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Preliminary Investigation on the Use of a Light-trap for Sampling Malaria Vectors in the Gambia

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Light-traps have been used successfully as mechanical sampling tools for insects of agricultural importance but medical entomologists have had only limited success because of the assumption that light-traps would attract vectors, even when sited in open fields well away from hosts. The investigations reported in this paper suggest that vectors are attracted primarily by their hosts and that only when light-traps are placed in the immediate vicinity of hosts, or in the narrow flight paths followed by host-seeking females, are appreciable numbers caught.

When the CDC miniature light-trap was placed at various distances from hosts, the number of anopheline and culicine species captured decreased as the distance from the host increased. There were statistically significant differences between the means of catches in light-traps suspended on or in human dwellings, placed inside village compounds, and placed near the breeding site about 1.6 km from the nearest house. The maximum catch of Anopheles gambiae s.l. *and culicines exceeded 3000 and 7000 per trap per night, respectively, and the average was in excess of 1200* A. gambiae s.l.

The investigations showed that 6 anopheline species could be caught in appreciable numbers in human dwellings and thus demonstrated that light-traps could be used for sampling both endophilic and exophilic anophelines. It also appears that the effective range of the CDC miniature light-trap is about 5 m.

The use of light-traps for sampling populations of insects in general, and mosquitos in particular, has been investigated by many workers. Many types of traps have been used and various modifications suggested in order to improve their efficiency as sampling tools.

The attention of various entomologists has been focused on the factors affecting efficiency of traps. Among the factors investigated were: the colour of traps (Mulhern, 1942; Kohler & Fox, 1951; Barr et al., 1963); the air movement in the trap (Pincus, 1938; Mulhern, 1948, 1953; and other authors); the intensity and wavelength of light emitted by traps (Frost, 1953; Gui et al., 1942; Breyev, 1958, 1963; and several other authors); effects of screening the catch (Huffaker & Back, 1943; Mulhern, 1953; Hemmings, 1959; Hollingsworth et al., 1961) and the effect of lunar phase on the catch (Pratt, 1948; Provost, 1959). Other factors already investigated are: the influence of heat on catches (Peterson & Brown, 1951; Barr et al., 1963), the height of trap (Love & Smith, 1957) and the effects of baffles in certain traps (Frost, 1958). Barr et al. (1960, 1963) investigated 5 of these factors and suggested that the variation in catches from night to night and the location of traps probably overshadow other sources of variation in most operational sampling.

The present preliminary investigations were aimed at demonstrating the phenomenal effect of the location of light-traps on the catches, determining the probable range of effect of the CDC miniature light-trap, and suggesting a new use for light-traps in sampling malaria vectors. Other aspects involved a field application of the " palpal index technique " (Coluzzi, 1964) for the separation of the freshwater from the saltwater *A. gambiae* complex of species, and a comparison between catches made by pyrethrum space-spray and by light traps.

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AREA, MATERIALS AND METHODS OF INVESTIGATION

Area and conditions of capture

The investigation was carried out mainly over a period of 3 months (June–September 1967) at Keneba, the up-river field station of the Medical Research Council Laboratories in the Gambia. Keneba, a small village of about 350 huts, lies some 80 km from the coast but is only 2 km–4 km distant from an expanse of mangrove swamps extending for about 30 km² (Giglioli, 1964). These are composed mainly of orchards of *Avicennia germinans*, described by Muirhead-Thomson (1945) as the typical breeding ground of *A. melas*. Keneba experiences great seasonal variation in the prevalence of mosquitos, with extremely high densities in June–August and very low ones from January to early June. Superimposed on these are fortnightly fluctuations in density, conditioned by massive breeding at the times of spring-tide flooding of the swamps throughout the year (Giglioli, 1965).

During the periods of high mosquito density, particularly of *A. gambiae sensu lato*, the nuisance they cause is so severe that all the inhabitants of Keneba sleep under some kind of mosquito net throughout the night. This fact has an important bearing on the results to be recorded in the present paper. It means on the one hand that the occupied huts contain, at all times of the night when the mosquitos are active, a high proportion of unfed mosquitos; on the other hand, it is certain that many of the mosquitos are obliged to fly from hut to hut and often to visit several before they can obtain a blood-meal. The presence of a large population of unfed females indoors at night has been demonstrated at Keneba with sticky traps in experimental huts baited with calves (Gillies, personal communication). It was found that the catch of unfed females always greatly exceeded that of fed ones, and in this instance it was considered that the restlessness of the host caused mosquitos to resettle repeatedly on the walls before feeding.

In view of what has been said, it is clear that different methods of sampling will yield catches representing different parameters of "indoor density" under the conditions described. For instance, indoor catches made on human baits would clearly give different results depending on the presence of other persons who were or were not using mosquito nets, even imperfect ones. An efficient light trap or other attractant might be expected to catch a majority of all the mosquitos entering the hut during the night. Finally, a morning catch by pyrethrum spray will collect for the most part only those mosquitos which succeeded in feeding in a particular hut and which remain there to digest their blood-meal. The correct interpretation of the results recorded in the Gambia, and the inferences to be drawn concerning the incidence of mosquito–man contact, are discussed in this context in the Annex.

All the houses in Keneba have deep eaves, the roof projecting 60 cm–100 cm beyond the walls. The doors (and windows, if any) are locked when the people retire for the night. Under these circumstances it is considered unlikely that any light within the hut would exercise an important influence on the number of mosquitos entering.

