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AN INVESTIGATION INTO THE BEHAVIOUR OF *ANOPHELES PARENSIS* GILLIES AT MALINDI ON THE KENYA COAST

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As part of a programme of malaria control round the coastal town of Malindi, 70 miles north of Mombasa, Kenya, spraying of houses with DDT was initiated in March 1961. The first cycle of treatment extended into, but not beyond, the village of Ganda, 5 miles inland from Malindi. The second cycle, in October 1961, extended one mile beyond Ganda. During the third cycle, the area immediately round Ganda was left unsprayed in order to facilitate investigation of some unexpected entomological findings. In October 1962, the whole area was sprayed again. Treatment was with 50 per cent. wettable powder at a dosage of 200 mg. per sq. ft. (2g. per sq. m.).

In order to assess the efficacy of these control measures, detailed entomological studies were organised in the village of Ganda. The observations made included all-night catches indoors and outdoors and gland dissections of mosquitos for sporozoites. These observations revealed that large numbers of females resembling those of *Anopheles funestus* Giles were being caught biting man outside houses within the sprayed area. Closer examination of the material showed that most of the specimens caught were not the vector species *A. funestus*, but belonged to the newly described *A. parensis* Gillies (1962). The latter species was originally found in the Pare area of Tanganyika following the elimination of

A. funestus by spraying. But in this district it was always scarce and was obviously of no medical importance, and hence very little was known of its biology. At Ganda the position was quite different. The species was present in large numbers and was attacking man readily outdoors; in addition, in the early stages of the spraying campaign a small number of sporozoite-positive females of the *funestus* group had been caught biting inside or on the verandah of an unsprayed house.

It became necessary therefore to investigate the possibility that *A. parensis* was acting as a mainly exophilous vector of malaria and was maintaining transmission despite the presence of insecticide in houses. This paper records the results of investigations carried out from January to November 1962.

The village of Ganda had been the scene of earlier detailed studies on mosquitos, especially Culicinae, carried out by members of the Division of Insect-borne Diseases, Nairobi. The reader is referred to the paper by van Someren, Heisch & Furlong (1958), where a detailed account of the topography and climate of the district is to be found. It is only necessary here to provide the additional information that there were almost no domestic animals in the villages themselves, but that several small herds of 10–20 cattle were stalled outdoors at night in the open fields near Ganda. The main breeding sites of *A. parensis* were located in very large semi-permanent swamps, the nearest point of which was just under a mile north of the village.

Malaria in the villages round Malindi is hyperendemic, preliminary surveys having shown that 40–50 per cent. of children in the 0–10 years age-groups harboured *Plasmodium falciparum*. In September 1962, the parasite rate in 120 children at Ganda was 25 per cent. It is presumed that many of these infections had been acquired outside the controlled area.

Methods of study

Standard all-night catches of mosquitos biting human bait formed the basis of the investigation. Each catching team consisted of one supervisor and two collectors, who worked in three 5-hour shifts, starting at 5 p.m. (East African Standard Time) and continuing up till 8 a.m. The mosquitos were caught in tubes, the time of capture of each specimen being recorded on the tube by the supervisor. Four catching sites were used. The first was about 100 yards outside the village beneath a large mango tree and sheltered by a clump of bushes. The second was on the verandah of an unsprayed house in the centre of the village. The third was inside the same house, while the fourth site, which was only used in the later part of the investigation, was in a very small and rather open type of hut situated with four others about a quarter of a mile away from the main village.

After identification in the laboratory, the mosquitos were dissected for the presence of sporozoites and the wings removed and mounted on slides for subsequent checking. A large number of salivary glands were mounted and stained with Giemsa for the purpose of confirming the preliminary examination; but the method proved unreliable, and the results of dissections recorded in this paper are based on the examination of fresh material in saline.

Identification of *Anopheles parensis*

A. parensis is indistinguishable from *A. funestus* in the egg, larval and pupal stages. About 90 per cent. of males can be separated from *A. funestus* by the presence of an additional pale patch at the base of the palpal clubs, and from *A. leesoni* Evans and *A. confusus* Evans & Leeson by the genitalia, which are similar to those of *A. funestus*. The small proportion of males that lack the extra pale patch cannot be separated from *A. funestus*.

About two-thirds to three-quarters of females of *parensis* can be distinguished from all others of the *funestus* group by the presence of a small patch of pale scales at the tip of the sixth vein. In some of these females there is in addition a pale fringe spot opposite the sixth vein. Thus all females with such wing markings can be reliably identified. The remaining quarter to one-third of the female population are indistinguishable from *A. funestus*, so that individual specimens cannot be identified. However, the species composition of a particular population can be inferred from the ratio of those with and without obvious *parensis* wings, as was done in the case of *A. rivulorum* Leeson by Gillies & Smith (1960).

