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The rodent *Abrothrix olivacea* and its role as a host of micro- and macroparasites in Chile: A systematic review and meta-analysis

El roedor *Abrothrix olivacea* y su papel como hospedero de micro y macroparásitos en Chile: Una revisión sistemática y metaanálisis

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The olive grass mouse (*Abrothrix olivacea*) is a South American rodent with ecological and life history characteristics that suggest a high reservoir capacity for zoonotic pathogens. The objectives of this study were to determine the micro- and macroparasites of the olive grass mouse in Chile and to compare the prevalence of these parasites in other sympatric rodents. A systematic review was carried out on the micro- and macroparasites of the olive grass mouse in Chile reported in articles available in the PubMed, Web of Science, and Scielo Scientific Library databases using the PRISMA method. In addition, a meta-analysis of the prevalence of these micro- and macroparasites in the olive grass mouse was performed, and their prevalence in other rodents was compared using meta-regression. Of the 51 articles available in the literature, a total of 68 micro- and macroparasites were recorded, of which 6 are zoonotic. Prevalence varied between parasites, highlighting a higher overall prevalence of helminths in the olive grass mouse (8.4 %) compared to other rodents (2.8 %). The presence of micro- and macroparasites and their high prevalence (in some cases, compared to the prevalence observed in other rodents) highlight the potential role of the olive grass mouse in the epidemiology of pathogens. Therefore, further research on disease ecology focused on this rodent species is required.

Key words: Cricetidae; pathogens; small mammals; Rodentia; zoonosis.

El ratón oliváceo (*Abrothrix olivacea*) es un roedor sudamericano que presenta características ecológicas y de historia de vida que sugieren una alta capacidad reservoria para patógenos zoonóticos. El objetivo de este estudio fue realizar un análisis de los microparásitos y macroparásitos en el ratón oliváceo en Chile, así como comparar la prevalencia con otros roedores simpátricos. Se realizó una revisión sistemática sobre microparásitos y macroparásitos en el ratón oliváceo en Chile consultando las bases de datos PubMed, Web of Science y Scielo Scientific Library, utilizando el método PRISMA. Además, se realizó un metaanálisis de la prevalencia de estos microparásitos y macroparásitos en el ratón oliváceo y se comparó con la prevalencia en otros roedores utilizando metarregresión. De 51 artículos disponibles en la literatura, se registraron 68 micro y macroparásitos en total, de los cuales 6 son zoonóticos. La prevalencia varió entre parásitos, destacando una mayor prevalencia general de helmintos en el ratón oliváceo (8.4 %), en comparación a otros roedores (2.8 %). La presencia de micro y macroparásitos y alta prevalencia (en algunos casos comparado a otros roedores), resalta el potencial papel del ratón oliváceo en la epidemiología de patógenos, por lo que se sugiere una mayor investigación sobre ecología de enfermedades enfocada en esta especie de roedor.

Palabras clave: Cricetidae; patógenos; pequeños mamíferos; Rodentia; zoonosis.

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The order Rodentia is the group of mammals that hosts the largest number of host species of zoonotic pathogens, associated with more than 80 diseases that affect humans (Han *et al.* 2016). Rodent species considered reservoirs of zoonotic pathogens share several attributes related to their ecology and life history. For instance, they tend to have a wide geographic distribution, are generalists regarding habitat and diet, and exhibit fast life history traits (*e.g.,* rapid growth, early maturity, large litter size; Han *et al.* 2015; Plourde *et al.* 2017). Considering these characteristics, recent studies include the olive grass mouse (*Abrothrix olivacea*, Cricetidae: Abrotrichini) within the group of species with a high capacity to host pathogens with zoonotic potential (Han *et al.* 2015), above that of many other Neotropical species (Han *et al.* 2020). In addition, it stands out as a host of possible new Orthohantaviruses (Mull *et al.* 2022).

The olive grass mouse is a small rodent (30.4 g ± 4.3 g) native to Chile and Argentina. In Chile, this rodent is widely distributed, from Tarapacá to Tierra del Fuego and from sea level to 2,500 m (Spotorno *et al.* 2000). It inhabits various environments and is highly adapted to anthropic habitats (Iriarte 2008; Moreno-Salas *et al.* 2020; Barceló *et al.* 2021). This species has been described as a host of various potentially zoonotic or zoonotic pathogens, such as *Leptospira* spp., *Yersinia enterocolitica*, and *Cryptosporidium* spp. (Llanos-Soto and González-Acuña 2019; Infante *et al.* 2022).

In this context, aiming to know the current status of the parasites recorded in the olive grass mouse in Chile, this study conducted a systematic review of the microparasites (bacteria, viruses, protozoa, and fungi) and macroparasites (helminths and arthropods) in this rodent. In addition, a meta-analysis of the prevalence of micro- and macroparasites was carried out to record and compare this prevalence with the one reported in other sympatric rodents. This information will give us a general and up-to-date overview of this rodent from an epidemiological standpoint.

