Control of the European rabbit in central Spain

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Abstract

The European rabbit is a growing problem for agriculture in parts of its natural range. In this paper, our aim was to use historical records over two periods within the last 50 years to analyze trends in the number of requests made for rabbit control in Central Spain. We gathered data on rabbit control applications made for 1967(derived from Rabbit and Hare Control Authorization Records) and corresponding information for 2005 from Technical Hunting Plans. Technical Hunting Plans are currently the official mechanism to apply for rabbit control licenses in the country. We show that although only 4.2% of municipalities requested to control rabbits in 1967, this proportion was 71% in 2005. Given that there is no evidence of rabbit increases in the study region, we suggest that other factors may explain the observed increase in such requests. We argue that sport hunting, which has risen significantly since the 1960ssupported by the fact that the shotgun was the most requested method of control, is the main reason for this rise in rabbit control requests. We recommend the creation of a more detailed form, similar to that used in Spain in the 1960s, in which the reason(s) for a rabbit control request can be clearly declared. The use of such a document would allow managers to obtain a more realistic assessment of rabbits as a pest.

Keywords: Vertebrate pest; keystone species; crop damage; *Oryctolagus cuniculus*; hunting.

Introduction

The European rabbit (*Oryctolagus cuniculus*) is native to the Iberian Peninsula (Monnerot et al. 1994). The species is considered to be a keystone species in Mediterranean ecosystems (Delibes-Mateos et al. 2007) since it is a prey to more than 40 species in these environments (reviewed in Delibes-Mateos et al. 2008). Rabbits are also viewed as ecosystem engineers (e.g., Gálvez-Bravo et al. 2009) and are one of the most important game species in the Iberian Peninsula (e.g., Angulo and Villafuerte 2003).

Rabbits have been introduced to many regions of the world (Flux and Fullagar 1992), and have rapidly become major environmental and agricultural pests (e.g., Mills 1986; Thompson and King 1994). Although most Iberian rabbit populations have declined dramatically in recent decades (Villafuerte and Delibes-Mateos 2008; Delibes-Mateos et al., 2009a), the species is an agricultural pest in some regions (Barrio 2010; Barrio et al. 2010).

Herbivorous vertebrate pests significantly affect agricultural interests by browsing foliage, debarking trees, grazing pasture and eating crops. Although there are examples of invasive species becoming pests (i.e. Chapman 2003; Elliot 1989; Engeman 2004), keystone species which play a major role in an ecosystem are rarely regarded pests in their native ranges. Examples of keystone species that affect farming activities include pikas (*Ochotona curzoniae*) on the Tibetan plateau (Smith and Foggin 1999) and prairie dogs (*Cynomys* spp.) in the North American prairies (Kotliar 2000). In the Iberian Peninsula, rabbits may parallel prairie dogs and plateau pikas because of their direct impact on crops, and the associated socioeconomic impacts of this damage (Delibes-Mateos et al. 2011).

Recent research on the control of rabbit populations emerged from countries where the species has been introduced. Information on the ecological and economic the effects of rabbits, as well as mechanisms for their control (e.g. poisoning, gassing and destruction of burrows, release of predators, erection of wire fences, myxoma and rabbit hemorrhagic disease viruses as biological control agents) are available for Australia(Cooke 2008). However, data of the impact of rabbits in Iberia are relatively scarce (however, see Barrio et al. 2010).

Research on rabbits in the Iberian Peninsula, which mainly commenced in the 1970s, has focused primarily on the causes and consequences of population declines (Piorno 2006; Delibes-Mateos et al. 2009a). However, rabbit populations causing crop damage have been little studied (i.e. Catalan et al. 2010). As a consequence, current, but also historical rabbit control, remain virtually unknown. Given the high ecological prominence of rabbits in the Iberian Peninsula, understanding situations in which the species is at conflict with human interest is important for rabbit management.

The ability to detect the effects of short- and long-term processes may be clouded by collective “amnesia”, or ignorance of past human events and their residual effects on landscapes (Dovers 2000). Thus, to understand ecosystems and facilitate appropriate management scientists and managers must explore environmental history (Swetnam et al. 1999). The use of historical perspectives will better our understanding of natural dynamics.

