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Original paper

Intestinal parasites of *Apodemus mystacinus* along altitudinal stratification of Ibrahim River, Mount Lebanon

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ABSTRACT. This study documents the diversity of intestinal parasites in the eastern broad-toothed field mouse (*Apodemus mystacinus*) along the altitudinal gradient of Ibrahim River in Mount Lebanon during the spring and autumn of 2017. A total of 190 *A. mystacinus* were trapped in seventeen sites (6 riparian, 11 non-riparian) and examined for intestinal parasites. Eight intestinal parasites were identified including *Heligmosomoides polygyrus*, *Trichuris muris*, *Syphacia frederici*, *Protospirura muris*, and *Aspiculuris tetraptera* (nematodes), *Hymenolepis diminuta* (cestode), *Brachylaima* spp. (trematode), and *Eimeria alorani* (coccidian). Most of the trapped mice (85%) were infected with intestinal parasites and 38.84% showed concurrent infection with at least two parasitic species. The season had a significant effect on mice infection with *Syphacia frederici*, and mice are most likely to have infection with this nematode in spring season. The vegetation zone had a significant overall impact on mice infection with the nematodes *Heligmosomoides polygyrus* and *Trichuris muris* while gender did not influence significantly mouse infection with intestinal parasites. This is the first study that has been carried out to identify the intestinal parasite community in *A. mystacinus* of Ibrahim River region. The findings pave the way for future studies on intestinal parasites in rodents and the environmental variations affecting their dynamics.

Keywords: intestinal parasites, *Apodemus mystacinus*, riparian ecosystem, Ibrahim River, Lebanon

Introduction

The broad-toothed field mouse, *Apodemus mystacinus*, is a small mammal of the Murinae subfamily. It is a nocturnal rodent that inhabits moisture hills, rocky scrublands and mountain ranges in the Mediterranean region. Its habitat is the dense oak forests that provide a continuous canopy cover for this species [1]. Its habitat ranges from sea level to an altitude of 2700 m [2]. The range of *A. mystacinus* extends from Arabia to Asia Minor, western Transcaucasia, Greece, former Yugoslavia and Crete [1]. In Arabia, it occurs in Iraq [3], Syria [4–7], Israel [8], and Jordan [1,9,10]. *Apodemus mystacinus* is common and widely distributed all over Lebanon with a range that extends from sea level to the alpine zone above tree line [6].

Rodents are major carriers and transmitters of intestinal parasites. Many studies investigated the diversity of intestinal parasites in different species of rodents but few addressed the diversity of intestinal parasites in *A. mystacinus*. Wertheim et al. [11] found the nematode *Heligmosomoides polygyrus polygyrus* in *Apodemus mystacinus* in Israel. In Bulgaria, *Heligmosomum aberrans*, *Syphacia obvelata* (zoonotic in rare cases), *S. stroma*, *Mastophorus muris*, and *Trichocephalus muris* species were reported [12,13]. Later Genov [14] recovered *Trichocephalus muris*, *Heligmosomoides polygyrus*, *Syphacia frederici*, *S. stroma*, *Rictularia proni*, and *Mastophorus muris* in the broad-toothed field mouse. Other than intestinal nematodes, Hurkova et al. [15] worked on intestinal protozoa and focused on studying three *Eimeria* species in *A. mystacinus* in Jordan, of which two were described as new.

In Lebanon, studies on the diversity of intestinal parasites in *Apodemus mystacinus* are still lacking; therefore, the aim of this study is to investigate the diversity of intestinal parasites in *Apodemus mystacinus* along the Ibrahim River along altitudinal stratification and to examine the influence of season, zone and site on the abundance and diversity of these parasites.

The outcome of this research provides insight into the effect of current environmental changes on the dynamics of rodents' population and their intestinal parasites and open the door for further research and investigations. In addition, the study sheds the light on the potential role of *A. mystacinus* as zoonosis reservoir for specific internal parasites that might affect the health of human beings.

Materials and Methods

Study site

The Ibrahim River basin is located in central Lebanon, extending 30 km inland from the Mediterranean Sea (where it discharges) and covering an area of 330 km^2. Afqa and Roueiss springs in Mount Lebanon are the main sources of this river, located at an altitude of 1200 m [16]. The study area along the Ibrahim River extends from 0 m above sea level (asl) to 1250 m asl covering different sites and vegetation cover in the region. Seventeen sites were chosen for the trapping process, covering four vegetation zones: Thermo-Mediterranean, Eu-Mediterranean, Supra-Mediterranean, and agricultural zones. Six of the chosen sites were riparian and eleven were non riparian (Tab. 1).

Intestinal parasites in Apodemus mystacinus

The transect along the Ibrahim River extended from 0 m above sea level (asl) to 1250 m asl. Seventeen plots were chosen in the trapping area such that six were located on the river bank and eleven were located 300–500m away from river bank. Plots were evenly spaced with an average distance of 3 km between each two plots. Due to the limited number of traps, the study area was divided into two zones, upper and lower zones: the lower zone extended from 0 m asl to 521 m asl, and the upper zone extended from 735 m asl to 1250 m asl. The vegetation zone characterizing each plot (Eu-Mediterranean, Thermo-Mediterranean, Supra-Mediterranean and agricultural) was identified while the temperature and rainfall for each plot were provided by CNRS (National Council for Scientific Research).

