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Breeding places and seasonal incidence of *Aedes aegypti*, as assessed by the single-larva survey method *

T. RAMACHANDRA RAO,[1] M. TRPIS,[2] J. D. GILLETT,[1] C. TEESDALE,[1] & R. J. TONN [3]

The single-larva survey method was employed to study the breeding places and seasonal incidence of Aedes aegypti *in Dar es Salaam, Tanzania. From May 1968 to May 1969, 28 462 containers of water—located in approximately equal numbers indoors and outdoors—were investigated. The highest frequency of breeding (8.0%) of* A. aegypti *was observed in tires and motor parts. Drums, barrels, water-pots, and other receptacles left outdoors showed a higher frequency (3.1%) than those kept indoors (0.6%). Metal containers were infested to a greater extent than those made of mud, wood, or other materials; 2.5% of coconut shells, snail shells, etc. and 1.3% of tree holes, plant axils, and cut bamboos were infested. The seasonal prevalence, expressed as a container index, closely followed and paralleled the fluctuations in rainfall. The value of this survey method for both ecological studies and practical control purposes is discussed.*

The city of Dar es Salaam (longitude: 39° 12′ E; latitude: 6° 53′ S), with a population of approximately 275 000 and a total area of about 830 ha, is situated on the coast of Tanzania. Dar es Salaam is an important seaport and has a busy international airport. It is the seat of the Government of Tanzania and the commercial and industrial centre of the country.

The hot, humid climate of Dar es Salaam is typical of coastal areas in the tropics. The average annual rainfall is 1 096 mm in 108 days of rain (Table 1), and there are two main seasons of rainfall: the so-called short rains during November and December and the long rains during March, April, and May. There is some rain in every month of the year, but the heaviest precipitation occurs in April. The mean maximum temperature ranges between 28.6°C (July) and 32.4°C (March), and the mean minimum between 18.1°C (August) and 23.5°C (January). Extreme temperatures on any day of the year are 35.2°C and 12.8°C. The relative humidity ranges daily between a low of 54–74% and a high of 94–97%.

Except in the commercial and thickly populated central areas, the city is characterized by the presence of numerous trees. Coconut and mango, cashewnut, jackfruit, and other tropical trees are very common. The grass is lush and tall and has to be kept mown. Shrubs of various types flourish wherever they are allowed to grow. Sisal is cultivated in one or two districts on the periphery of the city.

There are three main types of housing: (1) large multi-storey buildings in the commercial and residential areas of central Dar es Salaam; (2) bungalows, each located within its own compound. These vary from small to fairly large buildings and are characteristic of the northern and north-western parts of the city, including areas such as Oyster Bay; (3) a new type of single-storey residential building in the more recent extensions of the city. The population density is highest in the first type of housing and lowest in the second type. Buildings of the last type are usually occupied by more than one family.

Abundant and continuous piped water is supplied by the city authorities. Most buildings have their own water taps. It is only in some of the most outlying areas that water has to be brought from distant public taps. Wells are extremely rare.

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[1] Acting project leader.

[2] Ecologist.

[3] Project leader.

Table 1. Temperature and relative humidity statistics for Dar es Salaam (airport) [a]