In Spain, to the best of our knowledge, there is only one historical data source on rabbit control : the Rabbit and Hare Control Authorization Records

(CARs). As early as the 1960s, these records resulted , from applications made by landowners seeking to protect agricultural crops and areas of reforestation from rabbit damage. These documents were requested by the Central Government throughout the 1960s but no records were kept after 1970. Subsequently, Spanish legislation dictated that hunters were responsible for any agricultural damage caused by game species, and commencing in the 1990s, all requests for rabbit control would have to feature within a hunting estate's Technical Hunting Plans (THPs; Gávez 2004). These documents have been mandatory since 1990 and are periodically submitted to the appropriate Regional Government (depending on the Region, every These documents have been mandatory since 1990 and are periodically submitted to the appropriate Regional Government (depending on the Region, 4 to 5 every years). Their main goal is to protect and foster game variety. To this end, the intention to carry out the main management practices (including rabbit control) and the expected hunting bag sizes must be reported in the document (Vargas et al. 2006). In summary, information on rabbit control over two distinct periods is available.

In the present study, our principal objectives were i) to compare the number of rabbit control requests made in the 1960s and during 2005; ii) to describe the principal rabbit control methods currently employed in Central Spain (the Castilla-La Mancha region); iii) to explore whether municipalities that requested rabbit control during the 1960s currently report high levels of rabbit abundance; iv) to analyze the principal land types for which rabbit control was requested during the 1960s and recently; and v) to analyze whether current rabbit control is performed principally in regions of high rabbit abundance.

Materials and Methods

Regulation and management of European rabbits causing crop damage in Spain

In Central Spain (Castilla-La Mancha) agricultural areas are highly favorable for rabbits and red-legged partridges (*Alectoris rufa*); here, both species are present at their highest recorded densities (e.g., Villafuerte and Delibes-Mateos 2008). Because of this abundance, farmers take advantage of hunting as an additional resource. Because hunting is only allowed in "hunting estates", farmers may either create a hunting estate, or grant permission (e.g., by renting out the land) to a game manager or hunting association to hunt on their land (see below). Currently, there are almost 6,000 hunting estates in Castilla-La Mancha covering about 84% of all land (Ríos-Saldaña 2010).

In Spain, some Regional Governments have recently approved special guidelines for the control of rabbits in response to concerns regarding crop damage. Valencia (E Spain) issued a relevant Order on June 11, 2009 and Andalucía (in S Spain) promulgated a Resolution on June 30, 2011. The control of rabbits is not regulated by Pest Laws of Spain (e.g., see the Royal Order of April 19 of 1929; the Order of April 20 of 1932; and the Law of 20 December 1952, all of which seek to protect forests from pests). This is because Hunting Laws regulate the control and management of damage caused by game species. The Laws are based on the Hunting Act of May 16 1902, which states (article 9): "Any farm owner can legally hunt on that farm, but will be directly responsible under the Civil Code for damage caused by such hunting to the

property of adjacent property owners". This principle remains in force, and is currently included in all Laws dealing with damage caused by game species. For example, the Hunting Act of April 4 of 1970 includes a section (Title V) devoted to liability for damage. Article 33 states that "holders of hunts will be responsible for damage caused by game to neighboring lands; the owner of the land is the person who will be held to account". The current laws of most Regional Governments contain essentially identical text (i.e., that of Castilla-la Mancha, Central Spain; Article 17 of Law 2; 15 July 1993).

The THPs of some regions (including Castilla-la Mancha) contain specific sections detailing how rabbits are to be controlled when they cause damage to crops. Managers must register their intent to control the species, and must identify the proposed control period as well as the preferred control method. A permit is usually granted after the extent of crop damage is formally assessed. "Control" refers to practices used to reduce rabbit numbers to alleviate agricultural damage.

As the rabbit is a game species, shooting is considered an important control method in Spain. Rabbit hunting periods, regulated by the Spanish government, have not changed since at least 1902; shooting being permitted October - December inclusive (Angulo and Villafuerte 2003). However, when control is required, shooting outside of this time period may be allowed. In addition, ferrets (Cowan 1984) and corral trapping (employing a wire-fenced trap resembling the gill net described by Shepherd and Williams 1976) are also used to control rabbits. The trap-and-snare method, the exclusive means of rabbit eradication 40 years ago, is currently prohibited.