The study covered two seasons, spring season (May 2017) and autumn season (October 2017). Opportunistic trapping method was used to capture the rodents. Fifteen Sherman live traps were placed in each plot, spaced 2–4 m apart and baited with bread and peanut butter, oat seeds, and canary feed mix. The traps were set in the afternoon of the first day and checked at dawn of the following day for five consecutive nights.

Captured rodents were anesthetized using ethyl ether, euthanized and dissected for the separation of the intestinal tract from the body. The cecum was removed and the intestinal tract was cut longitudinally for the observation of adult helminths using a stereoscope. Few cecal and intestinal segments were removed randomly and placed in 2 ml physiological saline solution (9/1000 NaCl w/v) for further observation of eggs using compound microscopes at 100× magnification.

Faecal pellets were collected from the captured rodents. These pellets were vortexed in saturated NaCl solution to perform flotation test for the observation of protozoa using a compound microscope at 100× magnification [17]. Observed parasites were identified at the Animal Research and Diagnostic Lab at the Faculty of Agricultural and Food Sciences at the American University of Beirut [18–24].

Statistical analysis

Data collected were analyzed using the Statistical Package for the Social Sciences version 25.0 computer software program (SPSS Inc., Chicago, IL, USA). Frequency of mice with specific intestinal parasites within seasons, sites, zones and gender were compared using the Chi-square test at a significance level of 95%, but these are not shown for reasons of space. Based on the initial tests, multivariate analyses, using logistic regression were then performed to model responses, as these provide a convenient way to undertake categorical data analyses. Forward Wald logistic regression was used to specify the model with a significance $P<0.05$. The explanatory variables for the analyses included: zone (upper and lower), season, gender, and vegetation zone. The likelihood ratio goodness

Table 1. Characteristics of the trapping sites

Site	Site label	Zone	Vegetation zone	Altitude (m asl)	Average rainfall (mm)	Average temperature (°C)
1	Coastal	Lower zone	Thermo-Mediterranean	0	900–1000	20.1
2	Rkham down	Lower zone	Riparian Thermo-Mediterranean	61	900–1000	19.2
3	Rkham up	Lower zone	Thermo-Mediterranean	185	900–1000	19.2
4	Wadi	Lower zone	Riparian Thermo-Mediterranean	212	1100–1200	18.9
5	Cross Roads	Lower zone	Thermo-Mediterranean	293	1000–1100	17.5
6	Rocky Massar	Lower zone	Thermo-Mediterranean	362	1200–1300	17.8
7	Chowwen River	Lower zone	Riparian Thermo-Mediterranean	396	1300–1400	16.8
8	Snoubar	Lower zone	Eu-Mediterranean	521	1200–1300	17.5
9	Janneh down	Upper zone	Riparian Eu-Mediterranean	735	>1400	16
10	Janneh up	Upper zone	Eu-Mediterranean	776	>1400	13.3
11	Joe Marie	Upper zone	Riparian Eu-Mediterranean	807	>1400	15.8
12	Lassa	Upper zone	Eu-Mediterranean	862	>1400	16
13	Qartaba	Upper zone	Eu-Mediterranean	959	>1400	15.1
14	Ghabat	Upper zone	Riparian Agricultural	989	>1400	13.4
15	Bahij	Upper zone	Agricultural	1002	>1400	14.8
16	Chicken farm	Upper zone	Supra-Mediterranean	1083	>1400	14.7
17	Afqa	Upper zone	Supra-Mediterranean	1114	>1400	12.7

of fit test of the model was described using Chi-square goodness of fit statistics. Model performance on the testing sets was evaluated by calculating the area under the curve (AUC) of receiver operation characteristics (ROC) plots. ROC values range from 0.5 to 1.0. Values above 0.7 indicate strong model fit, while those above 0.9 indicate a highly accurate model [25].

Results

The 1275 trapping nights per season resulted in trapping a total of 190 *Apodemus mystacinus*. Most of the mice (21.05%) were trapped in site 11 a riparian Eu-Mediterranean site, while none were trapped in sites 1 (Thermo-Mediterranean) and 17 (Supra-Mediterranean) (Fig. 1). The majority of *A. mystacinus* (72.11%, N=137) were trapped during spring season from different sites in the study area along the Ibrahim River while few individuals (27.89%, N=53) were trapped in the autumn (Fig. 4). Moreover, mice trapped from the upper zone of the study area were more numerous (61.05%) than those trapped from the lower zone (38.95%) (Fig. 2).

