also suggests that a careful adjustment between take and abundance is critical for population sustainability in this game species.

Globally, our results indicate that the best strategy to reinforce wild red-legged partridge populations would be to concentrate in improving food and water availability, either directly through providing supplementary food and water (as currently done) or indirectly through improving habitat quality, what could be expected to be a more efficient, stable and profitable long-term strategy (Guthery 2002b, Casas and Viñuela 2010, Duarte 2012). In that sense, measures such as maintaining the right percentage of scrub habitats or keeping a proper density of field edges and other cover within the agrarian landscapes, would be also a basic measure to increase wild summer red-legged partridge abundances, and thus, the availability of this singular renewable resource. On the other hand, our results reinforce that investing in re-stocking with farm-bred partridges in small amounts while hunting is occurring in the estates, is inefficient, and should be limited in most circumstances. Thus, the "management panacea" of releasing farm-bred birds does not seem to be efficient or secure enough to justify its expanding use as a replacement of *in situ* wildlife management, as has been suggested for recreational fisheries too (Van Poorten et al. 2011).

More generally, our results indicate that some game management practices are more efficient than others, and that their joint application may not thus lead to additive results. In the case of those tools including some controversial ones (such as releases or predator control) studies identifying the relative importance of individual management tools may help in evaluating the relative economic and conservation value of different managerial scenarios.

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CHAPTER 4. ECONOMIC CONSEQUENCES OF RED-LEGGED PARTRIDGE RESTOCKING IN SPANISH PRIVATE HUNTING ESTATES

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ABSTRACT

Management of red-legged partridge hunting in Spanish commercial estates increasingly integrates annual restocking of farm-reared partridges, whose economic yield is not clear. Worrying medium-term effects on wild partridge populations have been proved, whereas efficacy of releases to improve harvest is restricted to massive restocking. To study economic consequences of restocking at the level of management decision, the hunting estate, we gathered information on management in 59 partridge estates through face-to-face interviews with hunting managers. We defined the main generic expenses and revenues of red-legged partridge hunting, and took stock of 9 commercial estates with different release intensity. We found greater revenues, profitability and expenses in intensive estates (massive releases) than in others, but also lesser expenses per partridge hunted. Their great production, much over the limits of wild populations, was a key for their competitiveness. The real options of deferring investments and expanding the offer

that restocking gives to hunting estates are another advantage of releases, and may be a possible explanation of the widespread motivation to restock in hunting estates, although in non-intensive estates the inefficacy of restocking to increase partridge availability compensates the possible financial advantages from real options. We found 4 cases where commercial partridge hunting was not profitable (occurring in estates where hunting is a complementary activity), and 3 of them released annually farm-reared partridges. Red-legged partridge hunting in our study estates without releases was profitable, but not competitive with intensive estates within the same market and prices. Possibly there is margin to optimize management costs in estates that manage only wild partridges. Moreover, if releases had a social cost (which should be evaluated) and we wanted to reduce it, mechanisms as internalization of costs, such as market or fiscal differentiation through quality or eco-labels, would be necessary to encourage managers to implement sustainable wild red-legged partridge hunting.

INTRODUCTION

The red-legged partridge (*Alectoris rufa*) is a game bird mainly distributed around Southwestern Europe, with most of its worldwide population within Spain, where the highest densities are found in its central and southern part (Blanco-Aguiar et al. 2003). Hunting is allowed in approximately 75% of Spain, and more than 90% of the hunting area is organised in private hunting estates (MARM 2006), where private persons own the hunting rights, make decisions on hunting management, and are legally responsible of this management (Gálvez 2006). Red-legged partridges are usually hunted in those estates in which they are considered abundant enough (e.g., 96.5% of hunting estates in Castilla La Mancha, central Spain, declare to hunt red-legged partridge; Ríos-Saldaña 2010). In a high (but not precisely known) proportion of estates, these red-legged partridge hunts are commercialized; in these cases, red-legged partridge hunting may be the only economic activity in the estate or, more generally, this is shared with hunts of other species or with other land uses like agriculture, livestock or forestry (Bernabéu 2002, Arroyo et al. 2012).

Thus, a significant proportion of Spain (and thus of the world red-legged partridge population) is privately managed to offer partridge hunts for commercial purposes.

One management practice currently used in many Spanish private hunting estates is the annual release of farm-reared partridges. The amount of partridges released annually in the country is not precisely known, but estimations range between 3 and 6 million (Delibes 1992, Garrido 2002, González-Redondo et al. 2010, Martínez et al. 2002, Pérez y Pérez 1992). Releases are performed in both commercial and non-commercial estates, although more intensively and frequently in the former (Arroyo et al. 2012). However, there is also a broad range of densities of partridges released in commercial hunting estates, from none to thousands of birds per square kilometre (the latter in legally labelled "intensive" estates, allowed to release unlimited number of birds through all the hunting season, which are less than 3 percent in Castilla La Mancha, central Spain; Ríos-Saldaña 2010).

The use of releases in hunting was set in the historical context of the mid twentieth century. After the civil war, with Spain in a delicate economic situation, the Government set up price controls over different basic products like cereal, and encouraged initiatives addressed to fight against population hunger. This created incentives to look for new ways to generate legal income from the land, different to meat or cereal production destined to the black market (Biescas 1989). In the late 1940s and 1950s, these events triggered the attention toward hunting. The national and foreign demand of red-legged partridge hunting increased and this, together with the intensification of agriculture, lead to a decline in wild red-legged partridge populations, numbers of which probably fell to a minimum about the 1970s and 1980s. To halt these declines and cover the demand at the same time, Spanish governmental programs started in the 1960s aimed at increasing partridge productivity through rudimentary artificial incubation facilities, using eggs taken from wild birds (González-Redondo 2004). These governmental programs were quickly followed by private promotion of red-legged partridge industrial production for releasing in hunting estates. Number of farms and farm-reared partridges produced increased exponentially achieving the greatest increase during the 90s and arriving to the current situation of millions released yearly (Blanco-Aguiar et al. 2008, González-Redondo et al. 2010).

The release of millions of farm-reared animals into the wild implies some problems for the survival of wild stocks. From a biological point of view, when the release of farm-reared animals is general, continuous and intense in relation to wild densities, this may reduce local evolutive adaptations and general genetic variability (Olsen et al. 2004). They both are the pillars in which the medium-term success of a wild species is based (Darwin 1859), in which the success of biodiversity preservation is based (Olsen et al. 2004), and by extension, in which the human use of ecosystems should be based (Millennium Ecosystem Assessment 2005, Carpenter et al. 2009). Shorter-term effects of annual restocking with farm partridges, like disease spread, anthropogenic hybridization, reduction in fitness, or overhunting have been documented (Blanco-Aguiar et al. 2008, Sokos et al. 2008, Villanúa et al. 2008, Barbanera et al. 2010, Casas et al. 2012).

However, medium- or long-term problems for both the species and its hunting due to the use of releases are not apparent within a hunting season for an individual estate, and it is currently not mandatory to internalize (sensu Hennart 1986) the costs of the ecological risks of this practice. Moreover, it is known that the release of thousands of birds (as in intensive estates) is effective to increase annual harvest within the hunting season in which partridges are released much over what would be possible from wild stocks (Díaz-Fernández et al. 2012). From a market analysis conducted in 1997, reducing the uncertainty in bag size was suggested as a need for hunting to be competitive as an economic activity (Bernabéu 2002), which could be also influencing the use of releases for commercial hunting. However, intensive estates are also related to a much more intense application of other hunting management practices (Arroyo et al. 2012), which may reduce the potential profitability of restocking against the use of wild stocks. Effort in other management practices (like food and water supplementation or predator control) in commercial estates where low numbers of partridges are released annually is also higher than in those where no releases were made, but it is known that releases in low numbers are not generally effective to increase harvest (Díaz-Fernández et al. 2012). Thus, short-term economic consequences of using releases in a hunting estate are not clear.

A detailed analysis on the economic consequences of management, and more specifically on the use of releases versus the sole use of wild stocks of red-legged partridges at the level of decision making, the hunting estate, is currently lacking. Thus, it is not clearly known which economic parameters releases are affecting if any. Here, we qualitatively and quantitatively defined the revenues and expenses of red-legged partridge hunting in a hypothetic generic estate, and then analyzed economic parameters within the hunting season using real data coming from some hunting estates with different release intensity. Specifically, we analyzed total revenues, total expenses, profitability, expenses per partridge hunted, and revenues per partridge hunted. This provides tools to understand the key economic traits that decision makers are currently taking into account to manage red-legged partridge hunting in commercial hunting estates, and to analyze economic results of different management or economic scenarios. We present real economic results related to specific amounts of partridges released, not to be generalized for all estates, but to exemplify possibilities that reject some common assertions. Finally, we discuss results in terms of understanding current management trends. We suggest some ideas to prevent a reduction in private and social benefits from wild-stock hunting, and encourage others to feed the tools we give here with data from other estates to broaden and strengthen our results.

MATERIAL AND METHODS

Generic Revenues and Expenses in Red-legged Partridge Hunting Estates

There is no public database where revenues, expenses, general outcomes or detailed and accrual information on the whole management in hunting estates was detailed. This information is necessary to define every single item, that is to say every single revenue or expense that has to be calculated to take stock of a hunting estate. Thus, to know the most common items and their generic functions to take stock of red-legged partridge hunting in commercial estates we used 'face-to-face' in-depth interviews with game managers after arranging appointments by phone. We interviewed a sample of 59 managers of different small game hunting estates, in which red-legged partridge hunting is important in relation to other species hunted. We inquired exhaustively for qualitative and quantitative data on management for a specific hunting season in each estate and less intensively for prices, costs and incomes, as a reference for calculations. Although full quantitative information of specific items was not given for every estate, qualitative information was obtained for most of them. Interviews were conducted in 2005, 2008 and 2009 (more information on this survey in Arroyo et al. 2012).

To define the main items necessary to take stock of a generic hunting estate with enough detail to detect large economic differences among estates with different management, we selected those items that appeared in any one of the interviewed estates and excluded from them those that managers considered negligible in relation to the total revenues or expenses in their hunting estates, and that were very difficult to be estimated with enough precision to accomplish our goal. However, these secondary items were also recorded and enumerated in results.

In each estate there may be agriculture, livestock, forestry or some big game hunting in addition to small game hunting. These activities were considered independent from small game hunting in the estate, because their revenues and expenses are easily separable. In fact, land owners can be (and frequently are) different from hunting managers, who frequently lease the hunting rights of the land to administratively create the hunting estate and thus, be able to hunt (Bernabéu 2002, Gálvez 2006). Although all the other land uses occur in the territory and may affect small game through externalities, we did not consider those externalities here. Hospitality industry related to red-legged partridge hunting that exist in some estates was also considered independent and not taken into account in this work.

In relation to small game, red-legged partridge may be the only species hunted in the estate or be hunted together with others. In the latter case, when some management practice is directed jointly to different species, the corresponding item (revenue or expense) was attributed to the partridge hunting proportionally to the income received from red-legged partridge in relation to the total income from all the species for which the specific management practice is aimed. When the price paid for hunting includes the hunting of different species, the incomes attributed to each species was considered proportional to the number of animals hunted per species.

In general, there are two different ways to sell hunts in Spain (Bernabéu 2002), which we included in our calculations: i) selling the hunting rights for the estate for the whole hunting season to the same group of hunters; in this case, the revenue from hunting is a unique payment at the beginning of the season, independent of the number of the animals shot; ii) selling independent hunting days; in this case, the hunting revenue of the estate is the sum of all the payments made in different moments throughout the hunting season. When selling individual hunts, the price for one is composed by a fixed fraction (for the right to hunt a minimum number of birds) and a variable one (that may include a price per additional partridge hunted); both the fixed and variable fractions may be null. Moreover, partridges hunted may stay in the estate and be subsequently sold as meat, which represents additional revenue of hunting; this is usually paid per partridge.

Methods typically used for shooting partridges in central Spain include the following (Buenestado et al. 2009, Arroyo et al. 2012): 1) driven shooting, where assistants beat the land to flush partridges and drive them towards a strategically arranged line of hunters; 2) walked-up shooting, where hunters (with or without dogs) shoot the birds as they encounter them; 3) decoy shooting, where a male partridge decoy is placed in a territory to attract wild partridges. In driven and decoy shooting only red-legged partridges are hunted, whereas a walked-up shooting hunt may or may not include the possibility of hunting rabbits and/or hares together with red-legged partridges. Other small game species commonly hunted in the same estates than partridges, such as pigeon, doves, quails or thrushes, are not usually hunted during red-legged partridge hunts, in some case because methods or legal dates to hunt these other species differ or they are not common in winter. In any case, in our studied estates, these species had very low importance in the overall game bags.

From the information above we defined the formulas to calculate the main items of red-legged partridge hunting in individual estates. Items calculated proportionally to the income from red-legged partridge hunting in relation to the total income from all small game hunting in the estate were reparation and maintenance of vehicles, vehicle insurance, purchase of vehicles, civil responsibility insurance, and the payment for renting the hunting rights or the opportunity cost of it in case of own property. Items proportional to the income from red-legged partridge hunting in relation to the total income from hare, rabbit and red-legged partridge hunting were the expenses of labor, and the purchase of tools for predator control. Revenues of walked-up shooting hunts sold as individual hunting days were attributed to partridges proportionally to the number of partridges hunted in relation to the total number of animals hunted, and revenues of partridge hunting when hunting in the estate was sold jointly for the whole season were calculated also proportionally to the number of partridges hunted in relation to the number of all animals hunted in the estate. Incomes from driven shooting, from hunting with decoy, or from selling partridges as meat were attributed exclusively to red-legged partridge hunting. Finally, taxes for the town ("Gastos suntuarios") and for the region ("Matrícula") are proportional to the number of animals shot in the estate (Ministerio de Economía y Hacienda 1984), and we directly calculated the proportion corresponding to the number of partridges hunted.

Parameters

For analysis, we used the following 5 parameters related to different perspectives of decision making on the use of releases. (1) Total revenues, equal to the sum of revenues minus the sum of expenses, divided by the estate area. (2) Total expenses, equal to the sum of expenses divided by the estate area. (3) Profitability, equal to the total revenues divided by the total expenses. (4) Expenses per partridge hunted, equal to the sum of expenses divided by the sum of partridges hunted. (5) Revenues per partridge hunted, equal to the sum of revenues divided by the sum of partridges hunted.

Taking Stock of 9 Hunting Estates

We can distinguish three generic changes that annual restocking may imply in the economy of the estates: (1) Direct expenses of purchase of farm-reared partridges delivered in the estate to be released. This is the only item exclusively present in estates that use releases, and can be easily calculated. (2) A possible change in revenues that the releases may produce because of the number of sold products, the timing of the releases, or the different market price of hunts depending on the origin of partridges (farm/wild). Although the large amounts of partridges released in intensive estates lead to high number of partridges hunted, the release of low numbers of partridges does not have a clear effect in increasing annual harvest (Díaz-Fernández et al. 2012), and even is apparently negatively related to availability of wild stock (Díaz-Fernández et al. 2011). Market prices of hunting farm-reared partridges instead of wild ones are also apparently similar at least in a segment of the hunting market (authors, unpublished data). Thus, specific functions relating releases and income that may be useful to our analysis are not described in the literature. (3) Possible changes in other expenses or revenues due to changes in management related to the use of releases. Although intensive hunting estates were associated to a higher intensity in the application of all other management practices, high variability among other estates in the application of each management practice exists, being impossible to give a pattern of management in relation to the amount of partridges released with the available information (Arroyo et al. 2012). In consequence, we used the generic functions defined by us to take stock of some hunting estates, and to get conclusions on their economic results.

We selected from our interviewed sample 9 commercial estates for which we had enough data to take stock of them. They were 3 intensive estates, 3 non-intensive estates with releases, and 3 non-intensive estates without releases. Apart from management practices, we recorded the percentage of land of the hunting estate that belonged to the hunting managers, which small game species were hunted, and the way hunting was sold (seasonally, or as independent hunts) (table 1).

Values for variables arising from management decisions were used as recorded in each interview. These variables referred to the number of animals hunted, the number of partridges released, number of partridges sold as meat, number of hunters taking part in a hunting day times the number of hunting days sold in the season, the amount of times that food-supplementation devices were refilled, number of vehicles in the estate, area cultivated exclusively for game, number of gamekeepers, number of day´s wages paid to supplementary staff, number of cage-traps or supplementation devices, and area of the hunting estate.

Values of prices, average amortization periods of different materials, rate of interest, and characteristics of materials, were considered equal for all the estates (table 2). For prices, we used the average value recorded in these 9 interviews, except for the price of fodder and wheat, for which we phoned the main providers in the region and estimated an averaged value for the studied hunting seasons. Moreover, in addition to the average price paid per partridge in driven shooting hunting, as this price was quite variable among interviews and affect importantly the economic results, we took stock for two other options: the minimum and the maximum price recorded in the interviews. Similarly, in addition to the average price of hunting in the estate when all hunts were sold jointly for the whole season, we took stock for the minimum and the maximum price recorded in the interviews. Only 2 out of 5 estates that sold hunting as individual hunting days sold walked-up shooting and decoy hunts, being the harvest less than 7% of total partridge harvest in these estates. In consequence, a variation in price would no affect or contribute importantly to results, and thus we used only the average price recorded for these hunts in these 2 estates. For other variables, we used widespread values looking at the market. Summarizing, we calculated 5 price scenarios to take stock for the nine hunting estates (specific values for all scenarios in table 2).

Table 1. Descriptive information of the nine hunting estates studied in this work, with the first column showing the identifier number used in this work for each studied estate.

