

MOSQUITOES AND COCONUT PALMS.

A MOSQUITO SURVEY OF PALM TREES IN EAST AFRICA AND THE
PROBLEMS RESULTING THEREFROM.

BY

W. E. HAWORTH, M.B., C.M., B.Sc. (Public Health).

Late Acting Director of The Laboratory, Dar-es-Salaam.

With an APPENDIX describing Two New Species of Mosquitoes from Coconut Palms in East Africa

By F. W. EDWARDS.

(Published by permission of the Trustees of the British Museum.)

CONTENTS.		PAGE
1.	THE DISCOVERY	162
2.	APPARATUS USED AND METHOD OF EXAMINATION	164
3.	TESTING THE RELIABILITY OF THE CLIMBER	165
4.	HATCHING, EXAMINATION AND RECORDING	170
5.	FEEDING THE LARVÆ	172
6.	EXTENT OF THE INVESTIGATION	172
7.	RESULTS OF HATCHING	173
8.	ANALYSIS OF THE RESULTS	175
9.	THE QUANTITY OF WATER OBTAINED... ..	178
10.	THE HEIGHT OF THE PALMS... ..	178
11.	SOURCE OF THE WATER	179
12.	EMERGENCE OF IMAGINES	182
13.	NUMBER OF IMAGINES PER COLLECTION	184
14.	DAILY OUTPUT OF MOSQUITOES	184
15.	COMPARISON WITH OTHER BREEDING-PLACES	185
16.	ANOPELES... ..	186
17.	ASSOCIATION IN BREEDING	187
18.	PERFECTION OF IMAGINES	188
19.	METEOROLOGICAL CONDITIONS	189
20.	ENEMIES OF LARVÆ AND PUPÆ	189
21.	HATCHING OF EGGS	190
22.	PECULIARITIES OF DIFFERENT SPECIES	190
23.	OTHER ASSOCIATES	191
24.	NEW SPECIES	191
25.	IDENTIFICATION OF SPECIES	191
26.	POSSIBLE SOURCES OF ERROR	192
27.	OTHER SPECIES FOUND AT THE STATIONS	192
28.	NOTES ON THE STATIONS	193
29.	GENERAL CONCLUSIONS	195
30.	PREVENTIVE MEASURES	196
31.	IN APPRECIATION OF ASSISTANCE	196
	APPENDIX	197

1. THE DISCOVERY.

The duties of Medical Officer of Health for the town and district of Tanga, Tanganyika Territory, were taken over by the author in June, 1920.

Anti-mosquito measures had already been instituted by the Senior Sanitation Officer, Lieut.-Colonel D. S. SKELTON, and work on the lines laid down was vigorously carried on by the staff of native inspectors acting under the energetic and enthusiastic Sanitary Superintendent, Mr. W. A. MOORE. As the months passed by, while recognising the probable assistance of a seasonal factor, we appeared justified in regarding ourselves as not unimportant elements in diminishing the insect pest for which the town had been infamous. To January of the following year there was a fairly steady reduction in the mosquito index, that is, the percentage of inhabited premises in which larvæ were found, and also in the total collections of larvæ secured. Thereafter, there was an increase in both figures, though by May they had not reached the level of the preceding July, the monthly records being as follows:—

	1920.						1921.				
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.
Mosquito Index ...	1·6	1·2	0·5	0·4	0·3	0·5	0·1	0·2	0·3	0·6	0·5
Total Collections of Larvæ ...	81	46	27	32	19	23	14	9	20	60	52

The number of mosquitoes in houses in the European portion of the town was noticed to increase considerably during February, March and April, and early in May it was remarked that, while the larvæ brought in by the inspectors from tanks, barrels, and other water receptacles in and about dwellings, during April and early May, were, with a solitary exception, *Stegomyia*, yet the imagines observed and caught in the houses were mainly *Culex*. A record of those killed by the Medical Officer of Health, in his residence, was not kept during the first half of the last-mentioned month, but the figures for the second half will give an idea of the reality of the pest and the prevalence of the *Culex*; from the 16th to the 31st of May, inclusive, the tally was:—

<i>Culex fatigans</i> ...	...	...	1,542
Other <i>Culex</i> ...	...	...	19
<i>Stegomyia</i> (probably <i>Aedes argenteus</i>)			2
<i>Anopheles mauritianus</i> ...	...	...	2

These observations pointed to the conclusion that the mosquitoes infesting houses must have breeding-places at least insufficiently inspected and controlled, and probably altogether outside the range of the routine anti-mosquito work. There were at the time, in and near the town, several large deposits of storm-water, resulting from heavy rains during April; these had been examined at frequent intervals, but on no occasion had larvæ been found, notwithstanding which, the largest and nearest to the European portion of the town had been treated with oil. In considering what unexplored nurseries the *Culex* might have, it seemed reasonable that rain might lodge in the tops of the coconut palms (*Cocos nucifera*), and there in the axils of the large eaves the female *Culex* might find congenial environment for egg-laying on

warm, still nights. A plan for the investigation of this was thought out, and the Sanitary Superintendent instructed to select from the labourers one expert at climbing. He chose a trolley-boy, Sefu bin Mbwana, who, on being told the nature of the work for which he was required, informed the Superintendent that on occasions he had seen water up in the tops of the palms. He was brought into the office and at once grasped the drawing up of water with his mouth into a rubber tube and thus transferring it from a glass into a bottle. Equipped with the rubber tube and bottles, he was taken out to the north-western portion of the inhabited area of the township by Native Sanitary Inspector David Marks, on the afternoon of 18th May. Twelve palms were examined, and bottles with water containing larvæ were brought in from two of them, that from one having been obtained from a step in the stem, and that from the other from amongst the leaves of the crown. From the latter collection the first imago emerged six days later and was identified as *Aedes argenteus*. The examinations were continued daily, the climber going out alone, being deemed intelligent and trustworthy, and the inspectors being required in the discharge of ordinary sanitation and port health duties.

2. APPARATUS USED AND METHOD OF EXAMINATION.

Sefu proved himself a most industrious and expert worker, using no artificial aids whatever in climbing, and though handicapped by the possession of only two pairs of appendages and the inability to spin a life-line, nevertheless he moved about amongst the leaves of the highest palms with the assurance and dexterity of a spider on her web. His rubber sucking-tube and bottles already have been mentioned; the former he discarded after a few days and replaced by about ten inches' length of the hollow leaf-stalk of the pawpaw (*Carica papaya*), which he found handier in use on account of its stiffness. The bottles were of many kinds, ranging in size from Messrs. Burroughs, Wellcome & Co.'s 100 "Tabloid" 5-grain quinine bottles to whisky and gin bottles of capacity six to the gallon, the most convenient being found to be 13-ounce beer and stout, and nip size, that is 6-ounce, stout bottles. They were washed by the climber prior to use, and usually were carried in a basket made by him from the plaited leaflets of the coconut palm. His clothing, at work, was an undervest and pair of khaki shorts.

When proceeding to climb, he stuck the sucking-tube in a bottle and carried up the latter, either in a hip pocket in his shorts or secured to his belt by a piece of cord tied round its neck. He does not climb the stem in the manner described on pages 164 and 165 of "The Coconut Palm," by H. C. SAMPSON, C.I.E., B.Sc., which method, by drawing up the feet while clinging with the hands, forearms, and chest pressed against the stem, is that regularly used by natives engaged in cutting down the nuts when gathering the crop in East Africa, though here the loop of rope is placed not over the insteps but round the ankles, and no ladder is used. Sefu, however, dispenses with the rope and does not hug the stem, but, placing his hands round the far side, literally walks up the near side, shifting his hands higher as he proceeds, now and then stopping to rest by placing the inner side of the sole

of one foot against the stem he hangs on, leaning out from the stem with one hand passed round one side of it and the instep of the other foot round the other side, often in this position, when descending, employing his free hand to brush off ants which have attacked his legs and body: only very occasionally, when the stem is smooth or slippery with wet, does he change his method to clasping the stem to his chest and drawing up his legs, to take a higher hold with his thighs and the inner aspect of the soles of his feet pressed to its sides.

Having reached the crown, he climbs on to the large leaves and explores their axils by sight and pushing down his fingers, or a twig or strip of leaf, to ascertain whether moisture is present; being satisfied on this point, he places the bottle and tube securely in the axil of a higher leaf, and, with his face towards the centre of the crown, sits astride the leaf to be examined and forces its stalk away from the stem by pressing on the latter with his feet, aided by swaying the leaf up and down with his weight, and tearing away with his hands the dry fibrous stipules; the flowering branch, if present, is forced aside, or if dry and decaying is twisted out and thrown down; admission to the axil having thus been made free, he clears away the débris, consisting mainly of dry male flowers, and by suction with his mouth to the tube draws up any water found in the axil and transfers it to the bottle. After examining the other leaves in the same way, the descent is made by a reverse procedure to the ascent, that is, by walking backwards down the stem; the time taken over one palm, from leaving the ground to again reaching it, varying from a quarter to half-an-hour. At the end of the spell of work he brought the bottles, usually six to ten for the half-day, to the office, where he plugged the mouth of each with cotton-wool and gummed on its side a piece of blank paper to serve as a label.

3. TESTING THE RELIABILITY OF THE CLIMBER.

Sefu bin Mbwana, as a trolley-boy, had borne a good character, and Native Inspector David Marks, who supervised his work as climber on the first day, was esteemed for his honesty and diligence; the latter, on returning to the office to report and hand in the collections, stated that he had witnessed Sefu climb a coconut palm with an empty bottle, at work in the crown of it, and from it bring down the bottle, containing water with living larvæ, which, as already related, subsequently yielded *A. argenteus* imagines; and Sefu was emphatic in his statement that he had got all the water from the crown, and it may be explained that then, and for a considerable time subsequently, the latter had no knowledge of larvæ and knew only that his work was to search for water and, when obtained, bring it in to the office as instructed. As he continued with his work and brought larvæ from an appreciable proportion of the palms according to his reports, it became still further of interest to witness his methods and secure indisputable evidence of the source of the larvæ. It was not anticipated there would be any difficulty in this, and he was, as occasion offered, now and then visited and inspected at his work, by both the Medical Officer of Health and the Sanitary Superintendent, without his

taken out by trolley to the last house on the right-hand side nearing the golf course. Here three trees were examined near a pig-sty, and water without larvæ got only from the third. A move was then made across some cultivated ground to a small village, about a quarter of a mile nearer town. Four trees were examined, larvæ being obtained from the first and second, and water only from the other two. The first was No. 285, in which the larvæ hatched out as *Culex*. The second was No. 284. It contained only one larva, the imago of which proved to be a *Megarhina*.

"On the morning of the 8th the climber, after getting one lot of larvæ and three of water from eight trees on the municipal area, was taken out by trolley about half-way to the golf course, and to a small village on the south side of the railway. In addition to strict observance of all the other conditions, he was searched prior to ascending the first tree chosen. While he was at work amongst the leaves some dead nuts and leaves fell. They were examined, the former being quite dry inside, and the latter only slightly damp at the bases. Water was brought down in the bottle, containing many larvæ and some pupæ. He was again searched and his sucking-tube washed out with boiled water. This tube is the hollow stem of a plant, and is about 10in. long. It was adopted by the climber soon after commencing the work in May, being found handier than the rubber tube. The second tree yielded a little water only. After being searched again and the sucking-tube washed out with boiled water, he was sent up a third tree. While climbing the stem some thirty or so bats flew out of the top. This added to the interest with which his return to earth was awaited. This tree was distant thirteen paces from the first. Its stem was judged to be about 40 feet, and that of the first about 45 feet. About 2½oz. of water containing one larva was brought down. A fourth tree examined yielded water without larvæ. From the base of the first tree examined this day 233 other well-grown coconut palms were counted, and many small ones were also in sight; although the view was partly obstructed by eight native houses and three mango trees. The bottles from the first and third trees were numbered 307 and 308 respectively, and the imagines hatched out from both were identified as *S. calopus*."

The examination of many other coconut palms was witnessed subsequently by the author at Tanga, and at each of the other stations, but after leaving Tanga the use of sterilized bottles was given up, and usually the climber was not taken away from the area where, at the time, he may have been working, though he was searched and the bottle and sucking-tube examined prior to his ascent. From and including the morning of 6th July, 1921, the author personally supervised the examination of palms at the various stations on fifty-four separate occasions, on forty-seven of which living larvæ or pupæ, and on three dead larvæ, were obtained, the four when water only was obtained being at Kismayu, at Mombasa, when during the return journey one palm previously yielding dead larvæ was examined, at Mafia, and at Kilwa Kiswani.

