Temporal abundance pattern of the wild rabbit in Doñana, SW Spain

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Summary. — From May 1983 to May 1985, sunset rabbit transect surveys (8.14 km long) were carried out on a weekly basis at Doñana Biological Reserve (SW Spain). No changes in relative abundance were observed between years, however rabbit abundance showed abrupt seasonal changes. A bimodal pattern was observed, with maxima in June (mean : 8.34 rabbits/km) and December (3.59 rabbits/km), and the annual minimum in October (1.57 rabbits/km). Rabbit abundance was similar in shrubland (2.63 rabbits/km) and pastures close to marshland (2.28 rabbits/km), and significantly lower in both than in the transitional band between shrubland and pastures (9.08 rabbits/km). Rabbit abundance into the shrubland was significantly different between years, suggesting some intra-population movements influenced by ***environmental factors.***

Résumé. — Deux ans de suite, on a réalisé des comptages hebdomadaires de lapins de garenne au crépuscule, le long d'un transect de 8.14 km dans la Réserve Biologique de Doñana. On n'a pas observé de changements significatifs dans leur abondance d'une année à l'autre, mais par contre des fluctuations saisonnières abruptes. Deux pics d'abondance relative ont été mis en évidence, l'un en juin (8.34 lapins/km) et l'autre en décembre (3.59 lapin/km), tandis que le minimum annuel a été enregistré en octobre (1.57 lapins/km). L'abondance relative moyenne, significativement la plus élevée, a été constatée dans la bande de transition du matorral aux pâturages (9.08 lapins/km), puis dans le matorral (2.63 lapins/km) et les pâturages (2.28 lapins/km). L'abondance des lapins de garenne dans le matorral montre des variations significatives inter-annuelles, influencées par les facteurs **environnementaux**.

INTRODUCTION

The rabbit *(Oryctolagus cuniculus)* is a native species from the Western Mediterranean Basin (Arthur 1989) although its present distribution also includes other areas of several continents (Rogers 1981). In some of those original areas, as the Iberian ecosystem, the rabbit is prey for 40 predators (Soriguer 1981), being a key prey for endangered species as the Iberian Lynx *(Lynx pardinus)* and the Spanish Imperial Eagle *(Aquila adalberti)* (Delibes and Hiraldo 1981, IUCN 1986). Impacts on rabbit populations such as the recent epizootic of Viral haemorrhagic disease (VHD) (Argüello *et al.* 1988, Buonavoglia *et al.* 1988, Morisse 1988) may be a serious threat for these specialized rabbit predators, most restricted to non-viable populations (Soulé 1987).

For an evaluation of these impacts, it is necessary to know how such an epizootic can affect rabbit population parameters, in particular rabbit abundance. However, there is little published information on rabbit population trends in its native countries (Soriguer 1981, Rogers 1981, Vandewalle 1989). In Doñana, Southwestern Spain, the epizootic of VHD was detected in March 1990 (S. Moreno, pers. comm.). In this area, preliminary studies have documented rabbit reproductive patterns (Delibes and Calderón 1979), distribution and abundance (Rogers and Myers 1979, Soriguer and Rogers 1981), daily activity and habitat use (Rau *et al.* in press), warren use (Rau 1988), and predator-prey relationshisps (Kufner 1986, Villafuerte *et al.* 1989, Moreno and Delibes in prep.).

The aims of this paper are threefold : a) to characterize the pattern of rabbit monthly relative abundance in Doñana, b) to determine the variation of this pattern between consecutive years, and c) to assess the relative abundance among biotopes.

STUDY AREA AND METHODS

The Doñana Biological Reserve (DBR) is a 70 km^2 protected area located on the right bank of Guadalquivir River mouth (37° N, 6° 30'W). In the landscape of this representative portion of the Doñana National Park (DNP) (Fig. 1), three environmental units can be recognized : marshland (8 % of total surface of DBR), shrubland (86 %) and sand dunes (6 %). An ecotone of pastures (up to several hundred meters wide, depending on the zone) is defined between marshland and shrubland.

Climate is Mediterranean with Atlantic influence ; summers are hot and dry (average temperature in August is 24.4° C) in contrast with winters that are mild and wet (average temperature in January is 10.6° C). Average annual rainfall is 525 mm, 88 % falling between October and April (data from 1973-1985, Beltrán 1988). Detailed descriptions of DBR and DNP can be found in Valverde (1958, 1967), Allier *et al.* (1974), Amat *et al.* (1979), Rogers and Myers (1980).

