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IMPACT OF CATTLE KEEPING ON HUMAN BITING RATE OF ANOPHELINE MOSQUITOES AND MALARIA TRANSMISSION AROUND ZIWAY, ETHIOPIA
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IMPACT OF CATTLE KEEPING ON HUMAN BITING RATE OF ANOPHELINE MOSQUITOES AND MALARIA TRANSMISSION AROUND ZIWAY, ETHIOPIA

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ABSTRACT

***Objective*: To assess the impact of livestock keeping on the human biting rate (HBR) of anopheline mosquitoes and malaria transmission around Ziway in the middle course of the Ethiopian Rift Valley.**
***Design*: As a passive experiment, man landing captures were done in homesteads with mixed dwelling, separate cattle shed and without livestock; and as an active experiment, captures were in experimental *tukuls* (huts) of cattle, goats, and without livestock. Parasite and spleen rates of children were compared among those residents under variable living conditions mentioned for passive experiment.**
***Subjects:* For entomological study, human-baits were used for man-landing captures of mosquitoes. Study subjects for parasitological and clinical studies were children below 10 years old.**
***Main outcome measures:* Human-biting rate (HBR) of anopheline mosquitoes; and the parasite and spleen rates of the study subjects in different living conditions.**
***Results:* In the passive experiment, the mean HBR of *Anopheles arabiensis* in mixed dwelling, separate cattle shed and without livestock was 8.45, 4.64 and 5.97, respectively. Similarly, the HBR of *An. pharoensis* was 2.88, 1.79 and 1.61, respectively. In the active experiment, the mean HBR of *An. arabiensis* in *tukuls* with cattle, goats, and without livestock was 3.50, 3.38 and 1.43 respectively; while that of *An. pharoensis* was 0.37, 0.70 and 0.55 respectively. Parasitologically, mean parasite rates of 26.67%, 15.05% and 23.85% were, respectively, recorded from children living under the above conditions stated for passive experiment. Similarly, the mean spleen rates of 50.0%, 26.9%, and 47.37% were recorded, respectively.**
***Conclusion:* These observations in the present study indicate that the presence of cattle in homesteads tends to increase the man biting rate of *An. arabiensis,* although differences in the mean HBR of vector mosquitoes were not statistically significant for all groups. In contrast, cattle keeping in separate cattle sheds outside of the human dwellings tends to reduce the man biting rate of *An. arabiensis* and malaria transmission in the study area.**

INTRODUCTION

Despite the tremendous control efforts malaria continues to be a major cause of morbidity and mortality in tropical and sub-tropical countries. It is responsible for an estimated 1.5 to 2.7 million deaths and 300 to 500 million cases each year(1). Tropical Africa accounts for the overwhelming majority of these cases. About 75% of the people of Africa live in areas of highly endemic and stable transmission of malaria and another 18% live in epidemic prone areas where transmission is seasonal and unstable and where all age groups are vulnerable to infection and disease(2). Malaria epidemics have been both more frequent and more widespread with high mortality rates among all age groups in Ethiopia(3)

Efforts to control malaria have been focused on the use of chemical insecticides for several years. However, insecticide resistance has been documented in more than 100 species of mosquitoes(4). Mosquito resistance to insecticides is now an immense practical problem that has threatened the control of malaria in different parts of the world. Furthermore, due to toxicological and environmental considerations, the search for alternative control methods including appropriate technologies to reduce the human vector contact is being intensified throughout the world.

Zooprophylaxis has been defined as the use of wild and domestic animals, which are not the reservoir hosts of a given disease, to divert the blood-seeking mosquito vectors from the human hosts of that disease(5). In the past, diversion of mosquito vectors to animal hosts has been used in some parts of the world as a method of malaria vector control. Deviation of the local *Anopheles* vectors to animal hosts was found to be partly responsible for the decrease of malaria from the Northern Europe and much of North America (6). Similarly, a shift in agricultural practices towards crop production which result in livestock depletion led to malaria outbreaks in Guyana mainly due to a change in the feeding habits of local malaria vector, *Anopheles aquasalis* (7).