From 21 to 25 August observations with the light-trap were carried out in 5 villages near the agricultural experimental station at Sapu. This is a purely freshwater district located about 300 km from Bathurst.

The light-trap and the method of operation

The light-trap used during this investigation was the CDC miniature light-trap described and illustrated by Sudia & Chamberlain (1962). A thin wad of moistened cotton-wool covered with filter-paper was put at the bottom of each collapsible catching bag to increase the humidity, and preserve the catches in good condition.

Electricity for the traps was provided by 12-volt automobile batteries transformed into 2 6-volt batteries by the insertion of an extra terminal between the original ones. This device proved advantageous because it facilitated the operation of 2 traps from the same battery.

The traps were operated from sunset to sunrise (i.e., from 19.00 hours to 07.00 hours). Every *Anopheles* caught was classified according to species, sex and gonotrophic stage, but culicines were in general classified by sex and genus only. The catches were counted between 08.00 hours and 12.00 hours on the day of collection, the number of any found stuck to the fan blades being estimated and added to the total.[1] Catches were not weighed as many American investigators have done.

[1] Normally, no part of the catch became stuck to the fan, but this happened occasionally when the blades were oily. The maximum number of mosquitos stuck to the fan was 20.

Location of light-traps

The light-traps were operated in the following locations:

(1) Hung on trees at the edge of mangrove swamps near the breeding places, about 2 km from the nearest house (20 trap nights);

(2) Suspended from trees in the open fields, 250 m–300 m away from nearest houses;

(3) Attached to poles, trees and sometimes to frames erected in the middle of village compounds [1] (20 nights);

(4) Affixed to human dwellings:

(*a*) in *houses with ceilings and no open eaves*, they were suspended from the roof under the eaves, opposite a window which was kept open throughout the night (26 nights);

(*b*) in *houses with wide open eaves but no ceilings*, they were suspended inside the room *with the point of light on the same level as the eaves* (17 nights);

(5) A comparative study was also made of catches in traps placed in and on houses with ceilings and no open eaves:

(*a*) inside the room within 2 m of a window kept open all night (6 nights); and

(*b*) outside the houses at 1 m–2 m from a window kept open all night (10 nights).

All houses in these experiments were occupied during the nights of observation. The number of occupants in each station is shown in the tables where appropriate. The doors were always closed through the night. The performance of the trap with no source of light was checked on 11 nights, by operating a trap in proven productive locations but without the light-bulb.

Testing the range of influence of the light-trap

An attempt was made to determine the range of influence of the CDC miniature trap by means of trap catches at various distances from occupied houses. For 10 nights the trap was hung under the eaves of house No. 14 (one of the productive ceiled houses) opposite an open window; for 4 nights on a movable frame placed in the centre of a compound, 13 m from the open window of house No. 14; for 5 nights at 7 m from the window and for 5 nights at 5 m from it. To offset the expected nightly fluctuations of density, on 11 nights a " distant " trap was operated simultaneously with the one under the eaves.

[1] A compound consists of a group of houses (usually between 8 and 12 belonging to close relatives) built around a central open space. These houses are almost invariably enclosed within a fence.

Observations in a freshwater district

The method of trap operation in the freshwater area was the same as in Keneba. During each of the 5 nights of observation 2 traps were operated simultaneously in selected houses in 5 villages—1 trap was affixed to the eaves of a ceiled house opposite an open window and the other hung inside an unceiled house with wide-open eaves through which mosquitos could enter or leave the house freely.

Identification of members of the A. gambiae *complex in the saltwater district*

A total of more than 1200 *A. gambiae s.l.*, selected at random from 33 of the catches obtained by various techniques, served as a sample for determining the proportions of saltwater and freshwater *A. gambiae* present from June to September. The heads were preserved in 70% alcohol in small vials prior to dissection. All the palps dissected were mounted on microscope slides in Berlese fluid under cover-glasses and the palpal index as defined by Coluzzi (1964) was measured.

Pyrethrum space-spray catches

Spray catches were performed by the standard method, using partially dewaxed type (25% w/w) pyrethrum extract supplied by the Pyrethrum Marketing Board of Nairobi. Because of the impossibility of covering every inch of floor space with sheets and the fact that a few of the houses had large open spaces in the walls, the roofs and around the doors and windows, some 20% of the 71 catches must be regarded as incomplete.

Presentation of results

Analysis of the data collected shows that certain external factors (such as the lunar cycle, weather conditions and the number of persons occupying the capture stations) could possibly have had some effects on the results. Although it is believed that the over-all effects of these factors were not significant, the results obtained should be considered as preliminary.

To assess the effects of the location of the trap, the data were grouped into the 7 locations of traps

TABLE 1

SUMMARY OF LIGHT-TRAP MOSQUITO CAPTURES AT 7 LOCATIONS (INDOOR AND OUTDOOR) AT KENEBA, A SALTWATER DISTRICT IN THE GAMBIA, FROM JUNE TO SEPTEMBER 1967

