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Unusual multiparasitism causes overweight in a wood mouse, *Apodemus sylvaticus* (Rodentia: Muridae), from a post-fire regeneration area

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Abstract. Multiparasitism is a common ecological phenomenon, being the norm rather than the exception, in the wild. This article describes the case of a wood mouse, *Apodemus sylvaticus*, originating from a post-fire regeneration area, infected with multiple helminth species and remarkable overweight. The mouse analyzed was captured at a post-fire regeneration site in the Serra Calderona Natural Park (Comunitat Valenciana, Spain). The rodent was captured and marked for the first time in the spring of 2011, weighing 22.5 g. When it was recaptured in the winter of 2012, it weighed 44.0 g. The mouse was parasitized by a total of 31 helminths belonging to seven species, including six *Taenia parva* metacestodes. These tapeworm juveniles reached a weight of 12.0 g, more than 25 % of the host's weight. Therefore, multiple parasitism should be considered the real cause of its elevated weight. Although only one case of this unusual overweight has been found in this post-fire regeneration area, it, nevertheless, supports the theory that ecosystem instability can induce unusual situations in the parasite-host system.

Key words: multiple parasitism, massive infection, *Taenia parva*, perturbed Mediterranean ecosystem, Serra Calderona, Spain

Introduction

Multiparasitism, defined as the simultaneous presence of two or more parasite species in one host, is the rule rather than the exception in Nature (Bordes & Morand 2011). From an ecological point of view, multiparasitism can be understood as an evolutionary strategy aiming at the increase of fitness of the parasite species involved in the infection. Nevertheless, some authors consider this situation unusual given the weakening of the host and the resulting increase in susceptibility in acquiring multiple infections (Cansi et al. 2012).

The presence of two or more individuals belonging to the same parasite species in one host is frequently found. Moreover, intraspecific interactions between parasites may have a negative impact on the body size and fecundity of the parasites and may even produce a stronger immunological response (Bush et al. 2001). This interaction known as crowding effect and experimentally evidenced in some helminth species leads to an adjustment of the biomass of the parasite infrapopulation to the host capacity (Roberts & Janovy 2009).

Parasites are considered an important source of information concerning the stability of ecosystems (Marcogliese 2005), and numerous publications propose the role of parasites, particularly helminths, as biological tags of environmental impacts (Sures 2001, Jankovská et al. 2005, Fuentes et al. 2010). The binomial host-parasite tends to have a balance between the two species, requiring a long process of co-evolution which involves the establishment of a parasite population without implying the death of the host (Bush et al. 2001). Although these interactions are usually more stable in unaltered environments, they exercise a rather negative impact on areas affected by anthropic actions or natural disasters given their lower stability and resistance to environmental alterations due to the long-lasting regeneration process.

Environmental impacts influence the density of intermediate and definitive hosts, making them more susceptible to infections (Lafferty & Holt 2003) and giving way to an increase in prevalence and even to the pathogenicity of parasites (Holmes 1996). The behaviour of parasites after a perturbation of the ecosystem is the result of multiple factors guaranteeing

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Fig. 1. The studied wood mouse (*Apodemus sylvaticus*), from the Serra Calderona Natural Park (Comunitat Valenciana, Spain), before dissection, showing the presence of swellings in the abdominal region. Bar: 1 cm.

the restructuring of the biological cycle in such a way that the regulation of a parasite infracommunity will be conditioned by the direct effects of the perturbation, the changes in host population dynamics and by the pressure exercised by the other infrapopulations as well as climatic conditions (Fuentes et al. 2009).

Herein, an unusual case of multiparasitism in a wood mouse, *Apodemus sylvaticus*, originating from a post-fire regeneration area is described, highlighting the potential relationship between multiparasitism and a perturbed ecosystem.

Material and Methods

This study forms part of the research line of the scientific group Parasites and Fire (PAF) of Universitat de València, Spain, concerning the study of the role of helminths of small mammals as biological tags in the post-fire regeneration process of a Mediterranean ecosystem, namely Serra Calderona Natural Park, situated between the provinces of Castelló and València (Comunitat Valenciana, Spain), having suffered a devastating wildfire in the summer of 1992 (Fuentes et al. 2007, 2010, Sainz-Elipe et al. 2012). Periodic surveys to analyze the epidemiological evolution of the helminthfauna of small mammals related to post-fire regeneration as well as the influence of various intrinsic and extrinsic factors have been carried out. The study of small mammals and the helminthological analysis were done following the methodology proposed by Galán-Puchades et al. (1999) and Fuentes et al. (2000, 2007, 2010), having analyzed more than 1000 wood mouse specimens hitherto.