In contrast, however, there are reports showing increased malaria prevalence associated with livestock keeping. In Indonesia, the prevalence of malaria was found to be higher in villages where cattle sheds were close to the human dwellings than villages with cattle sheds far away from the human dwellings(8). Similarly, direct correlations were observed between the prevalence of malaria and cattle-man ratio in Pakistan(9). These reports also showed that the prevalence of malaria was found to be significantly higher in families owning cattle. In addition, entomological investigations revealed that sleeping close to cattle/goats significantly increased the human biting rate of zoophilic anophelines, whereas it appears to have little effect on highly anthrophophilic anopheline species(10).

These conflicting reports have shown the complexity of interactions between livestock keeping and malaria/mosquitoes and the need to investigate the impact of domestic cattle keeping on the human biting rate of local anopheline vectors and malaria transmission in any particular area.

Despite the very large cattle population and repeated malaria outbreaks in Ethiopia, no detailed study has ever been made on the impact of keeping livestock on man-vector contact and hence malaria transmission. Indirect information is only available from blood meal analysis(11-13) that reported human blood index (HBI) of 20-88% in *An. arabiensis* collected from mixed dwellings in different parts of the country. Only one of these (13) which reported a HBI of 20% showed the possible prophylactic effect of cattle keeping and recommended further investigations on the potential use of livestock to divert the blood-seeking mosquito vectors from the human host. However, the preponderance of bovid feeds in *Anopheles arabiensis* in this study was difficult to interpret in light of the recent resurgence of malaria in many areas of Ethiopia where mixed type of dwelling is common. However, it may be argued that data obtained from analysis of blood meals of resting mosquitoes can be biased by the nature of the differences in the resting and feeding habits of mosquitoes, as mosquitoes having fed in different hosts either indoor or outdoor often rest elsewhere. This study was thus designed to investigate the impact of livestock keeping on the human biting rate (HBR) of anopheline mosquitoes and malaria transmission in a peri-urban settlement village around Ziway, one of the malaria epidemic prone areas in the country.

MATERIALS AND METHODS

Study area: The study village, Gerbi-gilgle, is located at a distance of 165km south of Addis Ababa, on the outskirts of Ziway Town, in the middle course of the Ethiopian Rift Valley at an altitude of about 1,600m above sea level. It is a semi-arid area with sparsely distributed *Acacia* trees and thorny bushes. The community, with a total population of 1,200 belongs to the Oromo ethnic group and most families own cattle and goats, and people commonly sleep in close proximity to their livestock. Most of the people reside in circular huts of a single room, made of mud wall and thatched roof. Adjacent to the study village, there is an irrigation canal of the Gerbi-State Farm. The principal malaria vector in the study area is *An. arabiensis,,* while *An. pharoensis* is considered as a secondary vector(3).

Entomological studies: Mosquito collections were carried out based on passive and active experiments. In passive experiments, man-landing/biting catches of mosquitoes were made at monthly intervals at three sites: (a) homesteads with mixed dwelling (both human and cattle), (b) homesteads with separate cattle shed outside the human dwelling and (c) homesteads with human dwelling alone which are all equidistant from the mosquito breeding habitat (the irrigation canal). At each site, two vector collectors whose legs and arms were exposed worked the whole night in two shifts which changed over at midnight to collect mosquitoes landing/biting on themselves and on each other using glass vials and torch light. At each site, collection was made for three consecutive nights each month from September, 1997 to September, 1998 (i.e. a total of thirty six nights), the collectors being rotated between the three sites each evening.

Mosquitoes were also collected using CDC light traps from the three collection sites, but on different dates of the night biting/landing catches.

For the active experiment, three similar and unoccupied *tukuls* (huts) in the village were used as collection sites. At two of the experimental *tukuls*, livestock (a cow at a *tukul* and two goats at the other) were tethered at about 2m from the collectors which were moved 90° at quarterly intervals throughout the night, in a clockwise direction around the collectors. The third *tukul* was left free of livestock as a control. The collectors were also rotated among the three sites each evening. All night collections were conducted as described above for three consecutive nights each month from October, 1997 to September, 1998.

Mosquitoes collected from each site were separately kept and identified using identification key developed for anopheline mosquitoes in Ethiopia (14).