Intestinal parasites isolated from these individuals included 5 nematode species, 1 cestode species, 1 trematode species, and 1 coccidian species. Among the parasites isolated from the trapped mice in the two seasons, nematodes represented the highest percentage (86.93%), while coccidia (protozoa) represented the lowest (0.38%) (Fig. 3). Identified nematodes included: *Heligmosomoides polygyrus* most common, *Trichuris muris, Syphacia frederici*, *Protospirura muris*, and *Aspiculuris tetraptera* least common; the cestode was

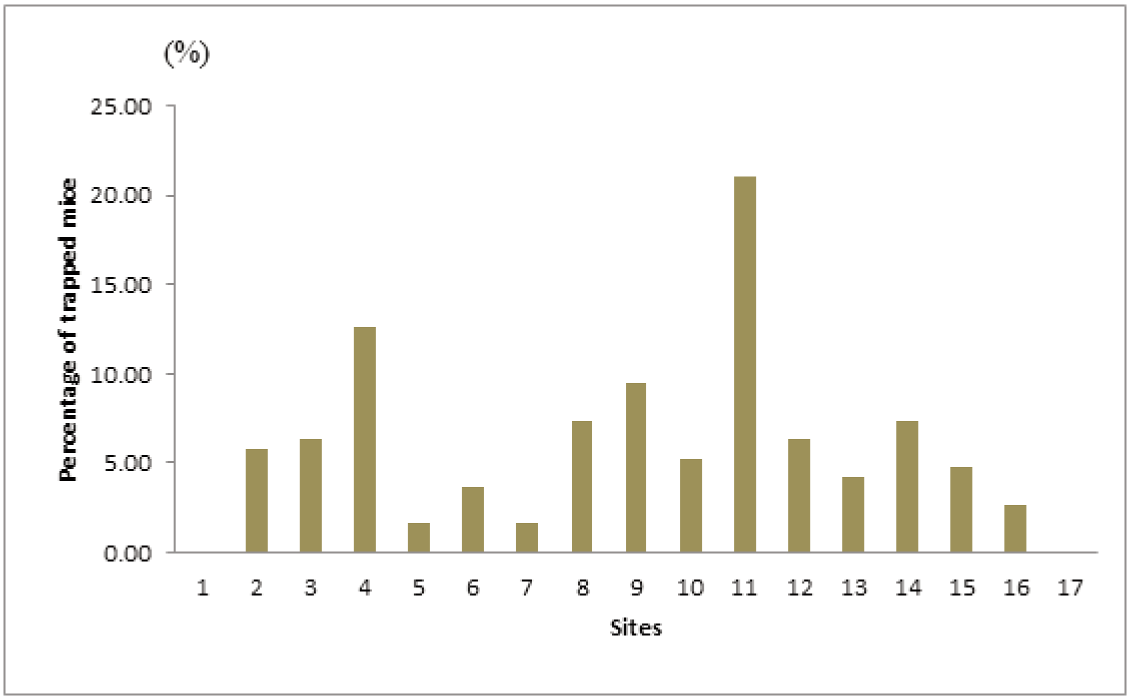

Figure 1. Percentage of mice trapped in each site in the study area

Hymenolepis diminuta; the trematode was *Brachylaima* spp. and the coccidian was *Eimeria alorani.*

Most of the trapped *A. mystacinus* (85.26%) were infected with intestinal parasites and 48.42% of individuals were infected with at least a single parasite, followed by those infected with two parasites (26.84%), and few (10%) were infected with more than two parasites (Fig. 4). It is worth noting that the coccidian *Eimeria alorani* was only present in individuals trapped in spring season.