A systematic review of scientific articles on micro- and macroparasites of the olive grass mouse in Chile was carried out, guided by the PRISMA statement (preferred reporting items for systematic reviews and meta-analyses; Moher *et al.* 2014). The survey was carried out in the PubMed, Web of Science (WoS), and Scielo Scientific Library databases using the following Boolean operators and keywords: ((rodentia) OR (rodent*)) OR (rodents)) AND ((pathogen*) OR (bacteria*) OR (helminth*) OR (fungi*) OR (protozoa*) OR (virus*) OR (parasite*) OR (flea*) OR (tick*) OR (mite*) OR (lice*) OR (zoonoses)) AND (Chile)). The articles were compiled according to title and abstract, regardless of language or year of publication, to obtain as much literature as possible. The inclusion criteria were as follows. The studies were carried out in Chile and were related to the detection of micro- or macroparasites in the olive grass mouse. Review articles and duplicates between the different databases were eliminated, and a full-text review was carried out, discarding those publications that did not meet the inclusion criteria. In addition, we performed a manual review and selection of articles that were not identified in the database search as such but were cited in the bibliography of the articles identified.

The information in the articles was extracted and organized in an Excel spreadsheet with the following data: type of parasite, detection of parasites in other rodent species, diagnostic method, author, and year. For the taxonomy of micro- and macroparasites, the names indicated in each article were maintained. Those publications that did not provide quantitative data were included only for the systematic review. On the other hand, those that reported prevalence and sample size were also used to perform a meta-analysis. To this end, the data were again organized in an Excel spreadsheet according to the type of parasite, host species, sample size, number of positive samples, prevalence, author, and year.

For the prevalence analysis, a meta-analysis was performed with random models weighted by sample size, with a 95 % confidence interval (Nikolakopoulou *et al.* 2014). Heterogeneity between studies was measured with the I^2 index (Higgins *et al.* 2003), and plots were constructed showing the prevalences arranged according to the group of micro- or macroparasites studied, considering 2 subgroups: *A. olivacea* and "other rodents", the latter considering any other rodent species (native or introduced species) analyzed exclusively in the same studies that included the olive grass mouse. Parasite prevalences according to host were compared using meta-regressions (Baker *et al.* 2009) carried out according to the groups and subgroups used in the meta-analyses. In addition, within a group of parasites (*e.g.*, helminths), meta-regression analyses were separated when different diagnostic methods were used (*e.g.*, microscopy and PCR analysis). The entire meta-analysis was performed with the the R packages 'metafor' (Viechtbauer 2010) and 'meta' (Balduzzi *et al.* 2019).

According to the literature search and review, 51 articles were included in the systematic review, and 38 articles were used in the meta-analysis. All included articles are cited in Table 1. In addition, some articles included in the meta-analysis where the prevalence in the olive grass mouse was 0 are listed in Appendix 1. The literature review process is summarized in the flowchart in Appendix 2. The studies are distributed in all administrative regions of Chile, mainly concentrated in the Coquimbo region (north-central zone, with 14 studies, 27.5 %), followed by the Metropolitan region (central zone, 11 studies, 21.6 %) and the Los Ríos region (southern zone, 11 studies, 21.6 %; Figure 1). According to the type of parasite, 13 (25.5 %) articles analyzed ectoparasites, 12 (23.6 %) protozoa, 10 (19.6 %) bacteria, 9 (17.6 %) viruses, and 7 (13.7 %) helminths. No articles were found on parasitic fungi in the olive grass mouse. The largest number of publications ($n = 8$) reported the Hantavirus (Andes virus, ANDV), the protozoan *Trypanosoma cruzi* ($n = 7$), and the bacterium *Leptospira* sp. ($n = 6$; Table 1). In total, 68 micro- and macroparasites were recorded, 40 (58.8 %) described at the species level and 28 (41.2 %) to genus, family, or phylum (Table 1). Of the 68 parasites, 52 are macroparasites (35 arthropods and 17 helminths), and 16 are microparasites (8 protozoa, 6 bacteria, and 2 viruses); of the total, 6 are recognized as zoonotic.

First, the analysis of the ANDV virus was performed, as it was the only virus with a sufficient number of publications for the meta-analysis. For this analysis, the subgroups were (1) *A. olivacea*, (2) *Oligoryzomys longicaudatus* (main ANDV reservoir), and (3) other rodents. The prevalence of ANDV showed a high heterogeneity between articles ($I^2 = 92$ %). Furthermore, the overall prevalence was higher in *O. longicaudatus* (4.6 %) compared to the olive grass mouse (0.4 %) and all other rodents (0.9 %; Table 2, Appendix 3). These differences in prevalence among rodents were statistically significant ($P < 0.001$; Table 3).

For bacteria, 9 studies were included in the meta-analysis. The prevalence of bacteria was highly heterogeneous between studies ($I^2 = 95$ %), showing marked differences in the prevalence of *Mycoplasma* spp. between the olive grass mouse (75 %) and all other rodents (19.7 %; Appendix 4). In general, there were no significant differences in the prevalence of bacteria in the olive grass mouse (32 %) compared to the other rodents (22 %; $P = 0.336$; Table 3). Similarly, there were no statistical differences when only the prevalences of *Leptospira* spp. were compared ($P = 0.611$; Table 3).