As recorded later on in this paper, the proportion of females with pale sixth veins at Ganda was consistent with the population being virtually composed entirely of *A. parensis*. The only other member of the *funestus* group found at Ganda was *A. rivulorum*, of which not more than half a dozen specimens were seen throughout the period of study.

Results

Density

Table I shows the results, by months, of catches made in the three situations; outdoors, away from the village; on the verandah of an unsprayed house in the centre of the village; and inside two unsprayed houses. Between them, these records illustrate the rise of the population after the rains in April and May, and its decline in October and November as the swamps dried up. The outdoor catches remained at very high levels for several months.

TABLE I. *Monthly catches of females of* A. parensis *at Ganda in different situations, 1962*

	Outdoors			Verandah			Indoors		
	Total catch	No. of nights	Mean catch	Total catch	No. of nights	Mean catch	Total catch	No. of nights	Mean catch
January				46	11	4·2	8	5	1·6
February				149	12	12·4	46	12	3·8
March				89	13	6·8	30	14	2·1
April				83	12	6·9	14	12	1·2
May				95	14	6·8	31	13	2·4
June	374	4	93·5	709	11	64·5			
July	1483	7	211·9	925	12	77·1			
August	632	3	210·7	1013	9	112·6			
September	796	5	159·2	407	9	45·2	979	9	108·8
October							820	16	51·2
November	16	8	2				15	7	2·1

During the initial observations it became clear that *A. parensis* was biting in larger numbers outdoors, away from the village, than on the verandah of a house, and in much larger numbers than inside the same house. Thus catches made inside the house were three or four times smaller than those made outside on the verandah (Table I, January to May). The indoor catches were accordingly discontinued until late in the season, when a new unsprayed house on the edge of the village became available.

At Goshi, outside the sprayed area, an exact picture of the biting densities of *A. parensis* was more difficult to obtain, since the population was a mixed one of this species and *A. funestus*, with the latter predominating. In June, catches made just outside the village, from 6 p.m. to 6 a.m., yielded an average of 36 females per night, of which 21 per cent. were identifiable as *parensis*. In August, catches averaged 76 females with 36 per cent. *parensis*, and in September, 57

females with 36 per cent. *parensis*. Since about one-quarter to one-third of females of *parensis* are indistinguishable from those of *funestus*, it follows that the proportion of *parensis* actually present was appreciably higher than this. By November, catches had fallen to much lower levels and appeared to consist almost exclusively of *funestus*. Thus there is evidence here of a more restricted season of abundance of *parensis* compared with *funestus*.

Identification

Since accurate determination of the species collected was of paramount importance, a constant check was kept on the wing markings of captured material. Table II shows the percentage of females in different months at Ganda with *parensis* type wings. It will be seen that throughout the year two-thirds to

TABLE II. *Wing markings of female mosquitos of the* funestus *group from Ganda, 1962*

Month	Numbers of *parensis*-type	Total	% *parensis*-type
January	30	45	67
February	75	117	64
March	65	98	66
April	25	37	68
May	65	92	71
June	397	512	77·5
July	251	317	79
August	161	211	76
September	225	294	76·5
October	203	268	76
November	24	38	63

three-quarters of the catches were composed of assured *parensis*. Since this proportion is the same as that found in pure populations of *parensis*, it follows that the overwhelming majority of the catches belonged to this species. Table III shows the break down of the totals according to the type and location of the

TABLE III. *Wing markings of females of the* funestus *group from different collections at Ganda*

Site of catch	Numbers of *parensis*-type	Total caught	% *parensis*-type
Verandah or house	914	1231	74·2
Outdoors	468	611	76·6
Resting indoors	63	83	76
Biting cattle	34	40	85

catch. The uniformity of the results, regardless of whether the mosquitos were caught indoors or biting outside, indicates that in all situations and at all times at Ganda we were dealing with populations of the same species. In addition, eight males caught resting in an unsprayed house by day were also all typical of *parensis*.

Biting cycle

Table IV sets out the results of 68 all-night catches, divided up into hourly periods. During the period of study the time of sunset varied from 1815 to 1823 hr. E.A.S.T. To facilitate comparison with other species, the time of capture

has been adjusted so that, in every catch, 1800 hr. corresponds to the time of sunset (Lumsden, 1952). The results have been converted into 'Williams' means' (M_w) for the density in each period of the night, this being a form of the geometric mean such that $\log (M_w + 1) = \frac{\Sigma \log (n + 1)}{N}$, where n_1, n_2 . . . represent actual values of individual catches (Haddow, 1960). The results have been further converted into percentages of the total all-night catch (calculated from the sum of Williams' means) collected in each hourly period.

