TABLE 15

Annual variation in the larval prevalence of A. culicifacies *and the total of all other anopheline larvae caught in village breeding places at Malaria Observation Stations during the period* 1935-1950.

Year	Number of dips	*A. culicifacies*		Other anopheline species	
		Number of larvae	Larval rate	Number of larvae	Larval rate
1935	12711	605	4·76	9610	75·61
1936	42740	203	0·47	33092	77·43
1937	40100	184	0·46	30337	75·67
1938	37677	209	0·55	28021	74·37
1939	56342	942	1·67	39877	70·79
1940	66196	342	0·52	36710	55·46
1941	71419	108	0·15	36819	51·54
1942	74483	39	0·05	35514	47·66
1943	85459	100	0·12	22752	26·62
1944	80412	9	0·01	36147	44·94
1945	81656	755	0·92	32556	39·87
1946	78803	74	0·09	28544	36·21
1947	136158	4	0·003	38749	28·34
1948	102308	33	0·03	24963	24·41
1949	110055	0	0	16494	14·96
1950	148851	0	0	17018	11·44

at Alawwa in the epidemic year of 1939. The highest larval rate was only 2·25 in pools, while that for the total of all other anopheline larvae was as high as 79·83. The larval rate of 2·25 in pools may be compared with some of the very high rates recorded in sand and rock pools in 1939 (Tables 11 and 13), to show how negligible was the incidence of the vector in village breeding places.

(*b*) **Adult Prevalence.** The examination of dwellings for *A. culicifacies* and other anopheline mosquitos has always been carried out from 7 a.m. to 12 noon. The results of these hand catches, showing the variation in catching rate per hour for all Malaria Observations, is given in Table 17. The fact that the catching rate for *A. culicifacies* has never exceeded one, even in a epidemic year such as 1939, when the larval rate was as high as 31·62, can be explained by the peculiar habit of this mosquito in secreting itself in cracks and crevices, first recorded by James and Liston (1911). The wattle and daub dwellings in rural Ceylon, thatched with the woven fronds of the coconut palm, are ideal for this purpose and it is not surprising that the catches of adults in the Maha Oya Basin are low. This is proved by the results of the spray and hand catches given in one of our previous papers (Rajendram

TABLE 16

Larval rates for Anopheles culicifacies *and the total of all other anopheline species caught in all types of village breeding places at Alawwa in* 1939.

Type of breeding places	Number of examinations	Number of dips	*A. culicifacies*		Other anopheline species	
			Number of larvae	Larval rate	Number of larvae	Larval rate
Built wells	154	529	0	0	99	18·71
Unbuilt wells	260	1438	1	0·07	1600	111·11
Borrow pits	47	530	7	1·32	278	52·45
Swamps	52	1055	2	0·19	1526	144·64
Drains	87	1100	9	0·82	662	60·18
Pools	36	665	15	2·25	531	79·83
Soakage pits	16	270	0	0	143	52·96
Coconut trenches	24	330	2	0·60	229	69·04
Irrigation channels	36	1015	9	0·88	546	53·80
Paddy (fallow)	48	860	8	0·93	316	36·74
Paddy (planted)	20	400	0	0	256	64·00
Paddy (full-grown)	10	150	0	0	9	6·00

and Jayewickreme, 1951a). These observations showed that in the sprayed houses nearly thirteen times as many adult *A. culicifacies* were collected as in the unsprayed houses.

1. *Prevalence in Dwellings.*—In Table 17, is summarised the annual variation in the mean catching rate per hour for all Observation Stations examined each year. The only feature of note in this table is that, although the catching rates are exceedingly low, they tend to rise in epidemic years. Thus in 1939-40 the catching rates were 0·88 and 0·23; in 1943 it was 0·25, and in 1945-46, 0·24 and 0·13 respectively. The catching rates for all other anopheline mosquitos are also low. This is because, apart from *A. culicifacies*, the other predominantly domestic mosquito of Ceylon, *A. subpictus*, is not very prevalent in this river basin.

In Table 18, is given the catching rate for *A. culicifacies* at each Observation Station for each year that observations were made. At certain stations fairly high annual catching rates have been recorded. These stations are Alawwa, where the catching rates in the epidemic years of 1935, 1939 and 1943, were 1·82, 1·56 and 2·16 respectively; Giriulla where a catching rate of 2·06 per hour was recorded in 1935; Makandura, at which a catching rate of 1·05 was recorded in 1939 and Rambukkana, at which the catching rate in 1939 was 1·47.

