TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE, VOL. 71, NO. 5, 1977.

The natural decline of *Wuchereria bancrofti* infection in a vector control situation in the Solomon Islands

R. H. WEBBER
Ministry of Health and Welfare, Honiara, Solomon Islands

Summary

In a situation where filariasis and malaria are transmitted by the same vector, as seen here in the Solomon Islands, the Malaria Eradication Programme aimed at controlling the vector, was found to have an effect on both diseases.

In an area of Choiseul island first surveyed by the author in 1970, three follow-up surveys were conducted—in 1974, 1975 and 1976. These showed a progressive decrease in persons infected. When the densities, especially the median microfilarial counts, were expressed as percentage values of the pre-spray survey, there was found to be a proportional decrease over eight years.

It is possible that the *Anopheline* vector needs to be reduced less for the cessation of transmission of filariasis than for malaria. A theoretical ratio was calculated and supporting field evidence presented.

Introduction

In the Solomon Islands, *Wuchereria bancrofti* is a nocturnally periodic infection transmitted by the *Anopheles punctulatus* group of mosquitoes, particularly *Anopheles farauti* and to a lesser extent *Anopheles koliensis*, in the area surveyed. Since 1960 (1968 in the survey area) a Malaria Eradication Programme has been in operation, and although not an intention of this campaign, it was hoped that there would be a concurrent reduction in filariasis.

Unfortunately no vector studies were done in the survey area, except to confirm the presence of the two vectors before spraying commenced but data from the pilot project area on Guadalcanal are relevant. After spraying *A. koliensis* almost disappeared (0·01 per man hour) whereas *A. farauti* changed its biting pattern.

Number of *A. farauti* per man-hour

Number of months after spraying	Human bait collection		Indoor surface collection
	Outdoors	Indoors	
Before spraying	50·6	46·7	81·0
Three months after first spraying	19·3	0·0	0.0
Five months after second spraying	83·0	0·7	1·0

Also the peak of this outdoor man biting pattern occurred between the hours of 18.30 and 20.30, when in fact most people were out of doors. Despite these vector results, the malaria rates fell in the survey area from an I.P.R. of 24 and two to nine age group parasite rate of 53 to 13·7 and 32·5 respectively, five months after the first spray round.

WEBBER (1975a) summarized the filariasis situation on the available information and produced a theoretical model (WEBBER, 1975b) to estimate the future progress. This paper contains follow-up survey data on the observed decrease of the infection.

Region and methods

In the filariasis surveys conducted in 1970–71 (WEBBER, 1975a), an extensive area of north-west Choiseul was examined. The disease was found to be focal, so the two centres of these foci, an area on the south coast around Voza village and a corresponding area on the north coast around Ogo, were chosen for follow-up.

The first follow-up survey in these two areas was conducted in April to June 1974. The survey in 1970 was carried out with unmeasured blood films so it was decided on this occasion to try out the three more accurate methods then available, namely,

(i) the membrane-filtration technique;
(ii) the counting chamber;
(iii) 60 mm³ measured blood film.

(i) The membrane-filtration technique (CHULARERK & DESOWITZ, 1970) which requires venepuncture of 1·0 ml of blood, its haemolysis and passage through a Millipore(c) filter and subsequent staining, is more fully described by DESOWITZ *et al.* (1970). The necessity for venepuncture reduced the number of people who were willing to be surveyed, as did the extra time involved (no trained assistants were available). Also the problems of balancing all the equipment on a shaky table in an overcrowded leaf hut, working only by the light of a hurricane lamp, with all the insects falling into the solutions and a gentle breeze blowing the moist filter papers on to the sandy floor made working conditions very difficult. For these reasons and the considerable cost involved it was decided to use this technique only on the island of Fauro where extremely low levels of infection were anticipated.

(ii) The counting chamber (DENHAM *et al.*, 1971) was found to be a practical method in the field, even with the light of a hurricane lamp. Counting chambers were made by cutting a 45 mm × 15 mm hole in an X-ray film, gluing this to a glass slide and engraving 5 mm lines within the chamber. The chamber was filled with water and 60 mm³ of blood added and the motile microfilariae counted at a ×60 magnification. However, the problems of tiredness while examining the slides at night and the reduced number of people that could be bled during these restricted hours (for even if the technician was prepared to stay up all night, the people were not) still remained.