Particulars of the number of palms, the examination of which was personally witnessed by the author, and from which living mosquito larvæ or pupæ were obtained, are here set out, with the number of collections of water in which living imagines subsequently developed:—

	Tanga	Dar-es-Salaam	Zanzibar	Mombasa	Lindi	Mikindani	Total
Number of Palms... ..	19	12	3	5	71	3	113
Collections in which all Larvæ or Pupæ died, or from which only Dead Imagines were secured ...	4	3	(2 collections not retained)	2 (also 1 collection not retained)	22	Nil	31
<i>Anopheles costalis</i>	—	—	—	—	2	—	2
<i>Megarhinus brevipalpis</i>	1	—	—	—	—	—	1
<i>Eretmopodites quinquerrittatus</i>	—	—	—	—	1	—	1
<i>Aedes argenteus</i>	3	8	—	1	31	—	43
<i>Aedes simpsoni</i>	—	—	—	—	9	—	9
<i>Aedes metallicus</i>	—	2	—	—	—	—	2
<i>Aedes albocephalus</i>	—	—	—	—	2	—	2
<i>Lutzia tigripes</i>	4	—	—	—	2	—	6
<i>Culex fatigans</i>	9	—	1	2	18	3	33
<i>Culex decens</i>	—	—	—	—	1	—	1
<i>Culex decens</i> var. <i>invidiosus</i>	1	—	—	—	—	—	1
<i>Culex nebulosus</i>	—	2	—	—	1	—	3
<i>Culex horridus</i> (probably)	1	—	—	—	—	—	1
<i>Culex sitiens</i> or <i>Culex decens</i> var. <i>invidiosus</i>	—	—	—	—	2	—	2

On a number of these occasions there were present with the author colleagues, officials, or other friends who witnessed the examinations; arranged chronologically they were:—

		Palms
Dr. Vos, Leyden University, Surgeon of S.S. Netley Abbey.	Tanga, 12th Sept., 1921.	2
Dr. G. G. BUTLER, M.B.E., M.D., Director of Laboratory	Dar-es-Salaam, } 26th Jan., 1922. }	1
Dr. R. R. SCOTT, M.C., M.R.C.S., M.O.H., Dar-es-Salaam.		
Mr. FISHER, Government Dentist.		
Lt.-Col. D. S. SKELTON, D.S.O., Sen. Sanitation Officer	Dar-es-Salaam, 20th Feb., 1922	2
Miss M. E. SPENCER	Dar-es-Salaam, 22nd June, 1922	1
Miss M. E. SPENCER	Dar-es-Salaam, 1st July, 1922	1
Dr. W. MANSFIELD ADERS, D.Sc., Zanzibar Gov. Service.	Zanzibar, } 22nd Sept., 1922 }	2
Mr. GRANT, Plantations Department, Zanzibar.		
Dr. R. HUNTER, M.O.H., Mombasa	Mombasa, 25th Sept., 1922	1
Wazir CHAND, Sub-Assistant Surgeon	Mombasa, 25th Sept., 1922	5
Major ORD BROWNE, Senior Commissioner	Lindi, 9th Nov., 1922	2
Mr. MACEDO, Sub-Assistant Surgeon	Lindi, 18th Dec., 1922	3
Major CADIZ, Acting Senior Commissioner	Lindi, 31st Jan., 1923	1
Mr. C. V. NICOLLE, Supervisor of Customs	Lindi, 23rd Feb., 1923	1
Mr. W. W. CALLANDER, Manager, Standard Bank of South Africa	Lindi, 13th March, 1923	3
Mr. J. H. EARLEY, Cashier, Standard Bank of South Africa	Lindi, 13th March, 1923	2
Mr. H. V. THEAKSTON, Junr. Staff Surveyor	Lindi, 17th May, 1923	2
Dr. J. B. DAVEY, Principal Medical Officer	Dar-es-Salaam, 14th Jan., 1924...	1

taken out by trolley to the last house on the right-hand side nearing the golf course. Here three trees were examined near a pig-sty, and water without larvæ got only from the third. A move was then made across some cultivated ground to a small village, about a quarter of a mile nearer town. Four trees were examined, larvæ being obtained from the first and second, and water only from the other two. The first was No. 285, in which the larvæ hatched out as *Culex*. The second was No. 284. It contained only one larva, the imago of which proved to be a *Megarhina*.

“On the morning of the 8th the climber, after getting one lot of larvæ and three of water from eight trees on the municipal area, was taken out by trolley about half-way to the golf course, and to a small village on the south side of the railway. In addition to strict observance of all the other conditions, he was searched prior to ascending the first tree chosen. While he was at work amongst the leaves some dead nuts and leaves fell. They were examined, the former being quite dry inside, and the latter only slightly damp at the bases. Water was brought down in the bottle, containing many larvæ and some pupæ. He was again searched and his sucking-tube washed out with boiled water. This tube is the hollow stem of a plant, and is about 10in. long. It was adopted by the climber soon after commencing the work in May, being found handier than the rubber tube. The second tree yielded a little water only. After being searched again and the sucking-tube washed out with boiled water, he was sent up a third tree. While climbing the stem some thirty or so bats flew out of the top. This added to the interest with which his return to earth was awaited. This tree was distant thirteen paces from the first. Its stem was judged to be about 40 feet, and that of the first about 45 feet. About 2½ oz. of water containing one larva was brought down. A fourth tree examined yielded water without larvæ. From the base of the first tree examined this day 233 other well-grown coconut palms were counted, and many small ones were also in sight; although the view was partly obstructed by eight native houses and three mango trees. The bottles from the first and third trees were numbered 307 and 308 respectively, and the imagines hatched out from both were identified as *S. calopus*.”

The examination of many other coconut palms was witnessed subsequently by the author at Tanga, and at each of the other stations, but after leaving Tanga the use of sterilized bottles was given up, and usually the climber was not taken away from the area where, at the time, he may have been working, though he was searched and the bottle and sucking-tube examined prior to his ascent. From and including the morning of 6th July, 1921, the author personally supervised the examination of palms at the various stations on fifty-four separate occasions, on forty-seven of which living larvæ or pupæ, and on three dead larvæ, were obtained, the four when water only was obtained being at Kismayu, at Mombasa, when during the return journey one palm previously yielding dead larvæ was examined, at Mafia, and at Kilwa Kiswani.

Particulars of the number of palms, the examination of which was personally witnessed by the author, and from which living mosquito larvæ or pupæ were obtained, are here set out, with the number of collections of water in which living imagines subsequently developed:—

	Tanga	Dar-es-Salaam	Zanzibar	Mombasa	Lindi	Mikindani	Total
Number of Palms...	19	12	3	5	71	3	113
Collections in which all Larvæ or Pupæ died, or from which only Dead Imagines were secured ...	4	3	(2 collections not retained)	2 (also 1 collection not retained)	22	Nil	31
<i>Anopheles costalis</i> ...	—	—	—	—	2	—	2
<i>Megarhinus brevipalpis</i> ...	1	—	—	—	—	—	1
<i>Eretmopodites quinquevittatus</i> ...	—	—	—	—	1	—	1
<i>Aedes argenteus</i> ...	3	8	—	1	31	—	43
<i>Aedes simpsoni</i> ...	—	—	—	—	9	—	9
<i>Aedes metallicus</i> ...	—	2	—	—	—	—	2
<i>Aedes albocephalus</i> ...	—	—	—	—	2	—	2
<i>Lutzia tigripes</i> ...	4	—	—	—	2	—	6
<i>Culex fatigans</i> ...	9	—	1	2	18	3	33
<i>Culex decens</i> ...	—	—	—	—	1	—	1
<i>Culex decens</i> var. <i>invidiosus</i> ...	1	—	—	—	—	—	1
<i>Culex nebulosus</i> ...	—	2	—	—	1	—	3
<i>Culex horridus</i> (probably) ...	1	—	—	—	—	—	1
<i>Culex sitiens</i> or <i>Culex decens</i> var. <i>invidiosus</i> ...	—	—	—	—	2	—	2

On a number of these occasions there were present with the author colleagues, officials, or other friends who witnessed the examinations; arranged chronologically they were:—

		Palms
Dr. Vos, Leyden University, Surgeon of S.S. Netley Abbey.	Tanga, 12th Sept., 1921.	2
Dr. G. G. BUTLER, M.B.E., M.D., Director of Laboratory	Dar-es-Salaam, } 26th Jan., 1922. }	1
Dr. E. R. SCOTT, M.C., M.R.C.S., M.O.H., Dar-es-Salaam.		
Mr. FISHER, Government Dentist.		
Lt.-Col. D. S. SKELTON, D.S.O., Sen. Sanitation Officer	Dar-es-Salaam, 20th Feb., 1922	2
Miss M. E. SPENCER	Dar-es-Salaam, 22nd June, 1922	1
Miss M. E. SPENCER	Dar-es-Salaam, 1st July, 1922	1
Dr. W. MANSFIELD ADERS, D.Sc., Zanzibar Gov. Service.	Zanzibar, } 22nd Sept., 1922 }	2
Mr. GRANT, Plantations Department, Zanzibar.		
Dr. R. HUNTER, M.O.H., Mombasa	Mombasa, 25th Sept., 1922	1
Wazir CHAND, Sub-Assistant Surgeon	Mombasa, 25th Sept., 1922	5
Major ORD BROWNE, Senior Commissioner	Lindi, 9th Nov., 1922	2
Mr. MACEDO, Sub-Assistant Surgeon	Lindi, 18th Dec., 1922	3
Major CADIZ, Acting Senior Commissioner	Lindi, 31st Jan., 1923	1
Mr. C. V. NICOLLE, Supervisor of Customs	Lindi, 23rd Feb., 1923	1
Mr. W. W. CALLANDER, Manager, Standard Bank of South Africa	Lindi, 13th March, 1923	3
Mr. J. H. EARLEY, Cashier, Standard Bank of South Africa	Lindi, 13th March, 1923	2
Mr. H. V. THEAKSTON, Junr. Staff Surveyor	Lindi, 17th May, 1923	2
Dr. J. B. DAVEY, Principal Medical Officer	Dar-es-Salaam, 14th Jan., 1924...	1

In the case of the examinations witnessed by Dr. ADERS and Mr. GRANT, we did not recognize the presence of larvæ till the bottles were brought to the Public Health Laboratory, where they were seen by both Dr. ADERS and the author; this occurred also in the examination witnessed by Dr. DAVEY, and the author alone saw the larvæ when inspecting the collection at the Laboratory; in all other cases the presence of living larvæ and pupæ was observed as soon as the climber came down from the crown of the palm.

On 11th October, 1923, Mr. W. A. MOORE, at the time Sanitary Superintendent at Tabora and on leave in Dar-es-Salaam, witnessed Sefu examine and bring down water containing living larvæ from three coconut palms.

At Lindi, on 6th February, 1923, the author, while witnessing the examination of a palm, the collection of water from which was afterwards numbered 1,085, observed Sefu sucking with the tube and then water running from the end of it into the bottle; this showed up very clearly, the bottle having the bright sky for a background.

The last piece of evidence may be submitted by quoting notes made on the day of the experience, immediately after returning to the hospital; it happened in Lindi: "1,474. At about 10.3 a.m., 8.3.23, after witnessing examination of 1,472 and 1,473, sent climber up a palm with shallow steps, telling him to inform me if he found water. These three palms were in compound of native house belonging to, and occupied by, Bakari bin Selimu, on small cross-road just behind U.M.C.A. rest house. After examining several leaves, Sefu told me he had found water. Taking off coat, vest, and hat, I climbed the palm by the steps and got amongst the leaves, and there, on the opposite side to the steps, saw a small pool of water in the little basin where the large leaf joins the stem. Between the stem and leaf was the stem of a flower branch. Getting close down I saw numerous larvæ in the water. Then sent Sefu down to get a small mirror out of my jacket pocket. With it I reflected the sunlight on to the water and, with a magnifying-glass, made out the larvæ very distinctly. Sefu then sucked up the water in my presence and transferred it to the bottle. This palm grew at the edge of the house verandah, had one bunch of nuts, and had a tube and nutshell fixed for drawing off the juice. We then descended, and on examining the water in the bottle I again saw the larvæ. The quantity of water was about $\frac{1}{2}$ oz. At the bottom of the water was a thick mud of vegetable débris."

4. HATCHING, EXAMINATION, AND RECORDING.

On the day of collection when possible, and usually as soon as plugged and labelled, each bottle was examined by the author by holding it up sloped in front of a window and surveying the water through a lens. An identification number was then put on the label, and also entered in the record book with the date, place of collection, number of palms examined in the half-day, number from which water was obtained both with and without larvæ, and any other particulars considered of interest. The bottles were then put aside to

wait for hatching out of the imagines. In Tanga they were placed on shelves against the inside wall of the office, where they were not exposed immediately to strong light from the windows; in Dar-es-Salaam on the work-tables in front of the windows in the entomological room, where they were exposed to strong light, but not to the direct rays of the sun, except the necks only of some of them for an hour or two each morning; and in Lindi on a table in a similar position in the hospital operating theatre, which was at the time awaiting repairs. The bottles were examined for imagines daily if time permitted; in Tanga and in Dar-es-Salaam, in 1922, a daily inspection was usually made; in Lindi all collections were examined regularly each morning and afternoon, with the exception of two days on which one inspection only was made, and two days, 25th and 27th June, 1923, just prior to leaving that station, when no examinations were undertaken; in Dar-es-Salaam, in 1923, during the greater portion of the investigation, time was not found for examinations beyond the initial one to determine the presence or absence of larvæ. The method of ascertaining the presence of imagines was to lift the bottle by the neck with one hand and tap it smartly on the side with the fingers of the other, upon which the insects were readily seen to fly up if they had been resting on the lower parts of the sides or on the surface of the water. When imagines were detected, a large test-tube was taken up and held near the mouth of the bottle, from which the plug was withdrawn and the test-tube quickly applied; a few taps on the side of the bottle then usually drove the mosquitoes out into the tube, which was plugged with cotton-wool, the plug replaced in the bottle, the latter put down on the table, the tube plug eased up and a drop of chloroform put on its lower part; the insects were quickly killed without damage, and then were tipped out into a petri dish, standing on a sheet of white paper, and examined with a lens. For more detailed inspection a microscope with $\frac{1}{2}$ in. or $\frac{3}{8}$ in. objective was used. Known species were entered in the record by their names and any unknown one by a number, usually that of the first bottle from which it was obtained. The particulars entered in the record were the name of the species and the date on which the first living imago of the species was obtained from the collection; at the same time was recorded on the bottle label the name and the number of living individuals of each species secured from the bottle at that examination. Specimens for identification were pinned at the time and put away labelled in collection boxes, descriptive notes being recorded in a separate note-book of any which appeared to differ from species previously obtained. When larvæ or pupæ no longer were detected in any bottle, the contents were poured out into a white enamelled dish and carefully searched with a lens; if any were found, they were poured back with the water into the bottle and the latter replaced for further observation; if none were detected, the total number of each species obtained from that collection was made up from the label and entered in the record book, with the date of discarding, and the bottle was put aside for washing and use again by the climber.

It was only in Lindi that all the particulars mentioned were regularly recorded. In Tanga and in Dar-es-Salaam, in 1922, the number of individuals secured was not kept, and during the greater part of the second spell of work

in the latter town no record was attempted beyond the palms examined, and the number of them which yielded water with and without larvæ.

