Epidemiol. Infect. (1992), **108**, 483–493
Printed in Great Britain

Bancroftian filariasis in Pondicherry, South India – epidemiological impact of recovery of the vector population

P. K. DAS, A. MANOHARAN, S. SUBRAMANIAN, K. D. RAMAIAH, S. P. PANI, A. R. RAJAVEL AND P. K. RAJAGOPALAN

Vector Control Research Centre (Indian Council of Medical Research), Medical Complex, Indira Nagar, Pondicherry–605 006, India

(*Accepted 2 January 1992*)

SUMMARY

An Integrated Vector Management (IVM) strategy was implemented from 1981 to 1985 in one part of Pondicherry, South India, for the control of the bancroftian filariasis vector *Culex quinquefasciatus* (the IVM area). The rest of the town (the comparison area) received the conventional larvicidal input. After 1985 both the areas were managed conventionally. The switch to conventional strategy resulted in an increase of vector density in both areas. The microfilaraemia prevalence in humans showed a general decline ($P < 0{\cdot}05$) from 1986 to 1989 only in the IVM area whereas its intensity did not change significantly in either area. While the age-specific rate of gain of infection was generally unchanged in the IVM area, an increase in all age classes was observed after 1985 in the comparison area, where the Annual Transmission Index was high during the previous years. In both areas the rate of loss of infection increased during 1986–9 compared to 1981–6. The results suggest that 3 years is too short a period to relate the changes in entomological parameters to those in the microfilaraemia status of the population.

INTRODUCTION

An Integrated Vector Management (IVM) strategy for the control of *Culex quinquefasciatus*, the vector of *Wuchereria bancrofti*, was implemented in one part of Pondicherry urban area (the IVM area) during 1981–5. In the other part of Pondicherry (the comparison area) the conventional method of control, which is mainly treatment of breeding habitats with the larvicide, malariol, was implemented by the National Filaria Control Programme [1]. Pre-control observations and the impact of control measures on epidemiological parameters have been reported earlier [2, 3]. The control programme was handed over to the state health authorities in 1986 and subsequently the conventional methods of control were adopted in the whole area of Pondicherry. However, the Vector Control Research Centre (VCRC) continued to monitor the entomological and parasitological parameters in both the IVM and comparison areas. Though the epidemiological impact of vector control programmes has been assessed [3–9], the impact of the recovery of the vector population after the withdrawal of programmes has not hitherto been studied. Such a post-control evaluation is an important aspect of the epidemiology of a chronic parasitic disease and could provide information on the process of re-establishment of the infection. In this paper, the epidemiological impact of the recovery of the vector population during the years 1986–9 is assessed.

MATERIALS AND METHODS

The data

The study area and methods used in the control and evaluation aspects of the programme have been described elsewhere [1–3]. A mass blood survey was conducted from January to June 1989 to detect microfilariae (mf) in peripheral blood by the finger prick method. The sampling design was similar to that of earlier surveys carried out in 1981 and 1986 [1–3]. The samples (both areas combined) were age stratified and weighted according to the demography of Pondicherry as a whole (since the census data did not provide age-structure of the population for the two areas separately) with a minimum target of 5% sample in each age group. Entomological parameters were also monitored continuously after the change-over to conventional control operations. Resting and biting densities were determined every 2 weeks at two sites, one each from the IVM and comparison areas. Details of the entomological procedures have been described elsewhere [1].

Statistical methods

The reductions in mf prevalence within each age group between the surveys carried out in 1986 and 1989 was compared using Pearson's χ^2 statistic. The Mantel–Haenszel χ^2 test stratified by age group was used to compare the reductions in the overall prevalence of microfilaraemia between the two surveys. The relative changes in prevalence between the IVM and comparison areas from 1986 to 1989 were compared by the log odds ratio interaction test based on a loglinear model [10]. The changes in the mf density distribution were compared using the non-parametric Mann-Whitney U test for independent samples. The method of Bekessy and colleagues [11] was used for estimating the loss and gain rates of infection from the resurvey data. Their model is based on the assumption that the phenomenon of patent parasitaemia can be represented by a reversible two-stage catalytic model, which is a Markov process. Application of this model involves the estimation of the two parameters h and r (the per capita gain and loss rates of infection respectively) from the data of those individuals whose blood was examined in two consecutive surveys. The individuals were classified as mf +ve or mf −ve for each survey. Transition frequencies from positive to negative and reciprocally were calculated as follows:

Let 'a' = the proportion of individuals who were −ve in the first survey and became +ve in the second (i.e. $N-+/N-$).