Location of light traps [a]	No. of nights' operation	*Anopheles gambiae* complex						Culicines		Others		Total catch
		Females		Males		Total *A. gambiae*						
		No. caught	Percentage of total catch	No. caught	Percentage of total catch	No. caught	Percentage of total catch	No. caught	Percentage of total catch	No. caught	Percentage of total catch	
1. Outside. under eaves, opposite open window (2.8 persons)	26	31 654	81.9	13	0.03	31 667	82.0	6 949	18.0	10	0.03	38 626
2. Inside room, no ceiling, point of light on the same plane as the eaves (7 persons)	17	21 743	75.7	17	0.06	21 760	75.7	6 962	24.2	19	0.07	28 741
3. Inside room, no open eaves, within 2 m of open window (3 persons)	6	1 442	53.4	0	0	1 442	53.4	1 257	46.6	0	0	2 699
4. Outside, under eaves, opposite open window but without light bulb (5 persons)	11	717	83.3	1	—	718	83.4	143	16.6	0	0	861
5. Inside compound	20	1 525	64.6	6	0.3	1 531	64.8	820	34.7	11	0.4	2 362
6. Near breeding site (1.6 km from village)	20	115	36.5	0	0	115	36.5	200	63.5	0	0	315
7. In open field	5	197	6.1	7	0.2	204	6.3	3 053	94.0	1	—	3 258
Catches by pyrethrum space spray		3 153	89.2	146	4.1	3 299	93.4	234	6.6	0	0	3 533

[a] Numbers of persons mentioned represent the average numbers present at the sites (during captures indoors and close to eaves only).

(see Table 1)—namely, (1) outside, under the eaves of ceiled houses opposite open windows (TUE); (2) inside, hung from the roofs of unceiled houses (TIR); (3) inside ceiled houses within 2 m of open windows; (4) under the eaves of ceiled houses as in (1) but without the lamp; (5) inside a compound; (6) near the breeding site (about 2 km from the village); (7) in an open field, about 270 m from any houses.

The arithmetic means and the percentages of *A. gambiae s.l.* and culicines in the total catch per location were calculated. The differences were tested statistically for significance. The data indicating the effective range of the light-trap were analysed separately.

The CDC trap caught few large insects, most being excluded by the screen fitted above the fan. On rainy nights it was not uncommon to find many flying ants in the catches. At Keneba, where the catches were mainly of mosquitos, identification was rapid—up to 2000 mosquitos an hour, after some practice—owing to the ease with which the prevalent groups (*A. gambiae s.l.*, *A. coustani s.l.*, *A. pharoensis*, *Culex* spp. and *Mansonioides* spp.) are distinguishable. More time was required for the counting of the large catches and for the analysis of the abdominal stages, sometimes confirmed by dissection.

RESULTS AND DISCUSSION

Effect of location on performance of the light-trap

Table 1 summarizes the numbers and percentages of mosquitos caught at each light-trap location; the mean catches of female *Anopheles gambiae s.l.* and of culicines per trap per location are shown in Tables 2 and 3, respectively. It must be emphasized that, as the numbers of trap-nights in each category are few (at most 26), the results obtained are of limited statistical reliability. Thus it is not certain that the distribution was normal for the application of the *t*-test.

A breakdown by location (Table 2) shows that the highest indices of *A. gambiae s.l.* were obtained in locations 1, 2 and 4 and that the catches diminished as the distance of traps from the house increased.

A comparison between the means of the *A. gambiae s.l.* catches in traps put under the eaves (location 1), inside a compound (location 5), and at the breeding site 2 km from the village (location 6), shows statistically significant differences ($P<0.001$). Also the difference between the mean catch at location 2 (trap inside a room without ceiling or window but with open eaves) and at locations 5 and 6 is statistically significant ($P<0.001$), and since the

TABLE 2

MEAN CATCH PER NIGHT OF FEMALES OF THE *ANOPHELES GAMBIAE* COMPLEX OF SPECIES BY TRAP LOCATION IN KENEBA FROM JUNE TO SEPTEMBER 1967

Location of light-traps [a]	No. of observations	Total No. of ♀ *A. gambiae*	Average catch/trap/night
1. Outside, under eaves, opposite open window (2.8 persons)	26	31 654	1217.5
2. Inside room, no ceiling, point of light on the same plane as the eaves (7 persons)	17	21 743	1279.0
3. Inside room, no open eaves, within 2 m of open window (3 persons)	6	1 442	240.3
4. Outside, under eaves, opposite open window but without light bulb (5 persons)	11	717	65.2
5. Inside compound	20	1 525	76.3
6. Near breeding site (1.6 km from village)	20	115	5.8
7. In open field	5	197	39.4

[a] Numbers of persons mentioned represent the average numbers present at the sites (during captures indoors and close to eaves only).

TABLE 3

MEAN CATCH PER NIGHT OF CULICINES BY TRAP LOCATION IN KENEBA FROM JUNE TO SEPTEMBER 1967

Location of light-traps [a]	No. of observations	Total no. of culicines	Average catch/trap/night
1. Outside, under eaves, opposite open window (2.8 persons)	26	6 949	267.3
2. Inside room, no ceiling, point of light on the same plane as the eaves (7 persons)	17	6 962	409.5
3. Inside room, no open eaves, within 2 m of open window (3 persons)	6	1 257	209.5
4. Outside, under eaves, opposite open window but without light-bulb (5 persons)	11	143	13.0
5. Inside compound	20	820	41.0
6. Near breeding site (1.6 km from village)	20	200	10.0
7. In open field	5	3 051	610.2

[a] Numbers of persons mentioned represent the average numbers present at the sites (during captures indoors and close to eaves only).

same is true of the difference at locations 5 and 6, it may be inferred that the nearer the light-trap to the host concentration, the greater is the likelihood of obtaining large samples of the mosquitos that bite the host. It is therefore concluded that the optimum location of a light-trap for the sampling of house-visiting mosquitos under these conditions is either under the eaves opposite an open window (where the house has closed eaves and a ceiling) or inside the room with the light-source on the same plane as the eaves (in the case of houses without ceilings or windows but with wide-open eaves).

