Host/parasite postfire responses: the helminths of *Apodemus sylvaticus* (Rodentia, Muridae) as bioindicators of its movements after fire

M. T. Galán-Puchades, M. V. Fuentes, A. M. Cerezuela, R. Fons & S. Mas-Coma

Galán-Puchades, M. T., Fuentes, M. V., Cerezuela, A. M., Fons, R. & Mas-Coma, S., 1998. Host/parasite postfire responses: the helminths of *Apodemus sylvaticus* (Rodentia, Muridae) as bioindicators of its movements after fire. *Misc. Zool.*, 21.2: 35-43.

Host/parasite postfire responses: the helminths of Apodemus sylvaticus *(Rodentia, Muridae) as bioindicators of its movements after fire.*– The close relationships between helminth parasites (trematodes, cestodes, nematodes and acanthocephalans) and their hosts are able to yield a variety of information. Likewise, environmental characteristics exert a marked influence on both the host communities and on those stages of the helminth biological cycles that develop in the external environment (i.e. eggs, larvae). The present paper investigates two Mediterranean ecosystems affected by fire, with the aim of determining the value of the helminths of a typical recolonizing small mammal (*Apodemus sylvaticus*) as bioindicators of host movements after fire. For this purpose, an index of similarity is presented to reflect helminth species'importance in both burnt and control areas.

Key words: Helminths, *Apodemus sylvaticus*, Bioindicators, Postfire responses, Mediterranean ecosystems.

(Rebut: 26 V 98; Acceptació condicional: 20 X 98; Acc. definitiva: 1 XII 98)

Maria Teresa Galán-Puchades, Màrius Vicent Fuentes i Ferrer, Ana Maria Cerezuela Bravo & Santiago Mas-Coma, Depto. de Parasitología, Fac. de Farmacia, Univ. de Valencia, 46100 Burjassot, Valencia, España (Spain).- Roger Fons, Lab. Arago, Univ. P. et M. Curie (Paris VI) and CNRS, URA 2156, 66650 Banyuls-sur-Mer, France (France).

Studies were supported by Acción Integrada Hispano-Francesa N° 68/240, 91 and 121, Interuniversity Agreement Valencia - P. et M. Curie of Paris VI, Spanish DGICYT Projects PB 87-0135, PB 92-0517-C02-01, and postdoctoral fellowship of the MEC/MRES (France) for M. T. Galán-Puchades.

ISSN: 0211-6529

Introduction

In addition to the major importance of parasites in medical pathology and in veterinary practice, parasitological studies have been found to provide important and varied information on the characteristics of their hosts. Helminths (trematodes, cestodes, nematodes and acanthocephalans) may provide highly useful data on the biology, ecology, biodiversity, biogeography, systematization, evolution and phylogeny of their hosts (see reviews by MAS-COMA, 1992 and THOMAS et al., 1996). Emphasis should be placed on the importance of parasites, particularly of helminths, as specific biological tags.

In the Mediterranean regions the spread and proliferation of forest fires has become a matter of considerable concern, so that research aimed at evaluating the consequences of fire upon the flora and fauna of the affected zones is needed. Studies addressing the scarring and recovery of burnt ecosystems, are of maximum priority for they allow the *in situ* evaluation of the hypothesis of ecological succession.

The results reported to date in the Mediterranean regions suggest that the study of the dynamics of parasite populations in animals captured in areas affected by fire represent a new source of information about the scarring processes of the affected areas. It is evident that host dissemination strategy after fire has repercussions upon its parasitic fauna, which can thus be used as an indicator of recolonization. The parasitological data confirm those obtained in studies of the repopulation dynamics of the hosts in zones affected by fire, which is in turn dependent upon vegetation regeneration speed. To date, the results obtained indicate that parasites may be used as biological tags of regeneration in areas affected by fire (GALÁN- PUCHADES et al., 1990, 1992, 1993, 1996; FELIU et al., 1993; FUENTES et al., 1993; GALÁN-PUCHADES & FUENTES, 1996).

