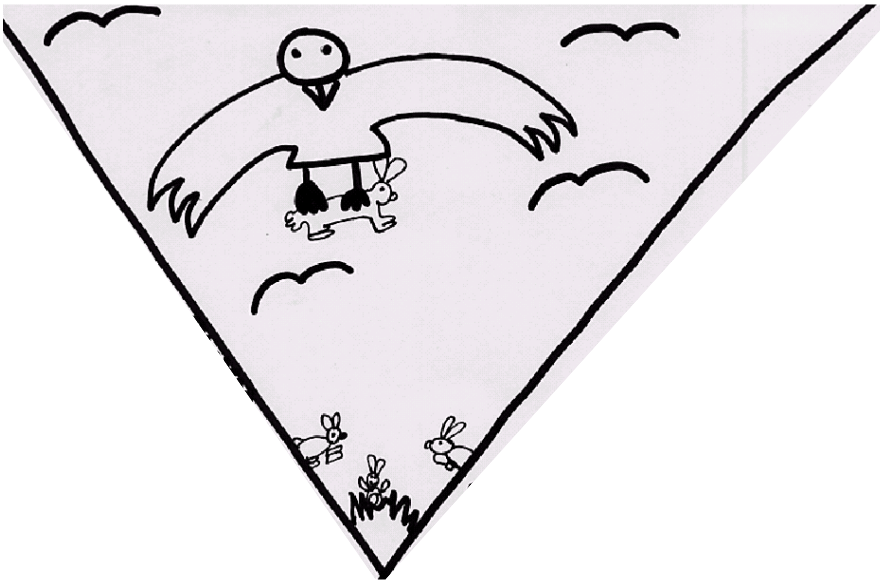

CAPÍTULO 2

Multiple strategies for the management of small game: implications for wildlife conservation

El uso de las estrategias múltiples para la gestión de la caza menor: implicaciones en la conservación natural

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"Conservation is in crisis. Conventional approaches have not worked. Development and conservation are on an accelerating collision on course, and proposed solutions are no more than hopeful improvisations"
Robinson JG, Bennett EL. 2000. Hunting for sustainability in tropical forests.

Resumen

El conejo y la perdiz son las especies reina de la caza menor en España, y también son especies básicas para la comunidad de depredadores de los ecosistemas mediterráneos. Dado que las poblaciones de ambas especies se encuentran en declive en la Península Ibérica, la gestión de las poblaciones se ha convertido en una herramienta imprescindible. Sin embargo, poco se conoce sobre las medidas de gestión que se aplican, la intensidad de las mismas y su evolución en los últimos años. Tampoco hay estudios globales que cuantifiquen el efecto de dichas medidas sobre las poblaciones diana a las que van directamente dirigidas o sobre las poblaciones de depredadores a las que van indirectamente dirigidas.

El Capítulo se plantea en formato de dos publicaciones. La primera aborda, desde una perspectiva regional, la descripción de la gestión cinegética de caza menor, su intensidad y evolución temporal y su relación con las especies diana de la gestión y con el resto de fauna silvestre. En la segunda publicación se expone un caso práctico representativo de la importancia de los conejos (y las perdices) en la ecología de los depredadores del ecosistema mediterráneo, en este caso, del águila azor perdicera (Hieraaetus fasciatus).

En la primera publicación realizamos una valoración cuantitativa de la efectividad de las estrategias de gestión analizando las estrategias múltiples de manejo, a través de encuestas y censos en 307 áreas andaluzas. Más del 95% de las áreas usan estrategias para recuperar las poblaciones de conejo y perdiz. El uso de dichas estrategias ha aumentado en las últimas tres décadas significativamente. El manejo de hábitat, la reducción de la caza y el control de

depredadores fueron estrategias más usadas que las translocaciones o la prevención de parásitos y enfermedades. No se ha podido mostrar que las estrategias de manejo estén relacionadas con un incremento significativo en la abundancia poblacional a corto plazo; sin embargo, este incremento está directamente relacionado con el nivel de abundancia inicial. Es decir el incremento poblacional es mayor en las áreas en las que la abundancia es mayor. En los lugares en que las poblaciones de perdiz se han considerado en declive en los últimos diez años, la intensidad de manejo es significativamente más alta que en las áreas en las que dichas poblaciones se han considerado estables. Sin embargo, esta relación no se ha observado para el caso del conejo.

Se estimaron los gastos medios que supone cada estrategia de manejo, con el objeto de analizar la intensidad de manejo en cada área. Los resultados indican que la media de gastos para la gestión de la caza menor en un área de 2 000 ha. varía entre 4 500 y 8 800 euros al año. Los gastos más altos corresponden a las áreas donde la abundancia de ambas especies es mayor, probablemente debido a que los cazadores están más interesados en la actividad cinegética de la que obtienen un beneficio económico. La intensidad de manejo está relacionada con un mayor nivel de conservación natural de las áreas, estimado éste a través de la cantidad de especies de fauna que se encuentran en el área y del valor ambiental de dichas especies .

En conclusión, los resultados que se exponen en la primera publicación de este Capítulo, indican que la gestión de la caza menor es utilizada muy frecuentemente y con gran intensidad en Andalucía y que puede tener un papel muy importante en la conservación de las especies silvestres. Sin embargo, se requieren nuevos estudios que evalúen con mayor detalle los beneficios que la gestión cinegética tiene, no sólo para las especies diana de dicha gestión sino también para los depredadores que de ellas dependen.

La segunda publicación de este Capítulo, analiza los factores que pueden afectar a la duración del período comprendido entre el primer vuelo del joven de águila azor perdicera y el comienzo de la dispersión. Este período, denominado de post-emplumamiento, es un período de aprendizaje de las jóvenes águilas. Además de los posibles efectos de la disponibilidad de alimento (abundancia y evolución temporal de las especies que consume, conejos y perdices), se analizaron otros factores como la fecha de puesta, la fecha de eclosión, la condición corporal y el estado nutricional de los individuos. Para determinar los cambios temporales en la disponibilidad de conejos durante el período de post-emplumamiento se muestrearon, mediante censos mensuales, las abundancias de conejo y perdiz en el área de estudio. A partir de un índice de abundancia media mensual, a cada joven águila se le asignó una disponibilidad de presas en función de los meses que duró su período de post-emplumamiento.

