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Does *Sarcoptes scabiei* synchronize its breeding cycle with that of the Iberian Ibex, *Capra pyrenaica*?

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Abstract

We have analyzed 5 samples from the skin of 368 Iberian ibexes from Sierra Nevada Natural Space (southern Spain) in order to characterize the age structure of the *Sarcoptes scabiei* metapopulation affecting this host population and, particularly, to search for possible reproductive peaks of the parasite. Monthly mean mite density and number of larvae peaked in November, coinciding with the rutting season of its host, when the size of ibex mixed groups becomes larger. On the other hand, monthly number of nymphs differed significantly, reaching higher values in May (coinciding with the peak of parturitions), August and November. Our results suggest that (i) there is some extent of synchronization between the breeding cycles of both the host and the parasite and (ii) nymphs could play an important role in the mite transmission to offspring. We discuss the potential role of sexual hormones in such increase of larvae and, therefore in mite numbers.

Key words: breeding cycle, *Capra pyrenaica*, host-parasite relationships, *Sarcoptes scabiei*, synchronization

Introduction

Certain ectoparasites, particularly those feeding on host blood, synchronize their breeding cycles to those of their hosts; peak breeding of the parasites coinciding with peak production of host reproductive hormones. This results in sufficient parasite numbers to be transmitted to the new hosts. It has been observed in avian lice (Foster 1969; Wheeler and Threlfall 1986; Chandra et al. 1990) and fleas (Rothschild and Ford 1972).

42 Among wild host species, sarcoptic mange affects most of the Euro Asiatic bovid
 43 species (Bornstein et al. 2001). In Spain, for instance, the disease reached several
 44 populations of Cantabrian chamois, *Rupicapra pyrenaica* (Fernández-Morán et al.
 45 1997), Iberian ibex, *Capra pyrenaica* (Fandos 1991; León-Vizcaino et al. 1999),
 46 European mouflon, *Ovis orientalis musimon* (León-Vizcaino et al. 1992) or aoudad,
 47 *Ammotragus lervia* (González-Candela et al. 2004). In the case of the epizooty affecting
 48 Iberian ibex from the Sierra de Cazorla, Segura y Las Villas Natural Park (southern
 49 Spain), the mortality due to the disease reached over a 95% of the population animals
 50 (Fandos 1991; León-Vizcaino et al. 1999).
 51 The life-cycle of the mite comprises several phases or stages: egg, larva (hexapod),
 52 protonymph, tritonymph and adult (Fain 1968). The life-cycle of *Sarcoptes scabiei* (var.
 53 *canis*) is completed within 10-13 days (Arlian and Vyszynski-Moher 1988) or 21 days,
 54 in the case of human scabies (Mellanby 1944). Under similar conditions, adult females
 55 and nymphs survive more time than larvae and adult males do (Arlian et al. 1989).
 56 Sarcoptic mange shows seasonal dynamics in terms of prevalence and intensity of
 57 parasitisation (Christophersen 1986; Pérez et al. 1997; Mimouni et al. 2003) together with
 58 certain inter-annual periodicity regarding both epidemiological variables and mortality
 59 of scabietic hosts (Walton et al. 2004; Rossi et al. 2007). Despite such periodicity has
 60 not already clearly demonstrated, the disease exhibits density-dependent patterns
 61 (Valenzuela et al. 2000; De Danieli and Sarasa 2015).
 62 As occurs in many social ungulates, Iberian ibex shows sexual segregation during most
 63 of the year (Alados 1985). During the rut season, which extends from mid-November to
 64 mid-December (Fandos 1991) mixed groups become more frequent and larger (Alados
 65 and Escos 1996 a). In this species, ovulatory activity (e.g., peak of progesterone
 66 concentration in peripheral blood) extends from December to January (Santiago-

Moreno et al. 2003). Ibex males show the highest values of plasma testosterone concentration in October-November (Toledano-Díaz et al. 2007) coinciding with a greater allocation to testes mass (Sarasa et al. 2010). Parturition season of ibex extends from the end of April to the first days of July, with a peak in May (Fandos 1991). A higher reproductive synchrony has been suggested for the Sierra Nevada ibex population with regards to other populations (e.g., Sierras de Cazorla, Segura y Las Villas Natural Park (Alados and Escos 1996 b)).