In the present study, an example which reflects the correspondence among the movements of small mammals after fire, regeneration of the vegetation, and the helminth fauna from the affected zones is presented. The rodent/parasite model (*Apodemus sylvaticus* /helminths) in two Mediterranean ecosystems affected by fire is used.

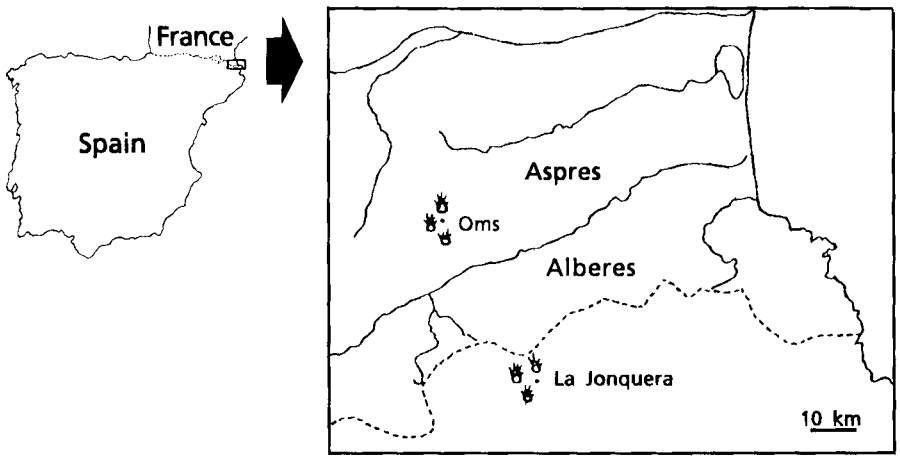

Fig. 1. Geographical localization of the studied areas.
Localización geográfica de las áreas de estudio.

Material and methods

Studies by FONS et al. (1988, 1993) in two Mediterranean ecosystems affected by fire established the dynamics of recolonization by small mammals (specifically, insectivores and rodents) in the successive years after the fire. The study areas were located in the Massif of Aspres, Department of the Eastern Pyrenees, in the South of France and near the locality of Oms (FONS et al., 1988); and in the Alberes mountains (province of Gerona) in the north of Spain near La Jonquera (FONS et al., 1993). The two areas are separated by about 40 km (fig. 1).

In order to carry out the helminthological study, we analysed material from hosts found dead in traps used in the studies of FONS et al. (1988, 1993). Host material analysed included 432 long-tailed field mice *A. sylvaticus* (Linnaeus, 1758) (Rodentia, Muridae), of which 279 were from the burnt ecosystems (147 from the fire near Oms and 132 from the fire of La Jonquera), versus 153 from unburnt (control) areas. The control areas were chosen taking into account their ecological similarity (fundamentally edaphic and concerning vegetation cover) to the affected zones before the fire. These areas included trapping stations in proximity to both burn areas.

The helminths detected were studied using common helminthological techniques. Trematodes were stained with Grenacher's boracic carmine, and cestodes with alcoholic chlorhydric carmine. Plathyhelminths were later differentiated with acidified alcohol, dehydrated in an alcohol series, cleared with xylene and mounted in Canada balsam between slide and coverslip. Nematodes were studied by direct examination between slide and coverslip with clearing fluid (e.g. lactophenol). No acanthocephalans were found.

The composition of the isolated helminthfauna in the burnt zones was studied on a yearly basis over the years following the fire. Helminth postfire communities were compared between years using Sorensen similarity index, as calculated in MAGURRAN (1988). This index is designed to equal 1 in cases of complete similarity (when the two sets of species compared are identical) and 0 if the sites are dissimilar and have no species in common. In order to investigate the degree of similarity of the helminths of each pair of helminthfaunas considered, all possible pairing combinations were tested.

The values obtained for the comparison of each pair of helminthfaunas were arranged in the form of trellis diagrams (MACFADYEN, 1954), widely employed in the analysis of both plant and animal communities.