'b' = the proportion of individuals who were +ve in the first survey and became −ve in the second (i.e. $N+-/N+$).

The loss (r) and gain (h) rates were then estimated from the proportions a and b by the following formula:

$$h = [a/t(a+b)]\log[1/(1-(a+b))]$$

$$r = [b/t(a+b)]\log[1/(1-(a+b))]$$

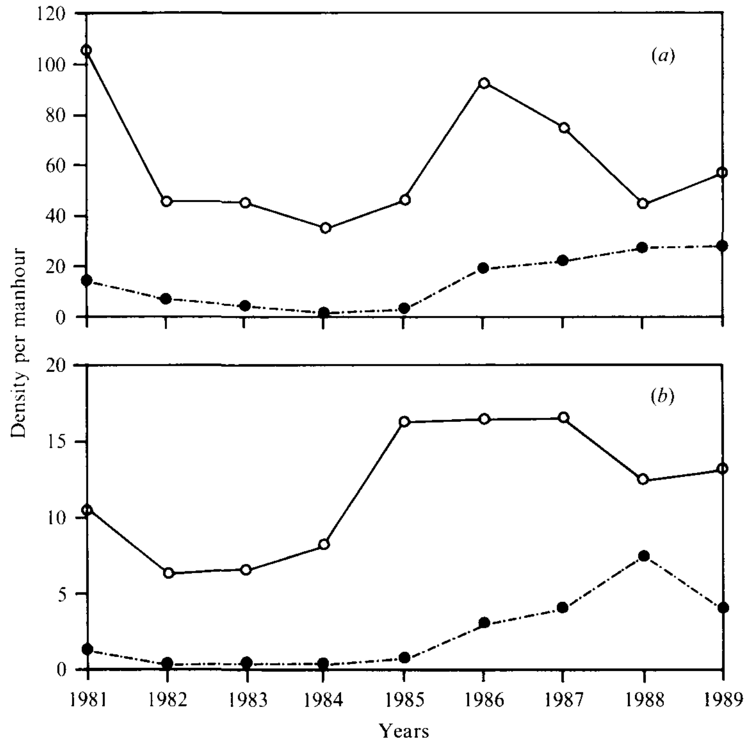

Fig. 1. (*a*) Average resting density (no. of females per manhour) of *C. quinquefasciatus* in the comparison (○) and IVM (●) areas. (*b*) Average biting density (no. of females per manhour) of *C. quinquefasciatus* in the comparison and IVM areas.

where,

t is the interval in years between the two surveys.

According to Bekessy and colleagues [11] these parameters can be estimated only when $(a+b) < 1$. If $(a+b) \geqslant 1$, it means that either the process is non-Markovian or the parameters were not constant between successive observations. The loss and gain rates were estimated only for those age classes which satisfied the above condition.

RESULTS

Entomological parameters

The yearly resting and biting density of *C. quinquefasciatus* from 1981 to 1989 is illustrated in Fig. 1a and 1b respectively. While in the IVM area the resting density increased steadily after 1985, in the comparison area it declined after an initial increase (1985–6). In the comparison area, the biting density remained high from 1984 to 1987 and then declined, whereas in the IVM area it steadily increased from 1985 to 1988. However, in the IVM area both the resting and biting populations were lower than those of the comparison area throughout the study period.