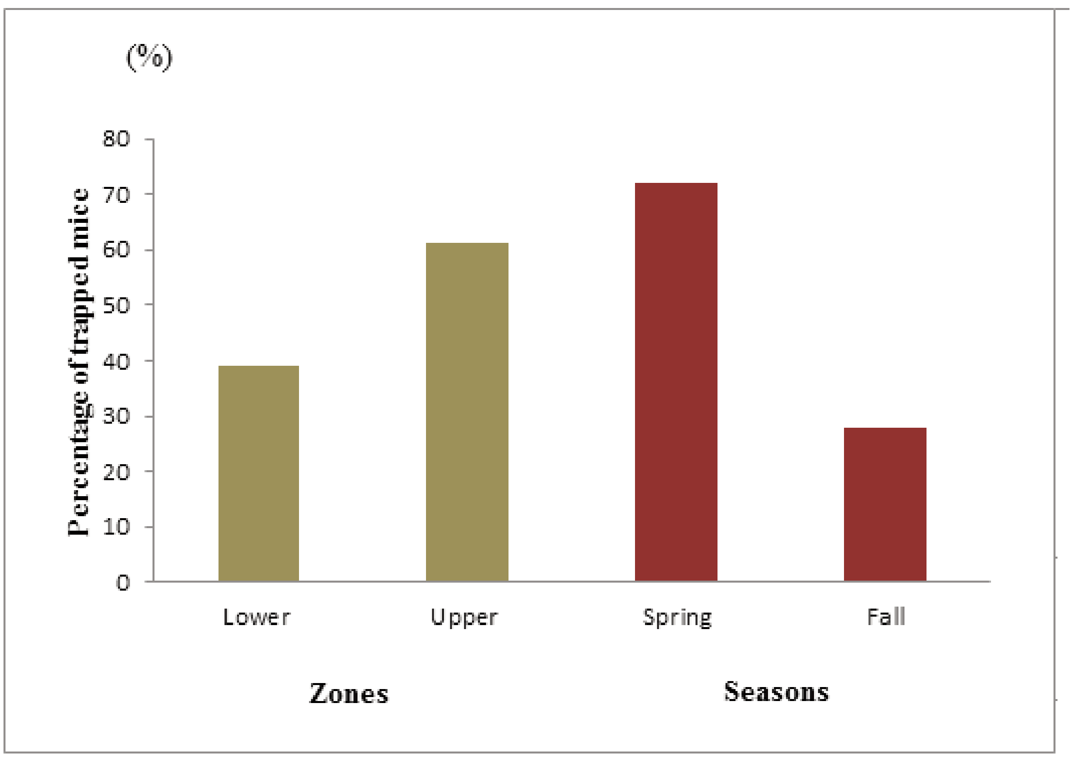

Figure 2. Percentage of mice trapped in different zones and seasons

Table 2. Impact of extrinsic and intrinsic factors on *A. mystacinus* infection with specific internal parasites

Parasites	Factor	B	S.E.	Wald	Sig.
Heligmosomoides polygyrus	Vegetation Zone			27.094	0.000
	Thermo-Mediterranean	-23.589	1.797E4	0.000	0.999
	Riparian Thermo-Mediterranean	-21.334	1.797E4	0.000	0.999
	Eu-Mditerranean	-20.656	1.797E4	0.000	0.999
	Riparian Eu-Mediterranean	-21.411	1.797E4	0.000	0.999
	Agricultural	-23.282	1.797E4	0.000	0.999
	Riparian Agricultural	-20.287	1.797E4	0.000	0.999
	Constant	21.203	1.797E4	0.000	0.999
Trichuris muris	Vegetation Zone			15.473	0.016
	Thermo-Mediterranean	18.900	1.797E4	0.000	0.999
	Riparian Thermo-Mediterranean	18.313	1.797E4	0.000	0.999
	Eu-Mediterranean	19.357	1.797E4	0.000	0.999
	Riparian Eu-Mediterranean	19.961	1.797E4	0.000	0.999
	Agricultural	21.896	1.797E4	0.000	0.999
	Riparian Agricultural	0.000	2.094E4	0.000	0.999
	Constant	-21.203	1.797E4	0.000	0.999
Syphacia frederici	Spring season	1.548	0.554	7.810	0.005
	Constant	-2.506	0.520	23.215	0.000

Intestinal parasite populations
Heligmosomoides polygyrus

Heligmosomoides polygyrus was the most prominent parasite among the trapped mice (61.05%; Fig. 5). The total infected individuals of the spring season capture were insignificantly less (58.39%) than those captured in the fall season (67.92%) (P>0.05; Tab. 3).

The overall model for factors that might have impacted mice infection with *Heligmosomoides polygyrus* explained 70% of the variance with an ROC value of 0.76, indicating a strong fit to the model. The zone and vegetation zone played the most important role in determining the mice infection with *H. polygyrus.* Mice caught in the upper zone were most likely to be infected. Furthermore, vegetation zone had an overall effect on mice infection with *H. polygyrus* without any clear impact between different zones (Tab. 2), although mice of the Thermo-Mediterranean zone are most likely to be infected with this worm.

Trichuris muris

This nematode was found in 15.26% of the trapped mice (Fig. 5). Individuals infected with *Trichuris muris* in spring capture were insignificantly more frequent (16.06%) than those in the autumn capture (13.21%) (P>0.05; Tab. 3). The overall model for factors that might have impacted mice infection with *T. muris* explained 86.3% of the variance with an ROC value of 0.747, indicating a strong fit to the model. Again, the vegetation zone played the most important role in determining this infection (Tab. 2). Therefore, the vegetation zone had an overall effect on mice infection with *T. muris* without any clear impact between various zones although mice of the riparian agricultural zone were most likely to be infected with this parasite.

