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ORIGINAL ARTICLE

Gastrointestinal nematode community of spiny mice (*Acomys dimidiatus*) from St. Katherine, South Sinai, Egypt

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Abstract The objective of this work was to study gastrointestinal nematode community infecting *Acomys dimidiatus* in different wadis of St. Katherine, South Sinai, Egypt. Fieldwork was conducted in three Wadis over a 4 weeks period during April–May, 2003 in St. Katherine, South Sinai, Egypt. Faecal samples from 47 spiny mice were analysed for gastrointestinal nematode community. The nematodes community consisted of four genera *Dentostomella* spp., *Syphacia* spp., *Aspicularis* spp. and Spirurids species. The overall prevalence of infection was 55.3 %. A significant difference in prevalence was found per wadis. Wadi Toffaha showed the highest diversity when compared to other Wadis. Mean species richness was higher in Wadi Tlah (0.87) when compared to other Wadis. *Syphacia* spp. was frequently found coexisting with other nematodes. A significant interaction was found between both site and co-infection for *Aspicularis* spp. The spatial stability of nematode community was discussed compared to other related studies. In terms of similarity, the nematode community from Wadi Toffaha was closest to Wadi Tlah. In conclusion, this study showed that there is spatial variation in the distribution of nematode community. Possible factors affecting the stability of parasite community were discussed and further studies are needed.

Keywords Gastrointestinal nematodes · *Acomys dimidiatus* · Spatial variation

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Introduction

Parasite species are not randomly distributed among host species or geographical areas (Brouat et al. 2007). Many factors are known to affect the parasites community structure (Kehr et al. 2000). The extrinsic factors such as seasonal variation and the intrinsic ones such as host age and sex are now well documented for some host–parasite systems such as those involving rodents and their parasites (Behnke et al. 2004; Pawelczyk et al. 2004; Hawlena et al. 2005; Krasnov et al. 2005; Brouat et al. 2007; Behnke et al. 2009). However, the considerable variability of parasite community structure between different populations of the same host species remains largely unexplained (Behnke et al. 2001). Parasite communities and infracommunities are usually described only numerically, especially in rodents (Simões et al. 2012). Nevertheless, the size of the parasites is relevant information in order to understand how much parasite biomass can be sustained and how it can determine the helminth community structure (Simões et al. 2012).

Fragmentation of the environment has important consequences for the local flora and fauna, and human activities in particular have exacerbated naturally occurring barriers to animal movement and hence gene flow through the construction of towns, major roads and through agricultural activities (Bajer et al. 2005). Animals from such isolated or semi-isolated patches may be subject to different stresses in each site, including different infections, and hence experience different selection pressures created by the specific conditions in their home range (Thompson 1994; Bajer et al. 2005).

It has been shown that spiny mice (*Acomys dimidiatus*) from semi-isolated wadis in the montane wadis in the south of the Sinai Peninsula in Egypt experienced differences in parasite exposure and that mice from wadis where parasite challenge was high were less inquisitive and aggressive compared with those from wadis where they experienced less helminth infection (Behnke et al. 2000, 2003, 2004). In addition, site of capture was more important than the intrinsic factors in explaining variation in helminth communities in such region (Behnke et al. 2004). They expected that each wadi is distinct in terms of its rodent parasites, spatially different coevolutionary pressures on their hosts, with resultant variation in life-histories. The objective of this work was to study gastrointestinal nematodes community infecting *A. dimidiatus* in different wadis of St. Katherine, South Sinai, Egypt.

Materials and methods

Study area

Fieldwork was conducted over a 4 weeks period during April–May, 2003 in St. Katherine, South Sinai, Egypt. Trapping was carried out in three sites (Fig. 1) namely Wadi Arbaein (N28.533, E33.966), Wadi Tlah (N28.566, E33.933) and Wadi Tofaha (N28.533, E33.933).

Collection of rodents

At each site, rodents were captured alive using Sherman traps placed selectively among the rocks and boulders, mostly in the wadi bases, around walled gardens, and occasionally along the lower slopes (Behnke et al. 2004). These were set out at dusk, and inspected in the early morning before exposure to direct sunlight. All traps were brought into the local camp where the animals were removed, identified and processed. The rodents were identified according to Atallah (1967). Total examined mice were 47 divided among Wadis as follows: Wadi Arbaein, 9 (19.2 % of total), Wadi Tofaha 22 (46.8 %) and Wadi Tlah, 16 (34.0 %). The captured rodents were released after examination.

