

ANOPHELINE-BORNE FILARIASIS AND ITS CONTROL

WITH PARTICULAR REFERENCE TO THE SOLOMON ISLANDS

by

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ABSTRACT

Wuchereria bancrofti infection in the Solomon Islands is nocturnally periodic, transmitted by the same vectors as malaria: Anopheles farauti, A. punctulatus and A. koliensis.

A survey was conducted in 1970 in part of the Western District measuring the microfilaria and elephantiasis rates of one part that had been sprayed with residual insecticides in the Malaria Eradication Programme for 2 years (Choiseul) with another for 10 years (Shortlands). In Choiseul 15 per cent of the population had microfilariae and 0.8 per cent elephantiasis, whereas in the Shortlands islands 0.27 per cent had microfilaria, but 1.8 per cent elephantiasis.

This disease was considered an underrated problem in the islands and to have an appreciable morbidity. Previous surveys have shown it to be widely distributed. In Choiseul island it appeared to have a focal distribution.

The possible reduction of this disease by vector control measures was then explored and the apparent success in the Shortland Islands compared with other areas. An attempt was made to construct a model of the decrease in positive cases since year of infection, using retrospective data on infected persons removed to a vector-free situation, and a calculation made of the degree of vector control required to achieve this ideal.

Follow up surveys of Choiseul were conducted in 1974 and 1975 which showed that the level of filariasis had continued to fall. Different techniques used were equated and a baseline measure made which showed that the density was the most useful indicator of progress. In 1968 the

median microfilarial count (MfD_{50}) was calculated to be 16.4. By 1970 it had fallen to 12.2, 1974 to 5.4 and 1975 to 3.0. In 1974 (6 years after spraying had started), the youngest positive was 9 years old.

The previous theoretical model on the decline of filariasis under vector control was found to be unsatisfactory in the field and a revised model based on density measurements is put forward. From this it would appear that the adult *W. bancrofti* can survive about 8 years with a probable absolute maximum of 12 years, as a survey of Shortlands, 15 years after spraying started, using the Millipore technique, found no microfilariae at all, in a previously highly endemic area.

Pichon (1974, 1975) calculated with Anopheline-transmitted filariasis exhibiting facilitation that there was an unstable level of infection below which the disease would naturally decline to eradication. A critical level is calculated for this point using malaria as a measure, and field results presented that support it.

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2. INTRODUCTION

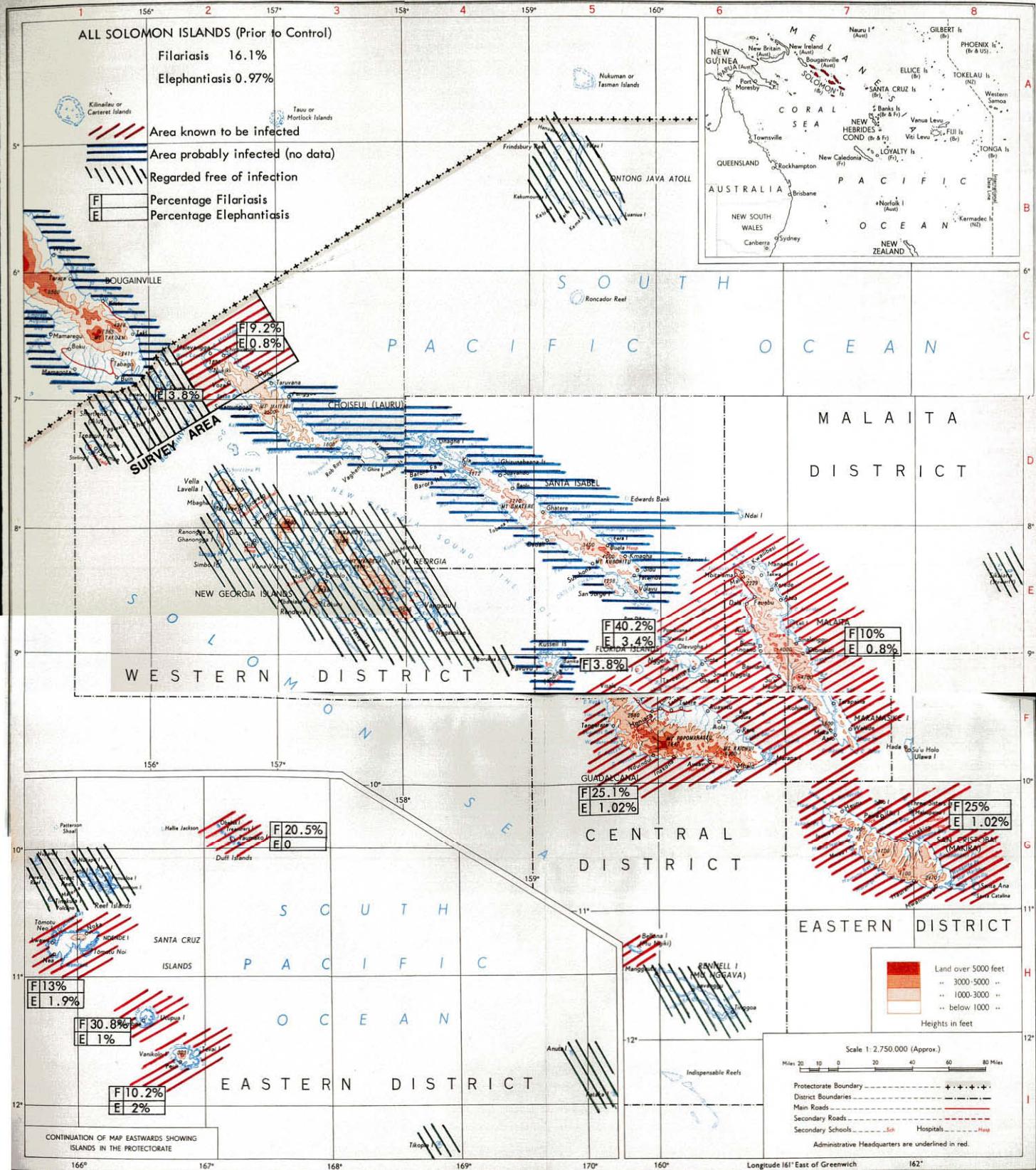
Of the filarial diseases affecting man, Wuchereria bancrofti is the most widespread, taking advantage of several different mosquito vectors. Amongst these are various species of Anopheles, the vectors of malaria. This anopheline-borne filariasis is found in the Caribbean, East and West coasts of Africa, Malaysia, Borneo, Phillipines and New Guinea-Melanesia.

Where the same vector is shared by both malaria and filariasis and a malaria eradication or control campaign is in operation, one can anticipate that filariasis will be affected as well. A reduction was noted in West Irian (Iyengar et al., 1959 and Van Dyk, 1964) and in Togo (Southgate, 1975, personal communication), but these have not been fully followed-up.

A Malaria Eradication Campaign was started in the Solomon Islands in 1962 and it was hoped to monitor the effects of vector control on filariasis during the course of the Programme. Basic epidemiological surveys and a first assessment of vector control effects was conducted in 1970 (Webber, 1973). These results were followed up in 1974 and 1975 and a complete picture is now presented. An attempt has been made to work out the parameters and pattern of reduction of anopheline-borne filariasis by vector control so that it can have wider application to similar situations in other parts of the world.

Fig. 1
DISTRIBUTION OF FILARIASIS IN THE SOLOMON ISLANDS 1975

BRITISH SOLOMON ISLANDS



GENERAL*

A. GEOGRAPHY

A look at figure 1 will show that the Solomons consists of a double chain of large islands in the Western Pacific lying between latitudes 5° and 12° South. These islands are volcanic in origin with high, mountainous interiors, little coastal plain, and surrounded by fringeing coral reefs. Some of these coral reefs are developed into established islands and well formed lagoons. Outside the main islands are isolated volcanic peaks or atolls, some of considerable size, and others raised up by subsidiary eruption. The total land area is some 11,500 sq. miles.

The climate is hot and wet of the Equatorial rain forest type. The temperature averages 85° F and rainfall from 100 to 300 inches per annum. The average number of rainy days is 195 and relative humidity 82. The weather is unseasonal, although marginally wetter between December and March, when it is very turbulent and often leads to the formation of revolving tropical storms.

The smaller islands also receive a heavy rainfall, so that even on the coral atolls, the depressed central part of the island left after the formation of the barrier reef, becomes a mosquito infested swamp. On all islands there is a surprising sparcity of animal life, apart from small mammals (especially the rat), but this is counteracted by a profusion of bird and sea life.

*

This section which formed part of the author's dissertation for the D.T.P.H., 1973, has been revised and included here.

B. PEOPLE

The total population is approximately 200,000, Melanesians being 184,000. The main islands are inhabited by the Melanesians, Polynesians being restricted to the outlying atolls and islands. A few communities of Gilbertese people have recently settled in parts of the Western Solomons, whereas Chinese and European minorities are found in the few urban centres, especially Honiara, the capital.

People mainly live in small villages around the coast, but a few primitive heathen tribes inhabit the dense bush interiors of Malaita and Guadalcanal. The major occupation of the people is subsistence farming and fishing, copra (from the coconut) being the most important export.

The islands have been heavily missionised, so that the predominant religion is Christianity, but the indigenous beliefs in ancestor worship and tradition (custom) are still very strong in most people. Administration by tribal chiefs gave way to religious leaders, who are now being superseded by the awakening politician.

C. COMMUNICATIONS

Travel, except amongst the main centres, is slow and difficult and ranks as one of the major problems in all services especially Medical (the Malaria Eradication Campaign having particular difficulty). An internal air network serves the District centres, but the bulk of travelling is done by sea on rather small and slow vessels. The canoe is used around the coast in preference to walking, but reaching the interior can only be done by foot. This is through the most difficult of terrain, the main routes of access being the rivers.

D. HISTORY

Early

Over 2,000 years ago an Austronesian people originating from S.E. Asia, passed down the Malaysian peninsula and along the island chain of Indonesia and New Guinea to the Solomons and New Hebrides. They found a small and quiet, more negroid indigenous people. These were either killed or intermarried with, but remnants of them are seen in Santa Cruz, the Reef Islands, Vanikoro and Vella Lavella. Due to its comparative isolation the various forms of the Austronesian language found in the Solomons to this day are more like the original than other lands originally invaded by these people (Fox, 1967).

The second migration was of a more mongoloid people who mainly inhabited Micronesia, and only came to the Solomons very recently in small communities re-settled in the Western Solomons and Honiara. 1,000 years after the Austronesians, a fairer skinned people occupied Polynesia, but as to whether these peoples originated from S.E. Asia as did the previous two waves of people, or from South America, still lends itself to speculation. Secondary or possibly tertiary migrations of the Polynesians reached the Solomons and settled on the outlying atolls and coral islands.

However, even amongst the Melanesians there is considerable variation and the Austronesian type are best seen in the bush peoples of Malaita and Guadalcanal. The coastal people of these islands are very different and the Western islanders different again, so one can hypothesise that amongst the Melanesians themselves there were several minor waves of invasion and inter-marriage.

Western Discovery

The Solomons were discovered by the western world on 23rd January, 1568, by Alvaro de Mendana, a Spaniard, sailing from Peru. He discovered the islands of Isabel, Malaita, Gela, Guadalcanal, Choiseul, Ugi and Makira. On Guadalcanal he landed at Point Cruz, (where Honiara is now), and while exploring the immediate vicinity found traces of gold in the Metanikao river, and thought that these must be the legendary islands from which King Solomon obtained all his treasure.

Mendana was determined to return, which he did 30 years later, but this time to settle and form a colony. He landed at Santa Cruz on this voyage (also discovering the Reef Islands), but he met with disaster, most people died, including Mendana himself (probably from malaria), so the survivors abandoned the attempt and sailed to the Phillipines.

It is thought that the bearings given by Mendana were not accurate because many attempts were made to re-find the islands, but this was not achieved until 1767 by Carteret. This was followed by Bougainville in the next year and Surville in 1769. Other explorers visited the islands including Shortland who visited Guadalcanal, New Georgia and the islands that bear his name.

The presence of islands in this area offering shelter, food and water now became well known so that whaling ships, then planters and missionaries from about 1850 on, became regular visitors. However, the islands were famous for headhunting and cannibalism and this wanton murder was further intensified by the Blackbirders who coaxed, stole or bought (often for heads) people to take to work on the plantations in

Australia and Fiji. It is estimated that some 60,000 people were taken in this way from the Solomons and New Hebrides, but later on when public opinion forced their return, they were just left on the first island they came to and then promptly killed by the indigenous people. It is also out of this time that Pidgin English originated, accounting for the coarse nature of many of its expressions.

Pressure from the missionaries and Woodford himself (who became the first Resident Commissioner) forced a reluctant Britain to declare a Protectorate over the Solomon Islands in 1893. Gradually the head-hunting and blackbirding were brought under control only to be followed by a further killer in the form of new diseases not met with before, measles, influenza and polio. Medical care was given by the planters, missions and the small government hospital at Tulagi, but was of a somewhat limited nature.

There was very little advance in the Solomons being rather neglected and forgotten, until the Second World War, when Guadalcanal became an internationally known site as a decisive battle ground. Most development as seen today stems from this period, as the Solomon Islands rapidly progresses towards its own independence.

E. ANTHROPOLOGY OF REGION

In pre-protectorate days the small islands of the Shortland group were extremely powerful and ruled over the northern part of Choiseul island and the southern part of Bougainville. There was consequently some inter-marrying and considerable movement between these islands, which has continued to this day.

Choiseul island itself is divided into distinct ethnic areas. Land rights in these areas are on a tribal basis so nobody actually owned land, but it was proportioned out depending on needs (Sheffler, 1965) but defended by the whole group if threatened with attack from a neighbour. However, the frequent head-hunting raids drove these people from the coast into the central part of the island where they were reasonably safe. But with the coming of the Protectorate and increased missionary activity they were once more encouraged to return to the coast and build their villages there. So from the central part of the island some of the people came down to the west coast and some to the east with the result that identical ethnic groups will be found on diametrically opposite coasts, whereas going round the coast they are quite different.

3. REVIEW OF PREVIOUS WORK

Although reported by Bahr (1912) in settled Solomon Island labour in Fiji, filariasis is not mentioned in the islands until 1922 (Annual Medical Report) when it was stated "filariasis said to have been introduced on Guadalcanal by returned indentured labour from Fiji", an unwarranted supposition. A further report in 1928 (Annual Medical Report) described a visit to Lord Howe Atoll (Ontong Java) where two cases of elephantiasis of the leg and two of the breast were observed. However, the overall picture of the disease was well described by Crichlow (1929). "Filariasis is fairly common and widespread, but elephantiasis is not so common. The leg is the part most commonly affected. A survey made by the author has shown that 15% of the native population, harbour filarial embryos in the blood, although few show any symptoms. Savo showed an infestation rate of 25%....".

There is little progress and scant mention of this important disease until the War Years when the work done by the Filaria Survey Unit in the Solomon Islands, Byrd and St. Amant (1944) formed the basis on which all subsequent studies have been made. This will be mentioned in some detail here as repeated reference will be made to it throughout the course of this review.

They found that the microfilarial prevalence was higher in melanesian (22%) than in polynesian (14.9%) peoples, but that the elephantiasis rate was the reverse (1.4 to 2.6%).

Prevalence of Microfilariae and Elephantiasis in Different Islands Surveyed

Island	No. examined *	No. positive	Parasite rate	Mf density 20 cmm	No. eleph.	Eleph. rate
Guadal - canal	155	64	40.6%	72.8	5	3.2%
Malaita	481	48	10.19%	10.8	4	0.8%
Makira	244	99	40.74%	21.6	3	1.2%
Others	22	0	0%	0	0	0%
Totals	902	211	23.5%	34.6	12	1.4%

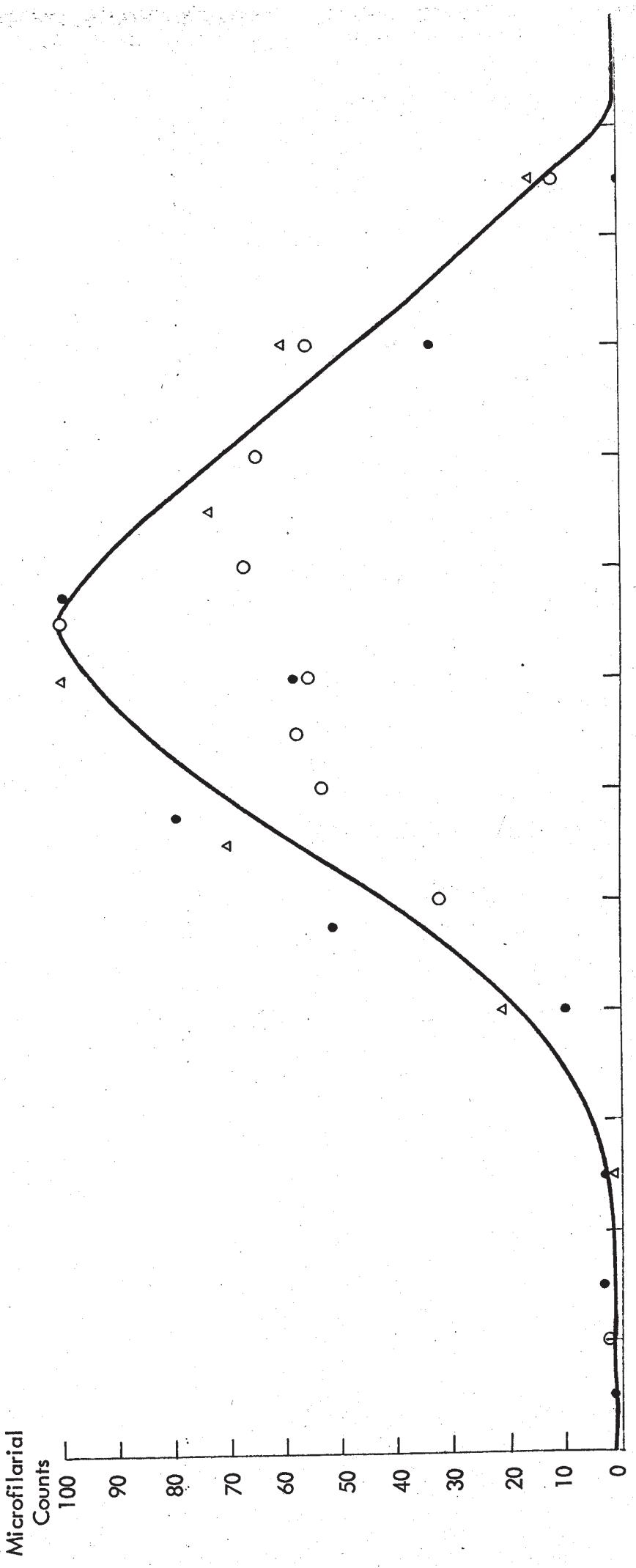
*Not representative for age and sex distribution

B. MICROFILARIAL PERIODICITY

Thorpe in 1896 discovered that in certain areas of the Pacific an aperiodic form of filariasis existed. Buxton (1928) further defined these areas, the Solomons being in the nocturnally periodic group.