Month	Latitude 0.6° 53′ S								Longitude 39° 12′ E					Altitude 58 metres				
	temperature °C (1955–1962)						relative humidity (1954–1963)		rainfall (1954–1962)				sunshine (1955–1963)			evaporation (1957–1963) (type 25.4 cm pan)		
	averages				extremes		0300	1200	monthly total (mm)			average No. of days of rain						
	max. + min. / 2	mean range	mean max.	mean min.	max.	min.	GMT	GMT	average	highest	lowest		average hours	highest hours	lowest hours	average mm	highest mm	lowest mm
January	27.5	8.1	31.6	23.5	35.0	18.1	94	65	77	216	7	9	233	307	158	208	243	165
February	27.5	8.9	32.0	23.1	35.2	18.4	95	65	90	192	22	8	221	260	151	203	248	157
March	27.5	9.7	32.4	22.7	34.6	19.6	96	68	125	167	30	11	217	254	177	188	229	162
April	26.6	8.4	30.8	22.4	35.0	20.0	97	74	245	314	163	18	159	204	114	151	189	119
May	25.5	9.0	30.0	21.0	32.2	16.2	96	67	154	372	28	13	223	276	143	172	199	140
June	24.3	10.2	29.4	19.2	33.0	16.4	97	60	31	69	3	7	219	237	186	155	183	137
July	23.4	10.4	28.6	18.2	30.3	14.2	97	59	39	155	2	6	220	248	152	160	177	135
August	23.7	11.3	29.4	18.1	31.7	12.8	96	54	31	95	1	4	270	313	223	179	209	154
September	24.3	11.7	30.1	18.4	32.5	14.3	96	55	21	51	5	5	255	276	219	195	222	161
October	25.3	11.2	30.9	19.7	33.4	15.8	97	58	69	284	13	6	276	310	229	209	264	143
November	26.3	9.5	31.1	21.6	33.7	17.7	97	64	108	415	1	10	249	306	171	207	250	131
December	27.3	8.8	31.7	22.9	34.5	19.1	95	66	106	304	24	11	236	316	201	210	268	160
total									1 096	1 733	823	108						

[a] Taken from *Climatological statistics for East Africa and Seychelles, Part III, Tanganyika and Zanzibar, 1934*, issued by East African Meteorological Department, Nairobi, Kenya (reprinted 1967).

As the water supply is excellent, the practice of storing water for long periods for domestic purposes is not prevalent. Because of the satisfactory pressure of the water, even overhead tanks are not as common as in other large cities. Among the poorer members of the community, who are without their own water taps, water is stored for short periods in pots or metal drums rather than in the large earthenware jars that are commonly used in other parts of Africa.

METHODS

Single-larva collections according to the technique developed by Sheppard et al. (1969) were made periodically in 15 districts of the city (Fig. 1). Houses and surrounding premises were examined. The survey consisted essentially in (*a*) searching for water

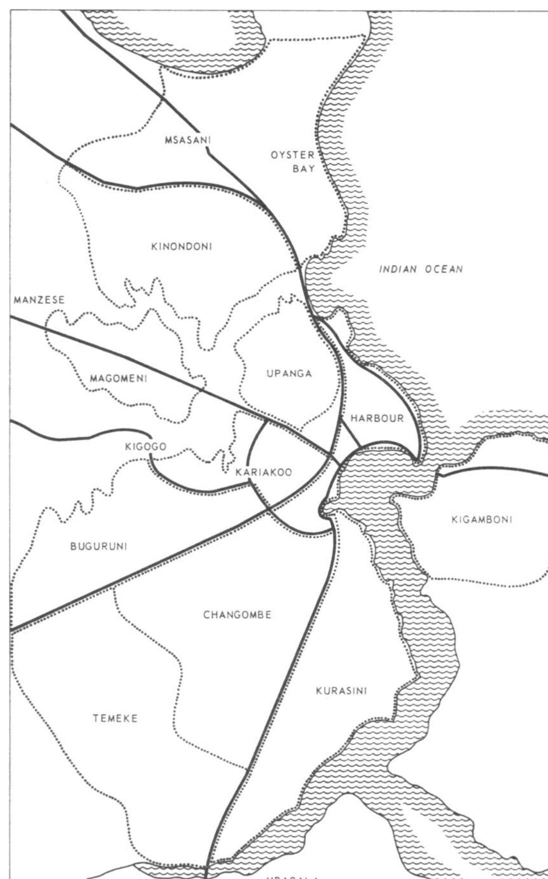

Fig. 1. Districts of Dar es Salaam searched for breeding places of *A. aegypti* by the single-larva survey method.