5. FEEDING THE LARVÆ.

In Tanga, from 1st September, till the termination of work at that station, a few grains of uncooked rice were put in each bottle after the first living imago was secured from it, but never previous to this; and usually at all stations at which the investigation was undertaken, whenever a collection was found to contain *Megarhinus* and no other larvæ or pupæ, *Culex*, *Stegomyia* or *Eretmopodites* larvæ were transferred to it from collections brought in by the native inspectors in the course of their routine anti-mosquito work, or occasionally, at Tanga and Dar-es-Salaam only, from other collections from coconut palms; otherwise on no occasion was food supplied or anything else added to any collection. A pipette or length of glass tubing was found convenient for transferring the larvæ.

6. EXTENT OF THE INVESTIGATION.

In Time and Space.—The investigation was carried on as continuously as possible from the date of the discovery, 18th May, 1921, till 22nd January, 1924, the day before embarking on home leave. Throughout this period, palms were examined daily, except on Sundays and holidays, with occasional breaks arising from sickness of the climber, his absence on leave, or travelling between stations. From 18th May to 17th December, 1921, the work was done in Tanga; from 24th January to 7th August, 1922, in Dar-es-Salaam; next, during a coastal trip on local leave, at Zanzibar, Mombasa, Lamu, and Kismayu, and again, during the return journey, at Lamu and Mombasa; then, after returning from leave and while voyaging to Lindi, at Dar-es-Salaam, Mafia, and Kilwa Kiswani; from 23rd October, 1922, to 25th June, 1923, at Lindi, during which period examinations were made also at Mikindani, during an official trip, and at Tanga, when the climber was given a holiday to visit his home; and lastly, from 3rd July, 1923, to 22nd January, 1924, again at Dar-es-Salaam. The investigation, therefore, extended in time over more than two years and eight months, and in space, roughly from near the equator to beyond 10° south latitude, between which approximate limits extends the coast-line of Kenya Colony and Tanganyika Territory, along which and on adjacent islands investigations were made at, and in the neighbourhood of, ten separate stations.

Number of Palms Examined and Collections of Water and Larvæ Therefrom.—These, in the order of examination as described above, at the various stations were as follows:—

STATION.	NUMBER OF PALMS EXAMINED.	PALMS YIELDING WATER.	
		Without living larvæ or pupæ.	With living larvæ or pupæ.
Tanga	2889	275	1406
Dar-es-Salaam, 1922	2412	21	2286
Zanzibar	10	6	3
Mombasa	11	5	5
Lamu	9	8	—
Kismayu	6	6	—
Lamu	4	4	—
Mombasa, re-examination	1	1	—
Dar-es-Salaam	10	—	10
Mafia	4	4	—
Kilwa Kiswani	3	1	—
Lindi	2760	11	2152
Mikindani... ..	5	—	5
Lindi, re-examination	6	1	4
Tanga, re-examination	18	—	14
Dar-es-Salaam, 1923	1943	17	1580
Dar-es-Salaam, re-examinations at short intervals	291	1	282
TOTAL	10382	361	7747

Of the 361 collections in the second column thirty-five contained dead larvæ or pupæ, namely, four at Tanga, six at Dar-es-Salaam in 1922, four at Mombasa, six at Lamu, four at Lindi, and eleven at Dar-es-Salaam in 1923; and at Dar-es-Salaam pupa cases were found in one collection in 1922 and in one in 1923.

7. RESULTS OF HATCHING.

Death of Larvæ.—In some bottles all larvæ and pupæ died, or imagines were found only after their death; the number of collections in which this occurred at the various stations was as follows:—

Tanga	113
Dar-es-Salaam, 1922	142
Zanzibar... ..	2
Mombasa	2
Dar-es-Salaam	Nil
Lindi	181
Mikindani	1
Lindi, re-examinations	2
Tanga, re-examinations	Nil
Dar-es-Salaam, 1923 ... ..	...Not recorded
Do. re-examinations at short intervals	19
Total	462

SPECIES OF WHICH LIVING IMAGINES WERE SECURED, AND NUMBER OF COLLECTIONS IN WHICH THEY WERE OBTAINED, AT EACH STATION.

	Tanga.	Dar-es-Salaam, 1922.	Zanzibar.	Mombasa.	Dar-es-Salaam.	Lindi.	Mikindani.	Lindi, re-examinations.	Tanga, re-examinations.	Dar-es-Salaam, 1923.	Dar-es-Salaam, 1923-24, re-examination.	TOTAL.
<i>Anopheles costalis</i> , THEO. ...	5	13	—	—	—	39	—	—	—	—	—	57
" <i>pretoriensis</i> , GOUGH	—	1	—	—	—	—	—	—	—	—	—	1
<i>Megarhinus brevipalpis</i> , THEO.	19	39	—	—	—	—	—	—	3	1	—	62
<i>Eretmopodites quinquevitatus</i> , THEO. ...	—	30	—	—	—	33	—	—	—	—	—	63
<i>Eretmopodites chrysogaster</i> , var. <i>subsimplificipes</i> , EDW.	—	—	—	—	—	72	—	—	—	—	—	72
<i>Aedes argenteus</i> , POIRET ...	238	1819	—	1	10	1361	—	2	—	180	191	3802
" <i>simpsoni</i> , THEO. ...	64	53	—	—	—	413	—	2	—	9	2	543
" <i>metallicus</i> , EDW. ...	14	277	—	—	—	44	—	—	—	48	53	436
" <i>calceatus</i> , EDW. ...	—	—	—	—	—	46	—	—	—	—	—	46
" <i>soleatus</i> , EDW. ...	—	—	—	—	—	—	—	—	—	2	—	49
" <i>pseudonigeria</i> , THEO. ...	—	—	—	—	—	—	—	—	1	—	—	1
" <i>rittatus</i> , BIG. ...	—	—	—	—	—	2	—	—	—	—	—	2
" <i>fulgens</i> , EDW. ...	1	6	—	—	—	1	—	—	—	—	—	8
" <i>fasciipalpis</i> , EDW. ...	—	—	—	—	—	1	—	—	—	—	—	1
" <i>adersi</i> , EDW. ...	3	12	—	—	—	1	—	—	—	—	—	16
" <i>albocephalus</i> , THEO. ...	—	—	—	—	—	19	—	—	—	—	—	19
" <i>haworthi</i> , EDW. ...	15	—	—	—	—	—	—	—	—	—	—	15
<i>Lutzia tigripes</i> , G. & C. ...	110	—	—	—	—	19	—	1	—	4	—	134
<i>Culex sitiens</i> , WIED. ...	—	—	—	—	—	7	—	—	—	—	—	7
" <i>trifoliatus</i> , EDW. ...	4	—	—	—	—	—	—	—	—	—	—	4
" <i>duttoni</i> , THEO. ...	5	—	—	—	—	7	—	—	—	—	—	12
" <i>fatigans</i> , WIED. ...	1158	255	1	2	—	841	4	1	14	60	18	2354
" <i>univittatus</i> , THEO. ...	1	—	—	—	—	3	—	—	—	—	—	4
" <i>decens</i> , THEO. ...	—	—	—	—	—	90	—	1	1	44	64	200
" " var. <i>invidiosus</i> , THEO.	63	—	—	—	—	—	—	—	—	—	—	63
" <i>simpsoni</i> , THEO. ...	—	—	—	—	—	20	—	—	—	—	—	20
" <i>nebulosus</i> , THEO. ...	35	723	—	—	—	13	—	—	—	15	—	786
" <i>horridus</i> , EDW. ...	1	1	—	—	—	14	—	—	1	—	—	17
Species inconclusive	10	—	—	—	—	—	—	—	—	—	—	10
Specimens escaped, unidentified	2	4	—	—	—	—	—	—	—	—	—	6
" lost ...	—	53	—	—	—	—	—	—	—	—	—	53
<i>Culex decens</i> var. <i>invidiosus</i> or <i>Culex sitiens</i> , or both (some specimens from these collections became mixed) ...	—	—	—	—	—	71	—	—	—	—	—	71
TOTALS ...	1748	3286	1	3	10	3117	4	7	19	364	328	8887

8. ANALYSIS OF THE RESULTS.

At eight of the stations, time permitted of the examination of so few palms that reliable general conclusions can not justifiably be based on an analysis of the results; and, during the greater part of the period of working in Dar-es-Salaam, in 1923, the observations made and recorded permit of little further investigation than the percentage of palms yielding water with and without larvæ; the detailed analysis following is, therefore, limited to the collections in Tanga, Dar-es-Salaam in 1922, and Lindi. When leaving Tanga, in December, 1921, the bottles, twenty-eight in number, still containing living larvæ, were handed over to Major ROBERT NIXON, M.B., Ch.B., D.T.M., D.P.H., the incoming Medical Officer of Health, who very kindly continued the observations and reported the results; but one bottle, from which no imagines had emerged, and still containing living larvæ, was lost when shifting to new office premises, shortly after the commencement of the work. In Dar-es-Salaam, three bottles, and in Lindi, thirty-three bottles, from none of which imagines had been secured, having not long been collected, but all containing living larvæ, were left behind. These collections, thirty-seven in all at the three stations, have been included in the analysis, although observations on them were not completed, as it is desired to show only results actually obtained; therefore, whatever they might have produced would have been in addition to the percentage shown as yielding imagines.

NAME OF STATION.	PERCENTAGE OF PALMS.		
	Yielding Water.	Yielding Living Larvæ or Pupæ.	Yielding Living Imagines.
Tanga	58.2	48.7	44.7
Dar-es-Salaam	95.6	94.8	88.8
Lindi	78.4	78.0	70.2

The figures for Tanga would, no doubt, be higher, but there, during the earlier part of the investigation, the climber naturally was not so expert as he became later, and also at first included in his examinations a large number of very young palms, which had not yet formed a stem; such were not examined later, as it was found they yielded water only occasionally for a little while after rain had fallen.

A striking feature shown by the percentages in the following table (see page 176) is the unequal distribution of the two commonest species, both proved disease-carriers, namely, *Aedes argenteus* and *Culex fatigans*. To test the probability of this being a seasonal variation, the weekly percentage of each has been calculated for the three stations.

For graphic representation and more ready comparison these percentages have been charted on one sheet (see page 177).

PERCENTAGE OF PALMS EXAMINED YIELDING EACH SPECIES.

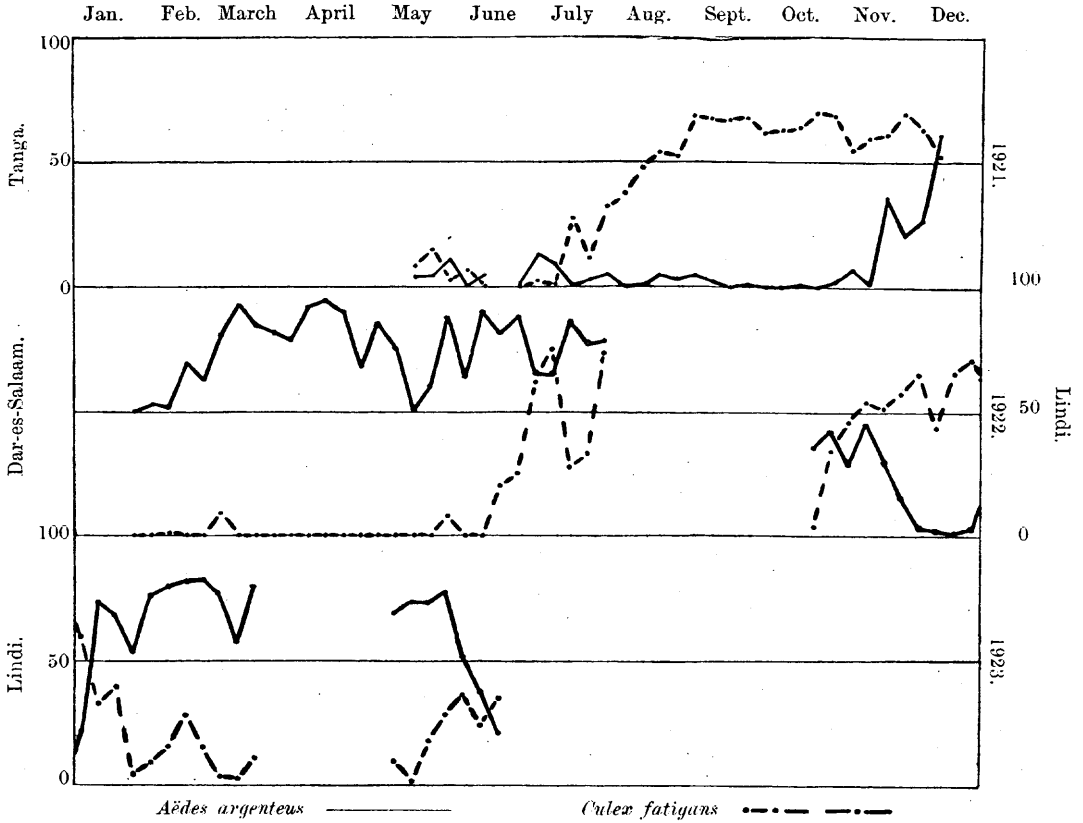
	Tanga.	Dar-es-Salaam.	Lindi.
<i>Anopheles costalis</i> , THEO.	0·17	0·54	1·41
.. <i>pretoriensis</i> , GOUGH	—	0·04	—
<i>Megarhinus brevipalpis</i> , THEO.	0·66	1·62	—
<i>Eretmopodites quinquevittatus</i> , THEO.	—	1·24	1·20
.. <i>chrysogaster</i> , var. <i>subsimplicipes</i> , EDW.	—	—	2·61
<i>Aedes argenteus</i> , POIRET	8·24	75·41	49·31
.. <i>simpsoni</i> , THEO.	2·22	2·20	14·96
.. <i>metallicus</i> , EDW.	0·48	11·48	1·59
.. <i>calceatus</i> , EDW.	—	—	1·67
.. <i>soleatus</i> , EDW.	—	—	—
.. <i>rittatus</i> , BIG.	—	—	0·07
.. <i>fulgens</i> , EDW.	0·03	0·25	0·04
.. <i>fascipalpis</i> , EDW.	—	—	0·04
.. <i>adersi</i> , EDW.	0·10	0·50	0·04
.. <i>albocephalus</i> , THEO.	—	—	0·69
.. <i>haworthi</i> , EDW.	0·52	—	—
<i>Lutzia tigris</i> , G. & C.	3·81	—	0·69
<i>Culex sitiens</i> , WIED.	—	—	0·25
.. <i>trifolius</i> , EDW.	0·14	—	—
.. <i>duttoni</i> , THEO.	0·17	—	0·25
.. <i>fatigans</i> , WIED.	40·08	10·57	30·47
.. <i>univittatus</i> , THEO.	0·03	—	0·11
.. <i>decens</i> , THEO.	—	—	3·26
.. var. <i>invidiosus</i> , THEO.	2·18	—	—
.. <i>simpsoni</i> , THEO.	—	—	0·72
.. <i>nebulosus</i> , THEO.	1·21	29·98	0·47
.. <i>horridus</i> , EDW.	0·03	0·04	0·51
Species inconclusive	0·35	—	—
.. escaped, unidentified	0·07	0·17	—
<i>Culex decens</i> var. <i>invidiosus</i> , and <i>Culex sitiens</i>	—	—	2·57

From Chart 1 (page 177) it appears possible there may be a general seasonal frequency of the two species, that is, one applicable to the three stations, namely, that from some meteorological condition or set of conditions, the months from January to June inclusive may be more favourable for the breeding of *A. argenteus* than of *C. fatigans*, and during the second six months of the year, more particularly in August, September and October, the latter species may be more favoured than the former. Other observations, however, fail to support the suggestion:—

1. On 10th October, 1922, the climber was sent across Dar-es-Salaam harbour, quite away from the more inhabited portion of the township area, the latter being the sphere of all previous and all subsequent investigations, and there near the shore, between the Pilot Station and some old military stores, examined ten palms, all of which yielded water with living larvæ, from which *A. argenteus* imagines and no other species developed.