Schlosser (1945) and Mataika (1965) measured the number of microfilaria on 3 and 8 men respectively, through a 24 hour period. A similar count on 3 women using 60 cmm of blood in a counting chamber was made by the author in 1974.

Fig. 2
PERIODICITY
PERCENTAGE MAXIMAL MICROFILARIAL COUNTS AGAINST TIME



Time hours	Schlosser (1945)	Mataika (1965)	Webber (1974)
1100	2.7		
1200		2.4	1
1300	5.7		
1500	3.0	2.4	
1600			0
1800	16.6	34.8	
1930	87.0		
2000			14
2100		114.8	
2130	134.0		
2200			23
2300			25
2400	98.0	163.5	24
0100			43
0130	168.0		
0200			29
0300		119.7	
0400			28
0600	57.0	98.8	24
0900	0.6	25.7	5

From this it can be said that microfilarial activity extends from 1600 hours to 0900 hours with a maximum output at approximately 0100 hours.

C. VECTORS

Byrd and St. Amant (1944) collected and dissected 1,494 mosquitoes from Guadalcanal. These consisted of 10 species, but only 4 contained infective larvae of Wuchereria bancrofti. The developmental age of the larvae was also determined as summarised in the modified table.

Distribution in Days of Age for Developing W. bancrofti Larvae from

Naturally Infected Mosquitoes

Species	Per-cent-age infected	Day												
		1	2	3	4	5	6	7	8	9	10	11	12	13
<u>Anopheles farauti</u>	51.90	168	75	74	42	43	31	14	28	9	18	6	26	1
<u>Anopheles koliensis</u>	4.84	14	1		1			1						1
<u>Mansonia uniformis</u>	23.37			1		2			2					1
<u>Culex fatigans</u>	40.00	2												

From these findings they considered A. farauti and A. koliensis to be vectors. Although Mansonia uniformis contained larvae as old as twelve days, Byrd and St. Amant did not consider this species to be a vector of any importance, but this possibility must always be borne in mind.

The ubiquitous Culex fatigans is at present comparatively rare in the Solomons and although 40% were found infected, these were all of only one day developmental age. Mataika (1965) also attempted to experimentally infect Culex fatigans on a heavily infected carrier. Out of 50 specimens, 2 developed third stage larvae 12 days after biting.

Schlosser (1949) found 15% of Anopheles punctulatus naturally infected with filarial larvae on Guadalcanal. Of these three

anophelines, A. farauti is by far the most important both in its infectivity and habits and one authority (Macgregor, 1966) has recorded the ratio of man-biting from several different areas as:

A. koliensis 1 : A. punctulatus 100 : A. farauti 800.

In fact Byrd and St. Amant remarked that "the 5 per cent infection rate reported for Anopheles farauti from Guadalcanal is the highest determined for any species during this survey (which covered many Pacific islands). In one village on the island with a microfilaria rate of 80 per cent in the native population, 87 per cent of A. farauti captured from the huts, harboured developing filarial larvae. Eight of the infected mosquitoes carried infective stage larvae within the labium." They also found an unusually large number harbouring more than a single developmental stage of the parasite.

• • • • • • • • •

Since the war years sporadic interest has been taken in filariasis. An annual medical report (1949) remarked "The general incidence of filariasis in the territory is not heavy, except in small pockets. One such, the small island of Santa Catalina, on survey, showed an incidence of 80%. Arrangements have been made to try out the effects of the drug Hetrozan in this area." There is no subsequent report on the results of this attempted control.

Some very useful data were collected by McDonnell (1970) for Eastern District, the only extensive and detailed survey of an area prior to the Malaria Eradication Campaign.

Bougainville and Buka, although geographically members of the Solomon Island group, are administered from Papua and New Guinea, so have not come under the same medical department. There are no

recorded survey data for these islands but in view of their proximity and similar conditions, especially with regard to the vectors and prevalence of malaria, it can be anticipated that the status of filariasis is identical.

All the various surveys conducted so far are summarised in Appendix I and illustrated in fig. 1.

4. REGION AND METHOD

The survey area consisted of the north-western half of Choiseul Island and Fauro and Shortland Island (see Fig. 1). The peoples of these islands are very similar and although separated by sea have always had considerable contact with each other. The part of Choiseul consisted of two complete ethnic sub-groups, making a reasonable demarcation from the rest of the island (see previous section on anthropology).

The Malaria Eradication Programme was commenced in the Shortlands group in 1960 (Annual Medical Report) but not until September 1968 in Choiseul. Surveys were conducted in the entire area between November 1970 and March 1971. Follow-up surveys in that part of Choiseul were in April-June 1974 and April 1975. Fauro island was re-surveyed in January 1975.

1970-71 Survey. In this original survey, which was to define the prevalence of the area studied, an attempt was made at total population coverage. This was virtually achieved on Fauro and the selected villages on Shortland Island. However, this was found to be more difficult on Choiseul, but the population sampled will be seen to match closely the age and sex distribution for the total island population.

All blood samples were taken between the hours 20.00-02.00. The method used was to visit the village in the daytime and explain to the headman and villagers the purpose of the survey, and then examine all cases of elephantiasis. The majority of the blood samples were taken by the author, that same night, using the Council clerk as recorder/interpreter.

Owing to the villages being situated on the coast with no connecting footpaths (all communications being by canoe), only one village (average 50 people) could be examined each night. So each village was visited in turn from the base by dinghy and outboard motor and the daytime visit had the equally important purpose of learning the passage through the reef for the night time return.

In the first survey unmeasured thick blood films were taken, spread out in a circle and air dried. These were stained rapidly with Field's stain and all examined by the author. The reasons for taking unmeasured films in the first survey were:

- 1) The difficulties in communication (sudden storms at sea) necessitated a technique which required the maximum number of slides to be taken in the shortest possible time.
- 2) Lack of available assistance and sufficient equipment.
- 3) It was originally hoped that surveys would be continued in other areas by the Malaria Eradication Campaign technicians who were used to this method, so this would have offered a reasonable comparison.

However, all slides were taken in a consistent manner, the entire film was examined and species and number of microfilaria per person determined.

1974 Survey. In the follow-up surveys it was decided to concentrate on smaller areas, allowing greater time for more accurate and sophisticated techniques. It was hoped to use the Millipore technique (Chularerk and Desowitz, 1970) in both Choiseul and Fauro, but this did not become available until 1975, so experiments were conducted with other methods.

The counting chamber introduced by Denham et al. (1971) and given successful field trials by Southgate and Desowitz (1971), Desowitz et al.

(1973) and Southgate (1973) showed this technique to be more sensitive than the conventional blood slide. However these trials were all in areas of aperiodic filariasis where daylight could be used for the microscope, so it was decided to try this out in nocturnal conditions.

Method

Home-made counting chambers were made from glass microscope slides with a chamber of 45 mm x 15 mm. 0.5 ml of water was placed in the chamber and 60 cmm of capillary blood was put in this and the motile microfilaria counted with a x 60 magnification. Blood was taken between the hours 20.00-01.00. It was soon found that a kerosene pressure lamp for preference, but even an ordinary hurricane lamp, were sufficient light sources for use with the microscope. Still, the problem 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.

Modification 1

It was found that a limited number of counting chambers, provided they were covered, could be left until the morning, before they were read; but once the sun began to get hot, these slides rapidly dried out and the motile microfilaria died.

Some of the counting chambers that were found positive during the night were counted in the normal way and then left to dry thoroughly. These were then stained the following morning using ordinary Giemsa which was filtered on to the blood film and left for the normal period of time to stain an ordinary thick blood film (in this case 15 mins). It is stressed that no dehaemoglobinising is necessary as with the ordinary

thick blood film. After the requisite time, the stain was poured off, without washing and left to dry. The slides were then examined with a $\times 60$ compound microscope and re-counted.

Results

32 slides were examined before and after staining and the results are given fully in the table. Microfilaria counts ranged from 0 to 71 per 60 cmm capillary blood. It will be seen that on some occasions more microfilaria were counted before staining and on others after, with a discrepancy of only 19 in the totals, which is not significant. These differences can be explained entirely on observer error.

There is a suggestion that the stained films give greater counts where the microfilaria numbers are small, but there are insufficient recordings here to substantiate this. There also seems to be a particular idiosyncracy on the blood of some individuals as the slides 9 to 17 were all from one individual during a periodicity study and they almost consistently gave higher counts before staining than after.

Discussion

In the studies by Southgate and Desowitz (1971), Desowitz et al. (1973) and Southgate (1973), it was found that the counting chamber gave much higher counts than the stained blood film despite the same quantity of blood being used. It was considered that microfilaria must be lost in the staining method, but it is shown here that if the blood is haemolysed before staining and not washed after, then there is no loss of microfilariae.

This further technique of staining the film adds to the usefulness of the counting chamber method in the following ways:-

Comparison of stained and unstained Counting Chambers on the Same
Blood Specimen.

Number of Microfilariae Counted

Slide No.	Before staining	After staining	Difference: After minus before
1	45	38	- 7
2	4	8	+ 4
3	1	5	+ 4
4	2	2	0
5	61	71	+ 10
6	12	14	+ 2
7	8	8	0
8	3	3	0
9	9	10	+ 1
10	21	13	- 8
11	22	21	- 1
12	22	9	- 13
13	32	28	- 4
14	24	21	- 3
15	14	9	- 5
16	16	11	- 5
17	1	0	- 1
18	1	1	0
19	0	1	+ 1
20	1	1	0
21	2	7	+ 5
22	2	4	+ 2
23	11	8	- 3
24	4	7	+ 3
25	4	4	0
26	1	2	+ 1
27	2	1	- 1
28	1	1	0
29	4	2	- 2
30	0	1	+ 1
31	3	2	- 1
32	0	1	+ 1
Total	333	314	- 19

P = 0.42

1. Extends the interval between taking the blood and counting the microfilariae, so allowing for greater ease in nocturnal work.
2. Slides can be transported, processed and examined in a central laboratory.
3. Species identification of microfilariae can be made so that the counting chamber method can now be used in areas where mixed infections occur.

In this third advantage it was soon found that the conventional glass counting chamber was too thick to allow the use of a high power objective on the edge of the film, so modification two was made.

Modification 2

It was found that a perfectly satisfactory counting chamber could be made using exposed x-ray film. This was cut to the shape of the slide, a hole 45 mm x 15 mm cut in the centre, and then glued to an ordinary glass slide with Araldite. 5 mm counting lines were then engraved in the chamber.

This counting chamber was easy to construct and proved as good as the glass one with the added advantage that it was thin enough to allow the higher power or oil immersion objective on the stained film. There was no increased risk of spillage with the lower walls as surface tension forces maintained the water within the chamber.

It was then decided to try and carry this development to its logical conclusions and use an ordinary glass slide with a chamber wall of adhesive cellophane tape only. Here a little more care had to be used to prevent spillage outside the chamber, but surface tension was quite

adequate to maintain the film.

These modified chambers using adhesive tape could only be used after the film had been dried and stained. These were then read on an ordinary compound microscope using a mechanical stage, so there was no need to engrave counting lines.

Results

9 slides were prepared from the same subject at the same time in this way, stained with Giemsa and microfilariae counted. Using the conventional counting chamber the expected count was between 9 and 21, showing that it performed perfectly satisfactorily.

Nine Counts of the Same Blood Specimen Using the Second

Modification of the Counting Chamber

Slide number	Number of microfilariae counted
1	12
2	21
3	23
4	8
5	10
6	21
7	7
8	15
9	6
Total	113
Mean	13

Counting chambers made from x-ray film were used in 1974 but before the final modification of cellophane tape masks was tried in the field, it was decided to compare again the efficiency of the counting chamber against the measured blood slide, but under nocturnal conditions. 60 cmm of blood was examined in a counting chamber and whenever a positive was found a 60 cmm and an ordinary blood slide (for comparison with the 1970 survey) were taken. These slides were stained directly with Giemsa for 15 mins without dehaemoglobinising. The slides stained in this way were perfectly clear to examine and there seems no need to dehaemoglobinise them at all.

The table shows the density counts on 20 positive blood specimens with identical quantities of blood (60 cmm) taken at the same time and examined by the two techniques.

Slide number	Microfilariae Counts		Difference Coun. Chamb. - Bl. Slide
	Counting Chamber	Measured Blood slide	
1	8	16	- 8
2	4	4	0
3	2	3	- 1
4	8	3	+ 5
5	3	3	0
6	65	77	-12
7	4	3	+ 1
8	3	1	+ 2
9	12	5	+ 7
10	5	6	- 1
11	3	2	+ 1
12	2	1	+ 1
13	3	6	- 3
14	4	9	- 5
15	9	2	+ 7
16	3	3	0
17	1	2	- 1
18	3	19	- 16
19	2	26	- 24
20	8	3	+ 5
	152	194	- 42

There was no significant difference between the two techniques, but this was rather a different result from that obtained by Southgate and Desowitz (1971), Desowitz et al. (1973) and Southgate (1973), who found that the counting chamber was more sensitive than the blood slide when exactly the same quantity of blood was measured. It would seem that the equitable results here were due to leaving out the de-haemoglobinising step in the staining. Denham et al. (1971) thought that microfilariae were lost in this way and examined the washings with a membrane filter, from which they recovered them.

Discussion

Much reliance is placed upon density counts in comparing techniques, effects of treatment etc., but little consideration is taken of the considerable variations that occur in several different parameters.

(1) Even if consecutive blood specimens of the same measured quantity are taken from the same sight at the same time, the range is considerable. When the modified counting chamber was tested, 9 specimens of 60 cmm blood were taken in this way and the range of counts was from 6 to 23.

(2) There is also the well-known fluctuations of periodicity. In any survey it is impossible to take specimens from a large number of people, all at the peak microfilarial output. In fact when the peak is 01.00 hours one must accept that almost everybody will be examined before this time if one is to obtain co-operation from the people as well as a representative sample.

During the 1974 survey, it was decided to see if the time of taking the blood samples did in fact make much difference to the number of

positives found.

People came forward to have their blood taken as and when they wanted, giving a reasonably random scatter of the population. Three time periods were taken and the number subsequently found positive in each group recorded.

Time period	No. examined	No. positive	% positive
20.00-21.59 hrs	151	32	21.1%
22.00-23.59 hrs	94	14	14.9
24.00-02.00 hrs	55	15	27.3
	300	61	20.3

From this it was concluded that the periodicity did not markedly affect the number of persons found positive.

However, other fluctuations have been recorded (Pichon, 1974, in an address to the Fourth SPC/ WHO Seminar on Filariasis and Vector Control, Apia, W. Samoa) of 7 days, 11 days and even every 8 minutes.

(3) Inaccuracies in the measurement of the blood sample are all too easy to make and microfilariae are often missed when the slide is examined.

January 1975 Survey. For this special survey of Fauro island, where extremely low (if present) microfilaria counts were expected, the Millipore membrane filtration technique (Chularerk and Desowitz, 1970; Desowitz et al., 1970) was tried out under night-time conditions.

One ml of venous blood was drawn into a syringe containing sodium

citrate solution, followed by 9 ml of a 10% Teepol in Normal saline solution. The blood was haemolysed, then forced through a Millipore filter (in a special holder) and washed through with normal saline. After the final washing, the filter was placed in hot Harris's haematoxylin for approx. 5 mins. blued briefly in water and allowed to dry. The filters were then taken back to the laboratory, cleared in immersion oil and read at x 40 magnification with a Watson compound microscope.