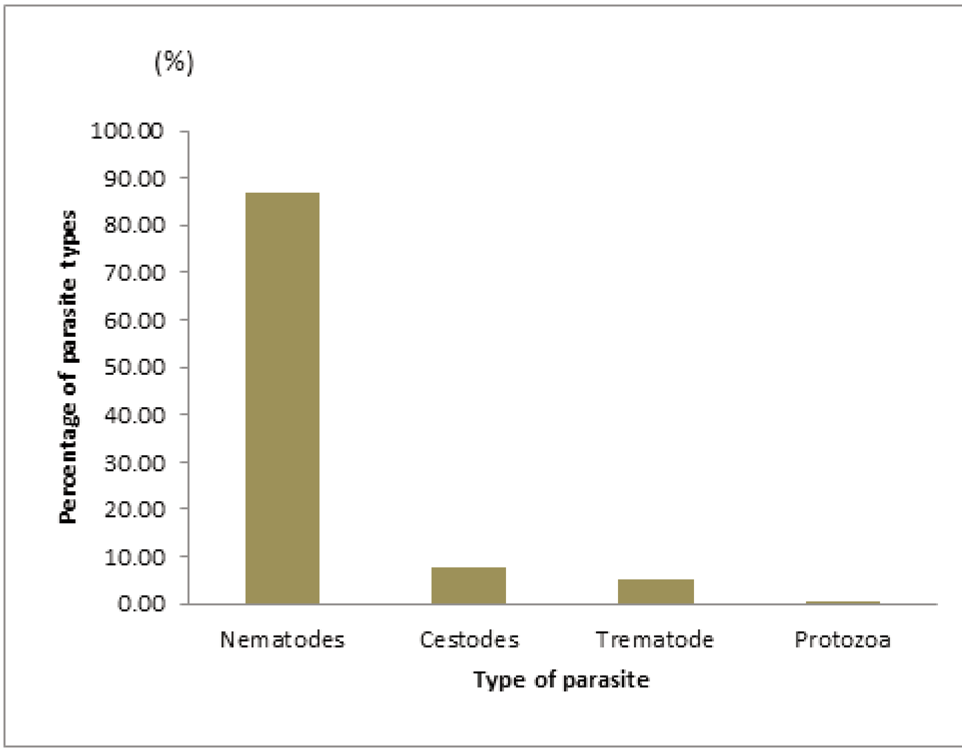

Figure 3. Percentage of each type of parasites in the trapped mice

Syphacia frederici

Syphacia was found in 22.11% of all the trapped *A. mystacinus* (Fig. 5). While gender and vegetation zone had no impact on the frequency of *Syphacia*-infected mice, season significantly influenced mice infection with *Syphacia frederici* (Tab. 2). The overall model for factors that might have impacted mice infection with *S. frederici* explained 77.9% of the variance with an ROC value of 0.618, indicating a satisfactory fit to the model. Season played the most important role in determining the infection of mice by *S. frederici*. Mice trapped during the spring season are most likely to be infected with this worm. The total infected individuals of the spring season

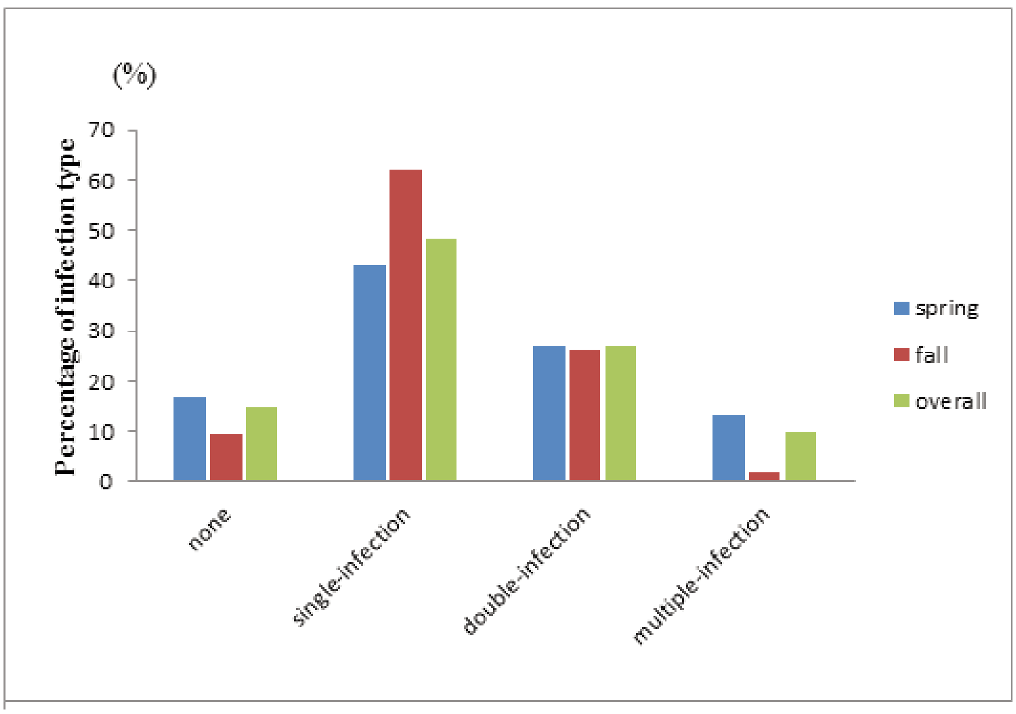

Figure 4. Percentage of each type of infection

Table 3. Percentage of *Apodemus mystacinus* infected with parasites of various genera in spring and autumn seasons

Parasites	% of infected mice		
	Spring (N=137)	Autumn (N=53)	Overall (N=190)
Heligmosomoides polygyrus	58.39	67.92	61.05
Trichuris muris	16.06	13.21	15.26
Syphacia frederici	27.74	7.55	22.11
Protospirura muris	16.79	13.21	15.79
Aspiculuris tetraptera	5.11	3.77	4.74
Hymenolepis diminuta	9.49	13.21	10.53
Brachylaima spp.	8.76	1.89	6.84
Eimeria alorani	0.73	0	0.53

capture were significantly more frequent (27.74%) than those captured in the autumn season (7.55%) ($P<0.05$, Tab. 3).