Another significant difference ($P < 0.01$) is found between the means of catches in locations 1 and 3. This suggests that the optimum location of the light-trap in a ceiled house with no open eaves is *outside* under the eaves opposite an open window and not *inside* near the window.

In the Culicini also (see Table 3) the differences between the mean numbers captured per trap per night either in locations 1, 5 and 6, or 2, 5 and 6 are statistically significant ($P < 0.001$) (see Table 3). The difference between the means of catches in locations 5 and 6 is also significant ($P < 0.01$). The nearer the trap to the host, the greater is the probability of trapping culicines. Thus, for this group also, the optimum location was either under the eaves opposite an open window or inside the room on the same plane as open eaves, depending on the type of house. The marked difference observed between the mean catches at locations 1 and 2 with regard to culicines may have been due to some variable factor such as the larger number of occupants per station in category 2.

Observations to determine the best height for the trap suspended outside an open window were inconclusive. The optimum level is probably at or about the middle of the window.

Comparing lines 1 and 4 in Tables 2 and 3 to assess the influence of the light in the trap, it is seen that the differences between the means are highly significant ($P < 0.001$), for both *A. gambiae s.l.* and culicines. This proves that the presence of the light decidedly enhanced the catches.

Range of influence of the CDC miniature light-trap

Some preliminary observations were made to test the hypothesis that the range of influence of the light-trap on the mosquitos is small and that, if it were placed some metres away from the narrow flight-path believed (Giglioli, 1965) to be followed by host-seeking females, most of them would not have been deflected by the trap.

TABLE 4

LIGHT-TRAP CATCHES OF FEMALES OF THE *A. GAMBIAE* COMPLEX OF SPECIES AT VARIOUS DISTANCES FROM 2 OCCUPIED HOUSES WITH WINDOWS [a]

Location of light-trap			Period of operation	No. of nights' observation	Catch of ♀ *A. gambiae s.l.*	
House No.	No. of sleepers	Distance from window (m)			Total	Average per night
1	4	0	24 June-7 July	3	2 858	952.7
14	2	0	27 July-16 August	6	2 614	435.7
14	2	0	30 August-5 September	4	2 669	667.2
1	4	1	8-17 July	5	1 923	384.6
1	4	2	9-18 July	5	1 454	290.8
14	2	5	1-5 September	5	505	101.0
14	2	7	14-31 August	5	419	83.8
14	2	13	10-13 August	4	315	78.7

[a] Paired and unpaired catches (see text).

On certain nights a trap was operated immediately outside an open window or at a distance of 1, 2, 5, 7 or 13 metres from it. The results are summarized for *A. gambiae s.l.* females in Table 4, while in Table 5 a comparison is given of the few observations that could be made with pairs of traps. It will be seen that they tend to support the hypothesis of a short range of influence (apparently less than 5 m) of the CDC trap, and the inference of a narrow flight-path on the part of the hungry mosquitos. Some reservations are necessary, however, since the differences in catch on different nights may reflect fluctuations of population density and of feeding activity, while in the paired observations there was some indication that the presence of the trap at the window may have reduced the catches in the trap 5 m away. Since moonlight can have an important influence on the flight activity of mosquitos, in reading these results the phase of the moon should be borne in mind: full moon occurred on 22 June, 21 July and 20 August 1967.

It should be added that all these catches, like the others here recorded, consisted overwhelmingly of unfed females. Blood-fed females almost always

TABLE 5

CATCHES OF FEMALE MOSQUITOS IN PAIRS OF LIGHT-TRAPS PLACED AT VARYING DISTANCES FROM AN OCCUPIED HOUSE [a]

Dates	Group	Trap just outside window Total catch (A)	Trap at distance from house		Ratio A : B
			Distance (m)	Total catch (B)	
13 August	*A. gambiae s.l.*	627	13	84	7.5 : 1
	Culicini	244		59	4.1 : 1
14, 16, 30 and 31 Aug.	*A. gambiae s.l.*	2 047	7	319	6.4 : 1
	Culicini	475		33	14.4 : 1
2 and 4 September	*A. gambiae s.l.*	1 389	5	129	10.8 : 1
	Culicini	137		8	17.1 : 1

[a] House No. 14 with 2 sleepers.

TABLE 6

ANALYSIS OF CAPTURES OF VARIOUS *ANOPHELES* SPECIES BY CDC MINIATURE LIGHT-TRAP AND BY PYRETHRUM SPACE-SPRAY AT SAPU, A FRESHWATER DISTRICT IN THE GAMBIA, FROM 21 TO 25 AUGUST 1967