Table 1. Micro- and macroparasites reported in *Abrothrix olivacea* in Chile. *Considered zoonotic; **belongs to a genus that includes zoonotic species; ~~ vectors "cf." indicates a comparison between the individual in question and the referred taxon, based on the consistency of observable characters, although these characters are not sufficiently numerous. [1]Virus tentatively named 'Olivaceaous mouse morbilivirus'. [2]Toxoplasmatinae gen. sp. P99 is genetically distinct at the genus level within the subfamily, so it is believed to be a new genus. Regions: AP (Arica and Parinacota), TA (Tarapacá). AN (Antofagasta), AT (Atacama), CO (Coquimbo), VA (Valparaíso), ME (Metropolitan), OH (O'Higgins), MA (Maule), ÑU (Ñuble), BB (Biobío), AR (Araucanía), LR (Los Ríos), LL (Los Lagos), AY (Aysén), MG (Magallanes). Diagnostic method: 1 (Strip Immunoblot Assay), 2 (ELISA), 3 (RNAseq), 4 (PCR), 5 (Immunohistochemistry), 6 (Dark-Field Microscopy), 7 (Bacterial culture), 8 (Microscopy agglutination test), 9 (Argentica stain), 10 (Indirect immunofluorescence), 11 (Immunoperoxidase), 12 (Telemann stool test for parasites), 13 (Ziehl-neelsen stool test for parasites), 14 (Flotation stool test for parasites), 15 (Light microscopy), 16 (Scanning Microscopy), 17 (Microscopy), 18 (Mini-FLOTAC stool test for parasites), 19 (Isolation by necropsy).

	Parasite	Location (regions)	Diagnostic method	Reference
Viruses	ANDV*	CO, VA, ME, OH, MA, ÑU, BB, AR, LR, LL, AY	1, 2	Rubio *et al*. 2019; Torres-Pérez *et al*. 2019; Medina *et al*. 2009; Toro *et al*. 1998
	R.O. Morbilivirus[1]	LR	3	Debat 2022
Bacteria				
	Mycoplasma sp.**	LR	4	Alabí *et al*. 2020.
	Leptospira spp. (*L. borgpetersenii* and *L. interrogans*)*	LR	4-5, 8-9	Luna *et al.* 2020; Riedemann and Zamora 1982
	Leptospira spp.*	ME, LR	4, 6-7	Correa *et al*. 2017; Zamora *et al*. 1999
	*Leptospira interrogans**	ME, LR	8, 10-11	Perret *et al*. 2005; Zamora *et al*. 1995
	*Yersinia enterocolitica**	LR	7	Zamora *et al*. 1998
	Bartonella spp.**	ME, OH, AR	4	Sepúlveda-García *et al*. 2023
Protozoans				
Metamonad	*Giardia* sp.**	MA	12	Infante *et al*. 2022
Apicomplexa	*Cryptosporidium* sp.**	MA	13	Infante *et al*. 2022
	Coccidia	LL	14	Carrera-Játiva *et al.* 2023
	Hepatozoon spp.	AP, TA, AT, CO, LR, LL	4	Alabí *et al*. 2021; Merino *et al*. 2009; Santodomingo *et al.* 2022
	Sarcocystis sp.	OH, ÑU, AR, LR, LL	4	Oyarzún-Ruiz *et al*. 2023
	Toxoplasmatinae[2]	OH, ÑU, AR, LR, LL	4	Oyarzún-Ruiz *et al*. 2023
Euglenozoa	*Trypanosoma cruzi**	CO, VA, ME	4	Botto-Mahan *et al*. 2010; Botto-Mahan *et al.* 2020; Correa *et al.* 2015; Ihle-Soto *et al*. 2019; Oda *et al*. 2014; Rozas *et al*. 2007
Amoebozoa	*Amoeba* sp.	LL	14	Carrera-Játiva *et al*. 2023
Ectoparasites				
Acari	*Ixodes* sp.~~	ME	15	Muñoz-Leal *et al*. 2019
	Ixodes abrocomae	CO	4-16	Guglielmone *et al*. 2010
	Herpetacarus eloisae~~	LL, AY	17	Silva-de la Fuente *et al*. 2021; Silva-de la Fuente *et al.* 2023
	Herpetacarus sp.~~	LL	17	Acosta-Jamett *et al*. 2020
	Paratrombicula goffi	LL, AY	17	Silva-de la Fuente *et al*. 2021; Silva-de la Fuente *et al*. 2023
	Paratrombicula neuquenensis~~	LL, AY	17	Silva-de la Fuente *et al.* 2023
	Paratrombicula sp.~~	LL	17	Acosta-Jamett *et al.* 2020
	Quadraseta chiloensis	LL, AY	17	Silva-de la Fuente *et al*. 2021; Silva-de la Fuente *et al*. 2023
	Quadraseta sp.	LL	17	Acosta-Jamett *et al.* 2020
	Argentinacarus expansus~~	LL, AY	17	Silva-de la Fuente *et al*. 2023
	Ornithonyssus sp.~~	MA	17	Veloso-Frías *et al.* 2019
	Androlaelaps sp.	MA	17	Veloso-Frías *et al.* 2019
Siphonaptera	*Ctenoparia inopinata~*	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Alarcón 2003; Bazán-León *et al.* 2013; Moreno-Salas *et al.* 2020
	Ctenoparia jordani	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al*. 2020
	Ctenoparia topalli	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al*. 2020
	Ectinorus angularis	AN, AT, CO, ME, BB	17	Bazán-León *et al.* 2013
	Ectinorus cocyti	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al*. 2020
	Hectopsylla cypha	AN, AT, CO, ME, BB	17	Bazán-León *et al*., 2013
	Hectopsylla spp.~~	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al*. 2020
	Neotyphloceras chilensis~~	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Bazán-León *et al.* 2013; Moreno-Salas *et al*. 2020
	Neotyphloceras crassispina~~	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Alarcón 2003; Bazán-León *et al.* 2013; Moreno-Salas *et al*. 2020
	Neotyphloceras pardinasi~~	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al.,* 2020
	Sphinctopsylla ares~~	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Alarcón 2003; Bazán-León *et al.* 2013; Moreno-Salas *et al*. 2020
	Tetrapsyllus corfidii	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Bazán-León *et al.* 2013; Moreno-Salas *et al*. 2020
	Tetrapsyllus rhombus~~	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Alarcón 2003; Bazán-León *et al.* 2013; Moreno-Salas *et al.* 2020
	Tetrapsyllus tantillus~~	TA, AN, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Alarcón 2003; Bazán-León *et al.* 2013; Moreno-Salas *et al*. 2020
	Tetrapsyllus amplus	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al*. 2020

Table 1. Continuation...