Faecal egg counts

Faecal samples were recovered from traps after the animals had been removed and were preserved in SAF (0.9 % w/v sodium acetate, 2 % acetic acid, 4 % formaldehyde, pH 4.15) fluid in 1.5 ml sample tubes (Behnke et al. 2004). All samples were centrifuged at 1,000 rpm for 10 min, and the volume of the deposit was recorded. The deposit was then re-suspended in a known volume of water and ten 10 µl samples examined on a microscope slide, and all the eggs of each type counted. Total egg counts were converted into eggs/ml (EPM) of faecal deposit (mean no. of eggs/10 µl sample × 100 × total volume of suspension (ml), divided by total volume (ml) of the original faecal deposit). Eggs were identified based on the morphology and morphometric parameters according to Ashour (1980) and Ashour and Lewis (1982). Eggs from the 4 species of spirurids (*Protospirura muricola*, *Mastophorus muris*, *Streptopharagus kuntzi* and *Streptopharagus numidicus*) could not be distinguished from one another (Behnke et al. 2004) therefore, they indicated in the text as spirurids egg. The species *P. muricola*, *M. muris*, *S. kuntzi* and *S. numidicus* were already previously described in *A. dimidiatus* from wadis of the study area (Behnke et al. 2004) and so, the eggs of spirurids found probably belong to some of these species.

Statistical analysis

Summary of statistics are presented as mean number ± standard error of EPM infection. Testing of effects of both individual and interacted factors (site and co-infection) on infection rate and eggs count was statistically analyzed using the General Linear Interactive Model (GLIM) after normalization of the data by log 10(x + 1) transformation (Crawley 1993; Wilson and Grenfell 1997; Behnke et al. 1999). At the component community level, two indices of diversity were quantified: numerical species richness (total number of species) and the Simpson's index which weight for abundance of the most common species (Magurran 2004). Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. All indices were calculated according to Magurran (2004) and Krebs (1998). All the statistical tests were performed by using the software packages SPSS 15.0.0 (USA).

Results

Fecal samples from the captured mice were analyzed for gastrointestinal nematodes. There was a significant difference in the numbers of animals sampled by Wadis ($\chi^2 = 8.4$, df = 2, $P = 0.04$). The gastrointestinal nematodes community consisted of four genera (Table 1). They were *Dentostomella* spp., *Syphacia* spp., *Aspicularis* spp. and Spirurids species.

Table 1 shows that all nematodes that found during the study represented by 50 % in Wadi Arbaein, 100 % in Wadi Toffaha and 75 % in Wadi Tlah. In terms of similarity, the helminth component community from Wadi Toffaha was closest to Wadi Tlah (the same three genera found in both wadis). The percentage of similarity among communities was 58.2 %. The diversity of helminths component community was differed according to site. The