Data sources and analysis

We collected and analyzed rabbit control applications made during the 1960s and in 2005, based on data from the Rabbit and Hare CARs and the THPs, respectively. The CARs are historical records collected from the early 1960s; the principal goal of the CAR system was to protect agricultural crops and areas of reforestation from rabbit damage. In each CAR, an estate manager requesting rabbit control detailed the farm location and the type of crop damaged. We selected CARs for 1967 because, prior to this year no property application form was required. Moreover, most CARs post-1967 were not available. We obtained 110 CARs filed in 1967 (>99% of all CARs for that year) . and 5,357 THPs for 2005 (100%). We used a chi-squared test to determine whether numbers of municipalities in each province requesting rabbit control were significantly different between 1967 and 2005.

Because managers record in THPs the specific control methods planned for use in the game estates we could determine the preferences for the different types of control methods used. Because managers typically request more than one control method, the main combinations of control methods requested were also analyzed.

To explore whether municipalities that requested rabbit control in 1967 currently have high rabbit numbers, we used average hunting yields (HYs) as estimates of rabbit abundance, as it is known that such yields realistically identify areas rich or poor in Iberian small game species at a macro-

geographical scale (Vargas et al. 2006; Farfán et al. 2008). Average HYs were estimated from THP data reported by the game estates. Digital maps of the estates were not available, so we assigned each estate to the appropriate municipality and estimated the average HY of rabbits in each municipality as:

$$HY = \frac{\text{Total number of rabbits captured in the game estates in the previous hunting season}}{\text{Total area of the game estates (ha)}} x\ 100$$

where HY is the hunting yield per municipality, expressed as the number of rabbits captured per 100 ha (1 km^2) of game estate (e.g., Delibes-Mateos et al. 2009b).

THP data for 2005 were compared, using one-way ANOVA, with rabbit abundance in municipalities that requested control during 1967 (n=36) and hunting estates within municipalities where such management was not performed (n=883). We also determined whether 2005 rabbit abundance levels differed significantly among hunting estates. Each dependent variable was normalized using the log (x + 1) transformation (Zar 1999).

We used information from the CARs and THPs to assess whether agricultural and forest resource areas in which rabbits caused most damage during 1967 and 2005. Land use was evaluated according to six main categories: cereal crops, olive groves, vineyards, grasslands, forests (including scrublands, native forest, and reforestation), and “other” (including cotton, garden crops, vegetables, legumes and unspecified crops). We determined the land types affected by rabbit damage within each municipality during 1967 from

data contained in the CARs. As land type damaged by rabbits in hunting estates was not specified in THPs we calculated the total surface area of each land use within hunting estates that had requested rabbit control, assigned a predominant land use type to each municipality, and assumed that this was the land type affected by rabbit damage. We used a chi-squared test to compare differences in the number of rabbit control requests per land use type between 1967 and 2005.

To explore whether any relationship existed between the control method requested and rabbit abundance (measured as HY), we performed a binary logistic regression on data derived for each control method used (shotgun, ferret control, and corral trap). To determine whether the type of rabbit control used was related to local rabbit abundance and/or current land use status, we used logistic regression to analyze the HY data in the THPs. We calculated the accuracy of prediction revealed by the area under the receiver operating characteristic (ROC) curve in a goodness-of-fit model (AUC; Fielding and Bell 1997; Manel et al. 2001; Brown and Davis 2006). All statistical testing employed SPSS for Windows (version 12, SPSS Inc.).

Results

The distribution of rabbit control requests in central Spain has changed during the past 50 years. The proportion of municipalities in each province requesting rabbit control during 1967 and 2005 differed significantly [χ^2(df=4)=45.81, p<0.001]. Rabbit control was requested by only 4.2% of

municipalities in 1967, but approximately 72% (of the 919 municipalities in our study area) of hunting estates in 2005 (Fig. 2).

In 2005, rabbit abundance was higher in those hunting estates within municipalities that had requested rabbit control in 1967 than in those hunting estates from which no such requests had been received ($F_{1, 3,981}$ =72.27, p<0.001).