	Nosopsyllus fasciatus~~	TA, AT, CO, VA, ME, OH, MA, ÑU, BB, AY, MG	17	Alarcón 2003; Moreno-Salas *et al.* 2020
	Plocopsylla wolffsohni	BB	17	Alarcón 2003
	Chiliopsylla allophyla~~	BB	17	Alarcón 2003
	Agastopsylla boxi	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al*. 2020
	Listronius spp.	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al.* 2020
	Leptopsylla segnis~~	TA, AT, CO, VA, ME, OH, MA, ÑU, AY, MG	17	Moreno-Salas *et al.* 2020
Phthiraptera	*Hoplopleura andina*	VA	17	González-Acuña *et al*. 2003; González-Acuña *et al*. 2005
Hemiptera	*Mepraia paraprática*~~	TA	4	Quiroga *et al*. 2022
Endoparasites				
Acanthocephala	*Moniliformis* sp.**	MA, LL	12, 18	Carrera-Játiva *et al*. 2023; Riquelme *et al*. 2021
Nematode	*Physaloptera* sp.	MA, LL	12, 19	Carrera-Játiva *et al*. 2023; Riquelme *et al*. 2021
	Physaloptera calnuensis	CO, VA, ME	19	Landaeta-Aqueveque *et al.* 2007; Landaeta-Aqueveque *et al*. 2018
	Syphacia sp.**	MA, LL	12, 18, 19	Carrera-Játiva *et al.* 2023; Riquelme *et al*. 2021
	*Syphacia obvelata**	CO, VA, ME	19	Landaeta-Aqueveque *et al*. 2007; Landaeta-Aqueveque *et al*. 2018
	Syphacia phyllotios	CO	19	Yáñez-Meza *et al*. 2019
	Capillaria sp.**	MA, ME	12, 19	Landaeta-Aqueveque *et al*. 2007; Riquelme *et al*. 2021
	Capillariidae**	LL	18	Carrera-Játiva *et al*. 2023
	Helminthoxys gigantea	CO	19	Yáñez-Meza *et al*. 2019
	Trichuris sp.**	LL	18, 19	Carrera-Játiva *et al*. 2023
	cf. Anatrichosoma sp.**	CO, VA, ME	19	Landaeta-Aqueveque *et al*. 2018
	Strongyloides sp.**	LL	18	Carrera-Játiva *et al*. 2023
	Pterygodermatites sap.	CO, VA, ME	19	Landaeta-Aqueveque *et al*. 2007; Landaeta-Aqueveque *et al*. 2018
	Protospirura sp.	LL	19	Carrera-Játiva *et al*. 2023
	Heterakis spumosa	CO, VA, ME	19	Landaeta-Aqueveque *et al.* 2007; Landaeta-Aqueveque *et al*. 2018
	Gongylonema sp.**	CO	19	Yáñez-Meza *et al*. 2019
Cestode	*Hymenolepis* sp.**	CO, VA, ME, MA	12, 19	Landaeta-Aqueveque *et al.* 2007; Landaeta-Aqueveque *et al*. 2018; Riquelme *et al*. 2021
	Rodentolepis sp.**	LL	18	Carrera-Játiva *et al*. 2023

The prevalence of protozoans was also highly heterogeneous between studies (I^2 = 97 %, Appendix 5). No differences (P = 0.659) were observed in the prevalence of these microparasites between the olive grass mouse (25.7 %) and other rodents (22.9 %). The protozoa *Sarcocystis* sp. and members of the subfamily Toxoplasmatinae were found only in the olive grass mouse and not in other rodents. In contrast, *Babesia* sp. was reported in other rodents but not in the olive grass mouse (Appendix 6). For *Trypanosoma cruzi*, there was a larger number of publications (n = 7), so a meta-regression was performed for this protozoan, but no significant differences (P = 0.578) were observed between the prevalences of both subgroups (Table 3).

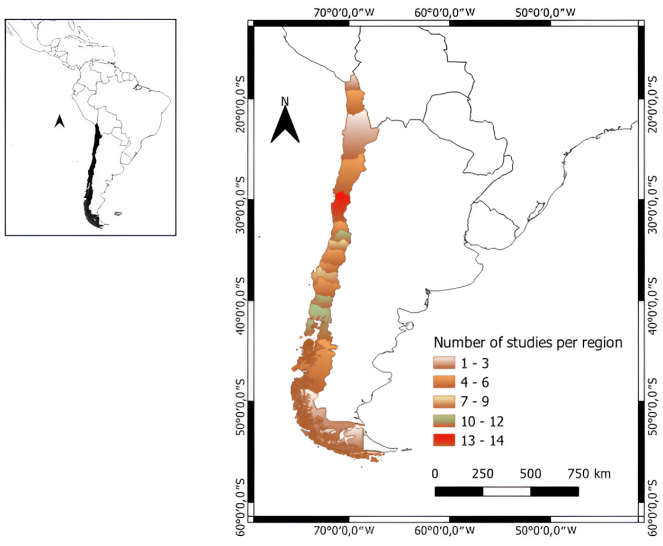

Figure 1. Distribution map of the number of studies by region in Chile.