The biting density per man hour, infection and infectivity rates varied significantly between the years ($P < 0{\cdot}05$) and between the IVM and post IVM periods ($P < 0{\cdot}05$) in the IVM area. In contrast, in the comparison area, while all

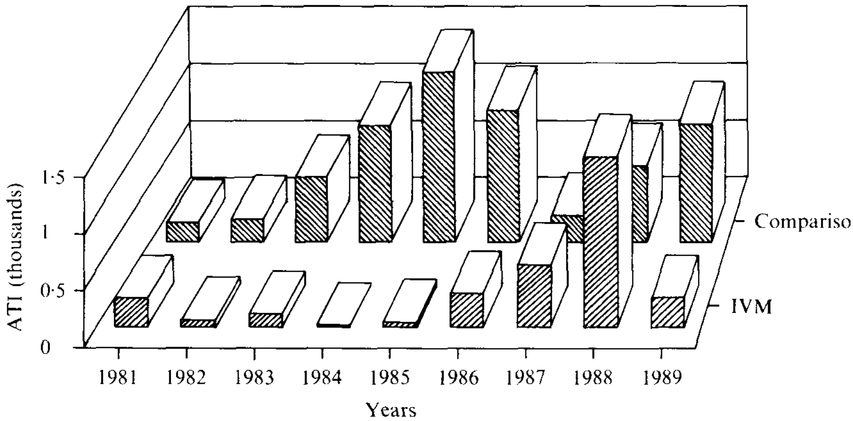

Fig. 2. Annual Transmission Index (ATI) in the comparison and IVM areas.

these parameters varied significantly between the years ($P < 0{\cdot}05$), only the biting density per man hour differed significantly ($P < 0{\cdot}05$) between the periods of 1981–5 and 1986–9. Hence the Annual Transmission Index (ATI), which is the product of the number of infective mosquitoes biting a man per year and the average number of infective larvae per infective mosquito [12], was used to show the combined effect of changes in these parameters on the transmission dynamics. The ATI showed an increasing trend in the comparison area from 1981 to 1985 but declined in the IVM area over the same period. In the IVM area it showed an increase from 1986 to 1988 and subsequently declined in 1989. In the comparison area the ATI declined markedly in 1987 but increased thereafter (Fig. 2).

Parasitological parameters

In 1989 blood smears were collected from 30813 individuals from IVM and comparison areas combined. This represented 9·15% of the estimated total population of 336604. The sampling distribution over different age classes was similar to that in the previous two surveys carried out in 1981 and 1986 [2, 3]. The target minimum of 5% sampling was achieved in all the age classes except in the 0–3 group (Table 1). The percentage of males and females in the sample was 47·0 and 53·0 in 1989 and 48·6 and 51·4 in 1986 respectively. The prevalence of microfilaraemia in males and females was 6·7 and 3·9% in 1989 and 7·1 and 5·6% in 1986 respectively and was significantly higher in males than in females in both the surveys ($P < 0{\cdot}05$). However, the decline in prevalence between the two surveys (1986 and 1989) was significantly higher in females than in males (Mantel–Haenszel test, $\chi^2 = 132{\cdot}549$, $P < 0{\cdot}001$).

Age prevalence and intensity

The age prevalence of microfilaraemia in 1981, 1986 and 1989 for the comparison and IVM areas is shown in Fig. 3a and 3b respectively. The age profiles in all surveys in the two areas remained qualitatively similar but differed quantitatively. The separation of age prevalence profiles between the three surveys was well marked in all age classes in the IVM area. In the comparison area the separation was well marked in older age classes (above 25) between 1981 and 1986 and in younger age classes (below 25) between 1986 and 1989. The reduction in prevalence from 1986 to 1989 was significant in two age classes in the comparison

Table 1. *Age structure of population compared with sample in 1989 (IVM and comparison areas combined)*

Age class (years)	Population size	Percent of total population	Sample size	Percent of total sampled	Percent of age class
0–3	29789	8·85	798	2·59	2·68
4–5	19860	5·90	1068	3·47	5·38
6–10	49649	14·75	3833	12·44	7·72
11–15	42076	12·50	4806	15·60	11·42
16–20	29285	8·70	4234	13·74	14·46
21–25	26592	7·90	3245	10·53	12·20
26–30	24909	7·40	2938	9·53	11·80
31–40	42412	12·60	4280	13·89	10·09
41–50	31641	9·40	2646	8·59	8·36
> 50	40392	12·00	2965	9·62	7·34
Total	336604	100·00	30813	100·00	9·15

