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Negative effect of the arthropod parasite, *Sarcoptes scabiei*, on testes mass in Iberian ibex, *Capra pyrenaica*

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ABSTRACT

Testes mass is a key factor in male reproductive success and is potentially exposed to so-called 'parasitic castration'. This is the result of the direct destruction or alteration of reproductive cell lineages (parasitic castration *sensu stricto*), or the indirect detrimental effects – for example, via body condition – on the ability of progenitors to produce or rear offspring (parasitic castration *sensu lato*). There are enormous gaps in our knowledge on the effects of parasites on the testes of wild mammals and in an attempt to rectify this dearth of data we examined the relationship between the skin parasite *Sarcoptes scabiei* and testes mass in Iberian ibex *Capra pyrenaica*. We considered data from 222 males that were culled in the population from the Sierra Nevada in Spain. Our results provide evidence that sarcoptic mange is associated with reduced size-corrected testes mass in Iberian ibex which supports the hypothesis that parasitism is a determining factor in gonad plasticity in male mammals. We discuss several hypothetical causes of this relationship and highlight the need to deepen the sub-lethal effects of pathogens if we are to accurately understand their modulator effects on host population dynamics.

1. Introduction

Testes size is a key factor in male reproductive success (Preston et al., 2003; Schulte-Hostedde and Millar, 2004) given that big testes are an advantageous trait in species with sperm competition (Preston et al., 2003; Schärer et al., 2004; Schärer and Vizoso, 2007). Primary sexual characters vary with mating tactics (Harcourt et al., 1981; Awata et al., 2006), body condition (Schulte-Hostedde and Millar, 2004; Schulte-Hostedde et al., 2005a) and season, at least in seasonal breeders (Goeritz et al., 2003). Gonads, however, are also potentially exposed to so-called 'parasitic castration' (Baudoin, 1975). This can result in the direct alteration or even destruction of reproductive organs (parasitic castration *sensu stricto*) and can be temporary or definitive (Baudoin, 1975; Ruiz-Martínez et al., 1993). 'Parasitic castration' can also refer to indirect detrimental effects – for example, via body condition – on the ability of progenitors to produce or rear offsprings (parasitic castration *sensu lato*) (Barnard and Behnke, 1990; Hudson and Dobson, 1997; Møller, 1997).

The direct effects of parasites on gonads have mostly been recorded to date in invertebrate taxa (Baudoin, 1975). In vertebrates most studies that have reported reduced mating and rearing capacity in parasitized hosts have been

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performed on birds (Hurtrez-Boussès et al., 1998; Bize et al., 2004; Marzal et al., 2005; Velando et al., 2006) and fish (Pélabon et al., 2005; Kolluru et al., 2009). What little data concerning wild mammals that exists generally deals with female fecundity (Iason and Boag, 1988; Pence and Windberg, 1994; Neuhaus, 2003; Newey and Thirgood, 2004; Newey et al., 2004; Pioz et al., 2008) or host behavior (Cramer and Cameron, 2007) and there are enormous gaps in our knowledge regarding the effects of parasites on the testes of wild mammals. Recently, Santiago-Moreno et al. (2010) examined the relationship between sperm quality and the level of parasitism in Iberian ibex. Nevertheless, all animals examined in their study were selectively hunted for their relatively small horn development and individual phenotypic quality was not considered in their analysis as a potential confounding factor. Also, despite some determining factors of testis traits have nonlinear effects and despite testis traits are governed simultaneously by multiple factors (Sarasa et al., 2010b), the most highlighted analysis in the study of Santiago-Moreno et al. (2010) looked separately for linear relationships. Moreover, only one from the six sperm variables considered showed a weak relationship with one from the five parasitic classes considered (Santiago-Moreno et al., 2010). Consequently, like in almost all wild-living mammal species, the relationship between parasites and testes traits has to be deepened in Iberian ibex.

