

**Bancroftian filariasis in Pondicherry, South India:  
2. Epidemiological evaluation of the effect of vector control**

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SUMMARY

This article examines the evaluation of a bancroftian filariasis control programme undertaken in Pondicherry from 1981–5. Integrated vector management was applied in one half of the town, and routine operations under the national programme (larviciding and chemotherapy) continued in the comparison area. The programme was evaluated by monitoring relative change in the epidemiological statistics of both populations. The results indicate that there was significant reduction in prevalence of microfilaraemia in juveniles in the controlled area. An apparent reduction in intensity of microfilaraemia was also observed but this was a consequence of the reduction in prevalence, since the density of microfilariae remained unchanged. The results suggest that primary constraints on the epidemiological evaluation of the vector control of filariasis are the longevity and the population characteristics of the parasite.

INTRODUCTION

Bancroftian filariasis remains a health problem in India despite the efforts of the National Filariasis Control Programme (NFCP) over the last 30 years (1). This lack of progress is attributable to a number of disease characteristics which frustrate control (2), but the major problem appears to be the difficulty in achieving sustained and extensive implementation of the current strategy of chemical larviciding and chemotherapy. In an attempt to identify a more appropriate technology, the Vector Control Research Centre (VCRC) of the Indian Council of Medical Research has been evaluating an Integrated Vector Management (IVM) approach with the major emphasis on the use of environmental methods to control vectors (3–5).

Relatively straightforward procedures for evaluating the effect of such programmes on the vector population are well established, but the evaluation of the effects on human infection is compromised by the difficulty in obtaining adequate epidemiological statistics (6–9). This contrast is illustrated by the attempts to evaluate the VCRC programme, where vector reduction was readily

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demonstrable (4), while preliminary attempts to detect an effect on human infection achieved equivocal results (10).

In this article we examine epidemiological data collected during the implementation of an integrated vector management programme to control bancroftian filariasis in Pondicherry, South India, with an aim to identify the constraints which, in practice, limit evaluation.

#### MATERIALS AND METHODS

Details of the town of Pondicherry and of the control procedures have been described elsewhere (4) as has the pre-control epidemiological situation (11). During the period 1981–5 control activity was maintained throughout the whole urban area. In the area (approximately half of the town) where the integrated vector management programme was implemented, the major emphasis was on environmental modification to permanently remove or reduce breeding sites of the vector mosquito (*Culex quinquefasciatus*). In the remainder of the town the routine control procedures of the National Filariasis Control Programme, consisting primarily of the application of larvicidal insecticides, were continued, and this area therefore provided a comparison. The VCRC programme did not utilize chemotherapy as a control measure, although individuals found to be infected during blood surveys were referred to the filariasis clinic of the national programme. The NFCP programme specifically includes the detection and treatment of microfilaria carriers. Entomological variables were monitored throughout the 5-year period. Resting density was determined every 15 days at 17 sites, and biting density every week at 5 sites. Details of entomological procedures have been described previously (4).

In order to determine the epidemiological features of the infection, a mass blood survey of the population was carried out during January to March 1986, following the design of the pre-control survey conducted in 1981 (4, 11). As in 1981 the target sample was 10% of the population from each geographical locality, to give a minimum coverage of 5% of the population in any one age class. A stratified random sampling protocol was adopted. The blood collection teams visited the households between 8 p.m. and 12 p.m. on the day after each inhabitant had been informed of the details of the project by a social worker. A 20 mm<sup>3</sup> peripheral blood smear was collected for subsequent staining and examination in the laboratory. Permission was received from all individuals, or in the case of children their parents or guardians.

As a result of anecdotal reports that treatment of infected individuals had been inadequately followed up by the filarial clinic after the 1981 survey, a sub-sample of referred individuals were interviewed to determine their treatment history.

#### RESULTS

Blood specimens were collected from 34615 persons (12.2% of the total population of Pondicherry) in 1986. The target minimum of 5% sampled in each age class was achieved for all age classes except 0–5 years where 4.92% was sampled. This sampling distribution is similar to that achieved in the pre-control survey (11) and appropriately reflects the age distribution of the population.