TABLE IV. *Biting cycle of* A. parensis *at Ganda*

	Outdoors (16)			Verandah (27)			Indoors (25)		
Hour beginning	Total catch	Mean (M_w)	%	Total catch	Mean (M_w)	%	Total catch	Mean (M_w)	%
1600	0	—	—	2	0·05	0·1	43	0·73	1·7
17	22	0·64	0·4	21	0·44	0·8	185	4·78	10·9
18	460	26·1	16·6	254	7·04	12·1	177	5·28	12·0
19	491	27·8	17·7	257	6·0	10·5	101	2·88	6·6
20	339	19·1	12·2	216	4·87	8·6	87	1·74	4·0
21	286	14·15	9·0	156	3·88	6·8	88	2·02	4·6
22	257	13·08	8·3	232	4·34	7·6	119	3·14	7·2
23	155	7·44	4·7	200	3·08	5·4	116	2·79	6·4
24	122	6·55	4·2	191	2·67	4·7	83	2·19	5·0
01	112	6·06	3·9	186	2·41	4·2	98	2·07	4·7
02	123	5·6	3·6	145	2·52	4·4	96	2·04	4·6
03	232	11·3	7·2	219	4·5	7·9	208	4·67	10·6
04	164	7·47	4·8	234	4·5	7·9	149	3·31	7·5
05	212	8·15	5·2	317	7·12	12·5	185	4·54	10·3
06	111	3·55	2·3	156	3·52	6·2	79	1·74	4·0
07	0	—	—	0	—	—	0	—	—
Total	3086		100·1	2786		99·7	1814		100·1

The time of capture has been adjusted so that 1800 hr. corresponds to sunset. The number of catches in each series is shown at the top in parentheses.

In fig. 1 the biting cycle is shown graphically for the three different situations in which catches were made. It is immediately apparent that the curve of the pattern of activity is essentially bimodal, with one peak in the first two hours after sunset and a second peak during the three hours before sunrise. The importance of the evening peak varies in the different locations, being most marked in the outdoor catches. Conversely, the pre-dawn peak is most marked in and round the houses. It is possible that this difference reflects the distribution of hungry mosquitos at various periods of the night. In the early evening they are likely to be moving in from distant outdoor shelters or breeding sites, whereas by the later part of the night host-seeking movements may have led to concentrations of mosquitos in the close vicinity of houses. A rather more puzzling feature is the relatively large number of females biting indoors during the hour before sunset. No obvious explanation can be put forward for this behaviour unless it was that the open structure of the hut made it particularly suitable as a resting site for unfed females by day. Such females, finding a host available in close proximity in a well sheltered environment, may well have been released to feed at an unusually early hour.

Observations were also made in the unsprayed village of Goshi. The catches, which were all made outside, were divided up into those with *parensis*-type wings and those with *funestus*-like wings. The former were entirely composed of *A. parensis*, while the latter would be a mixed population of *A. funestus* and *A. parensis* containing some 15–20 per cent. of the latter species. Despite the