2. On 3rd May, 1923, the climber, on leave in Tanga, examined on the municipal area eighteen palms—previously examined in the period July 5th to 15th inclusive, 1921—the result on the later date being fourteen collections of water with living larvæ developing *C. fatigans* imagines from all, *C. decens*

CHART 1.



and *C. horridus* each from one, *M. brevipalpis* from three, and *A. argenteus* from none.

3. When working in Dar-es-Salaam, in 1923, the observation and identification of imagines was almost confined to the bottles brought in during July and the last three weeks of December, and of those examined the former period yielded, besides other species, *A. argenteus* in 103 and *C. fatigans* in 51, and the latter in 77 and 9 respectively.

4. Re-examinations at short intervals of small groups of palms, from 24th December, 1923, to 22nd January, 1924, gave, besides other species, *A. argenteus* from 191 and *C. fatigans* from eighteen of those collections, on which observation was continued till imagines appeared. While not admitting that these investigations have either proved or disproved the existence of a seasonal frequency in breeding—for it may be that the factors of space, time, and material were all too limited, and the two first-named too broken, to afford evidence of its influence—yet it is considered that the irregularities in frequency with which the various species were found more probably arise from unequal distribution in space; that, in the equable climate in which the coco-

nut palm flourishes, breeding of all species is proceeding with considerable regularity throughout the year, but varying local conditions over any given area render the distribution patchy, and consequently when the chart shows an increase or decrease of either species, it is merely an indication that the climber was steadily proceeding with his work, and advancing towards or receding from the centre of an area more congenial as a breeding-ground for that particular species.

9. THE QUANTITY OF WATER OBTAINED.

The quantity of water in each of the first 236 collections at Tanga was estimated, and that in the last twenty-seven at Dar-es-Salaam, January, 1924, was carefully measured. Particulars of the quantities with the dates of collection, and the rainfall during each period and for the preceding thirty days, are here set out for comparison, but, unfortunately, the rainfall at Dar-es-Salaam for the 20th, 21st and 22nd January is not available. Speaking from recollection, it was slight, if any.

	TANGA.	DAR-ES-SALAAM.
Period of Collection	18th May to 9th June, 1921 ...	21st and 22nd January, 1924
Rainfall—previous 30 days	648·7 mm. ...	0·5 mm., excluding 20th Jan.
Do. during period	40·6 mm. ...	Slight, if any; record not available
Number of Collections—		
Without Larvæ	137 ...	Nil
With Larvæ	99 ...	27
Greatest Quantity of Water in one Collection—		
Without Larvæ	7½ oz. = 213 c.c. ...	—
With Larvæ	20 oz. = 568 c.c. ...	44 c.c.
Least Quantity of Water in one Collection—		
Without Larvæ	⅛ oz. = 1·8 c.c. ...	—
With Larvæ	1 oz. = 28·4 c.c. ...	20 c.c.
Average Quantity of Water per Collection—		
Without Larvæ	75·9 c.c. ...	—
With Larvæ	106·9 c.c. ...	31 c.c.

10. THE HEIGHT OF THE PALMS.

No palms were actually measured, but the height of many was fairly gauged, and noted at the time, by comparison with that of known objects, such as buildings, the length of the sections of standards at the wireless station at Lamu, and the measured length of fully formed leaves, also by pacing the length of the shadow cast by the palm and comparing it with that thrown at the same time by objects of known height. The particulars of the lengths of the stems from the ground to the commencement of the crowns, that is, to where the lowest and oldest leaves are attached, were as follows:—

	PALMS YIELDING NO WATER.	PALMS YIELDING WATER WITHOUT LIVING LARVÆ OR PUPÆ.	PALMS YIELDING WATER WITH LIVING LARVÆ OR PUPÆ.
Number of Palms	6	37	69
Highest... ..	30ft.	70ft.	65ft.
Lowest	6½ft.	10ft.	10ft.
Average	18ft.	26ft.	31ft.

The palm whose stem was estimated at seventy feet, yielded water with living larvæ on two subsequent occasions.

11. SOURCE OF THE WATER.

During the early part of the investigation it was considered, perhaps naturally, that the water found had its origin in rain falling on the leaves and being conducted along the grooved upper surface of the midrib and stalk to the leaf axil, and also falling on the central, erect portion of the crown, and the flowering branches, and thence trickling down to the same destination. The disappearance of the water by evaporation was, consequently, anticipated when rain did not fall for a number of consecutive days. The conditions for putting this theory convincingly to the test did not arise during the investigation in Tanga in 1921. There, from 18th May, when the work was commenced, till 3rd December, when the home-made gauge in use was, unfortunately, broken, there was no period during which no trace of moisture was recorded longer than the six days from 12th to 17th October inclusive.

When work was commenced in Dar-es-Salaam, on 24th January, 1922, the only rain recorded from the beginning of the year had been traces on the 7th and 18th, 0.5 mm. on the 19th, 0.1 mm. on the 21st, and a trace on the 23rd, after which last date there was no rain till 7th February. From 24th January to 6th February, inclusive, palms were examined daily, except on 27th and 29th January and 4th and 5th February, the total number examined being 165, from 114 of which water was obtained. The examinations on 6th February were eighteen, and of these palms fourteen yielded water. It seemed impossible to credit, especially considering the scanty fall during the previous three weeks, that water directly derived from the rainfall could have persisted unevaporated in the leaf axils throughout the dry fortnight and found in appreciable quantity on 6th February in more than 77 per cent. of the palms.

An even more striking objection to considering rain as the direct and only source of supply, was encountered during the second period of investigation in Dar-es-Salaam. Then, from 17th December, 1923, till 22nd January, 1924, small groups of palms were examined at frequent short intervals for the special purpose of seeking evidence on this question. The total rainfall from 17th December to 10th January, inclusive, was 0.36 mm., plus a trace on each

of four days; no rain was recorded from 11th to 17th January inclusive. On 11th January two groups of palms were examined; they are lettered in the tabulated records as C and E, the former consisting of seven and the latter of six palms. C is in an exposed situation on a strip of ground along the sea-front, and between it and the European Hospital and the Principal Medical Officer's and Medical Officer of Health's residences, and here there are very few other trees, so that every breeze has free play about the crowns of the palms. E is in the grounds on the landward side, that is, the front of the residence of the Director of Agriculture, formerly Government House, where the palms are considerably sheltered on the seaward side by the building, and otherwise by numerous trees both in the grounds and in the Botanical Gardens opposite. Group C had previously been examined on 18th and 26th December and on 2nd and 7th January, and on these occasions water obtained from 6, 6, 6 and 7 palms respectively, the one not yielding water on the first and third occasions, and not examined on the second, having a small straggly crown and a thick stem, estimated at over 70ft. in height. Group E had previously been examined on 22nd and 28th December and 2nd and 9th January, and on each occasion water had been obtained from all the palms. On 11th January, Group C yielded water from six palms, the dry one being the very tall palm, and Group E yielded water from five. After each of these examinations and re-examinations of groups, the climber expressed himself as confident that he had taken all the water obtainable with his sucking-tube. He was frequently questioned on this point, and there seemed no reasonable ground for doubting the thoroughness and reliability of his work. The two groups were next re-examined on 16th January, when water was got from the same six palms of group C and from all those of E. The average quantity of water brought down at these re-examinations was not noticeably less than that got at single examinations of other palms.

Rainfall having thus failed to account on all occasions for the presence of the water, attention was turned to the possibility of dew, perhaps, supplying it during rainless periods, or at least replenishing loss by evaporation. For the periods 1st January, 1922, to 31st August of that year, and 3rd July, 1923, to 20th January, 1924, the daily 9 a.m. and 4 p.m. dewpoints have been calculated by Glaisher's Hygrometrical Tables, from the wet and dry bulb readings recorded at the Bacteriological Laboratory, Dar-es-Salaam, and charted with the daily minimum temperatures.

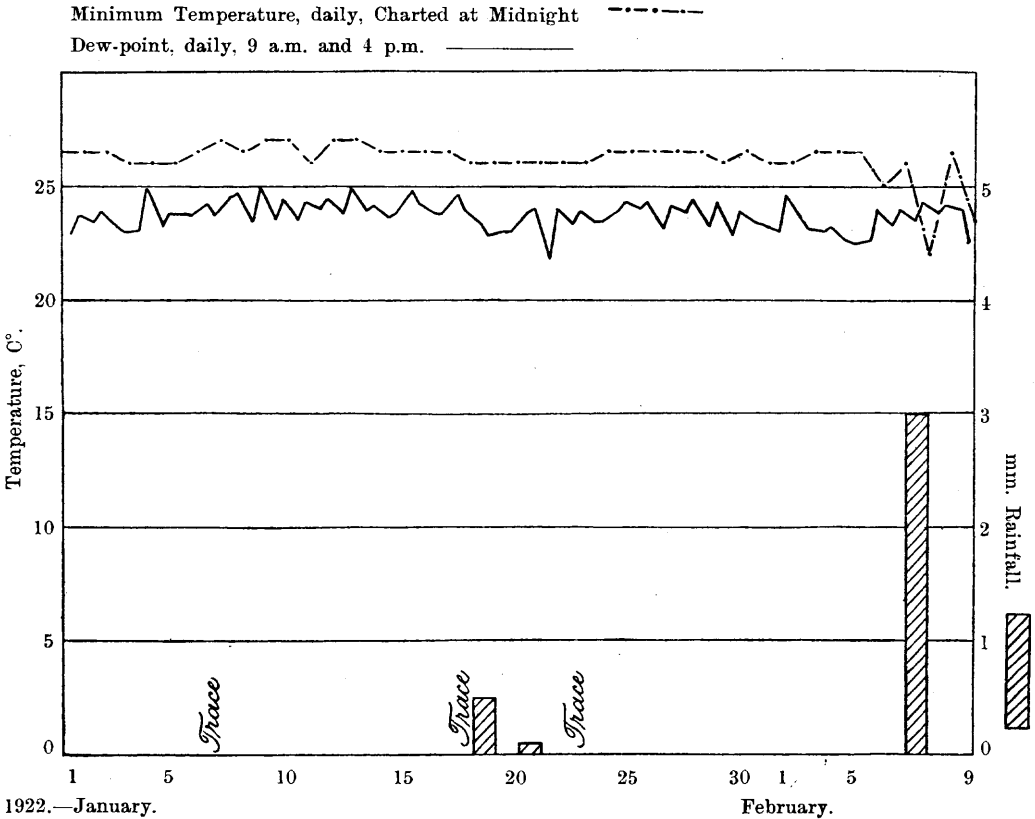
The following table gives the number of days in each month when the minimum temperature read at 9 a.m. on any day fell to, or below, the dew point (1) at 9 a.m. the previous day, (2) at 4 p.m. the previous day, (3) at 9 a.m. the same day, (4) at either 4 p.m. the previous day or 9 a.m. the same day, and (5) at either 9 a.m. or 4 p.m. the previous day or 9 a.m. the same day:—

MONTH.	1	2	3	4	5
	9 a.m.	4 p.m.	9 a.m.	4 p.m. or 9 a.m.	9 a.m., 4 p.m., or 9 a.m.
<i>1922.</i>					
January	0	0	0	0	0
February	4	5	4	6	6
March	17	11	17	19	20
April	19	8	20	21	21
May	21	15	22	23	25
June	23	13	19	23	27
July	25	11	26	26	30
August	26	25	30	31	31
<i>1923.</i>					
July 3rd to 31st ...	16	8	19	20	23
August	25	12	27	28	30
September	20	21	23	27	29
October	20	20	23	27	28
November... ..	18	20	19	25	26
December	10	13	13	16	17
<i>1924.</i>					
Jan. 1st to 20th ...	2	2	0	2	3

From this table it appears possible that, during the greater part of a year, dew may fall sufficiently often to meet the requirement, but in the month of January certainly not so. The charts for 1st Jan., 1922, to 9th Feb. of that year, and for the period 12th Dec., 1923, to 20th Jan., 1924, being of especial interest in this connection, are here reproduced (see pp. 182, 183). From these it appears improbable that any dew could have fallen during the periods 24th January to 6th February, 1922, and 11th to 16th January, 1924, at least under such conditions as those under which the meteorological observations were taken, since on no day did the minimum temperature fall so low as any dewpoint calculated from observations taken at the beginning, during, or at the termination of the same twenty-four hours; except that the minimum temperature for the twenty-four hours from 9 a.m., 16th January, 1924, to 9 a.m. on the 17th fell 0.3° below the dewpoint for 9 a.m., and 0.1° below that for 4 p.m. on the 16th; but the minimum temperature recorded at 9 a.m. on the 16th was 1.5° above that recorded on the following morning, so it would appear very improbable that the latter occurred on the 16th between 9 a.m. and 4 p.m., by which latter hour the climber had finished his examinations for the day, and still more improbable that the water from the palms in Group C, which were examined during the forenoon of the 16th, could have been deposited as dew between 9 a.m. and noon of that day.