Table 2. Surveys of water-filled containers for *A. aegypti* larvae, Dar es Salaam, 1968–1971

Period	Outdoor artificial containers		Automobile parts		Natural cavities		Indoor containers		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
May 1968	54/439	12.3	5/139	3.6	17/359	4.8	45/542	7.6	121/1 479	7.4
Aug.-Oct. 1968	37/1 818	2.0	8/163	4.9	1/64	0.2	7/3 993	0.2	53/6 038	0.8
Nov. 1968–Jan. 1969	135/5 440	2.5	55/707	7.8	12/771	1.6	20/7 659	0.3	222/1 457	1.5
April 1969	47/1 130	4.2	16/113	14.2	11/266	4.1	4/1 150	0.3	78/2 656	2.9
May 1969	35/1 038	3.4	18/117	15.4	18/362	5.0	15/1 360	1.1	86/2 877	3.0
June 1969	17/783	2.2	10/109	9.2	2/117	1.7	4/993	0.4	33/2 002	1.6
August 1969	12/681	1.8	5/95	5.5	3/206	1.5	2/658	0.3	22/1 640	1.3
December 1969	6/243	2.5	3/44	6.8	1/12	8.3	0/447	0	10/746	1.3
December 1970	5/762	0.7	0/42	0	0/48	0	0/507	0	5/1 653	0.3
Feb.–Mar. 1971	45/13 233	0.3	3/243	1.2	4/484	0.8	3/6 664	0.05	55/20 614	0.3
May 1971	92/3 066	3.0	4/42	9.5	4/453	0.9	31/4 441	0.7	131/8 002	1.6
July 1971	15/2 556	0.6	5/127	3.9	0/292	0	2/3 923	0.1	29/6 898	0.4

containers, counting them, and classifying them according to their type and location (indoors or outdoors); (*b*) examining the containers for the presence of *A. aegypti* larvae; and (*c*) collecting a single larva from each positive container for identification in the laboratory. The collections were made by mosquito scouts under the supervision of a malaria inspector.

Outdoor containers—mainly discarded artifacts and automobile parts—fill with rain water. They are found in all parts of the town, but are more abundant in the peripheral areas. Indoor containers are kept manually filled with water for domestic purposes. The following types of container were categorized in the survey.

Outdoor artificial containers : metal drums and tins, mud pots (in use or discarded), broken glass bottles, enamel dishes, and similar receptacles;

Automobile parts : discarded motor vehicle bodies and parts, and discarded rubber tires;

Natural cavities : tree-holes, the axils of banana, *Colocasia*, pineapple, and other plants, snail-shells, rock-holes (mainly in coral rock), and crab-holes;

Indoor containers : metal drums (capacity: approximately 100 and 200 litres), kerosene tins (capacity: about 18 litres), and mud pots with diameters of up to 45 cm.

When assessments were commenced in May 1968, they served only as a means of rapid reconnaissance. As experience was gained, the survey techniques were improved and standardized. The single-larva survey method was used until the end of 1970; in the surveys made in 1971, all the larvae in each mosquito-positive container were collected and identified.

RESULTS

Table 2 gives the container indices for indoor containers as a whole, whereas outdoor containers are divided into two categories: artificial and natural. Automobile parts constitute a separate category, which until January 1969 consisted only of tires, but from April 1969 onwards included also metal parts. These results should be considered in the light of the three seasons of the year: (1) June to October 1968: the dry, cool season; (2) November 1968 to February 1969: the hot season with short rains; and (3) March to May 1969: the heavy rainfall season. The percentage of water-filled containers infested reaches a maximum in May and decreases markedly during the second half of the calendar year. When the containers indices noted in the 15 different districts are compared (Table 3), it is evident that the lowest populations of *A. aegypti* are to be found in the harbour area and the highest in the outlying districts.