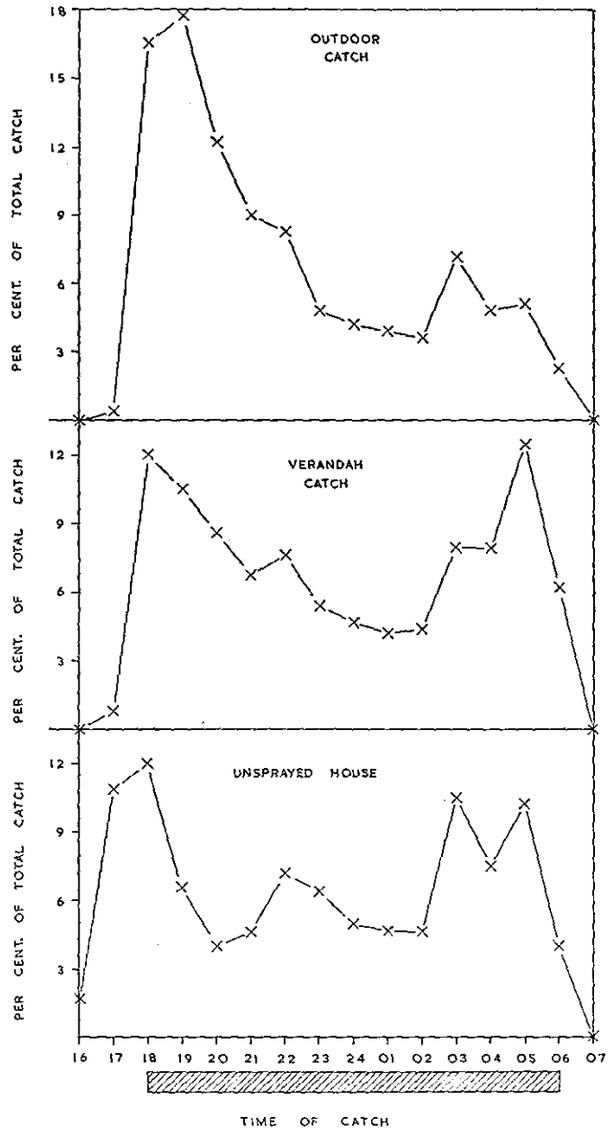

Fig. 1.—*Biting cycle of A. parensis at Ganda.* The catches are those for the one-hour periods beginning at the times indicated. The time of catch has been adjusted so that 1800 hr. corresponds to sunset. The shaded area at the bottom indicates the period from sunset to sunrise.

uncertainties in the identity of the mixed group, the results have been analysed in a similar way to the catches of pure *parensis* in the sprayed villages. This has been done in Table V and the results depicted graphically in fig. 2 (in both of which the mixed group is referred to as '*A. funestus*'). The analysis shows a striking difference in behaviour between *A. parensis* and the mixed population

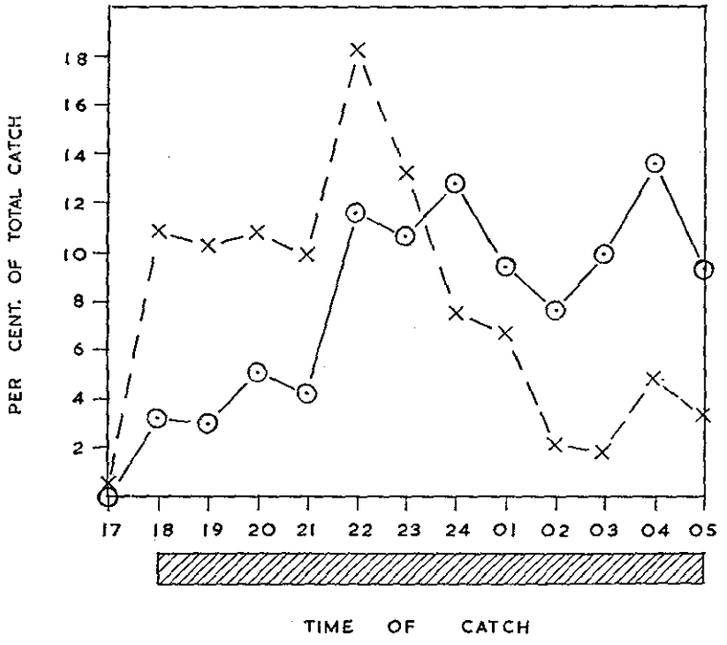

Fig. 2.—Biting cycle of *A. parensis* (interrupted line) and '*A. funestus*' (continuous line) outside an unsprayed village. The catches are those for the one-hour periods beginning at the times indicated. The shaded area at the bottom indicates the period from sunset to sunrise. For definition of '*A. funestus*', see above.

in which *A. funestus* was predominant. The early evening peak is entirely absent in the *funestus*-like group, in which 60 per cent. of feeding took place after midnight. This finding is in conformity with the well-known tendency of *funestus* to bite in the later part of the night. It may be noted that there is an apparent peak of activity in *parensis* between 2200 and 2400 hr. The numbers caught were small, but it is possible that this was related to the rather more exposed situation of the catching site at Goshi and the frequency of windy conditions in the early part of the evening.