An explanation of the presence of the water may possibly be found by the assumption, not apparently unreasonable, that the meteorological conditions at the tops of the palms differ considerably from those under which the observations were taken; the instruments being protected by a roof and placed at about five feet from the ground, while the palm tops from which water is obtained are usually exposed to free radiation and at a height of twenty to seventy feet. In the position of the latter it seems probable the minimum temperature may nightly throughout the year fall below the dewpoint, and

CHART 2.

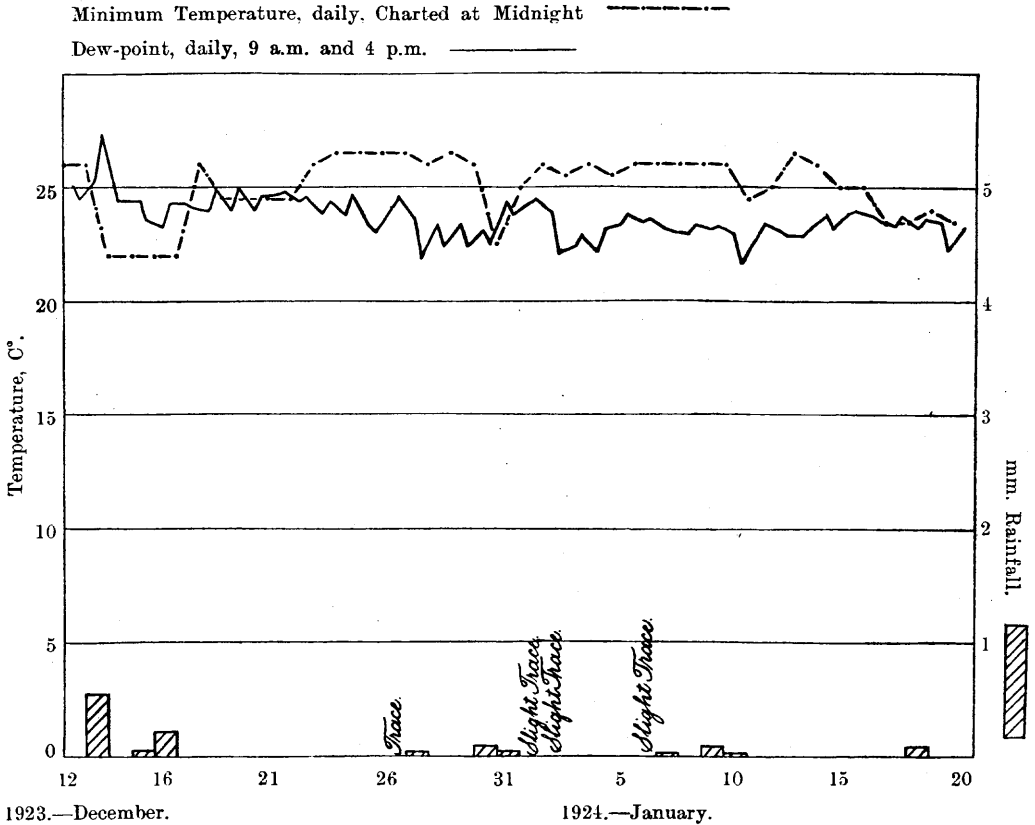


moisture be deposited in sufficient quantity, not only to replenish loss by evaporation during the day, but even after removal of the water, to afford a fresh supply to meet the wants of larvæ and pupæ which may have been left in damp débris in the leaf axils. There is, further, a possibility that the source of some of the water may be ground-water, absorbed by the roots and drawn up to the crown, and there lost by leaking away through insect-made perforations in the tender tissues of the cabbage, or by oozing from a mechanically injured or diseased inflorescence. It is not claimed that the problem of the source of the water has been completely and satisfactorily solved.

12. EMERGENCE OF IMAGINES.

A record was kept of the date on which the first imago of each species was secured from each collection. These dates correspond very closely to the dates on which the imagines must have emerged in the cases of Tanga, Dar-es-Salaam, 1922, and Lindi collections, since examination of the bottles was usually done daily, except that when emergence occurred in the evening

CHART 3.



the date recorded is usually that of the following day, for work with the bottles by artificial light was avoided as far as possible. The entire records for the three stations mentioned have been analysed and tabulated for each identified species, those of which the species was inconclusive, specimens which were subsequently lost, and a few which escaped at the time of examination, the total collections of the various classes amounting to 8,151. In 4 per cent. of these the first imago was secured on the day on which the water was collected from the palm, and the percentages for the succeeding six days were 17.6, 13.1, 10.5, 13.2, 13.8 and 9.7, that is, in 81.9 per cent. the first imago of a species was obtained within a week from the time of collection of the water. The longest period was in the case of a *M. brevipalpis*, which emerged ninety-two days after collection.

13. NUMBER OF IMAGINES PER COLLECTION.

It was only at Lindi that a record was kept of the number of living imagines. The average number per collection for the various species was as follows:—

<i>Anopheles costalis</i>	1.8
<i>Eretmopodites quinquevittatus</i>	4.1
.. <i>chrysoqaster</i> var. <i>subsimplicipes</i>	2.0
<i>Aedes argenteus</i>	5.7
.. <i>simpsoni</i>	2.7
.. <i>metallicus</i>	3.8
.. <i>calceatus</i> and <i>Aedes soleatus</i>	2.3
.. <i>vittatus</i>	1.0
.. <i>fulgens</i>	1.0
.. <i>fasciipalpis</i>	1.0
.. <i>adersi</i>	1.0
.. <i>albocephalus</i>	3.2
<i>Lutzia tigripes</i>	1.0
<i>Culex sitiens</i>	1.9
.. <i>duttoni</i>	2.1
.. <i>fatigans</i>	7.5
.. <i>univittatus</i>	1.0
.. <i>decens</i>	1.5
.. <i>simpsoni</i>	2.4
.. <i>nebulosus</i>	1.2
.. <i>horridus</i>	1.2
.. <i>decens</i> var. <i>invidiosus</i> and <i>Culex sitiens</i> , mixed ...	3.0

In forty-seven cases the number of imagines was not recorded, from inadvertence or from the bottle being abandoned while still containing larvæ when leaving the station; counting one imago only for each of these collections, the total number of living imagines secured amounts to 16,097. Excluding the thirty-three collections from which no imago had been secured when they were abandoned, still containing living larvæ, we have for 2,119 collections of living larvæ and pupæ an average of 7.6 imagines per collection, and from 2,727 palms examined an average of 5.9 imagines per palm.

A few of the most productive collections may be detailed:—

NUMBER OF COLLECTION.	DATE COLLECTED.	SPECIES OF IMAGINES SECURED AND NUMBER OF EACH.
292	Nov. 21st, 1922.	<i>Aedes argenteus</i> 32. <i>Culex fatigans</i> 34.
311	.. 23rd, ..	.. 1. .. 66.
1304	Feb. 23rd, 1923.	.. 63. <i>Aedes simpsoni</i> 4.

14. DAILY OUTPUT OF MOSQUITOES.

In Dar-es-Salaam, during December, 1923, and January, 1924, six small groups of palms were re-examined, at short intervals, with a view to ascertaining whether water could be got from them independently of rainfall; the number of imagines from the first examination was not recorded, but this was done with all subsequent collections, which were examined daily till noon of 20th January. The details are here set out:—

Group.	No. of Palms.	Date of First Examination.	Dates of re-examination.						No. of days from first re-examination to 20th January.	Imagines Obtained.	Imagines per Palm per Day.
			Dec. 24	Dec. 31	Jan. 4	Jan. 10	Jan. 15	Jan. 18			
A	7	Dec. 17	Dec. 24	Dec. 31	Jan. 4	Jan. 10	Jan. 15	Jan. 18	27	201	1'06
B	8	" 18	" 26	" 31	" 7	" 10	" 15	" 19	25	142	0'71
C	7	" 18	" 26	Jan. 2	" 7	" 11	" 16	" 21	25	93	0'53
D	15	" 21	" 27	" 3	" 8	" 12 (& 14)	" 17	" 23	24	207	0'58
E	6	" 22	" 28	" 2	" 9	Jan. 11	" 16	" 21	23	113	0'82
F	7	" 24	" 28	" 4	" 9	" 14	" 18	—	23	109	0'68

The average of the figures in the last column is 0·73, that is to say, these fifty palms during periods ranging from twenty-three to twenty-seven days yielded water containing larvæ or pupæ from which developed, within the period of examinations, imagines to the extent of 0·73 imago per palm per day. If this series of observations be taken as a basis for forming an estimate of the extent of output of mosquitoes from the breeding-places under consideration, several important points, arising out of the conditions under which the observations were made, must be given due weight; there is the possibility that the development from larva to imago may have proceeded either more or less rapidly in the bottles than normally in the natural haunts; other factors could only have been adverse:—

1. The improbability of all larvæ and pupæ being taken up in the sucking-tube, and sometimes into the climber's mouth, and transferred to the bottle.
2. The great probability of many being injured during collection.
3. The certainty that at times the development from pupa to imago and escape of the latter took place between the collecting and the plugging of the bottle.
4. The examination of the palms at only eight to four days previous to the first re-examination.
5. The average yield from collections taken at the first re-examination being only 4·4 imagines per palm as compared with 5·9 for the whole series taken over eight months in Lindi.

15. COMPARISON WITH OTHER BREEDING-PLACES.

In recounting the first witnessing of the collection of larvæ from the crown of a palm, it has already been described how other apparently probable breeding-places in the immediate vicinity were examined and found blank. On all occasions of inspecting the climber at work, also when attending to

ordinary sanitation, and at many other times, attention was directed to steps in the palms; indeed, certainly many hundreds of these were inspected by the author, but in only one were larvæ found. In evidence of the frequency with which breeding was taking place in the crowns of the palms as compared with other haunts, in a town where at the time vigorous anti-mosquito work on the usual lines was being conducted, may be quoted an extract from "Notes on Monthly Sanitation Report, Tanga Town and District," July, 1921:—

"During June and July the climber brought in 157 collections of larvæ from the tops of coconut palms. He was off work from 18th June to 1st July inclusive. During the same two months the four native Sanitary Inspectors, each with two labourers as assistants, working daily through the morning hours, brought in thirty-seven collections of larvæ from wells, tanks, pools, water-barrels, etc. During this period the total time, from coming on to going off duty, devoted to this work was $264\frac{1}{2}$ hours for each of the four Sanitary Inspectors and eight labourers, and 324 hours for the one climber. Hence the climber's work, as compared with the average for one of the others, was productive of larvæ collections in the proportion of 41·6 to 1."

16. ANOPHELES.

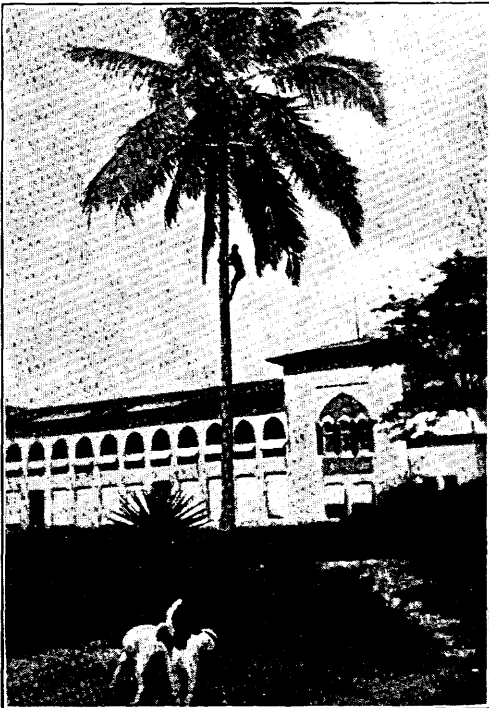
The following remarks apply to *A. costalis*, since all living imagines were of this species, except that at Dar-es-Salaam one collection yielded also *A. pretoriensis*.

The bare statement of the number of collections from which living imagines were secured, and of the percentage of palms examined yielding them, certainly gives an inadequate expression of the extent to which this species, in comparison with others, employs the crown of the coconut palm as a breeding-place.

While working in Tanga and Dar-es-Salaam it had been noted that *Anopheles* imagines usually appeared in the bottles without the larvæ having been recognised: in Lindi, therefore, great care was taken in searching for them. It was found that when the bottle was held up for inspection in a sloping position, they at first frequently were concealed amongst floating bits of vegetable matter, such as dry male flowers, towards the base of the bottle, and were not usually detected till they darted out to the clearer portion of the surface after the bottle had been held steadily for a time. The results of this careful search for larvæ has led to the conclusion that the method of collection of the water and its subsequent treatment, that is, retaining it in the bottles plugged with cotton-wool and standing in a closed room, was much more prejudicial to the life of *A. costalis* than of species of other genera. In Lindi the total of collections containing living larvæ or pupæ was 2,156, and in 183 of these all larvæ and pupæ died or dead imagines only were found, that is, there was what may be denominated a collection mortality for all species of 8·5 per cent. *Anopheles* larvæ were observed in, or imagines secured from, sixty-six collections, and in twenty of these the larvæ or pupæ died or only dead imagines were found, while seven of the collections in which *Anopheles*



1. The climber and his outfit—Examining the sucking-tube.



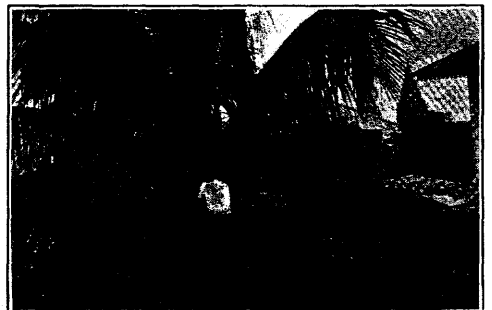
2. Ascending the stem—European Hospital, Dar-es-Salaam, in the background.