The aim of our study is to characterize the reproductive phenology of this parasite in a high mountain naturally-infested host population.

Materials and methods

The study area

We conducted our study on the Iberian ibex population from the Sierra Nevada Natural Space (SNNS) (36°00'–37°10' N, 2°34'–3°40' W, southern Spain). This area has an extension near 1700 km² and comprises the alpine massif with the highest peak of the Iberian Peninsula, the Mulhacén (3481 m above sea level) and eleven more peaks higher than 3000 m above sea level. Because of its proximity to the Mediterranean Sea, this natural space has a Mediterranean climate with important altitudinal gradients of temperature and rainfall, all the bioclimatic stages or thermotypes described for this climate being present (Rivas-Martínez et al. 1984).

The SNNS harbors one of the most important Iberian ibex populations, both from a demographic (over 10000 specimens) and genetic variability viewpoints (Pérez et al. 2002). The monitoring of the temporal dynamics of the disease and its impact on the host population started in 1992 and currently is still ongoing.

Sample collection and laboratory analysis

Between April 2002 and March 2016 we obtained the whole skin of 368 Iberian ibex specimens from the SNNS. The number of animals sampled in each month is included in Table 1. These animals were selectively shot within the context of a management program devoted to the control of both ibex density and the spread of the disease. From each skin we systematically removed 5 pieces (6.25 cm² each) from the more frequently affected areas, namely, mouth, forehead, chest, forelimb and hindlimb (León-Vizcaino et al. 1999). These pieces were then digested overnight in a 5% KOH solution at 45°C. After re-suspending the digestion products, a 10 ml aliquot was analyzed under the stereomicroscope for differential mite count (Castro et al. 2016). Mite specimens were classified as larvae, nymphs (including both protonymphs and tritonymphs) and adults, according to the descriptions of Fain (1968).

Data analysis

For each host, we obtained the absolute numbers of the different stages of the mite life-cycle as well as the mean density of mites as the average of the densities obtained for each skin piece digested (local density). Possible differences between monthly sex-ratio (female mites/male mites), numbers of larvae and nymphs and mean mite density were checked with a Kruskal-Wallis test (Siegel and Castellan 1988). Additionally, we performed a negative binomial regression analysis where counts is the outcome variable and months and host sex as explanatory variables with a general formula: $\log_{10}(\text{Nr. larvae} + 1) \sim \text{Month} * \text{Sex} + (1|\text{ORD})$. Statistical analyses were performed with the R V.2.15.1 Package (R Development Core Team 2011).

Results

Mites were detected and counted in 273 of the 368 samples analyzed. Local density ranged from 0 to 4519.29 mites/cm². Within each month, values of mean mite density

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showed a high level of dispersion (e.g., associated standard deviation) and monthly dynamics of the mean mite density is represented in Figure 1. Monthly dynamics of the number of larvae is depicted in Figure 2, and that regarding nymphs is included in Figure 3.

We found a significant drop in mite counts in October (t -value = -2.316; p -value = 0.0206). Monthly number of larvae did not significantly differ between months (Kruskal-Wallis test $K = 17.026$; 11 df; p -value = 0.1071) and the same occurred with nymphs (Kruskal-Wallis test $K = 12.128$; 11 df; p -value = 0.3541). Nevertheless, all the variables show a peak in November, and mean number of nymphs also peaked in May and August.

Monthly sex-ratio of adult mites did not also differ between months (Kruskal-Wallis test $K = 12.640$; 11 df; p -value = 0.3175) and reached highest values (over 6.5) in May and November (Figure 4).