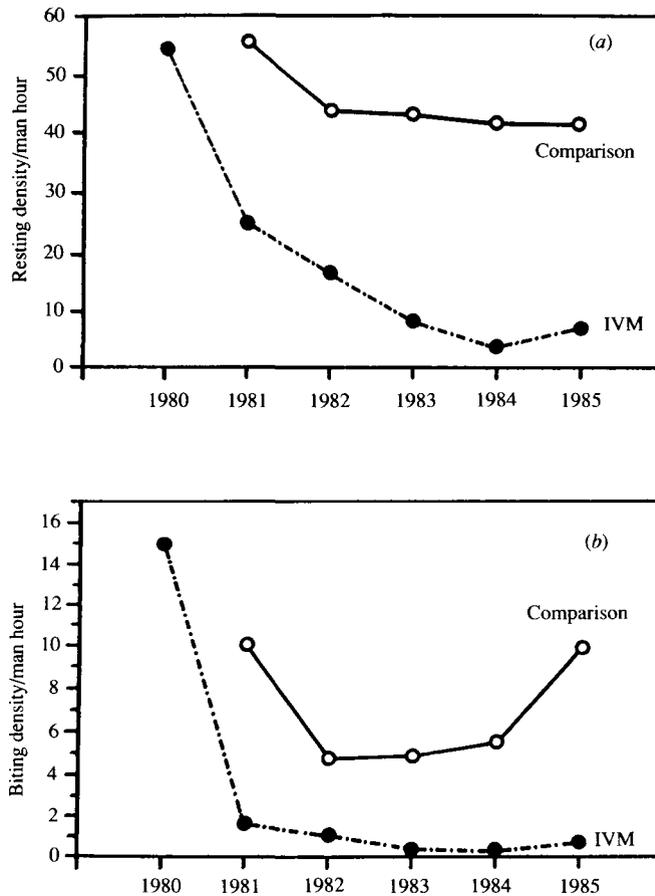


Fig. 1. Change in *Culex quinquefasciatus* numbers in the VCRC control (IVM) and comparison areas between 1981 and 1985. (a) Resting density (mean number collected per hour of search), each point represents the mean of 24 fortnightly observations. (b) Biting density (mean number biting per host per hour), each point represents the mean of 52 weekly collections.

The effect of the control programmes on the resting and biting density of *C. quinquefasciatus* in the two areas is shown in Fig. 1. It is apparent that mosquito densities in the VCRC area were markedly lower than those in the comparison area throughout the 5 years of the programme.

Interviews regarding treatment history were conducted by a social worker with persons referred during the 1981 survey. A definite history was available for 259 persons only 30.4% of whom had actually received diethyl carbamazine (DEC) therapy. To remedy this situation, all individuals identified as infected in the 1986 survey were given personal letters of referral as well as being directly referred to the filarial clinic, and an additional treatment clinic was established by the VCRC.

The initial (1981) age-prevalence of microfilaraemia and that observed after 5 years of control in both areas are compared in Fig. 2. The profiles for both surveys in both areas are qualitatively similar: prevalence rises monotonically over the age