3. Amongst the leaves—New Government House, Dar-es-Salaam, in the background.

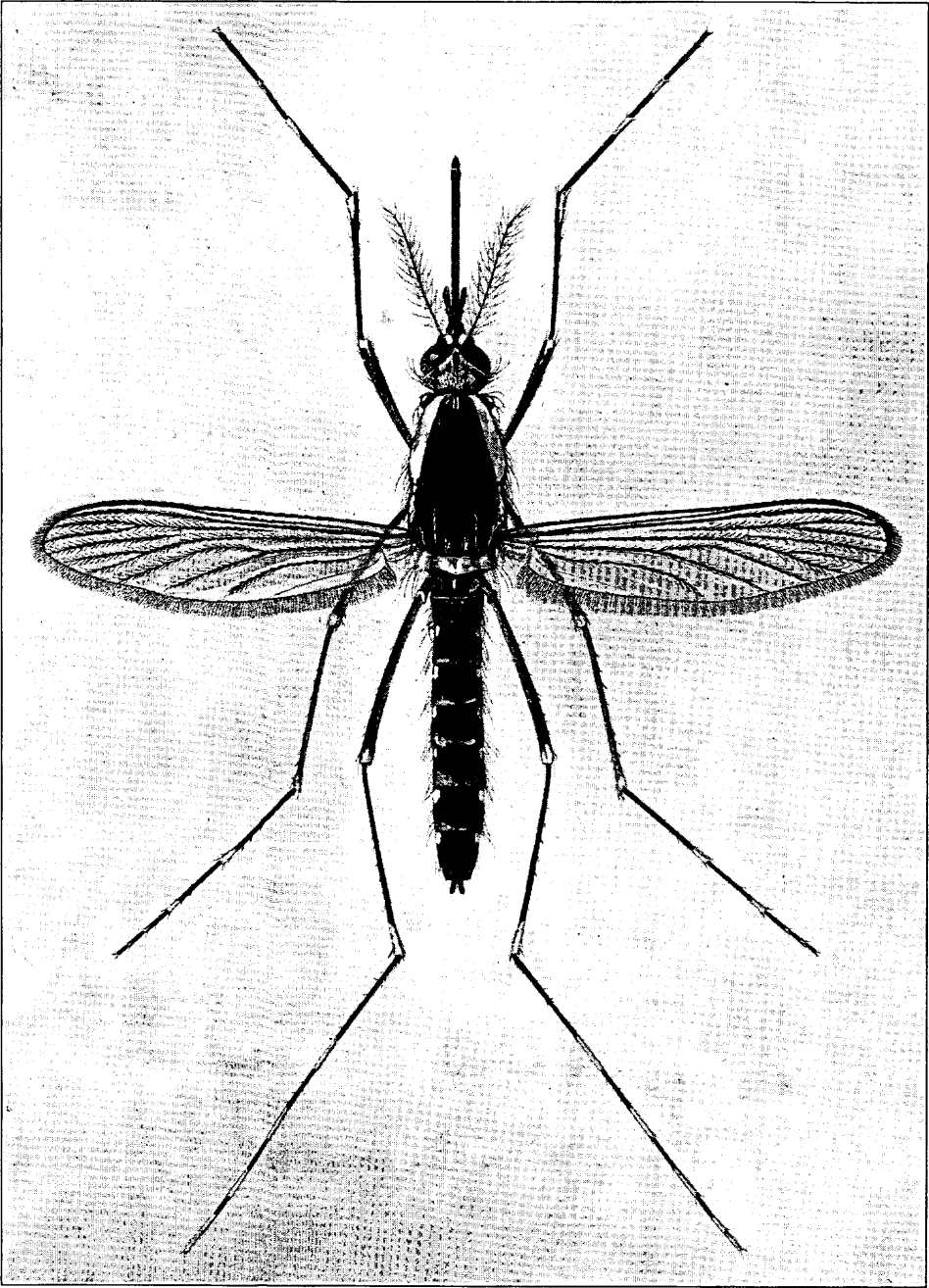


4. Exploring the crown—In Zanzibar.



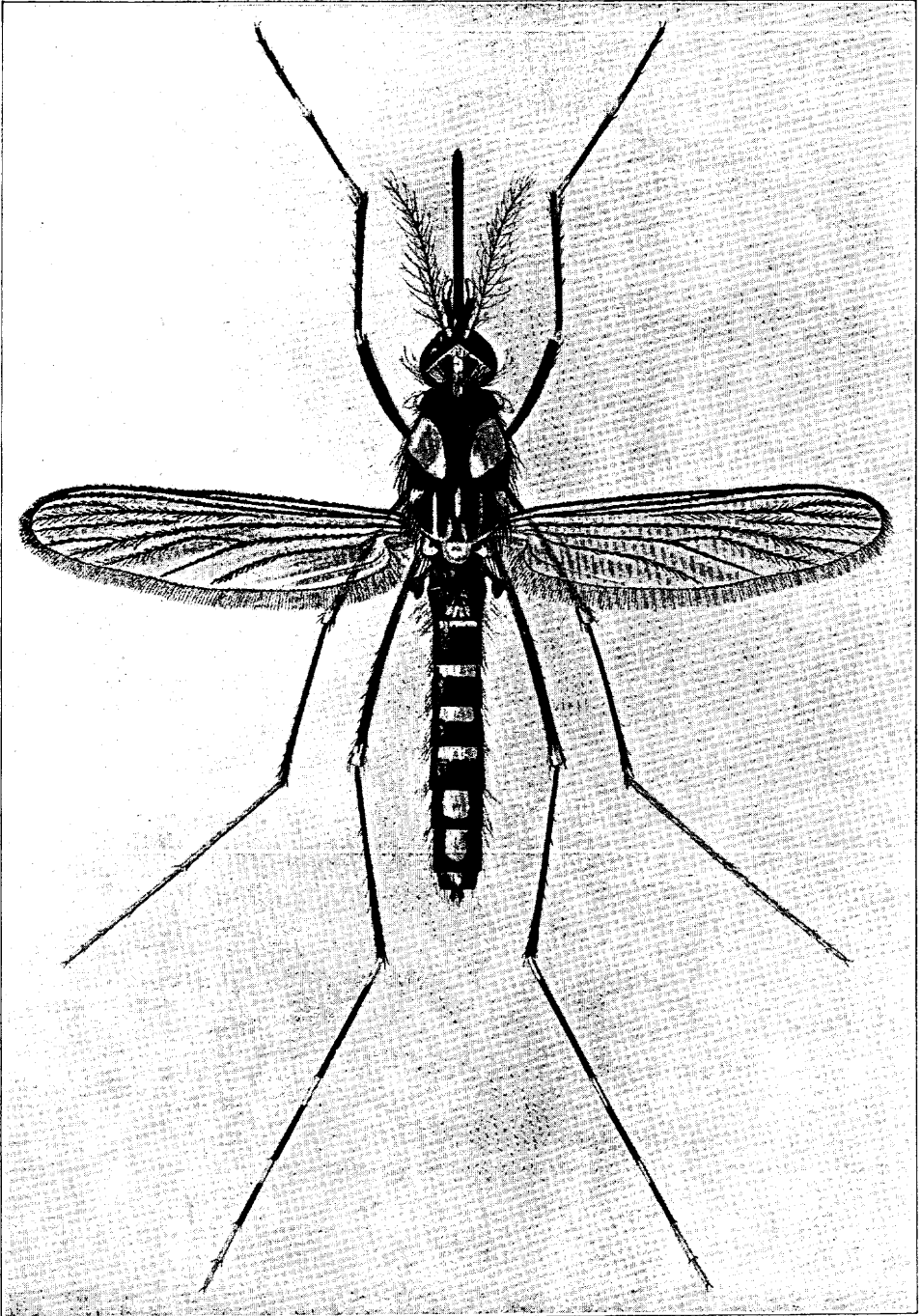
5. Astride a leaf stalk—Examining the axil—In Zanzibar.

AËDES HAWORTHI EDW.



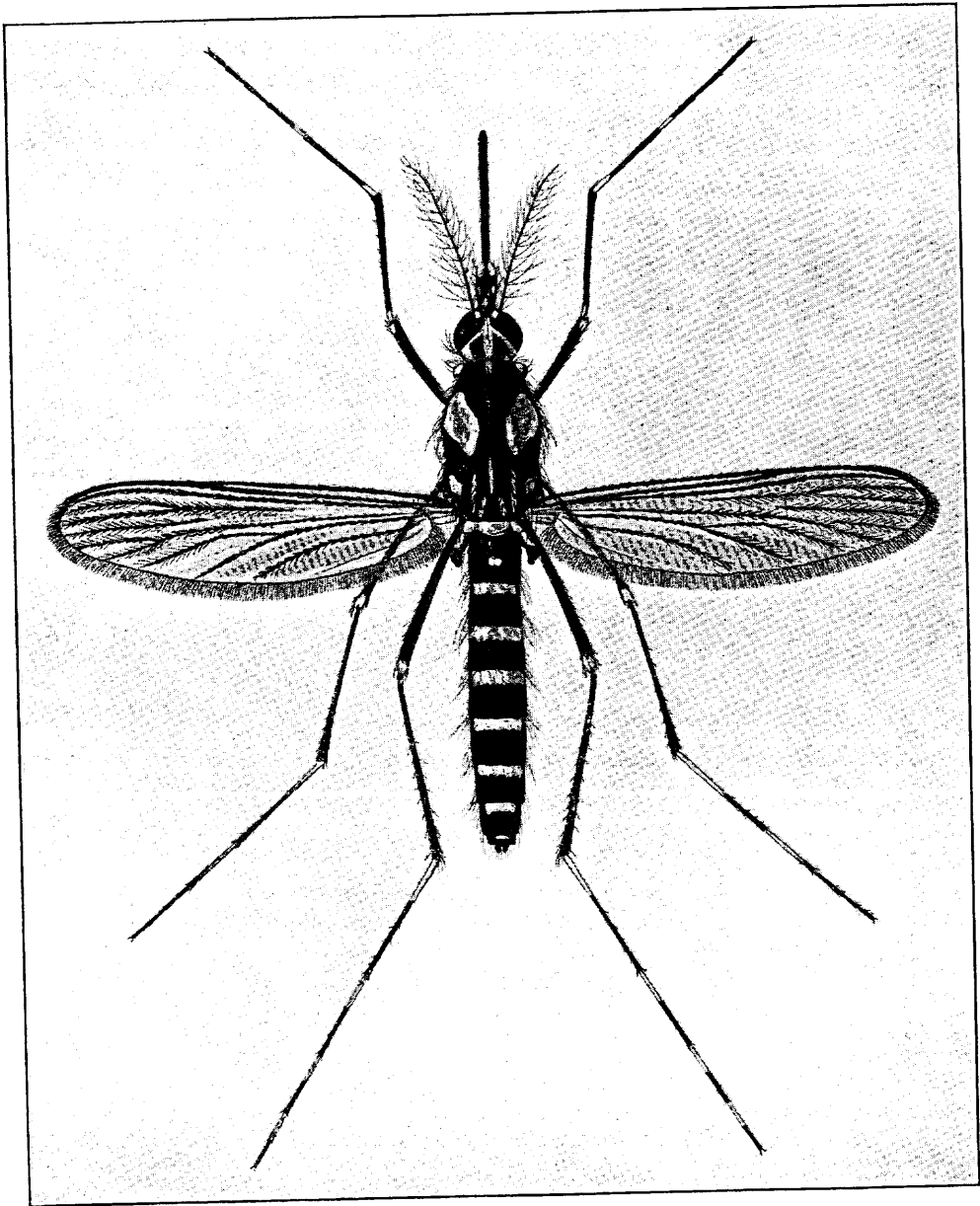
A. J. ENGEL TERZI, *del.*

AÈDES SOLEATUS EDW.



A. J. ENGEL TERZI, *del.*

AÈDES CALCEATUS EDW.



A. J. ENGEL TERZI, *del.*

larvæ were seen were abandoned when leaving the station, before appearance of imagines or death of the larvæ had occurred; excluding these latter, the collection mortality was, therefore, 33.9 per cent.

The collection mortality for all species was 8.0 per cent. in Tanga and 6.2 per cent. in Dar-es-Salaam (1922 investigation); proportionate rates for *A. costalis* would be 31.9 and 24.7 respectively for these stations, as compared with 33.9 for Lindi; and, calculated on these rates the percentage of palms yielding this species would be 0.3 for Tanga and 0.7 for Dar-es-Salaam, while for Lindi it was 2.4. These figures are small, but it must be borne in mind that the number of palms in each township is vast, and, further, that breeding is probably proceeding throughout the year, since collections were obtained in May, October and December at Tanga; in January and February at Dar-es-Salaam; and in December, January, February and June at Lindi. Hence it appears that the coconut palm may at least act as a safe and efficient reservoir for conserving the species and providing an ample supply to stock other breeding-places whenever such may appear.

17. ASSOCIATION IN BREEDING.

It was a frequent experience to find more than one species of larvæ in a collection; thus, of 1,292 Tanga collections yielding imagines, two species were obtained from 256, three from 65, four from 16, and five from 4; at Dar-es-Salaam (1922), out of 2,141 collections, two species were got from 586, three from 210, four from 26, and five from 2; while at Lindi, of 1,938 collections, two were secured from 601, three from 194, four from 17, and five from 9; that is, at Tanga 26 per cent., at Dar-es-Salaam 38 per cent., and at Lindi 42 per cent. of the collections yielding imagines gave more than one species. The association of each species with every other has been tabulated for each of these stations, and from the sheets a few details may be given (see p. 188).