Discussion

The age structure of the mite metapopulation analyzed was similar to that described by Skerrat et al. (1999) regarding wombat, *Vombatus ursinus*. The maximum density obtained in our study is also very close to those reported by Little et al. (1998) in red foxes, *Vulpes vulpes* and Skerrat et al. (1999) in wombats. Terada et al. (2010) did not find a seasonal trend in the case of mange affecting dogs. On the contrary, Sokolova et al. (1989) found seasonal changes in *S. scabiei* reproductivity in human scabies, determined by higher numbers of eggs in mite burrows in the period September-December. Moreover, these authors found latent females (with arrested oogenesis) from December to July. In a study of contact-transmitted particles (pseudoectoparasites) on Iberian ibex, Sarasa et al. (2011) evidenced that the higher

lifespan of such particles started in November, when ibex hair coat becomes longer and may play a greater role in surface cleaning efficiency).

Regarding ibex breeding phenology, ovulatory activity in captive females (peak of progesterone concentration in peripheral blood) extends from December to January (Santiago-Moreno et al. 2003), and males show peaks of plasma testosterone concentration in October-November (Toledano-Díaz et al. 2007). Anyway, we must consider that the reproductive physiology of free-ranging female ibex can differ in some extent from that of captive animals (Zalányi 2001).

During the rut period, mixed ibex groups (including animals of both sexes) are more frequent and reach their larger size during the period November - January (Alados and Escos 1996). Moreover, the period favouring the higher lifespan of contact-transmitted particles on Iberian ibex coat starts in November and this may play a role in surface cleaning efficiency (Sarasa et al. 2011). Nevertheless, the gregariousness period of ibex begins before and ends after the rutting period do so (Couturier 1962).

The immunosuppressive effect of steroid hormones is known. Decristophoris et al. (2007) found a strong positive effect of this hormone on the amount of nematode eggs in male Alpine ibex (*Capra ibex*) faeces. Progesterone is also a known immunosuppressant in humans (Wyle and Kent 1977). In Bovidae, these effects may be mediated by the presence of the uterine serpin, a progesterone-induced endometrial protein (Schust et al. 1996).

Mellanby (1944) suggested that young recently-fertilized mite females were responsible of mange transmission, since they wander on the host skin surface. In our study, all the mite stages might potentially play a role in horizontal transmission of sarcoptic mange during the rut period of hosts whereas nymphs might do so in vertical transmission as their numbers peak in the birth period.

The parasite sex-ratio, biased toward females could reflect higher longevity and/or survival of this sex (Arlian et al. 1989; Hengge et al. 2006), but also this is considered as an adaptation to increase the reproductive potential (Price 1980; Esch and Fernandez 1993). It is interesting to note that sex-ratio peaked in May and November. In our study, we tried to count gravid mite females, but after digesting the skin samples most of adult females were not transparent enough to assess if they harbored eggs or not. Regarding the egg count as a fertility index (Sokolova et al. 1989), apart from the increase in the effort to analyze samples, we don't know how longer, after hatching, the eggs remain in the burrows and, therefore, such numbers are difficult to be interpreted. On the basis of the results obtained in this study, we hypothesize that the breeding cycle of *Sarcoptes scabiei* might be synchronized with that of the Iberian ibex, and that this mite might be benefited by the host's reproductive immunosuppression (Arck et al. 2007; Decristophoris et al. 2007) and by related mechanical factors, such as ibex coat growth (Sarasa et al. 2011). Anyway, in order to fully assess this, the analysis of larger monthly sample sizes could be needed.

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316 Table 1. Monthly distribution of the number of Iberian ibex sampled in this study.

317

318	Month	Number of animals sampled
319	January	31
320	February	32
321	March	50
322	April	83
323	May	49
324	June	26
325	July	14
326	August	16
327	September	14
328	October	20
329	November	15
330	December	18
331	TOTAL	368

332

333 Figure 1. Monthly dynamics of the mean density of mites. Points represent the mean

334 value and bars the standard deviation.

335
 336 Figure 2. Monthly dynamics of the number of *Sarcoptes scabiei* larvae. Points represent
 337 the mean value and bars the standard deviation.
 338

339
 340 Figure 3. Monthly dynamics of the number of *Sarcoptes scabiei* nymphs. Points
 341 represent the mean value and bars the standard deviation.
 342

343
 344 Figure 4. Monthly dynamics of the mites sex-ratio (number of females / number of
 345 males).