ID	% Land owned by the hunting manager	Intensity of releases	Number partridges releases per km^2	Number of partridges hunted per km^2	Area (km^2)	Small game species hunted	Way of selling hunts	Season
1	0	Intensive	6000.0	3293.3	30.0	Partridge, dove	Individ. hunting days	07-08
2	0	Intensive	750.0	575.0	60.0	Partridge	Individ. hunting days	08-09
3	100	Intensive	500.0	375.0	40.0	Partridge, dove	Individ. hunting days	07-08
4	100	With some releases	62.5	37.5	8.0	Partridge, rabbit, hare	Huntin g season	04-05
5	100	With some releases	25.8	25.8	7.8	Partridge, rabbit, hare	Huntin g season	04-05
6	100	With some releases	25.0	37.5	4.0	Partridge, rabbit, hare	Huntin g season	04-05
7	100	Without releases	0.0	19.9	4.9	Partridge, rabbit, hare, dove	Huntin g season	04-05
8	100	Without releases	0.0	123.0	12.2	Partridge, rabbit, dove	Individ. hunting days	08-09
9	0	Without releases	0.0	84.6	66.1	Partridge, hare, dove	Individ. hunting days	08-09

RESULTS

Incomes and Outcomes in a Generic Red-legged Partridge Hunting Estate

We found 17 expense and 5 revenue main items (table 2) currently attributable to red-legged partridge management in hunting estates. These referred to releases, supplementation of water and food, predator control, staff, land price and taxes. In average, the greatest proportion of expenses in our 9 studied hunting estates were those of labour (gamekeepers = 22.5±10.7%, supplementary staff for hunting days = 7.9±7.7%, other supplementary staff = 0.4±1.2%, table 2). The proportion of expenses on purchase of farm-reared partridges delivered in the estate to be released was, in average, also big, but it was obviously very variable among estates (20.9±23.9%, table 2). Expenses on the hunting rights (13.6±8.6%, table 2) or expenses on the purchase of wheat delivered in the estate for food-supplementation devices (13.4±9.3%, table 2) were lesser but also important in relation to the rest of items. Other expenses were in average lesser in relation to total expenses, and always lesser (and usually much more) than 25% of expenses (table 2). In particular, taxes (for the region and the town) implied in our sample an average 3.9±2.7% of the total expenses in the estate. We included general functions defined in this work to calculate each main item in annex A. Items recorded as secondary (as explained in methods) and not included in the calculations to take stock of the estates were expenses on medicaments (generally to prevent *Escherichia coli* or taenias), water used in water-supplementation devices, clothes for gamekeepers, charge of firearms and other equipment provided for hunters, office material, and manager salary.

Table 2. Main items of revenues and expenses of red-legged partridge hunting, and average percentage over total expenses that each expense implies in the 9 studied hunting estates studied (expressed as average percentage ± standard deviation).

ITEM CODE	MAIN ITEMS	AV±SD
	EXPENSES OF MATERIALS	
1_1	Purchase of farm-reared partridges delivered in the estate to be released	20.9±23.9
1_2	Purchase of fodder delivered in the estate for food-supplementation devices	1.5±4.5
1_3	Purchase of wheat delivered in the estate for food-supplementation devices	13.4±8.7
1_4	Maintenance of vehicles	2.6±2.3
1_5	Vehicles insurance and traffic taxes	1.0±0.8
1_6	Cultures for game	6.6±14.8
	EXPENSES OF LABOUR	
2_1	Gamekeepers	22.5±10.7
2_2	Supplementary staff for hunting days	7.9±7.7
2_3	Other supplementary staff	0.4±1.2
	EXPENSES OF AMORTIZATIONS	
3_1	Purchase of vehicles	2.9±2.1
3_2	Purchase of tools for predator control	0.1±0.1
3_3	Purchase food-supplementation devices	1.5±1.0
3_4	Purchase of water-supplementation devices	0.8±0.7
	EXPENSES OF TAXES	
4_1	Tax for the town ("Gastos suntuarios")	2.2±1.5
4_2	Tax for the region ("Matrícula")	1.7±1.1
4_3	Civil responsibility insurance	0.6±0.4
4_4	Rent for the hunting rights or opportunity expenses of them in case of own property	13.6±8.6
	REVENUES	
5_1	Driven shooting hunts, sold as individual hunting days	
5_2	Red-legged partridge hunting through walked-up shooting, sold as individual walked-up shooting hunting days	
5_3	Hunts with decoy, sold as individual hunting days	
5_4	Red-legged partridge hunting, sold for the whole season	
5_5	Red-legged partridges sold as meat	

Table 3. Values for variables to take stock of the 9 hunting estates studied. In the first column, we showed the abbreviation of each variable to be identified in annex A and a short definition. For the first two variables, prices used differed according to different scenarios.

	SCENERIES OF PRICES				
VARIABLES	1	2	3	4	5
Ph- Price per partridge hunted in driven shooting	20	37.8	50.0	37.8	
U- Price per hunting season	3264.0			3000.0	3465.0
I- Annual interest rate	3.00				
E- Feeder volume refilled (l)	30				
f- Weight (kg)/Volume (l) of wheat	0.80				
G- Weight (kg)/Volume (l) of fodder	0.60				
PA- Price per farm-reared partridge to be released	7.3				
PB- Price per kg of fodder	0.35				
PC- Price per kg of wheat	0.35				
Pt- Price per partridge hunted with decoy	35.0				
Po- Price per partridge sold as meat	2.4				
PD- Expense in maintenance of a vehicle	1719.0				
PE- Expense in insurance and traffic taxes of a vehicle	608.8				
PF- Expense per hectare in cultures for game	270.0				
PG- Gamekeeper´s salary	22452.2				
PH- Day´s wage and person for supplementary staff in hunts	50.0				
PJ- Price of a vehicle	24290.0				
hJ- Amortization period for vehicles (years)	10				
hK2- Amortization period for cage-traps for back-billed magpies control (year)	15				
PK1- Price of a cage-trap for black-billed magpies	129.0				
PL- Price of a food-supplementation device	66.1				
hL- Amortization period of a food-supplementation device	10				
PM- Price of a water supplementation device	42.5				
hM- Amortization period of a water-supplementation device (years)	10				
PP- Price for the hunting rights	871.0				

Economic Parameters calculated for 9 Hunting Estates

Total revenues.– Revenues of the 3 intensive estates, in scenarios of average or high prices per partridge hunted (scenarios 2 and 3, respectively, in table 3), were positive and one or two orders of magnitude higher than any positive revenues obtained in the other 6 estates (table 4). In the case of average price (*Ph* = 37.8 €/partridge, scenario 2), benefits obtained in these intensive estates were 67123, 9086 and 5264 €/km^2 for 6000, 750 and 500 partridges released / km^2, respectively. On the other hand, only one non-intensive estate obtained positive revenues (512 €/km^2) in scenario 2, and only two (309 and 1567 €/km^2) in scenario 3, these being estates that do not restock at all (table 2). When we considered the lowest recorded price per partridge hunted (20 €), only one intensive estate obtained positive revenues (8952 €/km^2), whereas estimated losses for the other two intensive estates were the second (-1553 €/km^2) and fourth (-306 €/km^2) greatest losses among the 5 estates that sold individual hunts (table 4). All the estates that sold hunting jointly for the whole season, either with or without releases, obtained negative revenues from red-legged partridge hunting in all the scenarios considered (table 4).

Profitability.– In all scenarios, profitability was greater for the three intensive estates, where the values ranged between 1.61 and -0.17, than in the three non-intensive estates with releases (range -0.38, -0.65) or those without releases (range 0.55, -0.55, table 4). For the estates that sold individual hunting days, the variation of profitability between the scenarios for highest and lowest price per partridge hunted (scenarios 1 and 3) was greater for intensive estates (range 1.12, 1.47) than for non-intensive estates (range 0.60, 0.91, table 4). For the estates that sold hunting through an annual payment, the variation of profitability between the scenarios with the highest and the lowest annual price scenarios 4 and 5 was much lower and less variable among estates (range 0.05, 0.11, table 4). Just as orientation, we calculated the prices that would give profitability cero in our 9 studied estates, without changing any other characteristic: the 3 intensive estates would get profitability cero with a price per partridge equal to 18 €/partridge, 22 €/partridge and 24 €/partridge; the 3 non-intensive estates without releases that sell independent hunts would get profitability cero with a price per partridge equal to 32 €/partridge and 48 €/partridge; within the 4 non-intensive estates that sell hunting jointly for the whole season, the one that do not release farm-reared partridges would get profitability cero with a price of 4400 €/km^2, and the 3 estates that restocks with a price of 5600 €/km^2, 6100 €/km^2 and 8550 €/km^2.

Total expenses.– Total expenses were higher in the three intensive estates (range 9298 - 66273 €/partridge) than in non-intensive estates (range 1785 - 6270 €/km^2, table 4).

Expenses per partridge hunted.– The lowest expenses per partridge hunted were also found in the three intensive estates (24.80 - 20.10 €/partridge), while in the other estates values ranged from 33.70 €/partridge (in one estate without releases) to 106.56 €/partridge (in a non-intensive estate with releases) (table 4).

Revenues per partridge hunted.– In the three intensive studied estates, revenues per partridge hunted varied greatly depending on the price scenario, ranging from 32.5 with the highest price per partridge to -4.1 with the lowest price (table 4). In the three hunting estates without releases, values ranged from 18.5 to -23.1 (table 4). Finally, in the non-intensive estates with releases, the ratio was always negative, ranging from -19.5 to -69.2 (table 4). For the estates that sold individual hunting days, the variation of the ratio between scenarios with greatest and lowest price per partridge hunted ranged for intensive estates between 27.5 and 30.6, and for non-intensive estates it was 30.6. Lastly, for the estates that sold hunting through an annual payment, the variation of the ratio was between 4.2 and 9.4 (table 4).

DISCUSSION

Our results indicated that the main expenses of game management in red-legged partridge hunting estates were related to the management practices that usually are pointed out as most common in this kind of estates (releases, supplementation of water and food, and predator control; Ríos-Saldaña 2010), while expenses on hunting rights, taxes, and civil responsibility insurance, which are not directly

Table 4. Total expenses (E) in euros per square kilometre, expenses per partridge hunted (E / p) in euros, total revenues (R) in euros per square kilometre, profitability (P) and revenues per partridge hunted (R / p) in euros, for each studied estate (see table 2 for a description of their characteristics) and for each considered price scenario (SC., see table 3 for values).

SC.	ESTATE								
	1*‡	2*‡	3*‡	4†	5†	6†	7†	8‡	9‡
E									
All	-66273	-14098	-9298	-1920	-1667	-3996	-1785	-6270	-2866
E / p									
All	-20.1	-24.6	-24.8	-51.2	-64.6	-106.6	-89.6	-51.0	-33.7
R									
1	6597	-1460	-1553	-802	-773	-2472	-459	-3458	-1026
2	64767	7932	5264	-802	-773	-2472	-459	-1223	512
3	104637	14370	9936	-802	-773	-2472	-459	309	1567
4	64767	7932	5264	-892	-845	-2595	-567	-1223	512
5	64767	7932	5264	-731	-717	-2378	-378	-1223	512
P									
1	0,10	-0,10	-0,17	-0,42	-0,46	-0,62	-0,26	-0,55	-0,36
2	0,98	0,56	0,57	-0,42	-0,46	-0,62	-0,26	-0,20	0,18
3	1,58	1.02	1,07	-0,42	-0,46	-0,62	-0,26	0,05	0,55
4	0,98	0,56	0,57	-0,46	-0,51	-0,65	-0,32	-0,20	0,18
5	0,98	0,33	0,57	-0,38	-0,43	-0,60	-0,21	-0,20	0,18
R / p									
1	2.0	-2.5	-4.1	-21.3	-29.9	-65.9	-23.1	-28.1	-12.1
2	19.7	13.8	14.0	-21.3	-29.9	-65.9	-23.1	-10.0	6.1
3	31.8	25.0	26.5	-21.3	-29.9	-65.9	-23.1	2.5	18.5
4	19.7	13.8	14.0	-23.7	-32.7	-69.2	-28.4	-10.0	6.1
5	19.7	13.8	14.0	-19.5	-27.8	-63.4	-19.0	-10.0	6.1

*Intensive estates; ‡estates that sold hunting as individual hunting days; †estates that sold hunting as an annual payment.

related to specific management practices but globally with the exercise of this activity, were also detected as important expenses. We found other expenses mentioned in previous studies (Moreno de Arteaga 1983, Metra-Seis 1985, Bernabéu 2002) economically negligible, at least in our sample of estates.

In relation to the beneficiaries of red-legged partridge hunting, hunting estate expenses related to this activity created some indirect beneficiaries that, according to our results, were mainly the local labour force, the farm-reared partridge industry, the land owners, and the wheat sellers. The greatest proportion of estate expenses corresponded, on average, to labour, as in most of other traditional economic activities (Navarro-Arancegui 2008). However, in the case of intensive estates, the proportion of expenses corresponding to purchase of farm-reared partridges to be released surpassed, indeed, labour expenses. Expenses that go into the government as direct taxes per red-legged partridge hunting were in our sample an average of 4% of hunting estate expenses. In 1996, these taxes implied 2 million euros in Castilla La Mancha for all kind of small game hunting, and took up 46.9% of the income that government obtained directly from hunting (Bernabéu 2002). Bernabéu also found that the percentage of the hunting system incomes (money spent by buyers of game meat and hunters) that entered into hunting estates was only 57.4%. The rest of incomes had different destinies (e.g. legal licences, arms or hospitality), and thus other indirect beneficiaries unrelated to hunting estate expenses exist.

For our sample of 9 exhaustively studied estates, the 3 intensive estates that released annually thousands of partridges obtained greater profits and greater revenues per km^2 and per partridge hunted than others. In spite of their greater annual expenses per km^2 in operational, staff and capital costs, the elasticity of their offer to cover hunting market demands compensated the expenses, once the break even was achieved. The lesser expenses per partridge hunted that these kind of estates got, due to the much lesser attribution of fixed expenses to each product unit (partridge hunted), helped. The fact that, if harvest is extremely high, thousands of birds released implied greater expenses but also greater profitability, coincides with

Sotherton et al. (2009) for red grouse hunting, who concluded that reducing harvest would reduce total expenses less than proportionally, implying also a reduction of the estates profitability. As long as this lack of limitation in the offer of partridges to be hunted is the base of the greater commercial margin of intensive estates (a limitation that exists in estates that manage wild partridge populations, because they have a cap of turnover linked to the partridge population of the area), commercial hunting of wild partridge populations can not compete in price per partridge, profitability or revenues, *ceteris paribus*, with partridge hunting in intensive estates at scenarios of great demand. In scenarios with low price per partridge, losses were comparable between intensive estates that released a moderate number of partridges and non-intensive estates without releases. Thus, this intensive management is also sensible to prices, but possibly more advantageous for promoters because in case of low price, losses were similar and in case of high price, revenues were much greater. On the other hand, research related to real options valuation in business (Myers 1977) may explain other perceived advantages of restocking, whether massive or low intensity restocking, and thus could help to explain why the management of wild populations is being substituted by releases.

A real option is the right, but not the obligation, to take an action (e.g. deferring, expanding, contracting, or abandoning), for a predetermined period of time – the life of the option (Myers 1977). They are referred to as "real" because they usually pertain to tangible assets such as capital equipment, rather than financial instruments. Real options can greatly affect the valuation of potential investments, although oftentimes valuation methods (such as the Net Present Value) do not include the benefits that real options provide. Two kinds of real options seem to be particularly applicable to our case study. The *deferral option* (the right to delay the start of a project), happens in estates that base their activity on releases. Investments to get a proper environment for great densities of wild red-legged partridges have to be made quite before the hunting season starts, because to get a good population established in an area is obviously not immediate. They could be equal or lesser than investments on buying farm-reared partridges, however, they imply risks:

demand may be not enough to cover costs, and environmental contingencies may prevent to meet the goals of wild partridges availability. To use farm-reared partridges implies to defer the investments (made according to sales along the season in intensive estates, or made before the hunting season starts, but usually near to the start; Díaz-Fernández et al. 2012), and to invest with more certainty on the demand. The *option to expand* a project by paying to scale up the operations, to be able to buy farm-reared birds along the year, gives implicit value to restocking face to the only use of wild partridges, because this reduces, as explained before, the risk in estimating the demand for the season, and the risk of disappointing hunters by a possible lack of birds and losing clients. This suggests that real options may be an important motivation for hunting managers to use restocking in red-legged partridge estates, because they bring value to the hunting business that use farm-reared partridges, in spite of the sometimes greater margin per bird hunted in estates that do not restock at all. However, the mistake of this approach in non-intensive estates is that releases in low numbers do not imply an additive harvest with respect to seasonal wild harvest in the short (Díaz-Fernández et al. 2012) and in the medium term (Díaz-Fernández et al. 2011), and thus investments in releases may not be rewarded. The lack of information on the efficacy of low intensity restocking may be giving credit to the options to defer and expand that theoretically would reduce risks and costs in this kind of estates, encouraging managers to reinforce annually partridge availability with farm-reared birds. Conversely, real options from restocking may be effectively increasing the value of the business model of intensive estates.

According to our results, within the same market and under current conditions of management, if no clear differences in prices exist, profitability of wild partridge estates, whose natural limitations on harvest (amount and flexibility) cannot be overcome, cannot compete with estates that use large-scale releases. Promoter's economic advantage of industrial management of initially wild products is not new, it has been also observed with salmon (Pascual et al. 2009), pigs, or cow farms. Also, the artificial production of pearls has been increasing its market share (Sahoo

2002). It has to be taken into account, however, that our analysis includes mainly driven shooting as hunting style for the 6 analysed estates that include non-intensive estates without releases and intensive estates. The market for driven shooting is relatively small as compared with walked-up shooting, which daily bag is always smaller. It is not clear that artificial production of partridges increases the market share of hunting estates that are not based on driven-shooting, as partridge quality is a clear preference for hunters choosing walked-up hunting days (authors unpublished data). A lack of trustworthy guarantee on the origin (farm/wild) of partridges to be hunted in walked-up shoots was recently detected in Spain (authors, unpublished data), which means that both kinds of management are not easily dissociated by the current market and clear differences in prices may be difficult to find in spite of real hunter preferences Thus, it would be necessary to evaluate if these results are modified in estates that offer mainly walked-up shooting days and why.