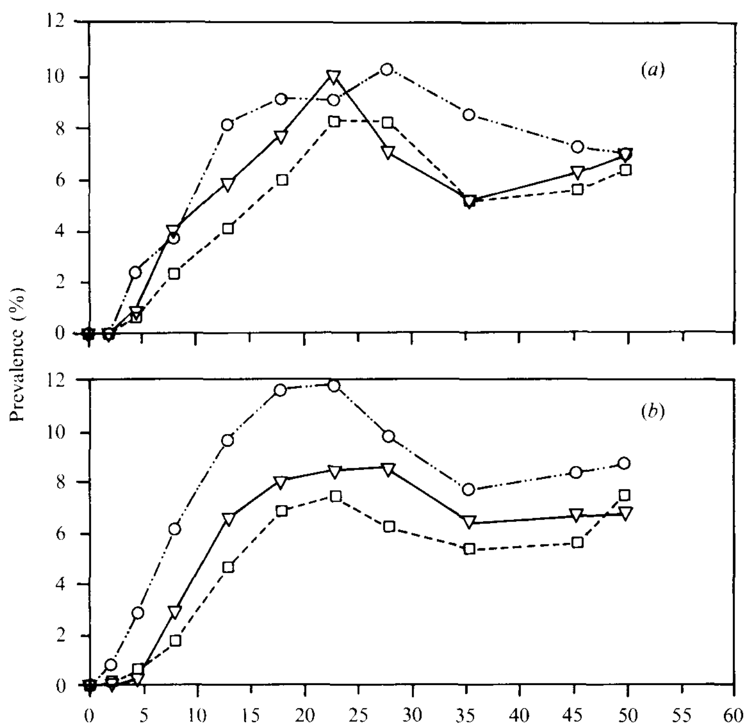

Fig. 3. (*a*) Prevalence of microfilaraemia in the comparison area. (*b*) Prevalence of microfilaraemia in the IVM area. ○, 1981; ▽, 1986; □, 1989.

area and in three age classes in the IVM area (Table 2). While in the IVM area the overall prevalence of microfilaraemia in 1989 was significantly lower than that of 1986, the difference was not statistically significant in the comparison area (Mantel–Haenszel χ^2 test). Statistical analysis based on a log-linear model (odds ratio interaction test) indicated that the relative change in the prevalence of microfilaraemia between the two areas was not significant (Table 2), as also observed between 1981 and 1986 [13].

https://doi.org/10.1017/S0950268800049992 Published online by Cambridge University Press

Table 2. *Age specific prevalence (%) and significance of reduction of microfilaraemia in the comparison and IVM areas*

Age class (years)	Prevalence of microfilaraemia: Comparison area 1986	Comparison area 1989	IVM area 1986	IVM area 1989	χ^2 probability (1986 vs 1989): Comparison area	IVM area	Odds ratio test Comparison vs IVM (p)
0–3	0·00	0·00	0·00	0·18	—	—	—
4–5	0·94	0·63	0·31	0·66	0·64	0·29	0·3104
6–10	4·09	2·31	2·94	1·80	0·01*	0·01*	0.7667
11–15	5·92	4·14	6·60	4·66	0·02*	< 0·01*	0.9652
16–20	7·72	6·03	8·10	6·90	0·07	0·08	0·6001
21–25	10·06	8·29	8·49	7·46	0·13	0·19	0·6804
26–30	7·10	8·22	8·56	6·27	0·33	0·01*	0·0147*
31–40	5·20	5·16	6·49	5·39	0·95	0·07	0·3284
41–50	6·28	5·57	6·72	5·60	0·50	0·17	0·7782
> 50	6·94	6·33	6·78	7·49	0·54	0·41	0·3184
Overall	6·34	5·32	6·36	5·21	0·48	0·001†	0·7100

* Denotes significant difference at 0·05 level using Pearson χ^2 test.
† Denotes significant difference at 0·05 level using Mantel–Haenszel χ^2 test.