Results

Table 1 specifies the qualitative composition and type of life cycle [indirect cycles with intermediate host(s) or direct cycles without them] of the helminthfaunas of the field mouse detected in the two burnt areas during the years after the fire, and of the control helminthfauna. Tables 2 and 3 show the results of Sorensen's index of similarity arranged in trellis diagrams.

Oms fire

The helminthfauna that qualitatively exhibited the greatest richness in terms of the number of species detected corresponded to specimens of *A. sylvaticus* from surrounding unburnt areas. Excluding those helminths which due to preservation deficiencies could not be specifically identified (*Hymenolepis* sp. indet. and *Aonchotheca* sp. indet.), 16 helminth species were found in the control field mice: 1 trematode, 4 cestodes and 11 nematodes. The helminthfauna found in *A. sylvaticus* captured in the burnt zone during the second postfire year exhibited the greatest qualitative richness (13 species: 3 trematodes and 10 nematodes) of the helminthfaunas detected in the postfire years investigated. In the course of the third and fourth years after the fire a decrease was recorded in the number of species found (possibly due to a loss of specimens, preferentially those which present an indirect life cycle) followed by a recovery during the fifth year.

Regarding the control helminthfauna, the results in Oms (table 2) show that the helminths of *A. sylvaticus* studied in the second postfire year exhibited the greatest similarity with respect to the helminths from unburnt zones. In the third and fourth years

Table 1. Qualitative composition of the helminthfaunas of *Apodemus sylvaticus* in the burnt and control areas during the post-fire years: O. Oms; J. La Jonquera; *A.s. Apodemus sylvaticus*; N. Number of *A.s.* examined; ILC. Indirect life cycle; DLC. Direct life cycle; ? Non experimentally demonstrated.

Composición cualitativa de las helmintofaunas de Apodemus sylvaticus *en las zonas quemadas y control durante los sucesivos años postincendio: O. Oms; J. La Junquera; A.s.* Apodemus sylvaticus*; N. Número de* A.s. *examinados; ILC. Ciclo biológico indirecto; DLC. Ciclo biológico directo; ? Sin demostrar experimentalmente.*

	Year post-fire									
	2nd		3rd		4th		5th		6th	
	O	J	O	J	O	J	O	J	J	Control
N	105	95	19	4	10	9	13	10	12	153
Parasite species / Life cycle										
Trematoda										
Brachylaima sp. / ILC	-	-	-	-	-	-	-	-	-	+
Cestoda										
Taenia parva larvae / ILC	-	+	+	-	-	-	-	+	-	+
Gallegoides arfaai / ILC	+	-	+	-	-	-	-	-	-	+
Skrjabinotaeina lobata / ILC	+	+	+	-	+	+	+	-	-	+
Hymenolepis fraterna / ILC	+	-	-	-	-	-	-	-	-	-
H. diminuta / ILC	-	-	-	-	+	-	-	-	-	+
H. sp. indet. / ILC	+	-	+	-	-	-	+	-	-	+
Nematoda										
Trichuris muris / DLC	+	+	+	-	+	-	+	+	-	+
Aonchothece annulosa / DLC?	+	+	-	-	+	-	+	-	+	+
A. muris-sylvatici /DLC?	+	-	-	-	-	-	-	-	-	+
A. sp. indet. / DLC?	+	-	-	-	-	-	-	-	-	+
Eucoleus bacillatus / DLC?	+	+	-	-	+	+	+	-	+	+
Calodium hepaticum / DLC	-	-	-	-	-	-	+	-	-	+
Heligmosomoides polygyrus/DLC	+	+	+	+	-	+	+	+	+	+
Syphacia stroma / DLC	+	+	+	+	+	+	+	+	+	+
S. frederici / DLC	+	+	+	+	+	+	+	+	-	+
Aspiculuris tetraptera / DLC	+	-	-	-	-	-		+	-	+
Mastophorus muris /ILC	+	+	+	-	-	-	+	-	+	+
Rictularia proni /ILC	+	+	-	+	-	+	-	-	+	+

after the fire the helminthfaunas found in the hosts analysed exhibited the least relation to the controls, followed by a recovered similarity in the course of the fifth postfire year.