Epidemic years naturally yielded *A. culicifacies* more readily as will be gathered from Table 19, where the catching rates at Alawwa (1939 and 1943), Aranayake

TABLE 17

Annual variation in the prevalence of female Anopheles culicifacies *and the total of all other anopheline mosquitos caught in dwellings and in cattle-baited traps at Malaria Observation Stations for the years* 1935-1950.

Year	DWELLINGS						CATTLE-BAITED TRAPS				
	Number of house examinations	Number of catching hours	*A. culicifacies*		Other anopheline mosquitos		Number of trapping hours	*A. culicifacies*		Other anopheline mosquitos	
			Number caught	Catching rate per hour	Number caught	Catching rate per hour		Number caught	Catching rate per hour	Number caught	Catching rate per hour
1935	1659	292	224	0·77	58	0·20	525	72	0·14	67	0·13
1936	4820	492	138	0·28	194	0·39	1050	23	0·02	7553	7·19
1937	4716	626	129	0·20	403	0·64	1050	10	0·01	13310	12·67
1938	4364	590	66	0·11	317	0·53	1050	9	0·008	13602	12·95
1939	3792	609	536	0·88	440	0·72	1050	97	0·09	11614	11·06
1940	4101	666	159	0·23	564	0·84	1129	7	0·006	10270	9·09
1941	4047	646	10	0·01	276	0·42	1193	1	0·0008	10721	8·98
1942	4549	726	2	0·002	301	0·41	957	3	0·003	10581	11·06
1943	5831	927	237	0·25	412	0·44	797	7	0·008	7451	9·35
1944	6969	1337	3	0·001	338	0·25	767	1	0·001	6072	7·91
1945	7449	1342	335	0·24	1359	1·00	763	25	0·03	5655	8·41
1946	6585	1060	143	0·13	311	0·29	739	2	0·002	4589	6·21
1947	6641	999	4	0·004	41	0·04	657	0	0	4703	7·15
1948	7929	1153	9	0·007	26	0·02	368	0	0	1833	4·98
1949	12995	1995	0	0	4	0·002	—	—	—	—	—
1950	5484	928	0	0	13	0·01	356	3	0·008	1113	3·12

TABLE 18

Annual variation in catching rates per hour for female Anopheles culicifacies *caught in dwellings at Malaria Observation Stations for the period* 1935-1950.

Station	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Alawwa	1·82	0·38	0·40	0·25	1·56	0·17	0·01	0·02	2·16	0	0·27	0·01	0	0	0	0
Aranayake	0	0·01	0·01	0·01	0·43	0·02	0	0	0	0	0·01	0·01				
Boyawalana													0	0·16	0	
Bujjomuwa													0	0	0	
Galigomuwa																0
Girana									0	0	0·09	0				
Giriulla	2·06	0·34	0·10	0·04	0·65	0·77	0	0	0·12	0·01	0·05	0·79				0
Katana																0
Kegalle	0	0·02	0·07	0	0·27	0	0·01	0	0	0	0·01	0	0	0		
Kondepaluwa													0	0·01		
Kosgollegedera													0	0	0	
Kudagammana									0	0·01	0·93	0·80	0	0		
Maharachimulla													0	0	0	
Makandura			0·06	0·08	1·05	0·16										0
Mawanella	0·11	0·06	0	0·07	0·39	0·19	0	0	0	0	0·11	0·05	0·01	0		0
Meddapola									0	0	0·21	0·13				
Mirigama						0	0	0	0	0	0·04	0				

A blank space indicates that the station was not worked in that particular year.

TABLE 19

Catching rate per hour for female Anopheles culicifacies *caught in dwellings at monthly examinations of certain Malaria Observation Stations in the epidemic years of* 1939 *and* 1943.

Station	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alawwa	1939	0·12	0	0·28	8·44	8·22	0·22	0·44	0	0·11	0	0	0
	1943	0	0·12	13·23	1·25	2·25	0	0	0	0	0	0	0
Aranayake	1939	0	0	4·67	3·83	0·50	0·50	0	0	0	0	0	0
Giriulla	1939	0	1·66	2·11	2·55	1·00	0·33	0	0	0	0	0	0
	1943	0	0	0	1·00	1·38	0	0	0	0	0	0	0
Kegalle	1939	0	0·17	0·67	1·00	0·67	0·17	0	0	0	0	0	1·67
Mawanella	1939	0·17	0·17	0·50	0·50	2·50	2·67	0·17	0	0	0·17	0	0
Makandura	1939	0·22	8·22	0·88	1·88	0·77	0	0	0	0	0·11	0	0
Rambukkana	1939	0·50	1·00	5·00	8·83	1·16	0·50	0	0	0	0	0	0·66

(1939), Giriulla (1939 and 1943) and Kegalle, Mawanella, Makandura and Rambukkana in 1939 are given. These monthly catching rates are most interesting as the adult has been found more frequently in dwellings in the first half of the year than in the second half. Some of the catching rates recorded are also comparatively high. Thus the highest rate of 13·23 was at Alawwa in 1943. In 1939 at Giriulla rates of 8·44 and 8·22 were obtained in May and June. Other high rates recorded have been 8·22 at Makandura in February 1939 and 8·83 at Rambukkana in April 1939.

