Preliminary investigation on rodent-ectoparasite associations in the highlands of Tigray, Northern Ethiopia: Implications for potential zoonoses

Article *in* Integrative Zoology · December 2011

DOI: 10.1111/j.1749-4877.2011.00265.x · Source: PubMed doi: 10.1111/j.1749-4877.2011.00265.x

ORIGINAL ARTICLE

Preliminary investigation on rodent–ectoparasite associations in the highlands of Tigray, Northern Ethiopia: implications for potential zoonoses

Meheretu YONAS,[1,2] Kiros WELEGERIMA,[1] Anne LAUDISOIT,[3] Hans BAUER,[4] Kindeya GEBREHIWOT,[5] Seppe DECKERS,[6] Abdul KATAKWEBA,[7] Rhodes MAKUNDI[7] and Herwig LEIRS[2,8]

[1]Department of Biology, Mekelle University, Mekelle, Ethiopia, [2]Evolutionary Ecology Group, University of Antwerp, Belgium, [3]Institute of Integrative Biology, University of Liverpool, Biosciences, Liverpool, UK, [4]Institutional University Cooperation Project, Mekelle University, Mekelle, Ethiopia, [5]Department of Land Resources Management and Environmental Protection, Mekelle University, Mekelle, Ethiopia, [6]Division of Soil and Water Management, K.U. Leuven, Heverlee, Belgium, [7]Pest Management Center, Sokoine University of Agriculture, Morogoro, Tanzania and [8]Department of Integrated Pest Management, University of Aarhus, Slagelse, Denmark

Abstract

We studied associations between rodents and their arthropod ectoparasites in crop fields and household compounds in the highlands of Tigray, Northern Ethiopia. Ectoparasite infestation indices, such as percent infestation, mean abundance, prevalence and host preferences, were calculated for each taxon. In total, 172 rodents from crop fields and 97 from household compounds were trapped. Rodent species and numbers trapped from the crop fields and household compounds were *Mastomys awashensis* (Lavrenchenko, Likhnova & Baskevich, 1998) (88 and 44), *Arvicanthis dembeensis* (Ruppel, 1842) (63 and 37) and *Acomys* sp. (21 and 16), respectively. A total of 558 insects and acarids (belonging to 11 taxa) were recovered from the rodents trapped in the crop fields, and 296 insects and acarid (belonging to 6 taxa) from the rodents trapped in the household compounds. Approximately 66% of the rodents trapped from the crop fields and 47% of those trapped from the household compounds were infested with ectoparasites. *Laelaps* sp. (64.9%) and *Xenopsylla* sp. (20.6%) comprised the highest proportion of the ectoparasites recovered in the crop fields, and the same ectoparasites, but in reverse order, comprised the highest proportions in the household compounds (*Xenopsylla* [50.3%] and *Laelaps* sp. [29%]). Our study revealed that crop fields and household compounds in the highlands share similar rodents and several ectoparasites. Furthermore, at least 1 of the rodent species and some of the ectoparasites identified in this study were reported to have posed medical and veterinary threats in other parts of Ethiopia and neighboring countries.

Key words: ectoparasites, Northern Ethiopia, rodents, zoonoses.

Correspondence: Meheretu Yonas, Department of Biology, Mekelle University, PO Box 3102, Mekelle, Ethiopia.
Email: meheretu@yahoo.com

INTRODUCTION

Rodents are often among the most abundant groups of wild animals around human settlements and the most common reservoir hosts of zoonotic infectious agents that live in close association to humans (Gratz 1974, 1999). They are known reservoirs of several pathogens of public health and veterinary importance, causing serious diseases with such notorious examples as plague, Lassa fever, rickettsiosis, leptospirosis, toxoplasmosis, leishmaniasis and trichinosis (Mills & Childs 1998; Meerburg *et al*. 2009). Humans become infected through direct contact with the rodents or their excretions, through vectors like fleas or ticks, or through consumption of other hosts that have been infected by rodents (Wall 2007). The risk of transmission differs considerably among habitats and depends on people's behavior and rate of contact. Although the most important negative impact of rodent-borne zoonoses is the loss of human health and lives, zoonotic diseases certainly contribute to poverty through lost days of productivity and medical treatment expenses (Mills 1999; Maudlin *et al*. 2009).

Arthropod ectoparasites are a diverse and highly adapted group of animals that intermittently feed on their hosts, usually vertebrates. Some ectoparasite species are host-specific, whereas others are able to exploit a wider spectrum of hosts.