The prevalence of ectoparasites between publications was highly heterogeneous (I^2 = 95 %, Appendix 6), and the prevalence in olive mice (10.8 %) was lower than that in other rodents (14.6 %). However, these differences are not statistically significant (P = 0.465; Table 3).

For the analysis of helminths, they were separated into 2 groups according to the diagnostic methodology: 1) studies where helminths were identified by stool examination (ova) and 2) studies where helminths were identified with macroscopic specimens (adults or larvae) after the necropsy of the host (Table 1). The heterogeneity in the prevalence of helminths between publications was high in stool tests (I^2 = 87 %) and macroscopic specimens (I^2 = 95 %, Table 2). The average prevalence of helminths from stool analyses was significantly different (P = 0.048) between the olive grass mouse (4.5 %) and all other rodents (1.3 %). Regarding the prevalences using data from macroscopic specimens, there was also a higher prevalence in the olive grass mouse (14.6 %) compared to other rodents (5.2 %), although it was not significant (P = 0.066; Table 3; Appendix 7).

Table 2. Prevalence, confidence intervals, and heterogeneity index of micro- and macroparasites in *Abrothrix olivacea* and other rodents in Chile. Prevalence and confidence intervals are expressed in %. *This rodent was only separated in the hantavirus analysis because it is recognized as the main reservoir of the virus.

	Abrothrix olivacea	Other rodents	*Oligoryzomys longicaudatus**	Total
Virus (ANDV)	0.4 (0.0-1.5), $I^2 = 84$ %	0.9 (0.4-1.5), $I^2 = 24$ %	4.6 (3.2-6.2), $I^2 = 44$ %	1.6 (0.6-3.0), $I^2 = 92$ %
Bacteria	32.3 (9.5-59.3), $I^2 = 95$ %	22.3 (12.2-34.3), $I^2 = 95$ %	--	25.3 (15.2-36.7), $I^2 = 95$ %
Leptospira	37.8 (12.6-66.9), $I^2 = 96$ %	30.0 (13.6-49.5), $I^2 = 97$ %	--	33.8 (20.4-48.6), $I^2 = 96$ %
Protozoans	25.7 (12.6-41.1), $I^2 = 97$ %	22.9 (12.4-35.3), $I^2 = 98$ %	--	24.1 (15.7-33.4), $I^2 = 97$ %
Trypanosoma cruzi	46.6 (31.9-61.5), $I^2 = 76$ %	40.7 (29.6-52.3), $I^2 = 95$ %	--	43.0 (34.1-52.1), $I^2 = 92$ %
Ectoparasites	10.8 (5.2-17.8), $I^2 = 95$ %	14.6 (8.0-22.7), $I^2 = 95$ %	--	12.6 (8.2-17.8), $I^2 = 95$ %
Helminths	8.4 (5.2-12.2), $I^2 = 94$ %	2.8 (1.1-4.9), $I^2 = 91$ %	--	5.4 (3.6-7.4), $I^2 = 93$ %
Coproparasitic helminths	4.5 (2.6-7.0), $I^2 = 89$ %	1.3 (0.3-2.8), $I^2 = 76$ %	--	2.9 (1.7-4.4), $I^2 = 87$ %
Helminths necropsy	14.6 (6.2-25.5), $I^2 = 95$ %	5.2 (1.7-10.1), $I^2 = 93$ %	--	9.7 (5.5-14.8), $I^2 = 95$ %

In this systematic review, we compiled the published information on macro- and microparasites found in olive grass mice inhabiting different locations in Chile. From a public health approach, the olive grass mouse can host at least 6 pathogens considered zoonotic, such as *Leptospira* spp., *Yersinia enterocolitica*, and Orthohantavirus. Pathogenic leptospires have been found mainly in central and southern Chile, and some studies have reported a higher prevalence in olive grass mice than in other rodents (Luna *et al.* 2020). The fact that we did not find significant differences between prevalences in our meta-analysis makes epidemiological sense because pathogenic *Leptospira* spp. are generally considered multihost (Boey *et al.* 2019). However, this type of analysis, which mainly included molecular analyses, is limited by not including the different types of serovars that circulate in rodents. This restricts a more in-depth analysis of the possible differences in the prevalence of *Leptospira* spp. Concerning *Yersinia enterocolitica*, only one descriptive study reports this pathogen in different species of Chilean rodents (Zamora *et al.* 1998) without particularly highlighting the role of the olive grass mouse. In the case of Orthohantavirus, the Andes strain (ANDV) thrives in the geographic range of the olive grass mouse; this strain is considered one of the most important Orthohantaviruses causing the Hantavirus Cardiopulmonary Syndrome (Kruger *et al.* 2015). For ANDV, the main reservoir is the long-tailed mouse (*O. longicaudatus*), whereas other rodent species, including the olive grass mouse, have shown antibodies against ANDV. However, it is still unknown whether these rodent species can act as vectors of ANDV to humans; therefore, additional virological studies are needed in these rodent species (Torres-Pérez *et al.* 2016). According to meta-analyses and other studies of ANDV in rodent communities in Chile and Argentina, the seroprevalence of ANDV tends to be higher in *O. longicaudatus* compared to other sympatric native rodents (Polop *et al.* 2010; Rubio *et al.* 2019; Torres-Pérez *et al.* 2019). ANDV infection in the olive grass mouse and other native rodents has been suggested to be mainly due to transmission from the main reservoir to these rodents (spillover; Polop *et al.* 2010; Rubio *et al.* 2019). However, all studies on Orthohantavirus, including those in this review, assessed only the presence of antibodies and not infection as such. On the other hand, a recent study that carried out predictive models using ecological and phylogenetic information of rodents indicates that the olive grass mouse and other rodents from America could be new hosts of Orthohantavirus (Mull *et al.* 2022). This highlights the need to conduct further studies on these viruses in the olive grass mouse throughout its range, where other undescribed Orthohantaviruses could exist (Mull *et al.* 2022). On the other hand, our systematic review evidenced the lack of knowledge about other viruses in the olive grass mouse since the review only identified several studies on hantavirus and a single study on morbillivirus.