2. *Prevalence in Cattle-baited Traps.*—Adults of *A. culicifacies* are not caught in any great numbers in cattle-traps. The annual variation in the mean catching rate per hour at all Observation Stations is given in Table 17. Other species of anophelines, notably *A. hyrcanus*, are caught quite frequently and in comparatively large numbers. In Table 20, is given the annual catching rate for *A. culicifacies* caught in cattle-traps at each Observation Station. The highest catching rates of 0·58 at Giriulla and 0·33 at Alawwa were recorded in 1935. Thereafter the only relatively high catching rates were recorded in 1939, 1940 and 1945 as follows. At Giriulla, Makandura and Rambukkana in 1939 the catching rates were 0·22, 0·13 and 0·12 respectively. In 1940 at Alawwa and Giriulla the rates were 0·20 and 0·16 respectively, and at Mawanella in 1945 a catching rate of 0·55 was recorded.

The catching rates at monthly examinations at Alawwa, Giriulla, Makandura and Rambukkana in 1939 are given in Table 21. Here once again adults are found to be more prevalent in the first half of the year, and a catching rate of 2·40 at Giriulla in February and 1·44 at Makandura in April are the only high rates recorded.

3. *Prevalence in Human-baited Traps.*—Human-baited traps, set in verandahs of dwellings with a man sleeping inside, were operated only from 1935-41, and the results are given in Table 22. Whether the exceedingly poor catches recorded were due to the fact that the trapping was done from 6 p.m. to 8-30 p.m. one cannot say. Only at Mawanella and Rambukkana in 1939, when catching rates of 0·43 and 0·32 were recorded, were moderately high catches obtained. The catching rates at each monthly examination for these two stations are given in Table 23.

(*c*) **Natural Infections.** Table 24 summarises the total infections, gut infections and gland infections found in *A. culicifacies* from 1935-50. These rates were naturally highest in epidemic years. Thus infection rates of 8·82, 5·32 and 5·44 were recorded in 1935, 1939 and 1943. During the epidemic of 1945-46, the infection rate was 1·24 and 1·25 respectively. Gut and gland infections were also highest in these years. In 1935, 1939 and 1943 oocyst rates of 4·70, 3·08 and 3·40 were recorded, while the sporozoite rates in these years were 5·29, 2·52 and 3·40 respectively. Details with regard to the infections recorded in *A. culicifacies* caught in cattle-traps are given in Table 25. They have been found only at seven Observation Stations, the last at Mawanella in 1945. A complete record of all dissections of *A. culicifacies* caught in dwellings, whether found infected or not, is given in Table 26, and finally in Table 27 is a list of all those Observation Stations at which no

TABLE 20

Catching rates per hour for female Anopheles culicifacies *caught in cattle-traps at Malaria Observation Stations during the period* 1935-1950.

Station	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Alawwa	0·33	0·03	0·01	0·02	0·09	0·20	0	0	0·02	0	0	0	0	0		0
Aranayake	0·01	0·01	0·02	0·01	0·04	0·01	0·01	0·01	0·02	0	0	0				
Boyawalana													0	0		
Bujjomuwa													0	0		
Galigomuwa																0
Girana									0	0	0·08	0				
Giriulla	0·58	0·03	0·01	0·01	0·22	0·16	0	0	0·01	0	0·02	0				0
Katana																
Kegalle	0	0	0		0	0	0	0	0	0	0	0	0	0		
Kondepaluwa													0	0		
Kosgollegedera													0	0		
Kudagammana									0	0·02	0	0	0	0		
Maharachimulla													0	0		
Makandura			0·02	0	0·13	0·11										0
Mawanella	0	0·01	0·01		0·03	0·01	0	0	0	0	0·55	0·02	0	0		0·06
Meddapola									0	0	0·17	0				
Mirigama						0	0	0	0	0	0	0				
Nakalagamuwa													0	0		

A blank space indicates that the station was not worked in that year.

TABLE 20 (*Contd.*)

Catching rates per hour for female Anopheles culicifacies *caught in cattle-traps at Malaria Observation Stations during the period* 1935-1950.