In Ethiopia, 84 species of rodents have been recorded and approximately 12 are reported as agricultural pests (Bekele *et al*. 2003). In the highlands of the Tigray region, Northern Ethiopia, *Mastomys awashensis* (Lavrenchenko, Likhnova & Baskevich, 1998) and *Arvicanthis dembeensis* (Ruppel, 1842) are reported as the most common rodent pest species in rainfed crop fields (Nyssen *et al*. 2007). Farmers in the highlands have identified rodents as the main pre-harvest and post-harvest crop pests, particularly in areas where habitat modifications have been made (Yonas *et al*. 2010). Some rodent species are found in human settlements or close to them, where they seek food and shelter. Few isolated reports are available regarding the role of rodents and their arthropod ectoparasites in the transmission of zoonotic infectious agents in Ethiopia (Wisseman 1978; Gebreselassie *et al*. 1990; Raoult *et al*. 2001). Taxonomic knowledge of rodents and their ectoparasites is also very much limited. Most of the available studies mainly target the associations between ectoparasites and cattle populations (Bekele 2002; Yacob *et al*. 2008; Mulugeta *et al*. 2010).

In the present paper, we report the associations between rodents and their arthropod ectoparasites using survey data independently collected from crop fields and household compounds in the highlands of Tigray, Northern Ethiopia.

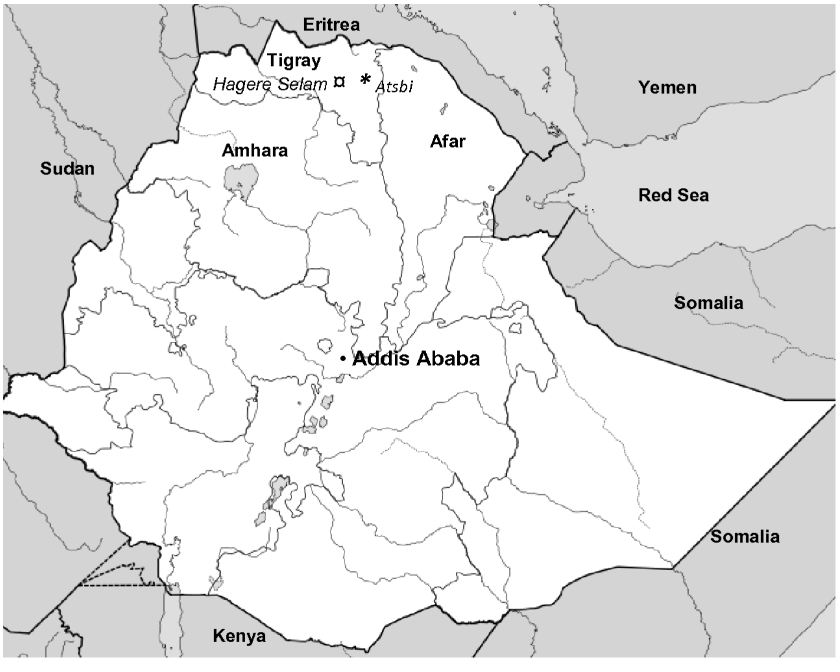

Figure 1 Map of Ethiopia (not to scale) showing the approximate positions of Hagere Selam (¤) and Astbi (*) towns in the highlands of Tigray regional state, approximately 55 and 64 km, respectively, from Mekele, capital of the regional state, Northern Ethiopia.

MATERIAL AND METHODS

The study area

The study was conducted in 3 hamlets, 2 of them (Hechi and Adikolakule) near the town of Hagere Selam (13°40′N, 39°10′E) and 1 (Golegole Naele) near the town of Atsbi (13°52′N, 39°43′E), Tigray, Northern Ethiopia (Fig. 1). These areas have previously been included in lists of rodent-prone areas in Tigray (Fredu *et al*. 2006; Nyssen *et al*. 2007). The highlands of Tigray have a tropical monsoon climate with wide topographically-induced variation in climatic factors (Nyssen *et al*. 2005, 2008). The altitude of Hagere Selam is 2621 m a.s.l. and that of Atsbi is 2630 m a.s.l. The average annual temperatures are 15 and 18 °C, respectively. The main rainy season in both areas runs from June to September. The average annual rainfall is 778 and 669 mm, respectively. The land is typically used as rangelands, with bushes and shrubs on the steep slopes and ridges and crop fields on lesser slopes.

Crop fields

Farmers in the survey areas generally engage in small-scale subsistence agriculture. Farming is mainly rain-dependent, with harvests in November and December. The crop fields are covered with stone bunds, stone heaps and terraces, built against water erosion. Individual crop fields are demarcated by stone or soil bunds, or strips of grasses and bushes (hedgerows). The crop fields consist of plots of several crops either intercropped or grown side by side. The main crops grown are barley (*Hodeum vulgare* L.), wheat (*Triticum* sp.), tef (*Eragrostis tef* [Zucc.] Trotter) and pulses, such as grass pea (*Lathyrus sativus* L.), horse bean (*Vicia faba* L.) and lentil (*Lens culinaris* Medik).