Los jóvenes que eclosionaron antes tardaron más tiempo en emplumarse, pero tuvieron un periodo de post-emplumamiento menor. Los jóvenes que eclosionaron más tarde tardaron menos tiempo en emplumarse pero tuvieron un período de post-emplumamiento mayor. Por otro lado, la duración de dicho período se correlacionó directamente con la abundancia de conejos e indirectamente con la abundancia de perdices. Estos resultados se explican por la fenología de las abundancias de las dos especies presa consideradas. Por un lado, la reproducción de los conejos acaba de empezar cuando las águilas ponen los huevos y, como consecuencia, se observa un incremento en las abundancias de conejo hasta alcanzar el máximo en junio y julio. Con la llegada del verano, la reproducción de los conejos finaliza y su abundancia va decreciendo hasta los mínimos poblacionales, en octubre y noviembre. En el caso de la perdiz, la reproducción es más tardía, comienza en marzo, y los máximos poblacionales se observan al final del verano.

Por tanto, las águilas que eclosionaron más pronto tardaron en emplumarse más porque disponían de pocos conejos (está empezando la reproducción del conejo) pero durante sus primeros vuelos (a partir del 15 de mayo) disfrutaron del pico de máxima abundancia de conejos. Por el contrario, las águilas que eclosionaron más tarde se emplumaron más rápido porque había una mayor disponibilidad de conejos, pero durante sus primeros vuelos el pico de máxima abundancia de conejos tocaba a su fin. Al disponer de menor abundancia de conejos, estas águilas “tardías” necesitaron más tiempo para adquirir una condición física adecuada para dispersarse. Sin embargo estas águilas tuvieron acceso a una mayor abundancia de perdices, y podrían haberse alimentado preferentemente de perdices en lugar de conejos, resultando en la misma duración del período de post-emplumamiento que los jóvenes que eclosionaron antes. El conejo parece ser una presa preferente (aparece en mayor proporción en la dieta del águila azor perdicera) y de mayor calidad (tiene más biomasa), lo cual podría explicar las diferencias observadas. En conclusión, se observa la importancia de la disponibilidad del conejo en la duración del período de post-emplumamiento del águila perdicera.

NOTA: Esta segunda publicación lleva una fe de erratas en la página 71.

Multiple strategies for the management of small game: implications for wildlife conservation

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Abstract

Declines in the populations of wild rabbit and red-legged partridge have made their management necessary since they are the most important small-game species in southwestern Europe and they sustain a great number of predators in Mediterranean ecosystems. Here we provide a quantitative assessment of small-game management effectiveness using a large sample of areas in southern Spain in which multiple strategies were applied. These strategies are used to improve both rabbit and partridge populations in more than 95% of the areas sampled, and their use has increased significantly during the past 3 decades. Among the strategies employed, habitat management, reduction in hunting, and predator removal have been more common than translocations and the prevention of diseases and parasites. Most strategies were significantly associated with a second strategy. The observed data fitted significantly to a combination of the following associations: partridge abundance and partridge annual growth rate, and rabbit and partridge translocations. The annual population growth rates of rabbit and partridge between 1998 and 1999 were not significantly associated with any management strategy. We have calculated that the mean annual expenditure on managing small game in an area of 2000 ha is 4500–8800 euros. High management intensity is associated with high abundance of both species, which probably reflects the large hunter interest in small game. When partridge populations are declining the intensity of management is significantly higher than when the population is stable, but this is not the case for rabbits. Areas with higher expenditure on management and that have high rabbit abundance have higher levels of wildlife conservation; in addition, wildlife conservation is enhanced by habitat management and the reduction of hunting. Our findings illustrate that small-game management is employed in most areas of southern Spain, and may have a role to play in wildlife conservation. There is a need to evaluate the long-term benefits of small-game management not only to improving small-game populations but also to wildlife conservation.

Keywords: wild rabbit, red-legged partridge, *Oryctolagus cuniculus*, *Alectoris rufa*, conservation, small game.

INTRODUCTION

The management of game species is necessary to maintain the desired level of population abundance, and the proportions of sex and age classes. The populations of wild rabbit (*Oryctolagus cuniculus*) and red-legged partridge (*Alectoris rufa*) in Europe, the most important small-game species in Spain, have been declining for many areas; hence, management of their populations has become necessary for their recovery. The primary goal of small-game management remains recreational hunting. More than 70% of the national territory is covered by hunting areas, and hunters kill more than four million rabbits and almost four million partridges annually (Ministry of Agriculture, Fisheries and Food, 1996; Millán et al. 2001). Moreover, rabbits and partridges are the most important vertebrate prey species in Mediterranean ecosystems, being preyed upon by more than 30 predator species. The biodiversity of Mediterranean ecosystems is usually associated with large numbers of these species (Delibes & Hiraldo, 1981). Moreover, rabbits are the main prey of two of the most endangered predators in the world: the Iberian lynx: (*Lynx pardinus*) and the Spanish imperial eagle (*Aquila adalberti*).

Management strategies are carried out in hunting areas by hunters or landowners, and in protected areas by government agencies responsible for environmental protection in order to increase the prey available to endangered predators. Several scientific studies have proposed small-game management as the best method to conserve endangered predators (Palomares et al. 1991; Castro & Palma, 1996; Real & Mañosa, 1997). Moreover, the Spanish government has provided considerable funding to projects over the last few decades, the main goal of which was to improve rabbit and partridge populations in order to conserve the Imperial Eagle and Iberian lynx. Thus, the effectiveness of the management of rabbit and partridge populations should be measured not only by increases in their populations, the main goal of hunters, but also by improvements in the conservation of wildlife, the ultimate goal for conservation purposes.