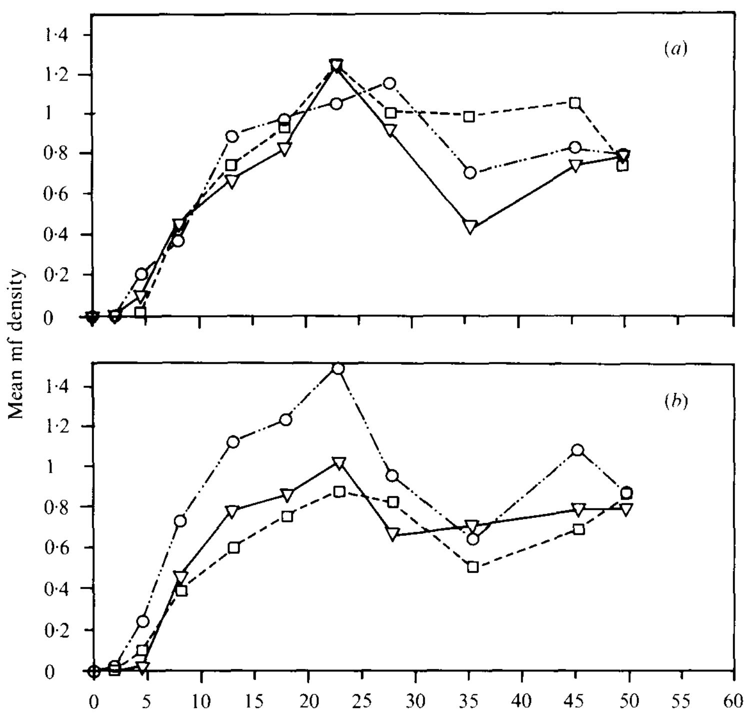

Fig. 4. (*a*) Intensity of microfilaraemia in the comparison area. (*b*) Intensity of microfilaraemia in the IVM area. ○, 1981; ▽, 1986; □, 1989.

The relationship of microfilaraemia intensity with age for the comparison and IVM areas is shown in Fig. 4. The intensity increased from 0 to 20 years of age and then tended to decline. Comparison of the age intensity profiles in the IVM area showed that the reduction between 1981 and 1986 was marked in almost all age

Table 3. *Comparison of 1989 microfilaraemia prevalence (%) between freshly surveyed and resurveyed people*

Age class (years)		Comparison area surveyed			IVM area surveyed		
		Once	Twice	Thrice	Once	Twice	Thrice
	n =	5859	3239	1299	11680	6353	2383
0–3		0·00	0·00	0·00	0·18	0·00	0·00
4–5		0·66	0·00	0·00	0·69	0·00	0·00
6–10		2·47	1·96	0·00	1·96	1·45	0·00
11–15		4·59	3·83	2·81	5·38	3·81	4·11
16–20		7·09	5·42	3·70	9·16	4·58*	4·55*
21–25		9·61	6·65	6·57	7·84	6·14	8·73
26–30		8·01	9·26	6·73	7·10	5·22	4·39
31–40		4·71	6·13	4·35	6·83	4·35*	2·25*
41–50		7·66	4·48	2·84*	7·31	4·73*	3·57*
> 50		7·79	5·76	4·28	8·74	6·95	5·64
Overall		5·58	5·28	4·23	5·75	4·44†	4·57†

* Significant at 0·05 level compared to people of the same age group surveyed once (Pearson χ^2).

† Significant at 0·01 level compared to people surveyed once (Mantel–Haenszel χ^2).

classes, whereas between 1986 and 1989 a marginal decline was observed only in some of the adult age classes. The temporal intensity age profiles in the comparison area appeared generally similar in most adult age classes except for an apparent increase from 1986 to 1989 in those aged 25–45. Comparison of the microfilaria densities between 1986 and 1989 showed no significant difference for any age class in either area (non-parametric Mann-Whitney U-test).