Protospirura muris

Among the trapped *A. mystacinus*, 15.79% contained the nematode *Protospirura muris* (Fig. 5). The total infected individuals of the spring season capture were insignificantly more frequent (16.79%) than those captured in the autumn season (13.21%) ($P>0.05$; Tab. 3). The overall model for factors that might have impacted mice infection with *P. muris* explained 85.8% of the variance with an ROC value of 0.768, indicating a strong fit to the model. Here also, the vegetation zone played the most important role in determining this infection (Tab. 2). Therefore, the vegetation zone had an overall effect on mice infection with *P. muris* without any clear impact between various zones.

Aspiculuris tetraptera

Aspiculuris was the least (4.74%) common nematode in all the infected individuals (Fig. 5). The total infected individuals of the spring season capture were insignificantly more frequent (5.11%) than those captured in the autumn season (3.77%) ($P>0.05$; Tab. 3). There was no significant difference in the number of individuals infected with *Aspiculuris tetraptera* among genders or vegetation zones ($P>0.05$).

Hymenolepis diminuta

Hymenolepis diminuta was found in 10.53% of the trapped mice (Fig. 5). Gender, vegetation and trapping zones had no significant impact on the prevalence of *H. diminuta* in mice ($P>0.05$; Tab. 2). The total infected individuals of the autumn season capture were more frequent (13.21%) than those captured in the spring season (9.49%) ($P>0.05$; Tab. 3).

Brachylaima spp.

Among the trapped *A. mystacinus* individuals, 6.84 % were infected with this parasitic trematode (Fig. 5). The total infected individuals of the spring season capture were more than those captured in the fall season (8.76 vs 1.89%, respectively) ($P>0.05$; Tab. 3).

The frequency of mice infected with *Brachylaima* spp. did not show any significant difference among genders, trapping and vegetation zones ($P>0.05$).

Eimeria alorani

This protozoan was only observed in 0.53% of trapped *A. mystacinus* individuals. *Eimeria alorani* was observed only from mice captured in spring ($P>0.05$; Tab. 3). The difference in the frequency of mice infected with this coccidian was not significant between genders, seasons, vegetation or trapping zones ($P>0.05$).

Discussion

A total of five nematode species: *Heligmosomoides polygyrus*, *Trichuris muris*, *Syphacia frederici*, *Protospirura muris*, and *Aspiculuris tetraptera*; one cestode species: *Hymenolepis diminuta*;