Moonlight and biting activity

It was noticed that in certain series of catches there appeared to be a shift in biting activity, so that more females were caught in the later part of the night than in the evening. The figures were accordingly analysed in relation to periods of moonlight. For the purposes of this analysis four periods were recognised, corresponding approximately to the four quarters of the lunar cycle. The 'new moon' phase covered those nights when the moon rose after 0300 hr.

up to those when it set before 2100 hr. The ' first quarter ' covered those nights with moonset between 2100 and 0300 hr. ' Full moon ' covered those nights when the moon set after 0300 hr. and rose before 2100 hr. The ' last quarter ' covered those nights with moonrise between 2100 and 0300 hr. The results of

TABLE V. *Comparison of biting activity of* ' A. funestus ' *and* A. parensis *outside an unsprayed village*

Hour beginning	Numbers		%	
	'funestus'	*parensis*	*'funestus'*	*parensis*
1700	0	2	—	0·6
18	18	36	3·2	10·8
19	17	34	3·0	10·2
20	29	36	5·1	10·8
21	24	33	4·2	9·9
22	66	61	11·6	18·3
23	60	44	10·6	13·2
24	73	25	12·8	7·5
01	53	22	9·3	6·6
02	43	7	7·6	2·1
03	56	6	9·9	1·8
04	77	16	13·6	4·8
05	52	11	9·2	3·3
Total	568	333		

The time of catch has been adjusted so that 1800 hr. corresponds to sunset. For definition of ' *A. funestus* ', see p. 5.

catches are shown in Tables VI and VII, the times given being East African Standard Time. The times of moonset were extracted from the Nautical Almanac for 1962 and converted from Local Mean Time to East African Standard Time.

The most obvious feature to emerge from the analysis is the presence of feeding mosquitos in all periods of the night, regardless of whether the moon was up or not. This elementary observation is in accordance with the general experience of mosquito workers. However, if the distribution of catches, expressed in Table VII as percentages of the total for the whole night, is examined more closely three points may be noticed. First, the proportion feeding during the first four hours of the night (1800 to 2200 hr.) varies very little in relation to the phases of the moon except in the case of the verandah catches. In this series the numbers caught in the first four hours of the night during the first quarter and new moon phases are significantly higher than during the rest of the month ($\chi^2 = 33{\cdot}75$ with 3 degrees of freedom; $P<0{\cdot}01$). Secondly, there is a tendency in all catches for a higher proportion of mosquitos to bite later in the night when the moon rises late compared with periods when moonset is early. Thus the percentage of the night's catch collected between 0200 and 0600 hr. is highest during the last quarter, when the moon rises between 2100 and 0300 hr., the difference in all three series being highly significant. Thirdly, there is a slight tendency for the feeding before 1800 and after 0600 hr. to be more marked during the new moon phase than during the rest of the lunar cycle. These results are illustrated in fig. 3, which shows the results of 32 catches on the verandah of a house.

These findings agree in general with those of Ribbands (1946) on *A. funestus* in West Africa. They indicate that, under certain conditions, there is a slight but definite tendency for increased activity during periods of moonlight compared with hours of greater darkness. It would appear that the effect is not very great, and if the behaviour on individual nights is examined it is seen to be

TABLE VI. *Catches of females of* A. parensis *in relation to phases of the moon*

Hour beginning	First quarter: Moonset 2100–0300 hr.			Full moon: Moonset 0300 hr.–dawn, Moonrise 1900–2100 hr.			Last quarter: Moonrise 2100–0300 hr.			New moon: Moonset 1900–2100 hr., Moonrise 0300 hr.–dawn		
	Outdoors	Verandah	Indoors	Outdoors	Verandah	Indoors	Outdoors	Verandah	Indoors	Outdoors	Verandah	Indoors
1700	3	10	7	0	2	74	1	1	64	0	1	28
18	99	90	8	30	17	81	158	56	56	53	59	50
19	165	122	10	82	19	32	167	52	49	86	80	8
20	126	89	11	71	29	47	137	38	30	61	53	0
21	85	78	19	53	24	35	66	30	31	44	32	0
22	146	117	17	46	25	56	71	34	27	44	45	15
23	71	91	17	37	48	66	43	31	24	31	33	12
24	32	59	14	14	55	48	36	43	22	25	33	5
01	20	63	24	20	46	47	46	52	21	21	24	3
02	28	36	18	12	30	32	46	55	33	18	33	0
03	43	51	18	38	35	108	95	80	79	55	40	1
04	40	63	24	23	6	51	100	114	71	23	54	1
05	44	75	22	17	0	55	70	84	86	19	62	17
06	76	118	23	13	—	29	76	62	69	38	104	11
07	0	0	0	0	0	0	0	0	0	6	1	0
Total	978	1062	232	456	336	761	1112	732	662	524	654	151
Number of nights	5	10	3	2	3	9	6	8	7	3	11	6

All times given are East African Standard Time.