Station	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
Narammala						0	0	0	0	0	0	0	0	0		
Pannala														0		
Pattanduwa													0	0·02		
Pittawela													0	0		
Polgahawela													0	0		0
Rambukkana	0·01	0·04	0	0·01	0·12	0·02	0	0·01	0·01	0	0·11	0	0	0		0
Warakapola	0·01	0·02														

A blank space indicates that the station was not worked in that year.

TABLE 21

Catching rate per hour for female Anopheles culicifacies *caught in cattle-traps at monthly examinations of four Malaria Observation Stations in* 1939.

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alawwa	0	0	0	0·80	0·16	0·08	0·08	0	0	0	0	0
Giriulla	0·08	2·40	0	0·08	0	0	0	0	0	0	0	0
Makandura	0·08	0·08	0	1·44	0	0	0	0	0	0	0	0
Rambukkana	0	0·40	0·80	0·08	0·16	0	0	0	0	0	0	0

TABLE 22

Anopheles culicifacies *females caught per hour in human-baited traps during the period* 1936-1941.

Station	1936	1937	1938	1939	1940	1941
Alawwa	0·02	0·02	0·03	0·03	0	0
Aranayake	0	0·01	0	0·01	0·01	0
Giriulla	0·03	0·01	0	0·04	0·05	0
Kegalle	0·02	0	0	0	0	0
Makandura		0·02	0	0	0	
Mawanella	0	0·01	0	0·43	0·10	0
Mirigama					0	0
Narammala					0·01	0
Rambukkana	0·01	0·02	0·02	0·32	0·01	0
Warakapola	0					

A blank space indicates that the station was not worked in that year.

TABLE 23

Catching rate per hour for female Anopheles culicifacies *caught in human-baited traps at monthly examinations of Malaria Observation Stations at Mawanella and Rambukkana in* 1939.

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mawanella	0	0	0·56	0·80	1·92	1·68	0·24	0	0	0	0	0
Rambukkana	0·08	0·88	1·28	1·52	0·08	0	0·08	0	0	0	0	0

TABLE 24

Natural infections in Anopheles culicifacies *caught in dwellings at all Malaria Observation Stations for the years* 1935-1948.

Year	Number dissected	Total Infections		Gut Infections		Gland Infections	
		Number	Infection rate	Number	Oocyst rate	Number	Sporozoite rate
1935	170	15	8·82	8	4·70	9	5·29
1936	118	2	1·69	2	1·69	0	0
1937	116	3	2·58	2	1·72	1	0·86
1938	63	1	1·58	1	1·58	0	0
1939	357	19	5·32	11	3·08	9	2·52
1940	119	2	1·68	1	0·84	1	0·84
1941	8	0	0	0	0	0	0
1942	1	0	0	0	0	0	0
1943	147	8	5·44	5	3·40	5	3·40
1944	3	0	0	0	0	0	0
1945	241	3	1·24	2	0·83	2	0·83
1946	80	1	1·25	0	0	1	1·25
1947	—	—	—	—	—	—	—
1948	3	0	0	0	0	0	0

In 1947 only four *A. culicifacies* were caught but were received dry.
In 1949 and 1950 none were caught.

TABLE 25

Natural infections in A. culicifacies *caught in cattle-traps at Malaria Observation Stations during the period* 1935-1950.

Year	Station	Dissections	Infections	Guts	Glands
1935	Alawwa	17	1	0	1
1935	Giriulla	39	4	3	2
1939	Makandura	19	1	1	0
1945	Mawanella	4	1	0	1
1935	Rambukkana	3	1	0	1
1936	Warakapola	1	1	0	1

TABLE 27

Malaria Observation Stations at which no natural infections in A. culicifacies *have been recorded.*

Station	Period of Observation
Boyawalana	1947-1948
Bujjomuwa	1947-1948
Galigomuwa	1950
Katana	1950
Kegalle	1935-1950
*Kondepaluwa	1947-1948
Kosgollegedera	1947-1948
Maharachimulla	1947-1948
Mirigama	1940-1946
*Nakalagamuwa	1947-1948
Pannala	1947-1948
*Pattanduwa	1947-1948
*Pittawela	1947-1948
Polgahawela	1947-1948
Warakapola	1935-1936

*Untreated control villages in a DDT experiment.

infections have ever been recorded. At ten of these stations observations were commenced in 1947 when DDT spraying of houses was being carried out.