This systematic review found other potentially zoonotic biological agents, such as *Bartonella* spp., *Giardia* spp. and *Cryptosporidium* spp., but since they have been identified at the genus level, there is no certainty that they are zoonotic species. In Chile, there are cases of giardidiosis and cryptospyridosis in humans within the geographic range of the olive grass mouse (Neira-Otero *et al.* 2005; Vidal *et al.* 2010). Therefore, further studies are required to deepen the taxonomic knowledge of these biological agents.

Ticks, mites, and fleas have been described in the olive grass mouse to date (Table 1). These ectoparasites may be important vectors of zoonoses. An interesting case to highlight is scrub typhus fever, an emerging disease whose causative agent is a rickettsia (*Orientia* spp.) and in which the olive grass mouse could play an important role. This vectorial disease (transmitted by thrombiculid mites) has recently been described in Chile (Abarca *et al.* 2020; Weitzel *et al.* 2021), highlighting a high infestation of thrombiculids infested with this rickettsia in the olive grass mouse (Acosta-Jamett *et al.* 2020; Silva-de la Fuente *et al.* 2023). Since the olive grass mouse is one of the native species of Chile that is most adapted to anthropic settlements (Moreno-Salas *et al.* 2020; Barceló *et al.* 2021), this rodent species could increase the transmission of scrub typhus fever by increasing the likelihood of contact between vector mites and humans.

Regarding fleas, some species parasitizing the olive grass mouse have been reported (*Hectopsylla* spp., *Neotyphloceras chilensis, Neotyphloceras pardinasi, Sphinctopsylla ares, Tetrapsyllus rhombus*, and *Nosopsyllus fasciatus*), which have previously been recognized as carriers of *Bartonella* spp. in *Rattus rattus*, *Abrothrix* sp., and other rodents in Chile (Moreno-Salas

Table 3. Meta-regression of prevalence according to parasite group. *Abrothrix olivacea* is considered a reference category. [c] analysis using stool tests for parasites; [n] analysis through isolates from specimen necropsy.

ANDV	Parameter	Standard error	Z value	*P* value
Intercept	0.09	0.02	4.64	< 0.0001
Oligoryzomys longicaudatus	0.17	0.03	6.26	< 0.0001
Other rodents	0.05	0.03	1.81	0.070
Bacteria				
Intercept	0.63	0.10	6.21	< 0.0001
Other rodents	-0.13	0.14	-0.96	0.336
Leptospira				
Intercept	0.68	0.12	5.54	< 0.0001
Other rodents	-0.09	0.17	-0.51	0.611
Protozoans				
Intercept	0.55	0.08	7.02	< 0.0001
Other rodents	-0.05	0.11	-0.44	0.659
Protozoa				
Intercept	0.57	0.10	5.95	< 0.0001
Other rodents	-0.04	0.13	-0.33	0.742
Trypanosoma cruzi				
Intercept	0.75	0.08	9.49	< 0.0001
Other rodents	-0.06	0.11	-0.56	0.578
Ectoparasites				
Intercept	0.35	0.05	6.65	< 0.0001
Other rodents	0.05	0.07	0.73	0.465
Helminths				
Intercept	0.31	0.03	9.44	< 0.0001
Other rodents	-0.10	0.05	-2.17	0.030
Helminths (c)				
Intercept	0.22	0.03	8.39	< 0.0001
Other rodents	-0.08	0.04	-1.98	0.048
Helminths (n)				
Intercept	0.40	0.05	7.96	< 0.0001
Other rodents	-0.13	0.07	-1.84	0.066

et al. 2019; Müller *et al.* 2020). In addition, 2 studies highlight the high richness of these ectoparasites in the olive grass mouse (Bazán-León *et al.* 2013; Moreno-Salas *et al.* 2020). Moreno-Salas *et al.* (2020) emphasize a higher richness of flea species in the olive grass mouse compared to all the other rodent species analyzed, as well as a greater number of rickettsia-positive fleas. Molecular analyses of these rickettsias indicated that the sequences are close to the rickettsia of the spotted fever group, so there is a zoonotic potential not yet studied in Chile (Moreno-Salas *et al.* 2020). Descriptions of ticks in the olive grass mouse are scarce since only the species *Ixodes abrocomae* (Guglielmone *et al.* 2010) and a larva of *Ixodes* sp. (Muñoz-Leal *et al.* 2019) have been described.