TABLE VII. *Catches of females of* A. parensis *in relation to phases of the moon*

Period (hr.)	Outdoors				Verandah				Indoors			
	First quarter	Full moon	Last quarter	New moon	First quarter	Full moon	Last quarter	New moon	First quarter	Full moon	Last quarter	New moon
17–1800	0·3	0	0·1	0	0·9	0·6	0·1	0·1	3·0	9·7	9·7	18·5
18–2200	48·6	51·8	47·4	46·5	35·7	26·5	24·0	34·2	20·6	25·6	25·1	38·4
22–0200	27·5	25·7	17·6	23·1	31·1	51·8	21·8	20·7	30·9	28·6	14·2	23·1
02–0600	15·9	19·6	27·9	21·9	21·2	21·1	45·5	28·9	35·4	32·6	40·6	12·7
06–0800	7·8	2·8	6·8	8·4	11·1	0	8·5	16·1	9·9	3·8	10·4	7·3
Percentage catch before 1800 and after 0600 hr.	8·1	2·8	6·9	8·4	12·0	0·6	8·6	16·2	12·9	13·5	20·1	25·8

The values given represent the catch in each period expressed as a percentage of the total catch per night.

far from consistent. Thus, even in the series from the verandah, which showed the most marked correlation between activity and phases of the moon, in two out of 10 catches during the first quarter and in two out of eight during the last quarter the pattern of behaviour was reversed. Thus for a proper analysis of the phenomenon a prolonged series of catches specifically planned for its detection would be required. However, the evidence presented here appears to show that, in the case of *A. parensis* at least, the basic pattern of feeding is influenced to a certain extent by a superimposed lunar effect, presumably associated with the duration of moonlight.

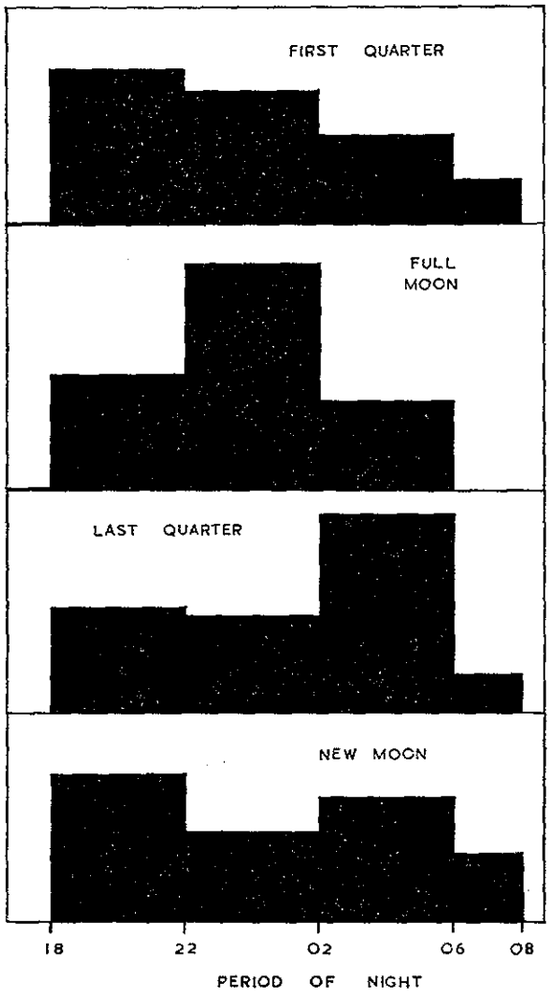

Fig. 3.—Biting cycle of *A. parensis* in relation to phases of the moon. Verandah catches only. The histograms represent the catches in successive 4-hr. periods beginning at the times indicated, expressed as percentages, on an arbitrary scale, of the total nightly catch.

TABLE VIII. *Age composition of catches of* A. parensis *in a sprayed village in relation to time of night and season*

Hour beginning	June		July		August		September		October		Whole period		
	N	T	N	T	N	T	N	T	N	T	N	T	% N
1700	—	—	—	—	1	2	—	—	—	—	1	2	—
18	26	42	53	100	35	54	28	36	27	34	169	266	63·5
19	54	83	53	77	44	53	38	44	3	3	192	260	73·8
20	41	57	25	43	15	22	17	21	2	3	100	146	68·5
21	27	41	12	27	1	3	2	3	0	1	42	75	56·0
22	28	41	4	10	1	5	6	8	2	5	41	69	59·4
23	29	42	4	6	3	5	2	6	2	4	40	63	63·5
24	19	34	1	1	4	12	2	3	11	15	37	65	56·9
01	19	27	—	—	0	1	2	4	11	16	32	48	66·7
02	8	15	1	1	—	—	3	5	5	10	17	31	54·9
03	7	19	1	3	—	—	4	12	5	14	17	48	35·4
04	6	9	—	—	—	—	2	7	4	7	12	23	52·2
05	5	10	—	—	1	1	2	3	16	28	24	42	57·2
06	2	2	—	—	1	2	—	—	11	13	14	17	—
Total	271	422	154	268	106	160	108	152	99	153	738	1155	63·9
%		64·2		57·5		66·2		71·0		64·7			

The times shown are East African Standard Time. N = nulliparous; T = total.