On considering the helminthfaunas of the postfire years, those recorded in the second and fifth years exhibited the highest index of similarity.

Table 2. Trellis diagram showing Sorensen's indexes of similarity between the helminths of *Apodemus sylvaticus* in the years after the fire of Oms (2nd-5th) and in the control (C).

Diagramas de Trellis mostrando el resultado de la aplicación del índice de similaridad de Sorensen a las helmintofaunas de Apodemus sylvaticus *entre los años tras el incendio de Oms (del 2° al 5°) y el control (C).*

					2nd
				0.64	3rd
			0.63	0.60	4th
		0.78	0.70	0.83	5th
	0.81	0.61	0.72	0.83	C
C	5th	4th	3rd	2nd	

La Jonquera fire

In the case of the fire near La Jonquera, the richest helminthfauna corresponded (as in the case of the fire at Oms) to the second postfire year, with a total of 10 species (2 cestodes and 8 nematodes). In the following years, a qualitative impoverishment was recorded, with few fluctuations as to the number of species found. The helminths whose presence is practically constant throughout the period of study always exhibit direct life cycles (i.e. *Heligmosomoides polygyrus, Syphacia stroma, S. frederici*).

The similarity study (table 3) regarding the control helminthfauna showed that, as in the case of the Oms fire, the helminths obtained from *A. sylvaticus* in the second year after the fire exhibited the closest relation to those observed in the unburnt areas. However, the most similar helminthfaunas from among the possible pairs examined were found to correspond to the third and fourth postfire years.

Discussion

The joint discussion of the results corresponding to both fires is schematically reflected in figure 2. Despite the fact that findings should be analysed with caution due to the low number of animals recorded in certain years, parasitological data seem to follow the results obtained in studies of the repopulation movements of *A. sylvaticus* in areas affected by fire, and are in accordance with the regeneration rate of the vegetation cover.

Host dissemination strategies after fire clearly have repercussions upon parasitic faunas which may thus be used as a biological tag of colonization. Thus, in studies conducted to obtain information on the impact of fire and the scarring process of burnt Mediterranean ecosystems, mention is deserved of the value of helminths as bioindicators of postfire host movements.

However, it must be pointed out that as the medium involved is not a closed system (i.e., the burnt zone should be regarded as an "open continental isolate"), the surface affected by fire continues to receive an influx of hosts from unaffected peripheral areas. These individuals gain access to the burnt area along with their non-reduced helminthfauna, which may thus partly mask the effects of postfire perturbations that tend to minimize the presence of certain parasites.

Table 3. Trellis diagram showing Sorensen's indexes of similarity between the helminths of *Apodemus sylvaticus* in the years after the fire of La Jonquera (2nd-6th) and in the control (C).

Diagramas de Trellis mostrando el resultado de la aplicación del índice de similaridad de Sorensen a las helmintofaunas de Apodemus sylvaticus *entre los años tras el incendio de La Junquera (del 2° al 6°) y el control (C).*

						2nd
					0.57	3rd
				0.80	0.75	4th
			0.55	0.67	0.67	5th
		0.36	0.67	0.60	0.75	6th
	0.55	0.48	0.55	0.40	0.77	C
C	6th	5th	4th	3rd	2nd	

Oms fire

The studies of the recolonization dynamics of small mammals after the Oms fire were carried out by Fons et al. (1988). In the first year after the fire very few animals were captured in the affected areas, due to both specimen deaths and escape to safer zones. According to Fons et al. (1988), it is in the second postfire year when *A. sylvaticus* begins to invade the burnt area. The parasitological findings confirm these recolonizing movements of the field mouse, for the helminthfauna recovered from the specimens studied in the second postfire year exhibits a high index of similarity to the helminthfauna detected in the control area. This similarity suggests that, in view of the absence of fire effects in the helminthfauna detected in this second year, the parasites observed in the burnt zone correspond to an introductory or allochtonous helminthfauna, i.e., introduced along with the corresponding host specimens that colonize the burnt areas from the control zones.