Prevalence and intensity among resurveyed people

The 30813 persons surveyed in 1989 are grouped into (i) 17539 sampled only in 1989, (ii) 9592 persons recruited twice, i.e. in 1981 or 1986 and 1989, (iii) 3682 surveyed three times, i.e. in 1981, 1986 and 1989. Since the administration of DEC to the microfilaria carriers in 1986 in both IVM and comparison areas might have influenced the microfilaria status of the population in 1989, the prevalence of microfilaraemia and its intensity in these three groups were analysed and compared (Table 3). Though the overall prevalence of microfilaraemia was significantly lower in the resurveyed people (groups ii and iii) than in the freshly surveyed (group i) in the IVM area, the difference was not significant in the comparison area (Mantel-Haenszel χ^2 test, Table 3). However, the overall microfilaria intensity was significantly lower (Mann-Whitney test) in resurveyed people (groups ii and iii) than in freshly surveyed people (group i) in both the areas.

Loss and gain of infections

The rates of loss and gain of microfilaraemia were estimated for both the areas for 1981–6 and 1986–9. The overall rate of gain increased marginally from 0·0126 per year during 1981–6 to 0·0142 per year during 1986–9 in the IVM area. In the comparison area also the overall rate of gain increased from 0·0094 per year to

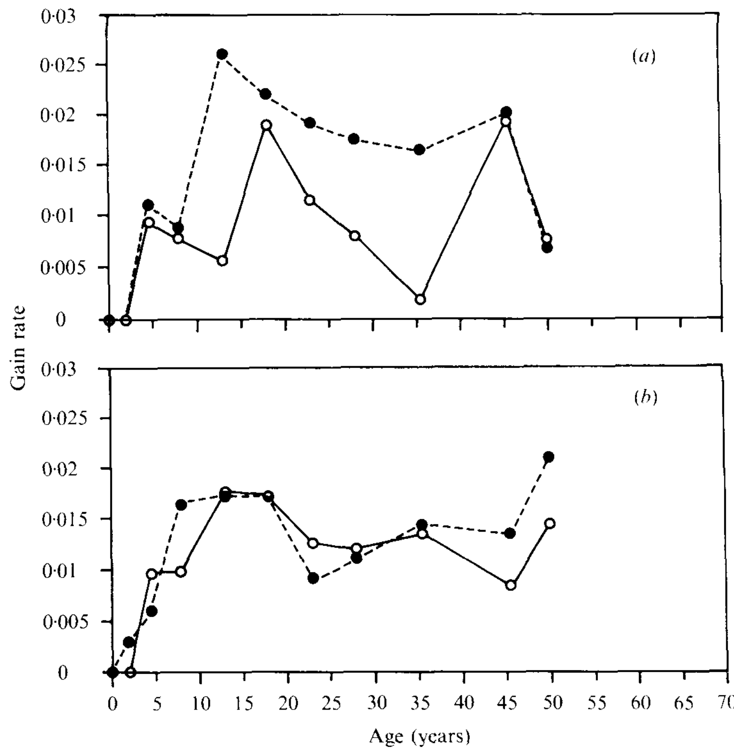

Fig. 5. (*a*) Rate of gain of infection in the comparison area. (*b*) Rate of gain of infection in the IVM area. ○, 1981–6; ●, 1986–9.

0·0158 per year over the same period. While the age specific rates of gain were generally unchanged in the IVM area (Fig. 5b), an increase was observed in the comparison area (Fig. 5a) in the 11–35 year age class.

The overall loss rate increased from 0·215 to 0·361 per year in the comparison area, and 0·196 to 0·409 per year in the IVM area. The age-specific rates of loss of microfilaraemia in the comparison and IVM areas are shown in Fig. 6. In both the areas, the rate of loss was higher than the rate of gain in all age classes both between 1981 and 1986 and in 1986–9. Furthermore, the rate of loss of infection for the period 1986–9 was higher when compared to 1981–6 in both the areas.

DISCUSSION

The relative impact of the IVM and conventional strategies on entomological and parasitological parameters has been reported in our earlier publications [1–3]. The present analysis highlights the effects of the withdrawal of IVM, on the pattern of vector recovery and consequent changes in the dynamics of the parasite.

