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Effect on red fox litter size and diet after rabbit haemorrhagic disease in north-eastern Spain

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Introduction

It is well known that a decrease in abundance of some predators occurred after the epidemics of myxomatoxis, causing as much as 99.9% mortality in some European rabbit (*Oryctolagus cuniculus*) populations (Sumption & Flowerdew, 1985). In Spain, rabbits are the most important prey for most vertebrate predators (Delibes & Hiraldo, 1981), and because of this, some 'specialist' predators such as imperial eagle (*Aquila adalberti*) or Iberian lynx (*Lynx pardina*) became seriously endangered species (i.e. Ferrer, 1993; Rodríguez & Delibes, 1990, respectively). This diminution of abundance of the top predator has been argued as one of the factors that led to an alarming increase of 'generalist' species, particularly red foxes, *Vulpes vulpes*, and mongooses (Palomares *et al.*, 1995). These species are more able to find alternative prey when the primary resource becomes scarce (e.g. Markstrom, Kenward & Engren, 1988).

Rabbits are the most consumed prey species of the red fox in Spain (Amores, 1975; Blanco, 1988), as well as in other Mediterranean areas (Reynolds, 1979). In those areas where rabbits are scarce, red foxes have been reported to prey upon rodents, insects or partridges (being important competitors for other predators or humans), but foxes can also prey on other predators such as

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kestrels (J. L. Tella, pers. comm.), or fledging vultures (Donázar & Ceballos, 1988). These are the reasons why foxes are the most persecuted species in Spain by hunters, gamekeepers, and conservationists.

Since 1988, a new viral disease for rabbits, rabbit haemorrhagic disease (RHD), which was first described in China (Liu *et al.* 1984), has been reported throughout Europe and has greatly affected many of the wild rabbit populations (Villafuerte *et al.* 1994). After its arrival, there is no information on the consequences of this new disease on predators, with the exception of Fernández (1993), who reported the decrease of the breeding success of the golden eagles (*Aquila chrysaëtos*) in the north of Spain.

In this paper, we studied the effect of rabbit decline due to RHD on red fox, measuring red fox litter size and fox diet at two areas with different rabbit density before and after RHD in north-eastern Spain.

Material and methods

Red fox carcasses were collected from hunters and gamekeepers from the 1988–89 to 1992–93 hunting seasons (October–February) in the Central Ebro Valley (40 °30′ 42 °15′ N, 1 °45′ W 0 °30′ E), north-eastern Spain. The carcasses of adult females were classified into two main geographical origins: semi-arid cereal land ($n = 81$), where rabbits were abundant before RHD, and irrigated land (20 carcasses), where rabbits were rare before RHD (Blanco & Villafuerte, 1993).

Each uterus was examined carefully estimating the litter size by counting the dark placental scars (Lindström, 1981). Foxes captured during the 1988–89 and 1989–90 hunting seasons were included in the 'before-RHD' group.

Rabbit consumption by both populations was measured by studying the frequency of the lagomorph in 270 red fox stomach contents, measured as the proportion of stomachs with remains (portions of ear, bone, hair) of one or more lagomorphs in its contents. Since the length of time in which a high number of rabbit carcasses are found after a RHD outbreak is around 42 days (Villafuerte *et al.*, 1994), reproductive season (immediately after the first outbreak) was included in the 'before-RHD' group, but stomach contents collected since October 1989 are considered 'after-RHD'.

Results and discussion

Rabbit haemorrhagic disease (identified by macroscopic lesions, histology, and haemoaglutination) was first reported in the eastern part of the study area in January 1989. Three months later the disease was widespread in Central Ebro Valley.

TABLE I

Rabbit density (individuals/ha), rabbit consumption by foxes (proportion of fox stomachs containing one or more rabbits), and fox litter size, depending on the arrival of the rabbit haemorrhagic disease, in the two study areas

		Rabbit density*	Rabbits consumption (%)	Fox litter size	U	*P*
Irrigated area	Before RHD	0.23	0 (10)	3.33 [0.81] (6)	1.31	0.19
	After RHD	0.09	8.4 (83)	4.0 [1.03] (14)		
Semi-arid area	Before RHD	1.71	34.3 (22)	3.91 [1.08] (122)	−2.16	0.03
	After RHD	0.82	33.1 (141)	3.14 [1.16] (55)		

Note. Values enclosed in parentheses represent *n*, while values enclosed in brackets represent S.D.
* Obtained from Blanco & Villafuerte (1993)

Red fox litter size did not change significantly (Mann-Whitney U-test = 1.31, $P = 0.19$) before and after RHD in the irrigated area (Table I), where rabbits are nearly absent [only seven out 93 (7.5%) stomachs contained rabbit].