The first responses to the different perturbations produced by the fire are seen in the third and fourth postfire years, when the indexes of similarity with respect to the controls are at their lowest. These results also confirm the fact that it is after the third postfire year that the field mouse population in the burnt area stabilizes (Fons et al., 1988); as a result, at least some of the individuals captured in this zone over these years correspond to animals that live in the affected areas, and their helminthfaunas should by then reflect the effects of the alterations caused by the fire (i.e., lack of a vegetation cover, drying and heating of the ground, the depletion of invertebrate populations, the absence of predators, etc.). These observations imply a qualitative impoverishment of the helminthfaunas due to a potential loss of species that are unable to complete their life cycles.

During the fifth year, the helminths detected again exhibit clear similarities to the controls, thus suggesting a gradual return of the field mouse helminthfauna recorded in the unburnt areas. Thus, likewise in this year, the helminths corroborate the repopulation dynamics of *A. sylvaticus*, for the studies of this mouse reveal that in the fifth postfire year the return to the initial status is quite apparent, with a stabilization of the population dynamics, a sex ratio of close to 1 and an age group distribution similar to that seen in the control zones (Fons et al., 1988).

La Jonquera fire

Fons et al. (1993) investigated the postfire recolonization dynamics of the small mammal community in the fire near La Jonquera.

As regards the repopulation dynamics of *A. sylvaticus*, the helminthologic results show that, as in the case of the Oms fire, the field mouse helminthfauna corresponding to the second postfire year exhibits the greatest similarities to the control zone. This similarity suggests the presence of a helminthfauna introduced along with the colonizing hosts originating from the unburnt control area. These parasitological observations agree with the mastozoological findings of Fons et al. (1993). These authors found the *A. sylvaticus* population to peak in March of the second year after the fire.

As regards the subsequent postfire years, it should be taken into account that additional specimens of *A. sylvaticus* could not be studied in certain years because only material found dead in traps was used; the sacrifice of further animals would have altered the natural recolonization process. Therefore, the qualitative impoverishment in the helminthfauna recorded in the subsequent years could also have been related to the limited number of samples obtained. However, in La Jonquera, and unlike the situation in Oms, there appear to have been fewer fluctuations in the number of parasite species in the course of the years studied. This parasitological situation could suggest two different circumstances. On one hand, the burnt characteristics in this zone could have caused the study area to be less affected, the parasitological responses therefore being less apparent. On the other hand, a number of factors could have led to a faster recovery of the burnt area. This latter possibility would imply the absence of a major loss of parasites as that observed in the case of the Oms fire.

The results reported by Fons et al. (1993)