Household compounds

Household compounds in the 3 hamlets are more or less similar. They are typically interspaced at approximately 50–100 m and are often surrounded by crop fields and patches of shrubs and bushes. The compounds generally consist of 1 to 3 houses (depending on income and social status), a separately built kitchen, a toilet, an animal house (only grass roof) for day use and a chicken house. Fodder is often stored on the roof of the animal house. The main house is where the family sleeps, eats and stores personal belongings. The second house is used to store grain (harvest) and animals. Grains are stored in materials made from bamboo and dung or in hide and jute. The main houses are constructed from mortared stone (locally called *hidmo* and most common in the Atsbi area), or wood and mud walls, supported by wooden beams. Depending upon the income of the household, the roofs are covered with mortared stone and mud, corrugated iron sheet or thatch. Floors are painted with a mixture of clay and dung. Each household compound is fenced (approximately 2 m high), with stone walls or half stone walls (below) and half wood (above) fences. Most households manage a small garden for vegetables, often within the compound.

Rodent collection

Rodents were live trapped using the Sherman LFA live trap (7.5 × 9.0 × 23.0 cm, HB Sherman Trap, Tallahassee, USA) baited with peanut butter, from 6 randomly selected household compounds from each hamlet and 3 nearby rainfed crop fields (1 60 × 60 m square grid from each hamlet). Each grid consists of 7 parallel lines, 10 m apart, with trapping stations also 10 m apart (i.e. a total of 49 trapping stations per grid). The trapping stations were identified by coordinates labeled A to G, and numbered 1 to 7. The trapping grids were rotated every trapping session. In the present study, we placed 8 traps in each household compound, 4 inside houses and granaries (near beds, food and clothing cabinets, holes, and hide or jute sacks) and 4 outside the houses (near walls and fences within the compound). Trapping was repeated in the same household throughout the trapping period. Trapping was conducted for 3 consecutive days, every 4 weeks, from April–September 2008 in the household compounds and from September 2008–February 2009 in the crop fields. Traps were checked every morning.

Collection and identification of ectoparasites

Rodents were anesthetized with ether in the temporary laboratory in the field and handled following the ethical policies and guidelines approved by the committee for Animal Care and Use (Mekelle University). Morphological measurements were recorded and fur combed to release ectoparasites. The softer body parts of the rodents, like belly, ear and tail regions, were further examined. The ectoparasites were preserved in 70% ethanol and transported to Mekelle University (Ethiopia), and later to the University of Antwerp (Belgium) for morphological identification. The ectoparasites were identified to genus and species levels according to Haeselbarth *et al*. (1966), Beaucournu *et al*. (1972), Beaucournu (2004) and Walker *et al*. (2003).

Table 1 Number and percent contribution (parentheses) of rodents trapped from rainfed crop fields (CF) and household compounds (HC) around Hagere Selam and Atsbi towns, highlands of Tigray, Northern Ethiopia. Single and coinfestations as well as minimum and maximum number of ectoparasites recovered from the host species are also summarized. First figures in the parentheses indicate percentage contributions for the species and the second indicate percentage contributions overall

Host	Number of hosts examined		Number of hosts infested		Single infestation		Coinfestation[1]		Ectoparasite taxa recovered[2]			
									CF		HC	
	CF	HC	CF	HC	CF	HC	CF	HC	Min	Max	Min	Max
Mastomys awashensis	88(51)	44(45)	65(74; 57)	28(64; 61)	42(48; 64)	7(16; 58)	23(26; 48)	21(48; 62)	1	3	1	4
Arvicanthis dembeensis	63(37)	37(38)	40(64; 35)	17(46; 37)	18(29; 27)	5(14; 42)	22(35; 46)	12(32; 35)	1	5	1	4
Acomys sp.	21(12)	16(17)	9(43; 8)	1(6; 2)	6(29; 9)	—	3(14; 6)	1(6; 3)	1	3	2	2
Overall	172	97	114(66)	46(47)	66(38)	12(26)	48(42)	34(74)				

[1] No. of rodents infested with two or more ectoparasite species. [2] For the infested rodents.

Data analysis

The following parameters were calculated for each ectoparasite taxon: percent contribution of each ectoparasite taxon per host (percent infestation = total number of individuals of a particular parasite taxon infesting a particular host species/total number of all parasites recovered from a host species), mean abundance (MA = total number of individuals of a particular parasite taxon infesting a particular host species/total number of hosts of that species, including both infected and non-infected hosts), prevalence (P = [number of the host species infested with 1 or more individuals of a particular parasite taxon/the number of host examined for that parasite] × 100) and host preference (HP = [number of parasites of a particular taxon on a particular host species/sum of number of parasites of that taxon on all host species] × 100).