MALARIA CONTROL MEASURES

An account of the history of malaria control in Ceylon may be found in our earlier paper (Rajendram and Jayewickreme, 1951a), and only a brief recapitulation is attempted here. Prior to the epidemic of 1934-35 no rural malaria control was ever attempted in Ceylon. During the epidemic oiling of rivers was carried out for the first time, and up to 1937 this was done as and when conditions demanded it, but never on a very large scale. In 1939, oiling was placed on a sounder basis and it was decided to commence Emergency River Oiling as a routine measure on March 1st and September 15th at Pannala, Narammala and Polgahawela each year. But the epidemic which broke out in April 1939, served to show how vast an area had

TABLE 26

...al infections in A. culicifacies *caught in dwellings at Malaria Observation Stations*, 1935-1950.

...		Kegalle				Kudagammana				Makandura				Mawanella				Mirigama			Naran...		nmala		Ramb...	
...	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections
5	1	—	—	—	—									—	—	—	—										
0	0	2	0	0	0									3	0	0	0									7	0
0	0	5	0	0	0					5	0	0	0	1	0	0	0									19	0
0	0	—	—	—	—					7	0	0	0	5	0	0	0									59	1
1	3	15	0	0	0					50	3	3	0	27	4	3	1				—	23	1			23	0
1	0	—	—	—	—					13	0	0	0	12	0	0	0	—	—	—	—	6	0			90	2
—	—	1	0	0	0									—	—	—	—	—	—	—	—	—	—	0	1	9	0
—	—	—	—	—	—									—	—	—	—	—	—	—	—	—	—	0	0	—	—
1	0	—	—	—	—									—	—	—	—	—	—	—	—	1	0	—	—	—	—
0	0	—	—	—	—									—	—	—	—	—	—	—	—	9	0	—	—	3	0
1	0	1	0	0	0	64	1	0	1					7	1	1	1	5	0	0	—	1	0	0	0	—	—
0	1	—	—	—	—	7	0	0	0					6	0	0	0	—	—	—	—	—	—	0	0	104	0
		—	—	—	—									—	—	—	—				—	—	—	0	0	35	0
		—	—	—	—									—	—	—	—				—	—	—	—	—	—	—
																					—	—	—	—	—	—	—

A dash indicates that no *A. culicifacies* were dissected although the station was worked.
A blank shows that the station was not worked in that particular year.

TABLE 26

Details of natural infections in A. culicifacies *caught in dwellings at Malaria Observation Stations*, 1935-1950.

Year	Alawwa				Aranayake				Boyawalana				Giriulla				Kegalle				Kudagammana				Makandura				Mawanella				Mirigama				Narammala				Rambukkana				Warakapola			
	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands	Dissections	Infections	Guts	Glands
1935	67	10	3	8	—	—	—	—					93	5	5	1	—	—	—	—									—	—	—	—									7	0	0	0	3	0	0	0
1936	50	2	2	0	—	—	—	—					35	0	0	0	2	0	0	0									3	0	0	0									19	0	0	0	9	0	0	0
1937	33	2	2	0	1	0	0	0					12	0	0	0	5	0	0	0					5	0	0	0	1	0	0	0									59	1	0	1				
1938	23	1	1	0	1	0	0	0					4	0	0	0	—	—	—	—					7	0	0	0	5	0	0	0									23	0	0	0				
1939	107	5	2	3	20	1	1	0					48	4	1	3	15	0	0	0					50	3	3	0	27	4	3	1									90	2	1	2				
1940	17	0	0	0	2	0	0	0					43	1	1	0	—	—	—	—					13	0	0	0	12	0	0	0	—	—	—	—	23	1	0	1	9	0	0	0				
1941	1	0	0	0	—	—	—	—					—	—	—	—	1	0	0	0									—	—	—	—	—	—	—	—	6	0	0	0	—	—	—	—				
1942	1	0	0	0	—	—	—	—					—	—	—	—	—	—	—	—									—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
1943	131	7	4	5	—	—	—	—					13	1	1	0	—	—	—	—									—	—	—	—	—	—	—	—	—	—	—	—	3	0	0	0				
1944	—	—	—	—	—	—	—	—					2	0	0	0	—	—	—	—									—	—	—	—	—	—	—	—	1	0	0	0	—	—	—	—				
1945	27	0	0	0	1	0	0	0					23	1	1	0	1	0	0	0	64	1	0	1					7	1	1	1	5	0	0	0	9	0	0	0	104	0	0	0				
1946	—	—	—	—	2	0	0	0					29	1	0	1	—	—	—	—	7	0	0	0					6	0	0	0	—	—	—	—	1	0	0	0	35	0	0	0				
1947	—	—	—	—					—	—	—	—					—	—	—	—									—	—	—	—					—	—	—	—	—	—	—	—				
1948	—	—	—	—					3	0	0	0					—	—	—	—									—	—	—	—					—	—	—	—	—	—	—	—				
1949	—	—	—	—					—	—	—	—																																					
1950	—	—	—	—																																					—	—	—	—				

A dash indicates that no *A. culicifacies* were dissected although the station was worked.

