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EVALUATION OF LIGHT TRAPS FOR SAMPLING ANOPHELINE MOSQUITOES IN KILIFI, KENYA

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ABSTRACT. Anopheline mosquitoes were sampled inside houses, where residents slept under untreated bednets, by CDC light traps and human-biting catches to evaluate light traps as a means for determining human exposure to malaria vectors in Kilifi District, Kenya. Mosquitoes were sampled during 2 all-night collections by light traps and one all-night biting catch in a series of 262 houses. Collections yielded 1,721 *Anopheles gambiae s.l.* and 46 *An. funestus,* and 60.3% of the houses were negative for anophelines. There was a significant correlation in numbers of *An. gambiae s.l.* captured by light traps and human-biting collections ($r = 0.64$), but light traps were biased and underestimated *An. gambiae s.l.* abundance. This bias increased with increasing mosquito abundance. In addition, the proportion of *An. gambiae s.l.* infected by *Plasmodium falciparum* was 2.3-fold higher in light traps than in human-biting collections. Along the coastal zone of Kenya where vector abundance is low, light traps do not provide an adequate estimate of man–vector contact when such information is required at the household level in epidemiological studies of malaria parasite transmission.

INTRODUCTION

A number of sampling techniques have been used to measure human exposure to anopheline mosquitoes, including human-biting catches, pyrethrum spray collections and light traps. Several studies have found that light traps underestimate host-seeking anophelines (Service 1976, Hii et al. 1986, Zaim et al. 1986), while others have used light traps with relative success (Odetoyinbo 1969, Service 1970, Chandler et al. 1975, Garrett-Jones and Magayuka 1975, Joshi et al. 1975). Recently, Lines et al. (1991) in Tanzania showed that CDC light traps used inside houses, in combination with bednets, yielded results comparable to standard human-biting collections and could be used to estimate anopheline abundance. Host-seeking females attracted to humans were diverted by the bednets and were readily caught by light traps. Potentially, this type of vector sampling by light traps could be used as a replacement for standard human-biting collections.

We tested the hypothesis that light traps, in combination with bednets, provide comparable data to human-biting collections in Kilifi District, Kenya. In this area, anopheline abundance is low, yet there is a high incidence of severe disease due to *Plasmodium falciparum* (Mbogo et al. 1993). The goals were to evaluate mosquito detection sensitivity, numerical trapping bias and bias in the bloodfeeding stages of mosquitoes sampled by the 2 methods.

MATERIALS AND METHODS

The study area in Kilifi District, Kenya, 60 km north of Mombasa, has been described previously (Mbogo et al. 1993). Children from the study area presenting with malaria infections at Kilifi District hospital were selected, and entomological sampling was conducted in their respective houses. The study was conducted for 11 months from August 1991 to June 1992. In June 1991, we conducted preliminary mosquito sampling using light traps set inside houses without bednets to examine the effects of bednets on the proportion of bloodfeeding stages of mosquitoes caught.

A total of 302 households were selected for study. Light traps were used on the first 2 nights, followed by one all-night biting collection in each house. A CDC light trap (Model 512, John W. Hock Company, Gainesville, FL) with a lid was hung inside houses where children slept, about 1.5 m from the floor and about 50 cm from the child's bednet. Occupants of these bedrooms were provided with untreated mosquito nets specifically for this study. Light traps were set at 1830 h and collected the following morning at 0700 h. Inquiries were made as to whether the trap fan and light had both worked all night, and catches from faulty traps were discounted. Human-biting catches were conducted on the 3rd night. Mosquitoes coming to bite indoors between 1830 h and 0600 h were caught at half-hour intervals by 2 locally hired and trained collectors (World Health Organization 1975).

All anopheline mosquitoes were identified, counted and classified according to bloodfeeding

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Table 1. *Anopheles gambiae s.l.* and *An. funestus* collected by CDC light traps and human-biting catches in Kilifi, Kenya (August 1991–June 1992).

Species	Light trap catches		Biting catches	
	No. collected	% positive houses	No. collected	% positive houses
An. gambiae s.l.	736	26.7	985	28.2
An. funestus	6	1.5	40	4.9
Total	742	28.2	1,025	33.1

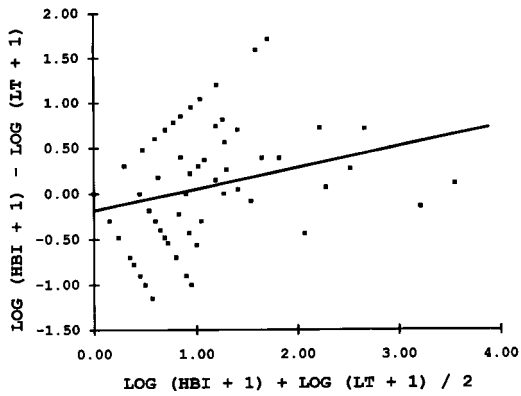

Fig. 1. Ratio of *Anopheles gambiae s.l.* caught by light traps and human-biting catches relative to their average abundance. The positive slope of the regression line ($P < 0.05$) indicates a significant underestimation of mosquito abundance by light traps as average abundance increases.