This is rather a cumbersome and involved technique in the best of circumstances, but when it has to be done in an overcrowded leaf hut by the light of a hurricane lamp, with all the insects falling into your solutions and a gentle breeze blowing your filter papers onto the sandy floor it can become very tiring indeed. Under nocturnal conditions this technique is only suitable for small numbers and in special circumstances where large volumes of blood are required to be examined.

Conclusions

Having tried out all these various techniques in the particular conditions that prevailed (nocturnal periodicity and scattered island communities), it was decided to use the conventional 60 cmm measured blood slides, with the modification in the staining method mentioned above, in the 1975 survey, and to recommend that this be the standard technique in all future surveys in the Solomon Islands.

PART 1* - EPIDEMIOLOGY

5. OBSERVATIONS

A. MORBIDITY

In the 1970 survey on Choiseul 15 per cent of the 1,385 people examined were found to have microfilariae in their blood, but only 11 cases of elephantiasis were seen. The youngest case was a male age 21 with elephantiasis of one leg; 5 cases had both legs affected.

In this survey only definite elephantiasis cases were recorded as this is the only definitive sign, but clearly the people were well aware of the nature of the disease as a large number of men had had orchitis or hydrocele and came forward for examination.

It is noticeable that the proportion of elephantiasis cases is surprisingly low, compared with other Pacific Islands (see Appendix III). This is borne out in other surveys conducted in the Solomons, except for Ngella where Mataika (1965) found 9 cases out of 266 people examined. This low rate of elephantiasis has tended to minimise the apparent importance of this disease, with a result that it has been rather overlooked in the past.

However, if the problem is considered more broadly, with microfilariae rates up to 80% (B.S.I.P. Medical Report, 1949), the impact of this parasite load on the population and its various effects can be shown to produce a much wider range of symptoms and resulting morbidity.

* Part I which formed part of the author's dissertation for the D.T.P.H., 1973, has been revised and included here.

The various symptoms which can be wholly or partially blamed on filariasis in the Solomons are considered to be the following.

1. Persistent, especially nocturnal, pyrexias.
2. Lymphadenitis.
3. Orchitis.
4. Hydrocele.
5. Pyomyositis.
6. Calabar type swellings especially around joints.

(Chyluria hasn't been recorded)

While it is difficult to corroborate these as due to filariasis, they match the distribution and intensity of infection and are improved by treatment with Banocide (diethylcarbamazine), although other measures may also be required.

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Filariasis having no proven mortality immediately loses the impact that a fatal disease has. But if one attempts to quantify disease effect especially in relation to the economic community, then morbidity often shows itself more important than mortality.

If a large proportion of the population are debilitated by disease, then one must anticipate a reduction in ability to work, plan, and care for the community. It then becomes harder to make any progress and the community may regress by either remaining static while associated communities advance, or actually regress so that lessened work output leads to malnutrition which only perpetuates the effect.

While the latter is not the case here, there is certainly sufficient suggestion from comparative community studies, (e.g. copra output) to

indicate that filariasis may have an overall effect. This is always considered to be due to malaria, and in this situation where the same vectors are shared, it is difficult to separate them. Malaria in this region is holo-endemic so an immunity status has built up and the community have become adapted to its attack. However, in filariasis the effect is different, there is the progressive debility of elephantiasis which only afflicts a minority, and the attack of a number of different illnesses already listed. These repeated incidents of sickness give little opportunity for adaption and would have a more considerable effect on the individual.

In a rural self-supporting community it is almost impossible to measure this effect in any terms of economic output. The other possible method is to find the proportion attending for treatment. Most complaints will be brought to outpatients where they are recorded by a wide variety of descriptions, so this will also be unreliable. However, if just that very small proportion that require hospital admission are compared, it will be seen that filariasis is similar to malaria and tuberculosis.

Retrospective Analysis of Admissions to Gizo Hospital for

the year 1 March 1970-28 February 1971

Filarisis	1.7% of total admissions
Malaria	1.6% " "
Tuberculosis	1.0% " "

The other important aspect to be considered, is the possibility of fear of developing elephantiasis, causing depopulation of particularly endemic areas. Certainly Fauro has always had a bad reputation, and

this was one of the initiating factors in this survey. It is said that the eligible men could not find any brides who would come back to Fauro with them, for fear of 'big leg', so these men have moved to other islands.

According to local tradition and earlier visitors, the population of Fauro was certainly very much bigger than it is today, but there are no reliable census figures prior to 1970. Whether this was due to filariasis or not can only be speculated, but there is no present evidence when analysing the population, to show a continuing depopulation or emigration.

B. PREVALENCE AND DISTRIBUTION

The data collected from the 1970 Choiseul survey were used to show the various epidemiological features of filariasis in this part of the Solomons. This pattern is probably similar in other parts that have not been affected by prolonged changes in the environment such as that resulting from the Malaria Eradication Programme. Where change has occurred, it is probable that the state existing before was similar.

Using the technique described 15 per cent of the population examined were found positive for microfilariae. The maximum number of microfilariae seen in any film was 86, but the arithmetic mean was only 9.4 and the MfD₅₀ 3.7. Wuchereria bancrofti was the only infecting species.

The youngest infected person was a male of $1\frac{1}{2}$ years, followed by a progressive increase, reaching a maximum in the 55-64 year age group. There were slightly less females infected, but they acquired their infection at an earlier age, although the 55-64 age group was by far the largest.

Fig. 3

PROPORTION POSITIVE FOR FILARIASIS AND ELEPHANTIASIS BY AGE GROUP
CHOISEUL

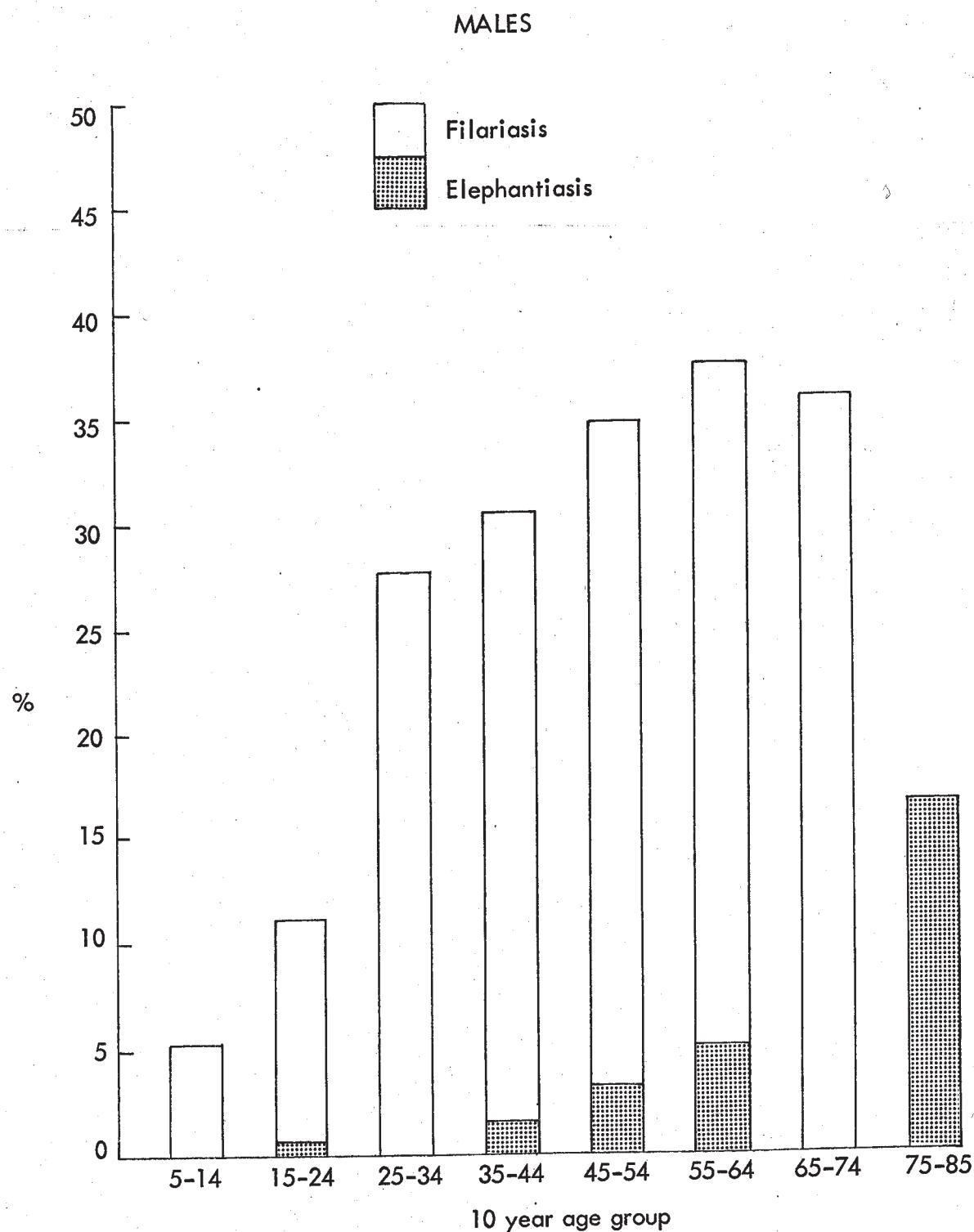
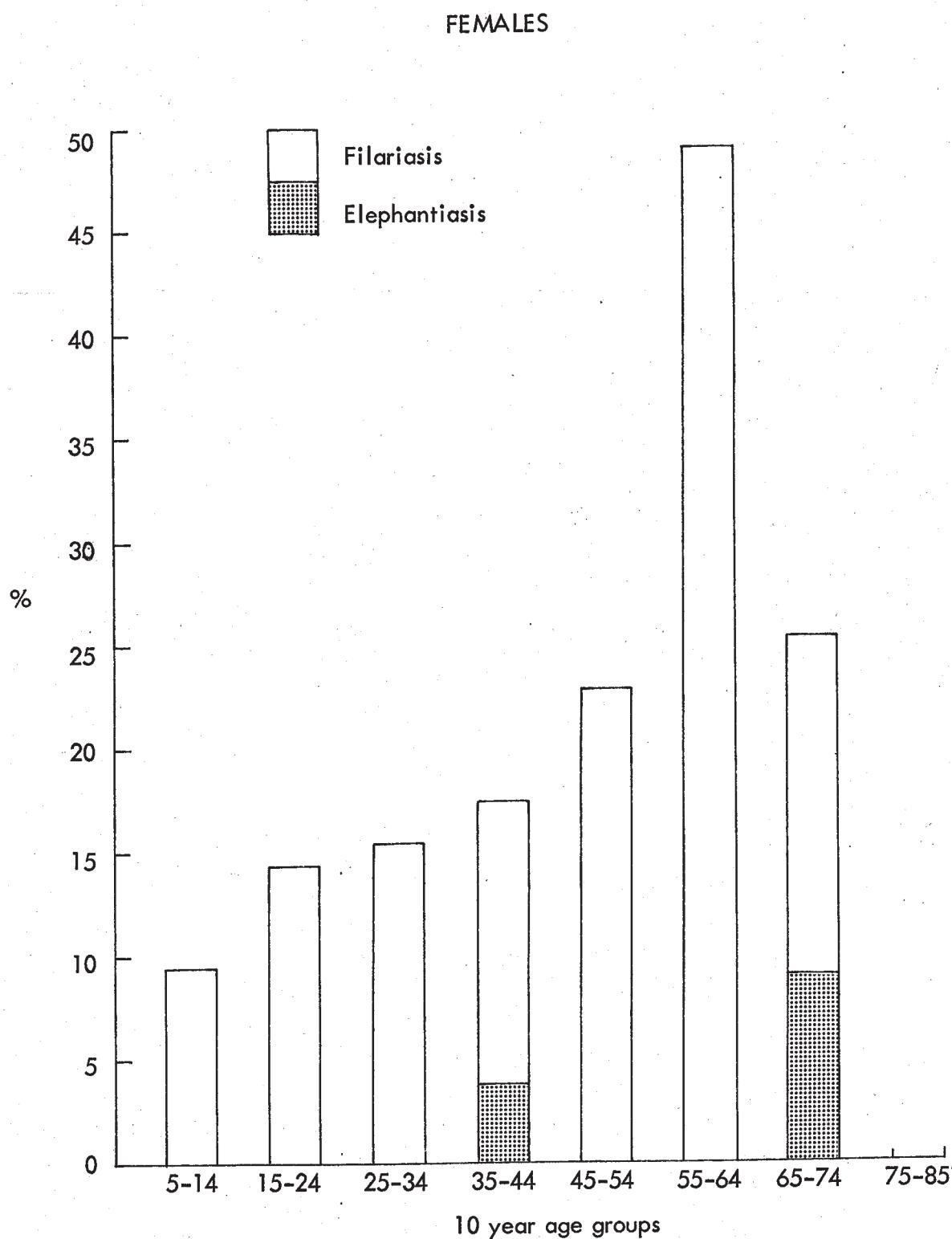


Fig. 4
PROPORTION POSITIVE FOR FILARIASIS AND ELEPHANTIASIS BY AGE GROUP
CHOISEUL



The youngest elephantiasis case was 21, after which there was a gradual increase into old age where the microfilarial rate conversely fell. Twice as many males as females developed elephantiasis.

The geographical distribution of filariasis is interesting as will be seen from fig. 5. It is a very focal disease with maximum intensity of infection in the Varise region at the two main village centres of Voza and Ogo which are on opposite sides of the island. There is a minor secondary centre at Moli.

This can be explained on previous migrations of the people (see Anthropology). The hypothesis is put forward that filariasis infected these people some time before Protectorate and was endemic when they were all living in the centre of the island. When they divided and came down to the original villages of Voza and Ogo on opposite sides of the island, they brought their infection with them. From these original centres it has spread along the coast.

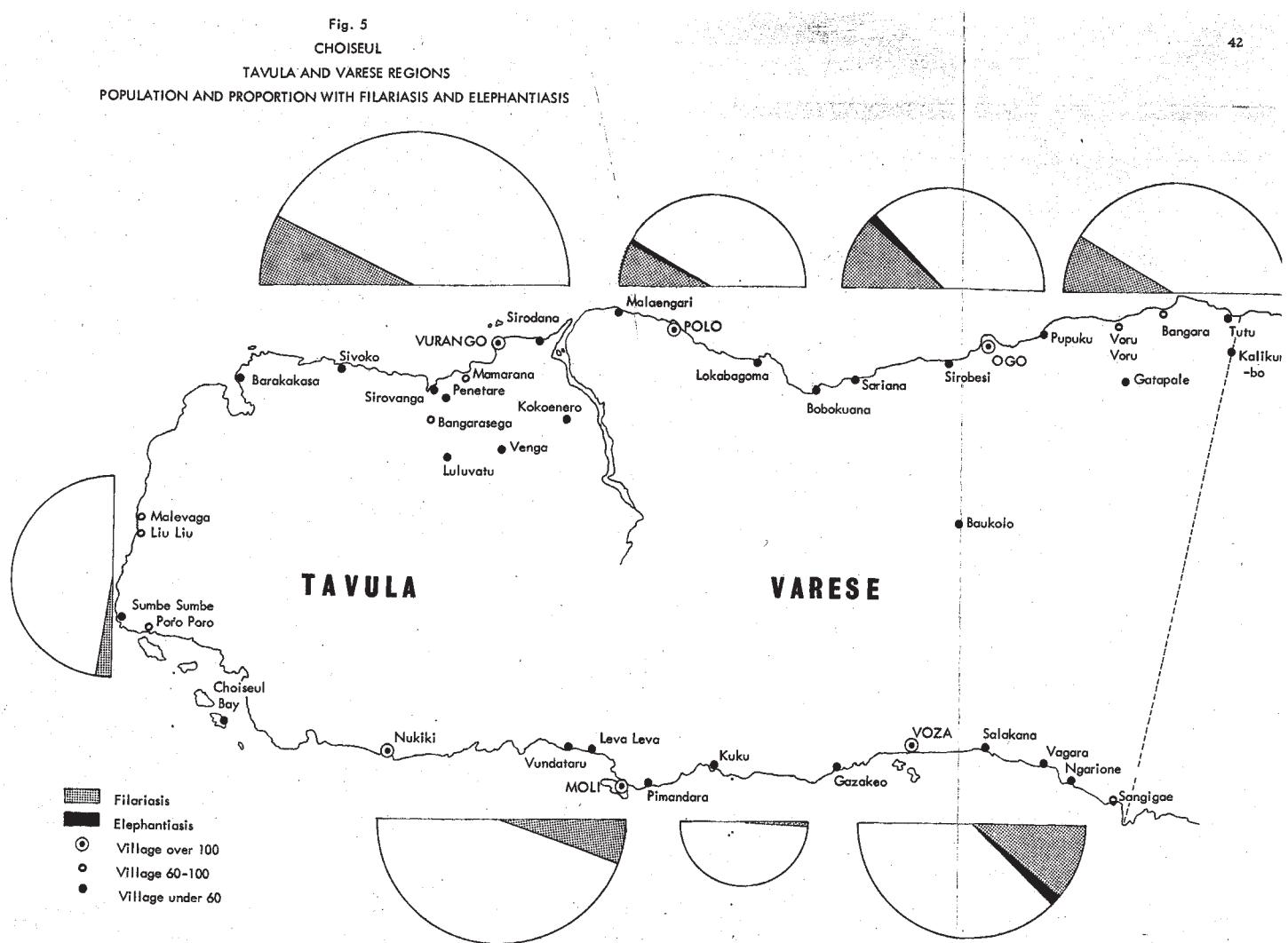
This is demonstrated even more convincingly by the distribution of the elephantiasis cases. 5 of the cases were from Voza and 5 from Ogo, the only other case coming from Polo which is close to Ogo.