Table 3. Container indices based on outdoor plus indoor containers, and Breteau indices (in parentheses), observed in 15 districts of Dar es Salaam

District	July 1968	August 1968	September 1968	October 1968	November 1968	Feb.–March 1971	May 1971	July 1971
Msasani	10.0	0	4.8	2.3	2.5	0.1 (0.5)	2.2 (18)	0.2 (1)
Magomeni	7.5	0	1.2	1.1	0.9	0.9 (6)	—	—
Kariabkoo	38.5	0	0	0.5	1.2	0.2 (1)	1.7 (16)	0.4 (3)
Kigamboni	2.0	6.3	—	2.2	1.0	0.1 (0.5)	—	—
Oyster Bay	12.5	8.6	0	1.9	0	—	—	—
Mbagala	13.1	5.3	7.2	2.2	3.4	—	—	—
Manzese	5.2	0	5.0	2.5	0.4	—	—	—
Buguruni	—	—	—	—	—	0.1 (0.5)	2.3 (17)	0.5 (4)
Temeke	—	—	—	—	—	2.3 (9)	2.3 (17)	0 (0)
Changombe	—	—	—	—	—	0.1 (0.5)	0.4 (4)	0.2 (2)
Kinondoni	—	—	—	—	—	0 (0)	1.3 (12)	0.3 (2)
Upanga	—	—	—	—	—	0 (0)	0 (0)	0.2 (1)
Harbour	—	—	—	—	—	0 (0)	1.7 (3)	0.5 (4)
Kurasini	—	—	—	—	—	0.4 (1.5)	1.3 (12)	0.7 (4)
Kigogo	—	—	—	—	—	1.4 (8)	4.1 (34)	0.2 (1)

Breeding indoors and outdoors

Except in the initial survey in May 1968, when as many as 7.6% of the indoor breeding places searched contained *A. aegypti* larvae, the rate did not exceed 1.0% in any of the other seasons. On the other hand, the percentage of water-containing outdoor breeding places with *A. aegypti* was always higher.

Types of container

During the year May 1968–May 1969, 28 462 containers of water were searched, of which 14 174 were inside houses and 14 288 outdoors. Of the outdoor containers, 11 101 were man-made; 3 187 were natural cavities. The proportions of different types of man-made container noted in April and May 1969, when a carefully regulated study was made, are shown in Table 4. It can be seen that metal containers predominated, both indoors and outdoors. They consisted mainly of drums and of kerosene and other tins; metal water-pots were rare. Rubber tires and automobile parts comprised about one-tenth of all water-filled man-made containers found outdoors.

It is not justifiable to comment on the relative proportions of different natural cavities, such as tree-holes, plant axils, rock-holes, and coconut shells, since they are difficult to count. In the present study, the numbers of such cavities found positive for *A. aegypti* between May 1968 and May 1971 were: tree-holes, 47; snail-shells, 23; rock-holes, 22; coconut shells, 21; plant axils, 9; and cut bamboos, 5.

Table 4. Proportions of different man-made containers found indoors and outdoors

Containers	Outdoors		Indoors	
	No.	%	No.	%
Metal containers				
drums, tanks, tins, buckets, water-pots, etc.	1 511	63.1	1 452	57.8
Mud, cement, and glass containers				
drums, pots, ant-traps, cisterns, etc.	654	27.3	1 058	42.2
Automobile parts				
tires, bodies, motors, etc.	230	9.6	—	—
total	2 395	100.0	2 510	100.0

Table 5. Percentages of containers found to be filled with water and of water-filled containers positive for *A. aegypti*, and Breteau indices (BI)