RESULTS

A total of 172 (from crop fields) and 97 (from household compounds) rodents belonging to 3 species, the multimammate rat *M. awashensis* (88 and 44), the grass rat *A. dembeensis* (63 and 37) and the spiny mouse *Acomys* sp. (21 and 16), respectively, were trapped, and all of them were examined for ectoparasites (Table 1). Approximately 66% of the rodents trapped from the crop fields and 47% of the rodents trapped from the household compounds were infested with ectoparasites.

In the crop fields, coinfestation (up to 5 taxa) was observed in 42% of the rodents, with the highest infection in *A. dembeensis* (35%) and the least infection in *Acomys* sp. (14%) (Table 1). In contrast, in the household compounds, coinfestation (up to 4 taxa) was observed in the majority (74%) of the rodents, with the highest infection in *M. awashensis* (48%) and the least infection in *Acomys* sp. (6%).

In total, 558 individual ectoparasites belonging to the following 11 taxa (a mixture ticks, mite, louse, and fleas) were recovered from the rodents trapped from the crop fields: *Laelaps* sp. (64.9%), *Xenopsylla* sp. (20.6), *Ixodes* sp. (3.9%), *Amblyomma* sp. (3.8%), *Ornithodoros* sp. (2.5%), *Polyplax* sp. (1.4%), *Boophilus* sp. (1.3%), *Ctenocephalides felis* Bouche, 1835 (0.9%), *Dinopysyllus lypusus* Jordan et Rothschild, 1913 (0.4%), *Leptopsylla aethiopica* Rothschild, 1908 (0.2%) and *Pulex irritans* L. ,1758 (0.2%) (Table 2).

On the rodents trapped from the household compounds, a total of 296 individual ectoparasites (mite and fleas) belonging to the following 6 taxa were recovered:

Table 2 Percent infestation (in parentheses), mean abundance (MA), prevalence (P) and host species preference (HP) for every ectoparasite associated with the rodents trapped from rainfed crop fields around Hagere Selam and Atsbi towns, highlands of Tigray, Northern Ethiopia

Ectoparasite	*Acomys* sp. (*n* = 21)				*Arvicanthis dembeensis* (*n* = 63)				*Mastomys awashensis* (*n* = 88)					
	Count	MA	P	HP	Count	MA	P	HP	Count	MA	P	HP	Overall	%
Acarid (tick)														
Amblyomma sp.	3(11.5)	0.14	4.8	14.3	16(8.0)	0.25	14.3	76.2	2(0.6)	0.02	2.3	9.5	21	3.8
Ixodes sp.	—	—	—	—	20(10.1)	0.32	12.7	90.9	2(0.6)	0.02	2.3	9.1	22	3.9
Ornithodoros sp.	—	—	—	—	13(6.6)	0.21	6.3	92.9	1(0.3)	0.01	1.14	7.1	14	2.5
Boophilus sp.	—	—	—	—	7(3.5)	0.11	6.3	100†	—	—	—	—	7	1.3
Acarid (mite)														
Laelaps sp.	8(30.8)	0.38	23.8	2.2	71(35.8)†	1.13†	19	19.6	283(84.7)†	3.22†	64.7†	79.2†	362†	64.9†
Anaplura (louse)														
Polyplax sp.	3(11.5)	0.14	4.8	37.5	4(2)	0.06	3.1	50	1(0.3)	0.01	2.3	12.5	8	1.4
Siphonaptera (flea)														
Dinopysyllus lypusus	—	—	—	—	2(1)	0.03	3.2	100†	—	—	—	—	2	0.4
Ctenocephalides felis	—	—	—	—	2(1)	0.03	3.2	40	3(0.9)	0.03	2.3	60	5	0.9
Leptopsylla aethiopica	1(3.8)	0.05	4.8	100†	—	—	—	—	—	—	—	—	1	0.2
Pulex irritans	1(3.8)	0.05	4.8	100†	—	—	—	—	—	—	—	—	1	0.2
Xenopsylla sp.	10(38.5)†	0.47†	28.5†	8.7	63(31.8)	1.0	41.3†	54.8	42(12.6)	0.47	22.8	36.5	115	20.6
Overall	26				198				334				558	
%	(4.7)				(35.5)				(59.8)					

†Maximum values in each column.

Table 3 Percent infestation (in parentheses), mean abundance (MA), revalence (P) and host species preference (HP) for every ectoparasite associated with the rodents trapped from household compounds around Hegere Selam and Atsbi towns, in the highlands of Tigray, Northern Ethiopia.