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In looking at the rest of the Solomon Islands there is insufficient information to give a very detailed picture.

There is no evidence to suggest that there is any other species of human microfilaria in the Solomons. In the neighbouring islands of the New Hebrides Brugia malayi is found in migrated Tonkinese people, but this does not apply to the Solomons. However, even W. bancrofti seems to be very specific in its habitat, with probable strain variations. The

Fig. 5
CHOISEUL
TAVULA AND VARESE REGIONS
POPULATION AND PROPORTION WITH FILARIASIS AND ELEPHANTIASIS



classic example is the aperiodic form found in the Pacific east of longitude 170°, but even within these well defined areas there seems to be a considerable amount of adaption. Byrd and St. Amant (1944) tried to infect the local vector A. farauti with the Gilbertese strain, but without success. Since this date there have been resettlements of Gilbertese people in the Solomons. The author surveyed (1974) two resident communities on Gizo island and out of the 100 blood slides taken, not a single one was found to have microfilariae.

An alarming recent finding by Eyres (1972) on Bellona island was that 5.2% of these Polynesian people were positive for microfilariae during the daytime after Banocide stimulation. Black (1952) found no positives on this island either by day or night and as Anophelines have not been found in this island there is the possibility that this is the aperiodic form probably transmitted by Aedes sp. or Culex fatigans introduced by Bellona people coming into close contact with Gilbertese, Ellis Islanders and Fijians in Honiara.

Apart from this isolated finding, the prevalence of the nocturnally periodic filariasis shows considerable variation from island to island. In a small island group such as Ngella, 40 per cent of the population has microfilaremia and 3.4 per cent elephantiasis, whereas the large and most densely populated island of all, Malaita, had a prevalence of only 10 per cent with 0.8 per cent elephantiasis. The highest prevalence of elephantiasis recorded in any island is that of 3.8 per cent found in Fauro during this survey. Taking all the islands together, 16.1 per cent were positive and 0.97 per cent had elephantiasis, prior to control measures.

Byrd and St. Amant (1944) recorded a case of elephantiasis in a boy of 15 from Makira. The distribution of lesions is also very variable, and although not surveyed, many cases of elephantiasis of the breast and some of the arm were seen on Malaita by the author, as well as similar reports from other islands.

As mentioned before, the amount of elephantiasis is not as high in the Solomons as in other Pacific territories (Appendix III). However, if microfilarial densities are compared, it will be seen that there is a close association between density and elephantiasis, irrespective of island, indicating that there is no racial difference, as thought by Byrd and St. Amant (1944).

In summary, filariasis occurs where malaria is found. This includes all islands except Rennell and Bellona and has probably largely disappeared from Ontong Java and Sikaiana. This is probably also the case in the Reef Islands (McDonnell, 1970), despite their previous infection in 1933 (Fiji Med. Rep.) and has probably never become established on the distant islands of Tikopia, Anuta and Fataka.

Recent surveys (1975) have shown most of the New Georgia group free of infection, probably as a result of the Malaria Eradication Campaign. Fig. 1 gives a picture of the present distribution from available information.

C. VECTOR HABITS

The elucidation of the vectors has been covered in detail in the Review of Previous Work, but it seemed appropriate, while dealing with the epidemiology of filariasis, to include an account here of their main habits in the Solomon Islands.

Anopheles farauti

This species breeds in small quantities of still water which are illuminated by sunlight for a good portion of the day. It particularly prefers transient collections of water (including brackish) in the vicinity of human habitation and takes advantage of footprints, empty coconut husks, old tin cans, ditches and the like. It also readily breeds along river banks, in open wells and between tangled tree roots. It nearly always breeds at ground level, which is also characteristic of its flight pattern and resting habits. The life cycle from egg to adult takes only 8 days at 70 to 91° F (Alves, 1965).

A. farauti occasionally bites during the daytime if disturbed, but the majority of its blood meals are at night, with a peak of nocturnal activity between 21.00 and 24.00 hours, both indoors and outdoors (Alves, 1965). Specimens collected on Guadalcanal gave a human blood index of 0.43 (Alves, 1965).

This vector bites near ground level then rests low down either indoors between wall slating, behind stored possessions, under bedding and the floors of raised houses, and amongst cooking stones; or outside in derelict buildings, under bridges, between tree roots or piles of coconut husks. It prefers to remain reasonably close to its food source, and although having a flight range of about a mile, will not cross open water to bite on heavily populated artificial islands, or go on extensive search for its blood meal.

Pre-spray collections on Guadalcanal from indoor resting surfaces found 95 mosquitoes per man hour coming to bite and from outdoor resting places 107 mosquitoes per man hour (Macgregor, 1966). The same

author carried out insecticide susceptibility tests and showed that the LC₅₀ was 0.45 per cent DDT and the LC₁₀₀ 4 per cent DDT.

Recent work (Bryan, 1973) has demonstrated that A. farauti may in fact be more than one species.

Anopheles punctulatus

The breeding sites of A. punctulatus are temporary rainwater pools, so that this species can become extremely abundant after heavy rains. A. punctulatus is found more commonly on Guadalcanal (Taylor, 1975). The life cycle is 8 days and human blood index approximately the same as A. farauti. Its biting habits are nocturnal, starting at about 22.00 hours and reaching a peak from 01.00-04.00 hours indoors and 01.00-02.00 hours outdoors.

LC₅₀ was 0.3 per cent DDT and LC₁₀₀ 2 per cent DDT (Alves, 1965). Outdoor man biting habit was 14.2 per man hour and indoor 0.2 per man hour (Macgregor, 1966).

Anopheles koliensis

A. koliensis is more anthropophilic in its nature, breeding in temporary pools in the vicinity of permanent human settlements and preferring to rest indoors after taking a blood meal (Taylor, 1975).

It is widely distributed in the islands. Outdoor man biting habit was 0.1 per man hour and indoor 0.2 per man hour (Macgregor, 1966).

Pre-spray surveys on Choiseul found A. farauti and A. koliensis. Unfortunately, no detailed entomological collection was carried out in the Shortlands, but the presence of A. farauti was confirmed.

PART II* - CONTROL

6. THE MALARIA ERADICATION PROGRAMME

Coverage of the Shortland Island group was commenced in 1960, but not until September 1968 on Choiseul. DDT was applied as a residual spray to all buildings (including garden huts) as a 75% wettable powder or as an emulsifiable concentrate at 2 gm per square metre.

Unfortunately there is little information available on the Shortlands as they were sprayed prior to the B.S.I. Project as part of the separate campaign on Bougainville. However this area was subsequently included in the Pilot Project which covered the rest of Western District (apart from Choiseul), Guadalcanal and Savo. This pilot project was considered successful and malaria transmission had been interrupted. Entomological data after the first 2 cycles showed an almost complete disappearance of A. koliensis and A. punctulatus, and a considerable reduction in A. farauti. It was also noted that the habits of the latter vector had apparently changed, for it now fed outdoors 5 times more often than indoors and the human blood index had changed from 0.43 to 0.8 (Macgregor, 1966).

DDT susceptibility remained the same, so spraying was continued. Sporadic cases still occur in the Shortlands group and there has been considerable reduction in Choiseul. By 1972 all malarious islands in the Solomons had been brought under the Malaria Eradication Programme.

* Part II which formed part of the author's dissertation for the D.T.P.H. 1973, has been revised and included here.

7. OBSERVATIONS

In 1970 a survey of filariasis carried out after vector control had been continuously in operation in the Shortland islands for 10 years and in Choiseul for 2 years showed:

Island	No. examined	No. positive	% positive	No. elephantiasis	Percentage
Choiseul	1385	209	15	11	0.8
Shortlands	376	1	0.27	7	1.87

An examination of the figures strongly suggests that a considerable reduction in filariasis has been produced by vector control methods alone.

The above statement presupposes the following suppositions:

1. That the level of endemicity of filariasis in Shortlands was similar to that in Choiseul prior to anti-mosquito measures.
2. That the level of endemicity of filariasis in Choiseul has so far not been affected, or only slightly affected by vector control method
3. That no other control methods (e.g. mass drug administration) had been in operation.

The last supposition is the easiest to confirm because it is a statement of fact. Treatment of cases using Banocide (diethylcarbamazine) has been on symptomatic criteria, with probable re-infection on return home. In the context of the Solomon Islands, no mass drug administration has been carried out, on financial grounds.

The other points require more detailed analysis and are considered in the next section.

8. DISCUSSION

A. PRE-CONTROL ENDEMITY OF FILARIASIS IN THE SHORTLANDS

It is unfortunate that there is no reliable pre-spray survey data on this area of the Solomons. However, it is unlikely that filariasis should be any different here from other parts of the Solomons and especially from the neighbouring area of Choiseul.

The strongest evidence is given by the elephantiasis cases which are very similar for age and sex distribution in both Shortlands and Choiseul (see Appendix II(c)). Indeed the youngest case of elephantiasis found in Choiseul was a male age 21 and in Shortlands (Fauro Island) a female of 27, suggesting intense, recent infection.

In order to obtain this level of elephantiasis, the pre-control levels of filariasis will have needed to be similar. If it is assumed for the moment that levels have remained almost unchanged on Choiseul, then a direct estimate can be made of the expected amount of filariasis in the Shortlands.

The number of positive cases per elephantiasis case for Choiseul is 7 cases of elephantiasis were found in Shortlands, so
 $19 \times 7 = 133$ expected positive cases in Shortlands.

376 people were examined which gives a percentage of 35.4. This is over twice the rate for Choiseul and would have been even more if the level here had been affected by the short period of anti-mosquito meas

Another estimate can be made with reference to Appendix III. In comparing a prevalence of elephantiasis of 1.87 with other areas of the Pacific, a figure of approximately 30 per cent can be taken.

B. EFFECT OF CONTROL METHODS ON ENDEMICITY OF
FILARIASIS IN CHIOSEUL

The figures for Choiseul suffer from the same difficulty as those in the Shortlands, in sofar as there is no base line data. However, the clock cannot be put back and circumstances dictated that this survey be conducted in this particular part of the Solomons at this time, but it would seem appropriate here to re-state the recommendation 5.2 of the W.H.O. Expert Committee on Filariasis in their second report (1967).

"In areas where filariasis and malaria are transmitted by the same species of mosquito, as in much of Africa and in West Irian, vector control measures will affect the transmission of both diseases....

Before malaria control measures are started, it is important that the filariasis surveys should have been carried out so that an assessment of the results of malaria control on the transmission of filariasis can later be made."

In view of the long life history of the adult worm (various estimates put it at about 10 years), it would be anticipated that interruption of transmission would have little effect for some time. In comparing the Choiseul figures with other surveys carried out (Appendix I), the results are conflicting. While there is little evidence to show a change in the percentage positive, the microfilaria density is lower than expected. Here also, there are difficulties in comparing arithmetic means, and the MfD₅₀ as proposed by Sasa (1967), is required for more data than are available. This limitation of data prevents any further analysis of the problem here, but in a subsequent section, the vector control effects are theoretically explored. But before considering this, it will be valuable to look at other programmes that have endeavoured to control filariasis

by vector control methods.

C. VECTOR CONTROL OF FILARIASIS

No filariasis campaigns have had any persisting success with vector control methods alone, but in at least two Malaria Eradication Campaigns, concomitant reduction in filariasis was noted. One of these, that in West Irian, has sufficiently similar conditions, including the same vector, to make a close appraisal of collected data particularly relevant.

Iyengar, De Rook and Van Dijk (1959) made a survey $3\frac{1}{2}$ years after indoor residual spraying had been continuously in operation (six monthly intervals) and obtained the following results.

Microfilarial Infection in Different Age Groups

Age group	No. examined	Percentage positive
0-9 yrs	98	0
10-19	55	3.6
20-29	46	39.1
30-39	49	28.6
40-49	37	51.4
Total	285	18.6

A limited pre-spray survey had shown an infection rate of 10% in children under 15 years, so they regarded the now absent infection of children 0-9 and the low incidence in the 10-19 group as indicative that transmission had been interrupted.

They also used the mosquito infectivity rate. I quote, "It will be seen that in none of the infected specimens had the development of the filaria larvae proceeded beyond the middle phase of the second instar. The presence of filarial infection in mosquitoes of the vector species (A. farauti, A. koliensis and A. punctulatus) collected within these villages would indicate that they can become infected through feeding on the inhabitants of these villages where a gross microfilaria rate of 18.6 per cent has been noted. On the other hand, the total absence of third instar larvae and even of stages more advanced than the middle phase of the second instar in the infected mosquitoes would indicate that they do not survive long enough for the completion of the development of the filaria larvae to the infective stage."

Van Dijk (1964) conducted a follow up survey $3\frac{1}{2}$ years later, that is 7 years after the commencement of indoor spraying. He was disappointed to find that 0.9 per cent of the 0-9 and 6.3 of the 10-19 year age groups were now infected and that the total rate was 14.2 per cent. He took his results from three villages and on further analysing these, concluded that transmission had probably continued in the worst, but not in the other two.

Van Dijk (1964) had felt that the continuing transmission was due to insufficient insecticide coverage. However, it seems unlikely that these three well known villages should have received such differing attention, especially after initial success, and it is suggested that in fact there might have been a change of vector, a matter that De Rook and Van Dijk had brought up in 1959.

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Returning to the Solomon Islands, Mataika in 1965 conducted a survey on Guadalcanal, 3 years after indoor residual spraying had been in operation. Ngella had not been sprayed, so he used this for comparison.

Island	No. examined	% positive	Density Mf per 20 cmm	MfD ₅₀
Guadalcanal	502	18.8%	53.6	14
Ngella	266	40.2%	109	40

He felt that the level of endemicity on Guadalcanal had been similar to Ngella before spraying, but although a summary of previous data (Appendix I) suggests that this was not the case, there is nevertheless a significant decrease ($p < 0.001$). Using 25.1% (Appendix I) as baseline, it is suggested that residual spraying has produced a decrease of 6.3% over the first 3 years (2.1% per annum).

In the Graciosa Bay region of the Eastern Solomons a follow up survey in 1973 (Watson *et al.*) showed a considerable decrease in filariasis with a concomitant drop in malaria but unfortunately these results are not strictly comparable, in quantity of blood taken and the use of an incomplete drug administration since the baseline survey in 1970 (McDonnell).

Survey	No. examined	% positive
McDonnell(1970)	450	9.5
Watson (1973)	830	2.7

Spraying was commenced in the Gela group of islands in 1970 so the above mentioned data formed a baseline for follow up surveys. A survey by Eyres in 1974, that is 4 years after spraying, showed a considerable reduction.

	No. examined	% positive
Mataika(1965)	266	40.2
Eyres (1974)	214	21

D. THEORETICAL CONCEPTS OF VECTOR CONTROL

So far there is some evidence that vector control reduces filariasis, but, due to the long life history of the adult W. bancrofti this is very difficult to assess. Previous surveys mentioned have shown only a slight reduction after 3 years of control, yet the survey conducted in the Shortlands could find only 1 microfilaria in the only positive out of 376 persons examined 10 years after the commencement of spraying. There thus seems to be an unusual pattern of decrease, gradual at first and then falling more rapidly, having almost disappeared after some 10 years. Unfortunately, there is no information from control campaigns that can be called upon to help elucidate this regression, especially as the anti-mosquito measures might not have been entirely effective, but there have been some studies on the persistence of microfilaremia in subjects removed to vector free situations. While it is appreciated that this approach might not be entirely relevant, it is put forward here entirely as a theoretical concept.

Jachowski, Otto and Wharton (1951) followed up a group of nurses in American Samoa who had been removed from their pre-nursing endemic village situation to a vector free one in the U.S. Naval Station. In the table below their results are re-arranged so that the decrease in positivity from the level of an equivalent group of village women is recorded.

Prevalence of Microfilarial Infections among Samoan Nurses,

Compared with a Comparable Group of Women from ten Villages

Age (years)	Months at hospital	No. examined	% positive	% positive start	Log %
16-25 (village women)	0 Baseline date	189	20.6%	100%	2.0000
17-19	4	21	19	92.4	1.9657
18-20	16	11	18.2	89	1.9494
19-21	28	12	16.7	81	1.9085
20-24	52	24	4.7	22.8	1.3579

Modified from Jachowski et al. (1951)

Leeuwin (1962) examined 207 Surinamese people who had been living in Amsterdam for varying lengths of time. He recorded the number found positive in increasing periods of time following removal from the endemic situation in Surinam.