It is noteworthy that we obtained positive revenues for non-intensive estates without releases, particularly in the average-to-high price scenarios, proving that although benefits were not comparable to those of intensives estates, the commercial hunting of wild partridge populations may currently be a profitable business. As seen above, intensive estates get more competitive prices due to the lack of limitation in their offer and the big volume of products sold. However, they are not internalizing any possible ecological costs. If they did, their competitiveness would be reduced in relation to estates that manage wild partridges with sustainability criteria. Thus, a debate arises: should we consider that releases of red-partridges have a social cost (Cross 1989), and should the government force the internalization of that cost (Hennart 1986)? This theoretically would be fairer, but the precise valuation of ecological consequences and other effects of restocking is always a difficult matter. If achieved, a differential fiscal pressure to estates that contribute differentially to preservation of natural heritage (due to releases or to intensity of other management practices) would be a possible way to internalize ecological costs. As general fiscal pressure of hunting is low (hunting together with agriculture are considered protected and disfavoured activities), there may be margin to study this possibility. Another way to encourage a more sustainable behaviour would be to help discern clearly in the hunting market between these two kinds of management as with eco-labels (e.g. Shen 2012), and thus give the consumer the power to select. In that sense, there is an initiative in our region of study for a Game Quality Label. If such a label (that would only be given if the estate, among other characteristics, could prove that no releases are made) were in place, this could help identify (and mark) estates that could charge a higher price per partridge shot, thus contributing to their profitability (assuming that there was a demand for such a market). It is currently being evaluated whether hunters would trust and use such a label for their hunting decisions.

We found that the red-legged partridge hunting in the 4 non-intensive studied estates that sold hunts jointly through an annual payment were not economically profitable. Bernabéu (2002) found that 69% of small game hunting estates in Ciudad Real (Castilla La Mancha) dedicated less than 25% of their annual activities to hunting, from which Bernabéu concluded that hunting give the opportunity to get additional revenues to the agriculture in the estates. Negative revenues in our estates that sold hunts annually could be indicative of the use of red-legged partridge hunting as a complementary economic activity in the estate. In all of these estates within our sample, land belonged entirely to the hunting manager, who can use the land for other purposes and obtain revenue from those. In fact, the annual selling of hunting implies a simplification of the sales management and marketing. Thus, this could be indicative of a low dedication of the owner to hunting activities, and thus the corresponding opportunity cost of land, the gamekeeper salary (who is the manager itself in some of theses cases), or criteria of efficiency in management may not be taken into account to take decisions on hunting. Whatever the cause, the lack of profitability estimated in these 4 estates, together with the fact that releases in low numbers occurred in 3 of them, is noticeable and worrying because partridges were released and the result was not even positive revenues. Considering that current predator control and farm-reared partridges releases in non-intensive red-legged partridge hunting estates has been found non-effective to increase harvest or summer partridge densities (Díaz-Fernández et al. 2012, authors unpublished data) and that we found important expenses related to these practices, it would be desirable to think about the efficiency of management in this kind of estates. Although, according to our results, the absence of expenses directly related to these practices would not be enough to make these estates profitable at current prices, this would reduce losses and thus the costs that hunters would have to support when selecting sustainable wild partridge population hunting.

The low profitability and revenues estimated for non-intensive estates (where hunting is mainly based on wild stock; Díaz-Fernández et al. 2012), at current prices, could be exacerbated by some possible differences between real values and the values used for calculations. However, the data we used are within the current real range and thus, we do not expect our results to be too different from reality. On the other hand, due to small sample size in this study and the variability of management that may exist among estates, one limitation of this study is that it is the difficulty to generalize. However, these results should be considered as study cases that indicate real possibilities. For generalization, more cases should be studied.

Finally, the impact that restocking to sustain hunts could be having on wild red-legged partridge should be valuated, to determine its social cost. This should be the previous step to establish control mechanisms in order to change, if necessary, the behavior in this business sector as in other has been previously done (Minton and Rose 1997). With this information and the knowledge on the economic implications of management decisions in hunting estates, we would be in a better position to evaluate what could be a win-win strategy for the red-legged partridge and for its hunting.

MANAGEMENT IMPLICATIONS

The estates that use a business model based on massive releases get the greatest total revenues, and profitability, mainly due to their almost unlimited offer, the flexibility of their offer, and the real options of deferring and expanding the yearly investments. However, these real options that apparently may be also increasing the value of the hunting in estates with low intensity of restocking (and may explain why managers are substituting the management of wild populations by releases) do not compensate the inefficacy of this kind of releases to increase partridge availability, and thus do not increase private revenues or profitability of these estates while wild stocks are damaged. Meanwhile, we showed examples of red-legged partridge hunting estates without releases currently profitable, but they had margin to optimize management costs, were not competitive with intensive estates within the same market and prices, and nowadays this necessary market differentiation does not clearly exist. Conclusively, if releases had a social cost (which should be evaluated) and we wanted to reduce it, mechanisms as internalization of costs, such as market or fiscal differentiation through quality or eco-labels, would be necessary to encourage managers to implement sustainable wild red-legged partridge hunting and to get a socially fairer red-legged partridge hunting management.

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ANNEX A

ITEM CODE	FUNCTIONS (in monetary unit/km^2 of the hunting estate)
1_1	$-\frac{A*PA}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*A_j)$
1_2	$-\frac{L*B*e*g*PB}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*B_j)$
1_3	$-\frac{L*C*e*f*PC}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*C_j)$
1_4	$-x*\frac{D*PD}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*PD_j)$
1_5	$-x*\frac{D*PE}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*PE_j)$
1_6	$-\frac{F*PF}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*PF_j)$
2_1	$-z\frac{G*PG}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*G_j)$
2_2	$-z\frac{H*PH}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*H_j)$
2_3	$-z\frac{I*PI}{S}*(1+\frac{i}{12}*\sum_{j=11}^{j=0} j*I_j)$

3_1 $$-x\frac{D*PJ}{hJ*S}*(1+\sum_{j=1}^{j=nJ-1} j*\frac{i}{hJ})$$

3_2

$$-z(\frac{K1*PK1}{hK1*S}*(1+\sum_{j=1}^{j=nK1-1} j*\frac{i}{hK1})+\frac{K2*PK2}{hK2*S}*(1+\sum_{j=1}^{j=nK1-1} j*\frac{i}{hK2}))$$

3_3 $$-\frac{L*PL}{hL*S}*(1+\sum_{j=1}^{j=nL-1} j*\frac{i}{hL})$$

3_4 $$-\frac{M*PM}{hM*S}*(1+\sum_{j=1}^{j=nM-1} j*\frac{i}{hM})$$

4_1 $$-PN*(1+\frac{i}{12}\sum_{j=11}^{j=0} j*PN_j)$$

4_2 $$0.75*item[4\_1]$$

4_3 $$-x*\frac{PO}{S}*(1+\frac{i}{12}\sum_{j=11}^{j=0} j*PO_j)$$

4_4 $$-x*PP*(1+\frac{i}{12}\sum_{j=11}^{j=0} j*PP_j)$$

5_1 $$\frac{R*PR+h*Ph}{S}*(1+\frac{i}{12}\sum_{j=11}^{j=0} j*R_j)$$

5_2

$$\left(\frac{X*a*PX}{(0.01+a+b+c)*S}+\frac{d*Pb}{S}\right)*\left(1+\frac{i}{12}\sum_{j=11}^{j=0} j*X_j\right)$$

5_3

$$\frac{T*PT+t*Pt}{S}*\left(1+\frac{i}{12}\sum_{j=11}^{j=0} j*T_j\right)$$

5_4

$$\frac{U*k}{(0.01+k+l+m+n)*S}*\left(1+\frac{i}{12}\sum_{j=11}^{j=0} j*U_j\right)$$

5_5

$$\frac{o*Po}{S}*\left(1+\frac{i}{12}\sum_{j=11}^{j=0} j*o_j\right)$$

Where:

A variable (capital or lower-case letter) followed by the subscript "j" means the proportion of the annual amount of this variable converted in expense or revenue along the month j, being in this case j=11 September, j=10 October, …, j=0 August.

a // b // c = Number of partridges // rabbits // hares hunted along the year included in the fixed price of walked-up shooting hunts individually sold. Partridges hunted in walked-up shooting hunts paid in addition to the fixed price of these hunting days, or sold together with the other hunting for the season, are not included in "a".

d = Number of partridges hunted in walked-up shooting hunts individually sold that are not included in the fixed price of the hunt. a+d are the annual number of partridges hunted in walked-up shooting hunts individually sold.

e = Feeder volume refilled expressed in litre.

f // g = Equivalence weight/volume of wheat // fodder expressed in kilogram/litre.

h = Number of partridges hunted in driven shooting hunts along the year, that are paid per partridge hunted (in addition to the possible fixed price paid for the hunt).

hJ // hK1 // hK2 // hL // hM = Amortization period for vehicles // cage-traps for black-billed magpies control // cage-traps for foxes control // food-supplementation device // water-supplementation device, expressed in years.

i = Annual interest rate.

k // l // m // n = Number of partridges // doves // rabbits // hares hunted in the estate along the year when hunts for the whole season are jointly sold.

o = Number of partridges sold as meat along the year.

t = Number of partridges hunted with decoy along the year, that are paid per hunted partridge (in addition to any fixed price per the hunting day).

w = Average number of hunters taking part in a dove hunt times the number of dove hunts given along the year.

x = Percentage of income from red-legged partridge hunting in relation to the total income from all small game hunting in the estate, calculated as:

$$x = \frac{item[5\_1] + item[5\_2] + item[5\_3] + item[5\_4] + item[5\_5]}{item[5\_1] + ((\frac{X * PX + d * Pb}{S}) * (1 + \frac{i}{12}\sum_{j=11}^{j=0} j * X_j)) + item[5\_3] + \frac{U}{S} * (1 + \frac{i}{12}\sum_{j=11}^{j=0} j * U_j) + item[5\_5] + \frac{w * Pw}{S}}$$

z = Percentage of income from red-legged partridge hunting in relation to the total income from all small game hunting in the estate, without taking into account dove hunting, calculated as:

$$z = \frac{item[5\_1] + item[5\_2] + item[5\_3] + item[5\_4] + item[5\_5]}{item[5\_1] + ((\frac{X * PX + d * Pb}{S}) * (1 + \frac{i}{12}\sum_{j=11}^{j=0} j * X_j)) + item[5\_3] + \frac{U}{S} * (1 + \frac{i}{12}\sum_{j=11}^{j=0} j * U_j) + item[5\_5]}$$

A = Number of farm-reared partridges released in the estate along the year.

B // C = Times that food-supplementation devices are refilled with fodder // wheat along the year.

D = Number of vehicles.

F = Area cultivated exclusively for game, expressed in hectares.

G = Number of gamekeepers.

H // I = Number of day's wages paid to supplementary staff for hunting days // different to the staff for hunting days.

K1 // K2 // L // M = Number of cage-traps for black-billed magpies // cage-traps for foxes // food-supplementation devices // water-supplementation devices in the estate.

Pw = Price of a dove hunt.

PA = Price per farm-reared partridge delivered in the estate.

Pb = Price per partridge hunted during walked-up shooting hunts, paid in addition to a possible fixed price per the hunt.

PB // PC = Price per kilogram of fodder // wheat.

PD // PE = Annual expense per vehicle in maintenance // insurance and traffic taxes.

PF = Annual expense per hectare of culture exclusively cultivated for game.

PG = Annual gamekeeper salary.

Ph = Price per each hunted partridge in driven shooting hunting days along the year (in addition to the possible fixed price paid per the hunting day).

PH // PI = Day's wage and person for supplementary staff for hunts // Day's wage for staff different to the supplementary staff for hunts.

PJ = Price of a vehicle.

PK1 // PK2 // PL // PM = Price of a cage-trap for black-billed magpies // cage-trap for foxes // food-supplementation device // water-supplementation device.

PN = Price of the tax for the town ("Gastos suntuarios") expressed in monetary units per square kilometre. This price is defined by legislation (Ministerio de Economía 1984) proportionally to the number of animals hunted.

Po = Price per partridge sold as meat along the year.

PO = Annual price of the insurance of civil responsibility expressed in monetary units.

PP = Annual price for renting hunting rights or opportunity cost in case of being proprietary of the hunting estate, expressed in monetary units per square kilometre.

PR // PT // PX = Fixed price of a driven // decoy // walked-up shooting hunting day (fixed price independent of the harvest).

Pt = Price per partridge hunted with decoy that are paid per partridge hunted (in addition to the fixed price per hunt that may be paid independently of the harvest).

R // T // X = Average number of hunters taking part in a driven // decoy // walked-up shooting hunt times the number of driven // decoy // walked-up shooting hunts offered along the year, sold for a fixed price independent on the number of partridges hunted.

S = Area of the hunting estate expressed in square kilometre.

U = Price of hunting in the estate, when all hunts are sold jointly for the whole season.

CHAPTER 5. MARKET VALUE OF RESTOCKING AND LANDSCAPE MANAGEMENT IN RED-LEGGED PARTRIDGE HUNTING

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[This chapter has not yet been published.]

ABSTRACT

In Spain, the release of farm-reared partridges to hunt is increasingly used, although is thought to affect sustainability of wild stocks, and to reduce the need of natural habitats for game. To explore the market value as incentive for current management, we evaluated within a segment of the red-legged partridge hunting market whether the use of farm-reared birds (as opposed to wild stock) or the naturalization of landscapes are affecting hunts market price. We considered estates that sell individual hunting days, and contact buyers through advertisements. We gathered all advertisements for season 2010 in 4 top hunting magazines and 2 websites, and conducted a telephone survey to record price and associated characteristics of hunts. We found no way to check if partridges sold as wild were

really wild or farm-reared, detecting possible cheating, which means that in relation to restocking our data show the proportion of estates saying openly (being true or false) that restocked. We looked for relationships between price and hunts characteristics sold using general linear models. Hunts varied largely in price, but at least for estates that use advertisements on magazines or the internet as selling channels, neither restocking nor naturalization of the landscape explained price variation. In consequence, market forces alone are not being useful to promote the public interest of the sustainable use of wild stocks face to the industrial hunting. If that were the goal, institutions in charge of sustainability in the use biodiversity should add some correcting forces.

INTRODUCTION

An example of game species with social and economical importance is the red-legged partridge (*Alectoris rufa*), a farmland species which has been traditionally (and is today) hunted in most of its distribution range, Southwest Europe. Within its range, this bird is most abundant (Blanco-Aguiar et al. 2003) and greatly hunted in Spain, although in Portugal, France, Italy, or United Kingdom (introduced population in this last case) is also frequently hunted (Delibes 1972, Fontoura 1992, López-Ontiveros 1994, Bernabéu 2002, Martínez et al. 2002). In Spain, small game represents 98% of all animals hunted, and generates more average number of hunting days per hunter and a greater amount of money paid for captures than big game (MARM 2006). Partridges amount to a quarter of all small game hunted annually (MARM 2006), and the red-legged partridge is widespread in Iberian ecosystems, where they play a key role as prey of many Iberian predators (Calderón 1977, Herranz 2000, Duarte and Vargas 2001, Virgós and Travaini 2005).

Hunting is allowed in 77% of the Spanish territory, and 88% of this area is organised in hunting estates that are privately managed (MARM 2006) for commercial or non-commercial hunting. The high demand of red-legged partridge hunts has led to widespread management practices usually focused on increasing the availability of birds to be hunted. One current practice is the release of farm-reared partridges (González-Redondo 2004). Partridges released took up an inicial annual number of 350000 during early 1980s and nowadays they are estimated between 3 and 6 million annually released (Delibes 1992, Pérez y Pérez 1992, Garrido 2002, Martínez et al. 2002, González-Redondo et al. 2010). Although current numbers seem difficult to be stated precisely due to illegal releases that, following some authors, exist (Garrido 2002), it is interesting that estimates are over the declared annual national harvest (3.3-3.5 million, MARM 2010). It is also certainly known that this practice has become relatively widespread (38% of hunting estates apply for licenses to release red-legged partridges in Castilla-La Mancha, Ríos-Saldaña 2010), although it is applied with very different intensity among areas and estates (Arroyo et al. 2012).

There is a concern among hunters and scientists about the spread of this technique (Delibes 1972, Garrido 2002, Blanco-Aguiar et al. 2008, Sokos et al. 2008). Negative consequences of farm-reared partridges stocking on wild populations have been highlighted in many scientific studies (Dowell 1992). These negative consequences are related to changes in population genetic pool through hybridization (Blanco-Aguiar et al. 2008, Barbanera et al. 2010), overhunting of wild populations, lower survival and reproductive success of farm partridges in the wild (Gortázar et al. 2000, Millán et al. 2001, Duarte et al. 2011, Casas et al. 2012), disease spread by farm partridges (Gortázar et al. 2006, Villanúa et al. 2008), and loss of important adaptive behavioural traits (Randi 2008). Additionally, farm-reared partridges are widely viewed by hunters as being of lower quality than wild stock (Authors, unpublished data). Interestingly, it has been pointed out that fraudulent selling of hunts with released partridges as if they were wild exists (Delibes 1992), although the generalization of this last practice is not known.