Ectoparasite	*Acomys* sp. (*n* = 16)				*Arvicanthis dembeensis* (*n* = 37)				*Mastomys awashensis* (*n* = 44)				Overall	%
	Count	MA	P	HP	Count	MA	P	HP	Count	MA	P	HP		
Acarid (mite)														
Laelaps sp.	—	—	—	—	7(8.75)	0.19	8.1	10.5	79(38)	1.8	38.6	91.8†	86	29
Siphonaptera (fleas)														
Dinopsyllus lypusus	—	—	—	—	6(7.5)	0.16	5.4	66.7	3(1.4)	0.07	6.8	33.3	9	3
Ctenocephalides felis	—	—	—	—	2(2.5)	0.05	5.4	40	3(1.4)	0.07	4.5	60	5	1.7
Leptopsylla aethiopica	—	—	—	—	8(10)	0.22	13.5	17.8	37(17.8)	0.84	27.3	82.2	45	15.2
Xenopsylla sp.	8(100)†	0.5†	12.5†	5.4†	55(68.8)†	1.5†	56.7†	37	86(41.3)†	1.95†	77.3†	57.7	149†	50.3†
Nosopsyllus sp.	—	—	—	—	2(2.5)	0.05	5.4	100†	—	—	—	—	2	0.7
Overall	8				80				208				296	
%	(2.7)				(27)				(70.3)					

†Maximum values in each column.

Xenopsylla sp. (50.3%), *Laelaps* sp. (29%), *L. aethiopica* (15.2%), *D. lypusus* (3%), *C. felis* (1.7%) and *Nosopsyllus* sp. (0.7%) (Table 3). All the ticks, the mite, the louse and 2 fleas could only be identified to the genus level. We did not include the associations between parasite infection and host age and sex in the analysis as there were very few young individuals and females captured. Moreover, we were not able to sex most of the ectoparasites because of the handling (preservation) mistakes we made during transport. We believe though, that it would be indeed much appropriate to include such associations in future work.

In the crop fields, 9 of the 11 ectoparasite taxa were recovered from *A. dembeensis*, 7 out of the 11 from *M. awashensis*, and 6 out of the 11 from *Acomys* sp. (Table 2). Of the 11 ectoparasites, 4 (one tick, mite, louse and flea each) were shared among the 3 rodent hosts. *Boophilus* sp. and *D. lypusus* were recovered from *A. dembeensis* only and *L. aethiopica* and *P. irritans* (1 each) from *Acomys* sp. only. While *Laelaps* sp. showed the highest host preference (HP) for *M. awashensis* (79.2), all the ticks showed higher HP for *A. dembeensis*. Furthermore, *Laelaps* sp. showed the highest percent infestation and mean abundance (MA) on *M. awashensis* and the least on *Acomys* sp. Although *A. dembeensis* recorded the highest percent infestation for 5 of the 11 ectoparasite taxa, *M. awashensis* had the highest overall percent infestation (59.8%). Ectoparasite prevalence (P) was less than 50% for almost all the parasites in each of the host species (except the 64.7% P of *Laelaps* sp. on *M. awashensis*).

In the household compounds, except for 1 flea (*Nosopsyllus* sp.), the 2 major hosts, *M. awashensis* and *A. dembeensis*, were infested with similar ectoparasites (Table 3). The *Acomys* sp. was infested only with *Xenopsyllinae* fleas. Overall, the *Xenopsyllinae* accounted for the highest percent infestation in the household compounds, followed by *Laelaps* sp. Ectoparasite P was less than 50% for the majority of the parasites on all host species (except 77.3 and 56.7% P of *Xenopsylla* sp. on *M. awashensis* and *A. dembeensis*, respectively). The flea *Xenopsyllinae* showed the highest percent infestation, MA, P and HP for each of the host species in the household compounds.

DISCUSSION

We trapped similar rodent species from both the crop fields and the household compounds surveyed. The 3 rodent species captured in the current survey were previously reported from rainfed crop fields in the highlands of Tigray (Nyssen *et al*. 2007). However, this report on rodent–ectoparasite associations from the highlands of Tigray is the first of its kind.

The proportion of hosts examined for ectoparasites, the proportion of hosts infested and the proportion of hosts with single infestation were highest for *M. awashensis* in the crop fields and least for *Acomys* sp. (Table 1). The highest proportion of coinfection occurred on *M. awashensis* in the household compounds, and on *A. dembeensis* in the crop fields.