Feeding habits

Information on the feeding habits of mosquitos should normally be sought by collections indoors and in animal shelters, as well as in outdoor resting sites. The present investigation was hampered by the presence of insecticide in most of the houses, and by our failure to find natural outdoor shelters. In much of the area and in the immediate surroundings of the village of Ganda there were no cattle and virtually no other domestic animals, and it was clear that most of the population must be feeding on man. There were, however, one or two herds of cattle between the village and the swamps that were available as alternative sources of food. Although quantitative catches could not be done, collections on cattle while they were tethered outside at night yielded moderate numbers of *A. parensis*.

Day-time collections were made in one or two newly built unsprayed houses in which resting females of *A. parensis* could be found, and a very small number was sent for precipitin testing. Of 14 tested, 8 were positive for man, 1 for bovid, 1 for horse (presumably donkey) and 4 were negative.

Thus the general impression obtained—one cannot be more precise than that —was of catholic feeding habits with a preference for feeding outside. In the area studied, owing to the predominance of human hosts, much of the population must have been feeding on man. In districts where cattle are more numerous, however, it seems that contact with man is much less close. For instance, among 45 specimens of *A. parensis* caught resting outside in the Pare district of Tanganyika in 1962, only one contained human blood while 41 were positive for bovid.

Age composition

Dissections were made to determine the proportion of nulliparous females in the catches. The method of tracheolar examination of Detinova (1945) was mainly employed, the wings and ovaries being mounted dry on slides by assistants and kept for later study. Although a certain number of preparations could not be determined, owing to the ovaries' having reached Christophers' stage III of development, the method was on the whole satisfactory. The results are shown in Table VIII. It will be seen that there was little seasonal change in age composition during the five months of observations, which corresponded to the main season of emergence of the species. There was, however, a marked difference in the proportion of nullipars during the course of the night, catches taken during the first three hours (1800 to 2100 hr.) containing significantly higher percentages of young females than there were in later catches, while the late-night catches contained the fewest nullipars of all (Table IX).

TABLE IX. *Summary of age composition of catches of* A. parensis *in relation to time of night at which catch was made*

Period of night	Nulliparous	Total	% Nulliparous	χ^2	P
17–2100	462	674	68·5	15·2	< 0·01
21–2400	123	207	59·4	1·3	0·25
24–0300	86	144	59·5	0·56	0·5
03–0700	67	130	51·5	4·0	0·05
Total	738	1155	63·9		

A small series of dissections was also made on mosquitos caught outside the unsprayed village of Goshi. Of 177 specimens of *A. parensis* dissected, 50·2 per cent. were nulliparous, whereas of 261 specimens with *funestus*-like wings, the

majority of which would have been *A. funestus*, only 24·1 per cent. were nulliparous. The results differ so strikingly that, despite the small numbers dissected, they must be regarded as a reflection of different survival rates for the two species. The rather higher proportion of nullipars at Ganda may have been caused by the house-spraying, although this had taken place 7–11 months previously.

Infectivity

As pointed out above, this investigation into the biology of *A. parensis* was prompted by the need to establish its rôle, if any, in the transmission of malaria. In the sprayed zone no infections were found in 1,300 gland dissections made, and none was found in 36 from the unsprayed village. At the same time, 5 positive females of *A. funestus* were found amongst 71 collected in the latter village. The data on *A. parensis* are not conclusive, owing to the very large numbers of negative examinations that would have to be made before the species could be declared harmless. This is especially so in view of the low parasite rates in the sprayed area and the possibility of a continuing insecticidal effect in the houses. They do, nevertheless, indicate that its rôle as a vector must be at most a very minor one.