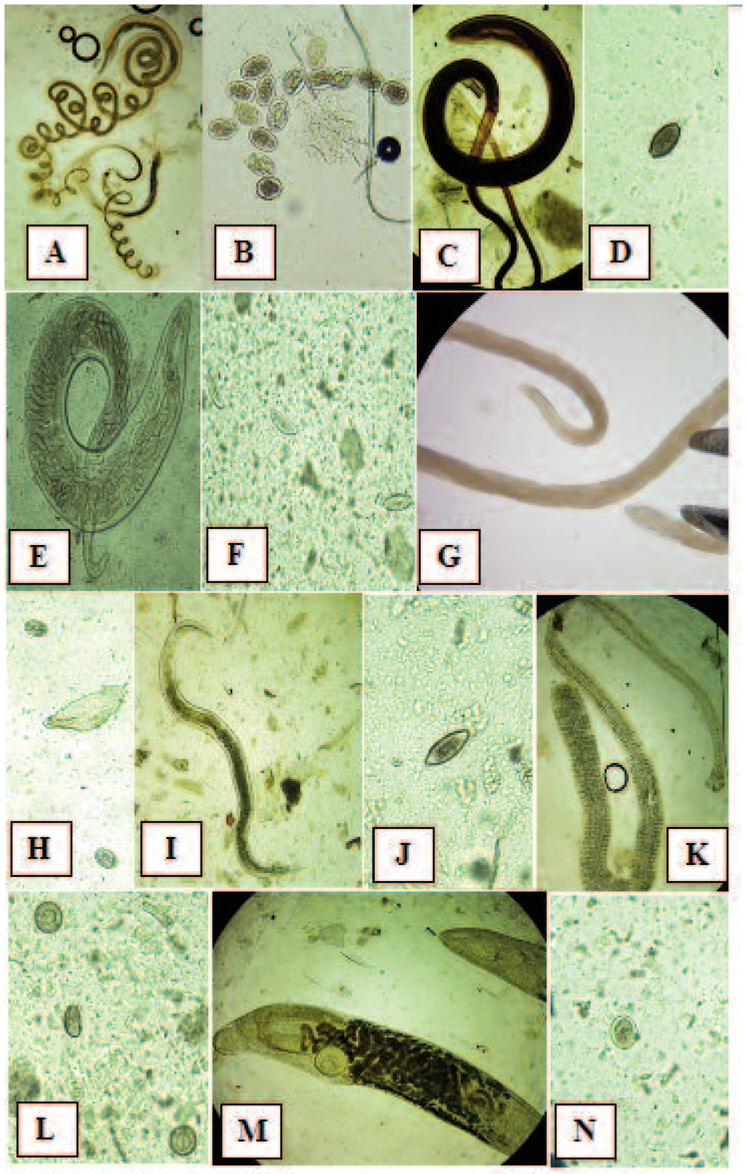

Figure 5. Intestinal parasites of trapped *A. mystacinus*: A. male and female *Heligmosomoides polygyrus* (40×), B. *Heligmosomoides polygyrus* eggs (100×), C. *Trichuris muris* (40×), D. *Trichuris muris* egg (100×), E. *Syphacia frederici* (40×), F. *Syphacia frederici* eggs (100×), G. *Protospirura muris* (40×), H. *Protospirura muris* eggs (100×), I. *Aspiculuris tetraptera* (40×), J. *Aspiculuris tetraptera* egg (100×), K. *Hymenolepis diminuta* segment (40×), L. *Hymenolepis diminuta* eggs (100×), M. *Brachylaima* spp. (40×), N. *Eimeria alorani* oocyst (100×)

one trematode: *Brachylaima* spp; and one protozoan species: *Eimeria alorani* were isolated from 190 *Apodemus mystacinus* that were trapped along the Ibrahim River basin in Mount Lebanon.

Heligmosomoides polygyrus was the most prominent among the parasites observed in the trapped *A. mystacinus* (61.05%). Various researchers similarly reported the presence of a species (*H. p. polygyrus*) in *A. mystacinus* in Israel [11]. Moreover, *Heligmosomoides polygyrus*, was the most prominent parasite in *A. sylvaticus* worldwide [26–28]. These findings are explained by the fact that even severe ecological conditions, including lack of vegetation, are favorable for the transmission of *H. polygyrus* in *Apodemus* spp. [29,30]. This could also explain why seasonality did not affect the abundance of this parasite in trapped *A. mystacinus* in this study. Eira et al. [28] rather reported higher frequencies of *A. sylvaticus* infection with *Heligmosomoides polygyrus* during the spring season. In our study, winter season was mild, thus lowering the chances of having a significant impact of the climatic conditions on the abundance of this parasite between different trapping seasons [31].

This nematode was present in mice from all the trapping vegetation zones with different prevalence

(*P*<0.001) among these zones. The highest prevalence of *H. polygyrus* was observed mainly in the Thermo-Mediterranean zones below 500 m asl. This nematode commonly infects *A. mystacinus* [32], and its abundance in specific sites in our study might reflect the suitability of site conditions for the survival and transmission of *H. polygyrus*.

On another hand, this is the first study revealing the presence of *Trichuris muris* in *Apodemus mystacinus*. *T. muris* was reported worldwide in several *Apodemus* sp. such as *A. sylvaticus* and *A. flavicollis* [33]. Seasonality had no effect on the number of individuals infected with *T. muris*. According to Fahmy [34], humidity and moderate temperature are essential for the survival of *T. muris*, thus the absence of seasonality effect can be attributed in our study to the absence of extreme fluctuations in humidity levels between the two trapping seasons. On the other hand, Montgomery and Montgomery [35] reported that the presence of *Trichuris* in *A. sylvaticus*, was most frequent in the first few months of the year, where temperature is low and humidity level is usually high. Such results reflect the importance of humidity in the abundance of *T. muris* that mostly occurred in the winter season.

The prevalence of *Syphacia frederici* in *Apodemus mystacinus*, as revealed in this study, is not uncommon. Members of this genus commonly parasitize rodents including *Apodemus mystacinus* [12–14,36]. Pinworms are usually species specific, thus they are not zoonotic [37]. Season had a significant effect on the number of mice infected with *S. frederici*, with a higher number during the spring season. Eira et al. [28] also reported the presence of an effect of seasonality on two *Syphacia* species (*S. stroma* and *S. frederici*) in *A. sylvaticus*, with *S. stroma* being more prevalent in spring and *S. frederici* in winter. Other researchers reported the prevalence of *S. frederici* in *Apodemus* sp. regardless of the environmental conditions due to the fact that *Syphacia* sp. worms have the peculiarity to be easily transmitted not only through oral infection from eggs in the perianal region but also by retroinfection [30,36].

Although *Protospirura muris* can be found in many rodents [23,38] including the striped field mouse (*Apodemus agrarius*), this is the first study reporting the presence of *P. muris* in *Apodemus mystacinus*. Seasonality had no influence on the number of mice infected with this parasite although higher levels of infections with *Protospirura* spp. were reported after drought periods in rodents including *Rattus rattus* and *Mus musculus domesticus*, with more infections in autumn [39]. *Protospirura muris* has an indirect life cycle, where intermediate hosts including cockroaches and beetles are required for transmission to the final host [40,41]. The prevalence of this nematode in certain sites, namely agricultural zones, is directly linked to the availability and abundance of its intermediate and definite hosts in these sites.