If it is assumed that people found positive in any one year were also positive in preceding years, then a cumulative number and percentage can be calculated. There is also no satisfactory baseline data, so the most recently immigrated group (0-1 in Leeuwin's original figures) is used as a baseline and the other groups expressed as a percentage of this

Microfilaraemia in Surinamese Resident for Differing Periods
in the Netherlands

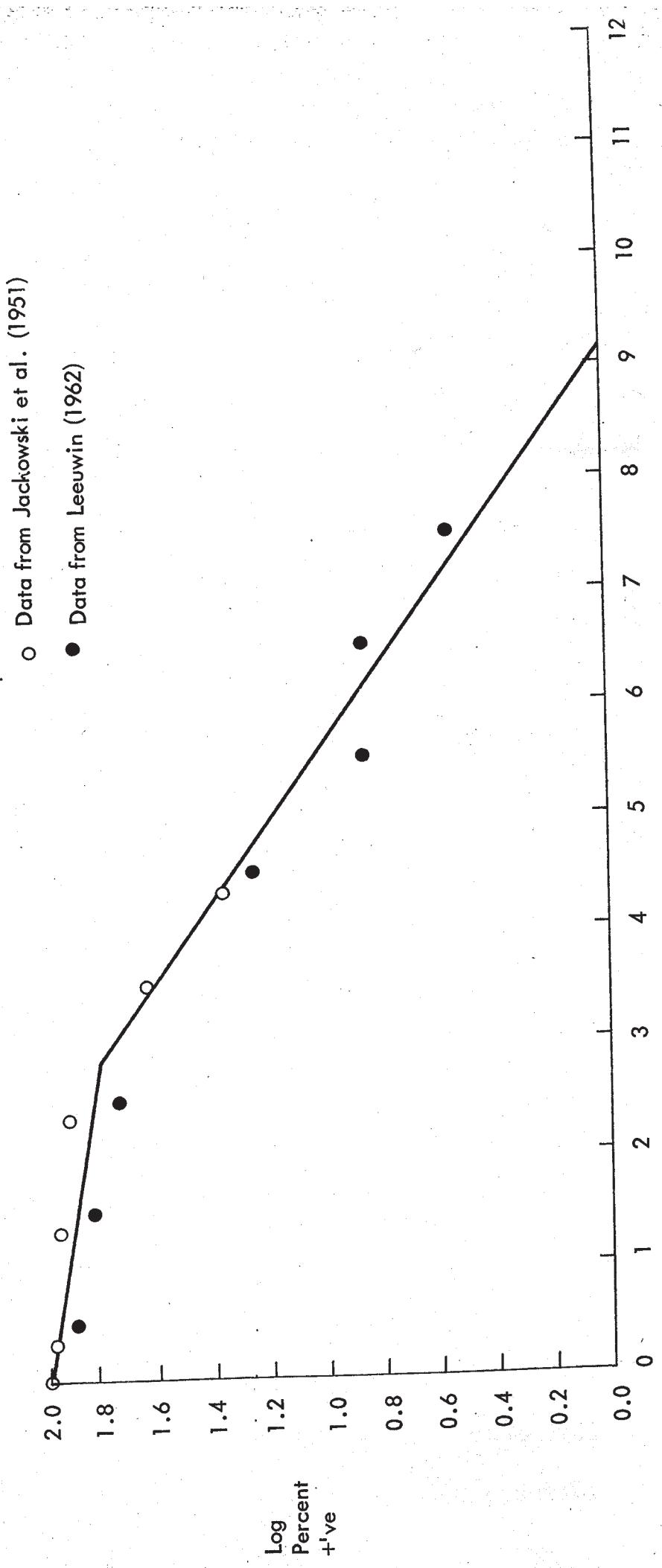
Time in Netherlands (years)	No. positive	Cumulative No. positive	% pos. of newest arrived group	Log.
0	6	28	100	2.0000
0-1	3	22	78.5	1.8949
1-2	3	19	68	1.8325
2-3	4	15	53.5	1.7284
3-4	7	12	43	1.6335
4-5	3	5	17.5	1.2504
5-6	0	2	7.2	0.8573
6-7	1	2	7.2	0.8573
7-8	1	1	3.6	0.5563
8+	0	0	0	0.0000

Modified from Leeuwin (1962)

Accepting the limitations of these two sets of data in applicability and numbers of observations, an attempt is made to trace the decline of microfilarial positivity in time. The baseline data at the time of undisturbed endemic transmission is taken as 100% and all recordings expressed as proportional to this.

Plotting the normal percentage decline against time gives a biphasic exponential curve. So in order to show this pattern more satisfactorily and allow some measurement, the Log % decline from the baseline is plotted against the time in years (Fig. 6). As will be seen, it appears that the number of positive cases becoming negative in the absence of

Fig. 6
DECREASE LOG % POSITIVE CASES SINCE YEAR OF INFECTION



re-infection occurs in two phases. In the first three years this is very gradual, after which there is a much more rapid decline reaching 1% at about 9 years. It will be noted, that had the rate of decline continued as it did in the first 3 years, it would take 28 years to reach 1%, a most improbable result. Yet, the limited data we do have from control programmes cover mainly the first 3 years, giving in most cases a rate of decline of even less than this. So, it seems reasonable to propose that the rate of becoming negative is not regular.

An attempt at explaining this unexpected pattern can be inferred from the variance of microfilarial counts as shown by Hairston and Jackowski (1968). They found that the output of microfilariae is not constant (irrespective of periodicity) throughout the life of the adult worm. It follows a wave-like pattern with microfilarial production rapidly rising to a peak where it remains for some while before declining rapidly again. This patent period ranged from 2.5-3.3 years. This fits very closely with the first part of the graph. The adult worm then probably continues to survive for about 10 years in all, but with a greatly decreased microfilarial output.

While this theoretical concept might seem plausible, it must be mentioned that the figures given by Mahoney (1970) do not fit this. He examined 178 Samoan immigrants to the United States in 2 year intervals from the time they left the islands. The number of persons remaining positive was almost constant for about 7 years and then rapidly descended to zero.

It has always been felt, in attempting to construct this model, that utilizing data that only gave the number of persons or proportion positive

had its limitations. For instance, it can be argued that perhaps Mahoney's cases showed considerable decrease in the number of microfilariae, although they still remained positive. Clearly, the ideal would be to construct a model, as has been attempted here, but using microfilarial densities, preferably making comparison of the MfD₅₀ recordings in the method proposed by Sasa (1967).

• • • • •

Having considered the probable rate of decline of natural infection in the ideal situation of complete absence of the vector, it would now seem reasonable to attempt to estimate by what amount the mosquito vector must be reduced by, in order to interrupt transmission.

Hairston and DeMeillon (1968) made the astonishing calculation that some 15,500 bites by mosquitoes carrying stage III larvae is necessary to produce microfilaraemia. But set against this is the considerable length of time an infected individual is producing microfilariae that can be taken up by mosquitoes. While it is extremely difficult to measure this period, it is in the region of 10 years (or 3,652.5 days) which is used in this calculation.

Following on from these basic assumptions, it is considered that the various factors acting on the vector as calculated by Macdonald (1952) for malaria will be very similar for filariasis.

Using the Critical Density which is defined as "The greatest density of mosquitoes, in relation to the numbers 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."

$$m = \frac{-r \log_e p}{a^2 b p^n}$$

but modified for filariasis such that

m The anopheline density in relation to man.

r The proportion of affected people who revert to negative in one day, is considered to represent the patent period of microfilaraemia.

$$\left(\frac{1}{3,652.5} \text{ days} \right)$$

p The probability of the mosquito surviving through one day.

a The average number of men bitten by one mosquito in one day.

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

n The time taken for completion of the extrinsic cycle of the Plasmodium becomes the number of days to produce stage III larvae (which is taken as 12 days).

The modified formula thus becomes

$$m = \frac{-2.74 \times 10^{-4} \log_e p}{a^2 \times 6.45 \times 10^{-5} p^n} \quad \text{or cancelling out}$$

$$m = \frac{-2.74 \log_e p}{a^2 0.645 p^n}$$

Using this formula for data on A. farauti in Guadalcanal

a = Human blood index 0.8 (Macgregor, 1966) x Gonotrophic cycle 0.5 = 1

p = 0.88 (Peters and Standfast, 1960. From New Guinea).

$$m = \frac{-2.74 \times 0.14}{0.4^2 \times 0.645 \times 0.88^{12}}$$

$$= 17.23$$

Comparing this with the unmodified formula for malaria

$$\text{where } m = -r \log_e p$$

$$\frac{a^2 b^n}{a^2 b p}$$

and using the same data for A. farauti in Guadalcanal

and with n the extrinsic cycle of P. falciparum of 12 days.

$$m = \frac{-0.005 \times 0.14}{0.4^2 \times 0.0125 \times 0.88^{12}}$$

$$= 1.62$$

From this theoretical calculation a considerably less efficient level of vector reduction is required to interrupt Anopheline transmission of filariasis than malaria.

PART III - FOLLOW-UP

9. INTRODUCTION

In Part II, there is a good deal of evidence to suggest that residual spraying alone can reduce the level of filariasis, but there are a number of parameters which were not substantiated.

- a) The continuing effect, the level and whether it is sustained.
- b) Correction of the 1970 survey results so that all subsequent surveys could be more accurately correlated.
- c) Attempt to calculate retrospective baseline data for the area surveyed prior to anti-mosquito control methods having been commenced.
- d) Find out the natural decline of infection under vector control and test the theoretical model constructed in Part II.
- e) Test the ultimate effect on filariasis in an area that had received prolonged spraying.
- f) Attempt to obtain additional information on the terminal end of the life cycle of W. bancrofti.
- g) Pursue the relationship of filariasis with malaria under shared-vector control conditions.

10. AREA

It will be seen from the survey of Choiseul in Part I, that two areas on opposite sides of the island had the highest levels of both microfilaraemia and elephantiasis. These are the Voza and Ogo areas respectively. It was therefore decided to concentrate on these two areas in detail. The method and the reasons for using these particular techniques have been fully described under section 4. In the follow-up surveys no reference was made to the previous surveys, until all blood samples had been taken and read.

In the Shortlands survey, the island of Fauro although not having a large population is so ideally contained and with a static population that it was chosen alone for the Millipore technique also described under section 4.

In all these areas, close on total population coverage was obtained, except that children under 5 years were excluded.

The follow-up Choiseul surveys were April-June 1974 and April 1975 and in Shortlands, January 1975.

11. RESULTS

A. CHOISEUL

1974

6 years after spraying operations had continued in operation, the first follow-up survey was done. The counting chamber measuring 60 cmm capillary blood and an ordinary unmeasured blood slide were taken at the same time. The two parts of the survey area are recorded separately.

Voza Area

	Counting Chamber			Unmeasured blood slide	
	No. exam.	No. pos.	% positive	No. pos.	% positive
Male	84	12	14.3	4	4.8
Female	88	13	14.8	7	8.0
Total	172	25	14.5	11	6.4

Ogo Area

	Counting Chamber			Unmeasured blood slide	
	No. exam.	No. pos.	% positive	No. pos.	% positive
Male	60	20	33.2	11	18.4
Female	68	17	25.0	10	14.7
Total	128	37	29.0	21	16.5

This is an unexpected difference between the two areas until one examines the densities.

Densities

Area	No. positive	% positive	No. microfilaria	Mean density	MfD 50
Voza	25	14.5	513	20.5	
Ogo	37	29.0	293	7.9	
Total	62	21.75	806	13.0	5.4

Incidence rates could also be calculated from those people examined in both surveys.

Incidence 1970-1974

Area	No. exam. both surveys	No. positive 1970	No. positive 1974	Difference	% Difference
Voza	81	15	7	8	9.9%
Ogo	79	17	14	3	3.8%
Total	160	32	21	11	6.9%

1975

The second follow-up survey exactly one year later showed a further reduction.

Voza Area

	No. examined	No. positive	% positive
Male	130	7	5.4%
Female	132	11	8.3%
Total	262	18	6.9%

Ogo Area

	No. examined	No. positive	% positive
Male	43	7	16.3%
Female	46	7	15.2%
Total	89	14	15.7%

Density

Area	No. examined	No. positive	% positive	No. microfilariae	Mean density	MFD ₅₀
Voza	262	18	6.9%	87	4.8	
Ogo	89	14	15.7%	114	8.1	
Total	351	32	9.2%	201	6.3	3.0

Incidence

a) Positives

Area	No. exam 74 re-exam 75	No. pos. 74	% pos. 74	No. pos. 75	% pos. 75	Difference
Voza	101	17	16.8	9	8.9	7.9%
Ogo	57	22	38.6	13	22.8	15.8%
Total	158	39	24.7	22	13.9	10.8%

b) Density

Area	No. exam 74 re-exam 75	No. pos. 74	No. Mf. 74	Mean density 74	No. pos. 75	No. Mf. 75	Mean density 75	Difference
Voza	101	17	424	24.9	9	63	7	17.9
Ogo	57	22	320	14.5	13	111	8.5	6.0
Total	158	39	744	19.1	22	174	7.9	11.2

Age DistributionProportion Positive for Each Age Group Expressed as aPercentage of the Total

Age group	Percentage positive		
	1970	1974	1975
5-14	4.0	1.8	1.8
15-24	7.0	14.4	19.4
25-34	11.8	12.5	13.1
35-44	13.0	16.3	26.0
45-54	15.7	15.7	5.0
55-64	23.7	22.9	8.4
65-74	16.8	0	26.3
75-85	7.8	16.3	0.0

Incidence Age Distribution

Age group	No. pos. 1974		No. Mf. 1974		No. pos. 1975		No. Mf. 1975	
	No.	%	No.	Mean density	No.	%	No.	Mean density
5-14	3	7.7	31	10.3	2	9.1	5	2.5
15-24	13	33.3	299	23	7	31.8	64	9.1
25-34	8	20.5	171	21.4	5	22.7	49	9.8
35-44	6	15.4	113	18.8	6	27.3	33	5.5
45-54	4	10.3	32	8	0	-	-	-
55-64	2	5.1	7	3.5	0	-	-	-
65-74	3	7.7	91	30.3	2	9.1	23	11.5
Total	39		744		22		174	

B. FAURO

In January 1975, after 15 years of continuous DDT spraying the Millipore technique (using 1 ml of venous blood) was used to examine the entire population.

Age group	Males	Females
5-14	18	20
15-24	7	18
25-34	6	6
35-44	7	6
45-54	6	5
55-64	2	5
65-74	5	1
75-85	0	0
	51	61
	112	

ALL NEGATIVE

The one patient found to be positive in 1970 was also re-examined by this more refined technique and now found to be negative.

12. DISCUSSION

A. RESULTS OF CONTINUED CONTROL

1) Prevalence

The three surveys show a continuing decrease in the prevalence of filariasis, but taking the two halves of the survey area we come across some surprising results. In 1970 the number of positives found in the Voza area was slightly less than that in Ogo (21.0 to 23.0), as were the densities of the unmeasured films (6.4 to 9.9). In 1974, the number positive (with the comparative unmeasured blood slide) had dropped in Voza to 6.4%, but only to 16.5% in Ogo. However when one comes to the densities, these had reversed in 1974. In the reduction of filariasis by vector control means, the important factor appears to be the total microfilarial (parasite) load on the community rather than the proportion of persons positive or the density alone.

The proportion positive depends upon the number of persons examined, whereas the density is related to two factors, the number of these persons found positive and the total number of microfilariae counted. If the number of microfilariae counted are equated in the same way, expressing them as a proportion of the number of persons examined rather than number positive we are able to compare different surveys' community parasite load. In 1974

Voza 513 microfilariae = 2.98 microfilaria per person in that comm
172 persons exam.

Ogo	<u>293</u>	<u>"</u>	<u>= 2.29</u>	<u>"</u>	<u>"</u>	<u>"</u>	<u>"</u>
	<u>128</u>						

Now comparing this with 1975 results

Voza 87 microfilariae = 0.33 microfilaria per person in that community
262 persons exam.

Ogo 114 " = 1.28 " " " " "

89

This still shows a smaller decrease in the Voza area than the Ogo, and without back-up entomological surveys, it is difficult to explain this. However, the trend is still rapidly downwards in both areas and there is no evidence to suggest continuing transmission of any significance.

Fig. 7 shows the effect of control on the cumulative percentage distribution of microfilarial density.

2) Incidence

The incidence results were very similar to the prevalence, supporting the conclusions that have been based on prevalence data alone. In the four years 1970-74 there had only been a decrease of 6.9%, whereas in the one year period 1974-75 this was now almost 11%.

Comparing the incidence studies in the 1974-75 period using the same method as above (difference in the microfilarial load in the community) we obtain the following results.