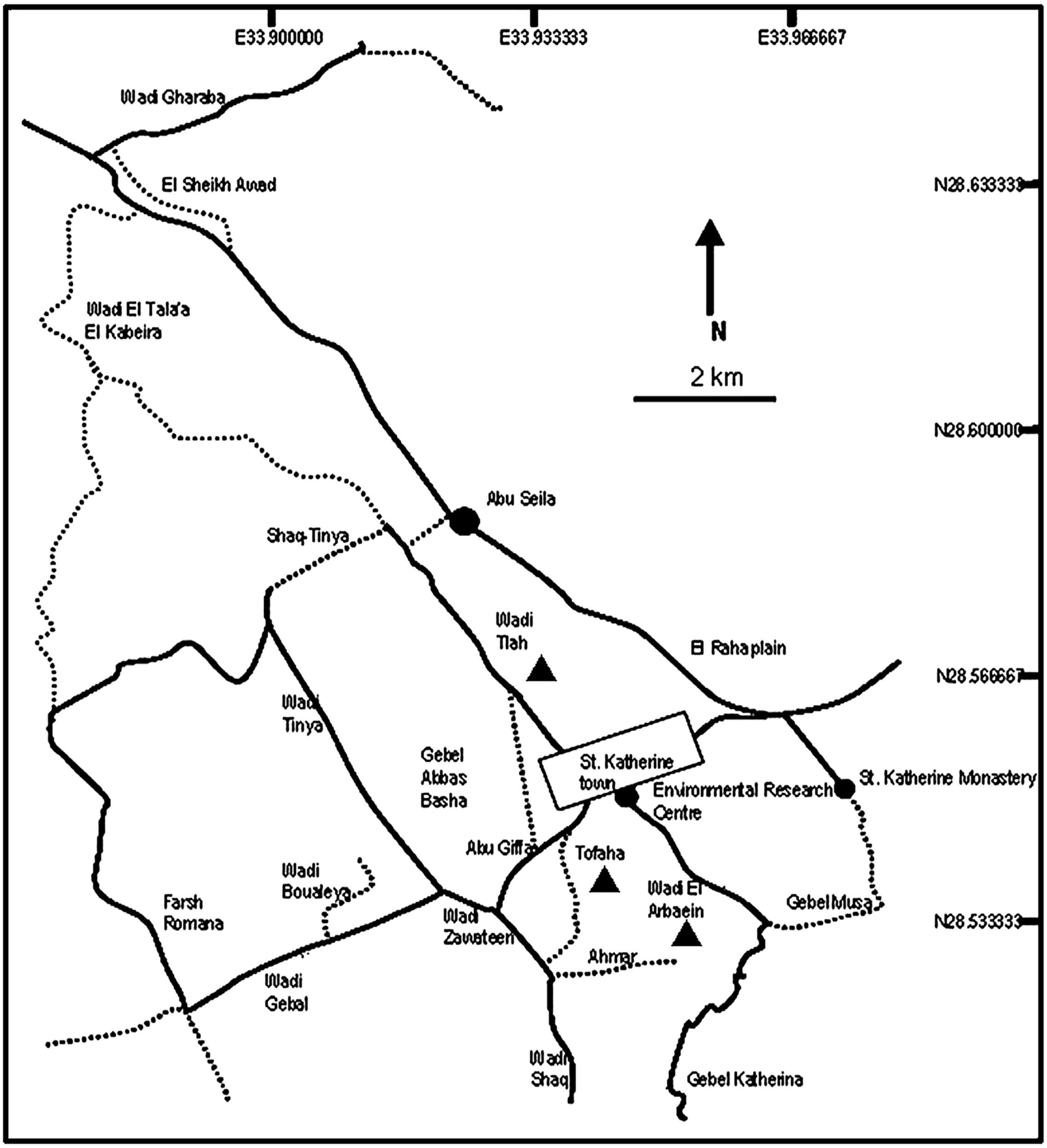

Fig. 1 Map of the study area (modified from Behnke et al. 2004). Sites of the study area were indicated by *arrow heads*

diversity in Wadi Arbaein, Wadi Toffaha and Wadi Tlah were 0.07 ± 0.03, 0.46 ± 0.02 and 0.23 ± 0.02, respectively (Fig. 2). Wadi Toffaha has the highest diversity compared with other Wadis.

The frequency of the distribution of nematode community species richness is shown in Fig. 3. Overall mean number of helminth harboured per host (all mice combined, $n = 47$) was 0.62 ± 0.76 (variance to mean ratio = 0.59). Mean species richness was higher in Wadi Tlah (0.87 ± 0.8) and lower in Wadi Arbaein (Table 1, 0.44 ± 0.72). There was no significance difference among the Wadis ($P = 0.\ 25$) (Table 1).

The overall prevalence of infection was 55.3 %. A significance difference in prevalence was found in Wadis ($P = 0.04$). The combined prevalences were 55.6, 40.9, 75 % in Wadi Arbaein, Toffaha, Telah respectively (Table 1). *Aspicularis* spp. (31.9 %) and *Syphacia* spp. (14.9 %) were the most prevalent nematode among all the mice combined. Spirurids species were found only in Wadi Toffaha. There was a significant difference in prevalence