(iii) The conventional measured blood film was also used, taking three 20 mm³ quantities of blood and making these into three circular films on the one slide. After drying and return to the laboratory, they were stained with Giemsa but without prior dehaemoglobinization. WEBBER (1976) found that there was no difference between the number of microfilariae counted in the counting chamber and the conventional measured blood film, using the same quantity of blood from the same person. The measured blood film was therefore adopted in all subsequent surveys.

All blood samples were taken between the hours 20.00 and 02.00. Close on total population coverage was obtained, except that children under five were excluded. Subsequent follow-up surveys were conducted in Voza and Ogo in April 1975 and again in April 1976.

In January 1975 a survey using the membrane-filtration technique was conducted in the island of Fauro. Vector control had been in operation here for a much longer time and the 1970 survey had shown a very low level of microfilaraemia.

Results

Vector control measures (Malaria Eradication Campaign) were commenced in Choiseul in 1968. The progressive decline of infection six, seven and eight years after these measures were commenced is shown in Table I.

The populations of these two villages are very stable, so it was possible to work out incidence which will be found in Table II. There were a greater number of people becoming negative in the one-year period 1974–75 than the four years 1970–74.

The membrane filtration technique survey on Fauro island, after 15 years of continuous DDT spraying, examined 112 persons (72% of the population) and found not a single positive.

Table I – The number of persons positive and the microfilarial density in the same survey area for three consecutive years

	Area	No. exam.	No. positive	% positive	No. Microfilaria	Mean density (arithmetic)	MfD_{50}
	VOZA	172	25	14·5	513	20·5	
1974	OGO	128	37	29·0	293	7·9	
	TOTAL	300	62	21·75	806	13·0	5·4
	VOZA	262	18	6·9	87	4·8	
1975	OGO	89	14	15·7	114	8·1	
	TOTAL	351	32	9·2	201	6·3	3·0
	VOZA	116	3	2·6	30	10·0	
1976	OGO	84	8	9·5	51	6·4	
	TOTAL	200	11	5·5	81	7·4	

Table II – The incidence of filarial infection of a known group of people between 1970 and 1974 and again between 1974 and 1975

Period	No. examined	No. positive	No. positive	Difference	% Decrease
		1970	1974		
1970–74	160	32	21	11	6·9
		1974	1975		
1974–75	158	39	22	12	10·8

Discussion

In examining the figures in Table I it will be noted that although there is a progressive decrease, it is not regular. There is either a sharp drop in the number of persons positive while the density remains high or else there is only a small decrease in the number positive, but the density is low. This would seem to be a result of individuals coming towards the end point of their infections.

If instead we express the total number of microfilariae found in each year as a percentage we find that in 1974 we have 269% $\left(\frac{806 \times 100}{300}\right)$; in 1975, 57%; and in 1976 40%.

A positive case can have just one microfilaria or several hundred, so comparing the number of positive cases on subsequent surveys is not a reliable method. The above shows that measurement of progress must be based on the microfilarial counts.