In the semi-arid area, rabbits are the most important singular prey item of the red fox. Rabbit consumption before and after RHD did not show significant variation, being above 30%. Conversely, red fox average litter size in this area decreased significantly (Mann-Whitney U-test = −2.16, $P = 0.030$) after RHD (Table I).

Reproduction in many vertebrate predators depends on prey availability (Smith, Murphy & Woffinden, 1990). Red fox populations show high spacial and temporal variability in reproductive parameters, depending on food availability, and in general their litter size depends on the availability of small or medium-sized vertebrates (Englund, 1970; Goszczynski, 1989). During the years immediately following the myxomatosis outbreak, foxes had lower litter sizes in western Europe. Later the diet of these fox populations changed to include greater amounts of voles, and litter sizes increased again (Sumption & Flowerdew 1985). Since voles and other alternative prey are not available in the Iberian Peninsula, local fox populations may have more difficulties finding abundant food resources. After RHD, fewer rabbits were available during the breeding season, and fox litter size was reduced. In a previous paper (Villafuerte *et al.*, 1994), it was shown that, during the RHD outbreaks, dead or ill rabbits could be easily found by predators. That could be the cause of our finding that foxes from both areas captured rabbits despite their decline.

Although we have no further evidence, according to the local hunters, fox abundance seems not to be decreasing in the area. Because of the fox's opportunistic feeding strategy, predation by foxes may buffer the natural recovery of the reduced rabbit populations after the RHD, helping the decline of other competing predators, less plastic in diet (i.e. the Iberian lynx, or the imperial eagle), which hardly survived the myxomatosis epidemics.

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Pipistrellus nathusii (Chiroptera: Vespertilionidae) in Britain in the mating season

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Introduction

Nathusius' pipistrelle, *Pipistrellus nathusii*, is found from western Europe east to the Russian republic and Asia Minor (Corbet & Harris, 1991). The most westerly nursery colonies found to date are in the Netherlands (Kapteyn & Lina, 1994). *P. nathusii* migrates south-west in autumn and winter (Strelkov, 1969). In Britain it is classed as a migrant winter visitor, which may breed (Speakman *et al.*, 1991; Hutson, 1993; Harris *et al.*, 1995).

The earliest record of *P. nathusii* in Britain is from the Shetland Islands in 1940 (Herman, 1992). Since then, there have been 27 documented records of *P. nathusii* identified in the hand (Stebbings, 1970; Speakman *et al.*, 1991, 1993), and a few unsubstantiated bat detector records, including one in summer in Scotland (Rydell & Swift, 1995). The records are mainly of single individuals, with numbers peaking in September and May, hence it is possible that the bats may overwinter here (Speakman *et al.*, 1991; Hutson, 1993).

In western Europe, males are found in mating groups with females in autumn (Heise, 1982; Gerell-Lundberg & Gerell, 1994). Males use roosts from which they perform an advertisement display to attract females (Sosnovtseva, 1974). A male bat either flies in the vicinity of the roost and repeats an advertisement call, or it repeats the call from its roost (Gerell-Lundberg & Gerell, 1994). The advertisement call consists of two parts. The first, or main part, has several components that sweep down and up in frequency between 14 and 28 kHz. This is followed after a pause of approximately 100 ms by the second part, or trill, of several components at around 35 kHz (Ahlén, 1990; Gerell-Lundberg & Gerell, 1994). Search phase echolocation calls produced by *P. nathusii* have frequency of maximum energy in the range 36 to 43 kHz (Ahlén, 1990; Zingg, 1990). *Pipistrellus pipistrellus* has a similar advertisement display during which calls of several components are produced (Lundberg & Gerell, 1986). These calls are referred to as songflight calls, as the advertisement display of *P. pipistrellus* is always performed whilst flying in the vicinity of the roost (Gerell-Lundberg & Gerell, 1994). Songflight calls of the 45 kHz and