Parasitological and Clinical sludies: Parasite rate of children in the study village were determined on monthly bases for ten months. Thick and thin blood films were prepared from all children below 10 years old present at the time of the survey. The dried blood films were brought to the laboratory, stained and microscopically examined for parasites. The spleen rate was also determined for all children who presented for blood film collection twice during the study period, one during the dry season (April 1998) and another, during the peak malaria transmission season (September 1998). Parents or guardians of each child were asked whether or not they owned cattle, where they keep them and other information pertaining to the study. In addition, regular inspections were carried out to confirm cattle ownership and where they are kept in each family throughout the study period.

Ethical considerations: Malaria chemoprophylaxis (chloroquine) were given for both the collectors and human baits who participated on man landing capture. Malaria treatment was given for all parasitologicaly positive and clinical malaria cases.

Data analysis: The human biting rate (HBR) of anopheline species was calculated as the average number of mosquitoes per person per night for each collection made every month. The 95% confidence limits for the overall mean HBR of anopheline mosquitoes from each collection site were calculated. The 95% confidence limits were also calculated for the mean parasite and spleen rates of children below 10 years of age whose families kept livestock in mixed dwelling, separate cattle shed and had no livestock.

RESULTS

Entomological observations: Anopheline mosquito commonly found in the study village are *Anopheles arabiensis* and *An. pharoensis;* the former being the dominant one in all collection sites. The highest HBR for *An. arabiensis* was from the mixed dwelling followed by the human dwelling alone (without livestock) throughout the study period (Figure 1). This was also evident from the mean HBR of *An. arabiensis* for the study period where highest HBR was recorded in the mixed dwelling: 8.45 (95% Cl: 4.25, 12.65), followed by human dwelling: 5.97 (95% Cl: 2.78, 9.15) and separate cattle shed: 4.64 (95% Cl: 1.96, 7.33).

Figure 1

Human biting rate of An. arabiensis in the three living conditions selected for the passive experiment, Ziway area

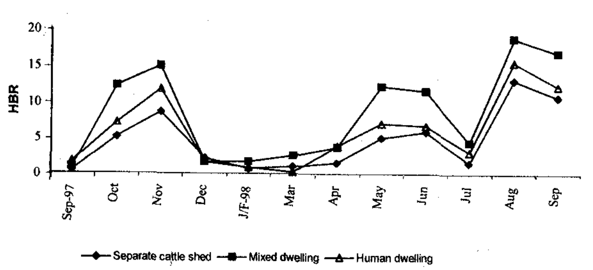
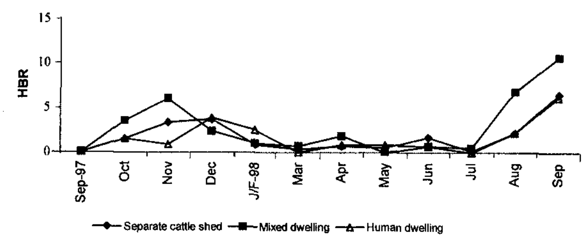


Figure 2

Human biting rate of An. pharoensis in the three living conditions selected for the passive experiment, Ziway area



Anopheles pharoensis followed more or less a similar pattern as that of *An. arabiensis* although the biting rates were much lower (Figure 2). The mean HBR of *An. pharoensis* from the mixed dwelling, separate cattle shed and human dwelling were 2.88 (95% Cl: 0. 77, 4.98), 1.79 (95% Cl: 0.56, 2.99), and 1.61 (95% Cl: 0.44, 2.78), respectively.

Similar observations were recorded in the active form of zooprophylaxis experiment where higher HBR of *An. arabiensis* was recorded in the presence of cattle or goats (Figure 3). The mean HBR in the presence of cattle, goats, and without livestock were 3.50 (95 % Cl: 1.34, 5.67), 3.38 (95% Cl: 1.47, 5.30), and 1.43 (95% Cl: 0.52, 2.33), respectively. No clear pattern was apparent for *An. phareonsis* (Figure 4), the mean HBR in the presence of cattle, goats, and without livestock being 0.37 (95% Cl: 0,11, 0.63), 0.70 (95% Cl: 0. 18,1.23), and 0.55 (95% Cl: 0.05, 1.04), respectively.