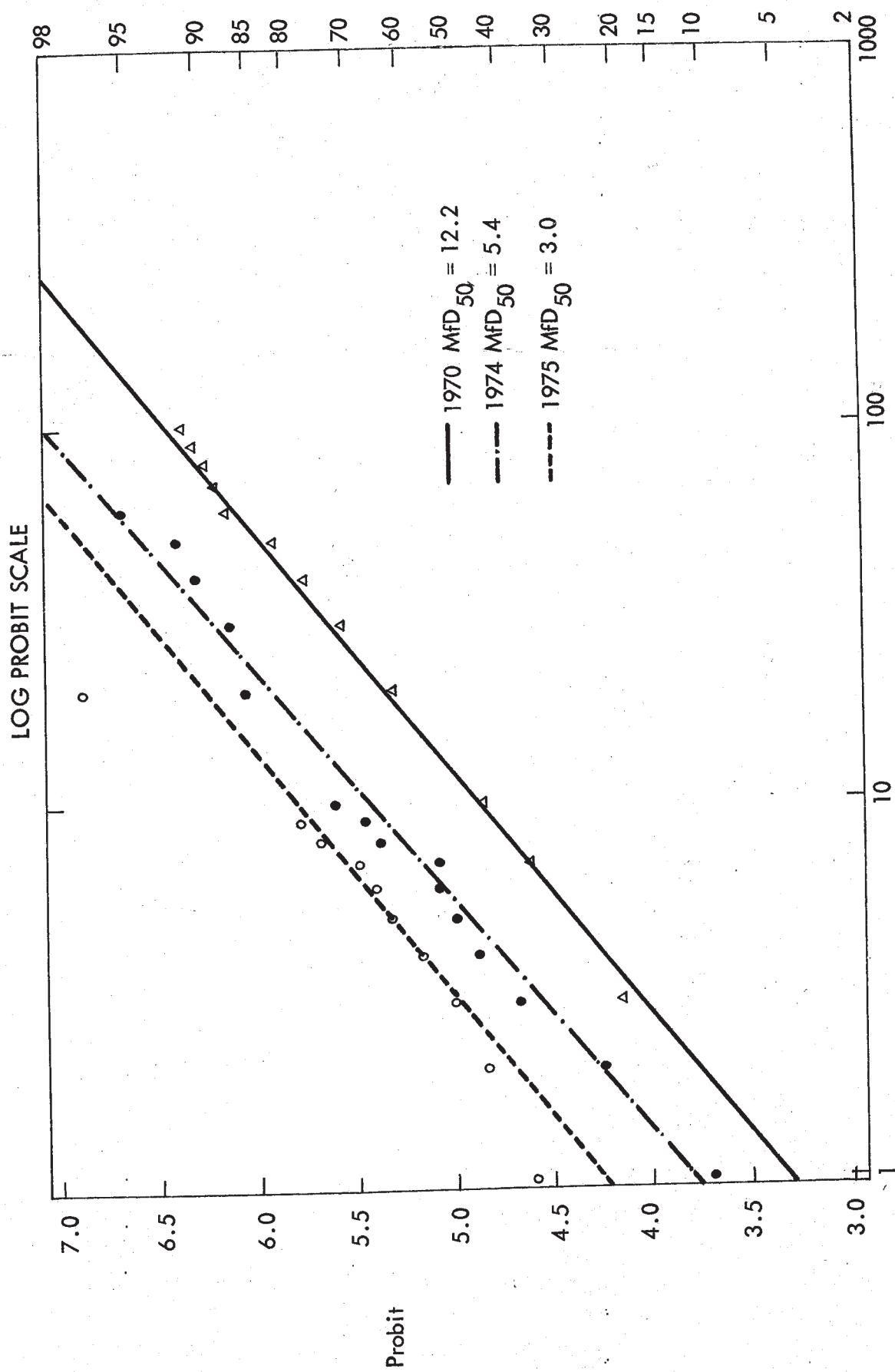
Area	No. exam 74 re-exam 75	No. Mf 74	Community den. 74	No. Mf 75	Community Den. 75	Difference
Voza	101	424	4.2	63	0.6	3.6
Ogo	57	320	5.6	111	1.9	3.7
	158	744	4.7	174	1.1	3.6

It would seem therefore that the actual rate of decrease of microfilariae from both communities (Voza and Ogo) is virtually the same, but as we

Fig. 7

CHOISEUL

CUMULATIVE PERCENTAGE OF MICROFILARIA POSITIVE CASES AGAINST THE MICROFILARIAL DENSITY



approach nearer and nearer the terminal end of the infection small numbers of positives and lower numbers of microfilariae tend to magnify the inaccuracies of technique.

3) Age Groups

The distribution of persons positive by age group in the endemic situation is illustrated in the fig. 8 for 1970. The 55-65 year age group was the peak with a decline either side of this.

By 1974, the same age group (55-65) was still predominant, but other groups now showed an equitable level (except for the 5-15 which was less). Finally in 1975 the mainly infected group was now between 15-45. This would suggest that the older infections are dying off and that the last cohort of most recent heavy infections, before vector control methods were introduced, are predominant, as adult worms continue to produce microfilariae for a considerable length of time. The second peak in the 1975 results are the 55-65 year cohort which have now moved on to the next age group.

At the lower end of the scale there is a steady decrease from 1970 in the 5-15 year age group. In 1974 the youngest positive found was 9 years old, (6 years after spraying had started). He was negative in 1970, but it is quite likely that the expected low density infection he would have had when he was only 4 was not picked up by the technique used. The next youngest, a 13 year old girl was found to also be positive in 1970. By 1975, the same boy, who was randomly examined, was again found to be positive, now 10 years old, he was the youngest in that survey.

Fig. 9 uses incidence data and expresses this trend even more.

Fig.8

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PROPORTION POSITIVE FOR EACH AGE GROUP EXPRESSED AS A
PERCENTAGE OF THE TOTAL FOR EACH YEAR SURVEYED

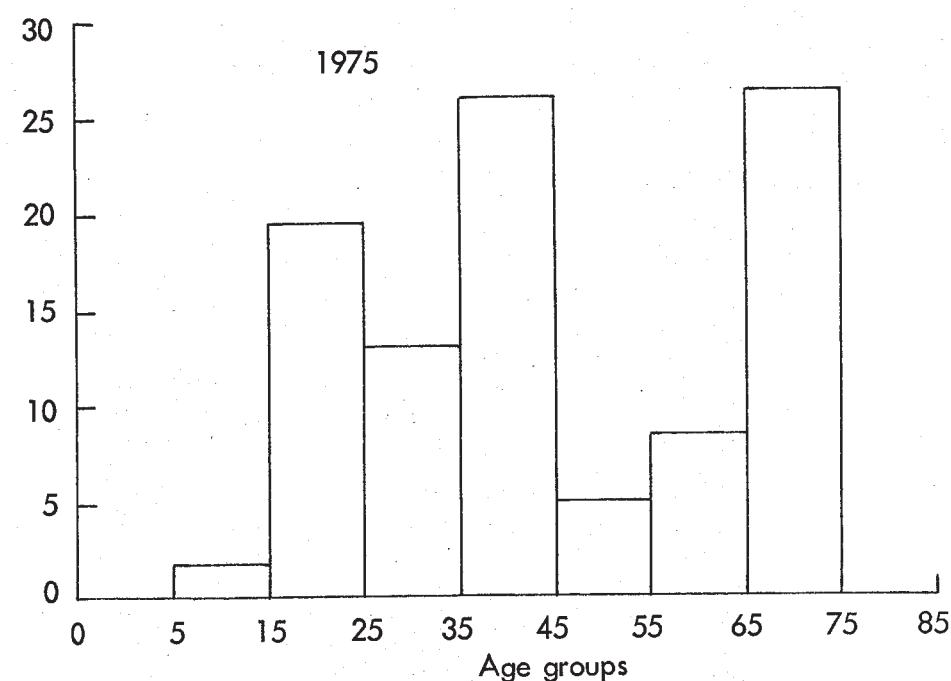
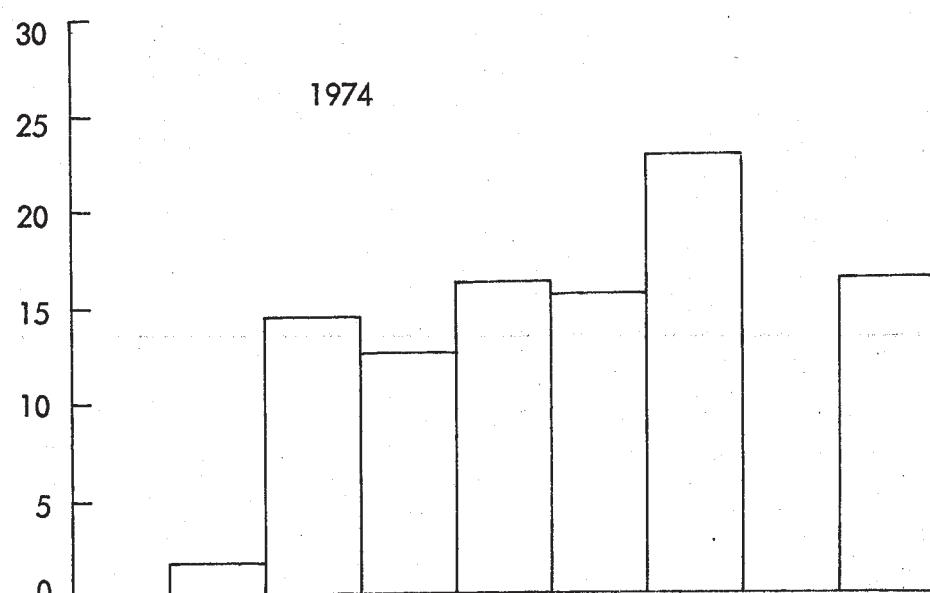
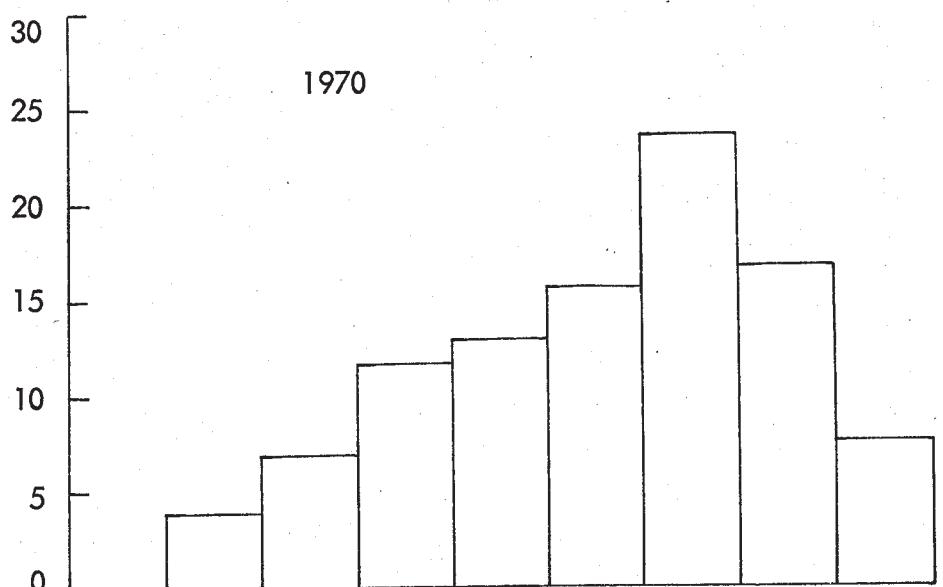
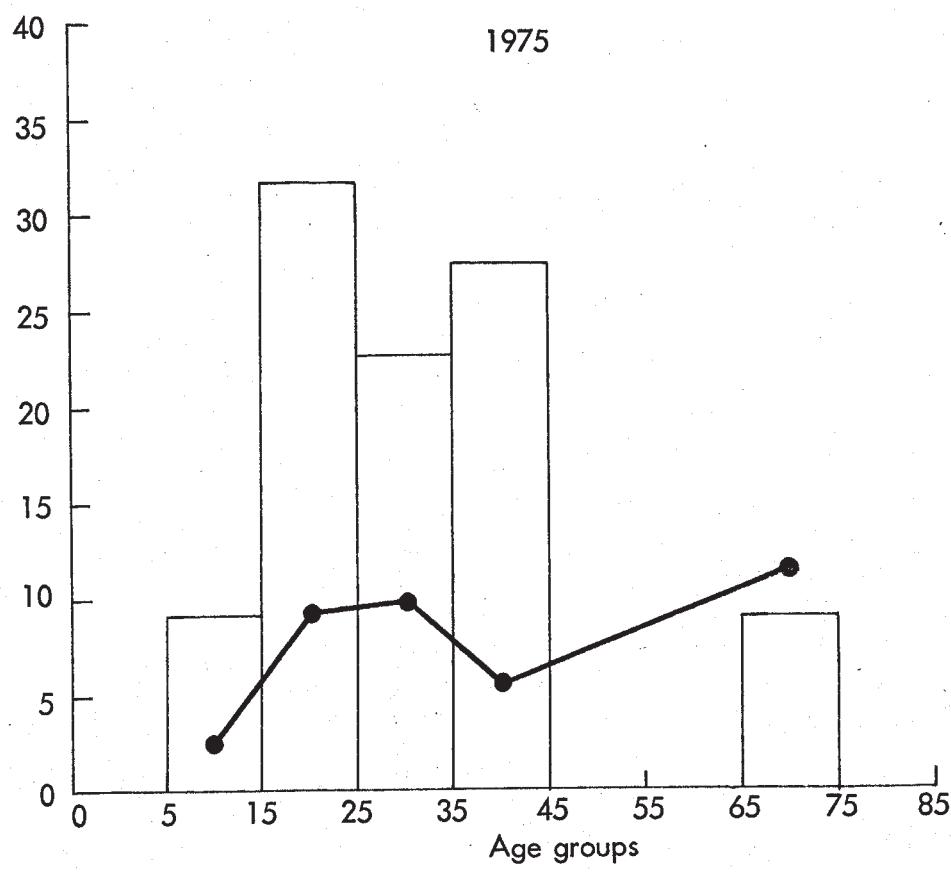
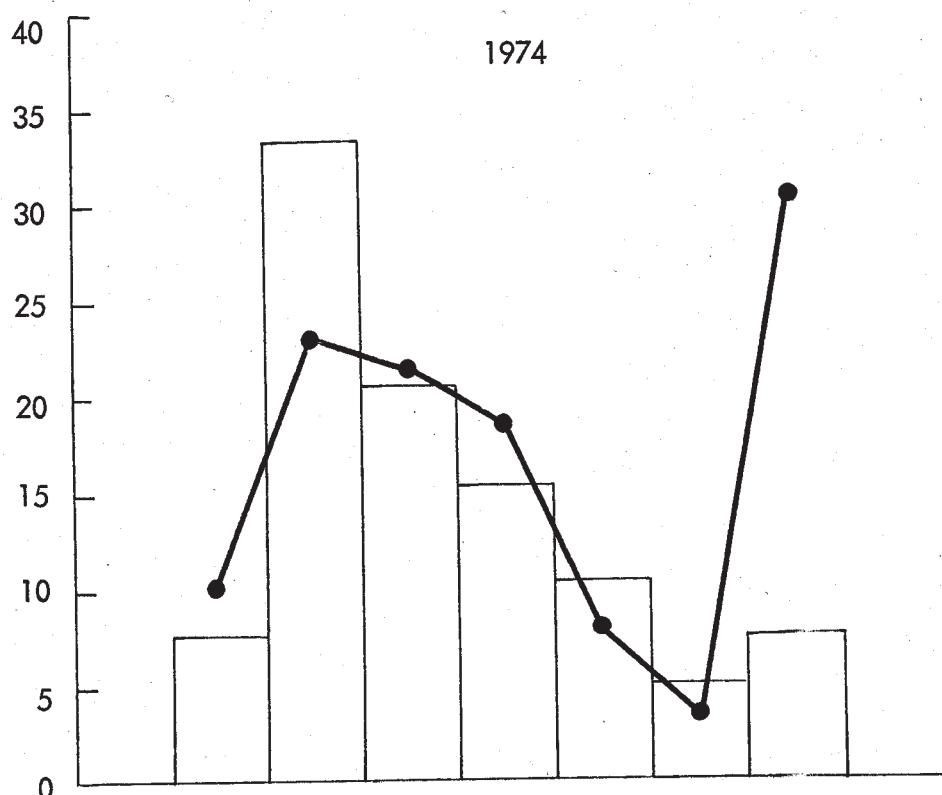


Fig. 9

74

THE AGE DISTRIBUTION OF POSITIVE PERSONS EXAMINED IN BOTH SURVEYS EXPRESSED AS PROPORTIONS AND MICROFILARIAL DENSITIES FOR EACH GROUP. (HISTOGRAM:PROPORTION OF POSITIVES IN EACH AGE GROUP; GRAPH:MICROFILARIAL DENISTIES)



dramatically. The graph of the densities explains why the peak in the older age group has persisted due to the high density of infection.

B. CORRECTION OF THE 1970 RESULTS

In order to bring more conformity and accuracy to the various surveys a double check was made in 1974. Modified counting chambers measuring 60 cmm of blood were used as the basic measurement tool, but a comparison was made of ordinary unmeasured thick films (as used in the 1970 survey) and standard 3 x 20 cmm thick films on a glass slide. As mentioned previously (section 4) there was found to be no appreciable difference between the counting chamber and the measured blood slide, using the same amount of blood, so it was decided to use the measured blood slide, (3 x 20 cmm) in all future surveys and as a standard technique in the Solomon Islands.

With the unmeasured blood slides, the difference in number found positive on the same people at the same time from those found by the Counting Chamber were as follows:

No. examined	No. positive by counting chamber	No. positive by blood slide	Ratio
300	62	32	2:1

However the number found positive is not proportional to the quantity of blood examined, although this does have a marked bearing on the number of microfilariae found.

No. both counting chamber and blood slide positive	No. microfilariae found by counting chamber	No. microfilariae found by blood slide	Ratio Counting chamber : blood slide
32	592	168	3.5:1

This means that the quantity of blood in the unmeasured blood slide can be estimated to be on the average $\frac{60}{3.5} = 17$ cmm or very nearly 20 cmm.