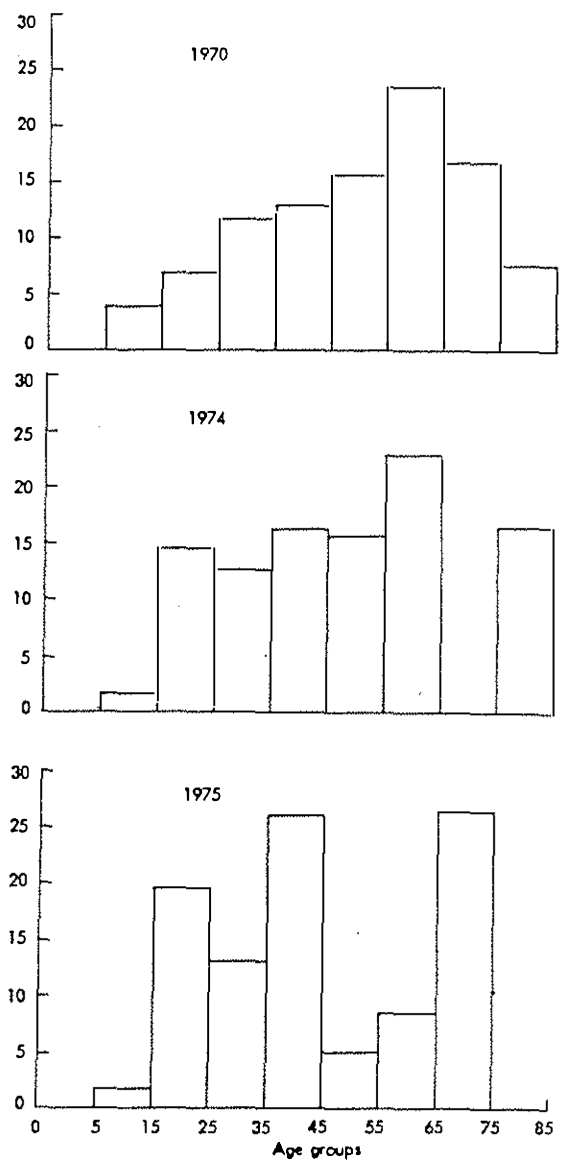

Fig. 1. Proportion positive for each age group expressed as a percentage of the total for each year surveyed.

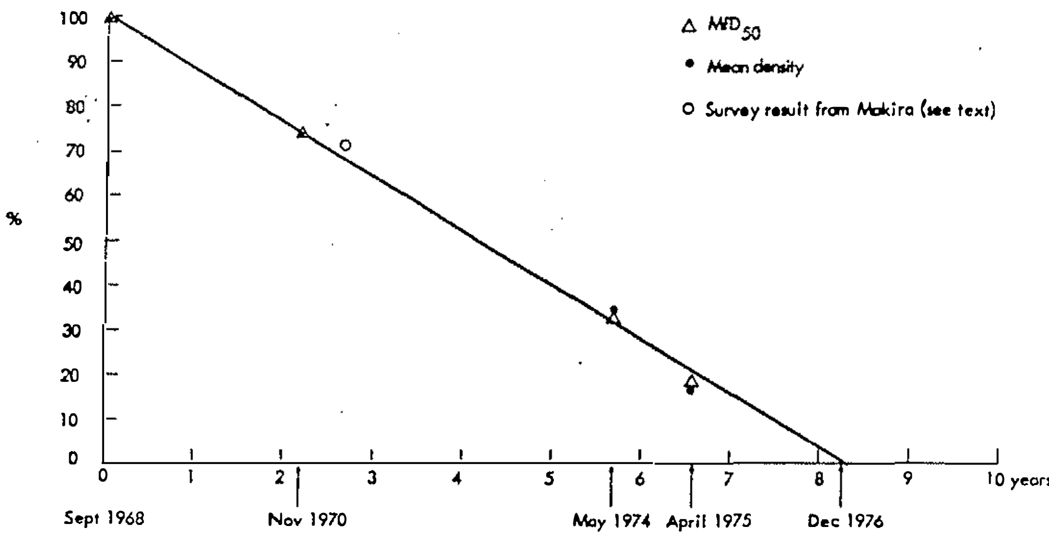

Fig. 2. Percentage Decline of Microfilaraemia with year of vector control.

Age groups

Effects of control can also be gauged from the age of children infected. In 1970 the youngest infection was a child of 18 months old, but by 1974 the youngest was nine. In 1975, the same boy found positive in 1974 was still infected, but by 1976 he was negative.

Fig. 1 illustrates the distribution of persons infected by age group.

In 1970 the endemic situation is shown with a peak in the 55 to 65-year-old group. This cohort has moved on to the 65 to 75 age group in 1975. In the younger age groups they would have only become infected just before vector control measures commenced so one would expect these infections to be maintained the longest and, if expressed proportional to the total infections (as in Fig. 1), this over-exaggerated trend is shown in 1975. However, the double peak in 1975 is interesting, suggesting that persons initially become infected when young, these infections increase to a maximum at about 40 years of age, then decline rapidly, to be followed by re-infection which follows the same pattern into old age. The densities mirror this trend.

By 1976 the numbers are too small to chart, but still show this double peak phenomenon.

Pattern of natural decline of infection under vector control

After the 1970 survey, a theoretical model was made (WEBBER, 1975b) to try to work out the possible decline of infection using the proportion of persons remaining positive after removal from the area of transmission. With the follow-up surveys in 1974, '75 and '76 these survey results were applied to this theoretical model, but despite many attempts, generating different base figures, no fit could be found. In the first part of the discussion, it was mentioned how the number of persons positive decreased in a step-like fashion and this would help to explain why no satisfactory pattern can be worked out using the proportion of persons positive.