Figure 3

Human biting rate of An. arabiensis in the active experimental tukuls with cattle, goats and with no animal (control)

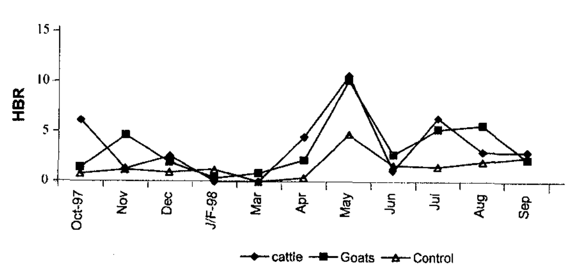
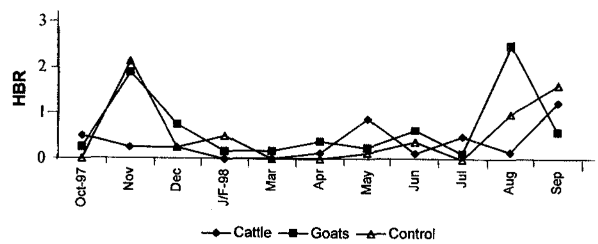


Figure 4

Human biting rate of An. pharoensis in the active experimental tukuls with cattle, goats and with no animal (control)



Very low number of mosquitoes were caught during most of the study period using CDC light traps, but has shown similar trends as that of the man landing captures when relatively higher number of mosquitoes were caught in August and September 1998. During the two months, a total of 40, 15 and 30 of *An. arabiensis* were collected in homesteads with mixed dwelling, separate cattle shed and without livestock, respectively.

Parasitological and Clinical studies: A total of 1180 blood samples were collected from children below the age of 10 years to assess the association of domestic cattle keeping on malaria transmission and its correlation with the entomological data. Overall parasite rates of 23.85% (95%C1: 18.4-30.1),15.05%(95%CI: 10.2-21), 26.67% (95% Cl: 17.9-37.0) and 12.46% (95%C1: 10-15.2) were recorded in human dwelling (without livestock), separate cattle shed, in mixed dwelling and in families with both cattle shed and mixed dwelling, respectively (Table 1). Similarly, the spleen rate of children determined during the dry and wet seasons were 47.37% (95% Cl: 34-61.1), 26.92 (95% Cl: 15.6-41), 50% (95% Cl: 28.2-71.8) and 34.13% respectively, in the above living conditions (Table 2). It can be seen that lowest parasite and spleen rates were observed in families with separate cattle shed and highest in mixed dwelling, but these differences between the various living conditions were not shown to be significant ($F=2.04$, $P>0.1273$).

Table 1

Blood film examination results and status of cattle keeping around Ziway, Central Ethiopia

Month & Year	No. Exam.	No. Pos.	*P.f.*	*P.v*	Percentage positive among families			
					without livestock	with livestock in cattle shed	with livestock in mixed dwelling	with livestock in cattle shed & mixed dwelling
Sep., 1997	127	8	6	2	1/19(5.26)	0/14(0)	2/10(20)	5/84(5.95)
Oct.	119	12	4	8	4/24(16.67)	4/21(19.05)	1/14(7.14)	3/60(5)
Nov.	145	11	6	5	1/21(4.76)	5/31(16.13)	0/8(0)	5/58(8.62)
Dec.	90	6	2	4	2/13(15.38)	1/14(7.14)	0/6(0)	3/57(5.26)
Apr., 1998	152	9	4	5	3128(10.71)	2/25(8)	1/10(10)	3/89(3.37)
May	125	22	16	6	8/27(29.63)	4/10(40)	1/9(11.11)	8/79(10.12)
Jun.	115	45	38	7	11/23(47.83)	5/14(35.71)	4/7(57.14)	25/71(35.21)
Jul.	82	25	24	1	8/17(47.06)	3/18(16.67)	5/7(71.4)	9/40(22.5)
Aug.	84	26	18	8	9/18(50)	1/12(8.33)	6/8(75)	10/46(21.74)
Sep.	141	23	14	9	5128(17.86)	3/27(11.11)	4/11(36.36)	11/74(14.86)
Total	1180	187	132	55	52/218(23.85)	28/186(15.05)	24/90(26.67)	82/658(12.46)
	95%C1				18.4-30.1	10.2-21.0	17.9-37.0	10.0-15.2