Period	Water-filled containers [a]		Positive for *A. aegypti* [a]		Positive containers per 100 houses [b]	
	No.	%	No.	%	No.	BI
May 1968	937/1 861	50.1	76/937	8.1	—	—
June 1968	—	—	15/252	6.0	—	—
July 1968	—	—	37/367	10.1	—	—
August 1968	—	—	10/445	2.2	—	—
September 1968	—	—	17/408	4.2	—	—
October 1968	—	—	19/1 202	1.6	—	—
November 1968	—	—	21/2 092	1.0	—	—
December 1968	—	—	132/2 259	5.8	—	—
January 1969	—	—	49/2 567	1.9	—	—
April 1969	—	—	74/1 506	4.9	78/5.54	14.8
May 1969	—	—	71/1 517	4.6	86/5.19	16.6
June 1969	—	—	29/1 009	2.9	33/4.88	6.8
August 1969	—	—	20/982	2.0	—	—
December 1969	299/711	42.1	10/299	3.3	10/2.7	3.7
December 1970	852/1 456	58.5	5/852	0.6	5/5.4	0.9
Feb.–March 1971	8 296/19 731	41.9	52/13 950	0.4	55/24	2.3
May 1971	3 561/7 820	45.4	100/3 561	2.8	131/10	13.1
July 1971	2 975/7 241	41.2	20/2 975	0.7	22/10	2.2

[a] Outdoor containers only.
[b] Indoor and outdoor containers.

Frequency of breeding in containers

The pooled results of the entire year (May 1968–May 1969) show that tires and motor parts were the places with the highest frequency of breeding (8.0%). Drums, barrels, water-pots, etc. located outdoors showed the next highest percentage (3.1%), whereas the same types of container kept indoors gave the lowest yield of *A. aegypti* (0.6%).

Among the natural cavities, the frequencies were 2.5% for coconut shells, snail-shells, and the like, and 1.3% for places such as tree-holes, plant axils, and cut bamboos. The breeding frequency in the latter category is as high as 5.1% if the figures obtained from more than a thousand plant axils in May 1968 are excluded from consideration.

Seasonal variation

If the average monthly container indices found outdoors (Table 5) are related to rainfall during the surveys of 1968 and 1969 and to the average monthly rainfall observed in the past, it is seen (Fig. 2) that there is remarkable parallelism between the container index and the amount of rainfall. The frequency of infestation is lowest in the cool, dry season and highest in the season of long rains. Even the unusual rainfall in November 1968 was reflected in a secondary peak of the container index. It had already been observed in the years 1920–1924 in Dar es Salaam that mosquito scouts collected the maximum numbers of *A. aegypti* larvae in the months of April and May (Tanganyika Territory, 1924, p. 143). The fall-off in the container index in the cool, dry season and its rise in the hot season with short rains did not exactly coincide with the rainfall curve but lagged behind it slightly.

If the container indices are considered in relation to the types of container (Table 2), it is seen that both the outdoor artificial containers (mainly drums