Different factors have contributed to the decline of rabbit and partridge populations, including fragmentation of habitat, habitat loss, excessive hunting, diseases, and excessive predation pressure by generalist predators. In particular, rabbit haemorrhagic disease (RHD) has caused a sharp decline in rabbit populations over the last decade. RHD became enzootic in wild populations (Calvete et al. 2002), and many populations continued decreasing and eventually became extinct (Villafuerte et al. 1995). Numerous management strategies have been implemented in an attempt to restore rabbit and partridge numbers. These strategies can be classified into five groups: directly increasing abundance by translocation, improving habitat, reducing hunting pressure, preventing diseases and parasites, and reducing predation pressure.

The effectiveness of some management strategies has already been evaluated, and where necessary new measures have been proposed. For example, Calvete et al. (1997), Gortázar et al. (2000a), and Putaala & Hissa (2000) have evaluated the effectiveness of translocation. The traditional method of management involves releasing large numbers of animals without any habitat management or reduction in predators, but this is ineffective, costly, and results in high mortality rates in the animals released. Trout et al. (1992) successfully manipulated vectors of myxomatosis (a rabbit disease) in the UK, to reduce their effects on populations, but an attempt by Osácar et al. (1996) to apply a similar procedure in Spain failed, probably because of the presence of a wider vector range. Habitat management such as scrub and pasture management have been evaluated by Moreno and Villafuerte (1995), who found that such measures improve rabbit populations. Hoodless et al. 1999) showed that supplementary feeding does not increase the abundance of small game birds. However, the supplementary feeding of partridges may improve the general condition of populations (Blanco-Aguiar et al. 2001), while reproduction in wild rabbits is associated with the availability of high quality food (Wallage-Drees & Michielsen, 1989; Villafuerte et al. 1997).

Other measures used for small-game management have been considered, not only in terms of their effect on small-game populations but also their effects on non-target species. For example, Trout and Tittensor (1989), Smedshaug et al. (1999), and Banks (2000) showed that removing predators improves small-game numbers, while Côte and Sutherland (1996) concluded that predator removal is not very effective for conservation. The effectiveness of these techniques in a Mediterranean ecosystem with a high number of predators has not been fully evaluated. For example, the conservation problems caused by the illegal control of non-target predator species is currently under investigation. The lack of selectivity of predator control measures has been demonstrated, as has their potential negative effects on the conservation of non-target species (Ruiz-Olmo 1986; Duarte & Vargas 2001). Moreover, Villafuerte et al. (1998) showed that a decline in the number of rabbits was followed by the illegal control of predators leading to the decline of a species of raptor.

The usual situation in Spain is that the management of small game within an area involves multiple strategies. However, there is little information available on the frequency of use of management strategies, on the expenditure in managing small game, or in which situations management is applied. For example, two goals that could be set by managers applying small-game management are (1) to recover the populations when their abundance is low or (2) to produce higher economic benefits when their abundance is high. Past studies on management effectiveness have focused on one management strategy at a time, with none having assessed quantitatively the effectiveness of using a large sample of areas where multiple strategies are applied. In addition, a full evaluation of the effects of general small-game management is needed, not only on rabbit and partridge populations, but also on other wildlife species.

Our study assessed the intensity of small-game management in southern Spain, with the aim of determining whether this intensity is related to the abundance (or trends therein) of small-game populations, and discovering the relationship between small-game management and wildlife conservation. Thus, we explored the importance of the management of small game in rabbits and partridges, the frequency of different management strategies, and the changes in their use over the past three decades. We hypothesised firstly that small-game management would be used most intensively in areas where rabbit and partridge population abundance were low or declining, and secondly that the areas managed most intensively would exhibit a better level of wildlife conservation. We also evaluated the short-term effect of different management strategies on rabbit and partridge populations.

METHODS

Interviews and field survey

Figure 1. Study area. Sampled areas are represented by black squares.

More than 35 people trained in wildlife surveys carried out 307 interviews and rabbit surveys in southern Spain during June and July of 1998 and 1999 (Figure 1). Survey points were based on a step-random sample based on altitude and topography, with areas lower than 1200 meters in altitude and with slopes of less than 30% were favoured in the selection of study areas. At each survey point, we conducted a census of rabbit and partridge abundance, identified the land ownership of the area, and personally interviewed a local hunter, landowner, or conservation manager.

The first interviews were carried out in June 1998. We asked about which game species was the focus of game management in each area. We used a questionnaire involving nine management strategies that favoured small game (Table 1). Participants were asked to indicate whether these management practices were usually applied in the area currently, and 10 and 30 years ago.

A second interview was conducted at the same survey points in June 1999 – involving the management strategies favouring small game applied during the 1998–1999 hunting season – using a more complete questionnaire. The participants were asked to indicate whether or not management practices designed to favour the increase of small-game numbers were applied in their area. Those practices that hunters or landowners may have applied voluntarily each year are listed in Table 1.

In the 1998 interview the participants were asked to indicate whether the following wildlife species were present in the area: predators such as Egyptian mongoose (*Herpestes ichneumon*), genet (*Genetta genetta*), polecat (*Mustela putorius*), stone marten (*Martes foina*), badger (*Meles meles*), wild cat (*Felis silvestris*), Iberian lynx, wolf (*Canis lupus*), and large and small eagles; big-game species such as feral pig (*Sus scrofa*), roe-deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), fallow deer (*Dama dama*), and Spanish ibex (*Capra pyrenaica*); and finally small-game species such as hare (*Lepus granatensis*), quail (*Coturnix coturnix*), turtledove (*Streptopelia turtur*), wood pigeon (*Columba palumbus*), thrush (*Turdus turdus*), rabbit, and red-legged partridge. In the case of rabbit and red-legged partridge, participants were also asked to indicate the levels of abundance 10 years ago and the trends in their populations during the previous decade in the area (allowed answers were no change, increasing, and decreasing).