On the other hand, Arroyo et al. (2012) showed that areas managed for commercial red-legged partridge hunting retain more areas of natural vegetation compared to non-commercial estates, and may thus have higher conservation value, as natural value of farmland areas increases with the presence of natural vegetation (Halladay and Gilmour 1995, Blondel and Aronson 1999, Olivero et al. 2011). However, the use of farm-reared partridges may theoretically relax the necessity of maintaining good habitats to sustain wild populations, so the use of this technique may also have negative consequences on the environment, beyond the impact on wild partridge populations.

We wanted to evaluate to what extent the use of farm-reared partridges in hunting estates or the maintenance of natural landscapes are currently affecting hunts market price, to give some light on the existence of commercial motivations for their current use.

STUDY AREA

As stated above, most hunting estates in Spain were privately managed. Owners of the hunting rights were most frequently individual persons (75% of the estates in Castilla-La Mancha, Bernabéu 2002), although enterprises or associations were sometimes promoters too. Owners of the hunting rights were not necessarily owners of the land (so land management decisions may be taken by different persons than hunting management decisions). Hunts may be self consumed by the owners of the hunting rights, or else sold. In the latter case, hunts may be sold for the whole season (or more than one season) to a group of hunters, or they may be sold as individual hunting days (with either an overall price or paying by each animal shot) (Bernabéu 2002). We restricted this study to commercial estates that sell independent hunting days.

Bernabéu (2002) indicated that fidelity was one of the reasons for hunting in particular estates, because small-game hunters usually bought hunting days in the same estates, season after season. Moreover, he said hunters usually got new contacts through friends, and thus fidelity or the word of mouth are basic for a big part of the hunting market (at least around 1997, when that study was conducted). However, some of the commercial hunts were advertised in hunting magazines or on the internet. Here, we considered only this last part, because nuances related to fidelity affecting prices could shade the effect of the characteristics we wanted to study. Thus, we considered the red-legged partridge market that use advertisements to put in contact sellers and buyers.

In Spain, the main modalities commercialized to hunt partridges were driven and walked-up shooting. In red-legged partridge driven shooting, assistants beat the land to flush partridges and drive them towards a strategically arranged line of hunters. In walked-up shooting, hunters (with or without dogs) shoot the birds as they encounter them (Buenestado et al. 2009). We studied here both of those modalities.

METHODS

Data collection

We used a telephone survey among hunting sellers to gather prices and some management characteristics of driven shooting and walked-up shooting hunts, as a hunter could do: collecting contact data on hunting magazines and on the internet. We gathered all individual hunt advertisements from 2 specialized web sites (www.vivahunting.com and www.elcotodecaza.com), and the main 4 specialized magazines in Spain (Trofeo, Jara y Sedal, Federcaza and Caza Castilla La Mancha, issues of September, October and November 2010). Commercial hunts may vary in the number of birds that a hunter is allowed (or likely) to hunt, on the number of hunters taking part in a hunt, or (in the case of walked-up shoots) on whether it is possible to hunt alternative prey without additional cost. All these variables could affect price. Other complements (not considered in the study) can also affect prices. Therefore, we considered only 2 products for the study, fixing common values for some of those complements. First, we considered a driven shooting day for one person, being able to hunt up to 100 partridges without additional cost, and including usual individual staff (2 people) for the hunter, charge of firearms and lunch. This product did not include lodging. Second, we considered a walked-up shooting day for one person, being allowed to hunt up to 3 partridges without additional costs, including staff (1 person) for the hunter, but no charge for firearms, lunch or lodging.

We gathered 131 different telephone numbers to contact sellers whose hunts could meet our requirements. Within the characteristics included in these advertisements, 16 out of 131 said that partridges were wild or genetically pure, 10 gave insight about landscape and 9 about the size of the group taking part in the hunt, showing that this characteristics are sometimes viewed by the seller with potential effect on the consumer election.

Telephone calls followed a fixed guide (table 1). Information recorded was price, if farm-reared partridges were released in the estate where the hunt was going to take place, the maximum number of hunters that were going to participate in the same hunt, and the landscape. For walked-up shooting hunts we also collected information on whether it was possible to hunt wild rabbit (*Oryctolagus cunniculus*) (the most important alternative small game species in the area) without additional cost (table 1). From the 131 contacts attempted, we obtained 51 successful contacts, 28 providing information for driving shooting and 45 for walked-up shooting (22 were successful contacts for both modalities). Unsuccessful contacts were due to telephone numbers being wrong, to sellers not offering the product we required, to sellers not providing the data we required, or to all hunts being already sold for the season in course (and thus the offer being closed). 71% of the final sample corresponded to hunting estates located in Castilla La Mancha (the most important hunting region for partridges in Spain, Ríos-Saldaña 2008), the remainder being distributed around Andalucía, Catalunya, Castilla y León, Extremadura and Madrid. Location of 6 estates was unknown.

Statistical analysis

We tested whether the driven hunt price was explained by the maximum number of hunters taking part in the hunt, by the naturalization of the landscape in the estate or by both variables at the same time (table 2). We did not test for the effect of releases as there were not enough sellers offering driven hunts of wild partridges (3 out of 28, table 3). We used a generalized model with the R function glm (R Development Core Team 2009) and a Gaussian distribution of errors, testing both linear and log-linear response functions. We assumed a variable would explain part of the hunt price when the analysis of variance (type III, with the R function Anova) gave a p value less than 0.05.

Table 1: Information recorded on red-legged partridge hunts through telephone surveys in 2010, in Spain: Information asked and variables derived from those questions.

	Questions asked in the telephone call	Variables (units)
DRIVEN SHOOTING	How much does a red-legged partridge driven shooting hunting day cost, being permitted to hunt until 100 partridges? Including usual individual staff (2 people) for the hunter, charge of firearms and lunch. Not including lodging nor taking hunted birds home.	Price-driven (euros per hunt)
DRIVEN SHOOTING	Are partridges for hunting farm-reared or wild ones?	Releases-driven (yes/no)
DRIVEN SHOOTING	How many hunters, maximum, would take place in this hunt?	Hunters-driven (number of hunters)
DRIVEN SHOOTING	The area where the hunt would take place, is mainly agricultural, mainly naturalized, or a mixture of both?	Landscape (agriculture/mixture/naturalized landscape)
WALKED-UP SHOOTING	How much does a red-legged partridge walked-up shooting hunting day cost, being permitted to hunt until 3 partridges? Including lunch, staff (1 person), but not including lodging or charge of firearms.	Price-walked up (euros per hunt)
WALKED-UP SHOOTING	Are partridges for hunting farm-reared or wild ones?	Releases-walked up (yes/no)
WALKED-UP SHOOTING	How many hunters, maximum, would take place in this hunt?	Hunters-walked up (number of hunters)
WALKED-UP SHOOTING	The area where the hunt would take place, is mainly agricultural, mainly naturalized, or a mixture of both?	Landscape-walked up (agriculture/mixture/naturalized landscape)
	For the same price, wild rabbit is permitted to be hunted?	Allowed to hunt rabbit (yes/no)
Name (not family name) of the person interviewed		
Other relevant comments		

Similarly, we tested whether the walked-up hunt price may be explained by the use of farm-reared partridges, by the maximum number of hunters taking part in the hunt, by the naturalization of the landscape in the estate, by the possibility of hunting wild rabbit without additional cost, or by different combinations of these variables (table 2). We used the same type of models and criteria as for driven hunts. Descriptive data on sample size, and mean price (± standard deviations) for variables studied are shown for discussion (table 3).

RESULTS

In the market we explored, our data showed that there was a large variation in prices of walked-up hunts (fig. 2), but the price of a hunt was not explained significantly by any of the evaluated variables: whether it consisted of wild red-legged partridges or farm-reared partridges, landscape naturalization, the possibility of hunting wild rabbit without additional costs or the number of hunters taking part in the hunt (min=1, max=50) (table 2).

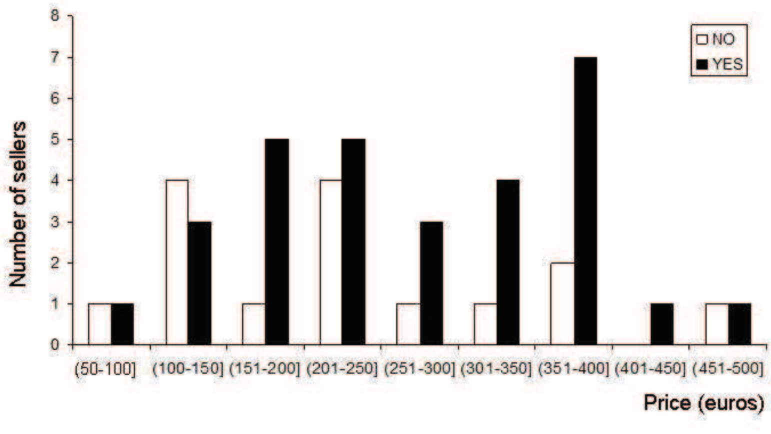

Figure 2: Distribution of walk-up shooting day prices (euro) for hunts with (black) and without (white) releases, from the telephone survey. In 2010, and in Spain.

Table 2: Combinations of explicative variables in the models explaining red-legged partridge hunts price in 2010 in Spain. Table shows p values obtained for each variable in the models, testing linear/log-linear response functions.

	Hunters-driven (number of hunters)	Landscape-driven (agriculture/ mixture/ naturalized)	Releases-walked up (yes/no)	Hunters-walked up (number of hunters)	Landscape-walked-up (agriculture / mixture / naturalized)	Rabbit (yes/no)
Models - driven shooting	0.450/0.462	0.654/0.678	-	-	-	-
	0.338/0.339	-	-	-	-	-
	-	0.467/0.468	-	-	-	-
Models - walked-up shooting	-	-	0.185/0.217	0.262/0.299	0.778/0.907	0.232/0.299
	-	-	0.271/0.253	0.224/0.225	0.862/0.883	-
	-	-	0.270/0.250	0.223/0.222	-	-
	-	-	0.373/0.373	-	-	-
	-	-	-	0.302/0.328	-	-
	-	-	-	-	0.991/0.991	-
	-	-	-	-	-	0.287/0.287
	-	-	-	0.367/0.406	0.890/0.929	0.348/0.357
	-	-	0.250/0.285	-	0.856/0.991	0.198/0.225
	-	-	0.377/0.378	-	0.956/0.977	-
	-	-	0.249/0.279	-	-	0.197/0.220
	-	-	-	0.306/0.331	0.942/0.932	-
	-	-	-	0.365/0.403	-	0.346/0.351
	-	-	-	-	0.942/1.000	0.291/0.293
			0.187/0.212	0.266/0.296	-	0.234/0.292

For driven shooting hunts, we also found large variation in prices (fig. 3). The offer of wild partridge hunts was scarce (3 out of 28 sellers in our sample). We found no price variation related to this in this unbalanced sample (2717 euros faced to 2781 euros, table 3). Similarly, variation in hunts price was not significantly explained by any of the other analysed variables: landscape naturalization or number of hunters taking part in the hunts, within the range recorded in our sample (min=1; max=20).

Table 3: Sample size and mean and standard deviation price for the different categories of the studied variables of red-legged partridge hunts and hunting methods in 2010, in Spain.

VARIABLE	CATEGORY	DRIVEN SHOOTING PRICE			WALKED-UP SHOOTING PRICE		
		n	MEAN	STD. DEV.	n	MEAN	STD. DEV.
Releases	Yes	25	2781.60	956.49	30	278.33	102.40
	No	3	2716.67	956.99	15	248.33	114.33
Maximum number of hunters	-	28	2774.64	938.87	45	268.33	106.18
Landscape	Mainly agriculture	2	2475.00	1449.57	4	273.75	59.35
	Mixture	14	2701.43	756.93	22	266.59	118.96
	Mainly naturalized	12	2910.00	1119.09	19	269.21	102.23
Rabbit	Yes	-	-	-	33	258.18	95.71
	No	-	-	-	12	296.25	131.48

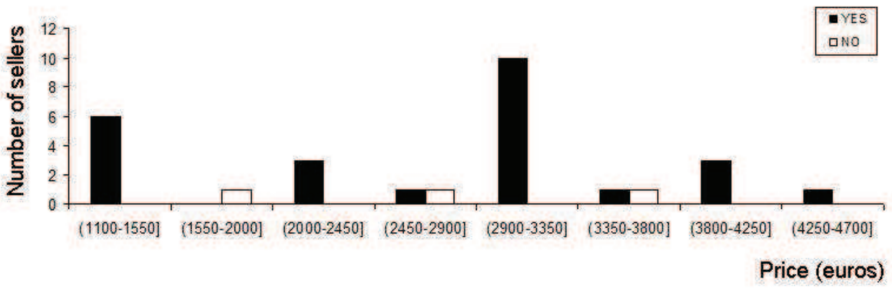

Figure 3: Distribution of driven shooting day prices for hunts with (black) and without (white) releases, from the telephone survey. In 2010, and in Spain.

DISCUSSION

Our results indicated that, at least when hunting estates use advertisements on specialized journals or the internet as selling channels, hunt price variation was not related to the use of farm-reared partridges. If hunting a wild red-legged partridge instead of a farm-reared one had higher value for hunters (as expected from their perceived lower quality), when maximum agreed harvest is kept constant we would expect a higher price for a wild partridge hunting day, but we did not find this. One possible reason for this may be a lack of trustworthy guarantee of the partridge wilderness when the hunter does not know directly the estate management or have not hunted previously there (which is the case of hunters that buy hunting days through the channels we are considering here). This may reduce the expected effect of wilderness on the hunt price, because hunters may assume the possibility of cheating on selling farm-reared partridges as wild ones that Delibes (1992) already pointed out that existed, although with unknown frequency. On the other hand, releases may be perceived by hunters as a way to reduce harvest uncertainty. Lower quality would be thus compensated by lower uncertainty. This could explain the slight tendency (although not significant, fig. 2) to value higher farm-reared partridges in walked-up shooting hunts. Whether consumers prefer wild or farm-reared partridges, the lack of guaranty on this characteristic we found while buying should be corrected to give the consumer some power of election in relation to a practice implying such ecological problems. This recommendation is also supported by sanitary or management points of view (Viñuela and Arroyo 2002).

As stated above, the estimated total number of farm-reared partridges annually released in Spain moves between 3 and 6 million depending on the author. This large number of released birds comes mainly from a small proportion of intensive estates, which have few legal restrictions for releasing unlimited numbers throughout the hunting season, and which provide mainly driven-shooting hunts (Arroyo et al. 2012). However, small-scale supplementation of wild stock with farm-reared birds is also widespread (Ríos-Saldaña 2002). The small number of sellers that offered hunts with only wild red-legged partridges in our sample (3 out of 28 in driven shooting, 15 out of 45 in walked-up shooting) agrees with a generalization of releases among estates, as reported in the above-mentioned studies. Additionally, it agrees with the perception of hunters that releases are necessary to maintain profitability of commercial hunting (authors unpublished data). The lack of price difference between hunts of restocked face to wild population estates, whatever the reason of it, suggests that the market is not giving incentives for the change of this trend.

On the other hand, our results did not show any relationship between hunt price variation in our sample and the presence of natural habitats in the landscape. Hunting has been claimed to be associated with the retention of natural habitats in the UK (Tapper 1999, Robertson et al. 2001, Duckworth et al. 2003). Similarly, commercial red-legged partridge hunting estates in Central Spain seem to be less occupied by farmland than non-commercial ones (Arroyo et al. 2012). But reasons for this relationship are not clear. One possible reason would be that hunters prefer more naturalized landscapes to hunt, being willing to pay more for these sceneries. However, the absence of effect of the naturalization of the landscape in the market price that we found in this work does not support that explanation, and implies that this characteristic of red-legged partridge hunting estates is probably not being managed to increase hunts market prices. Managers could be considering landscape as an indirect way to increase revenue, as landscape is associated with partridge abundance (Lucio and Purroy 1992, Fortuna 2002, Buenestado et al. 2008, Vargas et al. 2011), so a more naturalized landscape may result in more hunting days and thus more revenue, even if landscape does not increase hunts market price. Alternatively, commercial hunting estates could be located in areas where other more profitable agrarian uses would be less productive, and thus the relationship of commercial hunting with landscape was not a consequence of directed habitat management. Finally, managers could be managing habitat with goals different than revenue. Research on this issue would be interesting to understand the relationship between commercial hunting and habitat conservation that has been previously mentioned, and assess how long-lasting is this potential benefit for conservation attributed to hunting.

Globally, the absence of relationships in our results between hunts prices and any of our explanatory variables may be attributed to our small sample size (n_{driven} = 28, $n_{walked-up}$ = 45). However, our work while gathering data showed that the number of sellers who sell driven or walked-up hunting days through the internet or specialized journals in Spain is low (we found 131 advertisements selling one or both of them), and thus our sample size represents around a third of the whole population of sellers. We therefore believe that our results are representative for this fraction of the market. Thus, we conclude that for this way of commercialization, management characteristics related to game or habitat conservation do not affect hunts price importantly, although subtler effects may exist and not be statistically detected with our small sample size. Further studies should work on increasing the sample size, introducing alternative explanatory variables that may give light on other factors explaining the large price variability between estates, and the part of the red-legged partridge hunting market based on fidelity and the word of mouth to contact sellers, to clearly understand the current market value of management practices and the components of the red-legged partridge hunts price.

MANAGEMENT IMPLICATIONS

There was no evidence that market forces alone are not being useful to promote the public interest of the sustainable use of wild stocks face to the industrial use of hunting. First, because there is no trustworthy guarantee for hunters while buying a hunt on the origin of partridges to be hunt. Second, because the use of wild or farm-reared partridges or the naturalization of the landscape are not having sensible effects on hunts market prices. In consequence, when guaranteeing the sustainability on commercial uses of biodiversity was the goal, institutions in charge should implement some correcting forces, preferably based on the scientific knowledge of the weaknesses of the system, and on the foreseen specific consequences of these institutional actions.