A blank shows that the station was not worked in that particular year.

to be covered by the river oiling organisation, before it could cope successfully with another outbreak. Money was not spared in attempting this and there was no lack of Shell Malariol, the proprietary mineral oil larvicide used, throughout the war period. Four Oaks (Ross Pattern) hand operated knapsack sprayers were used throughout, and as time went on more and more of these were made available. Actual costs of spraying are very difficult to obtain now, but in 1945, when oiling was carried out almost uninterruptedly for nine months, the inclusive cost could not have been far short of Rs. 1,500,000.

In 1940 examination of rivers, other than at Malaria Observation Stations, was first commenced at places called Subsidiary Observation Sites. These examinations along a half-mile stretch of river were carried out fortnightly by Sanitary Inspectors or weekly when conditions were deemed dangerous. By 1945 a network of about 350 such sites covered the Wet and Intermediate Zones. Oiling of all rivers and streams was carried out within a three-mile radius of a Subsidiary Observation Site, whenever *A. culicifacies* was found breeding at any of them. Later whole areas were oiled in times of drought when pooling of rivers was widespread, even though larvae had not actually been reported from some parts of them. Such action was considered justifiable in view of the prolific breeding of the vector in pools.

Spray-killing of adult mosquitos with pyrethrum sprays was also carried out but never on the same scale as river oiling. This was chiefly due to the great difficulty of obtaining adequate supplies of pyrethrum during the war. But whenever supplies were available, as during the 1943 epidemic, spray-killing was actively carried out.

DDT spraying of dwellings as a residual spray against adult mosquitos was begun in the first quarter of 1946, when a single round of spraying was carried out in the Narammala, Pannala, Polgahawela, Kegalle and Rambukkana areas. By the end of 1947 DDT spraying had become well organised, and five Truck Units were being operated from Rambukkana, Polgahawela, Narammala, Mirigama and Negombo. Each of these Truck Units consisted of fifteen labourers and two overseers with a Sanitary Inspector in charge. Range Sanitary Inspectors assisted in the supervision of their respective areas.

When DDT spraying first commenced in 1946 a 5 per cent. solution of technical DDT in kerosene was used at a dosage of 120 mg. per square foot. In 1947 the kerosene solution was replaced by a 40 per cent. emulsion concentrate of DDT in xylene, with an emulsifier (Formula of emulsion—188 lb. technical DDT ; 30 gallons xylene ; 2·4 gallons emulsifier—Triton X-100 or Craft). The concentrate was diluted in the field to make up a 5 per cent. emulsion. From the end of 1948 the emulsion was abandoned, and a 50 per cent. water-wettable DDT suspension powder was used instead, at a reduced dosage of 100 mg. per square foot. The dosage was still further reduced in October 1949 to 50 mg. per square foot.

The interval between successive sprayings has been kept at six weeks, except in the health area of Polgahawela, where spraying has been carried out once in eight weeks from 1947 as an experiment. This experiment, which involved intensive entomological observations in this health area, has been reported in our earlier paper.

Discussion

The study of malaria and its control in this important river basin falls naturally into two periods. The first period may be said to have commenced in 1935 and ended in 1945, and the second period has lasted from 1946 to the present day. Malaria has long been known to exist in the Maha Oya catchment, and the first authentic record of an epidemic dates back to 1877. Since then epidemics have been known to occur every three to six years, more commonly every four or five years. Thus prior to the spring epidemic of 1939 three epidemics preceded it. They occurred at intervals of five, six and five years respectively in 1934, 1928 and 1923. After 1939, epidemics occurred in 1943 and 1945, and climatic conditions during the north-east monsoon period of 1947-48 were such that in normal circumstances a spring epidemic would have been quite likely in 1948. If this epidemic had materialised, the intervals between epidemics after 1939 would have been four, two and three years respectively. Thus in the decade 1939-48 climatic conditions appear to have deteriorated more frequently than in the period 1923-39. The important subject of climate in relation to malaria has yet to be dealt with satisfactorily and offers a wide field for research. K. J. Rustomjee has made many observations, mainly in departmental reports, publication of which would have enhanced our knowledge of this aspect of the malaria problem, which is of such great importance in the Intermediate Zone.