Entomological aspects

The relative impact of the two strategies (IVM and conventional) between 1981 and 1985 was reflected in the changes in resting and biting densities of the vector and other epidemiological parameters such as ATI and the Risk of Infection Index

https://doi.org/10.1017/S0950268800049992 Published online by Cambridge University Press

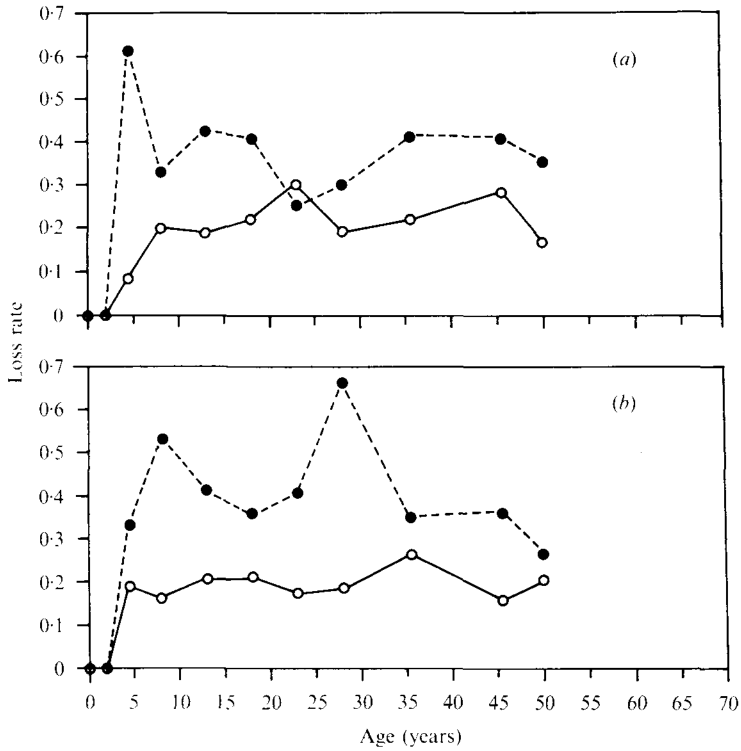

Fig. 6. (*a*) Rate of loss of infection in the comparison area. (*b*) Rate of loss of infection in the IVM area. ○, 1981–6; ●, 1986–9.

[1]. However, the gains achieved in the IVM areas could not be sustained after switching over to the conventional methods, and a gradual recovery of the vector population and rise in ATI was noticed in this area. The vector densities, though continuously increasing in the IVM area from 1986 onwards, were always lower than those of the comparison area. This could be due to permanent ecological changes brought about in the IVM area by environmental manipulation, which was the main plank of the IVM strategy. However, in the absence of the pre-control data (before 1981), interpretation as to the influence of ecological differences, between the two areas, on the changes in vector population cannot be made with certainty. The decline in the vector densities after 1986/7 in the comparison area could partly be due to ecological changes and localized and need/demand based interventions. Relatively high vector densities in the comparison area throughout the study period (1981–9) and in the IVM area after 1985 suggest that IVM yielded better results than the conventional measures.

Parasitological aspects

While a significant reduction in the prevalence of microfilaraemia was observed in 1986 compared to 1981, in the IVM area, the relative change in the prevalence between the IVM and comparison areas was not significant during the same period [3]. In the IVM area a clear separation of the age prevalence profiles between 1986 and 1989 was observed, but it is difficult to ascertain whether this was due to the prolonged effect of IVM or chemotherapy or combined effect of both. The chemotherapy in 1986 was ethically necessary and imparted to the mf carriers in both the areas. The significant reduction in microfilaria density and high loss rate of microfilaraemia in the resurveyed people between 1986 and 1989 compared to between 1981 and 1986, in both the IVM and comparison areas suggests the beneficial effect of chemotherapy. However, the prevalence declined significantly only in the IVM area possibly due to the prolonged effect of IVM. This is further evident from the nearly unchanged gain rate in the IVM area during 1981–6 and 1986–9, unlike in the comparison area where it increased considerably during 1986–9.