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CHAPTER 6. GENERAL DISCUSSION

RED-LEGGED PARTRIDGE MANAGEMENT UNRELATED TO GREATER HARVEST, ABUNDANCE, PROFITABILITY OR ECONOMICAL BENEFIT

According to our results, there are management practices that currently are not being effective to achieve management goals at the hunting estate level. In non-intensive estates, supplementing partridges in relatively small numbers (studied range: 12-189 partridges/km^2) had no noticeable effect on harvest (chapter 2) and was negatively related to summer partridge abundance (chapter 3). Considering that harvest is more tightly related to hunting pressure than to availability (chapter 2), and the percentage of rapid losses of released partridges when using traditional management is very high (Gortázar et al. 2000, Alonso et al. 2005, Duarte et al. 2011), the no recovering of low-density wild populations (Sokos et al. 2008), and a high probability of overhunting (Gortázar et al. 2000) happen when using restocking for hunting, and thus the possible usefulness of restocking to increase medium-term yield of wild populations is dubious. Commercial red-legged partridge hunting in estates with low wild partridge abundances usually kept as a secondary economic activity easily become unprofitable, in spite of low intensity restocking (chapter 4), not rendering either short-term profitability. Considering that low but possible survival of farm-reared partridges in the wild is proved (Duarte et al. 2011), the consequence of this restocking is not only an effect on availability, but on effective densities due to artificial changes in the genetic pool of wild red-legged partridge Iberian populations (Blanco-Aguiar et al. 2008). We found that direct expenses of purchasing farm-reared partridges delivered in the estate to be released were 13% (±10) of the total expenses in our 3 non-intensive estates studied in detail, that implies annually 283 € / km^2 (±160). Other costs like supplementation can not be attributed only to restocking as long as in estates without releases this practice is also applied (chapter 4). However, we found quite tight correlations between intensity of supplementation with food and water, and restocking (chapter 3), when general intensification of management was found in commercial estates (chapter 1), supporting that both practices are related to some extent. Would be investments on low intensity restocking enough to increase wild abundances and harvest if redirected to other management practices?

The widespread use of predator control in Central Spain (85.2% of small game estates in Castilla La Mancha, Ríos-Saldaña 2010) is not supported by the lack of effect of magpie or fox control intensity on partridge abundance that we found. The possible effect of predator control would be very small compared with other factors, or would be confounded with them (chapter 3). Our results agrees with the concerns of Arroyo and Beja (2002) about the lack of effect that predator control could have in real-life management situations, contrasted to the effectiveness of very intensive control found in experimental situations (Tapper et al. 1996, Fletcher et al. 2010). In addition to the possible negative effects for protected predators (Etheridge et al. 1997, Villafuerte et al. 1998, Whitfield et al. 2003, Valkama et al. 2005), we found that expenses related to the purchase of tools for predator control in the estates we studied was very small (0.1%+0.1 of the expenses of the estate), but expenses on gamekeepers was one of the greatest (22.5%+10.7) (chapter 4) and much of their time (although we could not precise how much) is devoted to predator control. Moreover, part of the critics of hunting activity is related to damages to biodiversity conservation through legal and illegal predator control, and these controversies, by definition, imply problems for the activity. Thus, this again would be interesting to study how redirecting the current investments in predator control to other strategies of management could, without additional costs for managers, increase their benefits and the sustainability of red-legged partridge hunting.

RED-LEGGED PARTRIDGE MANAGEMENT RELATED TO GREATER HARVEST, ABUNDANCE, PROFITABILITY OR ECONOMICAL BENEFITS

Intensity of water and food supplementation in the estates is related to greater summer red-legged partridge abundances in estates of central Spain (chapter 3), and density of Mediterranean shrubland is positively related to both summer abundances (chapter 3) and harvest (chapter 2). Thus, we agree that habitat keeps being a main factor determining red-legged partridge hunting yield (Buenestado et al. 2009, Casas and Viñuela 2010), whether being naturalized habitat or habitat constituted by artificial devices. In fact, supplementation was a good explicative variable for greater variance of abundance than “natural” habitat. This is surprising and possibly attributable to problems of food and water availability in the surrounding habitat (supporting previous research on the effect of current agricultural landscapes for biodiversity, e.g. Chamberlain et al. 2000, Bota et al. 2005), although our research was not deep enough to confirm this extreme. What we can confirm is that expenses on supplementation for red-legged partridge are a high amount in relation to total expenses in private hunting estates (including direct expenses on wheat or fodder, devices, time that gamekeepers dedicate to supplementation, etc) and that expenses in integrated management with agriculture or other uses (like agreements among users) were non-existent or considered negligible among hunting managers, because this approach is not common (chapter 4).

In private hunting estates, harvest is more tightly related to hunting pressure intensity than to partridge availability (chapter 2), and this may explain that intensity of hunting pressure is less related to summer partridge abundance than expected (chapter 3). Another good reason may be the important role that habitat and supplementation seem to have on productivity and survival along the year (chapter 3). However, habitat management and supplementation alone can not sustain wild populations when overharvesting happens. Incomes depending on hunting pressure and harvest may incite to overharvest (if only short-term is considered) or to control hunting pressure and harvest to keep incomes along time, although we saw that between commercial and not commercial estates hunting pressure was similar (chapter 1), and thus, it is difficult to point out that incomes are the reason to overharvest. Conclusively, it is more likely that overharvesting is something prone to happen when harvesting carrying capacity of a population is not precisely known by the decision maker, common scenery in many red-legged partridge hunting estates.

Massive releases are tightly related to harvest, with a mean return on harvest of partridges released around 45% (chapter 2). There, partridge summer densities are not greater than in non-intensive estates, suggesting mortality of more than half of the released birds both before and after the shoots, concurrently with the high mortality of released partridges reported in other studies (Gortázar et al. 2000, Alonso et al. 2005, Duarte et al. 2011). In spite of the farm-reared partridge losses, restocking is economically rewarded in the estates as long as benefits and profitability in this kind of business are very high (chapter 4). The almost unlimited offer, the elasticity of the offer, the no internalization of ecological costs and the real options of extent and expand investments along the year give to this business model competitiveness without of question within the current red-legged partridge hunting market. As hunting in these estates is based in artificial inputs, sustainability within them should possibly be considered in different terms than sustainability of the use of wild populations: in terms of their externalities. If negative externalities could be neutralized, economical benefits for promoter kept, and the presence of these estates keeps punctual, negative considerations of this business in relation to conservation could be reduced. We saw that intensity of management in intensive estates was greater than in others (chapter 1). Thus, implications in terms of ecological costs of this management, in case they exist, should be reduced or internalized to increase fairness in the competitiveness of this market. On the other hand, traceable hunts and a clear identification of the products in the market (hunting based on sustainable management of wild partridge populations or hunting based on restocking) should exist, to give consumers and society in general the right to select what management they prefer. However, this is always a difficult issue to value ecological costs and benefits of management practices, determine precisely their effects and the present value of present and future effects (Weiss 1992, Hilborn et al. 1995, Boardman et al. 2001). On the other hand, biodiversity depends in a big extent on habitat, which depends on all activities that overlap on the land. It is dangerous to attribute all benefits or damages on conservation to one activity as hunting, without integrating the attribution of them among all the uses them. Thus, to increase fairness and sustainability of management, we should be cautious on these issues when taking regulatory decisions.

EXPLAINING APPARENTLY INEFECTIVE MANAGEMENT

If some management systems or techniques are ineffective and red-legged partridge hunting in a commercial estate is unprofitable, why this keeps happening? Possibly, the deepest reason is that many managers do not know how to get sustainable and at the same time profitable red-legged partridge hunting based on wild populations management. Additionally, the fact that the market does not seem to reflect these choices in market price (chapter 4) does not encourage them to learn or research on this. On the other hand, precise evaluation on revenues and profitability in estates where red-legged partridge hunting is a secondary activity lacks, and economic losses are not precisely known by managers. However, due to the lack of noticeable benefits, small scale releases give the option to delay, extend and expand annual investments, which gives apparent value to this management model, although the non-additive effect (unknown) of these releases on harvest do not give back the expected results. Finally, an estate that is not established as a hunting estate is usually free for hunters to hunt without permission, creating possible problems to the owner. These conflicts, not considered in economical terms in this work, but existent, are commonly avoided creating a hunting estate, although not much economic benefits were waited or optimization of management was not planned.

AND THUS, WHAT?

The use of a natural renewable resource is useful and sustainable for society if this produces net benefits (net benefits in general terms, that is to say, increase of human well-being). These benefits are distributed among users and finally multiplied when they are extended, for example, as jobs in services industry or as production of knowledge. If the resource use does not produce net benefits, although some stakeholders benefit, conflicts are prone to appear, the sustainability of the use is not guaranteed, and its collapse is probable. Total economic movement that red-legged partridge hunting creates in a region gives not a whole valuation of economic benefits that this activity creates: economic movement does not mean guarantee for the populations to survive. In fact, we detected economic beneficiaries of the activity (local labour force, farm partridge industry, wheat producers, etc) while net benefits produced in many estates were not clear (chapter 4).

As we argued at the beginning of this dissertation, sustainability of red-legged partridge hunting in Spain depends in a big extent on ecological and economic management efficiency in private hunting estates. Without a sustainable management of this hunting, this is condemned to disappear as an *in situ* natural resource use. With this work we detected some black holes in current management systems that could be solved. Investments applied to small scale releases and predator control that are not useful to improve the state of wild partridge populations or to increase profitability or economic benefits in the estate, and have proved (or expected) negative consequences for conservation of biodiversity and particularly for conservation of wild red-legged partridge populations, should be redirected to more useful and safe management. The consequences of redirection of the high expenses in food and water supplementation, to habitat management or to management integration with agriculture or other overlapped uses should be studied.

Motivation to private managers for exploring new sustainable hunting management approaches should be encouraged. To favour the existence of traceable hunts from the point of view of their management, and the internalization of social (including ecological) costs and benefits of hunting management would be a good direction to follow by the institutions in charge of natural resource use and biological conservation.

Three main recommendations for the future of partridge management can be suggested by all these results, in accordance with previous research on this species too: 1) it is important that released partridges can be unequivocally distinguished in the field from wild partridges, by mandatory marking of farm-bred birds; 2) differential fiscal pressure (increasing pressure on estates with management negative for nature conservation, while waving taxes to estates using management favourable for the conservation of natural heritage) could be a logical and useful tool to favour good practices, particularly in association with some quality label; and 3) routine use of releases should be reassessed by managers, since when used at small scale, no obvious benefit seems to be obtained as compared to careful wild red-legged partridge management, both in terms of harvest or economic profit.

LITERATURE CITED

Aebischer, N.J. 1997. Utilisation of fowl-like birds. Pages 143-155 *in* H.H. Roth, and G. Merz, editors. Wildlife resources. A global account of economic use. Springer-Verlag, Berlin.

Aebischer, N., and J.A. Lucio 1997. The red-legged partridge. Pages 208–209 *in* E.J.M. Hagemeijer, and M.J. Blair, editors. The EBBC atlas of European breeding birds: their distribution and abundance. Poyser, London.

Aebischer, N., and G.R. Potts 1994. The red-legged partridge. Pages 214–215 *in* G. Tucker, and M. Health, editors. Birds in Europe: Their conservation status. BirdLife Internacional, Cambridge.

Alonso, M.E., J.A. Pérez, V.R. Gaudioso, C. Díez, and R. Prieto 2005. Study of survival, dispersal and home range of autumn-released red-legged partridges (*Alectoris rufa*). British Poultry Science 6:401–406.

Angulo, E. 2003. Factores que afectan a la distribución y abundancia del conejo en Andalucía. Dissertation, Complutense University. Madrid, Spain.

Arnold, T.W. 2010. Uninformative parameters and model selection using Akaike´s information criterion. Journal of Wildlife Management 74(6):1175–1178.

Arroyo, B., and P. Beja 2002. Impact of hunting management on biodiversity. Unpublished report to REGHAB Project (EKV-2000-00637). European Commission.

Arroyo, B., M. Delibes-Mateos, S. Díaz-Fernández, and J. Viñuela 2012. Hunting management in relation to profitability aims: red-legged partridge hunting in central Spain. European Journal of Wildlife Research *Online first* DOI: 10.1007/s10344-012-0632-4.

Arroyo, B., and J. Viñuela 2001. Conclusions that may have political applications in the near future. Unpublished report to REGHAB Project (EKV-2000-00637). European Commission.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R.E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and R.K. Turner 2002. Economic reasons for conserving wild nature. Science 297:950–953.

Baragaño, J.R., and C. Otero 2001. Status y perspectivas de la perdiz roja en España. Pages 96–110 *in* Proceedings of the symposium on the status, management, and conservation of the species *Alectoris*, black francolin, thrush, quail and turtle dove in the Mediterranean region. Game Fund Service, Ministerio del Interior. Nicosia, Chipre.

Barbanera, F., O.R.W. Pergams, M. Guerrini, G. Forcina, P. Panayides, and F. Dini 2010. Genetic consequences of intensive management in game birds. Biological Conservation 143:1259–1268.

Beja, P., L. Gordinho, L. Reino, F. Loureiro, M. Santos-Reis, and R. Borralho 2009. Predator abundance in relation to small game management in Southern Portugal: conservation implications. European Journal of Wildlife Research 55:227–238.

Bennett, E., and J.G. Robinson 2000. Hunting of wildlife in tropical forests. Implications for biodiversity and forests peoples. Working paper. World Bank. Washington D.C.

Berger, F. 1984. La perdrix rouge. Bulletin Mensuel de l’O.N.C. 83:42–43.

Bernabéu, R. 2002. La caza en Castilla La Mancha y sus estrategias de desarrollo. University of Castilla La Mancha, Cuenca.

Bibby, C.J., N.D. Burgess, and D.A. Hill 1992. Bird census techniques. Academic Press, London.

Biescas, J.A. 1989. Estructura y coyuntura económicas. Pages 21–164 *in* M. Tuñón de Lara, editor. Historia de España. Vol 10: España bajo la dictadura franquista. Labor, Barcelona.

Blanco-Aguiar, J.A. 2007. Variación espacial en la biología de la perdiz roja (*Alectoris rufa*): una aproximación multidisciplinar. Dissertation, Complutense University. Madrid, Spain.

Blanco-Aguiar, J.A., M. Delibes-Mateos, B. Arroyo, P. Ferreras, F. Casas, R. Real, M.J. Vargas, R. Villafuerte, and J. Viñuela 2012. Is the interaction between rabbit hemorrhagic disease and hyperpredation by raptors a major cause of the red-legged partridge decline in Spain? European Journal of Wildlife Research 58:433–439.

Blanco-Aguiar, J.A., P. Gonzalez-Jara, M.E. Ferrero, I. Sanchez-Barbudo, E. Virgós, R. Villafuerte, and J.A. Davila 2008. Assessment of game restocking contributions to anthropogenic hybridization: the case of the Iberian red-legged partridge. Animal Conservation 11:535–545.

Blanco-Aguiar, J.A., E. Virgós, and R. Villafuerte 2001. Preliminary results on the determinant of regional abundante of red-legged partridge in a central area of its natural distribution. International Union of Game Biologists XXVth Congress and Perdix IX International Symposium. Lemesos, Cyprus.

Blanco-Aguiar, J.A., E. Virgós, and R. Villafuerte 2003. Perdiz roja *Alectoris rufa*. Pages 212–213 *in* R. Martí and J.C. del Moral, editors. Atlas de las aves reproductoras de España. Dirección General de Conservación de la Naturaleza and Sociedad Española de Ornitología, Madrid.

Blondel, J., and J. Aronson 1999. Biology and Wildlife of the Mediterranean Region. Oxford University Press, Oxford.

Boardman, A.E., D.H. Greenberg, A.R. Vining, and D.L. Weimer 2001. Cost-benefit analysis: concepts and practice, second edition. Prentice Hall, New York, USA.

Bolker, B.M., M.E. Brooks, C.J. Clark, S.W. Geange, J.R. Poulsen, M.H.H. Stevens, and J-S.S. White 2008. General linear mixed models: a practical guide for ecology and evolution. Trends in Ecology and Evolution 24:127–135.

Borralho, R., A. Rito, F. Rego, H. Simoes, and P. Vaz Pinto 1998. Summer distribution of red-legged partridge *Alectoris rufa* in relation to water availability on Mediterranean farmland. Ibis 140:620–625.

Borralho, R., C. Stoate, and M. Araújo 2000. Factors affecting the distribution of Red-legged Partridges *Alectoris rufa* in an agricultural landscape of southern Portugal. Bird Study 47:304–310.

Bota, G., M.B. Morales, S. Mañosa, and J. Camprodon 2005. Ecology and conservation of steppe-land birds. Lynx Editions and Centre Tecnològic Forestal de Catalunya, Barcelona.

Buenestado, F., P. Ferreras, J.A. Blanco-Aguiar, F.S. Tortosa, and R. Villafuerte 2009. Survival and causes of mortality among wild Red-legged Partridges *Alectoris rufa* in southern Spain: implications for conservation. Ibis 151:72–730.

Buenestado, F.J., P. Ferreras, M. Delibes-Mateos, F.S. Tortosa, J.A. Blanco-Aguiar, and R. Villafuerte 2008. Habitat selection and home range size of red-legged partridge in Spain. Agriculture, Ecosystems and Environment 126:158–162.

Bunnefeld, N., E. Hoshino, and E.J. Milner-Gulland 2011. Management strategy evaluation: a powerful tool for conservation? Trends in Ecology and Evolution 26(9):441–447.

Burnham, K.P., and D.R. Anderson 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York.

Calderón, J. 1977. El papel de la perdiz roja (*Alectoris rufa*) en la dieta de los predadores ibéricos. Acta Vertebrata 4:61–126.