Prior to 1946, epidemics in this basin occurred at intervals whenever climatic conditions were suitable. Such conditions arose whenever a monsoon failed. Failure of a monsoon resulted in pooling of the rivers in the catchment, with a consequent increase in the incidence of *A. culicifacies*. The incidence of malaria then rose suddenly about three weeks after the first appreciable rains had broken the prolonged drought. This sequence of events has been described earlier for the epidemics of 1939-40, 1943 and 1945-46, and need not be recapitulated again. The spring and autumnal seasonal rises of malaria have also followed the same pattern, the rises following the intermonsoonal rains which end each dry spell.

The annual morbidity rate, inclusive of first and subsequent visits of patients, at all hospitals and dispensaries in the Maha Oya Basin in 1939 was as high as 1,032·9; in 1940 it was 623·5. In 1943 the rate was 454·7, while in the epidemic years of 1945-46 it was 870·2 and 821·8 respectively. The lowest rate in a non-epidemic year was 233·4 in 1944.

Spleen and parasite surveys carried out in 1938 and 1939 have been described by Sivalingam and Rustomjee (loc. cit.); Sivalingam (1943) has also described a survey carried out in 1940. The truth of Sivalingam and Rustomjee's observation that spleen rates tend to be higher immediately after an epidemic and then diminished progressively until the next, is borne out by a study of the March surveys from 1936 to 1941 (Table 3). The 1936 spleen rates are very high because of the 1934-35 epidemic; they came down from 70·0 in 1936 to 18·1 in 1939 just before the epidemic broke out in April. In 1940, after the spring epidemic of the previous year, the spleen rates went up again to 25·1 and came down to 22·1 in 1941, when the surveys were abandoned because of the war.

No study of species prevalence of malaria parasites has been attempted in this paper. Sivalingam and Rustomjee (loc. cit.), Sivalingam (loc. cit.) and D'Abrera (1945) all have at various times made contributions to this subject after 1935. For earlier studies reference may be made to Carter (1927). It is, however, evident from the figures given in Table 5, that even in non-epidemic years such as 1938, 1939 (survey carried out before the epidemic) and 1944, there is a high proportion of parasite carriers in the population, and that active transmission is only hampered by the low incidence of *A. culicifacies* in non-epidemic years.

A correlation between the entomological observations carried out monthly at Malaria Observation Stations and the weekly dispensary attendances and meteorological data is not possible. Weekly entomological observations at Giriulla or Polgahawela, both towns for which weekly morbidity and rainfall figures have been available for some considerable time would have proved invaluable prior to 1946. All that can be said now is that the incidence of both larval and adult *A. culicifacies* rose in epidemic years and fell in non-epidemic years and to that extent is correlated with the rise and fall in the morbidity and the spleen and parasite rates. For instance, in Table 9 it will be seen that the larval rate in sand pools was as high as 31·62 in 1939, an epidemic year, while it was only 0·02 in 1944, a non-epidemic year. From Table 10 it will be seen that there were seven Observation Stations in 1939 and that at all of them *A. culicifacies* larvae were found in that year. In 1944, on the other hand, only at one out of the nine Observation Stations was the vector species recorded.

After 1946 the malaria problem has undergone a vast change. The year 1950 was the fifth year after the 1945 epidemic, and not only has the Maha Oya Basin been free of epidemics, but also each year since 1946 there has been an appreciable decline in the morbidity rate. After the epidemic figure of 821·8 in 1946, the morbidity rate declined to 251·7 in 1947, 134·1 in 1948, 85·9 in 1949 and 85·0 in 1950. The 1950 rate is a little more than a third of the previous lowest non-epidemic figure registered in 1944. Sivalingam and Rustomjee (loc. cit.) were of opinion that the 1939 spleen rates would be the lowest that would be recorded in Ceylon at any time, when the rate for the Maha Oya Basin was 18·1. Yet in 1947 the March rate had declined to 6·7, after the September 1946 rate had been 12·9. Since then each year the spleen rate has declined progressively until in March, 1950 it had reached the record figure of 0·9. Similarly, the parasite rates, which prior to 1941 had always been high, have rapidly declined from 0·4 in 1947 to 0 in 1950.

The entomological data since 1947 is equally striking. From 1947 to 1950 the larval rate for *A. culicifacies* in sand pools has declined from 0·81 in 1947 to 0 in 1950, although no larvicidal control has been carried out in these years; a similar decline is seen in the prevalence of larvae in rock pools. But while the larval rate for *A. culicifacies* has been coming down the larval rate for the total of all other anopheline larvae has been going steadily up since 1946 (Graphs 2 and 3). That is, while the incidence of the domestic species, *A. culicifacies* has been gradually reduced, the effect on the non-domestic species has been quite the reverse.