stages (i.e., unfed, bloodfed, half-gravid, gravid) (World Health Organization 1975). Frequencies of the various bloodfeeding stages from light trap catches were compared by chi-square analysis with preliminary results from light traps set in houses without bednets. Head/thorax portions of female anopheline mosquitoes were tested by enzyme-linked immunosorbent assay (ELISA) using the 2A10 monoclonal antibody to detect circumsporozoite (CS) protein of *P. falciparum* (Wirtz et al. 1987).

To test the efficiency of light traps in estimating mosquito abundance, we utilized graphical and parametric methods of Altman and Bland (1983) to examine bias and error in methods. Light trap (LT) and human-biting (HBI) catches were log transformed as $\log_{10}(LT + 1)$ and $\log_{10}(HBI + 1)$. The difference in abundance between $\log_{10}(HBI + 1)$ and $\log_{10}(LT + 1)$ was graphed relative to the average of the log of abundance for the 2 methods. The presence of a significant slope was used as evidence of bias in the collection technique (Altman and Bland 1983). To examine the sensitivity of the 2 methods for detecting mosquito presence, mosquitoes captured by light traps and human-biting collections were summed for each house and the abundance per house was divided into quartiles. The percentage of houses that had at least one mosquito collected by each method was calculated for each quartile as a measure of the detection threshold relative to mosquito abundance.

RESULTS

Light trap failures or refusals for human-biting collections occurred in 40 of the original 302 houses. Of the remaining 262 houses, only 104 (39.7%) yielded at least one mosquito by either light traps or biting catches (Table 1). Light traps yielded 736 *Anopheles gambiae s.l.* and 6 *An. funestus* in 28.2% of the houses, while 985 *An. gambiae s.l.* and 40 *An. funestus* were captured by human-biting collections in 33.1% of the houses. Light traps underestimated the presence of an *An. funestus* at low vector densities ($\chi^2 = 3.89$, df = 1, $P = 0.049$).

There was a significant correlation in the number of *An. gambiae s.l.* captured by the 2 sampling methods ($r = 0.64$, df = 260, $P < 0.0001$). The potential bias in estimating anopheline mosquito abundance by light traps was examined graphically. There was a significant tendency for the ratio of HBI/LT to increase (Fig. 1) with increasing mosquito abundance ($r = 0.29$, df = 260, $P < 0.0001$). *Anopheles funestus* was not included in the analysis because too few were caught.

Of the 104 houses with at least one mosquito, the proportion of houses that had mosquitoes collected by either method increased with the number of mosquitoes captured (Fig. 2). Overall, light traps detected mosquitoes in 67.3% of the houses compared to 71.2% by human-biting collections ($\chi^2 = 0.36$, df = 1, $P = 0.55$). At the lowest quartile (one mosquito), light traps detected mosquitoes in 45.7% of the houses, while human-biting catches detected mosquitoes in 54.3% of the houses ($\chi^2 = 0.31$, df = 1, $P = 0.58$). At the upper quartiles of mosquito abundance (11+), light traps detected mosquitoes 88% of the time compared with 96% by human-biting collections.

Comparison of bloodfeeding stages of *An. gambiae s.l.* and *An. funestus* caught by light traps with or without bednets indicated that bednets significantly altered the feeding status of captured mosquitoes (Table 2). The proportion of bloodfed *An. gambiae s.l.* caught by light traps was lower

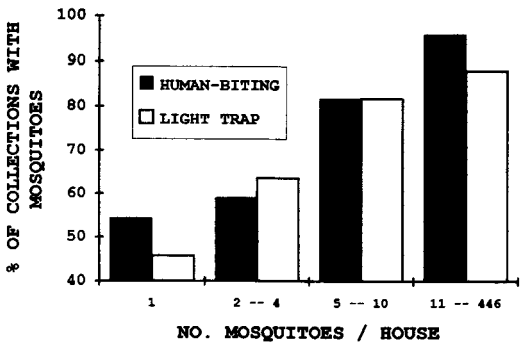

Fig. 2. Percentage of houses with mosquitoes caught by CDC light traps and human-biting catches relative to mosquito abundance.

in houses with bednets (8.7%) than in houses without bednets (16.3%) ($\chi^2 = 13.78$, df = 1, $P = 0.0002$). More unfed *An. gambiae s.l.* were caught by light traps set in houses with bednets (84.1%) than in those without bednets (73.8%) ($\chi^2 = 16.14$, df = 1, $P < 0.0001$).