It was therefore decided to attempt a pattern using densities. A correction factor had to be applied to the 1970 results and plotting this with the 1974 and 1975 results a baseline figure could be calculated (WEBBER, 1975c). With this baseline density (before control measures) as 100% and plotting the percentage of microfilariae of this base against time, there is a proportional decrease (Fig. 2). Densities are expressed either as the mean density or preferably as the median microfilarial count (MfD_{50}).

This pattern was tested by using data from another island in the Solomons group, Makira (WHO, 1973), which gave a close fit. The 1976 survey gave a proportional increase in the density over the 1975 result, but as figures were so small, no great reliance can be placed on this. It is quite possible that the lower end of the graph will need modification as theoretically zero density is to be reached by December 1976. It would seem though that the decline of infection where vector control has effectively stopped transmission can be expected to follow this general pattern.

Effect of prolonged spraying and life expectancy of W. bancrofti

In the Solomon Islands situation where residual spraying has continued for a considerable length of time (with fortunately no resistant anophelines developing), and *W. bancrofti* left to die naturally in the absence of transmission, we need to know how long the parasite can live.

Several authors have examined groups of people who moved from the endemic situation and found that microfilariae can still be detected after much longer periods when there was no chance of re-infection. LEEUWIN (1962) examined 207 Surinamese who had migrated to Amsterdam and found that one person was still positive eight years after leaving Surinam. MAHONEY & AIU (1970) conducted a similar examination on Samoan immigrants to the U.S.A. and found seven years to be the longest period anyone retained their infection.

Fig. 2 for the Choiseul surveys suggests that zero microfilaraemia will be reached in 8·25 years, but on Fauro there was probably one *W. bancrofti* producing microfilariae 10 years after infection. Five years later though, there was definitely no living worm left. It would therefore seem reasonable to suggest, that the reproductive expectancy of *W. bancrofti* is about eight years, a few individuals can continue to 10 years, but none beyond 15.

Relationship of filariasis with malaria and level of vector control

In a paper exploring the theoretical effects of vector control (WEBBER, 1975b) an attempt was made to apply MACDONALD's (1952) formula for the Critical Density, to filariasis, $m = \frac{-r \log_e p}{a^2 b p^n}$. As the vector is the same for both malaria and filariasis, we can compare the results obtained by the formula for each disease.

We have just seen that *W. bancrofti* can continue producing microfilariae for 10 years (the patent period of microfilaraemia but, in order to acquire an infection, HAIRSTON & DE MEILLON (1968) have calculated that some 15,500 bites by mosquitoes carrying stage III larvae are required. In the formula then:

r = the proportion of affected people who revert to negative in one day is considered as the reciprocal of the patent period of microfilaraemia $\left(\frac{1}{3{,}652{\cdot}5}\right)$ days);

b = the proportion of those anophelines with infective sporozoites must be changed to the proportion with stage III infective larvae which will produce a positive case of microfilaraemia $\left(\frac{1}{15{,}500}\right)$.

As we are comparing the value for malaria with that for filariasis, it is preferable that the original notation "r" and "b" be retained for malaria and the modified values above for filariasis be notated "r_f" and "b_f".

The same *Anopheles* vector is involved in the transmission of both malaria and filariasis, so the "p" value (the probability of a mosquito surviving through one day) and the "a" value (the average number of men bitten by one mosquito in one day) are the same for both diseases. Similarly "n" (the time taken for completion of the extrinsic cycle) is the same for *Plasmodium falciparum* and *W. bancrofti*, i.e. 12 days, in the Solomon Islands.

If we therefore compare the Critical Density values, calculated for filariasis and malaria, as defined by MACDONALD (1952), "the greatest density of mosquitoes, in relation to the number of people affecting any community, which will result in the progressive reduction of malaria (filariasis) to an utterly negligible level, it being assumed that the probability of a mosquito surviving through one day is constant and known", we have for:

$$\frac{\text{filariasis } m = \frac{-r_f \log_e p}{a^2 b_f p^n}}{\text{malaria } m = \frac{-r \log_e p}{a^2 b p^n}} \text{ which from the above gives } \frac{-r_f \times b}{-r \times b_f}$$

Values for *A. farauti* and *P. falciparum* in the Solomon Islands are r = 0·005 and b = 0·0125; the calculation then becomes $\frac{-2{\cdot}74 \times 10^{-4} \times 1{\cdot}25 \times 10^{-2}}{-5 \times 10^{-3} \times 6{\cdot}45 \times 10^{-5}} = 10{\cdot}62$.