Rabbit control requests per land use type varied between 1967 and 2005 [χ^2(df=3)=160.33, p<0.001; Table 1]. A greater proportion (compared to 1967) of control requests made in 2005 involved cereal crops and forest areas, with a lower proportion covering olive groves, vineyards, and other land types. Moreover, the types of agricultural and forest resources present in any area were found to be associated with the number of requests for rabbit control, as shown by chi-square tests. The data were statistically significant (p<0.001) and logistic regression was therefore able to predict if rabbit control was or not requested within a given area (Table 2).

The principal rabbit control method requested in THPs was the shotgun; this was true of >95% of the game estates. Use of ferrets was applied for by approximately 44.5% of hunting estates. Corral trapping by only 9.7% of estates.

We found no significant difference between the numbers of requests for use of shotgun control [Likehood ratio test, χ^2(df=1)=2.3, p= 0.12] and ferrets [χ^2(df=1)=0.02, p=0.88] in game estates varying in rabbit abundance in 2005.

However, requests for the corral trap method were more frequently made in game estates on which rabbits were abundant [χ^2(df=1)= 71.1, p<0.001] (Fig. 3).

Discussion

The present study, within central Spain, is arguably the first to provide direct evidence that the rabbit is considered a pest in the Iberian Peninsula. Here, we showed that although rabbit control was requested by 51% of game estates and 71% of municipalities in 2005 only 4.2% of municipalities in requested rabbit control 50 years earlier, in 1967. One possible explanation for the change over time may be that gamekeepers were previously allowed to take rabbits using snares and traps. These methods were commonly used during the hunting season (independently of the CARs), but are currently forbidden in Central Spain. An alternative explanation is that rabbit numbers were very low in Spain during the late 1960s because of widespread mortality caused by myxomatosis (Muñoz 1960). Although few reliable data are available, it is known that rabbit numbers recovered in Spain when resistance to myxomatosis developed, as was the case in Australia (e.g., Saunders et al. 2010). However, rabbit populations in Spain declined markedly from the 1970s to the 1990s (Villafuerte and Delibes-Mateos 2008; Delibes-Mateos et al. 2009a). Indeed, most rabbit population numbers are still declining, and recoveries have been documented in only a few instances (Delibes-Mateos et al. 2009a). It is therefore unlikely that rabbit numbers were higher in 2005 than during the 1960s.

Other factors may have contributed to the increase in rabbit control requests. For example, farmers might currently seek to extract greater economic benefit from their land than was the case in the past. Farmers may now be more sensitive when viewing rabbit damage to crops, resulting in an increase in rabbit control requests. Farmer sensitivity may be currently higher than in the sixties because they are accustomed to receiving subsidies via a number of different financial mechanisms (i.e. Common Agricultural Policy of the EU). It is also true that the loss of weeds and the impoverishment of plant communities caused by agricultural intensification may have had significant effects on rabbit food availability, consequently forcing the animals to browse crops (Barrio et al. 2010). Another explanations could be that hunters would request to control rabbits in order to extend the hunting season (and therefore increase rabbit hunter bags) independent of the amount of crop damage actually caused by the species. The fact that the most commonly requested rabbit control method was the shotgun may support this hypothesis. Administratively, such a situation may be promoted, or at least tolerated, because the terms “hunting methods” and “control methods” are used synonymously in THPs.

Differences between the data sources from the two study periods could also explain our results. Thus, whereas CARs expressly addressed mitigation of crop damage caused by rabbits and hares, THPs were developed as part of an effort to protect game species (FUNGESMA 2001). The focus of the two initiatives is therefore completely different. Further, the obligation to complete a

THP for rabbit control *a priori*, may encourage some game estates to request a THP as a preventative measure, despite the absence of any real need to control rabbits. If damages occur while the THP is in force, the farmer/hunter should only have to request an additional authorization to control rabbits.