In attempting to correct the unmeasured blood slides taken in 1970, it is reasonable to assume that there was a similar ratio of microfilariae to a 60 cmm specimen taken at that time. The manner of taking the unmeasured blood slide in 1970 was identical to that in 1974. The number of microfilariae can be estimated, equivalent to a 60 cmm specimen as follows:

1970

Area	No. microfilariae unmeasured blood slide	No. Mf equivalent to 60 cmm ($\times 3.5$)	Corrected mean density
Voza	269	941	22.4
Ogo	338	1183	34.8
Both	607	2124	27.9

Densities can also be expressed by taking the median microfilarial count (MfD_{50}) of the log-probit frequency distribution (Sasa, 1967). The individual microfilarial counts in 1970 were re-tabulated, each multiplied by 3.5 and again plotted on log-probit paper.

The corrected MfD_{50} value (equivalent to a 60 cmm measured blood sample) for 1970 was 12.2.

Community parasite load (as introduced in section 12A) can also be calculated for 1970 using the converted results above.

Voza 941 microfilariae = 4.73
199 persons examined

Ogo 1,183 microfilariae = 5.37
220 persons examined

Both 2,124 microfilariae = 5.07
419 persons examined

In attempting to convert the number of persons positive in 1970 a different method has to be used. Sasa (1967) produced a correction factor for different quantities of blood using his technique of taking three measured blood films (of 10 cmm) on one slide and counting the number positive out of the three for each slide. He designated these N_1 where 1 out of the 3 were positive, N_2 for 2 out of the 3 and N_3 where all three were positive. His correction factors were then:

$$\text{For } 30 \text{ mm}^3: \frac{N_1 + N_2 + N_3}{(N_1 + N_2 + N_3)}$$

$$\text{For } 20 \text{ mm}^3: \frac{2/3 N_1 + N_2 + N_3}{(N_1 + N_2 + N_3)}$$

$$\text{For } 10 \text{ mm}^3: \frac{1/3 N_1 + 2/3 N_2 + N_3}{(N_1 + N_2 + N_3)}$$

In the above surveys, three different slides were not read, but instead an unmeasured film and a measured 60 cmm film. It has also been estimated above that the amount of blood in the unmeasured film is approximately 17 cmm or about 1/3 of the 60 cmm film (2/7 precisely).

It is assumed that the unmeasured film is equivalent to Sasa's N_3 , that if three unmeasured films were made on the same slide they would all be positive, so no matter which one is read, it would be recorded as positive. We are not able to differentiate N_1 and N_2 , but it is found, using the example given by Sasa that the modified formula for the 10 mm³

$$\frac{1/3 N_1 + 2/3 N_2 + N_3}{(N_1 + N_2 + N_3)} \text{ is equivalent to } \frac{\frac{1}{2} (N_1 + N_2) + N_3}{(N_1 + N_2 + N_3)}$$

$$\text{or more accurately } \frac{2/7 (N_1 + N_2) + N_3}{(N_1 + N_2 + N_3)}$$

still gives a very similar result especially when the density is reasonably high.

So if N_3 is equivalent to the value of the unmeasured film and $(N_1 + N_2 + N_3)$ is equivalent to the value of the 60 cmm film then $(N_1 + N_2)$ is the value of the 60 cmm film minus the unmeasured film or the formula becomes.

$$\text{Correction factor} = \frac{\text{No. pos. unmeasured film} + 2/7 (\text{No. pos. 60 cm films} - \text{No. pos. unmeasured film})}{\text{No. positive 60 cmm film}}$$

If we now apply this to the 1974 results:

Voza 25 slides were positive by 60 cmm film and 11 positive by unmeasured films.

$$\text{Correction factor} = \frac{11 + 2/7 (25 - 11)}{25} = 0.6$$

and for Ogo with 37 positives by 60 cmm film and 21 positive by unmeasured film

$$\text{Correction factor} = \frac{21 + 2/7 (37 - 21)}{37} = 0.69$$

or for both areas together the correction factor is 0.65.

If these correction factors are applied to the 1974 60 cmm results, the corrected results are slightly higher than those actually found by the unmeasured film. It has already been mentioned that this modified formula loses sensitivity as the density decreases, but in 1970 where the density was much higher, it is likely to be more applicable.

In 1970 21.0% were positive in the Voza region (using the unmeasured

blood slide and 23.0% in the Ogo area. Applying the correction factors calculated above

$$\frac{21.0}{0.6} = 35\% \text{ positive for Voza}$$

$$\frac{23.0}{0.69} = 33.3\% \text{ positive for Ogo}$$

or 34.2% positive for the whole area.

Sasa in 1974 re-examined the problem of detecting microfilariae in various volumes of blood samples and using his method for estimating the efficiency of detection of microfilariae from the frequency distribution of microfilariae counts we obtain a different value of 17.05% positive ($\equiv 60$ cmm). However, the former method would appear to give a more realistic answer.

m(Mf count)	N (frequency)	Ne^{-m}	Ne^{-2m}
1	41	15.45	5.54
2	31	4.19	0.57
3	19	0.95	0.03
4	22	0.40	0.01
5	14	0.09	0.00
6	7	0.02	
7	4	0.00	
8	7		
9	3		
10	6		
11+	55		
Total	209	21.1	6.15
Mf rate	15	16.6	17.05
Ratio	1.00	1.11	1.14

C. CALCULATION OF RETROSPECTIVE BASELINE DATA

As explained in the introductory sections, there was no baseline data for Choiseul and in particular the area surveyed.

Having now equated the survey in 1970 to those more accurately performed in 1974 and 1975, an attempt is made to trace these results back to the baseline state in 1968 when no vector control measures had commenced. The desired results are for the density and the proportion positive and these will be dealt with separately.

Density

(1) It is a reasonable assumption that the decline of microfilariae is directly proportional to time. If the three results are plotted on a graph of density against time (fig. 10), a reasonable straight line graph is produced with a baseline figure of 37.5.

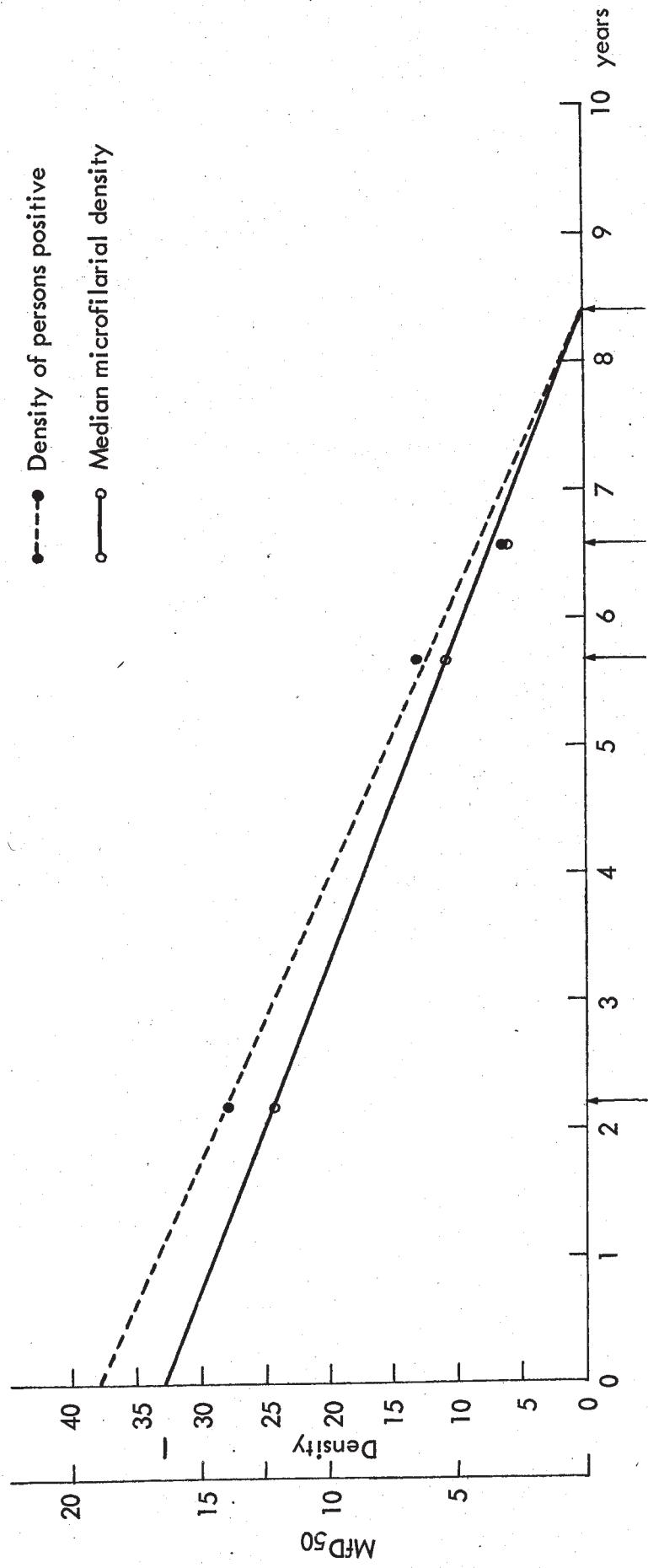
(2) When the microfilarial counts are converted to the mean microfilarial count (MfD_{50}) and these similarly plotted against time (fig. 10) there is an even closer association, the baseline result being 16.4.

Proportion Positive

As mentioned before, there is no strict relationship between the decrease in persons positive against time (in the absence of the vector). In an earlier section (8D) an experimental model was made to try and explain this decrease, so the three results are fitted to this graph (fig. 6).

From the graph we find that when the first survey was conducted in November 1970, the result should be 67.61% ($\log 1.83$) of the base figure. We have found that in 1970 29.2% of persons surveyed were positive, which gives a baseline figure of 43.2%. If using the base and the other two results expressed as a percentage of this and re-plotted, the results

Fig. 10
DENSITY OF MICROFILARIAE AGAINST TIME



are too far out to show any relationship. Many attempts were made, generating different base figures and reviewing the entire structure of the model, but no satisfactory figure could be discovered of the proportion of persons positive before vector control had commenced.

D. NATURAL DECLINE OF INFECTION UNDER VECTOR CONTROL

If a pattern of decrease of microfilaraemia can be worked out, while vector control is continuing, then progress can be checked at any time without having to wait the long periods (5 years) as was required here. There are two parameters that can be used. (1) The proportion positive, (2) Density of microfilariae.

(1) Proportion positive

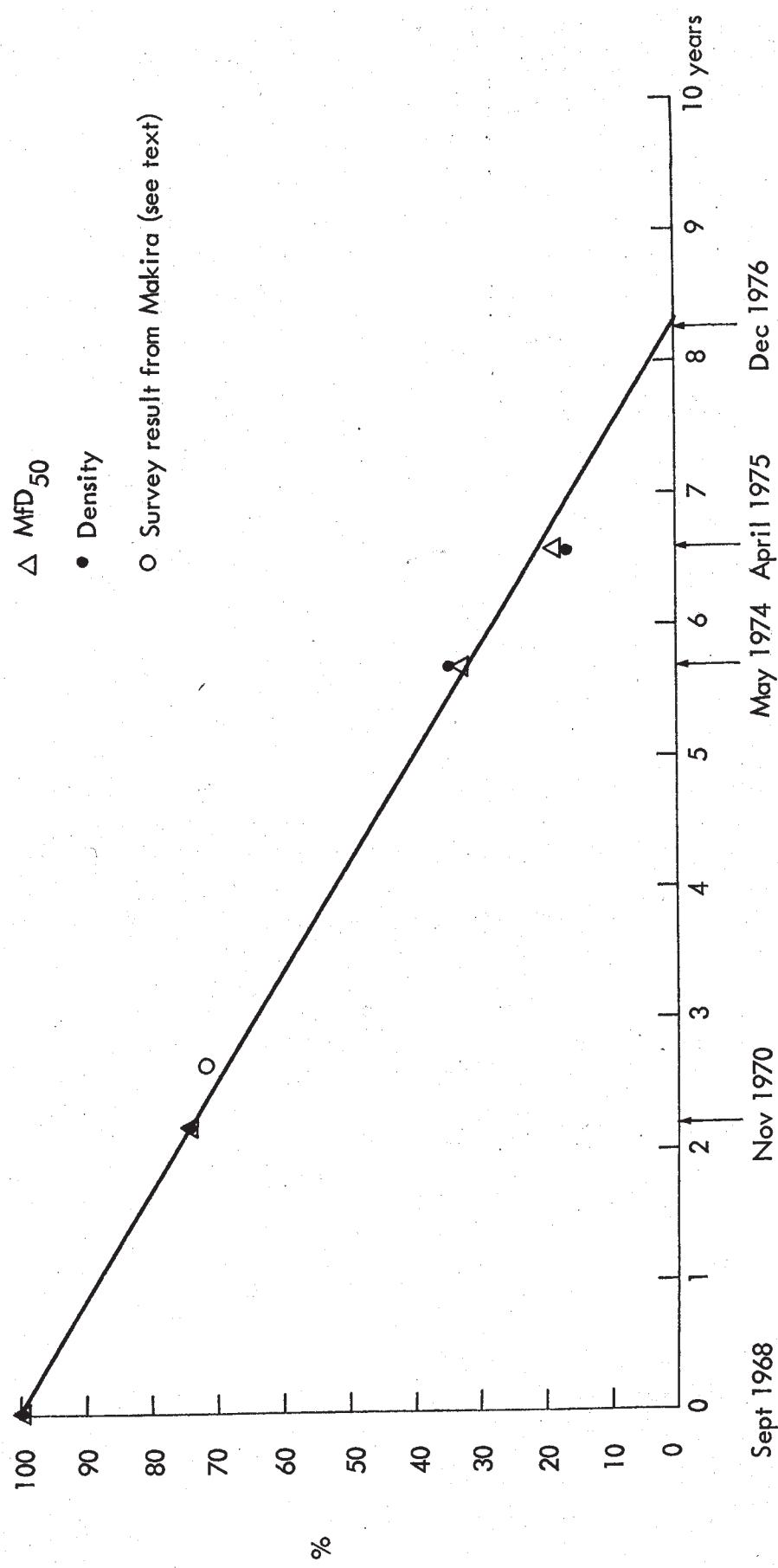
Earlier on, after the first survey in 1970 a theoretical pattern of decrease was formulated (section 8D) based on an ideal situation of decline of infection from persons removed from the vector situation. The decline was exponential, but in two phases, one for the first three years and a greater decline for the subsequent period.

With the surveys in 1974 and 1975 it was now possible to test this model. The 1970 survey should have fallen in the first phase, whereas the other two surveys should have been in the second. However, as explained in section 12C, it was impossible to make any fit. This model was therefore discarded as not representing the situation in these natural conditions.

(2) Density

Fortunately when we come to the densities either as number of microfilariae per positive case or preferably expressed as the median microfilarial count (MfD_{50}), a simple decline against time (fig. 10) is

Fig. 11
PERCENTAGE DECLINE OF MICROFILAREMIA WITH YEAR OF VECTOR CONTROL



produced. To convert this to a universal situation, the base figure (before spraying started) is regarded as 100% and all other densities measured expressed as a proportion to this base. The final pattern is illustrated in fig. 11, where it is noted that both density measurements now give the same straight line.

This can be tested by using data for Makira (see Appendix I).

Baseline data gave a density of 25.0 using 20 cmm blood slide, which is equivalent to 75 if 60 cmm was measured. In April-May 1973, the density was now 53.68, which if converted in the above manner and plotted against time (Sept. 1970 being the first survey), it is seen to lie close to the line in Fig. 11.

It will be seen that carried to its termination, all infection should have ceased by December 1976 or $8\frac{1}{4}$ years after vector control first started. This is discussed more fully in the next section.

E. EFFECT OF PROLONGED SPRAYING

Fauro island in the Shortlands Island group was first sprayed in 1960. When it was surveyed in 1970, the elephantiasis rate was 3.8%, yet only one positive microfilaria case could be found. 158 people were examined (the entire population) and the one person recorded positive had only one microfilaria, and even this was a little doubtful.

There was delay in obtaining the Millipore equipment (which is considered to be the most accurate method now available), so it was not until January 1975 that the investigation could be repeated. This time 112 persons were bled including the man who had been positive before, (the rest refusing venepuncture), and now, even with filtering 1 ml of blood, no microfilariae were found.

A similar survey was conducted by Morris (1975) on Savo island.

The malaria eradication campaign was commenced here in 1963 and fortunately baseline data were available. Crichlow (1929) found 25% positive. The survey by Vincent in 1943 (when he found only 2% positive) is excluded because it was conducted in the daytime.

The Millipore technique was used and a random sample, 186 (14.2%) of the population over 15 years was examined. 3.8% were found positive with a density of 63.3 (MfD₅₀ of 11). It is surprising that there should be such a low percentage positive, but with a high density which is in contrast to the pattern of decline found in Choiseul. The malaria eradication campaign has had many difficulties in this area, with an epidemic in 1973. There is great mobility of people and the results would suggest the import of a few highly infected persons, rather than the continuation of indigenous infection. Morris (1975) also considered it more likely that these positives were imported cases and the fact that 6 were men and only one a woman reinforces the argument.

It would therefore still be reasonable to suggest that after some 12-15 years of prolonged residual spraying and in the absence of imported cases, anopheline-borne filariasis can be expected to die out.