During two annual cycles (May 1983-May 1985) we conducted roadside counts of rabbits on a weekly basis, from a Land-Rover vehicle at constant speed (20 km/h). A transect 8.14 km long was defined using some of firebreacks and dirt roads of the study area (Fig. 1). Clear sunny days were selected to perform the rabbit surveys, which were begun half an hour before sunset ; all rabbits observed both sides of the transect (i.e. in a 10 m wide band) were counted (Alkon 1969, Eberhardt 1978, Villafuerte 1989, Rau *et al.* in press). The transect crossed three types of habitat : shrubland (4.87 km), pastures (1.51 km of open land, the so called Vera), and a mixed zone between shrubland and pastures we will describe as transition (1.76 km), with sparse shrubland and open grassland (Figure 1). Rabbit counts in each transect were averaged by months ; non-parametric statistical test were applied (U Mann-Whitney, Spearman correlation) using BMDP sofware (Dixon *et al.* 1983). In the text, mean values ($\bar{x}$) with their standard deviations ($\pm$ SD) or range of values are given.

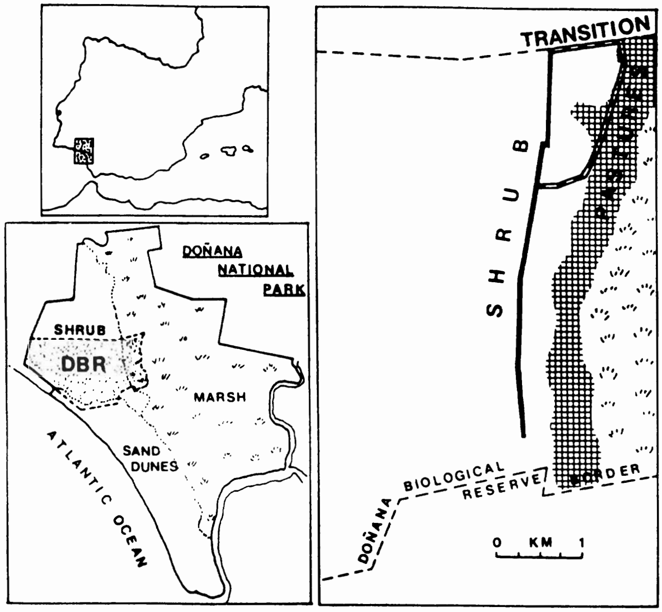

Fig. 1. — Location of the study area in the Doñana Biological Reserve. The transect, 8.14 km long, used for rabbit roadside counts was defined using firebreaks and dirt roads. Ecotones between main environmental units of Doñana National Park (left) have been marked with dotted lines.

RESULTS

During 25 months of rabbit abundance monitoring, up to 83 surveys were completed ($\bar{x}$ = 3.45 surveys/month), making a total distance of 675 kilometers.

Annual variations.

Comparison between both years showed no significant differences in relative abundance of rabbits (Table 1), so data of both years were pooled. However, when annual variation was segregated by habitat, the abundance of rabbits in the matorral was significant lower in 1983 than 1984 ; no significant differences were observed in the transition and in the pastures band.

Monthly and seasonal variations.

A cyclic annual pattern of rabbit abundance was observed (Fig. 2). Interannually, a bimodal pattern appeared, with a maximum in June ($\bar{x}$ = 8.34 rabbits/km, range : 6.43-10.25), and another, quantitatively less important, in December ($\bar{x}$ = 3.59 rabbits/km, range : 3.13-4.04). The minimum annual rabbit abundance was observed in October ($\bar{x}$ = 1.57 rabbits/km, range : 1.49-1.65).

TABLE 1. — Comparison of rabbit abundance by habitat as estimated by roadside counts during the same interval (May to Decembre, n = 8) in two successive annual cycles. Means (± SD) and range of values (rabbits/km) are given. Tests (U Mann-Whitney) compare values with the same superscript letter.