Location and technique (and number of observations)	Species of *Anopheles*	Unfed		Blood-fed		Gravid		Males		Total caught	Mean catch	Maximum daily catch
		No.	Percentage of total	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total			
Light-trap inside room (5)	*A. gambiae s.l.*	102	86.4	9	7.6	0	0.0	7	6.0	118	23.6	56
	A. funestus	221	89.5	22	8.9	0	0.0	4	1.6	247	49.4	83
	A. coustani ziemanni	228	91.9	12	4.8	1	0.4	7	2.8	248	49.6	99
	A. pharoensis	118	88.0	15	11.2	0	0.0	1	0.8	134	26.8	72
	A. squamosus	4	—	1	—	0	—	0	—	5	1.0	3
Light-trap under eave (5) [a]	*A. gambiae s.l.*	90	86.5	8	7.7	1	1.0	5	4.8	104	20.8	47
	A. funestus	378	97.9	7	1.8	0	0.0	1	0.3	386	77.2	189
	A. coustani ziemanni	262	92.9	15	5.3	5	1.8	0	0.0	282	56.4	127
	A. pharoensis	30	61.2	5	10.2	0	0.0	14	28.6	49	9.8	22
	A. squamosus	3	—	0	—	0	—	0	—	3	0.6	1
Pyrethrum space-spray (17) [b]	*A. gambiae s.l.*	2	2.5	28	34.5	7	8.6	44	54.3	81	4.8	11
	A. funestus	103	44.8	88	38.3	23	10.0	16	6.9	230	13.5	47
	A. coustani ziemanni	0	—	2	—	0	—	0	—	2	0.12	2
	A. pharoensis	1	—	0	—	2	—	0	—	3	0.18	1
	A. squamosus	0	—	0	—	0	—	0	—	0	—	0

[a] Light bulb burned out 1 night and fan stopped on another.
[b] Including 3 observations in rooms where a light-trap had been operated overnight (see text).

constituted less than 4% of the total catch of *A. gambiae s.l.*, gravid females less than 1.5% and males (frequently unrepresented) less than 1%.

Observations in the freshwater area

The mosquito catches in the freshwater area from 21 to 25 August, by light-traps fixed to the eaves outside the open windows of ceiled houses and suspended inside unceiled houses with the light-source at the level of the eaves, are summarized in Table 6.

The results are not assessed statistically as the small number of replications would invalidate any conclusions. Culicines predominated in the catches in the freshwater area, but the light-traps successfully sampled 4 species of *Anopheles* (*A. gambiae* sp. A, *A. funestus*, *A. coustani ziemanni* and *A. pharoensis*) in appreciable numbers compared with the results obtained by previous workers (e.g., Love & Smith, 1957; Hurlbut & Weitz, 1956).

Comparison of light-trap with pyrethrum-spray catches

In Table 7, a summary is given of 19 catches of *A. gambiae s.l.* females in the Keneba area by a combination of 2 methods: a morning spray-catch following the overnight operation of a light-trap in or on the same room. The 3 lines of the table relate to the first 3 locations of the trap, as shown in Table 1. It is clear that in the presence of protected sleepers the light-trap, wherever placed, caught on an average at least 98% of the combined catch of *A. gambiae*.[1] In these particular samples the proportions of females in the unfed condition when trapped were 98.0%, 98.3% and 95.3%, respectively. How many *A. gambiae* left the rooms while the light-trap was operating is not known.

A different result was obtained on 6 July in a single combined catch in an open-eaved experimental hut, baited with a calf: the light-trap operated inside the hut caught 3232 females of *A. gambiae s.l.* (a catch included in Tables 1 and 2 although it was much larger than the average catch in occupied houses). The spray-catch the next morning took 437 females, or 11.9% of the combined catch. Again we do not know how many females may have left the hut during the night, but it probably represented a smaller proportion than would have left the houses occupied by sleepers under mosquito nets.

[1] Further statistics show that in 9 out of the 19 combined observations the morning spray catch constituted less than 1% of the total catch. In 3 other observations (made in 3 of the same rooms but on different nights from the 9 just mentioned) the spray catch was respectively 6.4%, 6.0% and 5.7% of the combined catch, which suggests that one or more of the sleepers present was incompletely protected from the attacking mosquitos.

TABLE 7

SUMMARY OF COMBINED CATCHES OF FEMALES OF THE *A. GAMBIAE* COMPLEX OF SPECIES AT KENEBA BY LIGHT-TRAP AND PYRETHRUM SPRAY FROM 25 JUNE TO 10 JULY 1967

Position of trap and average number of sleepers [a]	No. of catches	Total catch of *A. gambiae s.l.*		Proportion (%) taken by spray
		By trap	By spray	
No. 1 (2.4 sleepers)	10	7 847	167	2.1
No. 2 (7.0 sleepers)	4	6 131	57	0.9
No. 3 (5.2 sleepers)	5	933	19	0.2

[a] See Table 1, column 1.

In the freshwater area the proportion of *Anopheles* females unfed when taken in the light-trap was above 85% of the total in each of the prevalent species (Table 6). The fact that 4 anopheline species were abundant in the light-trap catches, but only 2 in the pyrethrum-spray catches, indicates the potential value of the CDC trap for sampling exophilic species which visit houses by night. The 17 spray catches tabulated included 3 in rooms in or on which a light-trap had been operated overnight. Those 3 spray catches comprised a total of only 9 anophelines (7 of which were *A. funestus*), whereas the 3 corresponding light-trap catches took a total of 402 anophelines.

Sex composition and abdominal condition of trapped mosquitos

The proportion of blood-fed *A. gambiae s.l.* caught in the light-traps ranged from 1.2% to 3.6% while in the spray catches 63.5% were blood-fed in the saltwater area. A similar difference was observed in the samples caught by the 2 methods at Sapu (Table 6) except that the proportions blood-fed in the spray catches were relatively lower: 34.5% in *A. gambiae*, 38.3% in *A. funestus*. In the case of *A. gambiae* this was due to a preponderance of males in the catches.