Herein, the case of a sexually active *A. sylvaticus* male having reached the unusual weight of 44.0 g, is presented. The specimen was found dead in Rebalsadors, one of the regeneration sites, in the winter of 2012, the 20th post-fire year. The rodent had been captured and marked at the same site in the previous season of the survey, the spring of 2011, when the mouse was registered as an inactive male of 22.5 g. During the previous examination at the laboratory, the presence of some swellings in the abdominal region was noteworthy (Fig. 1).

Results

The wood mouse was found to be parasitized by a total of 31 parasites belonging to seven helminth species:

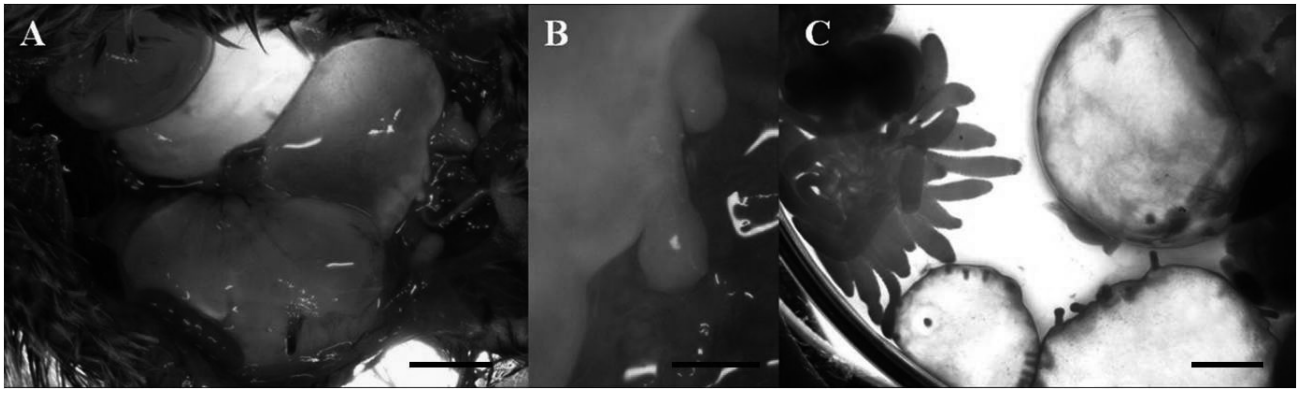

Fig. 2. *Taenia parva* cysts before and after extraction from the abdominal cavity of the studied wood mouse (*Apodemus sylvaticus*), from the Serra Calderona Natural Park (Comunitat Valenciana, Spain): A) view of the largest cysts; B) view of the smallest cysts; C) view of some metacestodes. Bar: A) and C) 10 mm; B) 5 mm.

four *Brachylaima* sp. (Trematoda: Digenea) in the small intestine; four adult *Gallegoides arfaai* in the small intestine and six metacestodes of *Taenia parva* (Cestoda) in the abdominal cavity; one *Mastophorus muris* in the stomach, six *Syphacia stroma* in the small intestine, seven *Trichurs muris* and three *Syphacia frederici* (Nematoda), the two latter species in the caecum.

The *T. parva* metacestodes encountered differed in size, being in various developmental stages (Fig. 2). One of these polycephalic metacestodes was completely formed, with a total of 21 long strobila, pseudosegmented and presenting scolices with 21 pairs of hooks, all of them wrapped in a cyst of 4.6 cm. Three other metacestodes presented a smaller diameter of 2-3 cm, having 21 scolices each, without strobila. The remaining two metacestodes, 1-2 cm in diameter, presented an incipient stage of development. The total weight of the cysts was 12 g.

The remaining helminths found had reached the adult stage and were encountered in their normal microhabitat. In the case of the four *G. arfaai* individuals, it was impossible to determine the exact weight of each one, as they had been damaged in the dissection process when some of the rings were broken. However, the total weight of these four adult tapeworms was 1.8 g. The remainder of the helminths was intact, having reached a total weight of approximately 0.1 g.