Year	Roadside counts	Habitat SHRUBLAND	TRANSITION	PASTURES	Annual total
1983	31	1.99^{a}(1.56)	11.17^{d}(8.85)	4.02^{e}(6.13)	3.72^{b}(2.94)
	2-5/month	0.49-4.25	5.2-29.7	0-18.6	1.49-10.2
1984	37	3.95^{a}(2.49)	9.40^{d}(4.30)	1.62^{e}(2.04)	4.45^{b}(2.21)
	2-5/month	0.82-6.87	3.3-15.0	0-6.1	1.65-7.58
Grand Means	83	2.63^{c}(1.67)	9.08^{c}(4.2)	2.28^{c}(2.73)	3.62 (2.06)
		8.7-5.4	4.87-17.2	0-9.8	1.57-8.34

[a]) $p \leq 0.05$
[b]), [d]), [e]) p = non-significative (n.s.)
[c]) Shrubland vs. Transition: $p \leq 0.001$
Shrubland vs. Pastures: p= n.s.
Transition vs. Pastures: $p \leq 0.001$

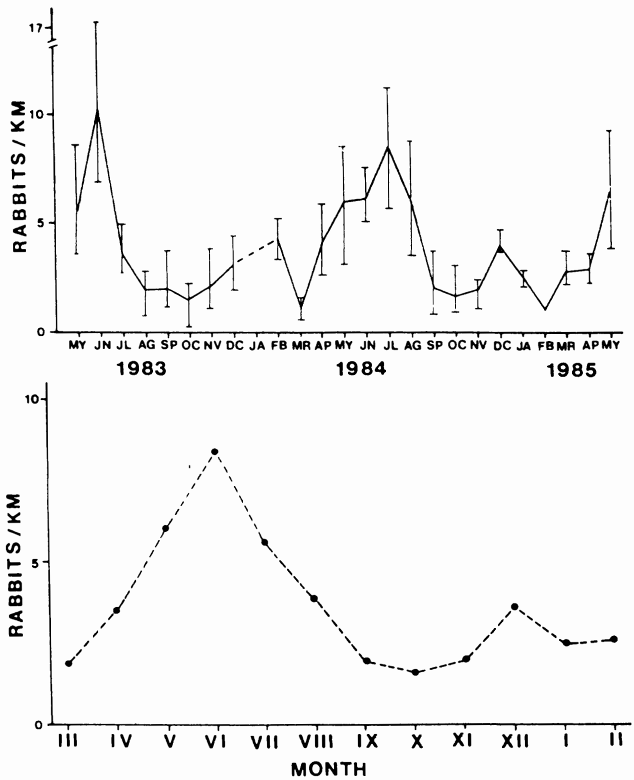

Fig. 2. — (Above) Monthly mean numbers of rabbits (rabbits/km) observed in weekly roadside counts, during two annual cycles. Vertical lines represent range of values and the dashed line indicates flooding of the transect. (Below) Average monthly variation in rabbit relative abundance.

By seasons, the greatest rabbit abundance was observed in summer (June-August, $\bar{x} = 5.94 \pm 2.24$), followed by spring (March-May, $\bar{x} = 3.79 \pm 2.06$), although differences were non-significant. However, the minimum registered during autumn (September-November, $\bar{x} = 1.83 \pm 0.22$) is significantly different ($p = 0.04$) from the winter mean value (December-February, $\bar{x} = 2.91 \pm 0.58$) ; rabbit abundances in autumn and winter were significantly lower than summer rabbit abundance ($p = 0{,}04$, both).

Spatial distribution.

Mean rabbit abundance in the transition zone was significantly greater than in the other two habitats, which showed similar rabbits counts (Table 1).

The annual variation of rabbit abundance in each habitat showed a similar pattern between transition and the other two habitats (transition vs. shrubland : $r_s = 0.79$, $p \leq 0.01$, transition vs. pastures : $r_s = 0.67$, $p \leq 0.05$, respectively) (Fig. 3). Interestingly, rabbit abundances in the shrubland and in the pastures were not correlated ($r_s = 0.34$, n.s.) (Fig. 3). In June, both the pastures and the transition showed their annual maxima of rabbit abundance ; at the same time, rabbit abundance decreased in the shrubland. In December, a reverse pattern was observed, with an increase in the rabbits counted in both the transition and in the shrubland, while rabbit numbers in the pastures fell to a minimum.