Thus, briefly, at the three stations the species in the collections yielding five were made up of various combinations of the two species of *Eretmopodites*, *Aedes argenteus*, *simpsoni*, *metallicus*, *calceatus*, *soleatus*, *haworthi*, *Lutzia tigripes*, and *Culex fatigans*, *decens*, *nebulosus*, and *horridus*.

Anopheles costalis was found associated with *A. pretoriensis* once, and with *Aedes argenteus* 19, *Aedes simpsoni* 5, *Lutzia tigripes* 2, *Culex sitiens* 4, *C. fatigans* 14, *C. decens* 1, *C. decens* var. *invidiosus* 3, and *C. simpsoni* 3 times.

Culex sitiens was found with *Anopheles costalis* 4, *Aedes argenteus* 3, *Aedes simpsoni* 1, *C. duttoni* 1, *C. fatigans* 2, *C. univittatus* 1, and with *C. simpsoni* 3 times.

C. trifoliatus, obtained only at Tanga in four collections, was the only species not found in conjunction with any of the others.

On 7th June, 1923, and the morning of the 8th, in the principal business and official quarter of Lindi township, twenty-nine neighbouring palms were examined, and from them were obtained twenty-four collections of water containing larvæ, from which developed eleven different species, viz., *Aedes argenteus* and *simpsoni*, *Lutzia tigripes*, and *Culex sitiens*, *duttoni*, *fatigans*,

univittatus, *decens*, *simpsoni*, *nebulosus*, and *horridus*; one of the collections probably yielded also *C. decens* var. *invidiosus*.

COLLECTIONS FROM WHICH FIVE SPECIES WERE OBTAINED.

Station.	Number of Collection.	Date of Collection.	Species.
TANGA	496	6th August, 1921	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes haworthi</i> . <i>Culex fatigans</i> . <i>Culex nebulosus</i> .
	1476	26th November, 1921	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Lutzia tigris</i> . <i>Culex fatigans</i> .
	1615	12th December, 1921	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Aedes haworthi</i> . <i>Culex fatigans</i> .
	1649	14th December, 1921	Same as 1615.
DAR-ES-SALAAM ...	1852	27th June, 1922	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Culex fatigans</i> . <i>Culex nebulosus</i> .
	1900	3rd July, 1922	<i>Eretmopodites quinquevittatus</i> . <i>Aedes argenteus</i> . <i>Aedes metallicus</i> . <i>Culex fatigans</i> . <i>Culex nebulosus</i> .
LINDI	1146	12th February, 1923	<i>Eretmopodites chrysogaster</i> var. <i>subsimplificipes</i> . <i>Aedes argenteus</i> . <i>Aedes metallicus</i> . <i>Aedes calceatus</i> or <i>soleatus</i> . <i>Culex fatigans</i> .
	1155	12th February, 1923	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Aedes calceatus</i> or <i>Aedes soleatus</i> . <i>Culex fatigans</i> .
	1159	12th February, 1923	<i>Eretmopodites chrysogaster</i> var. <i>subsimplificipes</i> . <i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Culex fatigans</i> .
	1164	12th February, 1923	Same as 1155.
	1309	23rd February, 1923	<i>Eretmopodites chrysogaster</i> var. <i>subsimplificipes</i> . <i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Aedes calceatus</i> or <i>soleatus</i> .
	1313	23rd February, 1923	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Aedes calceatus</i> or <i>soleatus</i> . <i>Culex decens</i> .
	1408	3rd March, 1923	<i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Aedes metallicus</i> . <i>Culex decens</i> . <i>Culex nebulosus</i> .
	1410	3rd March, 1923	Same as 1408.
	1619	11th May, 1923	<i>Eretmopodites quinquevittatus</i> . <i>Eretmopodites chrysogaster</i> var. <i>subsimplificipes</i> . <i>Aedes argenteus</i> . <i>Aedes simpsoni</i> . <i>Culex horridus</i> .

18. PERFECTION OF IMAGINES.

In the course of the whole investigation, nothing was observed which might justify entertaining a suggestion that the imagines were not normal,

vigorous individuals capable of reproducing their kind, indeed, just such as developed from larvæ collected from other breeding haunts. In evidence of their vigour, it was noticed that at times one led to its death through endeavouring to force its way out past the cotton-wool plug, and becoming jammed, died presumably from want of water, if the bottle was not examined for several days, or, if released earlier by gently withdrawing the plug, appeared no worse for its adventure. In support of their sexual maturity is the fact that at times they were seen already paired when being transferred from bottle to test-tube. That the females were ready and willing to feed on blood appeared undoubted, by the personal experience of the author when, working in haste, some were permitted to escape, as happened at times in Dar-es-Salaam in 1923.

After specimens had been obtained of harmless or useful species, such as *Megarhinus brevipalpis*, chloroforming was usually avoided if possible, and the imagines being liberated from the test-tube flew off at once with every appearance of strength and health.

19. METEOROLOGICAL CONDITIONS.

The possible influence of meteorological conditions on the extent of breeding has been tested by drawing up, for weekly periods, charts of the percentage of palms yielding water, of palms yielding larvæ, and of collections of water which contained larvae, for each of the series of examinations at Tanga, Dar-es-Salaam, 1922 and 1923, and Lindi, and comparing them with charts of the rainfall during the time at each station, and of the degree of humidity, the maximum and minimum temperatures and the mean temperature in shade for each period of work in Dar-es-Salaam, and the maximum temperature for the period in Lindi. No evidence has been found of these meteorological conditions influencing the breeding, and the conclusion drawn is that, at these stations, such conditions vary so little throughout the year that any influence they may exert could only be demonstrated by longer and less intermittent research.

20. ENEMIES OF LARVÆ AND PUPÆ.

Throughout the whole investigation, the only enemies observed preying on mosquito larvæ were the larvæ of *M. brevipalpis* and *Lutzia tigripes*, and at Tanga only a much larger caterpillar-like creature. The last mentioned was seen on one occasion eating one of the mosquito larvæ, and later all the latter disappeared, presumably eaten, and the former died, as did also a few others of its kind found in other collections, in all except one of which, however, some mosquito larvæ developed into imagines. *M. brevipalpis* imagines were obtained from fifty-eight collections, from twenty of which imagines of other species also were secured. Three *Megarhinus* larvæ were seen in one collection, two in one or two more, while all of the others contained solitary specimens. When no other species were present they were fed with larvæ brought in from other breeding-grounds. Their rate of

destruction appeared to be limited to six to ten per day, and they showed a decided preference for *Aedes* rather than *Culex*. At Lindi no *Megarhinus* imagines were obtained, but one collection contained a larva which died.

Lutzia tigripes imagines were obtained from 129 collections, 119 of which yielded also imagines of other species. Water beetles of various species were got in many collections, particularly at Tanga, but although careful watch was kept they were never seen to prey on larvæ. Mosquito pupæ were never seen to be molested by any creatures.

Thus, it appears that the enemies of mosquitoes, either in the larval or pupal stage, as observed in these collections, were infrequent and on the whole ineffective.

21. HATCHING OF EGGS.

During the earlier part of the investigation it was expected that, as bottles were kept, young larvæ would at times appear in them from the hatching out of eggs; a careful watch was therefore kept, but on no occasion was this ever observed to occur. Occasionally a larva, or seldom two or three, would be found after a day or two in a bottle in which none had been observed on the day of collection, but in no case did they appear very young, and it seemed undoubtedly they were individuals who had escaped being noted at the first examination.

22. PECULIARITIES OF DIFFERENT SPECIES.

A considerable difference in behaviour was noticed between *A. argenteus* and *C. fatigans*; the former, when the plug was removed, immediately rushing up the neck of the bottle and to the far end of the tube, while the latter frequently flew about for a considerable time before venturing to explore, indeed, often turning back in the neck several times, and this whether the tube were held down in a dark corner or up to the window or an electric light. Species allied to either of these more or less resembled them in this respect. The most enterprising of all, however, was *Lutzia tigripes*, which was usually found up on the bottom of the plug, and requiring to be driven away before the latter could safely be removed. It was usually *L. tigripes* or an *Aedes argenteus* which was found wedged in beside the plug in an attempt to escape.

All species were found about equally susceptible to chloroform, and all appeared to make a good recovery when exposed to the open air even after a considerable dose.

M. brevitalpis larvæ seemed capable of living healthily for long periods without having other larvæ as food, but made no further development; when, however, other larvæ were supplied pupation took place after a few days, and in about five more the imago emerged.

23. OTHER ASSOCIATES.

The collections of water at times contained many other creatures besides mosquito larvæ. Imagines of the following Diptera developed from their larvæ and were identified at South Kensington Museum:—

Psychodidæ.—*Pericoma* and *Psychoda*.

Chironomidæ.—*Dasyhelea*, *Culicoides nigripennis* and *Chironomus*.

Drosophilidæ.—*Drosophila*.

Phoridæ.—*Aphiochæta*.

Syrphidæ.—*Eristalis*.

There were also obtained amongst Coleoptera, specimens of *Bidessus*, *Dytiscid* and *Hydrophilid* larvæ. *Elaterid* larvæ were found in one collection accidentally present, and two moths, *Pyroderces* and *Tinea*, appeared in two of the bottles, presumably developed on bits of floating vegetable matter, such as the dry flowers of the palm.

24. NEW SPECIES.

Three new species of *Aedes* were encountered which have been named by Mr. F. W. EDWARDS, B.A., of the Department of Entomology, British Museum, *A. haworthi*, *A. calceatus* and *A. soleatus*. The first-named was described by Mr. EDWARDS in a contribution appearing in the TRANSACTIONS of the Royal Society of Tropical Medicine and Hygiene, Vol. xvi, No. 8, 15th February, 1923. The first collection yielding it was got at Tanga on 13th July, 1921, and subsequently it was found in August, September and December of the same year. The associates found breeding with it were *A. argenteus*, *simpsoni*, *metallicus* and *adersi*, *C. fatigans* and *nebulosus*.

Specimens of the other two species, unfortunately, were not all kept separate, and hence it is impossible to decide certainly in which collections each should appear, but the first found, probably *A. soleatus*, was from a collection taken at Lindi on 12th February, 1923. They were got from other later collections at the same station and also at Dar-es-Salaam. Their associates were *Eretmopodites quinquevittatus* and *chrysogaster* var. *subsimpli-cipes*, *A. argenteus*, *simpsoni* and *metallicus*, *Lutzia tigripes*, and *C. fatigans* and *decens*. No specimen of any one of these three new species was obtained from any other breeding-place. A detailed description of *A. calceatus* and *A. soleatus*, by Mr. EDWARDS, appears as an appendix to this paper.

25. IDENTIFICATION OF SPECIES.

Numerous specimens of the imagines were sent home and submitted to Mr. F. W. EDWARDS, B.A., of the Department of Entomology, British Museum, after which they were returned to the author, who from them identified others of which specimens were again sent to the same authority for confirmation.

The first batch was very kindly pinned and sent off by Dr. ADERS, Government Zoologist, Zanzibar, in 1921, and comprised some of those

collected in Tanga. A second lot, consisting of the Dar-es-Salaam collection of 1922 and the balance of those got in Tanga, was sent through the Royal Society of Tropical Medicine and Hygiene, on the invitation of the Secretaries, in October, 1922. The remainder, the Lindi and Dar-es-Salaam 1923 collections, were brought home by the author early in 1924.

26. POSSIBLE SOURCES OF ERROR.

The bottles, previous to use and usually just before going out to work, were washed by the climber, at Tanga, as a rule, in the compound of the Medical Officer of Health's residence or Health Office, in Dar-es-Salaam at the Bacteriological Laboratory or the residence of the Acting Director, and in Lindi on the hospital premises. At all places the water used was regularly subjected to inspection, and the possibility of a larva or pupa being occasionally so introduced into the bottles was very small indeed. It is possible some larvæ or pupæ from one palm may now and then have remained lodged in the sucking-tube and so been introduced to the bottle used for the next examination, but, admitting the feasibility of this having happened at times, it is not regarded as a reason for discounting the general conclusion which may be drawn from the evidence as a whole, since new tubes were very frequently procured by the climber, and even when the tube was washed with boiled water before each examination it was found that adjacent palms yielded similar associations of species.

The laying of eggs in the bottles before they were brought in and plugged may be disregarded as causing errors, since as has been related, young larvæ were on no occasion found to make their appearance after the collections had been once examined.

27. OTHER SPECIES FOUND AT THE STATIONS.

Anopheles mauritianus.—About seven specimens of this species were caught in the Medical Officer of Health's house at Tanga, in May, 1921. Its breeding-place was not discovered, but on the 26th of the same month one *Anopheles* larva, which subsequently died, was found in a collection of water taken that day from the crown of a palm in the same quarter of the town. No *A. costalis* imagines were at any time found by the Medical Officer of Health at his house in Tanga.

Mansonioides uniformis.—Two specimens were got in Tanga, one on 31st July and one on 4th August, both killed in the act of biting the author's hand when sitting at dinner, about 7 p.m. Two others were killed at Lindi under similar circumstances in February, 1923. Their breeding haunts were not discovered at either station. Major NIXON, Medical Officer of Health at Tanga, some time between January and April in 1922, obtained from the crown of a coconut palm the larva of an elephant mosquito which developed into a beautiful golden imago. This he entrusted to the author to despatch for identification, but unfortunately, apparently from faulty mounting or packing, it reached home, like some other specimens, in a condition unfit for examination.

28. NOTES ON THE STATIONS.

Kismayu, the most northerly of the stations, is the port of Jubaland, and is situated $22\frac{1}{2}$ ' south of the equator and ten miles south of the mouth of the Juba river. The soil is sand. It was visited on 29th September, 1922, and subsequently Dr. E. A. DAVISON, the Medical Officer, kindly sent a record of the rainfall for that and previous months of the year, which read:—January nil, February nil, March nil, April 0·37, May 1·8, June 2·25, July 1·8, August 0·27, and September 1·52 inches; the annual fall he informed me is 9 inches. There were scattered through the town, not more than 200 coconut palms, which looked very withered and bore few nuts. As no pawpaws grow there my colleague lent a silver catheter for use as a sucking-tube. He had not seen any *Anopheles*, but *Culex* were frequently found in his house, and in the evening three female *C. fatigans* were caught on the mosquito net in the bedroom. Six palms examined yielded from $\frac{1}{8}$ oz. to 1 oz. of water each, containing no larvæ.

