BLOODFEEDING BEHAVIOR OF *ANOPHELES GAMBIAE S.L.* AND *ANOPHELES FUNESTUS* IN KILIFI DISTRICT, KENYA

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ABSTRACT. Blood meal samples were tested by ELISA for 534 *Anopheles gambiae s.l.* and 76 *Anopheles funestus* collected from 25 sites in Kilifi District, Kenya. Human IgG was detected in 94.4% of the *An. gambiae s.l.* and in 90.8% of the *An. funestus*. No samples were positive for cow and only a few were positive for goat. Both species fed predominantly on humans irrespective of host availability. At these sites on the Kenyan coast, the high degree of human-feeding by malaria vectors contributes to the efficiency of malaria parasite transmission and the high incidence of severe malaria.

INTRODUCTION

The bloodfeeding behavior of anopheline vectors of malaria is an important parameter in malaria epidemiology. The degree of human-feeding influences the probability that mosquitoes will come in contact with gametocyte carriers and thus acquire *Plasmodium* infections. The most successful malaria vectors feed commonly on humans and secondarily on cattle and other domestic animals depending on host availability (Garrett-Jones et al. 1980).

In Kenya, mosquito feeding behavior has been studied extensively in the Kisumu area of western Kenya (Joshi et al. 1973, 1975; Service et al. 1978, Highton et al. 1979, Beier et al. 1988, Petrarca and Beier 1992, Petrarca et al. 1991) and in the Mwea-Tebere irrigation scheme (Ijumba et al. 1990), but there is limited information on anopheline feeding behavior on the coast (Mutero et al. 1984). This study examines the host feeding patterns of malaria vectors on the Kenyan coast relative to host availability.

MATERIALS AND METHODS

The study was conducted in Kilifi District, Kenya, 60 km north of Mombasa on the coast of Kenya. The study area has been described previously (Mbogo et al. 1993). Mosquitoes were collected in 25 sites from June 1991 to April 1992. In most of these sites, mosquitoes were from a series of 3-day collections in houses containing children who had reported, within one month, to the Kilifi District Hospital with *P. falciparum* infections. For each of the houses, the number of cattle, goats and other domestic animals was determined just prior to mosquito collections.

Blood-fed anophelines resting indoors were collected by day-resting collections, pyrethrum spray catch, and CDC light traps (World Health Organization 1975). Blood-fed mosquitoes from each collection were identified, placed in vials, and then air-dried at room temperature for up to 4 days. They were cut transversely between the thorax and abdomen, and posterior portions containing the blood meal were placed individually in labeled vials. Each mosquito was ground in 50 μl PBS, with 950 μl PBS added after

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Table 1. Blood meal sources for *Anopheles gambiae s.l.* and *An. funestus* collected by 3 trapping techniques in Kilifi District, Kenya.

Species	Trapping technique*	No. tested	% of samples			
			Human	Cow	Goat	Unknown
An. gambiae s.l.	DRI	333	96.7	0.0	0.0	3.3
	LT	61	91.8	0.0	3.3	4.9
	PSC	140	90.0	0.0	1.4	8.6
	Total	534	94.4	0.0	0.7	4.9
An. funestus	DRI	64	89.1	0.0	0.0	10.9
	LT	5	100.0	0.0	0.0	0.0
	PSC	7	100.0	0.0	0.0	0.0
	Total	76	90.8	0.0	0.0	9.2

* DRI = day-resting indoors; LT = CDC light trap; PSC = pyrethrum spray catch.

Table 2. Identification of human blood meals for *Anopheles gambiae s.l.* and *An. funestus* from 25 sites in Kilifi District, Kenya.

Site	*An. gambiae s.l.*		*An. funestus*	
	No. tested	% human	No. tested	% human
Bofa	1	100.0	0	0.0
Chumani	10	90.0	0	0.0
Chokwe	1	100.0	0	0.0
Dera	32	96.9	11	100.0
Fumbini	13	92.3	1	100.0
Gongoni	0	0.0	1	100.0
Kibarani	60	93.3	3	100.0
Kiwandani	1	100.0	0	0.0
Konjora	28	96.4	18	94.4
Kitengwani	41	97.6	11	81.8
Mtaani	9	100.0	1	100.0
Majajani	18	94.4	0	0.0
Majaoni	37	94.6	0	0.0
Mikingirini	1	100.0	0	0.0
Matsangoni	11	100.0	1	100.0
Mtondia	9	100.0	0	0.0
Mwandoni	1	100.0	0	0.0
Mdzongoloni	38	92.1	4	100.0
Ngerenya	13	100.0	0	0.0
Roka	8	100.0	0	0.0
Sokoke	116	96.6	1	0.0
Shauri moyo	3	100.0	0	0.0
Tandia	52	90.4	8	100.0
Tezo	1	100.0	1	100.0
Vipingo	30	80.0	15	80.0
Total	534	94.4	76	90.8