Aspiculuris tetraptera was the least common nematode infecting *Apodemus mystacinus* mice that were trapped in this study (<5%). This figure can be explained by the fact that *Mus musculus* is the common host of this nematode while *Apodemus* spp. is described as "abnormal host" by Behnke [42]. In addition, literature reporting the prevalence of *A. tetraptera* in *Apodemus* spp. is scarce [43]. Season had no effect on the number of *A. mystacinus* infected with this parasite; and researchers [44] also reported the absence of seasonality effect on the infection of rodents with *Aspiculuris* spp. Moreover, this nematode has a direct life cycle [45], and the fact that the frequency of mice infected with this parasite was not significantly different among vegetation zones reflects the suitability of various altitudes and environmental conditions for the lifecycle of this nematode. Sainz-Elip et al. [44] also reported the absence of zone variations in the number of *Mus spretus* infected with *Aspiculuris* spp.

Species identification of helminth by morphology can be challenging, not least in the case of *Hymenolepis* spp. [46]. The prevalence of *Hymenolepis diminuta* in *A. mystacinous* reported in this study is alarming as this parasite is a zoonotic cestode. These cestodes generally infect rodents and insectivores, with a distribution that includes most biogeographic areas around the world [47]. The tapeworm species *H. diminuta* was previously reported in the *A. sylvaticus* mouse population from St Kilda, Australia [48]. The life cycle of *Hymenolepis* spp. is not affected by climatic conditions in our study area. Similarly, Roberts et al. [49] reported the absence of a variation in the abundance of *Hymenolepis* spp. in *Rattus exulans* between different seasons, linking it to the year round presence of its vectors. Other researchers [50], on the other hand, reported a change in the prevalence of *Hymenolepis* according to seasons in *Rattus norvegicus*, where it was most prevalent in autumn. It is worth noting that the number of mice infected with *Hymenolepis* *diminuta* showed no variation among different vegetation in the study area, revealing that various site conditions and altitudes are equally suitable for the survival and transmission of this cestode and for the abundance of its intermediate (beetles) and definite hosts.

The presence of *Brachylaima* spp. in *Apodemus* mice is not uncommon. Various researchers reported the prevalence of *Brachylaima* spp. in *A. sylvaticus* and *A. agrarius* [35,51]. Although this study revealed that seasonality had no influence on the number of *A. mystacinus* infected with *Brachylaima* spp., Montgomery and Montgomery [35] reported that this trematode was most prevalent in *A. sylvaticus* during late spring (period of high humidity) in one site and during autumn (period of low humidity) in another site. This variation was linked to the dynamics and conditions of each site and their effect on intermediate hosts of *Brachylaima* spp.

The number of mice infected with *Brachylaima* spp. was not affected by the vegetation zones included in this study. These results might oppose the fact that this trematode requires the presence of land snails as intermediate hosts in specific sites [35,52,53]. Moreover, the higher number of *A. mystacinus* infected with this trematode in the upper trapping zone reflects the importance of altitude and higher humidity levels for the survival and transmission of this trematode and for the abundance of its hosts.

Several species of the *Eimeria* genus are common parasites of the genus *Apodemus* [54,55]; however, *Eimeria alorani*, identified in this study, was also reported in the works of Hurkova et al. [15] that documented its presence in *A. mystacinus* as a new species of *Eimeria* Schneider 1875 in Jordan. The impact of intrinsic and extrinsic factors on the prevalence of *E. alorani* in *A. mystacinus* was not assessed because this parasite was observed in one mouse only. Nevertheless, this study confirms the presence of this new coccidian in rodents of the Middle East next to the works of Hurkova et al. [15].

In conclusion, eight intestinal parasite species were isolated from *Apodemus mystacinus* individuals trapped along the Ibrahim River, Mount Lebanon. These parasites encompassed five nematode species: *Heligmosomoides polygyrus*, *Trichuris muris*, *Syphacia frederici*, *Protospirura muris*, and *Aspiculuris tetraptera*; one cestode species: *Hymenolepis diminuta*; one trematode: *Brachylaima* spp.; and one protozoan species: *Eimeria alorani*.

Heligmosomoides polygyrus was the most prominent among the observed parasites as it is a common parasitic nematode of *Apodemus* spp. Among the factors influencing intestinal parasites, host gender had no influence on all the observed parasitic species, reflecting the equal exposure of male and female hosts to these parasites.

Seasonality affected the number of *A. mystacinus* infected with *Syphacia frederici*, with higher number recorded in spring season, reflecting the suitability of moderate temperature and high humidity levels for the survival and transmission of this nematode. The absence of seasonality effect on the other parasites reflects the year round availability of their intermediate and/or definite hosts in the study area and the absence of extreme variations in temperature or humidity that would affect their survival and transmission.

Vegetation zone variation affected the number of *A. mystacinus* infected with *Heligmosomoides polygyrus*, and *Trichuris muris*. Such variation reflects the suitability of specific zones (their conditions and resources) for the survival and transmission of these parasites and for the availability and abundance of their intermediate and/or definite hosts. The absence of an effect of zone variation reflects the adaptability of the parasite to varying site conditions.

Any change in these conditions, either naturally or following anthropogenic activities, might affect the populations of both the parasites and their hosts. Anthropogenic activities and human population growth are causing alterations to the environment in addition to the loss of rodent predators, which leads to a continuous increase in rodent populations and results in greater interaction between human beings and rodents and a higher risk of some disease transmission.

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