Lamu was visited on 28th September and 1st October. On the first occasion, palms were examined in the town, and on the second, in the grounds about the wireless station, the quantity of water found varying in amount up to 1 oz. There are many coconut shambas close to the town, and scattered about in it are many odd palms. The town area has a 3-miles' radii from the Police Station, and Mr. AINSWORTH DIXON, the District Commissioner, was understood to estimate the number of palms within it at 70,000. The meteorological readings for the month, which he kindly had supplied later, give a rainfall of 1·63 in.; and temperatures, F., maximum 83, minimum 72, dry bulb mean 78·4, wet bulb mean 75·2. No rain fell for seven days previous to the first visit, nor between the visits.

Mombasa was visited on 25th September and 3rd October. On the morning of the first occasion, work was confined to palms in and near the club garden, where they were fully exposed to the fresh south-east monsoon; four out of five examined yielded each from $\frac{1}{2}$ oz. to 2 oz. of water containing large numbers of dead larvæ, which appeared to be quite young. In the afternoon, Dr. HUNTER, Medical Officer of Health, drove the author over to the Infectious Diseases Hospital, about which are large numbers of palms, and from them living larvæ were obtained. On the information of the Sub-Assistant Surgeon the various buildings are much infested with mosquitoes throughout the year.

Tanga.—The township area is confined to the land within a circle having a 2-miles' radius from the Boma, and in it there are estimated to be between 20,000 and 25,000 coconut palms. They are fairly thickly distributed in the European portion of the town, more so in the Goan and native quarters, and perhaps even denser in close proximity to the European Hospital. Work was commenced in May, 1921, at the west end, along the harbour, and steadily carried on through the entire European and Goan portions, after which it was extended into the native quarter. The first living *Anopheles* imagines were obtained from collections made during the first week of October, near the railway compound, and, with the few exceptions when the climber was taken

outside by the Medical Officer of Health, all palms examined up to that time, some 1,900 in number, were situated within the area occupied by Europeans and Goans.

Zanzibar.—Here, on the morning of 22nd September, the author was accompanied by Dr. W. MANSFIELD-ADERS, the Government Zoologist, who witnessed and took photographs of the climber at work. In the afternoon, in the centre of the town, living larvæ were got from a palm leaning over the principal business street, indeed, while the climber was working in the crown traffic was stopped, not merely from curiosity but from the fear that he or nuts might fall.

Dar-es-Salaam.—Work was begun here near the European Hospital, at the north-western portion, and carried on steadily through the inhabited European area in 1922, and in 1923 in part of the same area and the adjacent parts of the golf course. In the *Dar-es-Salaam Times* of 22nd December, 1923, the Director of Agriculture, in inviting tenders for the sole licence to collect coconuts from the Government palms in the township, stated that these alone were in number approximately 10,000. They are particularly numerous in the grounds of the new Government House. *Anopheles* larvæ were first obtained on the fourth day after work was commenced, from palms adjacent to the European Hospital, and the old Government House, which was at that time occupied as such.

Mafia.—In the presence of Mr. VAN SYCKEL, the Financial Officer under the Commissioner of Zanzibar, four palms were examined on 15th October, 1922, and yielded water, each from $\frac{1}{4}$ oz. to 1 oz., very discoloured with black decayed vegetable débris, and containing no larvæ. On the authority of the Financial Officer there are altogether on the Mafia group of islands about one million coconut palms.

Kilwa Kiswani.—This station was visited on 17th October, and two palms were examined in the town and another about $\frac{1}{4}$ mile distant; water was obtained only from one of the former, and it was very clear, about 2 oz. in quantity, and contained no larvæ. The palms in and close about the town were not numerous, and appeared poorly developed and rather parched.

Lindi is situated in 10° south latitude. The township area consists of the land on the west side of the inlet lying within a circle with a 1-mile radius from the Boma. The Senior Commissioner was understood to estimate the number of palms at 4,000, but it is considered they must appreciably exceed that figure, since 2,712 within the boundary were examined, and there appeared to remain quite as many again unexamined when work ceased. These figures refer only to well-grown ones which have reached the bearing stage, and, further, there are a considerable number younger, for although planting has been prohibited since 1918, it was still proceeding up to the time the author left in June, 1923. They constitute almost the whole of the larger vegetation, and in the inhabited portion of the township area are so dense that when half a gale is not blowing the air is constantly stagnant in all streets parallel to the direction of the inlet, except in the one immediately along the shore.

Work was commenced just outside the area and steadily pursued past the

hospital, and so into and through the most thickly inhabited native portion of the town, where *Anopheles* were first encountered on 9th December. As work progressed they were found at other portions, and most plentifully in June, near the Senior Commissioner's residence.

Mikindani, the most southerly of the stations, and about thirty miles from Lindi, was visited on 14th December, 1922, and five palms examined in the Boma Compound before departure on the following morning. The rising piece of ground occupied by the Boma, and a lower-lying flat stretch, over which spreads the town, are both fairly thickly studded with coconut palms.

29. GENERAL CONCLUSIONS.

As results of the investigation the following conclusions have been drawn:—

1. Mosquitoes breed in the crowns of coconut palms.
2. Breeding goes on there with considerable regularity throughout the year, not merely when other potential hatcheries, derived from heavy rainfall, are in existence, but also during times of comparative drought when collections of storm-water have subsided, and that in steps in the palms and in rot-holes in other trees has disappeared by evaporation.
3. Within the township areas, in which almost the whole of the investigation was conducted, harmless jungle mosquitoes are in a decided minority, the vast majority of those got from the crowns of the palms being biting mosquitoes, and of these, at all stations, the proved disease carriers predominated.
4. The species most plentiful was not the same at all stations: at Tanga it was *C. fatigans*; at Dar-es-Salaam it was *A. argenteus*. Until investigation settles the point there appears no reason for concluding that in some places species of *Anopheles* may not be the most prevalent.
5. Breeding taking place in them at all times of the year, the crowns of the palms act as reservoirs from which may be stocked other suitable places, whenever such may appear from rainfall or other causes.
6. Imagines are produced in sufficient numbers to prejudice the health of the community. The observations made and facts recorded do not enable me to fix a definite figure as the average output per palm per day; but from what has been done and set out, it is considered that it can scarcely reasonably be taken as less than one, and is probably very much higher. The minimum figure does not appear formidable when regarding a solitary palm for a single day, but even it assumes a menacing aspect when—realising that the life of an imago may extend over many months—it is applied for every day of the year to a township area containing from 4,000 to 70,000 coconut palms.
7. What has been demonstrated for a portion of the east coast of Africa is probably also taking place throughout tropical lands round the world, wherever the coconut palm flourishes, varying in degree as the conditions may be more or less favourable to the palm, and in species yielded according to their geographical distribution.

8. No anti-mosquito campaign can be considered otherwise than wanting in thoroughness which neglects to take account of the crown of the palm, since, although it may be found uninhabited, it must ever remain a potential nursery for disease-bearing pests.

9. The natural enemies of the mosquito, in all its stages, so far as observed, are inefficient; the harmful species have been found developing from the larval stage to the perfect insect in the presence of *M. brevialpis* and *L. tigripes* larvæ; and *Aedes* larvæ have been brought from crowns, the resting-places of numerous bats.

30. PREVENTIVE MEASURES.

Unfortunately, throughout the period of investigation, stress of routine duties and lack of sufficient staff, prevented the interesting experiment of testing the feasibility of dealing with selected groups of palms by treating the crowns with oily or other larvicidal substances. It is, however, not considered probable that any such measures, even if proved effective in dealing with small selected groups, could be generally applicable practically on a large scale; and this not merely on account of the large staff of labourers it would require and the necessity for their careful supervision, but that periodical mechanical damage alone to the crowns, which would of necessity frequently occur, would prove so prejudicial as to render the method but a prolonged and costly way of clearing the area not only of the pest but also of its breeding-place.

The ideal measure, undoubtedly, would seem to be to clear the coconut palm from all inhabited areas, both European and native; but economic considerations of compensation appear to stand in the way of so radical a measure. It is therefore advocated:—1, that planting should be prohibited within all township areas, and the prohibition enforced; 2, that these areas should be cleared without delay of all Government owned palms; 3, that on coconut plantations owners and occupiers should be required to provide a sufficiently extensive cleared area for the housing of all employees; 4, that natives generally should be instructed in the danger of building their houses amongst or near palms, and encouraged as much as possible to live in more open spaces.

31. IN APPRECIATION OF ASSISTANCE.

Besides to those already mentioned, who have assisted and given encouragement by witnessing the examination of palms and supplying meteorological records, etc., the author desires to express his thanks and appreciation of many kindnesses received from Mr. EDWARDS and other members of the staff of the Department of Entomology, British Museum, and from the Royal Society of Tropical Medicine and Hygiene and its Honorary Secretaries.

APPENDIX.

DESCRIPTIONS OF TWO NEW SPECIES OF MOSQUITOES FROM COCONUT
PALMS IN EAST AFRICA.

BY F. W. EDWARDS.

*(Published by permission of the Trustees of the British Museum.)**Aedes (Stegomyia) calceatus*, sp. n.

♂. Scales of *head* mostly white, with a very slight ochreous tinge; two rather large, but suffused, greyish patches above. Clypeus bare. Tori with large patches of silvery-white scales. Palpi with a narrow white ring near the base, a broader one beyond the middle of the long segment; small white spots beneath the bases of the two terminal segments.

Thorax black, the scutum mainly clothed with narrow black scales; bristles rather dark brown. In the middle of the front margin of the scutum is the usual small patch of flat, white scales; the subdorsal pair of snow-white patches are very large, and, as usual, composed of broadish curved scales; posteriorly these patches are somewhat pointed, and from the points a pair of narrow white lines extend backwards to the scutellum, the scales forming the anterior part of these lines being narrower and more ochreous-tinged than those of the posterior part. The bare ante-scutellar space is bordered with narrow lines of broadish white scales, which unite in front to form a single, median, ochreous line, composed of narrow scales, which extends forwards for a short distance. Scutellum almost completely clothed with silvery-white scales. A small white patch in front of the root of each wing. Anterior pronotal lobes with white scales; posterior pronotal lobes ("pro-epimera") mostly bare, but with a small patch of broad, silvery-white scales near the posterior margin, bordered above with a few narrow blackish scales.

Abdomen blackish; tergites all with basal, lateral, silvery-white spots, which on tergite 8 are very prominent from above; tergites 2-5 with nearly complete basal white bands, 6 and 7 with rather small, median, basal, silvery-white spots. Sternites silvery-white on the basal half, black on the apical half. Hypopygium with the ninth tergite rather broad; median emargination rather shallow, but double, the bristly lateral lobes not very prominent. Claspers rather short and stout, gently curved, with short and stout terminal spine. Basal plaque rather large, reaching to the middle of the side-piece, densely hairy, but none of the hairs modified. Tenth sternites with the dorsally-directed, subapical arm, usual in this group of species. Lobes of mesosome with some of the outer teeth rather long and strong.

Front legs nearly all black, the femora with a narrow, whitish, ventral line on the basal half; tibiæ with a narrow, white, basal ring, broader beneath; first two tarsal segments with narrow, white, basal rings. Claws very unequal, the larger simple, the smaller with a basal tooth. *Middle legs* with the femora all black, except for two rounded silvery-white spots on the

anterior surface, placed just beyond the middle and at the tip; tibiæ all black; tarsi with the first two segments white, except for a black line in front on the apical half or more; last three segments white. Claws as on front legs. *Hind legs* with the femora creamy-white on the basal half, black on the apical half, except for the silvery-white tip and a large silvery-white patch on the anterior surface adjoining the creamy area; tibiæ black, with a straight white line beneath on the basal fourth; tarsi with white rings at the bases of the first three segments, fourth segment white except at the extreme tip, fifth wholly black; claws simple.

Wings normal; base of upper fork-cell slightly before that of the lower; wing-length about 3 mm.

♀. Resembles the ♂, except that the dark patches on the head are larger, blacker, and more sharply defined. Palpi with the tip broadly silvery-white. Front and middle claws toothed.

TANGANYIKA TERR.: Lindi, 1923; a series reared from larvæ found in the water in the leaf-bases of coconut palms (Dr. W. E. HAWORTH). Type ♂, paratypes 7 ♂ 7 ♀ in the British Museum, presented by the collector.

This species belongs to the same group as *A. (S.) poweri* THEO. and *A. (S.) pseudonigeria* THEO., and most nearly resembles the recently described *A. (S.) chaussieri* EDW., but is distinct from all these in many details. The specific name chosen is intended to refer to the black (or shoe-like) tip of the hind tarsi.

Aedes (Stegomyia) soleatus, sp. n.

Closely related to *A. (S.) calceatus*, differing as follows: Bristles above wing-roots lighter brown to golden. White spot on the front margin of the scutum composed of narrow scales. White bands of the first five abdominal tergites incomplete, especially in the ♂, where they form median spots only; spots on tergites 6 and 7 larger, and almost reaching the hind margin. Ninth tergite of male hypopygium with a broad and deep median emargination; basal plaque with several of the hairs towards the inner margin somewhat thickened and twisted, and placed on a slight projection: clasper more slender and with much longer terminal spine. Second segment of middle tarsi without black line in front. Hind tibiæ with the white ventral line widened apically, so that a white patch is visible on the outer surface of the tibia, near the base. Fourth segment of hind tarsi wholly white; fifth also white, except beneath and at the extreme tip.

TANGANYIKA TERR.: Lindi, 1923; a series reared from coconut palms (Dr. W. E. HAWORTH); type ♂, paratypes 6 ♂ 6 ♀ in the British Museum, presented by the collector.

The specific name alludes to the black "sandals" of the hind feet, which form a naked-eye distinction from *A. (S.) calceatus*. The two species were not usually found mixed, though one or two odd specimens of *A. soleatus* occurred among series of *A. calceatus*.