Laelaps sp. (64.9%) and *Xenopsylla* sp. (20.6%) comprised the highest proportion of the ectoparasites recovered in the crop fields (Table 2). The same ectoparasites, but in reverse order, comprised the highest proportion of the ectoparasites recovered in the household compounds (*Xenopsylla* [50.3%] and *Laelaps* sp. [29%]) (Table 3). *Laelaps* sp. consistently had the highest percent infestation, MA and HP in *M. awashensis* in both survey areas. The most commonly infesting flea of the 3 hosts, in both survey areas, was *Xenopsylla* sp.

Arvicanthis dembeensis was more infested with ticks than the other 2 rodent hosts. Ticks were totally absent from the hosts trapped in the household compounds. Two *Nosopsyllus* sp. were recovered from 2 *A. dembeensis* trapped from the household compounds. *Acomys* sp. was more infested by fleas than other ectoparasites in both survey areas. The occurrence of a particular ectoparasite species on host species might be related to several factors, including the behavior and microhabitat choice of the host species (Laudisoit *et al*. 2009). Furthermore, *A. dembeensis* showed the highest percent infestation by 5 of the 11 ectoparasites in the crop fields. The highest overall percent infestation observed for *M. awashensis* in the crop fields was the result of the large number of *Laelaps* sp. recovered from this host. More *L. aethiopica* were recovered in the household compounds than the crop fields.

The highest P of *Xenopsylla* sp. in almost all the hosts in both survey areas (except *Laelaps* sp. once in the crop fields) indicated that a large number of individuals of the host species have been infested by the parasite, in relation to the total number of individuals of that host species examined (Tables 1 and 2). The higher HP values were indications that the ectoparasite has the highest preference to the corresponding host species in the survey area. HP equal to 100 indicated that the ectoparasite was collected only from that host. Therefore, little host specificity was evident in the associations for the majority of the ectoparasites.

The role played by most of the ectoparasites identified in this paper in the transmission of some zoonotic diseases has already been established in many Sub-Saharan African countries (e.g. Gratz 1999; Parola *et al*. 2005; Laudisoit *et al*. 2007). Some of them were also reported as potential vectors of certain diseases of medical and veterinary importance in different parts of Ethiopia. Wisseman (1978) reported infection with the spotted fever-group of rickettsiae (tick typhus) in Ethiopian rodents and their ectoparasites, including wild murines that entered domiciles. He reported that the infection rate in *Arvicanthis* trapped from fields and inside houses was as high as 25 and 30%, respectively. The dominant tick among cattle in eastern Ethiopia is *Amblyomma* sp., and one of the problems associated with the tick was that it acts as the agent of cowdriosis (Bekele 2002). The author also indicated that the patterns of infestation of the tick were associated with local wildlife fauna, including rodents, which might have played an important role by maintaining a population of the ticks and, ultimately, transferring them to cattle. Philip *et al*. (1966), Burgdorfer *et al*. (1973), Jensenius *et al*. (2003) and Mura *et al*. (2008) reported the detection of the spotted fever group rickettsiae (*Rickettsia africae*) in *Amblyomma* ticks collected from cattle in Ethiopia. Recently, infection with *R. africae* was reported in a man in France who had returned from visiting Ethiopia (Stephany *et al*. 2009).

There is no previous report whether the mite reported in our study had zoonotic importance. Members of the genus *Laelaps* are bloodsucking mites of small mammals, particularly rodents. *Laelaps* are not host-specific, and occasionally (e.g. when their hosts die or abandon their nests) they parasitize a wide variety of hosts, including humans (Lane & Crosskey 1993).

Few lice were recovered from the rodents trapped in the crop fields. Not much is known about their role as vectors of zoonotic pathogens in Ethiopia. Gebreselassie *et al*. (1990) reported the presence of louse-borne typhus in humans in Addis Ababa. *Polyplax* lice collected from rodents in Addis Ababa have been found to be infected with *Rickettsia mooseri*, the etiological agent of murine typhus (Wissman 1978).

At least 4 of the fleas recorded in this survey (*Xenopsylla* sp., *P. irritans*, *D. lypusus* and *C. felis*) have been reported to have relevance with respect to flea-borne zoonoses, including plague, in neighboring Kenya, Tanzania and the Democratic Republic of Congo (Schwan 1986; Kilonzo *et al*. 1997; Laudisoit *et al*. 2007; Oguge *et al*. 2009). Although there is no report of plague presence in Ethiopia, other flea-borne diseases have been reported from the central part of the country. Gebreselassie *et al*. (1990) reported the presence of flea-borne typhus in Addis Ababa, in a test conducted on humans. According to Wisseman (1978), fleas collected from rodents in central Ethiopia were positive for *R. mooseri.* Raoult *et al*. (2001) also reported detection of *R. felis* from cat fleas (*C. felis*) in Ethiopia. It should be noted that *Ctenocephalides* and *Pulex* fleas reported in this study are not primarily parasites of these rodents, but their presence indicates the possibility of contamination between rodents and humans.