Plasmodium falciparum infection rates for *An. gambiae s.l.* and *An. funestus* caught by light traps and human-biting collections are shown in Table 3. The proportion of infected *An. gambiae s.l.* was 2.3-fold higher for mosquitoes from light traps (5.7%) compared with those caught by human-biting collections (2.5%) ($\chi^2 = 11.5$, df = 1, $P = 0.0007$).

Table 3. *Plasmodium falciparum* infection rates for *Anopheles gambiae s.l.* and *An. funestus* captured by light traps and human-biting collections in Kilifi District, Kenya.

	% positive (*n*) by ELISA		
Technique	*An. gambiae s.l.*	*An. funestus*	Total
Light traps	5.7 (722)	0.0 (6)	5.6 (728)
Human bait	2.5 (971)	5.3 (36)	2.6 (1,007)

DISCUSSION

This study evaluated light traps as a sampling method for estimating human exposure to host-seeking anopheline mosquitoes in Kilifi District, an area with extremely low vector abundance along the coast of Kenya (Mbogo et al. 1993). The intention was to determine whether light traps could be used to estimate human-biting rates in individual houses during epidemiologic studies of malaria parasite transmission. Even though Lines et al. (1991) in Tanzania demonstrated clearly the potential value of light traps used in conjunction with bednets, we recognized that there may be special considerations in Kilifi where the same vectors are less abundant.

There were several possible sources of bias associated with light trap sampling. Although there was a significant correlation in numbers of *An. gambiae s.l.* between light trap and biting collections, light traps underestimated abundance, and this bias increased with increasing abundance. Light traps were also less efficient than biting collections for detecting the presence of *An. funestus,* a major vector in Kilifi District. Importantly, light traps caught mosquitoes with higher *P. falciparum* infection rates than those from biting collections. Even though the use of light traps in conjunction with bednets decreased the number of bloodfed mosquitoes caught so that >80% of the mosquitoes were unfed and presumably host-seeking, there is a good possibility that light traps attracted a substantial portion of the indoor-resting populations. In Kenya, such mosquitoes generally have higher parity rates and higher infection rates than host-seeking mosquitoes (Petrarca et al. 1991).

Understandably, the use of light traps under conditions of low vector abundance was less efficient than biting catches. We noted that the sources of error in light trap sampling were ob-

Table 2. Bloodfeeding status of *Anopheles gambiae s.l.* and *An. funestus* caught by CDC light traps indoors set near untreated bednets relative to those used in houses without bednets in Kilifi, Kenya.

	% of mosquitoes caught (*n*)			
Bloodfeeding status	*An. gambiae s.l.*		*An. funestus*	
	Bednet	No bednet	Bednet	No bednet
Unfed	84.1 (619)	73.8 (253)	50.0 (3)	63.2 (12)
Bloodfed	8.7 (64)	16.3 (56)	33.3 (2)	10.5 (2)
Half-gravid	0.3 (2)	2.3 (8)	0.0 (0)	0.0 (0)
Gravid	6.9 (51)	7.6 (26)	16.7 (1)	26.3 (5)
Total	(736)	(343)	(6)	(19)

served in comparisons of 2 light trap collections relative to one man-biting catch in each house (i.e., one man-night). Clearly, estimating anopheline abundance by light traps is extremely sensitive to sampling effort (Altman and Bland 1983, Lines et al. 1991). This highlights the probability that collections from a single night of trapping will underestimate abundance even further.

There are several important logistical advantages in the use of light traps. Compared with biting catches, light traps are more convenient and can be replicated many times if necessary. Even though care must be taken in the physical placement of light traps within houses and the supervision of trap collections, it is possible to achieve a satisfactory degree of standardization with light traps. In general, residents were more receptive to the use of light traps than all-night, visiting mosquito collectors.

As noted by Lines et al. (1991), it is important to determine relationships between light trap and biting collections for each geographic area. Apparently, light trap efficiency varies as a function of vector abundance. Findings that light traps are less efficient than biting collections under conditions of low vector abundance do not necessarily preclude the use of light traps for monitoring anopheline populations in vector control or epidemiologic studies when the scale of interest is the village level. Provided that a validation study is done, regression equations derived for each mosquito species can be used to estimate man–vector contact based on light trap collection data.

However, in Kilifi, the focus of our field studies is to evaluate malaria parasite transmission in individual houses, rather than at the village level. The extremely low vector abundance in this area necessitates intensified mosquito sampling. Our findings that light traps provide a biased collection of host-seeking mosquitoes both in terms of abundance and sporozoite rates emphasize that light trap sampling is not suitable for epidemiologic studies when vector-related information is required at the household level.

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