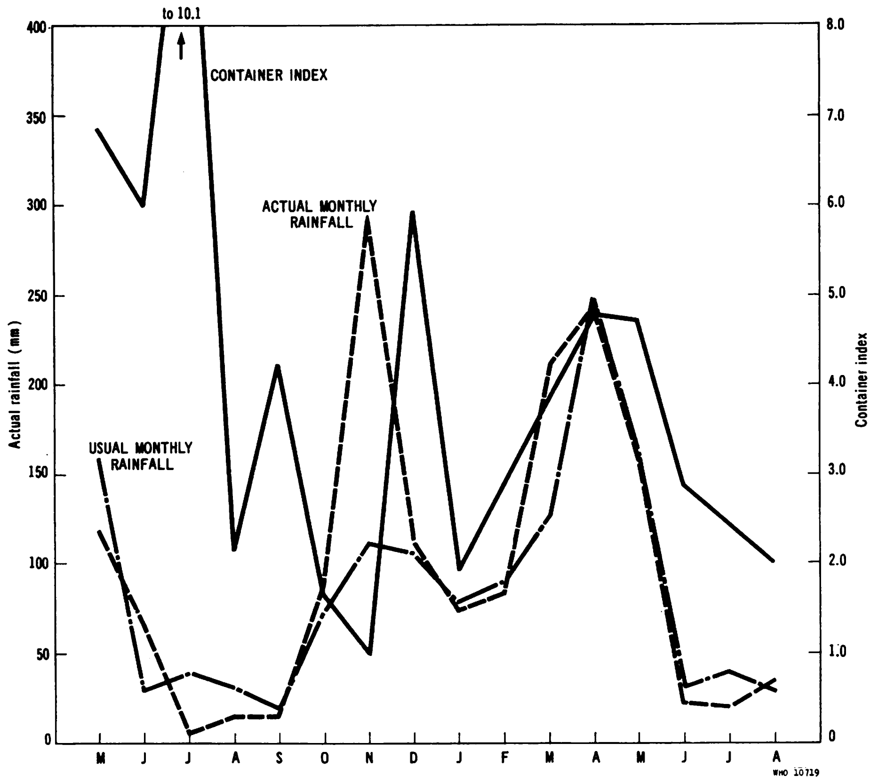

Fig. 2. Outdoor container indices found from May 1968 to August 1969, plotted alongside the actual monthly rainfall during that period and against the usual monthly rainfall taken from climatological data.

and tins) and the natural cavities (mainly tree-holes) show a decrease in infestation in the cool dry season (August–October). On the other hand, the percentage of infestation of automobile parts (mainly tires) steadily increased during the period May 1968–May 1969. At the same time, the frequency of infestation of indoor containers decreased from May 1968 to May 1969, with a detectable trough in the cool dry season.

Associated species

Of all the larvae collected between May 1968 and May 1969, 70% were *A. aegypti*. This proportion became as high as 98% in the collections made in April and May 1969. The associated species were *Culex fatigans* except for two samples of *Culex nebulosus*. Whereas the proportion of *C. fatigans* was 38% from May to November 1968, it was only 1.8% in April and May 1969. However, it increased again to an average of 38% between June and December 1969. Between February and July 1971 the proportion of *C. fatigans* rose from 4% to 27% of the larvae collected.

DISCUSSION

Since no attempt was made to count the numbers of each type of container in any locality, the results cannot be expected to give an accurate indication of the proportions of different types of container, actually or potentially water-holding. Still less do they show seasonal variations in terms of the absolute numbers of the *A. aegypti* population. For this purpose, a different type of survey, including an enumeration of all types of breeding place, would be necessary. Difficult as such a survey would be, even for man-made containers, it is questionable whether it would be feasible at all for natural cavities such as holes in rocks or trees, plant axils, and snail-shells. Perhaps estimates on the basis of a rigid survey in properly chosen sample areas (biotopes) could be attempted.

As the scouts participating in the present study did not show any bias in their search for containers, the figures given in this paper roughly indicate the relative abundance of the different types of man-made container. Certainly those made of metal, such as drums, barrels, and tins, predominated both indoors and outdoors. Nevertheless, containers made of mud and cement—particularly those of mud—were also quite common. Natural cavities, such as holes in trees and rocks, and leaf axils, comprised about one-tenth of all the water-filled breeding places searched.

Taking the year May 1968–May 1969 as a whole, it was found that tires were the most frequently infested containers (8.0%), followed by drums, barrels, water-pots, and similar receptacles found outdoors. Only a small percentage (0.6%) of indoor man-made containers yielded *A. aegypti*. The results obtained in April and May 1969, when a distinction was made for the first time between metal containers and those made of other materials, showed that 4.8% of the former, but only 2.3% of the latter, were infested with *A. aegypti*.

The relatively low degree of infestation of indoor containers calls for comment. As the practice of storing water for long periods is not generally prevalent, the chances that *A. aegypti* will breed in water containers, are minimized. When mud pots were experimentally introduced into some houses and kept filled with water, *A. aegypti* larvae promptly appeared. Therefore, it does not seem that, intrinsically, there is anything to prevent *A. aegypti* from breeding indoors if opportunities are available. In 1924, for example, more *A. aegypti* were collected from domestic tanks (cisterns) than from drums and barrels (Tanganyika Territory, 1924, p. 195).