Males were seldom caught in traps at the salt-water area but fairly high percentages were trapped in the freshwater area—28.6% of the total catch of *A. pharoensis* in traps under the eaves and 6.0% of *A. gambiae* from those inside the rooms. Comparatively, more males were obtained in both areas by the pyrethrum spray than in the light-traps. The observed preponderance of unfed females among the house-entering population agrees with Giglioli's (1965) extended observations in the Keneba area. Giglioli estimated that the proportion that were "not unfed" constituted between 6% and 8%. Hurlbut & Weitz (1956) recorded "about 5%" of blood-fed *A. pharoensis* in their catches with New Jersey light-traps in the Nile Delta.

A very low percentage of males in light-traps is the normal finding by previous workers. Pritchard & Pratt (1944) observed that "males were rarely trapped". Breeland & Pickard (1965) obtained just under 4% of males in catches of *A. quadrimaculatus*, and Sun (1965) in 9 New Jersey traps operated regularly over a period of 3 years, caught only 1.36% of male *A. tessellatus* and 3.5% of male *A. sinensis*.

Separation of A. melas *from freshwater* A. gambiae *at Keneba*

Coluzzi (1964) found a statistical difference in both sexes in the relative lengths of certain palpal segments in his laboratory colonies of *A. melas* and *A. gambiae* species A. His "palpal index" distinguishing these species is expressed as the sum of the fourth and fifth segments divided by the third segment, i.e., the ratio of length 4+5 to length 3 (the latter being taken as unity).

This time-consuming technique was applied to over 1200 specimens caught at Keneba, by the dis-

TABLE 8

IDENTIFICATION OF *A. MELAS* AND FRESHWATER *A. GAMBIAE S.L.* AT KENEBA, BY THE PALPAL INDEX

Month	Method and site of capture	Definite *A. gambiae s.l.*		Definite *A. melas*		Doubtful		Total examined
		No.	%	No.	%	No.	%	
June	Pyrethrum spray	4	4	82	76	22	22	108
	Light-trap under eaves	10	7	107	70	35	23	152
	Light-trap 1.6 km from village	0	0	16	70	7	30	23
	Total	14	5.0	205	72.5	64	22.6	283
July	Space-spray, females	14	9	93	42	44	29	151
	Space-spray, males	26	48	28	52	0	0	54
	Light-trap under eaves	6	8	51	77	19	25	76
	Light-trap inside room	7	3	153	74	47	23	207
	Mixed trap sample (both positions)	0	0	30	81	7	19	37
	Trap without light (inside room)	2	8	15	63	7	29	24
	Total	55	10.0	370	67.5	124	22.6	549
August	Space-spray	7	7	53	56	35	37	95
	Light-trap under eaves, females	29	13	124	56	68	31	221
	Light-trap under eaves, males	2	50	2	50	0	0	4
	Total	38	11.9	179	56.0	103	32.2	320
Grand total		107	9.3	754	65.4	291	25.2	1 152

section, measurement and permanent mounting of the palps. In the male the palpal index was found to be even more distinct in the Keneba populations than in Coluzzi's colonies: 0.74–0.84 for *A. melas*; 0.58–0.69 for *A. gambiae* sp. Accordingly, all the males examined could be definitely classified. The females were less easy. The index in a sample of 70 freshwater *A. gambiae s.l.* examined from Sapu showed a range from 0.66 to 0.85, which corresponds exactly to Coluzzi's finding for *A. gambiae* species A. In his *A. melas* females he found a range from 0.78 to 0.95. Therefore, in examining the samples from Keneba, those females having a palpal index below 0.79 were classified as *A. gambiae* sp. and those with an index above 0.85 as *A. melas*. The specimens with an index between these values were classed as " doubtful ".

The results of the measurements are summarized in Table 8. They indicate that in the months June–August the freshwater species constituted around 10% of the house-visiting *A. gambiae s.l.* The finding that *A. gambiae* males were relatively more prevalent in the houses than those of *A. melas* probably reflects the proximity to the village of the freshwater breeding places; the mangrove swamp where *A. melas* breeds is 2 km away. Giglioli (1964) observed, from examination of egg-batches, that *A. melas* constituted 96%–98% of the *A. gambiae s.l.* population at Keneba in May and June, but concluded that in August–September freshwater *A. gambiae* amounts to 45% of the house-resting population. The present results agree broadly with this.

CONCLUSIONS

(1) The CDC miniature light-trap (Sudia & Chamberlain, 1962) was found to be a very efficient mechanical instrument for sampling both anophelines and culicines in the salt- and freshwater districts of the Gambia. Anopheline species trapped in appreciable numbers were *A. melas* and other species of the complex *A. gambiae*, *A. funestus*, *A. coustani*, *A. pharoensis* and *A. squamosus*. The most common species of culicine was *Culex tritaeniorhynchus*. *Aedes irritans*, *Aedes furcifer*, *Aedes aegypti* and *Mansonioides* spp. were also found commonly in the captures.

(2) The optimum location of the light-trap for sampling house-visiting mosquitos was as near to the host or hosts as possible. The numbers caught in traps decreased as the distance from the host increased. Statistically significant differences were found between the mean catches in traps suspended in or on human dwellings, traps placed inside village compounds (that is, surrounded by houses some 15 m–20 m away) and traps placed near the breeding site about 1.6 km away from the nearest house. The average catch of *A. gambiae s.l.* per trap per night exceeded 1200.