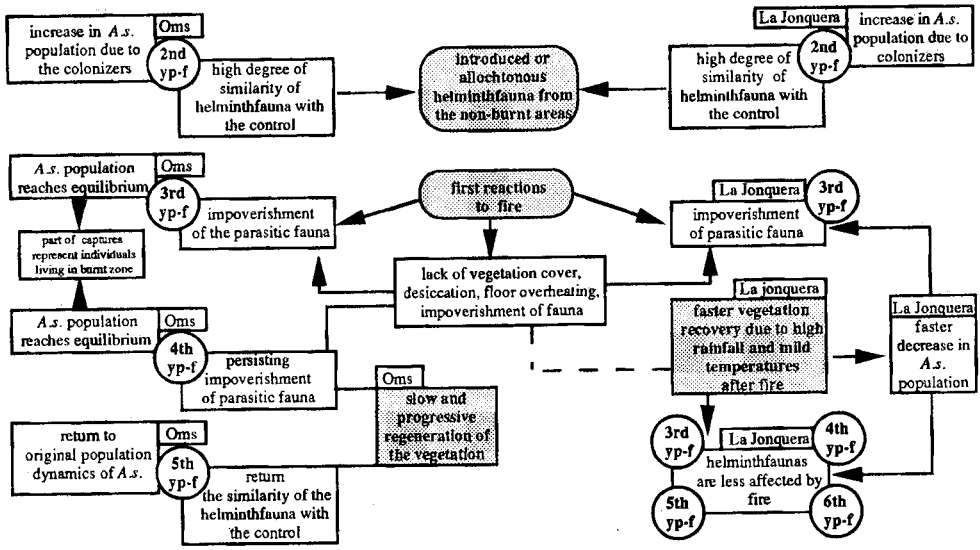

Fig. 2. Diagram showing the results obtained in Oms and La Jonquera fires by Fons et al. (1988, 1993) regarding the dynamics of post-fire recolonization by *Apodemus sylvaticus* and the helminthological results: Yp-f. Year post-fire; A.s. *Apodemus sylvaticus*.

Esquema de los resultados obtenidos por Fons et al. (1988, 1993) sobre la dinámica de recolonización postincendio de Apodemus sylvaticus *en Oms y La Junquera, conjuntamente con los resultados helmintológicos obtenidos: Yp-f. Año postincendio; A.s.* Apodemus sylvaticus.

support this latter possibility, based on the parasitological findings. According to these authors, after the *A. sylvaticus* population peak in March of the second postfire year, a sharp decrease was noted followed by population fluctuations. In the fire near La Jonquera, the decrease in the population of *A. sylvaticus* was faster than usual. Fons et al. (1993) pointed out that this could be explained by a faster vegetation recovery, the latter in turn being due to high rainfall and mild temperatures in the first months and years after the fire.

Acknowledgments

The heavy work in the field could not have been accomplished without the help of MM. B. Batailler, I. Grabulosa, J. P. Clara, Th. Fons and G. Sauvy, to whom we wish to express our gratitude.

Resumen

Respuestas postincendio del modelo hospedador/parásito: los helmintos de Apodemus sylvaticus *(Rodentia, Muridae) como bioindicadores de su movimiento tras el paso del fuego*

Los helmintos parásitos (trematodos, cestodos, nematodos y acantocéfalos) son capaces de proporcionar una variada información sobre sus hospedadores debido a las estrechas relaciones con ellos establecidas. Asimismo, las características medioambien-

tales ejercen una notable influencia, tanto sobre las comunidades hospedadoras como sobre aquellas fases del ciclo biológico de los helmintos que transcurren en el medio externo (huevos, larvas). En el presente trabajo se determina, en dos ecosistemas mediterráneos afectados por el fuego (fig. 1), el papel de los helmintos de un típico micromamífero recolonizador (*Apodemus sylvaticus*), como bioindicadores de sus movimientos tras el paso del fuego. Para ello se utiliza un índice de similaridad aplicado al estudio de las faunas helmintianas de hospedadores procedentes tanto de zonas quemadas como de zonas indemnes utilizadas como control. Los resultados obtenidos muestran cómo las helmintofaunas detectadas en ambas zonas de estudio (tabla 1) y en base a los resultados obtenidos tras la aplicación del índice de Sorensen (tablas 2, 3), muestran los movimientos seguidos por el ratón de campo en los años sucesivos al paso del fuego. Así, es destacable, que en ambos casos, es durante el segundo año post-incendio cuando se capturan en las zonas quemadas animales que presentan las helmintofaunas más similares a la que presentan en zonas no quemadas circundantes, mostrándose con ello el origen de la colonización de los hospedadores. Tras unos años de menor similitud entre zonas quemadas y testimonio por causa de las pérdidas de especies y/o imposibilidad de consecución de ciclos biológicos en las áreas afectadas por el fuego, se tiende a una progresiva mayor similitud de las helmintofaunas con respecto al control, como resultado de la regeneración del medio tras el incendio (véase el proceso esquematizado en la fig. 2).