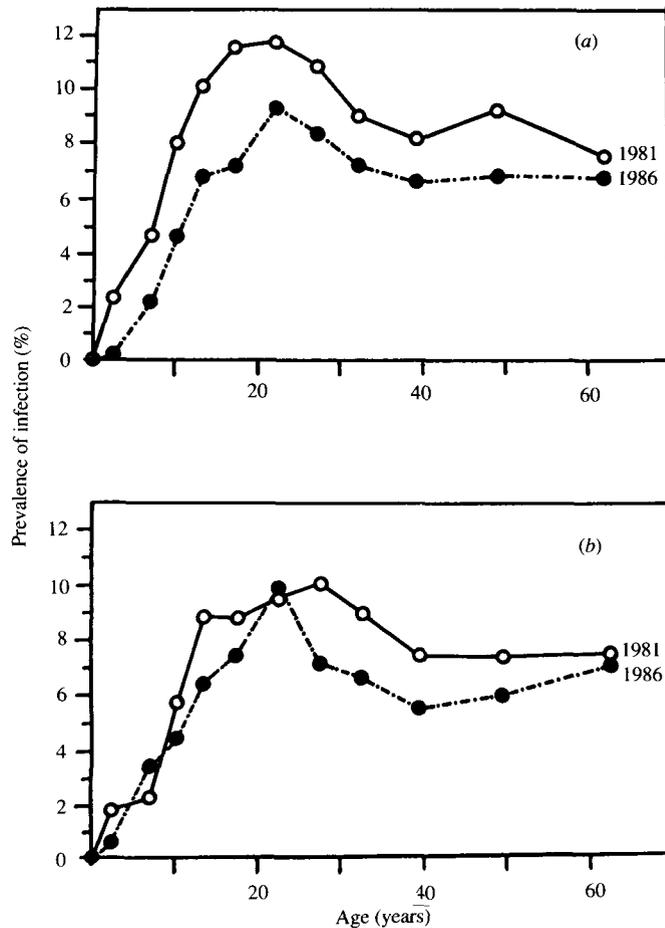


Fig. 2. Relationship between microfilaraemia prevalence (proportion with microfilaraemia) and host age during the survey in 1981 and 1986. (a) VCRC control (IVM) area; (b) comparison area.

range 0–20 years, attains a maximum in the 20- to 25-year age class, and exhibits a declining trend in adults.

In the VCRC area there is an apparent separation of the 1981 and 1986 profiles. This difference is particularly apparent in the younger age classes (Fig. 2a). Statistical analysis indicates a significant difference between the prevalence values for each age class over the age range 1–30 years, but for only one of the adult age classes (Table 1). Similar comparison for the comparison area, however, detected significant differences in only two age classes (Fig. 2b and Table 1).

Statistical analysis (odds ratio interaction test from a log-linear model (12)) of the relative change between the two areas for each age class, however, indicates that the prevalence in the VCRC area declined significantly (compared with the decline in the comparison area) in only two of the younger age classes (Table 1). A similar analysis of the data summed across juvenile (< 20 years) and adult

Table 1. Comparison of pre- and post-control age-specific microfilaraemia prevalence in vector control (IVM) and comparisons areas

Age class (years)	Sample size in 1986		Prevalence of microfilaraemia		$\chi^2$ probability (1981 vs. 1986)		Odds ratio test Comparison vs. IVM
	Comparison area	IVM control area	Comparison area	IVM control area	Comparison area	IVM control area	
0-5	618	1405	0.65	0.21	0.067	0.001†	0.114
6-8	728	1531	3.43	2.22	0.134	0.001†	0.002*
9-11	879	1886	4.44	4.67	0.276	0.001†	0.250
12-14	1111	2250	6.39	6.76	0.041*	0.001†	0.696
15-19	1764	3201	7.43	7.12	0.178	0.001†	0.036*
20-24	1384	2586	9.83	9.28	0.858	0.009†	0.080
25-29	1229	2164	7.16	8.32	0.020*	0.011*	0.674
30-34	996	1679	6.63	7.15	0.095	0.100	0.718
35-44	1387	2563	5.48	6.55	0.064	0.070	0.638
45-54	1013	1702	5.92	6.76	0.267	0.027*	0.688
≥ 55	1046	1493	6.98	6.63	0.811	0.504	0.818

Significant difference: \* 0.05 level; † 0.01 level.

(≥ 20 years) age groups indicates that, overall, the relative decline in the VCRC area compared to the comparison area is highly statistically significant in the juvenile group ( $P = 0.0009$ ) and not significant in the adults ( $P = 0.24$ ). Although these results should be interpreted cautiously, they do indicate a significant decline of prevalence in the vector control zone. This is particularly apparent in the 6- to 8-year age class, where microfilaraemia prevalences are increasing relatively rapidly with age (Table 1).

Figure 3 compares the initial (1981) age intensity of microfilaraemia with that observed after 5 years of control in both areas. The profiles are qualitatively similar: intensity rises monotonically over the 1- to 20-year age range, attains a maximum in the 20- to 25-year age class, declines sharply up to the age of 35, and thereafter remains relatively stable throughout adulthood. The age-dependent decline in intensity of microfilaraemia in adults is more marked than the decline in prevalence (cf. Figs. 2 and 3).