It is therefore hypothesized that in the vector control situation referred to in this paper, malaria transmission can continue when filariasis will have ceased. It is also possible to calculate that a theoretical level whereby malaria endemicity can be as much as 10·62 times that for filariasis before transmission will start again. This is a ratio value, so theoretically could be applied to either values comparing the vectors or infected persons for malaria and filariasis, in a stable situation.

An example is to compare this theoretical value with that found in the field for proportion of persons positive. MAFFI & McDONNELL (1971) carried out surveys in the Eastern Outer Islands for both filariasis and malaria, and it is fortunate that in some places the natural level of malaria transmission was very low (see Table III). When 3·8% persons were positive for malaria, there was still no filariasis, but when the level of malaria reached 13·8% persons positive, positive filariasis cases were found. Somewhere between these two values (for which we unfortunately have no field examples) it is suggested there is a critical level for proportion of persons positive for malaria, below which filariasis will not occur. Once this level is passed (theoretically calculated as 10·62), filariasis cases will occur.

Table III – Comparison of the proportion of persons positive for both malaria and filariasis in an area of low endemicity

Place	No. examined	Proportion positive for malaria	Proportion positive for filariasis
Mbanua, Ndende	53	13·8	3·7
Ndole, Ndende	63	13·8	1·6
Tanga, Reefs	57	2·6	0
Malubu, Reefs	97	3·8	0

PICHON (1974) and PICHON *et al.* (1975) studying the ability of the vector to transmit filariasis continued the two concepts of parasitic reduction (limitation and facilitation) to their logical conclusions. Facilitation, which has only so far been found in the *A. gambiae A.—W. bancrofti*, parasite-vector couple (but theoretically could occur in *A. farauti*), means that as the number of ingested microfilaria increases, their survival capacity increases up to a maximum point where mosquito mortality occurs. This is a stable situation, as is zero infection, but between these two limits it is unstable. Above a certain critical point the survival capacity of the microfilariae increases progressively until mosquito mortality occurs. Below this critical point there are insufficient microfilariae to maintain the infection and it progressively regresses to zero infection. (It should be noted that this is an entirely different situation from that found between *Aedes polynesiensis* and *W. bancrofti*, where limitation occurs.)

This critical point has very important implications in control of anopheline-borne filariasis. If either the level of parasites or the number of vectors is held below this critical point for sufficient time, then the disease will naturally die out. This critical point has yet to be determined, but one suggestion (using malaria level as a measure) is put forward in the calculation above.

Acknowledgements

I wish to thank Dr. P. Beck, Permanent Secretary, Ministry of Health and Welfare, Solomon Islands, for permission to publish this paper and to all the many people who assisted me. The World Health Organization generously donated the Millipore(c) equipment and the

South Pacific Commission very kindly furnished me with a considerable amount of bibliographical material. This work formed part of a thesis submitted for the degree of M.D. in the University of London.

References

Chularerk, P. & Desowitz, R. S. (1970). A simplified membrane filtration technique for the diagnosis of microfilaremia. *Journal of Parasitology*, **56**, 623–624.

Denham, D. A., Dennis, D. T., Ponnudurai, T., Nelson, G. S. & Guy, F. (1971). Comparison of a counting chamber and thick smear methods of counting microfilariae. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **65**, 521–526.

Desowitz, R. S., Chularerk, P. & Palumbo, N .E. (1970). Evaluation of a simplified membrane filtration technique for the diagnosis of canine filariasis. *Southeast Asian Journal of Tropical Medicine and Public Health*, **1**, 231–232.

Hairston, N. G. & de Meillon, B. (1968). On the inefficiency of transmission of *Wuchereria bancrofti* from mosquito to human host. *Bulletin of the World Health Organization*, **38**, 935–941.

Leeuwin, R. S. (1962). Microfilaraemia in Surinamese living in Amsterdam. *Tropical and Geographical Medicine*, **14**, 355–360.