Table 1. Management strategies for improving small game in southern Spain as used in the 1999 questionnaire. Strategies marked with an asterisk were used in the 1998 questionnaire. The mean annual expenditure on applying each managing strategy in a 2000-ha area is shown (in euros). Percentage of areas where such management are applied (1) and percentage of areas where each management is the only one applied (2) are also indicated.

GROUP OF MANAGAMENT STRATEGIES	MANAGEMENT STRATEGY	Expen-diture (euros)	% AREAS (1)	% AREAS (2)
Habitat improvement	Creation of pastures*	2300	64.0	13.2
	Scrub management*	755		
	Food supply*	2000		
	Water supply*	800		
	Management of rabbit warrens*	11000		
Predator and pest control*	Foxes control	11000	45.6	2.4
	Dogs and cats control			
	Corvids control			
	Rats control			
Prevention of diseases and parasites	Medication supply*	240	15.8	0
	Vaccination*	2150		
	Prevention of rabbit-disease vectors*	2400		
Translocations	Translocation of rabbits	900	12.5	0
	Translocation of red-legged partridges	600	21.7	1.7
Hunting strategies	Area of hunting reserve		61.0	10.8
	Reduction in hunting days			
	Reduction in hunters per day			
	Reduction in number of hunted animals			
	Reduction in number of hunting hours per day			

During June 1998 and June 1999, rabbit and red-legged partridge abundances were estimated along a 4-km route, checking for evidence of rabbits and partridges at each survey point. Each transect was walked along and sightings of rabbits and partridges were recorded, as well as evidence of three typical rabbit signs: faecal pellets, scrapes, and latrines. Such signs have been widely used in previous studies (Trout et al. 2000; Virgós et al. in press), with faecal pellets being particularly appropriate where the rabbits themselves are difficult to detect or the detection of certain signs may be influenced by other factors such as soil or habitat type (Moreno and Villafuerte 1995; Palma et al. 1999). Partridge abundance was computed on the basis of the number of partridges seen per 4-km transect. To assess rabbit abundance, we used principal component analysis (PCA) to express the four correlated variables of rabbit abundance using a single factor. The factor of rabbit abundance explains 75.99% of the original variance. A logarithmic transformation of the variables was necessary before applying PCA.

Hypothesis testing and statistical analyses

We constructed a multidimensional table based on the frequencies with which the various management strategies were employed so as to determine associations among the management strategies used in southern Spain during the 1998-1999 hunting season. We analysed the associations between the five groups of management strategies, but separating translocations by species (Table 1). In addition, we determined possible associations among those strategies and the annual population growth rates of partridges and rabbits between 1998 and 1999, and their abundances during 1999. The annual partridge population growth rate was based on the number of red-legged partridges seen per transect. The annual rabbit population growth rate was based on the factor of rabbit abundance, each value of which was converted to a positive number by addition of the lowest negative number prior to the calculation of the annual growth rate. For each species, abundance was categorized into two groups: above and below the mean. Annual growth rate was also categorized into two groups: increasing and decreasing. Data analysis was carried out using BMDP–4F (Dixon 1983); associations among variables were tested using G-tests and differences between percentages of areas in which two strategies were applied were tested using Fisher's exact tests.

To determine whether the small-game situation observed in southern Spain can be accounted for by the frequency with which the various strategies are used and the possible associations among strategies described in the above analysis, a log-linear model was constructed considering only the significant associations between strategies. We searched for the simplest model that showed no significant differences with the observed data, beginning with the complete model (incorporating all the significant associations) and then eliminating the association with the lowest G^2 at each step. The expected values generated by the final model (lambda) were compared with the table of observed values using a G-test (Heisey 1985). Standardized values of the log-linear parameters of the model were used to test the deviations of the predicted frequencies from randomness (Edwards 1989).

We used generalised linear models to analyse for differences in the use of the nine types of management strategy (1998 questionnaire, Table 1), for differences between the current use and the uses 10 and 30 years ago, and for differences in the change of use of different types of management strategy. We analysed a generalised linear model in which the dependent variable was the use of each management strategy (used or not used; a binomial variable); the independent variables were the historical period (with three levels: currently, and 10 and 30 years ago) and the type of management strategy (with nine levels corresponding to the management strategies of the 1998 questionnaire, Table 1). To test the goodness-of-fit statistics of each model, aggregating data before the computation of the test solved problems caused by sparseness of the binomial variable.

We performed a second analysis to determine whether differences in the use of different types of management strategy and differences in their current use with respect to their use during the previous decade were affected by the level of abundance of rabbit and partridge in each historical period. We grouped management strategies into three categories (habitat management, predator control, and prevention of diseases and parasites) in order to reduce the analysis levels. The types of management strategy considered were different for rabbit and red-legged partridge. All strategies were considered for rabbits. For red-legged partridge, in the prevention of diseases and parasites category, vaccinations and prevention of rabbit disease vectors were not used, while in the habitat management category, warren management was not used (Table 1). We analysed two generalised linear models (one for each species) in which the dependent variable was binomial (the use of each group of management strategies) and the independent factors were the type of management strategy (habitat, predator control, or prevention of diseases), level of abundance of each species (low or high), and historical period (currently and 10 years ago). Goodness-of-fit statistics of each model considered sparseness of the binomial variable.

Currently two opposing goals potentially motivate managers or hunters to apply management strategies for the improvement of small game: (1) to increase the population in an area where it is declining, and (2) to encourage small-game hunting, which is an economically important activity. We wanted to test both hypotheses. We performed two ANOVA tests, one for each species, to test for differences in the expenditure on management strategies in relation to the abundance and its trend of each species. We calculated the mean yearly expenditure for each management strategy when applied to a 2000-ha area from information provided by specialist managers; in these calculations we assumed that management covered 500 ha of the 2000-ha area each year (Table 1). Strategies for the reduction of hunting pressure were not considered. Since we knew which management strategies were usually applied in each area (see Table 1, from the 1998 interviews), we calculated the mean annual expenditure. As some management strategies are aimed at improving rabbit populations, such as management of warrens or vaccinations, the costs of rabbit management were different from those of partridge management. We related this amount to the level of abundance of both species in the area (low and high) and the trends of the rabbit and partridge populations over the last decade (no change, increasing, or decreasing) in each area.