Table 3. Human blood index relative to host availability for *Anopheles gambiae s.l.* and *An. funestus* in Kilifi District, Kenya.

Host availability	No. houses	Human blood index (no. samples)*	
		An. gambiae s.l.	*An. funestus*
Cows alone	0	0.0 (0)	0.0 (0)
Goats alone	61	0.96 (385)	0.93 (44)
Cows and goats	10	0.96 (68)	1.00 (3)
No cows or goats	24	0.89 (75)	0.86 (28)
Total	95	0.95 (528)	0.91 (75)

* Proportion of blood meals positive for human IgG.

grinding; these were stored at −20°C until testing. Blood meals were identified by direct enzyme-linked immunosorbent assay (ELISA) using anti-host (IgG) conjugates against human, cow and goat (Beier et al. 1988). Blood meals were screened first for human and cow, then non-reacting samples were tested for goat.

RESULTS

Human IgG was detected in samples from 94.4% of 534 *An. gambiae s.l.* and 90.8% of 76 *An. funestus* Giles (Fisher exact test, $P = 0.21$) (Table 1). No positive reactions were detected for cow and only 4 female *An. gambiae s.l.* were positive for goat. Overall, positive reactions were detected in 95.1% of the *An. gambiae s.l.* and in 90.8% of the *An. funestus*.

Table 2 shows the percentage of human blood meals identified for *An. gambiae s.l.* and *An. funestus* from 25 collection sites throughout Kilifi District, Kenya. Clearly, most blood meals were positive for human IgG.

The human blood index (HBI) was high irrespective of host availability (Table 3). Information on the presence or absence of cattle and other domestic animals was recorded for 95 houses out of 101 sampled. Out of these 95 houses, 75% had goats, 11% had cows with goats, but none of the houses had cows without goats.

DISCUSSION

Anopheles gambiae s.l. and *An. funestus* fed primarily on humans despite the presence of cows and goats at 11% and 75% of the houses, respectively. The high human blood index for indoor resting populations is unlike the situation in western Kenya (Beier et al. 1988, Petrarca and Beier 1992, Petrarca et al. 1991) and in Mwea irrigation scheme (Ijumba et al. 1990)

where the availability of cows is a determining factor for blood-feeding. Our findings are unexpected. Of the 3 species in the *An. gambiae* complex in Kilifi (*An. gambiae* Giles, *An. arabiensis* Patton and *An. merus* Dönitz), *An. arabiensis* and *An. merus* are at least partially zoophilic and partially endophilic (Iyengar 1962, White 1974, Mosha and Petrarca 1983, Mutero et al. 1984). At this point, there is no evidence that any of the 3 species of the *An. gambiae* complex in Kilifi feed to a significant degree on hosts other than humans. Further efforts are necessary to identify blood meals for each of the 3 species in the *An. gambiae* complex and to examine blood meals from outdoor resting populations.

The high degree of human-feeding may be a primary factor contributing to the efficiency of *Plasmodium falciparum* transmission on the Kenyan coast. In our initial studies, we found a high incidence of severe malaria associated with extremely low vector densities and entomological inoculation rates <10 per year (Mbogo et al. 1993). Transmission can be maintained year-round despite low vector densities because high rates of human feeding facilitate direct contact with gametocyte carriers and sporozoite-positive mosquitoes "waste" few infective bites on domestic animals.

In conclusion, evidence is presented that indoor-resting malaria vectors on the coast of Kenya feed predominantly on humans irrespective of the availability of cattle and other domestic animals. This situation is unusual given the complexity of the malaria vectorial system (Mosha and Petrarca 1983). In Kilifi, one reason why the incidence of severe *P. falciparum* malaria is high under conditions of low vector densities (Mbogo et al. 1993) is that high rates of human-feeding facilitate efficient malaria parasite transmission by vector populations.

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