The Maha Oya Basin since 1947 has become healthier each year, until in 1950 on the basis of the dearth of the vector, the spleen and parasite rates and the very low level to which morbidity has fallen it can be claimed that it is as healthy as such a

non-malarial district as Kalutara. This progressive improvement in the malarial endemicity of the Maha Oya Basin dates from the commencement of the residual spraying of houses with DDT, which began in 1946. By the end of 1947 the spraying had become well organised and has been regularly carried out up to the present day. This spraying has superseded all other forms of control, such as river oiling and the spray-killing of adult mosquitos. Its effect has been remarkable in reducing the incidence of malaria. But perhaps its most remarkable achievement has been that an almost certain spring epidemic, which on climatic grounds should have broken out in 1948, was completely averted. Such an event has never been possible before. From the time measures to combat rural malaria were put into operation after the epidemic of 1934-35, the most that could be hoped for was the reduction in the severity of epidemics. Thus although intensive river oiling failed to avert epidemics in 1943 and 1945, the first round of DDT spraying in 1946 so reduced the adult incidence of *A. culicifacies*, that a threatened spring epidemic in 1946 was brought to a summary conclusion. Since then, although there was a slight spring rise of malaria in 1948 (of considerably smaller magnitude than such rises prior to 1946), in 1949 and 1950 the small peaks seen in Graph 1 are the only evidence of any fever rise, and these are of such a small magnitude that they may well have been due to other causes.

Summary

Epidemiology:

1. There are two fever seasons in the Maha Oya Basin, beginning in April and November each year.

2. Epidemics have occurred generally every four or five years, but shorter periods such as two or three years or a longer period such as six years, have also been known to occur.

3. Epidemics, like the spring and autumnal fever seasons on a smaller scale, occur after appreciable rains have broken a spell of drought.

4. The spring epidemics of 1939 and 1945, described in this paper, commenced after a long spell of drought. But the spring epidemic of 1943 cannot so readily be explained on meteorological grounds.

5. The epidemic of 1945-46 was unusual because of the sequence, spring-autumn-spring. Also, the second wave of the epidemic was higher than the first, the reverse of the normal.

6. Since residual spraying of houses with DDT was begun in 1946 no epidemics have occurred in the Maha Oya Basin. Seasonal rises of malaria have been scarcely evident, particularly after 1948.

7. The morbidity rate per 1,000 population has come down from a non-epidemic figure of 336·3 in 1941 and 233·4 in 1944 to one of 85·0 in 1950.

8. In 1948 a spring epidemic, which on meteorological grounds should have broken out, was averted because of the successful control of the vector by residual spraying of houses with DDT.

9. In the period 1936-41 the lowest spleen rate of 18·2 was recorded in 1939. Since 1947 the mean spleen rate has been progressively lower each year, until in 1950 it was 0·9.

10. Parasite rates in the period 1938-41 were uniformly high, ranging from 3·3 to 6·1. Since 1947 the mean parasite rate has diminished rapidly and in 1949 and 1950 was 0.

Vital Statistics:

11. Birth-rates from 1939 to 1946 ranged from 27·3 to 34·9. From 1947 to 1950 the rate has ranged from 34·5 to 35·3.

12. Prior to 1947 the crude death-rate has been high in epidemic years, the highest being 17·7 in 1945 and the lowest 11·1 in the non-epidemic year of 1941. Since 1947 the rate has declined from 10·3 in 1947 to 9·6 in 1950.

13. Infant-mortality rates have also been highest in epidemic years, the highest being 170 in 1939 and the lowest 96 in the non-epidemic year of 1942. Since 1947 the rate has decreased each year and was 67 in 1950.

The Vector:

14. *Anopheles culicifacies* breeds prolifically in sand and rock pools in rivers and streams in times of drought. Its incidence, at all times, along the margins (banks) and in village breeding places is insignificant.

15. Prior to 1947 the incidence of the vector, whether larval or adult, was highest in epidemic years.

16. The catching rate for the adult does not reflect the true incidence of the mosquito in dwellings owing to its habit of secreting itself in the thatch of village houses.

17. *A. culicifacies* is caught in cattle-baited traps in negligible numbers.

18. Since the residual spraying of houses with DDT was begun in 1946 the catching rate for adult *A. culicifacies* has been negligible, while larval rates in sand and rock pools have been very low. In 1950 no larvae of the vector were caught at any Observation Station.

19. Although the larval rates for *A. culicifacies* in sand and rock pools have been very low from 1947 onwards, the larval rates for the total of all other anopheline species (non-domestic mosquitos) have increased each year.

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