To test the possible effects of small-game management strategies on environmental conservation, we related an environmental value of each area to the intensity of management. We used data on the presence of wildlife species in the area: carnivores, eagles, and large- and small-game species. We obtained the environmental value of each species for the whole study area that was dependent on the number of areas in which the species was present. Thus, the environmental value of each species in southern Spain was calculated as 100 minus the percentage of areas in which the species was present. We then calculated the environmental value of each area as the summation of the environmental values of all the species present in that area (Hiraldo & Alonso 1985).

We used the environmental value of each area as the dependent variable in a generalised linear model in which the independent variables were related to the intensity of management using the mean annual expenditure on small-game management in each area (from the 1998 interviews, see Table 1). To control for the effects of rabbit and partridge abundance, we included their abundance (low or high, as assessed in the 1999 field survey; number of partridges seen in the 4-km transect and PCA obtained from the indirect variables of rabbit abundance) in the analysis. This was done firstly because these two species are the most important prey in Mediterranean ecosystems (Delibes & Hiraldo, 1981) and their abundance could affect the presence of other wildlife species such as predators, thereby enhancing the level of conservation of an area, and secondly because the intensity of management could be related to their abundance. We tested the effects of the interactions between the intensity of management and rabbit and partridge abundance. We added five further independent variables in relation to the use of each group of management strategies (habitat management, predator control, prevention of diseases and parasites, reduction of hunting, and translocations) to test whether each group of management strategies could affect wildlife conservation.

All statistical analyses were performed using STATISTICA software (StatSoft, USA, 1999) except for the multidimensional log-linear analysis, which was carried out using BMDP–4F (Dixon 1983).

RESULTS

The areas selected in the sample varied greatly in size, type of ownership, hunting regime, primary habitat type, level of wildlife conservation, and management strategies applied. However, hunting areas represented more than 95% of the areas considered, with the remainder being environmentally protected areas. More than 25% of the questionnaires were either totally or partly invalid, and hence the number of cases included in each analysis varies with the number of valid answers. In most areas small-game species were the target species of the management strategies (84.45%), with rabbits and red-legged partridges being the species favoured in 81.82% of the surveyed areas (*N*=165).

The management strategies for improving small-game populations were applied in most of the surveyed areas during the 1998–1999 hunting season (94.5%, *N*=272). The frequencies with which each type of strategy was employed are listed in Table 1. Habitat management and reduction of hunting were the most widely applied strategies, while translocations and prevention of diseases and parasites were applied to a lesser extent. It is interesting to note that two or more management strategies were employed simultaneously in the majority of areas, indicating that the use of multiple strategies is the most common management situation in southern Spain. For example, rabbit translocations and prevention of diseases and parasites were never applied alone (Table 1).

We found no third-order associations among the use of management strategies during the 1998-1999 hunting season. As stated above, we found that most of the strategies were associated with another strategy (Table 2A); however, the relationship between the strategies in each pair was not always symmetrical (Table 2B). For example, prevention of diseases is applied in 19.5% of the areas in which habitat management is applied, whereas habitat management is applied in 79.1% of the areas in which prevention of diseases is applied.

Table 2. Associations among pairs of management strategies. (A) Percentage of areas in which both strategies are employed; in brackets, G2-values and significance levels of G-test, ***p<0.001, **p<0.01, *p<0.05, n.s.non-significant. (B) Percentages of areas in which a management strategy is applied within the total areas in which a second strategy is applied; the first value correspond to when row management co-occurs within column management [100*(number of areas in which both row and column management measures are applied)/(total number of areas in which column management measure is applied)], and the second value correspond to when column management co-occurs within row management [100*(number of areas in which both row and column management measures are applied)/(total number of areas in which row management measure is applied)]. Significance levels were obtained by Fisher's exact tests when comparing the two percentages; significance levels are as in (A). There was 1 degree of freedom in all cases.

A) G-test

	Habitat improvement	Predator and pest control	Prevention of diseases	Rabbit translocations	Partridge translocations
Predator and pest control	36.0 % (7.16 **)				
Prevention of diseases	12.5 % (0.00 *n.s.*)	12.1 % (5.17*)			
Rabbit translocations	9.6 % (0.61 *n.s.*)	8.8 % (0.43 *n.s.*)	7.0 % (15.15 ***)		
Partridge translocations	18.4 % (2.25 *n.s.*)	15.1 % (1.70 *n.s.*)	8.1 % (1.58 *n.s.*)	9.9 % (37.57 ***)	
Hunting strategies	45.2 % (4.16 *)	35.7 % (11.69 ***)	13.6 % (1.04 *n.s.*)	9.6 % (0.80 *n.s.*)	18.0 % (2.95 *n.s.*)

B) Fisher's exact test

	Habitat improvement	Predator and pest control	Prevention of diseases	Rabbit translocations	Partridge translocations
Predator and pest control	56.3 / 79.0 *n.s.*				
Prevention of diseases	19.5 / 79.1 ***	26.6 / 76.7 **			
Rabbit translocations	14.9 / 76.5 ***	19.3 / 70.6 **	44.2 / 55.9 *n.s.*		
Partridge translocations	28.7 / 84.7 ***	33.1 / 69.5 *	51.2 / 37.3 *n.s.*	79.4 / 45.8 *n.s.*	
Hunting strategies	70.7 / 74.1 *n.s.*	78.2 / 58.4 *n.s*	86.0 / 22.3 ***	76.5 / 15.7 ***	83.0 / 29.5 ***

We explored whether rabbit and partridge abundance and their annual population growth rates between 1998 and 1999 were associated with any management strategies and between themselves. We found that high rabbit abundance was significantly associated with the use of predator control and prevention of diseases and parasites (G^2 = 7.27, P =0.007 , and G^2 = 4.47, P = 0.035 respectively); no significant associations involving partridge abundance were identified. Rabbit and partridge abundance were both significantly associated with their respective annual growth rates (G^2 = 8,21, P =0.004 , and G^2 = 34.79, P < 0.001); high abundances were associated with positive annual growth rates and low abundances with negative ones. Rabbit and partridge abundances were significantly associated (G^2 = 5.31, P =

0.021). When a model was generated based on all the significant associations, the simplest model showing no significant differences with the observed data was formed by the associations between the use of rabbit and partridge translocations, and between partridge abundance and partridge annual growth rate (high partridge abundance was related to a high annual growth rate) (X^2 = 7.09, P = 0.63, d.f. = 115).