Table 1 Prevalence and number of EPM of nematodes community in the study area

Overall infection					Helminths							
Study site	Total examined mice	Number of infected mice	Total infection prevalence (%)	Mean species richness ± SE	*Dentostomella* spp.		*Syphacia* spp.		*Aspicularis* spp.		Spirurids egg	
					Prevalence (%)	EPM (rang)	Prevalence (%)	EPM (rang)	Prevalence (%)	EPM (rang)	Prevalence (%)	EPM (rang)
Wadi Arbaein	9	5	55.6	0.44 ± 0.72	22.2	1–198 (n = 2)	11.1	8 ($n = 1$)	0	0	0	0
Wadi Toffaha	22	9	40.9	0.50 ± 0.74	4.5	1 ($n = 1$)	18.2	8–83 ($n = 3$)	22.7	4–113 ($n = 5$)	9.1	5–20 ($n = 2$)
Wadi Tlah	16	12	75	0.87 ± 0.80	6.3	8 ($n = 1$)	18.8	7–63 ($n = 3$)	62.5	4–163 ($n = 10$)	0	0
Total	47	26	55.3	0.62 ± 0.76	8.5 %		14.9 %		31.9 %		4.3 %	

SE standard error, *EPM* egg/ml, *rang* minimum and maximum value of egg/ml, *n* number of infected animals

among different sites in *Aspicularis* spp. (Table 1, $P = 0.003$). The numbers of nematodes recorded in the mice from Wadis Toffaha and Tlah were higher than that from mice in Wadis Arbaein (Table 1). The number of EPM of *Aspicularis* spp. differed significantly among sites (Table 1, $P = 0.004$).

Dentostomella spp. was found as a single infection in all wadis except in Wadi Tlah, while *Syphacia* spp. was frequently coexisted with other genera (Table 2). Analysis of these data with GLIM (two ways ANOVA in GLIM with normal errors and site and co-infection as factors) revealed that there was interaction between site and co-infection in *Aspicularis* spp. (Table 3).

Discussion

The aim of this work was to study the nematode community of spiny mice (*A. dimidiatus*) in different wadis. As in numerous other studies (e.g. Behnke et al. 2000, 2001, 2004, 2008; Brouat et al. 2007) on gastrointestinal helminths of rodents, we found a considerable variability of parasite community structure between the different sites as indicated by species richness and diversity index. Helminths infracommunity structure was clearly dominated by the site effect when examined at a variety of levels (e.g. prevalence, aggregation, abundance etc.) for individual parasite species that were common and which could be treated quantitatively (Behnke et al. 2008). Such variability in community structure should be attributed to the fact that gastro-intestinal helminths of terrestrial mammals spend at least one part of their life-cycle in the external environment outside their host, and habitat characteristics might be crucial for the survival of eggs or larvae (Brouat et al. 2007).

Nematodes community structure of the spiny mice collected from Wadi Arbaein or Wadi Tlah apparently differed from those recorded by Behnke et al. (2004) when compared with our study. *Aspicularis* spp. and Spirurids spp. were found in Wadi Arbaein by Behnke et al. (2004) and not found in the present study. Spirurids species were found by Behnke et al. (2004) in Wadi Tlah but not found in our study. A variation was also recorded regarding nematode community of Wadi Toffaha compared with that reported by Behnke et al. (2000). *Syphacia* spp. and *Aspicularis* spp. were recorded in the present study and were not reported by Behnke et al. (2000). Although there are noticeable spatial variations through time in nematode community, species richness in Wadi Tlah has remained the highest as previously recorded by Behnke et al. (2004). Recording of two new species namely, *Syphacia* spp. and *Aspicularis* spp. in Wadi toffaha; which has not been reported by Behnke et al. (2000), pointed also to a possible