In this work, we examined the relationship between sarcoptic mange caused by *Sarcoptes scabiei* and testes mass in Iberian Ibex *Capra pyrenaica*. This endemic ungulate from the Iberian Peninsula has suffered in recent decades severe epizootic episodes of sarcoptic mange, which have become one of the most important destabilizing factors operating on the population dynamics of the Iberian ibex (Pérez et al., 2002). Sarcoptic mange is widespread in wild mammals and it is known to induce marked increases in mortality rates (Pence and Ueckermann, 2002). However, the sublethal effects of sarcoptic mange and, more particularly, its effects on reproductive success in wild fauna, are still under-considered.

According to the parasitic castration hypothesis (Baudoin, 1975; Lafferty and Kuris, 2009) or to the adaptive plasticity of parasitized hosts (Forbes, 1993; Perrin et al., 1996; Hurd, 2001), we would expect mange to have a negative effect on testes, to be expressed as a decrease in relative testes mass in mangy as opposed to uninfected individuals.

Clinical testicular alterations were recorded in individuals with severe sarcoptic mange infestation in some species (Little et al., 1998; Skerratt et al., 1999; Soulsbury et al., 2007). Despite the lack of consensus on the subject, negative effects of chorioptic mange (*Chorioptes bovis*) on testicular activity in domestic rams were reported (Rhodes, 1975, 1976; Heath, 1978). These studies highlight the need to go into this topic in 'mange-wild host' interactions.

2. Materials and methods

2.1. Study site and population

We studied the Iberian ibex population of the Sierra Nevada (36°00′–37°10′ N, 2°34′–3°40′ W, Spain) that is a reference population in long term monitoring and experimental approaches in Iberian ibex ecology (Pérez et al., 1994; Sarasa et al., 2009; Serrano et al., in press). In particular, numerous studies were focused on the interaction between sarcoptic mange and Iberian ibex (Pérez et al., 1997, 2006; Serrano et al., 2007; Alasaad et al., 2008; Sarasa et al., 2010a). In this study we considered three categories of mange infestation: 0 = mange-free males; 1 = moderate lesions that include cases with lesions in <50% of host skin surface and the initial and development stages described by León-Vizcaíno et al. (1999); 2 = severe lesions that include cases with lesions in more than 50% of host skin surface and the consolidation and chronic stages as per León-Vizcaíno et al. (1999). We considered data from 222 males (Table 1), which were culled by the Natural Space staff for management purposes in the periods 1995–1998, 2000–2003, 2007 and 2008. At culling, each individual was weighed to the nearest 500 g and measured to the nearest 0.5 cm; age was assessed by horn-segment counts (Fandos, 1991). At necropsy, the animals' testicles were removed and weighed to the nearest 0.01 g. The arithmetic mean of the mass of the two testicles was used as the initial testicle mass.

2.2. Analysis

To examine the relative effect of explanatory variables we estimated several residuals (detailed below) (Sarasa et al., 2010b) and in each case we chose the best fitted regression between linear and non-linear models based on the Akaike's Information Criterion, AIC (Burnham and Anderson, 2002). We log-transformed body mass and testes mass to normalize the data. Shoulder height is one of the highest growth priorities during juvenile skeletal development in Iberian ibex (Fandos, 1991) and so to control for allometry on testes mass we used the residuals of the linear regression of the log-transformed arithmetic mean of the mass of both testes on shoulder height. This

Table 1
Distribution of sampled animals.

(a) Distribution of sampled animals per months													
Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Sample size	11	22	26	33	10	28	6	16	18	32	17	3	222
(b) Distribution of samples animals per age (in years)													
Age	1	2	3	4	5	6	7	8	9	10	13		Total
Sample size	15	46	69	39	19	12	7	7	3	4	1		222
(c) Distribution of sampled animals per mange categories													
Mange category		Mange-free (0)				Moderate mange (1)				Severe mange (2)			Total
Sample size		175				19				28			222