We found significant differences in the use of the nine types of management strategy and in the historical changes in their use, but not in their interactions (Table 3, A). Differences are displayed in Figure 2, in which we show the frequency of use of each management strategy during different historical periods (between the use in the 1970s, the 1990s, and the current use as at 1998). The nine management strategies exhibit different patterns of use. In general, the most frequently used strategies are related to the improvement of habitat, such as pasture and scrub management, and to water and food supplies. The control of predators occupies a middle position, and the less-used strategies are those related to the prevention of diseases and parasites, such as vaccination, deparasitation, and the supply of medication.

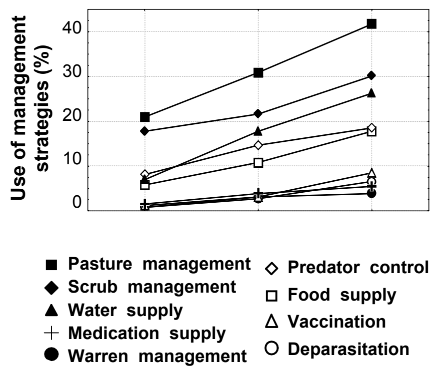

Figure 2. Frequency of use of management strategies during three historical periods.

The overall use of all management strategies has increased from the 1970s to the present day. Although differences in the interactions between historical changes and type of management are not significant, the use of some strategies has increased more than others. We can distinguish between more modern management techniques, such as the strategies related to the prevention of diseases and parasites and the supply of food and water, which have increased since the 1970s, and more traditional management techniques such as scrub

Table 3. Generalised linear model (binomial error and logit link function) to test for differences between (A) the use of nine small-game management strategies*, historical changes in their use**, and the interaction between both factors; (B) the use of groups of management strategies, historical periods, and rabbit abundance; and (C) the use of groups of management strategies, historical periods, and red-legged partridge abundance.

A	Wald stat.	*df*	*P*
Intercept	1537.31	1	<0.001
Type of management strategy	78.85	8	<0.001
Historical period	383.26	2	<0.001
Interaction	16.18	16	0.44
B	**Wald stat.**	***df***	***P***
Intercept	595.97	1	<0.001
1. Rabbit abundance	31.09	1	<0.001
2. Type of management strategy	123.34	2	<0.001
3. Historical period	31.32	1	<0.001
1*2	3.38	2	0.18
1*3	0.01	1	0.91
2*3	2.40	2	0.30
C	**Wald stat.**	***df***	***P***
Intercept	225.80	1	<0.001
1. Partridge abundance	17.47	1	0.003
2. Type of management strategy	45.33	2	<0.001
3. Historical period	8.92	1	<0.001
1*2	3.91	2	0.14
1*3	0.94	1	0.33
2*3	0.79	2	0.67

* For more details, see Table 1.
** Use of management strategies in 1970s, 1990s, and 1998.

management, pasture management, and predator control that are as common today as they were in the 1970s.

In Table 3 (B, C) we show the results on the influence of the levels of abundance of rabbit and partridge (low or high) on the differences in the use of different types of management strategy (habitat, predator control, or prevention of diseases and parasites) and in historical period (currently and 10 years ago). Results for both species confirm previous results showing statistical differences in the use of management strategies between historical periods, with management strategies more common today than 10 years ago. We also confirm previous results showing significant differences in the use of different types of management strategy, with habitat management and predator control strategies being more common than the prevention of diseases and parasites. The use of management strategies is greater in areas where rabbit or partridge abundance is higher. Interactions between rabbit and partridge abundance and historical periods or types of management strategy, and between the latter two, were not significant. We found that the goodness-of-fit statistics of both models did not exhibit overdispersion.

Table 4. Analysis of variance of the expenditure on rabbit and red-legged partridge management for different trends in their populations and for different rabbit and partridge abundances. Independent variables obtained through interviews.

	Rabbit management			Partridge management		
	F	d*f*	*P*	*F*	d*f*	*P*
Population trend	2.78	1	0.064	3.82	1	0.023
Population abundance	5.86	2	0.016	12.51	2	<0.001
Interaction	1.57	2	0.21	0.91	2	0.40

	Rabbit management			Partridge management		
Population abundance	Mean	SD	Tukey testψ	Mean	SD	Tukey testψ
Low	3449.78	5498.16	a	2866.89	4568.90	a
High	6523.37	6805.45	b	4544.53	5564.32	b

	Partridge management		
Population trend	Mean	SD	Tukey testψ
No change	2771.54	4303.50	a
Increase	4648.10	5381.79	ab
Decrease	4288.31	5691.67	b

To test whether small game species were being managed because their populations were declining or because their high abundance brings economic benefits, we performed two ANOVA tests, one for each species. We looked for mean differences in the expenditure on management strategies with two levels of abundance (low and high) and three trends in each species (no change, and increase or decrease during the past 10 years). There were significant differences in both species when considering the level of abundance, and in the case of red-legged partridges also when considering the population trend (Table 4). We did not find a significant interaction between the two factors, neither in rabbits nor in partridges. Using the Tukey HSD test to explore these differences, we found that the expenditure was higher in areas with a higher rabbit or partridge abundance. We also found that the expenditure was higher when partridge populations were declining than when populations had not changed (Table 4).