Overall, there is a larger number of zoonotic helminths described in rodents compared to other zoonotic biological agents such as viruses, bacteria, and protozoa (Han *et al.* 2016). In Chile, all the studies in this review (Table 1) have described helminths in the olive grass mouse by macro- and microscopic analyses, mainly at the family or genus levels. This makes it difficult to identify whether there are zoonotic helminth species in the olive grass mouse, although many genera of helminths described in this rodent species infect humans (*i.e.*, *Moniliformis, Syphacia, Capillaria, Trichuris,* and *Hymenolepis*; Salehabadi *et al.* 2008; Gomes da Rocha *et al.* 2015; Panti-May *et al.* 2020). The high prevalence (greater than 20 %) of certain helminths in the olive grass mouse (*Physaloptera calnuensis*, *Syphacia* sp., *Trichuris* sp., *Pterigodermatites* sp. *Hymenopepis* sp., and *Protospirura* sp.; Landaeta-Aqueveque *et al.* 2018; Carrera-Játiva *et al.* 2023) may be because this rodent is more exposed to various helminths due to its generalist habitat and diet, as well as its high densities (Spotorno *et al.* 2000). A prevalence greater than 20 % has been reported in few Chilean rodent species (Landaeta-Aqueveque *et al.* 2018; Grandón-Ojeda *et al.* 2022).

In general, high prevalence heterogeneity (I^2) values were found in the different parasites. This finding may be due to multiple factors, such as differences between the sampled locations and in the diagnostic methods used. Regarding the latter, 2 meta-analyses that produced higher I^2 values (*Leptospira* spp. and protozoa) use at least 3 different diagnostic methods. It is also worth mentioning that the measure used to estimate heterogeneity has some limitations because high I^2 values (< 90) have been reported as frequent in prevalence meta-analyses (Migliavaca *et al.* 2022).

Based on the results of this study, we propose the following: 1) increase the study of viruses with zoonotic potential, since most studies have focused on Orthohantavirus using serological techniques only; 2) advance the use of molecular techniques for more accurate identification of bacteria, protozoa, and helminths; 3) increase the study of ticks in the olive grass mouse and deepen the potential role of this species and its mites in relation to rickettsial infections such as scrub typhus; 4) from an ecological perspective, it is necessary to carry out comparative studies of the parasite-olive grass mouth association in relation to changes in land use, habitat fragmentation, and other human disturbances in environments. In addition, eco-epidemiological studies should include the rodent community coexisting with the olive grass mouse. This will generate additional knowledge about the pathogens circulating at the community level and deepen our understanding of differences in prevalence between rodent species. The above will provide additional information that can be used in meta-analysis studies and more robust spatiotemporal comparisons of the olive grass mouse and its parasites, thereby helping to better understand the epidemiological role of this rodent related to various zoonotic pathogens.

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Appendix 1

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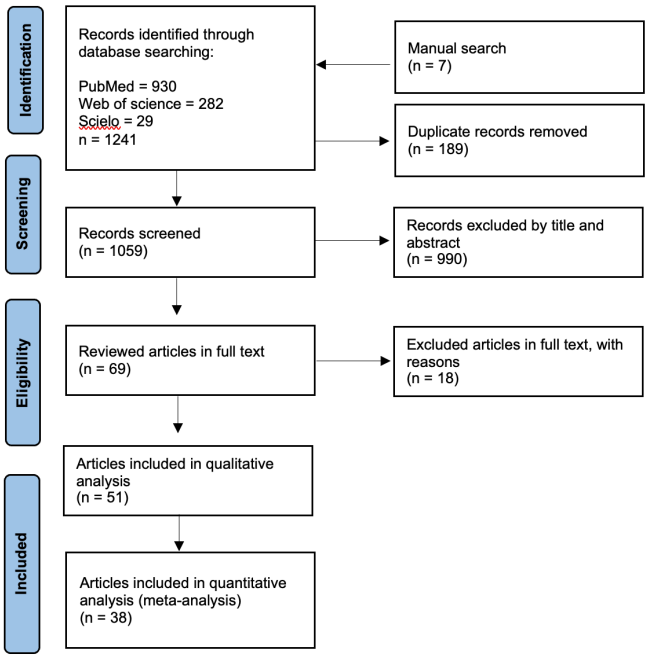
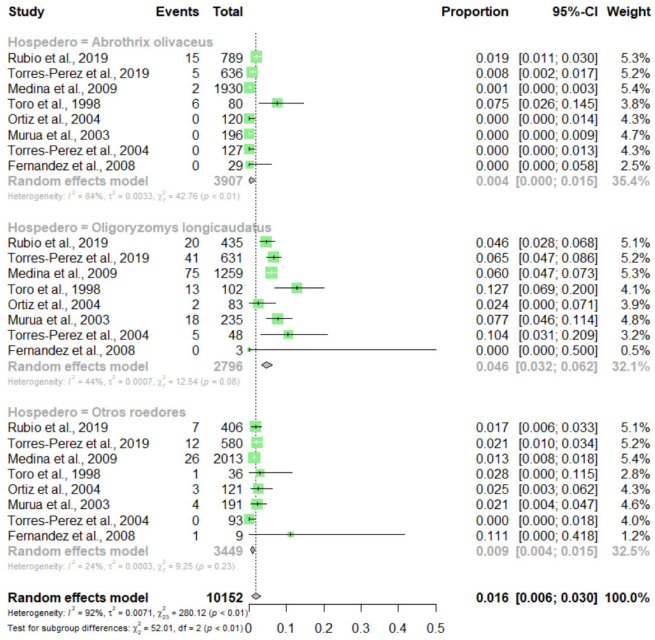
Appendix 2