Discussion

These investigations have shown that, despite the very close taxonomic affinity of *A. parensis* with *A. funestus*, there are a number of striking differences in the behaviour of the two species. Thus *A. parensis* has a very different pattern of feeding, the biting cycle showing two peaks of activity, with the first three hours after sunset and the last three hours before sunrise accounting for about 60 per cent. of the total catch. By contrast, *A. funestus* shows little activity before 10 p.m., the main feeding taking place after midnight (Hanney, 1960; Hamon, Dédéwanou & Eyraud, 1962). Then *A. parensis* showed a much greater tendency to feed outdoors, the largest numbers having been caught in a sheltered spot outside the village. *A. funestus*, on the other hand, is well known as an indoor feeder, and most observers have found that catches made inside are slightly more productive than those made just outside houses and much more so than catches made away from villages. In this, *A. parensis* resembles the other members of the *funestus* group, such as *A. rivulorum* (Gillies & Smith, 1960). We did not obtain a clear picture of the resting habits of *A. parensis*, owing to the treatment of the houses with DDT. However, despite the presence of large numbers biting by night, only small numbers of mosquitos were caught resting by day in individual unsprayed houses. Thus on the whole *A. parensis* cannot be described as a domestic mosquito, a finding that adequately explains its persistence in large numbers after residual house-spraying.

In the Ganda area it was concluded that the majority of mosquitos must have been feeding on man owing to the scarcity of domestic animals. Where they are present in numbers, cattle are undoubtedly of major importance as hosts and contact with man is accordingly reduced.

The proportion of young females in populations of *A. parensis*, both in sprayed and unsprayed villages, was of a much higher order than in *A. funestus*, indicating the reduced longevity of the former species. While the expectation of life in the sprayed area may have been influenced by the presence of old deposits of DDT in the houses, the results clearly indicate that, with only 36 per cent. of the mosquitos parous, the chance of any surviving long enough to become infective was negligible. Hence *A. parensis* appeared to be incapable of acting as a vector of malaria in the Ganda area, a viewpoint that is strengthened by our failure to find any specimens with positive glands. A proper

assessment of its potentialities as a vector in unsprayed areas was not obtained, but the age composition of the small numbers dissected would argue against its being of more than marginal importance. It may be added that it seems probable that the positive specimens of the *funestus* group caught at Ganda in the early stages of the campaign were of *A. funestus sens.str.* that had flown into the village from the immediately adjacent unsprayed area. Thus it appears that *A. parensis* is of no greater medical significance than the other non-vector members of the *funestus* group. Its main significance for malaria entomologists lies in the possibility of confusion with *A. funestus*, leading to a mistaken impression of the persistence of this major vector in the face of attack by residual insecticides.

The presence of such large populations of *A. parensis* in the sprayed zone calls for some comment. Surveys in the Malindi area revealed the presence of the species in small numbers in nearly all the localities searched. Only at Goshi were appreciable numbers caught and, even here, they were far smaller than in Ganda. This raises the possibility that the high density of *parensis* was linked with the disappearance of *funestus*. Without data on pre-spraying densities one can come to no conclusion on this point. But in view of the change in balance between *A. rivulorum* and *A. funestus* observed in the Pare area after spraying (Gillies & Smith, 1960), one cannot avoid the suspicion that a similar release from competition with *funestus* may have affected *parensis*. At Malindi, the existence of very large seasonal swamps would favour the replacement of *funestus* by *parensis*, whereas the many streams and irrigational channels of Pare were more suited to increased production of *rivulorum*. *A. parensis* was never found breeding in running water, so that there would have been little chance for increase in its numbers in Pare district.

Summary

In investigations made in January to November 1962, *Anopheles parensis* Gillies was found biting man in large numbers in a zone near Malindi, Kenya, in which house-spraying with DDT had been carried out between March 1961 and October 1962. Densities were greatest just outside villages, less so on the verandah of a house and least indoors. In one open type of unsprayed house, however, moderately large numbers were caught. The monthly average catch per night by two men was greatest (over 200) outdoors in July and August.

Biting activity reached two peaks during the course of the night, catches in all situations being greatest during the two hours following sunset and the three hours preceding sunrise. The evening peak was highest in the outdoor catches, and the late-night peak in the indoor collections. A distinct influence of moonlight on the catches was observed, the early evening peak under certain conditions being greater during the moon's first quarter and the late-night peak during its last quarter.

Numbers of examples were caught biting cattle, but owing to the absence of large herds of stock it is believed that most feeding took place on man. The proportion of nulliparous females was 64 per cent. in the sprayed zone and 50 per cent. in an unsprayed village, and in the latter the nulliparous rate in females resembling *A. funestus* Giles (the majority of which would have been that species) was 24 per cent. No specimen of *A. parensis* infected with sporozoites was found in the sprayed zone. In the unsprayed village, no infected glands were found in a small series dissected. Thus no evidence was obtained that *A. parensis* was acting as an exophilous vector of malaria in the sprayed zone. Moreover, in view of the high nulliparous rate observed in the unsprayed area, this species is considered unlikely to be of any importance under normal conditions.

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