Fig. 2 Diversity of helminth community per site

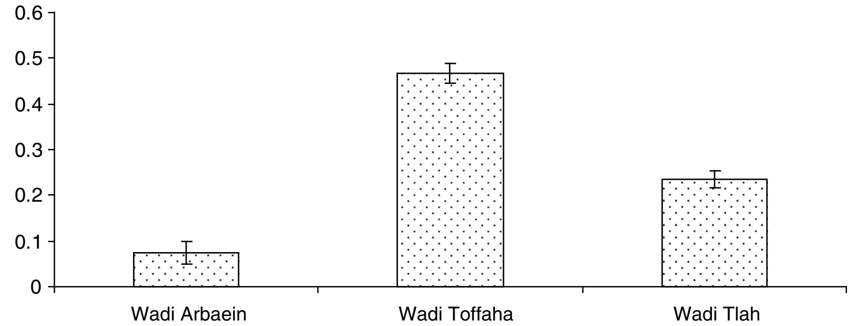

Fig. 3 Frequency distribution of infracommunity species richness per site

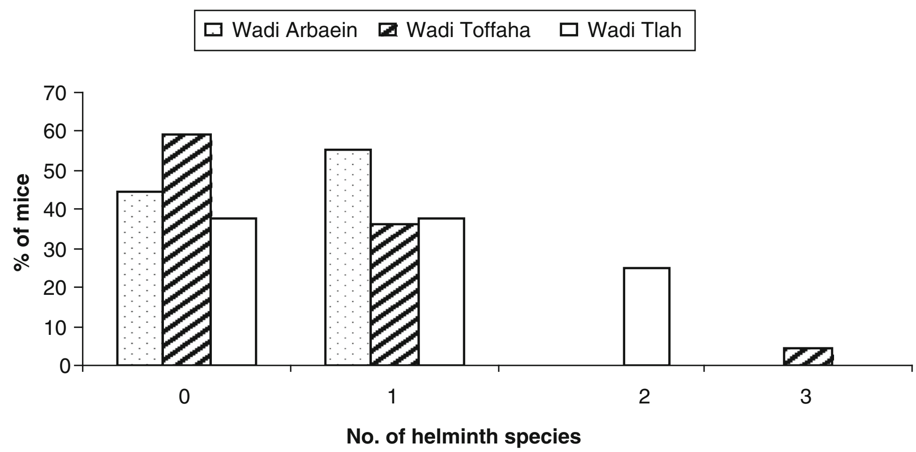

Table 2 Percentage of occurrence of either single or co- infection in the study sites

Study site	*Dentostomella* spp.		*Syphacia* spp.		*Aspicularis* spp.		Spirurids egg	
	Single infection	Co-infection	Single infection	Co-infection	Single infection	Co-infection	Single infection	Co-infection
Wadi Arbaein	100	0	0	0	0	0	0	0
Wadi Toffaha	100	0	66.7	33.4	80	20	0	0
Wadi Tlah	0	100	100	0	66.7	33.3	50	50

Table 3 Test of interaction between site and co-infection status of *Aspicularis* spp.

Source	Type III sum of squares	df	Mean square	*F*	Sig.
Corrected model	28544.58(a)	3	9514.86	6.10	0.011
Intercept	60024.27	1	60024.27	38.53	0.000
Co-infection	3873.47	1	3873.47	2.48	0.143
Site	1862.45	1	1862.45	1.19	0.298
Co-infection × site	15961.25	1	15961.25	10.24	0.008
Error	17134.75	11	1557.70		
Total	112346.00	15			
Corrected total	45679.33	14			

df degree of freedom, *F* value of *F* test, *Sig* significant difference spatial instability through time. EPM recorded in this study greatly varied compared to those recorded by Behnke et al. (2004). The prevalence of *Dentostomella* spp. and *Syphacia* spp. was different as compared to that recorded by Behnke et al. (2004). The possible instability of nematodes community as represented in prevalence, intensity and species richness may be attributed to factors such as sample size, possible host migration and some ecological factors. Hence, further investigation is needed. In contrast, some authors (Mollhagan 1978; Thul et al. 1985; Calvete et al. 2004; Booth 2006; Behnke et al. 2008) demonstrated that there is considerable medium-term stability in the parasite communities as in other helminth and protozoan infections. In addition, Bajer et al. (2005) reported that the structure of helminth communities in wild rodents is subject to seasonal variation, and is dependent on host age within year.

Single and co-infection as mentioned in the present results regarding *Dentostomella* spp. or *Syphacia* spp. for example, and the significant effect of both site and co-infection on *Aspicularis* spp. may indirectly result in instability of parasite community through times. In this regards, Géraldine et al. (2007) reported that among the potential biotic factors affecting population dynamics, relations between different parasite communities has received relatively little attention. Similarly, Brooker and Clements (2009) pointed to the importance of mono- and co-infection with helminth parasites in spatial epidemiology especially in developing world.

In conclusion, this study showed that there is instability in gastrointestinal nematode community in the semi isolated and xeric habitat. Further studies and analyses are needed to test such factors in controlling the stability or instability of parasite community.

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