Calderón, J. 1983. La perdiz roja, *Alectoris rufa* (L.). Aspectos morfológicos, taxonómicos y biológicos. Dissertation, Complutense University. Madrid, Spain.

Caro, J., S. Díaz-Fernández, J. Viñuela, C. Sunyer, and B. Arroyo 2011. Contribución de los Parques Nacionales al desarrollo rural: estudio comparativo con la caza. Pages 277–291 *in* L. Ramírez, and B. Asensio, editors. Proyectos de investigación en Parques Nacionales: 2007-2010. OAPN, Madrid.

Carpenter, S.R., H.A. Mooney, J. Agard, D. Capistrano, R.S. Defries, S. Diaz, T. Dietz, A.K. Duraiappah, A. Oteng-Yeboah, E.M. Pereira, C. Perrings, W.V. Reid, J. Sarukhan, R.J. Scholes, and A. Whyte 2009. Science for managing ecosystem services: beyond the millennium ecosystem assessment. Proceedings of the National Academy of Sciences USA 106:1305–1312.

Casas F., F. Mougeot, I. Sanchéz-Barbudo, J.A. Dávila, and J. Viñuela 2012. Fitness consequences of anthropogenic hybridization in wild red-legged partridge (*Alectoris rufa*, *Phasianidae*) populations. Biological Invasions 14:295–305.

Casas, F., F. Mougeot, and J. Viñuela 2009. Double nesting behaviour and differences between sexes in breeding success in wild Red-legged Partridges *Alectoris rufa*. Ibis 151:743–751.

Casas, F., and J. Viñuela 2010. Agricultural practices or game management: which is the key to improve red-legged partridge nesting success in agricultural landscapes? Environmental Conservation 37:177–186.

Cattadori, I.M., D.T. Haydon, S.J. Thirgood, and P.J. Hudson 2003. Are indirect measures of abundance a useful index of population density? The case of red grouse harvesting. Oikos 100:439–446.

Cattadori, I.M., and P.J. Hudson 1999. Temporal dynamics of grouse populations at the southern edge of their distribution. Ecography 22: 374–384.

Chamberlain, D.E., R.J. Fuller, R.G.H. Bunce, J.C. Duckworth, and M. Shrubb 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. Journal of Applied Ecology 37:771–788.

Champagnon, J., G. Matthieu, M. Gauthier-Clerc, J-D Lebreton, and J. Elmberg 2009. Consequences of massive bird releases for hunting purposes: Mallard *Anas platyrhynchos* in the Camargue, southern France. Wildfowl 2:184–191.

Chardonet, Ph., B. des Clers, J. Fischer, R. Gerhold, F. Jori, and F. Lamarque 2002. The value of wildlife. Revue scientifique et technique de l'Office international des épizooties 21:15–51.

Cody, M.L. 1985. Habitat selection in birds. Academic Press, London.

Consejería de Agricultura y Medio Ambiente 1996. Decreto 141/1996, de 9 de diciembre, por el que se aprueba el Reglamento general de aplicación de la Ley 2/1993, de 15 de julio, de caza de Castilla-La Mancha. Diario Oficial de Castilla-La Mancha 57(20 December):20.

Costanza, R., R. D´Arge, R. De Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. Van Den Belt 1997. The value of the world´s ecosystem services and natural capital. Nature 387:253–260.

Cramp, S., and K.E.L. Simmons 1980. The birds of the Western Palearctic. Vol. 2. Oxford University Press, Oxford.

Cross, F.B. 1989. Natural resource damage valuation. Vanderbilt Law Review 42(2):269–321.

Daly, H.E. 1990. Towards some operational principles of sustainable development. Ecological Economics 2:1–6.

Darwin, C. 1859. On the origin of species by means of natural selection, or the preservation of favoured races in the struggle of life, first edition. John Murray, London.

Daily, G., editor 1997. Nature´s services: societal dependence on natural ecosystems. Island Press, Washington D.C.

DeStefano, S., S.L. Schmidt, and J.C. deVos 2000. Observations of predator activity at wildlife water developments in southern Arizona. Journal of Range Management 53:255–258.

Degen, A.A. 1985. Responses to intermittent water intakes in Sand Partridges and Chukar. Physiological Zoology 58:1–8.

Delibes, J. 1992. Gestión de los cotos de la perdiz roja. Pages 141–146 *in* La perdiz roja: gestión del hábitat. La Caixa, Barcelona.

Delibes, M. 1972. La caza en España. Alianza Editorial. Madrid.

Delibes-Mateos, M., P. Ferreras, and R. Villafuerte 2008a. Translocations as a risk for the conservation of European wild rabbit *Oryctolagus cuniculus* lineages. Oryx 42:259–264.

Delibes-Mateos, M., P. Ferreras, and R. Villafuerte 2008b. Rabbit populations and game management: the situation after 15 years of rabbit haemorrhagic disease in central-southern Spain. Biodiversity and Conservation 17:559–574.

Delibes-Mateos, M., P. Ferreras, and R. Villafuerte 2009. European rabbit population trends and associated factors: a review of the situation in the Iberian Peninsula. Mammal Review 39:124–140.

Díaz-Fernández S., B. Arroyo, F. Casas, M. Martinez-Haro, and J. Viñuela 2011. Effects of hunting management on red-legged partridge summer abundance. XXIX International Union of Game Biologists Congress. 5–9 September, Barcelona, Spain.

Díaz-Fernández, S., J. Viñuela, and B. Arroyo 2012. Harvest of red-legged partridge in central Spain. Journal of Wildlife Management *Online first* DOI: 10.1002/jwmg.391.

Díaz-Ruiz, F., J.T. García, L. Pérez-Rodriguez, and P. Ferreras 2010. Experimental evaluation of live cage-traps for black-billed magpies *Pica pica* management in Spain. European Journal of Wildlife Research 56:239–248.

Dirección General de Conservación del Medio Natural 1993. Resolución de 29 de marzo de 1993 por la que se regula la caza intensiva. Diario Oficial de la Generalitat Valenciana 2004(15 April).

Donald, P.F., R.E. Green, and M.F. Heath 2001. Agricultural intensification and the collapse of Europe´s farmland bird populations. Proceedings of the Royal Society of London Series B 268:25–29.

Dowell, S.D. 1992. Problems and pitfalls of gamebird reintroduction and restocking. Gibier Faune Sauvage 9:773–780.

Draycott, R.A.H., D.M.B. Parish, M.I.A. Woodburn, and J.P. Carroll 2002. Spring body condition of hen pheasants *Phasianus colchicus* in Great Britain. Wildlife Biology 8:261–266.

Draycott, R.A.H., M.I.A. Woodburn, J.P. Carroll, and R.B. Sage 2005. Effects of spring supplementary feeding on population density and breeding success of released pheasants *Phasianus colchicus* in Britain. Wildlife Biology 11:177–182.

Duarte, J. 2012. Ciclo reproductor y aprovechamiento cinegético de la perdiz roja (Alectoris rufa) en Andalucía. Dissertation, University of Málaga. Málaga, Spain.

Duarte, J., M.A. Farfán, and J.M. Vargas 2011. New data on mortality, home range, and dispersal of red-legged partridges (*Alectoris rufa*) released in a mountain range. European Journal of Wildlife Research 57:675–678.

Duarte, J., and M. Vargas 2001. Mamíferos depredadores de nidos de perdiz roja (*Alectoris rufa*) en olivares del sur de España. Galemys 13:47–58.

Duarte, J., and M. Vargas 2002. Los sumideros de perdiz roja a lo largo del ciclo anual. Pages 63–79 *in* A. Lucio, and M. Sáenz de Buruaga, editors. Aportaciones a la gestión sostenible de la caza. FEDENCA-EEC, Madrid, Spain.

Duckworth, J.C., L.G. Firbank, R.C. Stuart, and S. Yamamoto 2003. Changes in land cover and parcel size of British lowland woodlands over the last century in relation to game management. Landscape Research 28:171–182.

Duncan, R.P., T.M. Blackburn, and T.H. Worthy 2002. Prehistoric bird extinctions and human hunting. Proceedings of the Royal Society of London B 269(1490):517–521.

Escandell, V. 2006. Seguimiento de aves comunes reproductoras en España. Pages 4–9 *in* J.C. Del Moral, V. Escandell, A. Bermejo, B. Molina, and D. Palomino, editores. Programas de seguimiento de SEO/BirdLife en 2006. SEO/BirdLife, Madrid.

Etheridge, B., R.W. Summers, and R.E. Green 1997. The Effects of Illegal Killing and Destruction of Nests by Humans on the Population Dynamics of the Hen Harrier Circus cyaneus in Scotland. Journal of Applied Ecology 34(4):1081–1105.

FACE 2005. Hunting in Europe, statistics – census of the hunters in Europe. <http://www.face.eu/huntingin_census-en.htm>. Accesed 7 February 2012.

Fletcher, K., N.J. Aebischer, D. Baines, R. Foster, and A.N. Hoodless 2010. Changes in breeding success and abundance of ground-nesting moorland birds in relation to the experimental deployment of legal predator control. Journal of Applied Ecology 47:263–272.

Fontoura, A.P. 1992. Importante socio-économique de la chasse à la perdrix rouge (*Alectoris rufa*) au Portugal. Gibier Faune Sauvage 9:871–878.

Fortuna, M.A. 2002. Selección de hábitat de la perdiz roja *Alectoris rufa* en el período reproductor en relación con las características del paisaje de un agrosistema de La Mancha (España). Ardeola 49(1):59–66.

Gálvez, M.R. 2006. El derecho de caza en España. Comares, Granada.

García, A., G. Gauville, P. Landry, and A. Lartiges 1983. Influence des aménagements généralement préconisés sur une population de perdrix rouges. Bulletin Mensuel de l'O.N.C. 66:9–23.

Garrido, J.L. 2002. Capturas de perdiz roja. Pages 141–147 *in* J.A. Lucio, and M. Sáenz de Buruaga, editors. Aportaciones a la gestión sostenible de la caza, tomo I. Fedenca, Madrid.

Gaudin, J.C., and J.C. Ricci 1987. Refuge capacity of a linear environment for the red-legged partridge. Evidence of the reserve effect of such an environment. Case of the National Hunting Office's reserve at Donzere-Mondragon [*Alectoris rufa* L.]. Bulletin Mensuel de l'Office National de la Chasse 114:19–22.

Gaudioso, V.R., C. Sánchez-García, J.A. Pérez, P.L. Rodríguez, J.A. Armenteros, and M.E. Alonso 2011. Does early antipredator training increase the suitability of captive red-legged partridges (*Alectoris rufa*) for releasing? Poultry Science 90:1900–1908.

Gaudioso, V.R., C. Sánchez-García, R. Prieto, D.J. Bartolomé, J.A. Pérez, and M.E. Alonso 2010. Small game water troughs in a Spanish agrarian pseudo steppe: visits and water site choice by wild fauna. European Journal of Wildlife Research 56:591–599.

Geroudet, P. 1955. Observaciones ornitológicas en la costa catalana. Ardeola 2(1):31–56.

González-Redondo, P. 2004. Un caso de cambio en el manejo de los recursos cinegéticos: la historia de la cría en cautividad de la perdiz roja en España. Estudios agrosociales y pesqueros 204:179–203.

González-Redondo, P., M. Delgado-Pertinez, S. Toribio, F.A. Ruiz, Y. Mena, F.P. Caravaca, and J.M. Castel 2010. Characterisation and typification of the red-legged partridge (*Alectoris rufa*) game farms in Spain. Spanish Journal of Agricultural Research 8:624–633.

Gortázar, C., P. Acevedo, F. Ruis-Fons, and J. Vicente 2006. Disease risks and overabundance of game species. European Journal of Wildlife Management 52:81–87.

Gortázar, C., R. Villafuerte, M.A. Escudero, and J. Marco 2002. Post-breeding densities of the red-legged partridge (*Alectoris rufa*) in agrosystems: A large-scale study in Aragón, Northeastern Spain. Zeitschrift für Jagdwissenschaft 48:94–101.

Gortázar, C., R. Villafuerte, and M. Martín 2000. Success of traditional restocking of red-legged partridge for hunting purposes in areas of low density of northeast Spain Aragón. Zeitschrift für Jagdwis-senschaften 46:23–30.

Grado, S.C., R.M. Kaminski, I.A. Munn, and T.A. Tullos 2001. Economic impacts of waterfowl hunting on public lands and at private lodges in the Mississippi Delta. Wildlife bulletin Society 29:846–855.

Grau, S. 1973. El actual derecho de caza en España. Revista de Estudios Agrosociales 85:7–32.

Green, R.E. 1984. The feeding ecology and survival of partridge chicks (*Alectoris rufa* and *Perdix perdix*) on arable farmland in East Anglia. The Journal of Applied Ecology 21(3):817–830.

Green, R.E., M.R.W. Rands, and S.J. Moreby 1987. Species differences in diet and the development of seed digestion in partridge chicks Perdix perdix and Alectoris rufa. Ibis 129:511–514.

Guthery, F.S. 2002a. On bobwhites. Second printing, 2006. Texas A&M University Press, Texas.

Guthery, F.S. 2002b. The technology of bobwhite management: the theory behind the practice. Iowa State Press, Ames.

Guthery, F.S. 2002c. Harvest. Pages 95–114 *in* F.S. Guthery, editor. The technology of bobwhite management. The theory behind the practice. Iowa State Press, Ames.

Guthery, F.S., and N.E. Koerth 1992. Substandard water intake inhibition of bobwhite reproduction during drought. Journal of bobwhite management 56:760–768.

Guzmán-García, J.L. 2011. Variación espacio-temporal de la productividad de la perdiz roja Alectoris rufa. Master thesis, University of Castilla-La Mancha. Ciudad Real, Spain.

Halladay, P., D.A. Gilmour, editors 1995. Conserving biodiversity outside protected areas. The role of tradicional agro-ecosystems. IUCN, Cambridge.

Hennart, J.F. 1986. What is internalization? Review of World Economics 122(4):791–804.

Herranz, J. 2000. Efectos de la depredación y del control de depredadores sobre la caza menor en Castilla-La Mancha. Dissertation, Autonomous University. Madrid, Spain.

Hilborn, R., C.J. Walters, and D. Ludwig 1995. Sustainable exploitation of renewable resources. Annual Review of Ecology, Evolution and Systematics 26:45–67.

Holland, D.S. 2010. Management strategy evaluation and management procedures: tools for rebuilding and sustaining fisheries. OECD Food, Agriculture and Fisheries Working Papers, number 25, OECD, Paris, France.

Hoodless, A.N., R.A.H. Draycott, M.N. Ludiman, and P.A. Robertson 1999. Effects of supplementary feeding on territoriality, breeding success and survival of pheasants. Journal of Applied Ecology 36:147–156.

Hudson, P.J. 1992. Red grouse population studies. The Game Conservancy Trust, Fordingbrigde.

Hunter, C.M., and M.C. Runge 2004. The importance of environmental variability and management control error to optimal harvest policies. Journal of Wildlife Management 68:585–594.

Jackson, L., T. Rosenstock, M. Thomas, J. Wright, and A. Symstad 2009. Managed Ecosystems: Biodiversity and ecosystem functions in landscapes modified by human use. Pages 178–194 *in* S. Naeem, D. E. Bunker, A. Hector, M. Loreau, and C. Perrings, editors. Biodiversity, ecosystem functioning and human wellbeing. Oxford University Press, New York.

Keane, A., M. de L. Brooke, and P.J.K. Mcgowan 2005. Correlates of extinction risk and hunting pressure in gamebirds (Galliformes). Biological Conservation 126:216–233.

Laikre, L., M.K. Schwartz, R.S. Waples, and N. Ryman 2010. Compromising genetic diversity in the wild: unmonitored large-scale release of plants and animals. Trends in Ecology and Evolution 25:520–529.

Lartiges, A., and C. Mallet 1983. Conséquences sur le petit gibier de l'évolution del'agriculture française. Bulletin technique d'information 377–378:103-117.

Lee, K.N. 1993. Greed, scale mismatch, and learning. Ecological Applications 3(4):560–564.

Leopold, A. 1944. The nature of heritable wildness in turkeys. Condor 46:133–197.

Lessells, C.M., and P.T. Boag 1987. Unrepeatable repeatabilities: A common mistake. Auk 104:116–121.

Lewin, R. 1982. Extinction leaves its mark in Ecology. Science 218(4567):42–43

López-Ontiveros, A. 1986. Caza y actividad agraria en España y Andalucía: su evolución reciente. Agricultura y Sociedad 40:67–98.

López-Ontiveros, A. 1994. Caza, actividad agraria y geografía en España. Documents d´anàlisi geogràfica 24:111–130.

Lucio, A.J. 1990. Influencia de las condiciones climáticas en la productividad de la perdiz roja (*Alectoris rufa*). Ardeola 37:207–218.

Lucio, A.J. 1991. Selección de hábitat de la perdiz roja (*Alectoris rufa*) en matorrales supramediterraneos del NW de la cuenca del Duero. Aplicaciones para la gestión del hábitat cinegético. Ecología 5:337–353.

Lucio, A.J. 1998. Recuperación y gestión de perdiz roja en España. Pages 63–92 *in* FEDENCA, editor. La perdiz roja. I Curso. Grupo Editorial V, Madrid.

Lucio, A.J., and F.J. Purroy 1987. Selección de hábitat de *Alectoris rufa* en la llanura cerealista del SE de León. Pages 225–264 *in* Actas I Congreso Internacional de Aves Esteparias. 21–24 September 1987, León, Spain.

Lucio, A.J., and F.J. Purroy 1992. Red-legged partridge (*Alectoris rufa*) habitat selection in northwest Spain. Gibier Faune Sauvage 9:417–429.