Relating entomological parameters to parasitological variables

Though the vector density increased steadily in the IVM area after 1985, the rate of acquisition of infection did not change perceptibly, suggesting that either the vector density did not reach a level which could enhance the rate of acquisition of microfilaraemia in humans or the time period of 3 years (1986–9) was too short to reflect the impact of vector recovery on the prevalence of microfilaraemia. The latter possibility is more likely in view of the fact that though the exposure of human hosts to infective larvae was higher during 1986–9 than during the IVM period (1981–5) as is evident from the increased ATI from 1986 onwards (Fig. 2), a corresponding increase in the rate of gain was not observed. In contrast, though the vector density increased (at least in 1986–7) in the comparison area, the ATI was markedly lower after 1986 than during 1981–5. The observed increase in rate of gain of microfilaraemia during 1986–9 in this area could be due to high ATI during 1981–5.

The major objective of the study was to evaluate the effect of vector recovery on microfilaraemia in the population. The marked changes in the vector parameters have not been reflected in the parasitological parameters suggesting that a period of 3 years is too short to make a conclusive assessment of changes in the dynamics of the parasite. In the absence of an appropriate method to determine the prevalence of pre-patent infection in the human population, evaluation of impact of vector recovery on the dynamics of the parasite is difficult. Therefore, it is of utmost importance to establish a quantitative relationship between transmission potential of vectors and incidence of infection in humans.

ACKNOWLEDGEMENTS

The authors are grateful to Dr D. A. P. Bundy, Parasite Epidemiology Research Group, Imperial College, London and Dr B. T. Grenfell, Cambridge University, Cambridge for critically reviewing the manuscript.

REFERENCES

1. Rajagopalan PK, Das PK. *The Pondicherry project on integrated disease vector control* (Filariasis Control Demonstration Project). Pondicherry: Vector Control Research Centre, 1987: 1–164.
2. Rajagopalan PK, Das PK, Subramanian S, Vanamail P, Ramaiah KD. Bancroftian filariasis in Pondicherry, South India. 1. Pre-control epidemiological observations. Epidemiol Infect 1989; **103**: 685–92.

3. Subramanian S, Pani SP, Das PK, Rajagopalan PK. Bancroftian filariasis in Pondicherry, South India. 2. Epidemiological evaluation of the effect of vector control. Epidemiol Infect 1989; **103**: 693–702.
4. Webber RH. Vector control of filariasis in the Solomon Islands. South East Asian J Trop Med Publ Hlth 1975; **6**: 430–4.
5. Chelbowsky HO, Zielke ZE. Studies on bancroftian filariasis in Liberia, West Africa. III. Efficacy of repeated treatment with Di-ethyl carbamazine and vector control on the microfilarial reservoir in a rural population. Tropenmed Parasit 1980; **31**: 181–93.
6. Webber RH. The natural decline of *Wuchereria bancrofti* infection in a vector control situation in the Solomon Islands. Trans Roy Soc Trop Med Hyg 1977; **71**: 396–400.
7. Webber RH. Eradication of *Wuchereria bancrofti* infection through vector control. Trans Roy Soc Trop Med Hyg 1979; **73**: 722–4.
8. Dissanaike AS. Filarial infections. In: Gilles HM, ed. Recent advances in tropical medicine. Edinburgh: Churchill Livingstone, 1984: 115–52.
9. Hairston GN, Jachowski LA. Analysis of the *W. bancrofti* population in the people of American Samoa. Bull WHO 1968; **38**: 29–59.
10. Baker D, Nelder JA. Numerical Algorithms Group: GLIM Version 3.77: User Manual. Oxford, 1978.
11. Bekessey A, Molineaux L, Storey J. Estimation of Malaria incidence and recovery rates of *Plasmodium falciparum* parasitaemia from longitudinal data. Bull WHO 1976; **54**: 685–93.
12. Beye HK, Gurian J. Epidemiology and dynamics of transmission of *Wuchereria bancrofti* and *Brugia malayi*. Indian J Malariol 1960; **14**: 415–40.
13. Rajagopalan PK, Das PK, Panicker KN, et al. Environmental and water management for mosquito control. In: Curtis CF, ed. Appropriate technology in vector control. Florida: Boca Raton, 1990: 121–38.