References

Feliu, C., Fons, R., Mas-Coma, S., Galán-Puchades, M. T., Fuentes, M. V., Blasco, S. & Grabulosa, I., 1993. The helminth parasites as markers on the dynamics of micromammals recolonisation after fire. In: *Fire in Mediterranean Ecosystem*: 271-279 (L. Trabaud & R. Prodon, Eds.). Commission of the European Communities, Brussels.

Fons, R., Grabulosa, I., Saint Girons, M. C., Galán-Puchades, M. T. & Feliu, C., 1988. Fire and regeneration of mediterranean ecosystems. Dynamics of micromammals repopulation. *Vie Milieu*, 38: 259-280.

Fons, R., Grabulosa, I., Feliu, C., Mas-Coma, S., Galán-Puchades, M. T. & Comes, A. M., 1993. Postfire dynamics of small mammals community in a Mediterranean forest (*Quercus suber*). In: *Fire in Mediterranean Ecosystem*: 259-270 (L. Trabaud & R. Prodon, Eds.). Commission of the European Communities, Brussels.

Fuentes, M. V., Galán-Puchades, M. T., Cerezuela, A. M., Mas-Coma, S., Feliu, C. & Fons, R., 1993. Análisis helmintoecológico del ratón de campo, *Apodemus sylvaticus* (Linnaeus, 1758) (Rodentia: Muridae) en un área quemada de bosque mediterráneo. *Acta Parasitol. Portug.*, 1: 190.

Galán-Puchades, M. T. & Fuentes, M. V., 1996. Parasites and Fire. *Parasitol. Today*, 12: 327.

Galán-Puchades, M. T., Fuentes, M. V., Cerezuela, A. M. & Mas-Coma, S., 1996. Dynamique de la recolonisation et étude helmintho-écologique post incendie de mammifères (Insectivores et Rongeurs) de la Chaîne Calderona (Comunidad Valenciana, Espagne). *Vie Milieu*, 46: 377.

Galán-Puchades, M. T., Fuentes, M. V., Mas-Coma, S., Feliu, C. & Fons, R., 1993. Estudio de la recuperación de dos áreas mediterráneas quemadas mediante el análisis de las helmintofaunas del ratón de campo, *Apodemus sylvaticus* (Linnaeus, 1758) (Rodentia: Muridae). *Acta Parasitol. Portug.*, 1: 191.

Galán-Puchades, M. T., Fons, R., Feliu, C., Torregrosa, M., Jimenez, A. M. & Fuentes, M. V., 1990. Etude bioècologique de l'helminthofaune d'*Apodemus sylvaticus* (Rodentia: Muridae) dans les écosystémes perturbés par l'incendie. *Vie Milieu*, 40: 263-264.

Galán-Puchades, M. T., Mas-Coma, S., Fuentes, M. V., Jimenez, A. M. & Fons, R., 1992. Dinámica de la comunidad helmintiana parásita de poblaciones del ratón de campo, *Apodemus sylvaticus* (Linnaeus, 1758) (Rodentia: Muridae) en ecosistemas perturbados por el fuego. In: "In Memoriam" *al Profesor Doctor D. F. de P. Martínez Gómez*: 467-480 (S. Hernández, Ed.). Servicio de Publicaciones de la Universidad de Córdoba, Córdoba.

MacFayden, A., 1954. The invertebrate fauna of Jan Mayen Island (East Greenland). *J.*

Anim. Ecol., 23: 261-297.

MAGURRAN, A., 1988. *Ecological diversity and its measurement*. Croom Helm, London.

MAS-COMA, S., 1992. Parasitología ecológica y evolutiva. In: *Avances en Parasitología-Protozoología*, 1: 43-65 (M. L. Sanmartín Durán, Ed.). Servicio de Publicaciones e Intercambio Científico, Universidad de Santiago, Santiago de Compostela.

THOMAS, F., VERNEAU, O., MEEUS, T. DE & RENAUD, F., 1996. Parasites as to Host Evolutionary Prints: Insights into Host Evolution from Parasitological Data. *Int. J. Parasitol.*, 26: 677-686.