The relationships between variables are displayed in Figure 3. The mean expenditures on managing small game in southern Spain during the 1998–1999 hunting season were 6880 and 8800 euros for partridge and rabbit, respectively. These amounts were lower when calculated for the strategies more frequently applied in each area, at 3800 and 4500 euros, respectively.

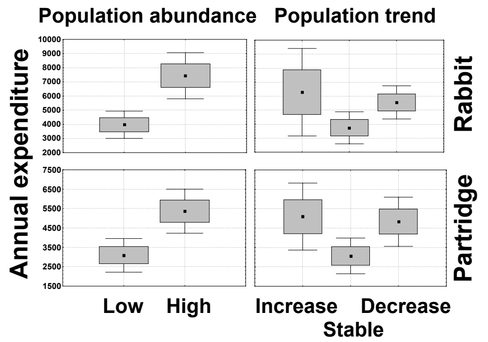

Figure 3. Annual expenses of small-game management for different levels of population abundance and for different trends in their populations. Central black square is the mean, the box limits indicate SE, and vertical lines indicate 1.96×SE.

To test the possible effects of small-game management strategies on environmental conservation, we related the environmental value of each area to the intensity of management using a generalised linear model, in which we tested the effects of rabbit and partridge abundances and the use of each group of management strategies (habitat management, predator control, prevention of diseases and parasites, reduction of hunting, and translocations). Rabbit abundance and its interaction with the intensity of management were related to the environmental value of an area (Figure 4), while the relationship with the intensity of management was marginally significant (Table 5). In relation to the management strategies applied in the area, only habitat management and reduction of hunting were related to the environmental value of an area (Figure 4). The environmental value was higher in areas where habitat management or reduction of hunting were applied.

Table 5. Generalised linear model of the factors affecting environmental value of an area: rabbit and partridge abundance, intensity of management, and the use of different management strategies.

Variables	Parameter	SE	F	df	P
Intercept	294.30	21.51	187.26	1	<0.001
1. Rabbit abundance	–35.45	17.10	4.30	1	0.04
2. Partridge abundance	3.16	2.80	1.27	1	0.26
3. Expenditure on management	0.004	0.002	3.70	1	0.05
1*3	0.006	0.002	5.50	1	0.02
2*3	–0.0003	0.0002	1.33	1	0.24
Habitat management	–50.67	12.20	17.24	1	<0.001
Predator control	17.99	12.13	2.19	1	0.14
Prevention of diseases/parasites	20.29	16.84	1.45	1	0.23
Hunting reduction	–37.53	12.22	9.42	1	0.002
Translocations	–6.25	13.75	0.21	1	0.65

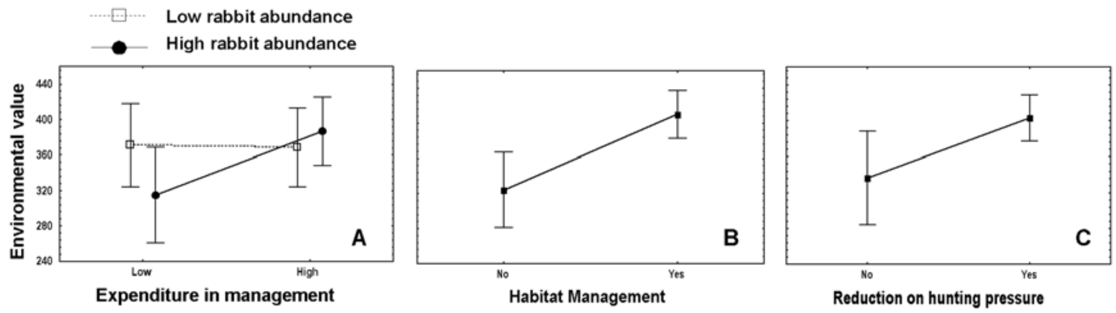

Figure 4. Relationship between the mean environmental value and: (A) high and low rabbit abundance for high and low expenditure (categories of rabbit abundance: low, ≤ –0.3; high, > –0.3 factor of rabbit abundance; expenditure categories: ≤1000 or >1000 euros); (B) habitat management; and (C) hunting reduction.

DISCUSSION

Towards the end of the 20th century there was a decline in the range and numbers of wild rabbits and red-legged partridges, to the extent that they required intensive management. In this paper, we have shown that in 85% of the areas surveyed in southern Spain, game management has focused on rabbits or partridges. Both species were favoured through management strategies in 95% of the areas during the 1998–1999 hunting season. We have calculated that the annual mean expenditure on managing small game in an area of 2000 ha ranged between 4500 and 8800 euros, with the maximum reaching 33500 euros. Management is applied more intensely through strategies related to habitat management, reduction of hunting pressure, and control of predators than through those related to translocations and the prevention of diseases and parasites. These strategy preferences could be attributed to the former strategies being easier and cheaper to apply. The intensity of management has increased in recent decades, showing that both hunters and landowners are aware of the decline of both species. It is interesting to note that the prevention of diseases and parasites has experienced a large increase in recent decades, showing that managers perceive diseases as one of the main causes of the decline of small-game populations.

The simultaneous use of multiple management strategies was the most common situation in southern Spain during the 1998-1999 hunting season, as reflected in our finding that most management strategies were significantly associated with another strategy. The associations between pairs of variables were not symmetrical, with less-used management strategies usually being associated with more-used strategies. The observed data fitted significantly to a combination of two associations, specifically, the associations between translocations of rabbits and partridges, and between partridge abundance and partridge annual growth rate. Rabbit and partridge abundances were significantly associated, consistent with the findings of a previous study of northern Spain (Gortázar et al. 2000b). This correlation may reflect the fact that rabbit and partridge translocations are usually applied in the same areas, an approach that is becoming increasingly common in Spain (Calvete et al. 1997; Gortázar et al. 2000a). Although this strategy does not always lead to an increase in abundance, it is employed to ensure a high hunting bag through the release of animals just before the hunting season (REGHAB 2002). Consistent with these results, we have shown that in general, intensity of management was related to high rabbit and partridge abundance. However, we would note that the association we established between high rabbit abundance and the use of individual strategies cannot be considered a causality relationship; it simply reflects the fact that these management strategies are more frequently employed when rabbit abundance is high.