A significant finding was that in 2005, the use of corral traps was common in areas of high rabbit density, where large numbers of animals are hunted annually. Corral trapping (also termed the drive corral approach) is a traditional hunting method whereby a group of hunters flushes rabbits into a large fenced plot, after which the animals are captured (Palmer 1896). This method requires substantial effort (Henke and Demarais 1990) and can allow the capture of multiple numbers of animals (Powell and Proulx 2003). However, the approach is appropriate only where rabbits are very abundant. In contrast, shotguns are usually employed within low rabbit density sites though shotgun use may also reflect a desire to hunt outside the designated hunting season (see above). The use of ferrets (described as early as Strabo; see Garcia and Bellido 1983) originated in Spain but has subsequently been employed in many countries (Cowan 1984). In Spain, this method is normally prohibited, although ferret use may be authorized under exceptional circumstances (Castilla-La Mancha Hunting Law, Decree 141/1996). Our results showed that this control method is frequently requested in central Spain, usually in areas where rabbits do not attain high numbers (Fig. 3).

In 2005, rabbit hunting yields were higher in municipalities where rabbits were controlled during the 1960s. One such locality,the Montes de Toledo, in

the north of our study area has been considered a good hunting area since the 16th century (López-Ontiveros 1991). The high HYs (104 rabbits/100 ha; Ríos-Saldaña 2010) in this area reflect the large numbers of rabbits present (Villafuerte et al. 1998). Such rabbit densities explains why several endangered predators that depend on rabbits, including the Spanish imperial eagle, are found in many game estates in this region (Delibes-Mateos et al. 2007). These data are consistent with studies on rabbit population dynamics that suggest that areas in which had high rabbit densities in the past recovered more quickly from the effects of rabbit hemorrhagic disease than those areas where rabbit densities were low (Blanco and Villafuerte 1993; Cotilla et al. 2010).

Our model reveals a strong link between the type of agricultural or forest resource and the number of requests for rabbit control. An AUC value can be interpreted as the probability that the model will correctly distinguish between two distinct possibilities. In the present example, the AUC data suggest that our model (which includes data on land type) can accurately distinguish between the presence or absence of rabbit control requests for a particular land use type with an accuracy of 0.7 (Table 2). AUC values of 0.5–0.6 indicate low accuracy, 0.7–0.9 indicate intermediate but useful accuracy, and > 0.9 indicate high accuracy (Swets 1988).

Agricultural and forest resources supposedly damaged by rabbits differed between 1967 and 2005. During the late 1960s, the principal resource type damaged was “forests”. This was unexpected, as rabbits are usually associated with agriculture and typically are not abundant in woodlands (Farfán et al.

2004). A significant reforestation campaign was conducted in Spain between 1940 and 1970 (Gómez and Mata 2002), which may explain why damage to forest resources was significant during this period. In contrast, the main land use types for which requests for rabbit control were made in 2005 were cereal crops, followed by forests. Unfortunately, information on resources subject to rabbit damage is not collected in THPs, and, consequently, the damage recorded in localities with a significant proportion of forest may have been influenced by damage to adjacent agricultural land.

In summary, we have provided the first direct evidence that the rabbit is broadly considered to be harmful to agriculture over its natural range, as exemplified by our study area in Central Spain. We also demonstrate that the perception of rabbits as a pest has increased significantly over the last 50 years. This could have important management consequences. For example, conservation biologists may find it difficult to accept that a keystone species currently labeled as “vulnerable” should be controlled in a manner appropriate for a pest (Delibes-Mateos et al. 2011). A possible means for targeting management solutions appropriate to whether the rabbit is a pest or a keystone species is to encourage administrators to devise a simpler system for estate managers to request measures for rabbit control. However, this is not easy. Hunters may exploit the current system to increase hunting activity even in circumstances where crop damage is not really a problem. Therefore, we recommend the implementation of a more specific application form, similar to the one employed in the 1960s, that allows an applicant to ask for rabbit control measures whenever the clear evidence of damage to crops, and after being

assessed by competent authorities. The management authorities may even allow further methods to control rabbits on assessment of the actual problem. The area damaged by rabbits should be described in more detail, as was the case in the CARs. Such a form, perhaps not necessarily to be completed by hunters, would help researchers and managers develop a more realistic understanding of rabbits as pests. Finally, further research on methods of rabbit control in Spain should be encouraged, such as the quantification of extent of damage to on agriculture, the efficacy of the traditional rabbit control, and the development of new methods to reduce impacts or numbers.