Inspection of the comparative age-intensity profiles in the VCRC area gives an initial impression that there was a reduction in microfilaraemia intensity in all age classes less than 60 years, and that the reduction was most marked in the 0- to 25-year age range. In contrast, the 1981 and 1986 age-intensity profiles in the comparison area appear similar to each other, and suggest that the intensity of microfilaraemia was unchanged by that programme. Comparison of the ranked distribution of microfilarial densities in 1981 and 1986 (using the non-parametric Mann-Whitney  $U$  test) did not however reveal any significant differences for any age class in either area. This paradoxical result suggests that since the populations were inadequately treated and the longevity of infection is greater than the period of control, the intensity of microfilaraemia in both infected populations did not change over the 5 years period of observation. Thus the observed difference in microfilaraemia intensity in the VCRC area between 1981 and 1986 is a

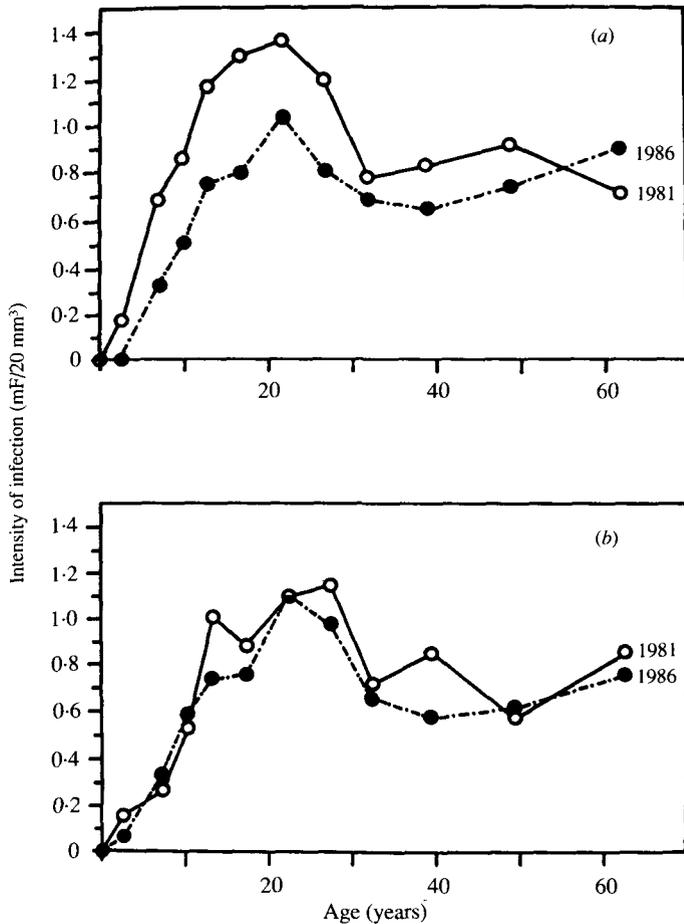


Fig. 3. Relationship between microfilaraemia intensity (mean microfilaria density for the total sample in each age class) and host age during the survey in 1981 and 1986 (mean includes amicrofilaraemic individuals). (a) VCRC control (IVM) area; (b) comparison area.

consequence of an increased proportion of uninfected individuals, as was indicated by the analysis of prevalence (Fig. 2). The programme may have influenced the rate of acquisition of new infections but not the rate of loss of existing infections.

Comparison of frequency distributions of microfilarial density between 1981 and 1986 (Fig. 4) showed that there is a significant difference between the distributions in both the VCRC area ( $\chi^2 = 71.84$ ;  $P = 0.0001$ ; D.F., 29) and the comparison area ( $\chi^2 = 65.99$ ;  $P = 0.0001$ ; D.F., 29). Further analysis was carried out to see whether the observed change in distribution had occurred in low or high microfilaria counts (Table 2). The results indicate that there was a significant increase in proportion of amicrofilaraemic individuals in both areas. It was also observed that, in contrast to the comparison area, there was a significant reduction in proportion of microfilaraemic individuals with different microfilaria counts in IVM area.