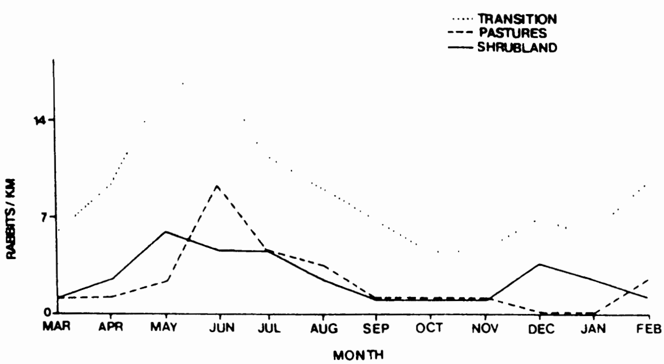

Fig. 3. — Monthly evolution of relative abundance of rabbits, as estimated by roadside counts, in three biotopes of Doñana Biological Reserve.

DISCUSSION

The pattern of temporal variation of rabbit abundance described here is close to the one observed by Rau (1988) in the same area, for a period partially simultaneous with our study (from October 1983 to November 1984). This author applied Taylor and Williams (1956) method for estimation of rabbit density using pellet counts in permanent plots (Rau *et al.* in press). However, as noted by Rau (1988), the correlation between his estimates of absolute abundance of rabbits and our relative estimates reached statistical significance only when a time-lag of two months was used ($r_s = 0.56$. $p \leq 0.05$, $n = 11$ months compared). This delay can be explained, at least partially, by the behaviour of juvenile rabbits which tend to stay near their natal burrow in the first weeks of life, making it difficult to detect them from a roadside transect (Soriguer 1983 a, Rau 1988).

From a seasonal perspective, the summer peak and autumn trough in rabbit numbers registered in this study were also detected by Kufner (1986), who conducted a bimonthly survey partially simultaneous with our study (from July 1984 to July 1985), taking roadside counts four times a day for three consecutive days. Nevertheless, Kufner (1986) did no detect the increase of rabbit abundance during winter, probably due to her sampling strategy. In other mediterranean rabbit populations (Camargue, SE France : Rogers 1981 ; Sierra Morena, SW Spain : Soriguer 1983 b, see also Soriguer and Rogers 1981) have described a pattern of intra-annual dynamics rather similar to the one observed in Doñana, including the winter peak have been described. However, this pattern is different from the one noted in Doñana by Valverde (1957), before myxomatosis reached this area (Autumn 1957) : the annual threshold of rabbit numbers tended to occur during summer, simultaneously with resources *parching*. Ten years later, Valverde (1967) had already noted the strong decrease of rabbit abundance during winter.

Regarding the factors determining the seasonal fluctuations of rabbit population at Doñana, they can be included in two groups of hypotheses. The first group considers such fluctuations to be a consequence of « extrinsic » factors to the rabbit population (mainly predation, see Erlinge *et al.* 1984, Sih *et al.* 1985, Kufner 1986, Newsome *et al.* 1989). The second group of hypotheses postulates that more « intrinsic » factors (density dependent effects, myxomatosis, etc., Fullagar 1977, Vandewalle 1989) are the basic mechanisms of regulation of rabbit abundance in a given area. In Doñana, evidence suggests that both factors may be important in regulation of rabbit population dynamics ; in particular, predation may reach a decisive importance in relation to other rabbit areas (Soriguer and Rogers 1981). During the study the incidence of myxomatosis fit well with the pattern described by Soriguer and Lopez (in press) ; traveled distance and diet of radiotracked lynxes (Beltrán 1988) let us to suggest that, in 1983, myxomatosis incidence peaked in Doñana around August.

The onset of reproduction of the rabbit in Doñana is annually triggered by the first rains of October-November (Delibes and Calderón 1979). This could explain the increase in rabbit abundance detected in December in our study. On the other hand, Soriguer (1981) and Soriguer and Rogers (1981) have pointed the universality of this reproductive pattern in all the areas where rabbits occur around the world.

Soriguer and Rogers (1981) also found the higher densities of rabbits near the border of land systems, particularly when grassland was closer to dunes. The higher abundance of rabbits in a mixed shrubland-pastures habitat could be interpreted as the best choice between feeding and defense of predators (Jaskic and Soriguer 1981, Moreno and Delibes in prep.). Local displacement to the pastures adjacent to marshland has been described as one possible foraging strategy for Doñana herbivores when ressources become scarce (Soriguer 1983 b). Our data suggest that rabbits adjacent to marshland may move up to several hundred meters, as a response to effects of drought, as registered for several years up to 1983. Similar rabbit-habitat relationships has been observed previously (Cf. Rogers and Myers 1979). It seems likely that foraging of rabbit predators could follow this intra-population movement of their prey ; these relationships should be tested by further studies.

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