P.f = Plasmodium falciparum; p. v = Plasmodium vivax; ()=percentage

Table 2

Splenomegaly in children below ten years of age by cattle keeping status around Ziway, Central Ethiopia

Month	No. Exam	Spleen consistency		Splenomegaly among families			
		Not palpable	Palpable	without livestock	with livestock in cattle shed	with livestock in mixed dwelling	with livestock in cattle shed & mixed dwelling
Apr.	157	101	56	14/29 (48.28)	8/25(32)	4/11 (36.36)	30/92 (32.61)
Sep.	141	88	53	13/28 (46.43)	6/27 (22.22)	7/11 (63.63)	27/75(36)
Total	298	189	109	25157 (47.37)	14152 (26.92)	11/22(50)	51/167 (34.13)
		95% CI		34.0-61.1	15.6-41.0	28.2-71.8	

DISCUSSION

The present entomological data showed relatively highest HBR for *An. arabiensis* in homesteads with mixed dwelling. This indicates that close proximity of livestock to humans in the mixed dwelling can increase the chance of being bitten by *An. arabiensis* especially during periods of high mosquito density. In contrast, keeping livestock in separate cattle shed near homesteads can reduce the HBR of *An. arabiensis*. The increased HBR for *An. arabiensis* in homesteads with mixed dwelling could be explained by its anthrophophilic tendency and indicates that a proportion of the species might be diverted to the human host while approaching the domestic animal. *Anopheles arabiensis* has been observed to be highly exophagic in the area if given equal opportunities both indoors and outdoors(3) and this may account for the relatively lower HBR in homesteads with separate cattle shed in the present study. During the dry or low transmission season, there are no special trends on the HBR of *An. arabiensis* from the three entomological collection sites. Overall, a similar trend was also for *An. pharoensis* although clear pattern in the HBR was not observed through out the study period, perhaps because of its lower biting density. This species is probably an opportunistic feeder whose host selection pattern markedly changed as shown by variable level of HBR at different times with and without livestock.

The 95% confidence limits of the overall mean HBR of both species, however, showed no significant differences at 5% significance level in all collection sites of both experiments. However, the trend shows that keeping cattle in separate sheds reduced HBR for both *An. arabiensis* and *An phareonsis*, particularly during the period of high mosquito density. Similar investigations in Pakistan where the vector abundance is relatively higher, showed that zoophilic anopheline species are likely to have worthwhile prophylactic effect only when the animals are deployed to form a barrier between the vector and man. However, sleeping close to cattle or goats at night significantly increases the HBR by zoophilic anophelines (10). This indicates that the associations can vary depending on local ecology, species of vector mosquitoes and their abundance.

In this study, the number of mosquitoes collected using CDC light trap was lower compared to the man landing captures, even during the periods of high mosquito density in August and September. The observation is similar with those reported from Kenya and Venezuela where vector abundance was low or moderate (15,16). In contrast, studies in Tanzania where vector abundance was high, CDC light trap was found to be superior over human bait collection (17).

Both parasitological and clinical results have shown similar trends with the biting rate of *An. arabiensis* and *An. pharoensis*. Previous studies on the association of cattle ownership and the prevalence of malaria in Pakistan showed domestic animals can enhance malaria transmission when vectors are zoophilic (9). In the present study, however, malaria was equally frequent in families who lived in a *tukul*, mixed dwelling with their cattle as in families who had no cattle at all, but malaria was less frequent in families who lived in separate *tukul* to their cattle. Therefore, keeping livestock in a separate cattle shed outside of the human dwellings is advisable to reduce the incidence of malaria where the principal vector is *An. arabiensis*.

By virtue of its higher man biting rate and wider distribution, *An. arabiensis* is the most important vector in many areas of the country. A recent study in the same area, has also shown *An. arabiensis* as the principal vector and *An. pharoensis* as a secondary vector (3). Therefore, the effect of cattle keeping on the man-vector contact must be viewed in relation with the biting rate of *An. arabiensis*. However, the possible prophylactic effect of domestic cattle keeping as suggested in the present study, though not significantly need to be assessed further in other endemic regions of the country, especially where large numbers of cattle are kept as in the northeast Rift valley by the Afar pastoralists.