Table 2. Comparison of proportional frequencies at each count between pre- and post-control for both IVM and comparison areas

MFC	IVM area				Comparison area			
	1981 (n = 15427)		1986 (n = 22460)		1981 (n = 9519)		1986 (n = 12155)	
	% of n	% of n	Z*	P value	% of n	% of n	Z*	P value
0	91.1	93.6	9.38†	0.0000	92.4	93.7	3.65†	0.0003
1	1.3	1.0	2.86†	0.0042	1.2	1.2	0.17	0.8650
2	1.2	1.0	2.26†	0.0238	1.0	0.9	1.14	0.2543
3	0.9	0.6	3.08†	0.0021	0.7	0.5	1.87	0.0615
4	0.6	0.5	1.82	0.0688	0.4	0.5	0.39	0.6965
5	0.6	0.4	2.96†	0.0031	0.5	0.4	1.72	0.0854
6-10	1.6	1.1	4.28†	0.0000	1.4	1.2	0.99	0.3222
11-50	2.5	1.6	6.23†	0.0000	1.9	1.3	3.82†	0.0001
≥ 51	0.2	0.3	0.31	0.7566	0.3	0.3	0.11	0.9124

MFC, Microfilaria Count.

\* Two sample proportion test.

† Significant.

DISCUSSION

The entomological aspects of this study have been discussed elsewhere (4). The summary data (Fig. 1) clearly demonstrate that the integrated vector management activities achieved a reduction in vector numbers over the course of the programme, and that this reduction was not achieved by conventional larviciding in the comparison area.

The evaluation of the effects of vector reduction upon the filariasis infection status of a population is intrinsically difficult (9). Previous attempts to evaluate the effects of periods of control similar to that of the present study have tended to show little or no measurable impact on epidemiological statistics (13-15), although the effects are apparently clearer after longer periods of control (6, 7). Adult *Wuchereria bancrofti* have a mean expected lifespan in the range 8-15 years (16). In the absence of chemotherapy, therefore, it would be expected that most infected individuals would retain their infections over a period as short as 5 years. The present interview data indicate that despite referral of infected individuals by VCRC, and the explicit requirement of treatment by the NFPCP programme, only 30% of the individuals identified as infected actually received treatment. Since only 10% of the urban population was examined in the pre-control survey, and only 30% of referrals received treatment, the overall treatment coverage of infected individuals in the general population may have been as low as 3.0%. Thus a reduction in the intensity of infected individuals was an unlikely outcome and was not observed in the present study.

The more probable outcome of a reduction in vector biting rate would be a reduction in transmission. This would in turn lead to a reduction in the incidence of new infection, and therefore prevalence. Two factors, however, make such a reduction difficult to identify from epidemiological statistics.

The first is a consequence of the population dynamics of bancroftian filariasis. The form of the age-prevalence profiles indicates that microfilaraemia prevalence

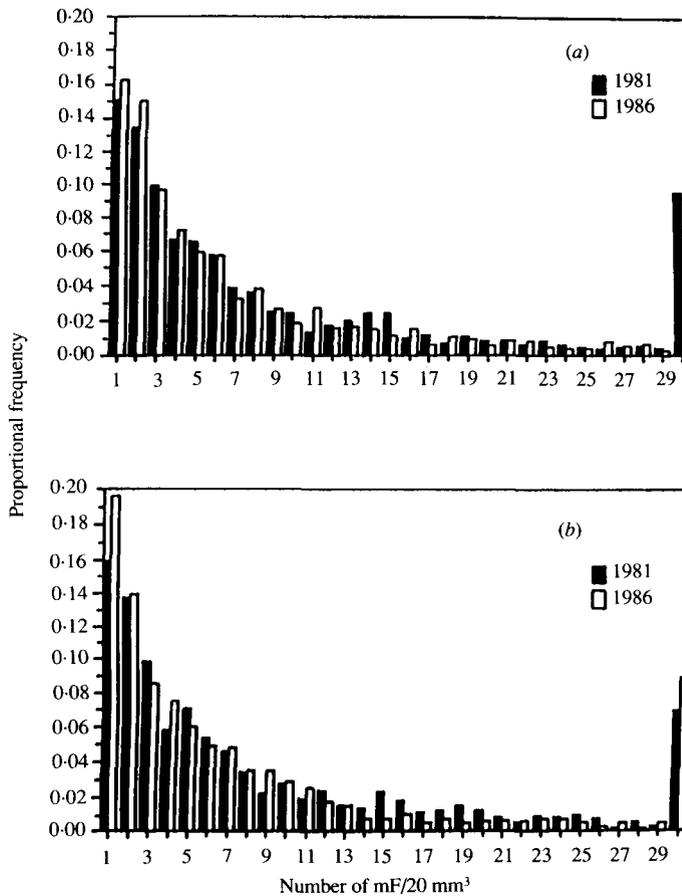


Fig. 4. Frequency distribution of microfilarial numbers (expressed as a proportion of total positives) during 1981 and 1986 surveys. (a) VCRC control (IVM) area; (b) comparison area.