Lucio, A.J., F.J. Purroy, M. Sáenz de Buruaga, and O. Llamas 1996. Consecuencias del abandono agroganadero en áreas de montaña para la conservación y aprovechamiento cinegético de las perdices roja y pardilla en España. Revista Florestal 9: 305–318.

Ludwig, D., R. Hilborn, and C. Walters 1993. Uncertainty, resource exploitation and conservation: Lessons from history. Science 260(5104):17+36.

Martínez-Garrido, E. 2009. Territorial view of the spanish cinegetic boom, 1970–1989. Boletín de la Asociación de Geógrafos Españoles 51:325–351.

Martínez, J., J. Viñuela, and R. Villafuerte 2002. Socio-economic aspects of gamebird hunting, hunting bags, and assessment of the status of gamebird populations in REGHAB countries. Report to the EC. http://digital.csic.es/handle/10261/8259.

Metra-Seis 1985. Turismo cinegético en España. Secretaría General de Turismo. Subdirección General de Infraestructura Turística. Ministerio de Transporte, Turismo y Comunicaciones. Madrid.

Messmer, T.A., M.W. Brunson, D. Reiter, and D.G. Hewitt 1999. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin 27:75–85.

Mileson, S.A. 2009. Pages 15–44 *in* J. Blair, and H. Hamerow, editors. Hunting. Medieval history and archaeology: Parks in medieval England. Oxford University Press, Oxford.

Millán, J., C. Gortázar, and R. Villafuerte 2001. Marked difference in the splachnometry of farm-bred and wild red-legged partridge (*Alectoris rufa*). Poultry Science 80:972–975.

Millán, J., C. Gortázar, and R. Villafuerte 2003. Does supplementary feeding affect organ and gut size of wild red-legged partridges *Alectoris rufa*? Wildlife Biology 9:229–233.

Millán, J., C. Gortázar, and R. Villafuerte 2004. A comparison between the helminth faunas of wild and farm-reared red-legged partridge. Journal of Wildlife Management 68(3):701–707.

Millennium Ecosystem Assessment 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington DC.

Milner-Gulland, E.J., B. Arroyo, C. Bellard, J. Blanchard, N. Bunnefeld, M. Delibes-Mateos, C. Edwards, A. Nuno, L. Palazy, S. Reljic, P. Riera, and T. Skrbinsek (2010). New directions in management strategy evaluation through cross-fertilization between fisheries science and terrestrial conservation. Biology Letters 6(6):719–722.

Ministerio de Agricultura 1953. Decreto 11 agosto 1953. Juntas provinciales de extinción de animales dañinos y protección a la caza. Constitución y funciones. BOE 261(18 September):1237.

Ministerio de Agricultura 1970. Ley 4 abril 1970, núm. 1/70. Caza. Normas reguladoras. BOE 82(6 April):579–581.

Ministerio de Economía y Hacienda 1984. Orden de 28 de diciembre de 1984 sobre actualización de rentas del Impuesto Municipal de Gastos Suntuarios en su modalidad de cotos de caza y pesca. BOE 1(1 January):5

Ministerio de Medio Ambiente y Medio Rural y Marino [MARM] 2006. Anuario de estadística forestal. MARM, Madrid. Available from http://www.marm.es/es/biodiversidad/temas/montes-y-politica-forestal/estadisticas-forestales/indice_estadisticas_forestales_2006.aspx.

Ministerio de Medio Ambiente y Medio Rural y Marino [MARM] 2008. Anuario de estadística forestal. MARM, Madrid. Available from http://www.marm.es/es/biodiversidad/temas/montes-y-politica-forestal/estadisticas-forestales/indice_estadisticas_forestales_2008.aspx.

Ministerio de Medio Ambiente y Medio Rural y Marino [MARM] 2010. Anuario de estadística forestal. MARM, Madrid. Available from http://www.marm.es/es/biodiversidad/temas/montes-y-politica-forestal/estadisticas-forestales/indice_estadisticas_forestales_2010.aspx.

Minton, A.P., and R.L. Rose 1997. The effects of environmental concern on environmentally friendly consumer behaviour: An exploratory study. Journal of Business Research 40(1):37–48.

Moreno de Arteaga, I. 1983. Algunos aspectos de la economía de la caza en España. Pages 53–76 *in* I Jornadas Nacionales de Turismo Cinegético. Almagro-Ciudad Real 1983. Dirección General de Empresas y Actividades Turísticas, Madrid.

Mulero, A. 1991. Turismo y caza en España. Estado de la cuestión. Agricultura y Sociedad 58:147–171.

Musil, D.D. 2004. Effectiveness of transplanting pheasants as a management tool. Completion report, Project W-160-R031, subproject 47. Idaho Department of Fish and Game, USA.

Mustin, K., S. Newey, J. Irvine, B. Arroyo, and S. Redpath 2011. Biodiversity impacts of game bird hunting and associated management practices in Europe and North America. Report for the Royal Society for the Protection of Birds (RSPB). The James Hutton Institute, Scotland.

Myers, S.C. 1977. Determinants of corporate borrowing. Journal of Financial Economics 5(7):147–175.

Nadal, J. 1992. Problemática de las poblaciones de perdiz roja, bases ecoetológicas para tener éxito con las repoblaciones. Pages 87-100 *in* La perdiz roja. Gestión del Hábitat. Fundación La Caixa, Barcelona.

Nadal, J., J. Nadal, and J.D. Rodríguez-Teijeiro 1996. Red-legged partridge (*Alectoris rufa*) age and sex ratios in declining populations in Huesca (Spain) applied to management. Revue d'Ecologie 51:243–257.

Navarro-Arancegui, M. 2008. El entorno económico y la competitividad en España. Serie Economía, Vol 36. University of Deusto, Bilbao.

Negro, J. J., M.J. Torres, and J.A. Godoy 2001. RAPD analysis for detection and eradication of hybrid partridges (*Alectoris rufa* x *A. graeca*) in Spain. Biological conservation 98:19–24.

Notario, A. 1992. Panorámica de la perdiz roja en España. Análisis de los factores de amenaza de sus poblaciones. Pages 5-14 *in* La perdiz roja. Gestión del Hábitat. Fundación La Caixa, Barcelona.

Novoa, C. 1984. Statut de la perdrix rouge en Languedoc-Roussillon: résultats de l'enquête nationale 1980. Bulletin Mensuel de l'Office National de la Chasse 83:37–39.

Office National de la Chasse 1986. La Perdrix Rouge. Note Technique, Fiche no. 39, Supplément au Bulletin Mensual 106.

Olivero, J., A.L. Márquez, and B. Arroyo 2011. Modelización de las áreas agrícolas y forestales de alto valor natural en España. Report to the Spanish Ministry of Environment (MARM).

Olsen, E.M., M. Heino, G.R. Lilly, M.J. Morgan, J. Brattey, B. Ernande, and U. Dieckmann 2004. Maturation trends indicative of rapid evolution preceded the collapse of northern cod. Nature 428:932–935.

Olson, S.L., and H.F. James 1982. Fossil birds from the Hawaiian Islands: Evidence for wholesale extinction by man before Western contact. Science 217(4560):633–635.

Onrubia, A. 1998. Métodos de censo y estima poblacional. Pages 49–60 *in* FEDENCA, editor. La perdiz roja. I Curso. Grupo Editorial V, Madrid.

Otero, C. 1995. Control de predadores en la gestión integrada de un territorio. Pages 151–180 *in* Predación, caza y vida silvestre: jornadas técnicas. Fundación La Caixa, Barcelona.

Otero, C. 2000. Patrimonio natural y propiedad rural en España. Exlibris, Madrid.

Palmer, W.E., S.D. Wellendorf, L.A. Brennan, W.R. Davidson, and F.E. Kellogg 2002. Hunting success and northern bobwhite density on Tall Timbers Research Station: 1970–2001. Pages 213–216 *in* Quail V: Proceedings of the Fifth national Quail Symposium. S.J. DeMaso, W.P. Kuvlesky, Jr.F. Hernández, and M.E. Berger, editors. Texas parks and Wildlife Department, Austin, USA.

Panek, M. 2005. Demography of grey partidges Perdix perdix in Poland in the years 1991-2004: reasons of population decline. European Journal of Wildlife Research 51:14-18.

Parish, D.M.B., and N.W. Sotherton 2004. Game crops as summer habitat for farmland songbirds in Scotland. Agriculture, Ecosystems and Environment 104:429–438.

Pascual, M.A., J.L. Lancelotti, B. Ernst, J.E. Ciancio, E. Aedo, M. García-Asorey 2009. Scale, connectivity, and incentives in the introduction and management of non-native species: the case of exotic salmonids in Patagonia. Frontiers in Ecology and the Environment 7(10):533–540.

Pépin, D., and J. Blayac 1990. Impacts d'un amenagement de la garrigue et de l'instauration dun plan de chasse sur la demographie de la Perdrix Rouge (*Alectoris rufa*) en milieu Mediterranen. Gibier Faune Sauvage 7:145–158.

Pérez y Pérez, F. 1981. La perdiz roja española. Ed. Científico-Médica, Barcelona.

Pérez y Pérez, F. 1992. La perdiz roja, factor de revalorización de las tierras más pobres y deprimidas de España. Nuestra Cabaña 233:50–55.

Pérez-Garrido, J.A. 2008. Determinación de los principales factores ecoetológicos de la perdiz roja (*Alectoris rufa* Linnaeus, 1758) y su aplicación a la evaluación de animales destinados a repoblación. Dissertation, University of León, León.

Ponce-Boutin, F., J.F. Mathon, and J.B. Puchala 2001. Essai de modélisation de la dynamique des populations de Perdrix Rouge *Alectoris rufa*: un outil pour la gestion des populations. Office National de la Chasse 2001:23–28.

Potts, G.R. 1986. The partridge. Pesticides, predation and conservation. Collins, London.

Potts, G.R. 1989. The impact of releasing hybrid partridges on wild red-legged populations. Game Conservancy Annual Review 20:81–85.

Punt, A.E., and G.P. Donovan 2007. Developing management procedures that are robust to uncertainty: lessons from the International Whaling Commission. ICES Journal of Marine Science 64:603–612.

R Development Core Team 2009 R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. ISBN 3-900051-07-0, URL http://www.R-project.org/.

R Development Core Team 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Ralph C.J., and J.M. Scott, editors 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology, no. 6. Allen Press, Lawrence, Kansas.

Ramalho, M., F. Lopes, and E. Cruz de Carvalho 1996. O problema da perdiz vermelha *Alectoris rufa* L. Na Contenda Norte. Revista Florestal 9:61–73.

Randi, E. 2008. Detecting hybridization between wild species and their domesticated relatives. Molecular Ecology 17:285–293.

Rands, M.R.W. 1988. The effect of nest site selection on nest predation in Grey Partridge *Perdix perdix* and Red-legged partridge *Alectoris rufa*. Ornis Scandinavica 19:35–40.

Rao, M., S. Htun, T. Zaw, and T. Myint 2010. Hunting, livelihoods, and declining wildlife in the Hponkanrazi Wildlife Sanctuary, North Myanmar. Environmental Management 46:143–153.

Reboussin, B. 1991. Fonctions et significations sociales de la chasse: exemple de la chasse de Francueil (Indre et Loire). Bulletin Mensuel de l´Office National de la Chasse 161:41–48.

Rengifo, J.I. 2008. Un segmento del turismo internacional en auge: el turismo de caza. Cuadernos de Turismo 22:187–210.

Reudet, D. 1992. Etude des éléments du milieur nécessaires à la fixation d'un couple de perdrix rouge sur l'île de Porquerolles. Master thesis, University Montpellier 2. Montpellier, France.

Reynolds, J.C., and S.C. Tapper 1996. Control of mammalian predators in game management and conservation. Mammal Review 26:127–156.

Ricci, J.C. 1985. Influence de l'organisation sociale et de la densité sur les relations spatiales chez la perdrix rouge. Conséquences démographiques et adaptatives. Revue d'Ecologie (la Terre et la Vie) 40:53–85.

Ríos-Saldaña, C.A. 2010. Los planes técnicos de caza de Castilla-La Mancha y su aplicación en la gestión y conservación de las especies cinegéticas. Dissertation, University of Castilla-La Mancha, Ciudad Real, Spain.

Robertson, P.A., K.J. Park, and A.F. Barton 2001. Loss of heather *Calluna vulgaris* moorland in the Scottish uplands: the role of red grouse *Lagopus lagopus scoticus* management. Wildlife Biology 7:11–16.

Rocamora, G., and D. Yeatman-Berthelot 1999. Oiseaux menaces at à surveiller en France. Listes rouges et recherches de priorités. Societé d´Estudes Ornithologiques de France/Ligue pour la Protection des Oiseaux, Paris.

Rodríguez, A., and M. Delibes 2004. Patterns and causes of non-natural mortality in the Iberian lynx during a 40-year period of range contraction. Biological Conservation 118:151–161.

Rose, A.L. 2001. Social changes and social values in mitigating bushmeat commerce. Pages 59–74 *in* M.I. Bakaar, G.A.B.D. Fonseca, R.A. Mittermeier, A.B. Rylands, and K.W. Painemilla, editors. Hunting and bushmeat utilisation in the African Rain Forest: perspectives towards a blue print for conservation action. Conservation International, Washington.

Rueda, M. J., J.R. Baragaño, and A. Notario 1992. Alimentación natural de la perdiz roja (*Alectoris rufa* L.). Pages 27–40 *in* La perdiz roja. Gestión del hábitat. Fundación La Caixa, Barcelona.

Sahoo, D. 2002. Towards a blue revolution in the sea. Pages 1–20 *in* D. Sahoo, and P.C. Pandey, editors. Advance in marine and antarctic science. S.B. Nangia and A.P.H. Publishing Corporation, New Delhi.

Sahlsten, N., N. Bunnefeld, J. Månsson, G. Ericsson, R. Bergström, and H. Dettki 2010. Can supplementary feeding be used to redistribute moose *Alces alces*? Wildlife Biology 16(1):85–92.

Sauer J.R., J.E. Hines, and J. Fallon 2008. The North American breeding bird survey, results and analysis 1966-2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel.

Schluter, M., R.Rj. Mcallister, R. Arlinghaus, N. Bunnefeld, K. Eisenack, F. Holker, E.J. Milner-Gulland, and B. Muller 2012. New horizons for managing the environment: a review of coupled social-ecological systems modeling. Natural Resource Modelling 25:219–272.

Shen, J. 2012. Understanding the determinants of consumers´ willingness to pay for eco-labeled products: An empirical analysis of the China Environmental Label. Journal of Service Science and Management 5:87–94.

Simpson, E.H. 1949. Measurement of diversity. Nature 163:688.

Smith, A. 1776. An inquiry into the nature and causes of the wealth of nations. *In* R.H. Campbell, A.S. Skinner, and W.B. Todd, editors 1981. The Glasgow edition of the works and correspondence of Adam Smith. LibertyClassics, Indianapolis.

Sokos, C.K., P.K. Birtsas, and E.P. Tsachalidis 2008. The aims of galliforms release and choice of techniques. Wildlife Biology 14:412–422.

Sotherton, N., S. Tapper, and A. Smith 2009. Hen harriers and red grouse: economic aspects of red grouse shooting and the implications for moorland conservation. Journal of Applied Ecology 46:955–960.

Tapper, S.C., editor 1999. A question of balance. Game animals and their role in the British countryside. The Game Conservancy Trust, Fordingbridge.

Tapper, S.C., G.R. Potts, and M.H. Brockless 1996. The effect of an experimental reduction in predation pressure on the breeding success and population density of grey partridges *Perdix perdix*. Journal of Applied Ecology 33:965–078.

The Wildlife Society 2012. Position Statement of The Wildlife Society on Shooting Preserves. Available in: <http://joomla.wildlife.org/documents/positionstatements/Shoooting_Preserves_comment.pdf>. Accessed 26 Feb 2012.

Thirgood, S., S. Redpath, I. Newton, and P. Hudson 2000. Raptors and red grouse: conservation conflicts and management solutions. Conservation Biology 14:95–104.

Valkama, J., E. Korpimäki, B. Arroyo, P. Beja, V. Bretagnolle, E. Bro, R. Kenward, S. Mañosa, S.M. Redpath, S. Thirgood, and J. Viñuela 2005. Birds of prey as limiting factors of gamebird populations in Europe: a review. Biological Reviews 80:171–203.

Van Poorten, B.T, R. Arlinghaus, K. Daedlow, and S.S. Haertel-Borer 2011. Social-ecological interactions, management panaceas, and the future of wild fish populations. Proceedings of the National Academy of Sciences USA 108:12554–12559.

Vargas, J.M., J. Duarte, and M.A. Farfán 2011. Red-legged partridge (*Alectoris rufa*) chick survival in relation to habitat structure in Mediterranean farmlands. Page 300 *in* XXX IUGB Congress and Perdix XIII. 5–9 September, Barcelona, Spain.

Vargas, J.M., J.C. Guerrero, M.A. Farfán, A.M. Barbosa, and R. Real 2006. Land use and environmental factors affecting Red-legged Partridge (*Alectoris rufa*) hunting yields in southern Spain. European Journal of Wildlife Research 52:188–195.

Vicente, J., U. Höfle, J.M. Garrido, I.G. Fernandez-de-Mera, P. Acevedo, R. Juste, M. Barral, and C. Gortázar 2007. Risk factors associated with the prevalence of tuberculosis-like lesions in fenced wild boar and red deer in south central Spain. Veterinary Research 38:451–464.

Villafuerte, R., J. Viñuela, and J.C. Blanco 1998. Extensive predator persecution caused by population crash in a game species: the case of red kites and rabbits in Spain. Biological Conservation 84:181–188.

Villanúa, D. 2007. Parásitos de la perdiz roja (*Alectoris rufa*): Implicaciones para su aprovechamiento cinegético y conservación. Dissertation, University of Castilla-La Mancha. Ciudad Real, Spain.