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Table 1.

Numbers (with percentages) of rabbit control requests for six types of agricultural and forest resources.

Type of agricultural and/or forest resource	1967	2005
	n (%)	n (%)
Cereal crops	17 (15.5)	970 (45.9)
Forests	36 (32.7)	913 (43.2)
Olive groves	1 (0.9)	38 (1.8)
Vineyards	24 (21.8)	55 (2.6)
Other land uses	32 (29.1)	138 (6.5)
Total rabbit control requests	110	2,114

Table 2.

Logistic regression exploring whether rabbit control requests in 2005 were associated with local rabbit abundance (estimated as hunting yields) and/or land use at that time.

Variable	**Coefficient**
Hunting yield	0.012*
Olive groves	0.374*
Grasslands	0.333*
Cereals	0.579*
Vineyards	0.311*
Number of observations	**3,975**
χ^2 Wald	158.399*
AUC	0.70

* $p<0.001$

Fig. 1 The Castilla-La Mancha region of central Spain showing the positions of the La Mancha Plain and the main mountain ranges and the boundaries of the five provinces

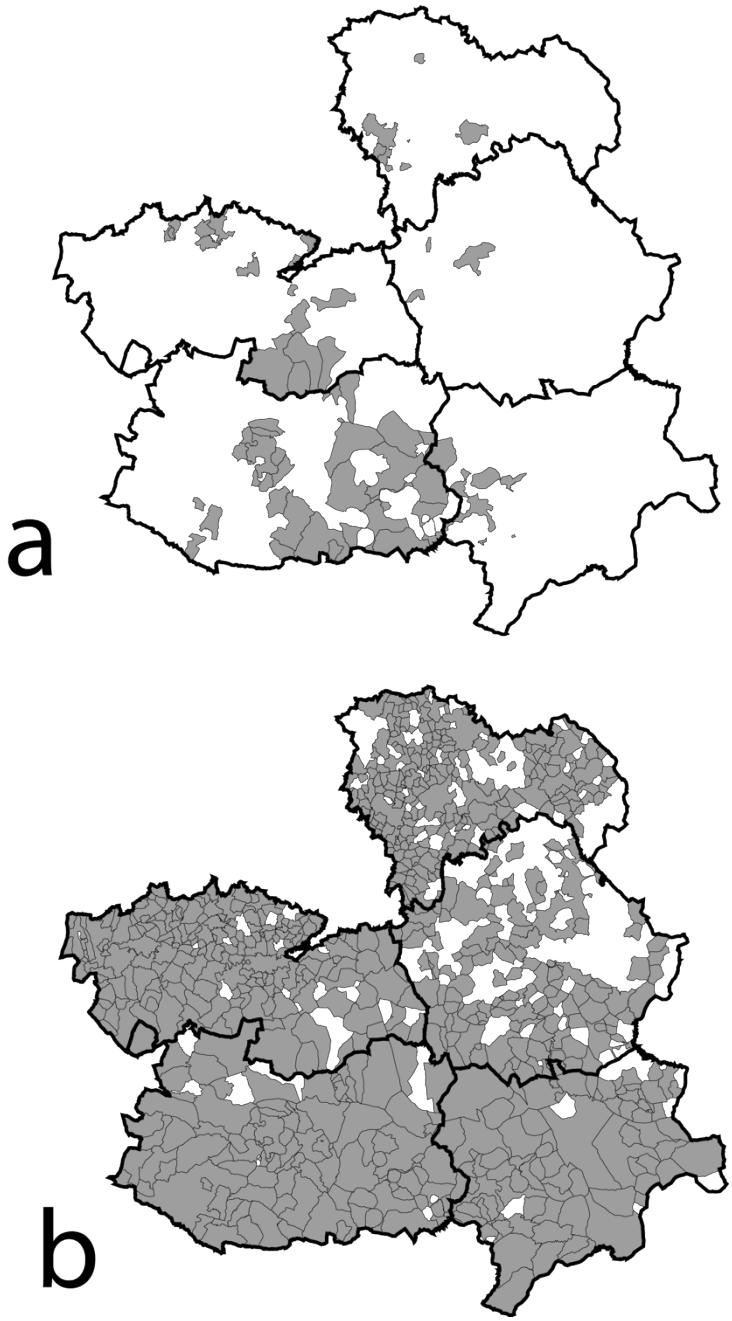

Fig. 2 Municipalities (shaded) within the five provinces of the Castilla-La Mancha region that requested rabbit control in 1967 (a) and 2005 (b) because of crop damage