An increase in rodent sightings in the highlands of Tigray has been reported in response to habitat manipulation (Nyssen *et al*. 2007; Yonas *et al*. 2010). Changes in environmental conditions and poor socioeconomic conditions in rural Africa favor rodent infestation and increased incidences of human–rodent contact (direct and indirect), which has epidemiological importance (Patz *et al*. 2000; Masi *et al*. 2010; Omudu & Ati 2010). Our study revealed that crop fields and household compounds share similar rodent species and several ectoparasites in the highlands of Tigray. Furthermore, at least 1 of the rodent species and most of the ectoparasites reported in this study have already been indicated as potential vectors of some diseases of medical and veterinary importance in other parts of Ethiopia and neighboring countries. We believe that the findings provide a springboard for further in-depth study into the host–parasite associations and the need for screening of some zoonotic pathogens from the hosts and the parasites.

ACKNOWLEDGMENTS

We are grateful to the Flemish Interuniversity Council (VLIR) for funding the project. We thank the Departments of Biology in Mekelle (Ethiopia) and Antwerp (Belgium) Universities for provision of laboratory facilities, and the entire Mekelle University–Institutional University Cooperation Project staff for facilitating the fieldwork. We are also grateful for the contribution of Maxime Madder from the Institute of Tropical Medicine, Antwerp during the identification of the ticks.

REFERENCES

Beaucournu JC (2004). Catalogue des Puces de la Région Afrotropicale (Insecta-Siphonaptera) (sous-région malgache exclue). *Beiträge für Entomologie* **54**, 185–239.

Beaucournu JC, Rodhain F, Houin R (1972). Insects (Siphonaptera, Anoplura), mammalian ectoparasites, in the lower valley of the Omo, Ethiopia. *Bulletin of the Society of Exotic Pathology* **65**, 867–80 (In French).

Bekele A, Leirs H, Verhagen R (2003). Composition of rodents and damage estimates on maize farms at Ziway, Ethiopia. In: Singleton DR, Hinds LA, Krebs CJ, Spratt DM, eds. *Rats, Mice and People: Rodent Biology and Management. ACIAR Monograph*. No. 96, Canberra, Australia pp.564.

Bekele T (2002). Studies on seasonal dynamics of ticks of Ogaden cattle and individual variation in resistance to ticks in Eastern Ethiopia. *Journal of Veterinary Medicine* **49**, 285–8.

Burgdorfer W, Ormsbee RA, Schmidt ML, Hoogstraal H (1973). A search for the epidemic typhus agent in Ethiopian ticks. *Bulletin of World Health Organization* **48**, 563–9.

Fredu N, Zaid N, Kidanemariam *et al*. (2006). *Tigray livelihood papers*, Participatory Rural Appraisal Report of Selected Villages in Tigray. VLIR–Mekelle University–IUC Program, Ethiopia.

Gebreselassie L, Abebe A, Abebe S (1990). Serological study of louse borne and flea borne typhus in Addis Ababa. *Ethiopian Medical Journal* **28**, 77–80.

Gratz NG (1974). The role of WHO in the study and control of rodent-borne disease. Proceedings of the 6th Vertebrate Pest Conference, 5-7 March 1974, University of Nebraska-Lincoln, USA.

Gratz NG (1999). Urbanization, arthropod and rodent pests and human health. In: Robinson WH, Rettich F, Rambo GW, eds. Proceedings of the 3rd International Conference on Urban Pests, 19-22 July 1999, Prague, Graficke zavody Hronov, Czech Republic.

Haeselbarth E, Segerman J, Zumpt F (1966). *The Arthropods Parasites of Vertebrates in Africa South of the Sahara* (Ethiopian Region), Vol. III. The South African Institute for Medical Research, Johannesburg.

Jensenius M, Fournier PE, Kelly P, Myrvang B, Raoult D (2003). African tick bite fever. *Lancet Infectious Diseases* **3**, 557–64.

Kilonzo BS, Mvena ZSK, Machangu RS, Mbise TJ (1997). Preliminary observations on factors responsible for long persistence and continued outbreaks of plague in Lushoto district, Tanzania. *Acta Tropopica* **68**, 215–27.

Lane RP, Crosskey RW, eds (1993). *Medical Insects and Arachnids*. Chapman and Hall, London.

Laudisoit A, Leirs H, Makundi RH (2007). Plague and the human flea, Tanzania. *Emerging Infectious Diseases* **13**, 687–93.