rises at a constant rate over the age range of 0–20 years, whereas in adults the prevalence remains relatively constant or actually declines. Since the acquisition of infection in adults is not reflected in an age-dependent change in prevalence and in the relative absence of chemotherapy little reduction in existing adult prevalence is expected, then the adult prevalence would be expected to remain unchanged over a 5-year period even in the presence of perfect vector control. In the age range 0–20 years, transmission is reflected in an age-dependent increase in prevalence which reflects the rate of acquisition of infection. Thus total interruption of transmission should result in zero increase in prevalence, but not necessarily a reduction; individuals who were already infected would be expected to remain infected 5 years later. Hence, the age-prevalence profile observed for the 0–20 years age range in 1981 would by 1986, in the presence of perfect vector control, merely be shifted by 5 years along the age axis. The population of 10-year-old children in 1986 would be expected to exhibit almost the same prevalence as the population of 5 year olds in 1981. Comparison of Fig. 2a and b) indicates that

this approximately describes the situation in the VCRC area but not in the comparison area.

The second constraint on identifying the effect of transmission on human infection is related to the scale of change. Detectable change is only likely to be found in the younger age classes. In the limit case, changes in prevalence should be most apparent in the 0–5 years age class where, with perfect vector control for 5 years, no new cases should occur. These youngest age classes, however, also exhibit the lowest prevalence; even when infection was endemic and uncontrolled in 1981 the prevalence was only 2.39%, or only 23 cases out of nearly a thousand infants examined. In 1986 only 3 cases were detected in the VCRC area out of more than 1400 children examined, a prevalence of 0.21%. Despite the unusually large sample sizes obtained in this study, such data are at the limits of acceptability of significance tests due to the gross asymmetry in the scale of positive and negative values. Thus the absence of overall significance in comparing relative change between the two control programmes in this age group will be difficult to detect with current statistical techniques and our current level of understanding of the population biology of filariasis.

This study also illustrates the importance of a comparison group when attempting epidemiological evaluation of vector control programmes. Analysis of the integrated vector management area alone indicates a significant reduction in microfilaraemia prevalence in all the younger age groups. When the analysis include the comparison area, this reduction is only significant for the age class with the highest rate of change of prevalence (although the reduction in the VCRC area is still significant for juveniles overall). Thus without the comparison area the scale of the reduction in the control area would tend to be overestimated.

The analysis of frequency distribution of microfilaria counts indicate that the proportion of amicrofilaraemic individuals increased in both areas in 1986 when compared to 1981. But the significant fall in proportion of individuals with different microfilaria counts in IVM area and not in comparison area may be due to (a) the lowered fecundity of adult parasites in people who were already infected at the beginning of the control programme in course of 5 years (as the rate of acquisition of new infections have been influenced by the IVM programme and not the existing infections) and hence (b) the rise in proportion of amicrofilaraemic individuals.

In conclusion, this study has demonstrated that sustained control of *C. quinquefasciatus* breeding can be achieved by integrated vector management on an extensive scale in a complex urban environment. Reduction in mosquito numbers on this scale has important subsidiary benefits; reducing the general mosquito nuisance and minimizing the negative health impact of other mosquito related diseases (17). The results indicate, however, that even when vector control is unusually complete, the ability to detect and evaluate the effect of control on epidemiological statistics is compromised by the population biology of the parasite and the statistical distribution of its infections. The major constraint is the unusual longevity of the parasite which has the important consequence that changes in microfilaraemia prevalence occur on an extended time scale. Some of the problems of analysis and understanding could, in theory, be alleviated by the development of more accurate epidemiological models.

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