PRISMA flowchart showing the item selection steps



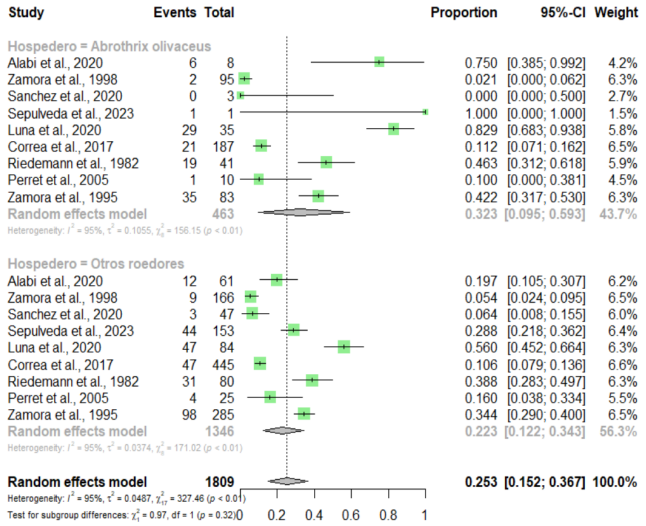
Appendix 3

Forest plot of the prevalence of ANDV by host subgroup (*Abrothrix olivacea, Oligoryzomys longicaudatus*, and other rodents). Each green square represents prevalence. Black lines represent the 95 % confidence intervals. Gray diamonds represent the mean prevalence of each subgroup.



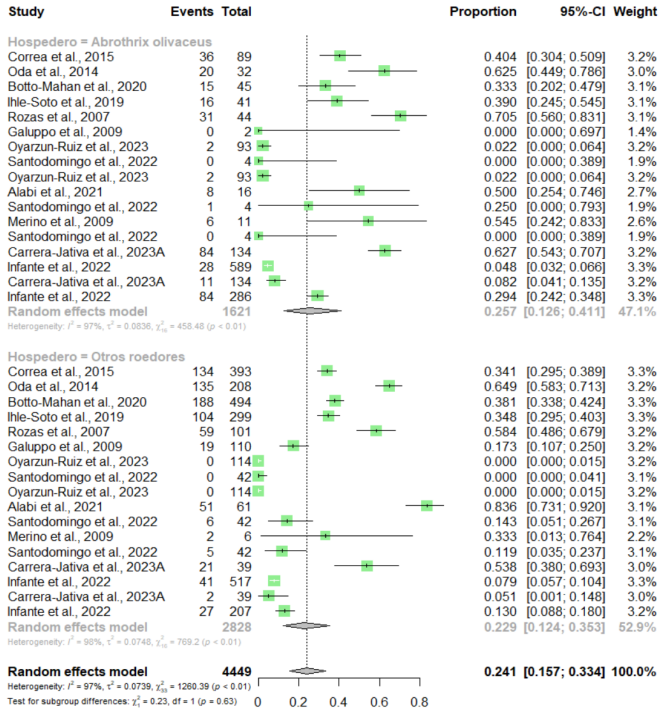
Appendix 4

Forest plot of the prevalence of bacteria by host subgroup (*Abrothrix olivacea* and other rodents). Each green square represents prevalence. Black lines represent the 95 % confidence intervals. Gray diamonds represent the mean prevalence of each subgroup.



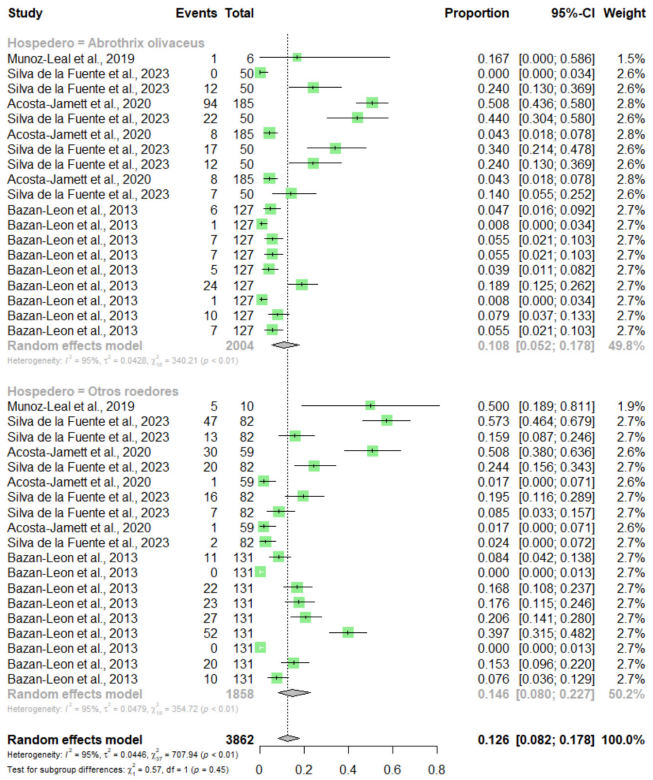
Appendix 5

Forest plot of the prevalence of protozoa by host subgroup (*Abrothrix olivacea* and other rodents). Each green square represents prevalence. Black lines represent the 95 % confidence intervals. Gray diamonds represent the mean prevalence of each subgroup.



Appendix 6

Forest plot of the prevalence of ectoparasites by host subgroup (*Abrothrix olivacea* and other rodents). Each green square represents prevalence. Black lines represent the 95 % confidence intervals. Gray diamonds represent the mean prevalence of each subgroup.



Appendix 7

Forest plot of the prevalence of helminths by host subgroup (*Abrothrix olivacea* and other rodents). Each green square represents prevalence. Black lines represent the 95 % confidence intervals. Gray diamonds represent the mean prevalence of each subgroup.