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REFERENCES

1 Trigg, P. and Kondrachine, A. The Global Malaria Control Strategy. *Wld. Hlth.* 1998; **51**:4-5.
2. WHO. Vector Control for malaria and other mosquito-borne diseases. *Wld. Hlth. Org. Tech. Rep. Ser.* 1995; **857**:91.
3. Abose, T., Yeebiyo, Y., Olana, D., Alamirew, D., Beyene, Y., Regassa, L. and Mengesha, A. Re-orientation and definition of the role of malaria vector control in Ethiopia, WHO/MAL/98. 1998; **1085**:31.
4. WHO. Vector resistance to pesticides. Fifteenth Report of the WHO Expert Committee on Vector Biology and Control. *Wld. Hlth. Org. Tech. Rep. Ser.* 1992; **818**:62.
5. WHO. Manual on environmental management for mosquito control with special emphasis on mosquito vectors. WHO offset publication No. 66, Geneva., 1982: pp. 283.
6 Bruce-Chwatt, L.J. *Essential Malariology,* 2nd edition. London: Oxford University Press. 1985; 452 pp.
7. Giglioli, G. Ecological changes as a factor in renewed malaria transmission in an eradication area. A localised outbreak of *Anopheles aquasalis* - transmitted malaria on the Demerara river estuary, British Guyana, in the fifteenth year of *Anopheles darlingi* and malaria eradication. *Bull. Wld. Hlth. Org.* 1963; **29**:131-145.
8 Kirnowordoyo, S. and Supalin. Zooprophylaxis as a useful tool for control of *Anopheles aconitus* transmitted malaria in central Java, Indonesia. *J. Commun. Dis.* 1986; **18:** 90-94.
9. Bouma, M. and Rowland, M. Failure of passive zooprophylaxis: cattle ownership in Pakistan is associated with a higher prevalence of malaria. *Trans. Roy. Soc. Trop. Med. Hyg.* 1995; **89**:351-353.
'0. Hewitt, S., Kamal, M., Muhammed, N. and Rowland, M. An Entomological investigation of the likely impact of cattle ownership on malaria in an Afghan refugee camp in the North West Frontier province of Pakistan. *Med. Vet. Entomol.* 1994; **8**:160-164.
11 White, G.B., Tesfaye, F., Boreham, P.F.L. and Lemma, G. Malaria vector capacity of *Anopheles arabiensis* and *Anopheles quadriannulatus* in Ethiopia: chromosomal interpretation after 6 years storage of field preparations. *Trans. Roy. Soc. Trop. Med. Hyg.* 1980; **74**:683-684.
12. Adugna, N. and Petros, B. Determination of the Human Blood Index of some anopheline mosquitoes by using ELISA. *Ethiop. Med. J.* 1996; **34**:1-10.
13. Hadis, M., Lulu, M., Mekonnen, Y. and Asfaw, T. Host choice by indoor-resting *Anopheles arabiensis* in Ethiopia. *Trans. Roy. Soc. Trop. Hyg.* 1997; **91**:376-378.
14. Verrone, G.A. Outline for the determination of malarial mosquitoes in Ethiopia. Part I. Adult female anophelines. *J. Am. Mosq. Control Assoc.* 1962; **22**:37-49.
15. Mbogo, C.N., Glass, G.E., Forster, D. Kabiru, E.W., Githure, J.I., Ouma, J.H. and Beier, J.C. Evaluation of light traps for sampling anopheline mosquitoes in Kilifi, Kenya. *J. Am. Mosq. Control. Assoc.* 1993; **9**:260-263.
16. Rubio, P.Y. and Curtis, C.F . Host choice of anopheline mosquitoes in a malaria endemic area of western Venezuela. *Med. Vet. Entomol.* 1994; **8**:275-280.
17. Davis, J.R., Hall, T., Chee, E.M., Majala, A., Minjas, J., Shiff, C. J. Comparison of sampling anopheline mosquitoes by light-trap and human bait collections indoor at Bagamayo, Tanzania. *Med. Vet. Entomol.* 1995; **9**:249-255.