Rabbits and partridges are important game species, and are also the main prey species in Mediterranean ecosystems. Thus, if we are to conserve Mediterranean biodiversity, the declines in rabbit and partridge numbers must be arrested and measures put in place to increase their abundances to past levels. For this reason it is important to consider the high intensity of management carried out by hunters or landowners, focusing especially on these species. The efficiency of this management should be fully evaluated. The effectiveness of most management strategies has already been evaluated by other authors (Newsome et al. 1989; Trout & Tittensor 1989; Trout et al. 1992; Moreno & Villafuerte 1995, Calvete et al. 1997; Gortázar et al. 2000a). In these studies, the population of the game species was monitored over an extended period during which the management strategy under evaluation was continuously employed. We have shown in this paper that changes in rabbit and partridge numbers between 1998 and 1999 are not significantly associated with any applied management strategy. One possible reason for this lack of associations is that we analysed the annual growth rate over only 1 year, which may not be sufficient time to detect the effects of management. However, management strategies used in each area can change from year to year (depending on the hunter or manager agreements, which are normally based on their perception of small-game populations), complicating the assessment of management effects over periods greater than 1 year. As stated by Strickland et al. (1996), the effectiveness with which management goals are achieved can only be measured through the development of specific management strategies that are then implemented for a period of several years. Moreover, these same authors advise against changing objectives on the basis of year-to-year fluctuations in estimates of population numbers or establishing objectives for subpopulations. These recommendations should be applied regardless of whether management measures are employed for hunting purposes or for wildlife conservation.

We have shown that the level of wildlife conservation in an area is related to the use of habitat management and the reduction of hunting pressure. Habitat management has previously been shown to successfully increase small-game populations (Moreno & Villafuerte, 1995; Blanco-Aguiar et al. 2001). The level of conservation in an area was also related to the interaction between rabbit abundance and the intensity of management. This relationship shows that in areas where rabbit abundance is high, the level of conservation is higher only when there is also a high expenditure on management. This suggests the corollary that when rabbit abundance is high but the intensity of management is low, the conservation level of the area is low, and even lower than in areas with lower rabbit abundance. The reduction of hunting pressure and habitat management are the two management strategies commonly used by hunters and landowners, with the latter used also by environmental agencies when the main goal is the conservation of habitat and species. Our results suggest that habitat management for small game favours the conservation of all wildlife. Habitat suitability is essential for the conservation of endangered predators in Mediterranean ecosystems (Ferrer & Harte, 1997; Palma et al.1999), and habitat management and reduction of hunting have been suggested as measures for enhancing predator numbers (Castro & Palma, 1996; Real & Mañosa 1997).

The annual growth rates of rabbit and partridge populations are dependent on the level of abundance of each population, with the population growth rate being higher when the abundance is higher. This result is very important when trying to improve areas with a low abundance of rabbits or partridges, because management in such areas is expected to produce a lower population increase than is achieved by management in areas with a high abundance. Moreno and Villafuerte (1995) arrived at the same conclusion when studying the effectiveness of scrub and pasture management on the improvement of wild-rabbit populations.

This result leads to the conclusion that conservation should be applied more in areas of low rabbit and partridge abundance. We have shown that low-abundance areas are less favoured by hunting managers. Hunters are more interested in spending money when the abundance of small game is high and thus hunting is more likely to produce a higher financial return and satisfaction. However, we have also shown in this paper that hunters and landowners applied more intensive management when partridge populations were declining than when they were stable. This relation was not seen in the case of wild rabbit. Thus, when planning the conservation of rabbit and partridge populations in a large territory, such as nationally, a trade-off appears: on the one hand, high-abundance populations could be enhanced with an expected high improvement, but these areas are more managed by hunters and landowners; while on the other hand, low-abundance populations could be enhanced with a lower expected improvement, and these are less managed by hunters and landowners. Low-abundance areas are normally at the edges of the species distribution and hence are of higher interest for conservation purposes.

MANAGEMENT IMPLICATIONS

Small-game management is initiated to improve rabbit and red-legged partridge populations, but a by-product of their management is an effect on wildlife conservation. Small-game management may have a role to play in wildlife conservation, but this role requires qualification. The need to evaluate the long-term benefits of small-game management to wildlife conservation should continue to be the focus of political and scientific studies. In our study the level of conservation in an area is dependent on the rabbit or partridge abundance (the most important prey species in Mediterranean ecosystems), and on the intensity of management; in addition, the level of conservation is related to the application of habitat management or reduction of hunting pressure.

Where small game numbers are too low to make hunting and management economically viable, integrated programs should be implemented to enhance the numbers of these species and the economic cost of such programs should be included in conservation goals. Alternatively, where small-game management is economic, because the abundance of small-game species is higher, wildlife conservation might best be achieved by hunters and landowners through a guided management plan. Efforts should be made to maintain small-game management in areas with large rabbit and partridge populations, and to enhance and guide small-game management in areas with low population densities. In this sense, hunters, managers, conservation agencies and policy makers should favour an approach in which they first develop specific management goals, and then apply strategies aimed at achieving these goals over several years and monitor the effectiveness of the management scheme throughout the entire management period.

The management plans of hunters and landowners should be guided and improved with the optimisations resulting from scientific evaluations of management plans. Understanding the effectiveness of small-game management in improving their populations and in conserving wildlife biodiversity is of critical importance to policy and funding decisions. Much of the existing Mediterranean biodiversity is unlikely to survive without effective strategies for small-game management.

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