(3) Over 95% of the *A. gambiae s.l.* caught in light-traps at Keneba, and over 86% of those similarly caught at Sapu, were unfed females. The catches in and on houses represent mosquitos trapped while seeking a blood-meal, many of which (as demonstrated by the much lower house-resting densities found by morning spray-captures in comparable houses) would not have obtained a meal at that spot but would have been obliged to seek one elsewhere.

(4) The difference between the means of *A. gambiae s.l.* catches by traps with and without the lamp was highly significant indicating that the light-source (not the air current) was the main agency rendering this trap effective as a sampling device.

(5) The results suggest that the effective range of influence of the CDC miniature light-trap is less than 5 m. It is considered unlikely to attract many additional mosquitos into the house.

(6) The CDC miniature light-trap can be recommended as a tool for sampling African malaria vectors visiting occupied houses, and may be useful for assessing at those sites the relative night-time densities of different species, or the fluctuation of a species at different dates. The method cannot, however, yield a reliable index of the incidence of attack on man, nor of the resting-density of a vector species.

Annex

FURTHER COMMENTS ON THE FIELD TESTING OF LIGHT-TRAPS [1]

The observations reported in this paper were designed chiefly to test the efficiency of the CDC miniature light-trap as a tool for sampling malaria vectors in the field. Priority consideration was given to comparing the performance of the trap in different outdoor and indoor situations. The comparison of the light-trap catches with catches by standard sampling techniques was regarded as of only secondary importance at this stage of the work.

When the light-trap catches of *A. gambiae s.l.* at Keneba are examined (Table 2) it is seen that the trap was outstandingly successful in collecting large samples of females in 2 situations: when it was hung from the eaves of a hut, opposite an open window, and when hung from the roof of a hut having open eaves. In each of these positions the trap caught an average of over 1200 specimens per night. Inside rooms that had no open eaves but only an open window, the index fell to 240 per night, and in a family compound but at some distance from the huts an average of 76 per night was recorded. Of course, the very high seasonal density of *A. gambiae s.l.*, and particularly of *A. melas*, must be taken into account in assessing these catches. Nevertheless, there is no doubt that adequate samples of the local vectors can be taken by light-trap in the conditions which prevailed at Keneba, and this method of sampling might well prove, under similar conditions, to be more efficient and less laborious than the standard methods employed in assessing operations against malaria.

Equally striking was the relative failure of the trap when operated near the extensive breeding site of *A. melas*; the average catch in that situation was only 5.5 mosquitos per trap per night. Again, a trap placed in an open field part-way between the breeding place and the village gave an intermediate index: 39 *A. gambiae s.l.* per trap per night. These results may perhaps be due to the fact that in the Keneba area *A. melas* enjoys very extensive breeding sites but is obliged to concentrate at a much more restricted locality for the purpose of obtaining its blood-meals. It is easy to conceive that just the reverse situation might be found elsewhere.

[1] Prepared by C. Garrett-Jones, Division of Malaria Eradication, World Health Organization, Geneva, Switzerland.

Line 4 of Table 2 shows that the light-source in the CDC trap was of major importance in bringing in the catch. Without it the index was only 65 per night, which represents about 5% of the index when the trap was used complete with its light in the same situation.

Since the CDC trap, operated with its standard white-light bulb of feeble power, attracted such large samples of mosquitos inside and outside houses, it is reasonable to think that any device of greater attractive power might have taken even larger numbers under the same circumstances. This could be a trap with a more powerful light or one emitting light of a different wavelength (e.g., ultraviolet). It would be desirable to test such alternative traps in parallel with the CDC trap, if only because maximum efficiency may be required in operational sampling at times and places where the vectors are much less abundant than they were at Keneba. Equally, it would be worth while to compare the performance of the CDC trap with the catch yielded by direct biting-capture on unprotected baits, and with the catch in a bed-trap. Each of these methods could be said to be sampling the same "universe", that is to say, the totality of unfed mosquitos visiting the room in the course of the night. Thus the relative efficiency of the different devices and methods could be compared in terms of the average catch of female mosquitos by each.

In the present investigation, the only sampling method used for comparison was the morning pyrethrum-spray catch. As recorded in the text and in Table 7, the spray catches consistently yielded very much smaller numbers of mosquitos than were being taken in the light-trap—even when the spray catches were performed in occupied rooms where no light-trap had been working overnight. This appears also from the indices in the freshwater area of Sapu (Table 6). Several possible explanations must be considered in seeking to account for this finding. First, it might be supposed that the CDC trap drew into the room (or towards the window) large numbers of mosquitos that would not otherwise have approached the site. Indeed, the present writer at first placed this interpretation on Dr Odetoyinbo's results. But it is rendered highly improbable by the demonstration that light-traps situated away from the immediate vicinity of the host caught few mosquitos (see Tables 4 and 5), even at a distance of only 5 m from the nearest house, which suggests that the influence of the trap-light extended over a radius of less than 5 m. Secondly, the mosquitos feeding in a room might be considered to have a natural tendency to leave it before the morning hour when the pyrethrum-spray catches were made. While this may be true of the exophilic species, *A. coustani ziemanni* and *A. pharoensis* at Sapu, it is less likely to apply to blood-fed *A. funestus*, *A. gambiae s.l.* or *A. melas*.