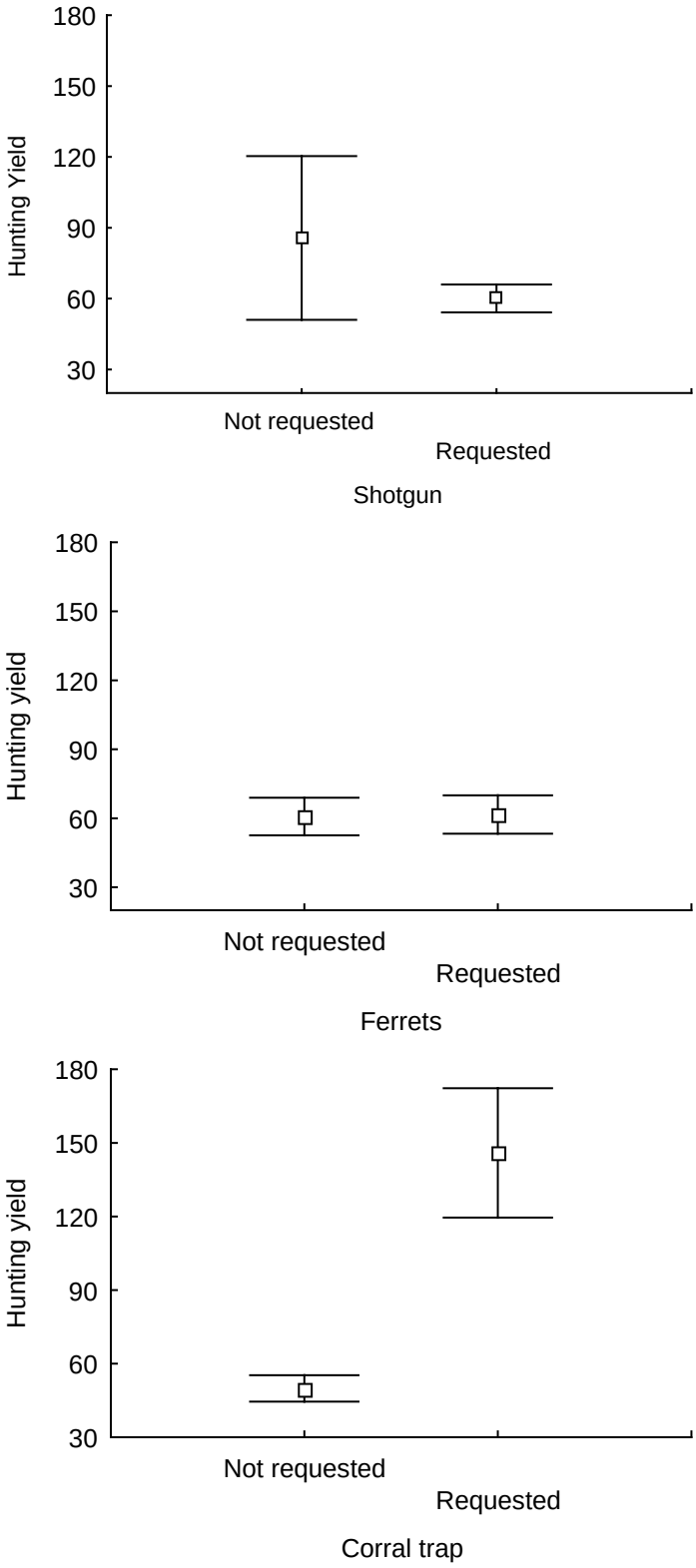

Fig. 3 Rabbit control methods and hunting yield in 2005 (average number of rabbits captured per 100 ha of hunting estate). Error bars represent the 95% confidence interval