In East Africa, *A. aegypti* frequently breed in natural cavities such as holes in trees and rocks, plant axils, coconut shells, and snail-shells. The proportion of such cavities found to be infested with *A. aegypti* during the current survey shows that they are not a negligible factor in Dar es Salaam, since 2.5% of all the coconut shells, husks, and snail-shells and 1.3% of all the tree-holes, plant axils, and similar cavities examined were infested. If the data for April and May 1969 alone are considered, it is seen that 3.7% of the former group and 5.5% of the latter were infested. The tops of the palm trees that abound in the city were not examined, as it had been shown many years previously that *A. aegypti* did not oviposit in tin containers placed in such tree tops.

The parallelism, and especially the time-lag, between rainfall and the container index (Fig. 2) are noteworthy. Rainfall might be expected to increase the number of breeding sites; yet there was little difference between the seasons in the percentages of water-filled containers (Table 5). However, since rainfall was found in this investigation to be associated with an increase in the container index, two possible explanations can be offered: First, the heavier rainfall in April and May could make the water bodies ecologically more suitable for *A. aegypti* than they were during the dry season, when evaporation greatly reduces the volume of water and concentrates any deleterious solutes that might be present in it. A second explanation might be that the heavy rainfall in April and May would keep containers continuously filled with water, thus allowing better survival of larvae than in the dry season, when rainfall is intermittent and only the deeper containers still contain water. At any rate, the general infestation, as measured by the Breteau index (the number of positive containers per 100 houses), showed levels in April and May that were at least four times as high as those from December to March (Table 5).

For practical purposes, the single-larva survey employed has highlighted the breeding potential of *A. aegypti* in different types of container and thus has provided valuable information for devising methods of controlling this species. From the ecological standpoint, the results of the survey have shown that, in Dar es Salaam, tires and other man-made containers are the most favourable sites for *A. aegypti* larvae. Natural cavities, such as holes in trees and rocks, also provide a habitat for *A. aegypti*, to an extent unknown in other parts of the world.

RÉSUMÉ

GÎTES LARVAIRES ET INCIDENCE SAISONNIÈRE D'*AEDES AEGYPTI*, D'APRÈS UNE ÉVALUATION FAITE PAR LA MÉTHODE DITE « DE RÉCOLTE D'UNE SEULE LARVE »

De mai 1968 à mai 1969, on a procédé à une enquête sur la prévalence d'*Aedes aegypti* à Dar es-Salaam (Tanzanie) en utilisant la méthode consistant à prélever un seul spécimen dans tous les récipients abritant des larves de moustiques. Au total, 28 462 conteneurs divers, à l'extérieur et à l'intérieur des habitations, ont été examinés. Une activité larvaire maximale (8,0%) d'*A. aegypti* a été observée dans les pneus et autres pièces d'automobile. Les fûts, tonneaux, pots à eau et autres récipients laissés à l'extérieur des habitations étaient plus fréquemment positifs (3,1%) que ceux placés à l'intérieur (0,6%). Les récipients métalliques étaient davantage colonisés que les récipients en terre, en bois ou en d'autres matériaux; 2,5% des coquilles de noix de coco, des coquilles de mollusques, etc., de même que 1,3% des creux d'arbre, des aisselles de plantes et des tiges de bambou hébergeaient des larves d'*A. aegypti*. La prévalence d'*A. aegypti*, exprimée par l'« indice récipient » (pourcentage de récipients renfermant des larves du vecteur) a varié en fonction des précipitations, présentant un clocher après les fortes chutes de pluie d'avril et un autre un mois après la petite saison des pluies de novembre et décembre.

La valeur de cette méthode d'enquête pour les études écologiques et la lutte contre le vecteur est examinée.

REFERENCES

Sheppard, P. M. et al. (1969) *Bull. Wld Hlth Org.*, **40**, 467
Tanganyika Territory (1924) Annual Medical Report