The correct explanation for the disparity in catches, according to the methods used, in both areas, is believed by the investigator to lie in the universal habit of the people, at Keneba in particular, of sleeping under a mosquito net in view of the severe nuisance from the numbers of mosquitos attacking them. This would mean that most of the hungry mosquitos are unable to obtain a blood-meal at the first house visited and have to fly from house to house several times before feeding. Those remaining in a house at daybreak are likely to comprise only the ones that succeeded in feeding there, together with any that happened to be seeking access to a host at that spot when dawn overtook them. The total number of mosquitos available for capture by the pyrethrum-spray catch would therefore be only a fraction of those that had visited the same room in the course of the night. It is of course the larger of these totals that is sampled by the light-trap (or by any other attractant that might be operated in the room overnight).

A similar discrepancy has been observed elsewhere between the numbers of blood-fed *A. gambiae* per sleeper collected in morning spray-catches and the numbers taken by direct capture on human baits stationed indoors. A ratio of about 1 : 8 has been noticed at Kankiya, Northern Nigeria. Although mosquito nets are not in general use among the people at that place, they may nevertheless avoid many bites by covering themselves during sleep to leave a minimum of skin surface exposed to attack. If this is confirmed by further observations, it will necessitate a revision of the mode of expressing the man-biting rate as equivalent to the average number of mosquitos caught attacking a human bait, whose legs remain exposed precisely in order to facilitate the attack and increase the catch. This was the expression recommended by Garrett-Jones[1] and it may still offer the best index of the incidence of biting in many areas. But where it is shown that the feeding mosquitos must circulate freely from house to house in search of an accessible host and habitually rest indoors through the next day, it is clear that the morning pyrethrum-catch of blood-fed females per sleeper will offer a truer index of the man-biting rate than does the direct biting catch. The major limitations of the former method—its inefficiency in " open " types of housing and its inapplicability in DDT-sprayed areas—underline once more the need to test alternative sampling methods in parallel, in advance of any application of residual insecticide, in the particular conditions of each malarious country.

[1] Garrett-Jones, C. (1964) *A method for measuring the man-biting rate* (unpublished WHO working document WHO/Mal/45). A limited number of copies of this document is available to persons officially or professionally interested on request to Distribution and Sales, World Health Organization, 1211 Geneva, Switzerland.

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RÉSUMÉ

RECHERCHES PRÉLIMINAIRES SUR L'UTILISATION D'UN PIÈGE A LUMIÈRE POUR L'ÉCHANTILLONNAGE DES VECTEURS DU PALUDISME EN GAMBIE

Tant dans les zones d'eau douce que dans les zones d'eau salée, le piège portatif à lumière CDC mis à l'essai en Gambie n'a capturé que des nombres limités d'insectes lorsqu'il était placé en plein air aussi bien près des gîtes larvaires que près des habitations. Par contre, dans les pièges placés à l'intérieur d'habitations occupées, ou

suspendus aux avancées de toit, les captures ont été très abondantes. Dans les zones d'eau salée, elles dépassaient en moyenne 1200 moustiques par nuit pour *Anopheles gambiae s.l.*, et 400 moustiques pour les culicinés les plus courants. Dans les zones d'eau douce où les densités sont plus faibles, des pièges disposés de la même façon ont capturé d'assez grands nombres d'*A. gambiae* sp., d'*A. funestus*, d'*A. coustani ziemanni* et d'*A. pharoensis*.

Les captures matinales par pulvérisation de pyrèthre dans les cases occupées des mêmes agglomérations ont donné des densités beaucoup plus faibles. On estime toutefois que le piège lumineux n'attire pas les moustiques en plus grand nombre et que les résultats n'ont pas pu être fortement modifiés par le nombre de moustiques quittant les habitations avant les pulvérisations. La différence s'explique plutôt par le fait qu'en raison de l'intensité des attaques, les habitants sont obligés de se protéger par des moustiquaires, de sorte que les femelles doivent aller de maison en maison à la recherche de leur repas de sang. Cette interprétation implique que, dans les zones étudiées, les captures matinales par pulvérisation de pyrèthre donnent une indication plus exacte de l'incidence des contacts moustique/homme que les captures au piège lumineux ou sur hôte. Cette supposition est corroborée par l'analyse des captures par piège lumineux, dans lesquelles les femelles non gorgées sont en forte majorité. Une analyse détaillée des résultats obtenus au cours de cette étude est présentée en annexe.

Le rayon d'action du piège à lumière semble être de moins de 5 m.

Pour la dissection des moustiques capturés par les pièges lumineux, on a appliqué la méthode de Coluzzi (1964) afin de distinguer d'*A. melas* les variétés d'eau douce du complexe *A. gambiae*. Dans la zone d'eau douce, l'indice palpal correspondait assez exactement à celui obtenu par Coluzzi pour *A. gambiae* sp. A. Les variétés d'eau douce constituaient environ 10% de la population d'*A. gambiae s.l.* pénétrant à l'intérieur des habitations entre juin et août dans la zone d'eau salée, le reste étant constitué par *A. melas*. Ce dernier provenait d'un marécage situé à 2 km environ, tandis qu'on trouvait des gîtes larvaires d'eau douce plus près du village.

Les pièges à lumière peuvent constituer des instruments très efficaces pour l'échantillonnage des anophèles et des culicinés dans cette partie de l'Afrique, à condition d'être placés dans des endroits où se produisent les concentrations de moustiques à la recherche de leurs repas de sang. Les captures par piège peuvent refléter les fluctuations de l'activité des moustiques, mais elles ne permettent pas d'estimer les densités d'attaque ou de repos.

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