Macdonald, G. (1952). The Analysis of Equilibrium in Malaria. *Tropical Diseases Bulletin*, **49**, 813–828.

Maffi, M. & McDonnell, M. (1971). Malaria in the Eastern Outer Islands, British Solomon Islands Protectorate. *Parassitologia*, **13**, 455–503.

Mahoney, L. E. & Aiu, P. (1970). Filariasis in Samoan immigrants to the United States. *American Journal of Tropical Medicine and Hygiene*, **19**, 629–631.

Pichon, G. (1974). Relations mathématiques entre le nombre des microfilaires ingérées et le nombre des parasites chez différents vecteurs naturels on expérimentaux de filarioses. *Cahiers ORSTOM, série Entomologie médicale et Parasitologie*, **12**, 199–214.

Pichon, G., Perrault, G. & Laigret, J. (1974). Rendement parasitaire chez les vecteurs de filarioses. *Bulletin of the World Health Organization*, **51**, 517–523.

Webber, R. H. (1975a). Vector control of filariasis in the Solomon Islands. *Southeast Asian Journal of Tropicl Medicine and Public Health*, **6**, 430–434.

Webber, R. H. (1975b). Theoretical considerations in the vector control of filariasis. *Southeast Asian Journal of Tropical Medicine and Public Health*, **6**, 544-548.

Webber, R. H. (1975c). *Anopheline-borne filariasis and its control with particular reference to the Solomon Islands*. University of London, M.D. Thesis.

Webber, R. H. (1976). Comparison of counting chamber and measured blood films in microfilaria estimation. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **70**, 537-538.

World Health Organization. Intercountry Team (1973). *Report on filariasis in the Solomon Islands*. World Health Organization, Manila, Philippines.

Accepted for publication 27th April, 1977.

SMA

V Kozuyo

Bull. ent. Res. 77, 191–200
Published 1987

Seasonal abundance, diel biting activity and parity of *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg) (Diptera: Culicidae) in Samoa

W. A. SAMARAWICKREMA*, FOLA SONE and R. F. CUMMINGS
WHO Samoa Filariasis Research Project, P.O. Box 77, Apia, Samoa

Abstract

The seasonal abundance, biting cycle, age composition and survival of females of *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg), the major vectors of subperiodic bancroftian filariasis, were studied in Samoa. *A. polynesiensis* density was low during the high rainfall months and increased immediately following them. *A. samoanus* density showed no clear relation to rainfall. *A. polynesiensis* was active throughout the day, with peaks indoors and out at 08.00–09.00 h and 16.00–18.00 h. The nulliparous and parous populations showed similar patterns of activity. The biting cycles of 2-parous and 3- plus 4-parous females were asymmetric with time. *A. samoanus* was active throughout the night, with highest activity at 23.00–01.00 h. A minor peak at 19.00–20.00 h was more pronounced among older females than among younger ones. Night biting by *A. polynesiensis* and day biting by *A. samoanus* were rare. The parous proportion of *A. polynesiensis* ranged from 36·3 to 59·5% and the epidemiologically significant 3- plus 4-parous proportion ranged from 1·0 to 6·7%. The parous proportion of *A. samoanus* was 37·9–49·7% and the 3- plus 4-parous proportion 1·4–2·6%. The proportions found to be parous in both vectors were generally higher in the cool than the warm season, suggesting higher daily survival during that period.

Introduction

Although filariasis due to subperiodic *Wuchereria bancrofti* is one of the most important public health problems in Samoa, there are only two reports on the ecology of the vectors, *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg), by Ramalingam (1968) and Suzuki & Sone (1974). Two of the objectives of the WHO Samoa Filariasis Research Project were to study the ecology and bionomics of the vectors and conduct vector control trials to determine the most effective and feasible methods of control that would supplement drug administration. Mass administration of diethylcarbamazine citrate (DEC-C) leaves a residual human population showing low levels of microfilaraemia in the peripheral blood (Desowitz & Southgate, 1973). It has been shown that these carriers can result in infective larvae developing in the local vector mosquitoes (Bryan & Southgate, 1976; Samarawickrema *et al.*, 1985*a*). The studies reported here were carried out between December 1977 and May 1979.

→ infe...

* Present address: Malaria Control Project, P.O. Box 22, Honiara, Solomon Islands.