Discussion

A weight of 40.0 g had until then been the maximum of adult specimens in Serra Calderona in the 20-year study period. However, the specimen described herein reached 44.0 g, a figure, according to the literature, larger than that considered the maximum for this species of small mammals (Blanco 1998).

After resection of the helminths, it was concluded that the actual weight of the mouse was approximately 30.1 g, in agreement with data gathered in the studies by Fuentes et al. (2000, 2007, 2010). Thus, considering that the helminth infracommunity itself presented a total weight of 13.9 g, it can be concluded that multiparasitism was the real cause of the overweight condition of this mouse.

Previous studies (Fuentes et al. 2007, 2010) demonstrated a greater diversity, abundance and species richness in perturbed areas undergoing a recuperation process, in which infracommunities of up to eight helminth species had been found.

Multiparasitism implies that members of the parasite infracommunity compete for food and space, but their success depends on the amount of resources and on the host's immunological response. In this sense, hosts able to tolerate a greater parasite burden could increase the transmission potential of a parasite species (Bordes & Morand 2011). The latter, in turn, would at the same time regulate the host's population growth, acting as a stabilizer of the ecosystem (Bush et al. 2001), and would simultaneously participate in natural selection, aiming at the preservation of the strongest genotypes. However, the host might be individually adversely affected, but its population might benefit (Combes 1996).

The helminth burden of each parasite species found corresponds to the values previously reported in this enclave, merely the number of *T. parva* metacestodes stands out. Fuentes et al. (2010) established that *T. parva* is a component species of the wood mouse host only in the non-burned area in Serra Calderona, which is verified by the greater prevalence as well as the average parasitism intensities registered in the control area. In the post-fire regeneration area a range of 1-3 metacestodes per host has been documented so far, while this range has increased to 1-6 metacestodes in the control area (unpublished data). Helminths of an indirect cycle, such as *T. parva*, are more susceptible to environmental perturbations, which makes it possible to use them as reliable biological tags of the reestablishment of the ecosystem's trophic chain, as they require the intervention of an intermediate host, in this case a rodent, serving as prey for its definitive host. In the Iberian Peninsula, the biological cycle of *T. parva* can usually only be completed through rodents of the genus *Apodemus* and the common genet (*Genetta genetta*), which act as intermediate and definitive host, respectively (Ribas et al. 2009). Therefore, the perseverance of this parasite in the ecosystem is only possible given the presence and interaction of the wood mouse and this carnivore. Moreover, in general, helminth infrapopulations remain stable along time, which is indicative of both a suitable trophic chain and of the ecosystem's stability. Thus, cases of most severe multiparasitism, massive infections and ectopic parasitism occur most frequently in perturbed ecosystems (Holmes 1996). In the present case, such a drastic increase in the helminth burden can be explained as a case of aberrant parasitism, a compensatory mechanism aiming at the increased likelihood of successful transmission. A large number of metacestodes in the intermediate host does not only increase the likelihood of successful infection of the definitive host but also causes the rodent to move in a clumsier manner and, thus, being

more vulnerable and more easily detectable by its predators (Combes 2001, Poulin 2007).

The fact that the metacestodes found were in different developmental stages, and morphologically easily identifiable (Świderski et al. 2007), stands out, as it is probable that the infestation took place as a consequence of the repeated ingestion of the infective form of the parasite, i.e. a taeniid egg. Previous studies indicate that *T. parva* adults reach enormous parasite burdens in the intestines of their definitive hosts (Ribas et al. 2009), resulting in millions of eggs expelled into the environment. Its omnivorous and opportunistic character prompts the wood mouse to ingest seeds, berries and invertebrates, thus facilitating the accidental and the repetitive ingestion of eggs which are fecal contaminants of these foods. On the other hand, experimental evidence has shown that some species of Taeniidae are able to exercise an immunological effect impeding the reinfection of the intermediate host by the same parasite species (Lightowlers 2010). Thus, it is likely that the wood mouse was parasitized as the consequence of only one infection, and the different development of the larvae might be due to a crowding-effect limiting their growth.

This is the first time, a case of overweight condition in *A. sylvaticus* as a consequence of multiparasitism has been registered, which means that parasitism, besides being a metabolic phenomenon, has to be considered as a possible cause of the abnormal increase in the host weight. Moreover, the presence of this wood mouse in a post-fire regeneration area could support the association between unusual parasitism and perturbed environments, which present a lower stability and resistance to external perturbations affecting all layers of the ecosystem, including the ecological niche of parasites.

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