Laudisoit A, Leirs H, Makundi R, Krasnov BR (2009). Seasonal and habitat dependence of fleas parasitic on small mammals in Tanzania. *Integrative Zoology* **4**, 196–212.

Maudlin I, Eisler MC, Welburn SC (2009). Neglected and endemic zoonoses. *Philosophical Transactions of the Royal Society* B **364**, 2777–87.

Masi E, Pino FA, Santos MDS *et al*. (2010). Socioeconomic and environmental risk factors for urban rodent infestation in Sao Paulo, Brazil. *Journal of Pest Science* **83**, 231–41.

Meerburg BG, Singleton GR, Kijlstra A (2009). Rodent-borne diseases and their risks for public health. *Critical Reviews in Microbiology* **35**, 221–70.

Mills JN (1999). The role of rodents in emerging human disease: examples from the Hantaviruses and Arenaviruses. In: Singlton G, Hinds L, Liers H, Zhibin Z, eds. *Ecologically-based Rodent Management, ACIAR,* Canberra, Australia, pp. 134-160.

Mills JN, Childs JE (1998). Ecologic studies of rodent reservoirs: their relevance for human health. *Emerging Infectious Diseases* **4**, 529–37.

Mulugeta Y, Yacob HT, Ashenafi H (2010). Ectoparasites of small ruminants in three selected agro-ecological sites of Tigray Region, Ethiopia. *Tropical Animal Health & Production*, **42**, 1219–224.

Mura A, Socolovschi C, Ginesta J *et al*. (2008). Molecular detection of spotted fever group rickettsiae in ticks from Ethiopia and Chad. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **10**, 945–9.

Nyssen J, Vandenreyken H, Poesen J *et al*. (2005). Rainfall erosivity and variability in the Northern Ethiopian Highlands. *Journal of Hydrology* **311**, 172–87.

Nyssen J, Poesen J, Desta G *et al*. (2007). Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia. *Soil and Tillage Research* **94**, 151–63.

Nyssen J, Naudts J, De Geyndt K *et al*. (2008). Soils and land use in the Tigray highlands (Northern Ethiopia). *Land degradation & development* **19**, 257–74.

Oguge NO, Durden LA, Keirans JE, Balami HD, Schwan TG (2009). Ectoparasites (sucking lice, fleas and ticks) of small mammals in southeastern Kenya. *Medical and Veterinary Entomology* **23**, 387–92.

Omudu EA, Ati TT (2010). A survey of rats trapped in residential apartments and their ectoparasites in Makurdi, Nigeria. *Research Journal of Agriculture and Biological Sciences* **6**, 144–9.

Parola P, Davoust B, Raoult D (2005). Tick- and flea-borne rickettsial emerging zoonoses. *Veterinary Research* **36**, 469–92.

Patz JA, Graczyk TK, Geller N, Vittor AY (2000). Effects of environmental change on emerging parasitic diseases. *International Journal for Parasitology* **30**, 1395–405.

Philip CB, Lackman B, Bell J, Hughes E (1966). Laboratory identification of typhus isolated by Reiss-Gutfreund from Ethiopian livestock ticks. *American Journal of Tropical Medicine and Hygiene* **15**, 950–53.

Raoult D, La Scola B, Enea M *et al*. (2001). A flea-associated Rickettsia pathogenic for humans. *Emerging Infectious Diseases* **7**, 73–81.

Schwan TG (1986). Seasonal abundance of fleas (Siphonaptera) on grassland rodents in Lake Nakuru National Park, Kenya, and potential for plague transmission. *Bulletin of Entomological Research* **76**, 633–48.

Stephany D, Buffet P, Rolain J, Raoult D, Consigny PH (2009). *Rickettsia africae* infection in man after travel to Ethiopia. *Emerging Infectious Diseases* **15**, 1867–9.

Walker AR, Bouattour A, Camicas JL *et al*. (2003). *Ticks of Domestic Animals in Africa: A Guide to Identification of Species*. Bioscience Reports, Edinburgh, UK.

Wall R (2007). Ectoparasites: future challenges in a changing world. *Veterinary Parasitology* **148**, 62–74.

Wisseman CL (1978). Clinical and epidemiological studies on rickettsial infections. *Annual Report.* Maryland University, Baltimore.

Yacob HT, Ataklty H, Kumsa B (2008). Major ectoparasites of cattle in and around Mekelle, northern Ethiopia. *Entomological Research* **38**, 126–30.

Yonas M, Welegerima K, Deckers S, Raes D, Makundi R, Leirs H (2010). Farmers' perspectives of rodent damage and management from the highlands of Tigray, Northern Ethiopia. *Crop Protection* **29**, 532–9.