Villanúa, D., F. Casas, J. Viñuela, C. Gortázar, E. García De La Morena, and M. Morales 2007. First occurrence of *Eucoleus contortus* in a Little Bustard *Tetrax tetrax*: Negative effect of Red-legged Partridge *Alectoris rufa* releases on steppe bird conservation? Ibis 149:405–406.

Villanúa, D., L. Pérez-Rodríguez, F. Casas, V. Alzaga, P. Acevedo, J. Viñuela, and C. Gortázar 2008. Sanitary risks of red-legged partridge releases: Introduction of parasites. European Journal of Wildlife Research 54:199–204.

Viñuela, J., and B. Arroyo 2002. Gamebird hunting and biodiversity conservation: synthesis, Recommendations, and future research priorities. Unpublished report to REGHAB Project (EKV-2000-00637). European Commission.

Virgós, E., and A. Travaini 2005. Relationship between small-game hunting and carnivore diversity in central Spain. Biodiversity and Conservation 14:3475–3486.

Watson, M., N.J. Aebischer, G.R. Potts, and J.A. Ewald 2007. The relative effects of raptor predation and shooting on overwinter mortality of grey partridges in the United Kingdom. Journal of Applied Ecology 44:972–982.

Weiss, E.B. 1992. Conference on human rights, public finance, and the development process. In fairness of future generations and sustainable development. American University Journal of International Law and Policy 8(9):19–26.

Whitfield, D.P., D.R.A. McLeod, J. Watson, A.H. Fielding, and P.F. Haworth 2003. The association of grouse moor in Scotland with the illegal use of poisons to control predators. Biological Conservation 114(2):157–163.

Williams, D., P. Acevedo, C. Gortázar, M.A. Escudero, J.L. Labarta, J. Marco, and R. Villafuerte 2007. Hunting for answers: rabbit (*Oryctolagus cuniculus*) population trends in north-eastern Spain. European Journal of Wildlife Research 53:19–28.

Woodworth, P. 2006. What price ecological restoration? Scientist 20:39–45.

Yanes, M., J. Herranz, J. de la Puente, and F. Suárez 1998. La Perdiz Roja. Identidad de los depredadores e intensidad de la depredación. Pages 135–147 *in* FEDENCA, editor. La Perdiz Roja. I curso. Grupo Editorial V, Madrid.

CONCLUSIONS / CONCLUSIONES

1. In Spain, red-legged partridge hunting is generally a complementary economic activity, and not a substitute, to other land uses as agriculture, livestock rearing and forestry in hunting estates.

2. Currently, commercialization of red-legged partridge hunting has implications on game and hunting management and on production. In the estates that commercialize red-legged partridge hunting as compared to non-commercial ones there are more and larger farm-reared partridge releases, more predators controlled, more food and water supplementation points, more gamekeepers hired and more partridges harvested. These increasing patterns of more intense management exist also within commercial estates, from commercial non-intensive to commercial intensive ones. On the contrary, the area covered by agricultural habitats and permanent crops is usually smaller in commercial estates, being substituted with *dehesas* or other more naturalized vegetation.

3. In contrast to what is sometimes stated, commercial estates do not leave lower densities in the field and do not hunt more time per unit area. Average summer red-legged partridge density did not vary significantly among estates in relation to commercialization or to the ownership of the legal "intensive" label (although the highest densities were always found in commercial non-intensive estates). Annual hunting pressure does not vary either, although their components do: commercial estates increase the number of hunting days/year and reduce the number of hunters/(km^2×hunting day).

4. In Central Spain, variation between estates in red-legged partridge harvest is related to both partridge availability and hunting pressure, but with marked differences between intensive and non-intensive estates. In intensive estates, harvest is linearly dependent exclusively on release intensity with a mean return on harvest of annual partridge releases of around 45%. In non-intensive estates, harvest increases with walked-up shooting hunting pressure, whereas

wild partridges and harvest have a scattered relationship at low densities (abundance index < 5). The main effect of habitat is an increase of harvest with increasing proportions of Mediterranean shrubland within a studied range from 0 to 79.3% (mean±SD = 24±25%).

5. Summer densities are similar in intensive than in non-intensive estates. In intensive estates there is no relationship between harvest and summer partridge abundance, confirming that in these estates hunting is detached from *in situ* natural resource management and is approaching an industrial activity based on external inputs. On the other hand, supplementing partridges in low numbers (our studied range was from 12 to 189 partridges/km^2), as it is made in non-intensive estates, has no noticeable effect on harvest.

6. Annual farm-reared partridge releases in low numbers to maintain hunting activity thus do not imply higher profitability of red-legged partridge hunting in the estates that use this practice. Current prices, legal mandatory expenses, and expenses of farm-reared partridges restocking are the main reasons that set red-legged partridge hunting in the limit of profitability in estates whose wild red-legged partridge current densities make this hunting just a complementary activity. Thus, ecological risks that releases are posing on wild red-legged partridge populations are not being compensated indeed in economical terms for private managers, and thus, to increase benefits of this hunting, the investments should be redirected from restocking to improving technical efficiency of wild population's management.

7. From our results, the generalization of annual partridge releases in low harvest hunting estates may be explained by the Real Options (*options to defer* and *to expand*) that restocking gives to the estate economy, restocking that would increase directly the net value of red-legged partridge hunting in the estate if their effect in harvest would be additive. The scarce technical and economic evaluation of hunting management in estates where partridge hunting is considered a complementary activity, implies a probable lack of knowledge

that these low intensity releases have no an additive effect; they have scarce efficacy to increase the total annual harvest, and they are probably reducing the future wild harvest. This lack of knowledge would favour that Real Options, more intuitive, were weighting more to make management decisions that net economic results of hunting management.

8. In central Spain, greater post-breeding red-legged partridge abundances were found in estates with mixed farmland and Mediterranean scrub, and greater densities of supplementary food and water points. As food and water supplementation explained better than habitat partridge abundance, we may suspect possible problems of food availability in the surrounding habitat, whose improvement should be compared in economic terms with that of provision of supplementary food, which we found as an important percentage of expenses in hunting estates. Partridge releases did not seem to increase summer densities, on the contrary, releases were negatively related to partridge productivity (lower ratios of young to adult were found in estates that release more frequently or intensively). More research is needed to assess which is the most important of several possible non-exclusive explanations for this result.

9. If predator control currently used in hunting estates had an effect on harvest or summer wild red-legged partridge abundance, this was lesser than the effect of habitat, food and water supplementation (positive), harvest intensity (negative) or releases (negative). Due to the cost this practice may imply in terms of both biodiversity conservation and economic results in hunting estates, the real usefulness of this practice should be additionally investigated, , at least as currently implemented.

10. This dissertation defined the generic functions defined to calculate each main expense and revenue item in a red-legged partridge hunting estate.

11. The main expenses (17) and revenues (5) currently attributable to red-legged partridge hunting in estates refer to releases, supplementation of water and

food, predator control, staff, hunting rights value and taxes. On average, the greatest proportion of expenses is that of labour, except in intensive estates where the expenses on farm-reared partridges surpassed it. Expenses of hunting rights or expenses on the purchase of wheat delivered in the estate for food-supplementation devices are lesser, but also great in relation to the rest of items. In particular, taxes (for the region and the town) implied in our sample an average 3.9%±2.7 of the total expenses in the estate. Conclusively, indirect beneficiaries of expenses in red-legged partridge hunting management in estates are mainly the local labour force, the farm-reared partridge industry, the land proprietaries, and the wheat producers.

12. Estates that release annually thousands of partridges (intensive) obtain greater profits and greater turnover per square kilometre and per partridge hunted than others. In spite of the greater annual expenses per square kilometre in operational, staff and capital costs in intensive estates, expenses per partridge hunted are less. Almost unlimited offer of partridges, the elasticity of their offer to cover hunting market demands, Real Options to expand and extend annual investments, and lack of internalization of ecological risks of farm-reared partridge restocking give to this business model a greater competitiveness face to the management of only wild red-legged partridge hunting, if they compete within the same market, at the same prices.

13. Non-intensive estates without releases, particularly in the average-to-high price scenarios, may currently be a profitable business, although their benefits are not comparable to those of intensives estates. More technical efficiency, greater market prices, and real possibility of distinguishing its product (real wild partridges) in the market would increase the interest of promoters in this business model.

14. In Spain, the current commercial offer of wild partridge driven shooting hunts is very scarce.

15. In the red-legged partridge hunting market that contact buyers through advertisements in specialized magazines and on the internet, there is a large variation in prices of walked-up shoots, but the price of a hunt is not explained significantly by the origin of partridges to be hunted (wild/farm), the landscape naturalization in the estate, the possibility of hunting wild rabbit without additional costs or the number of hunters taking part in the hunt. For driven shooting hunts there is also a large variation in prices, but this variation is not related to landscape naturalization or to the number of hunters taking part in the hunts. Due to our small sample size and small segment of the market studied here, more work should be done to state reliable conclusions on this issue.

1. En los cotos españoles, la caza de perdiz roja es generalmente una actividad económica complementaria, y no sustitutiva, de otros usos de la tierra como agricultura, ganadería o uso forestal.

2. Actualmente, la comercialización de la caza de perdiz roja tiene implicaciones en su gestión y su producción. En los cotos que comercializan la caza de perdiz roja se sueltan más perdices de granja, se controlan más depredadores, se suplementa agua y comida en más puntos, se contratan más guardas de caza y se cazan más perdices, que en cotos que no comercializan la caza. Estos patrones crecientes de la intensidad de gestión se encuentran también dentro de los cotos comerciales, creciendo de los comerciales no intensivos a los comerciales intensivos. Sin embargo, el área que ocupan los cultivos agrícolas y los cultivos permanentes es menor en cotos comerciales, siendo sustituida en ellos por dehesas u otra vegetación más naturalizada.

3. Al contrario de lo que a veces se afirma, anualmente, los cotos comerciales no dejan menor abundancia en el campo y no cazan más tiempo por unidad de superficie que los no comerciales. La abundancia estival de perdiz roja no varía de forma significativa entre cotos en relación a la comercialización de la caza o a la disponibilidad de la etiqueta legal de coto "intensivo" (aunque las mayores abundancias fueron siempre encontradas en cotos comerciales no intensivos).

La presión de caza tampoco varía, aunque sus componentes lo hacen: los cotos comerciales aumentan el número de días de caza/año y reducen el número de cazadores/(km^2 × día de caza).

4. En España central, la bolsa de caza anual de perdiz en los cotos está relacionada tanto con la disponibilidad de perdices en el campo como con la presión de caza, pero con marcadas diferencias entre los cotos intensivos y los no intensivos. En los cotos intensivos, la bolsa de caza depende linealmente y en exclusiva de la intensidad de suelta, con un retorno medio de un 45% de las perdices soltadas. En los cotos no intensivos, la bolsa de caza aumenta con la presión de caza en mano, mientras que la disponibilidad de perdiz y la bolsa de caza tienen una relación dispersa a bajas abundancias (índice de abundancia < 5). Por otro lado, la bolsa de caza aumenta cuando aumenta la proporción de arbusto mediterráneo, dentro del rango estudiado de 0 a 79.3% del coto (media ± SD = 24 ± 25%).

5. Las densidades estivales son iguales en cotos intensivos que en cotos no intensivos. Pero en los cotos intensivos la bolsa de caza y la abundancia estival de perdiz no tienen relación, confirmando que en estos cotos la caza se aleja de la gestión *in situ* de recursos naturales y se aproxima a una actividad industrial basada en materias primas externas. Por otro lado, la suelta de perdices en pequeñas cantidades (nuestro rango estudiado ha ido de 12 a 189 perdices / km^2), cuando se hace en cotos no intensivos, no tiene efecto apreciable en la bolsa de caza.

6. Las sueltas anuales de perdiz de granja de baja intensidad que se hacen para mantener la actividad cinegética no implican rentabilidad de la caza de perdiz para los cotos. Los precios actuales, los costes de la guardería, y los costes de las sueltas son las razones principales que sitúan la caza de perdiz roja en el límite de la rentabilidad en cotos cuyas bajas abundancias silvestres hacen considerar a esta caza una actividad complementaria de las fincas. Por tanto, los riesgos ecológicos que las sueltas están suponiendo para las poblaciones

silvestres no están siendo compensados ni siquiera en términos económicos para los gestores privados, y por tanto, para aumentar los beneficios que supone esta caza, las inversiones en los cotos han de redireccionarse de la suelta hacia la mejora de la eficiencia técnica de la gestión de las poblaciones silvestres, y a diferenciar claramente la calidad ecológica del producto en el mercado.

7. Dados nuestros resultados, la generalización de las sueltas anuales en cotos de baja extracción se puede explicar en gran parte por las Real Options (en este caso, opciones de retraso y de expansión) que proporcionan las sueltas a la economía del coto, la cuales aumentarían de forma directa el valor de la caza de perdiz roja en el coto si el efecto de estas sueltas fuera aditivo. La escasa evaluación técnica y económica de la gestión en cotos donde la caza de perdiz se considera una actividad complementaria, implica un probable desconocimiento de que estas sueltas (de baja intensidad) no tienen un efecto aditivo, sino que son poco eficaces para el aumento de la bolsa de caza total anual, y negativas para el aumento de la bolsa de caza silvestre total futura. Este desconocimiento favorecería que las Real Options, más intuitivas, pesen más en la toma de decisiones que los resultados económicos netos que supone esta práctica.

8. En España central, encontramos mayores abundancias estivales de perdiz roja en cotos con mezcla de tierras de cultivo y matorral mediterráneo, y con mayor densidad de puntos de suplementación de alimento y agua. Además, la suplementación explica mejor que el hábitat la abundancia de perdiz, por lo que podemos suponer problemas de disponibilidad de alimento en el hábitat. Dado que la provisión de alimento suplementario supone un importante porcentaje de los gastos medios de los cotos de caza, debería ser comparada económicamente con la mejora del hábitat, para optimizar la gestión. Las sueltas de perdiz no parecen aumentar las densidades estivales, al contrario, las sueltas estuvieron negativamente relacionadas con la productividad de perdiz (se encontraron menores ratios de jóvenes-adultos en cotos que sueltan más frecuentemente o

más intensivamente). Se necesita más investigación para determinar cual es la explicación más importante de todas las posibles explicaciones de este resultado.

9. Si el control de depredadores que actualmente se aplica en los cotos de caza tuviera un efecto en la bolsa de caza o en la abundancia estival de perdiz roja, sería menor que el efecto que tiene el hábitat, la suplementación de comida y agua (efecto positivo), la intensidad de caza (efecto negativo) o las sueltas (efecto negativo). En consecuencia, la utilidad de esta práctica tal como se aplica en la actualidad podría no justificar sus costes, ni en términos de conservación de biodiversidad, ni en términos económicos en los cotos de caza.

10. Esta tesis ha definido las funciones genéricas para calcular cada partida de gastos e ingresos en un coto de caza de perdiz roja.

11. Las principales partidas de gastos (17) e ingresos (5) actualmente atribuibles a la caza de perdiz roja en cotos se refieren a sueltas, suplementación de agua y comida, control de depredadores, personal, valor de los derechos de caza e impuestos. De media, la mayor proporción de gastos corresponde a la mano de obra, excepto en los cotos intensivos donde la proporción de gastos en perdices de granja la sobrepasa. Los gastos en derechos de caza o en trigo para rellenar comederos son menores, pero también grandes en relación al resto de partidas. En particular, los impuestos (matrícula y gastos suntuarios) implicaron en nuestra muestra una media de 3.9%±2.7 del total de gastos en los cotos. En conclusión, los beneficiarios indirectos de los gastos en la gestión de caza de perdiz roja en los cotos son principalmente la mano de obra local, la industria productora de perdiz de granja, los propietarios de la tierra, y los productores de trigo.

12. Los cotos que sueltan anualmente miles de perdices (intensivos) obtienen mayor rentabilidad y mayores beneficios por kilómetro cuadrado y por perdiz cazada. A pesar de los mayores costes anuales por kilómetro cuadrado en

costes operacionales, de personal y de capital de los cotos intensivos, sus costes por perdiz cazada son menores. Su oferta casi ilimitada de perdices, la elasticidad de su oferta para cubrir la demanda del mercado, sus Real Options de expansión, extensión y cambio de las inversiones anuales, y la ausencia de internalización de los riesgos ecológicos de las sueltas da a este modelo de negocio una mayor competitividad frente a la gestión exclusiva de perdiz silvestre, cuando ambos modelos compiten en el mismo mercado, al mismo precio.

13. Los cotos no intensivos sin sueltas, particularmente en escenarios de precios medios a altos, pueden ser actualmente negocios rentables, aunque sus beneficios no sean comparables con los de los cotos intensivos. Mayor eficiencia técnica, precios más altos y la posibilidad real de distinguir su producto (perdiz silvestre real) en el mercado aumentarían el interés de los promotores por este modelo de negocio.

14. En España, la actual oferta comercial de ojeos de perdiz silvestre es muy escasa.

15. En el segmento del mercado de la caza de perdiz roja que usa anuncios en revistas especializadas y en internet para contactar con los cazadores, hay una gran variación en el precio de las cacerías en mano, pero este precio no se explica ni por el origen de las perdices para ser cazadas (silvestre/granja), ni por la naturalización del paisaje en el coto, ni por la posibilidad de cazar conejo silvestre sin costes adicionales, ni por el número de cazadores que toman parte en la cacería. En ojeos también hay una gran variación de precios, pero esta variación tampoco está relacionada con la naturalización del paisaje o ni con el número de cazadores que toman parte en la cacería. Debido a nuestro pequeño tamaño de muestra y al pequeño segmento de mercado al que se refiere este resultado, se necesita más trabajo para obtener conclusiones sólidas generalizables a todo el mercado cinegético.

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