F. LIFE EXPECTANCY OF *W. bancrofti*

Hirston and Jachowski (1968) found that the mature adult worm produced microfilariae for a peak period of 2.5-3.3 years and thereafter declined to almost negligible levels, in fact they considered that this was probably the life expectancy of *W. bancrofti*. However 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 1 person was still positive 8 years after leaving Surinam. Mahoney (1970) conducted a similar examination on Samoan immigrants to the United States and found 7 years to be the longest period anyone retained their infection.

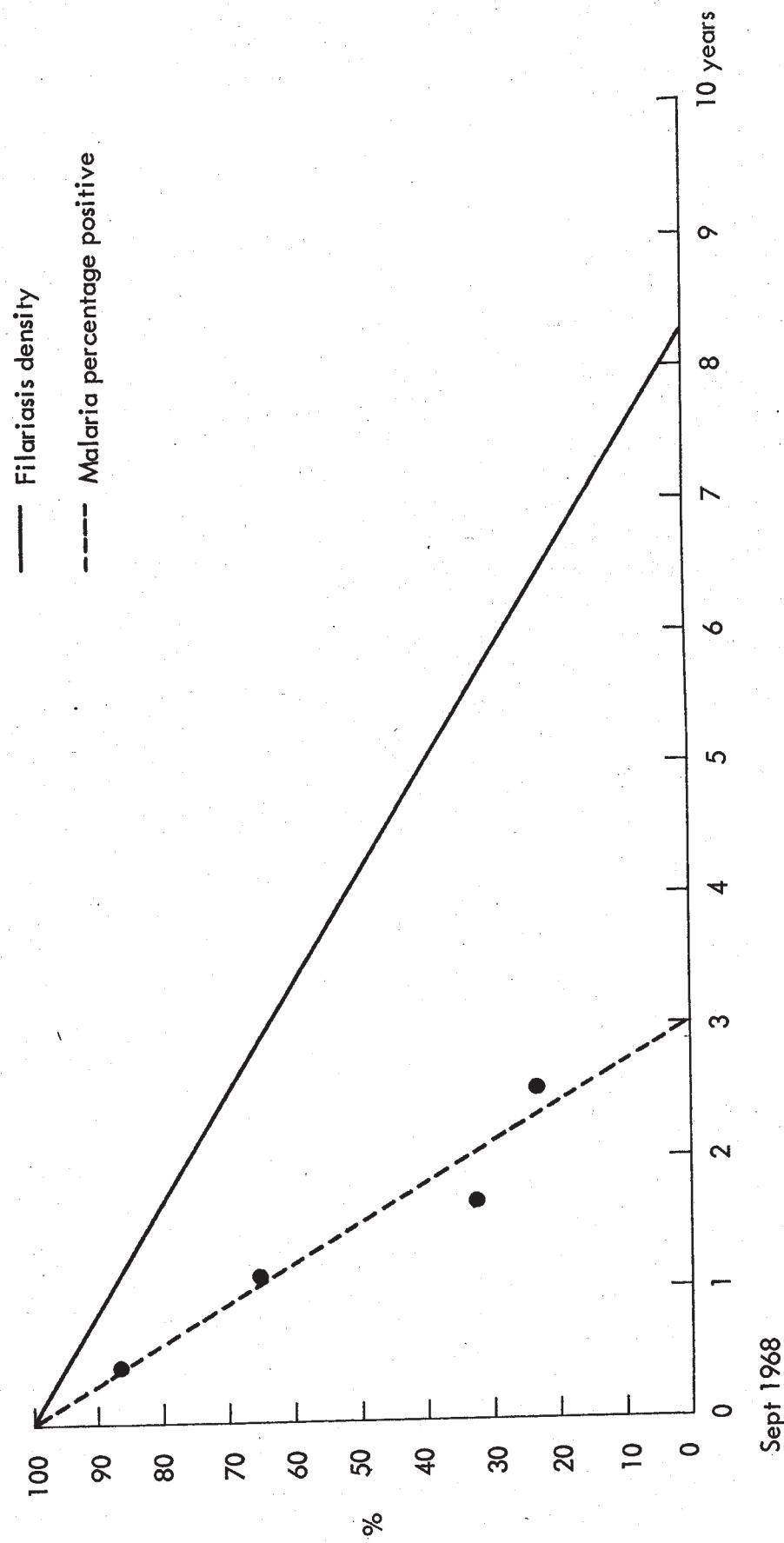
Fig. 11 for the Choiseul surveys suggests that zero microfilaraemia will be reached in $8\frac{1}{4}$ years, but on Fauro there was probably one microfilarial producing W. bancrofti 10 years after infection. Five years later though, there was definitely no living worm left. It would therefore seem reasonable to suggest, that the life expectancy of W. bancrofti is about 8 years, but a few individuals can survive to 10 years, but none beyond 12.

The output of microfilariae also seems to be more constant during the entire life span of the adult worm than the initial peak calculated by Hairston and Jachowski in 1968. During the period of surveys on Choiseul it was found that microfilariae were produced at a constantly declining rate (fig. 11). Also, when the two areas of Voza and Ogo were examined independently in 1974 it was found that the relationship between the proportion of persons positive and the densities had changed completely since 1970 (see section 12A). The density was the first to decline, then the proportion positive suddenly dropped as the density reached low levels followed by an apparent rise of the density again.

G. RELATIONSHIP OF FILARIASIS WITH MALARIA

- (1) In the situation of anopheline borne filariasis, where malaria is also transmitted, both diseases will be affected if vector control measures are applied to the same vector. In section 8D above it was

Fig. 12
CHOISEUL : DECLINE OF MALARIA COMPARED WITH THAT OF FILARIASIS



calculated that the anopheline density in relation to man (m) needs to be reduced to 17.23 for the transmission of filariasis to cease and to 1.62 for malaria. From this it follows that when malaria endemicity is naturally or artificially kept below a level of

$$\frac{17.23}{1.62} = 10.64, \text{ there will be no filariasis.}$$

As this is a proportion it can be applied to any measure comparing the level of these diseases, e.g. the proportion of positive cases.

This theoretical result can be compared with that actually found in the field. Maffi & McDonnell (1971) carried out surveys in the Eastern Outer Islands for Filariasis and Malaria, and it is fortunate that in some places the natural level of malaria transmission was so low, this comparison could be made.

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

Unfortunately this argument cannot be carried to its logical conclusions in saying that as the level of malaria increases, so does that for filariasis, as very many other factors come into play, and field results show considerable variation. The main differences are that filariasis requires intense local transmission over a considerable length of time to the same population, whereas malaria can be epidemic as well as endemic rapidly

following changes in population or local environmental conditions.

(2) Another way of testing this critical level is to monitor the malaria and filariasis levels once vector control methods have commenced. The level of malaria will fall rapidly, whereas that for filariasis much more slowly.

In the Central District of the Solomons which includes Savo (mentioned in section 12E) and Guadalcanal, malaria transmission has continued. Spraying was commenced in 1962 in Guadalcanal and 1963 in Savo yet the slide positivity rates for the last five years for this district are:

Year	No. slides exam. A.C.D. & P.C.D.	No. positive	No. <u>P. falciparum</u>	% positive
1969	33,994	4,723	1,945	13.9
1970	33,961	4,523	1,758	13.3
1971	28,898	1,923	527	6.7
1972	32,437	1,656	543	5.1
1973	35,830	4,085	2,065	11.4
1974	34,827	2,215	773	6.4

1974 Annual Review (1975)

Slide positivity rate is not strictly comparable to survey data, but the persistence of infection at a moderate level, with an epidemic in 1973 and constant P. falciparum infection is sufficient evidence of continuing transmission of filariasis. This source of continuing infection of filariasis was found by the W.H.O. Intercountry Team in 1973 who made a limited survey on Guadalcanal (near Honiara) and found 1.79 per cent positive out of 127 persons examined. The survey on Savo has been

mentioned previously (section 12E).

(3) Studying the ability of the vector to transmit filariasis Pichon (1974 and 1975) continued the two concepts of parasitic reduction (limitation and facilitation) to their logical conclusion. Facilitation, which has only so far been found in Anopheles gambiae - W. bancrofti, parasite-vector couple (but theoretically could occur in A. farauti), means that as the number of ingested microfilariae increases, their survival capacity increases up to a maximum point where mosquito mortality occurs. He used data from several sources and found a mathematical relationship between:

- x the mean number of ingested microfilariae in a vector.
- t the mean number of microfilariae which succeed in reaching the vector haemocoel.
- y the mean number of infective larvae in mature vectors resulting from the ingestion of x microfilariae.

In all cases, the inverse of the success probabilities t/x or y/x seem to vary linearly with x. This means that the relation between t and x, or between y and x, can be represented by an hyperbola, the general formula of which is

$$y = \frac{JHx}{t - Jx + H}$$

where J and H are two constants, not dependent on the number of ingested microfilariae.

J is the success likelihood of microfilaria, when their number tends to zero. Thus we have $0 \leq J \leq 1$

H is an algebraic number. It is positive when limitation occurs and negative when facilitation occurs.

So for facilitation the formula becomes

$$t = \frac{JHx}{Jx + H} \text{ with } H < 0$$

This mechanism of facilitation is more conveniently illustrated (fig. 13).

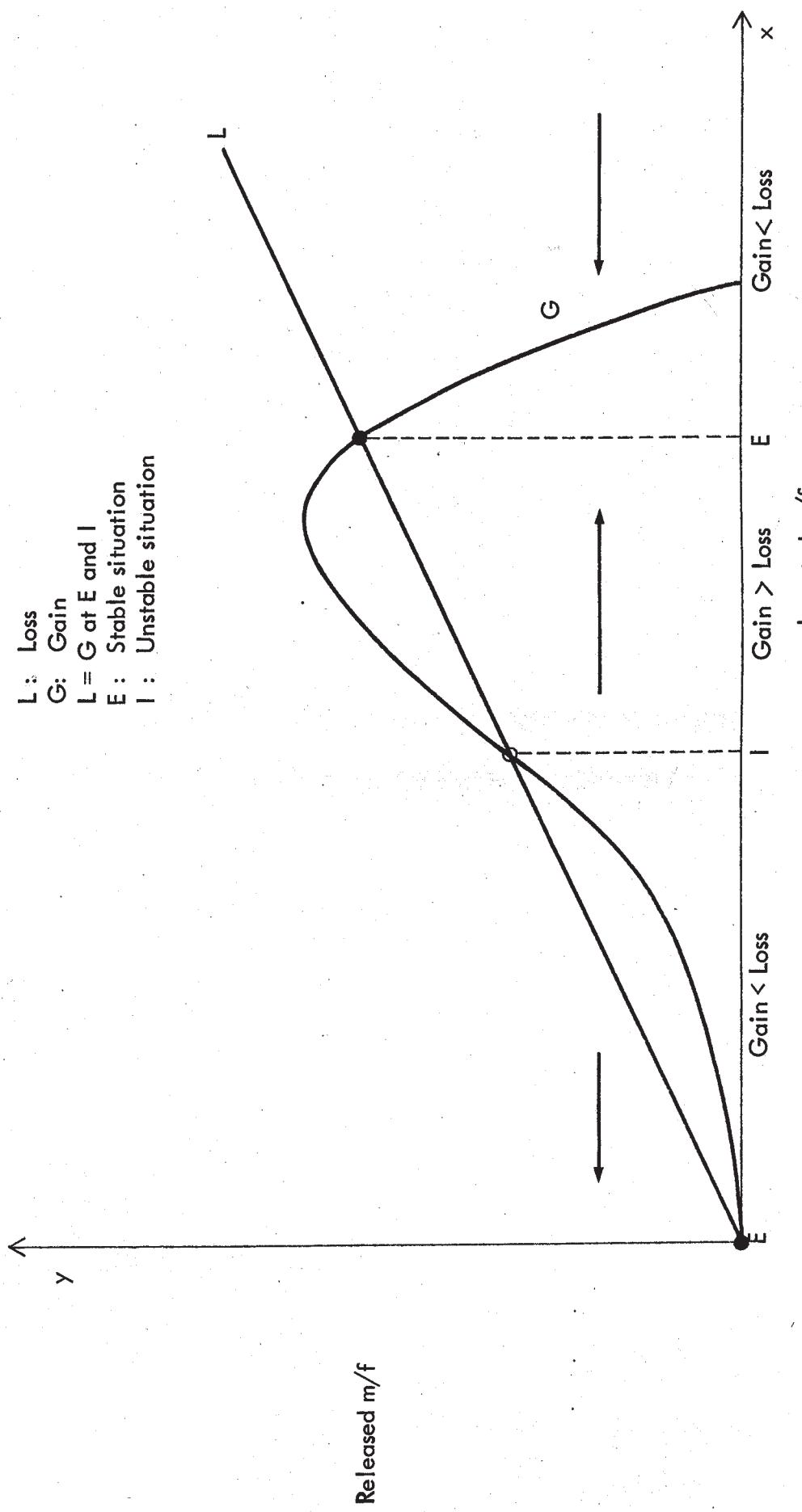
It will be seen that there are two stable situations, zero (erradication) and a point where maximal increase of ingested microfilaria is compatible with survival of the vector for sufficient time to transmit to the host.

Above this level, rapid death of mosquitoes occurs if more microfilariae are ingested.

Between these two stable situations is an unstable situation with a tendency for gain to proceed to the upper stable (endemic) situation or loss to naturally decrease to zero. This critical point of instability has very important implications in control. 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. What is the critical point? and what is sufficient time? have not been determined, but the steady progress to zero of the surveys on Choiseul do support this concept.

One way of trying to arrive at this critical point (using malaria level as a yardstick) is expanded in the first part of this section.

FACILITATION After Pichon (1974, 1975)



13. CONCLUSIONS

In a situation where filariasis and malaria are transmitted by the same vector, as seen here in the Solomon Islands, a Malaria Eradication Campaign aimed at controlling the vector, will have an effect on both diseases. Monitoring the filariasis level should be done by measuring the density (especially the median microfilarial count). If follow-up density counts are expressed as a percentage of the pre-spray survey, it will be found that there is a proportional decrease over 8 years.

It is possible that the reduction of the vector does not need to be so great for the cessation of filariasis transmission as is required in malaria. Below a critical point, calculated as 10.64 for malaria, filariasis can be expected to naturally die out, providing conditions are maintained at this level for some time. Some adult W. bancrofti can live up to about 12 years.

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15. REFERENCES

- ALVES, W. (1965) Final report on the malaria eradication pilot project in the British Solomon Islands Protectorate. Wld Hlth Org., Manila, Phillipines. (mimeographed document)
- BAHR, P.H. (1912) Filariasis and elephantiasis in Fiji. London Sch. trop. Med., Res. Mem. Ser., 1 (1), 1-192.
- BLACK, R. H. (1952) A survey of malaria in the British Solomon Islands Protectorate, Sth. Pacif. Com., tech. Paper Ser., No. 33.
- BRITISH SOLOMON ISLANDS (1922) Annual Medical Report, Suva, Fiji, 1923.
- BRITISH SOLOMON ISLANDS (1928) Annual Medical Report, Suva, Fiji, 1929.
- BRITISH SOLOMON ISLANDS (1949) Annual Medical Report, Honiara, B.S.I.P., 1950.
- BRITISH SOLOMON ISLANDS (1953) Annual Medical Report, Honiara, B.S.I.P. 1954.
- BRITISH SOLOMON ISLANDS (1960) Annual Medical Report, Honiara, B.S.I.P. 1961.
- BRITISH SOLOMON ISLANDS (1974) Malaria Eradication Programme, Annual Review, Honiara, B.S.I.P. 1975.
- BRYAN, J. H. (1973) Studies on the Anopheles punctulatus complex 1. Identification by proboscis morphological criteria and by cross-mating experiments. Trans. R. Soc. trop. Med. Hyg., 67, 64-69.
- BUXTON, P. A. (1928) Researches in Polynesia and Melanesia, London Sch. trop. Med., Res. Mem. Ser., 2.
- BYRD, E. E. & ST. AMANT, L. S. (1944) Report on the findings of the Filaria Survey Unit in the Solomon Islands. U.S. Navy (mimeographe

BYRD, E.E. & ST. AMANT, L.S. (1959) Studies on the epidemiology of filariasis on Central and South Pacific Islands. Sth. Pacif.

Com., tech. Paper Ser., No. 125.

CHULARERK, P. & DESOWITZ, R.S. (1970) A Simplified Membrane Filtration Technique for the Diagnosis of Microfilaraemia.

J. Parasit., 56, 623.

CRICHLOW, N. (1929) The prevalent diseases of the British Solomon Islands. Trans. R. Soc. trop. Med. Hyg., 23, 179-181.

CUMPSTON, J.H.L. (1923) Disease distribution in the Pacific basin. Proc. Pan-Pacif. Sci. Congr. Australia, 2, 1400-1407.

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. Trans. roy. Soc. trop. Med. Hyg., 65: 521.

DE ROOK, H. (1957) Report of an Investigation on filariasis in the Berau region. Sth. Pacif. Com., tech. Paper Ser., No. 105.

DE ROOK, H. & VAN DIJK, W.J.O.M. (1959) Changing concept of W. bancrofti transmission in Netherlands New Guinea. Trop. geogr. Med., 11, 57-60.

DESOWITZ, R.S. & SOUTHGATE, B.A. (1973) Studies on filariasis in the Pacific. 2. S.E. Asian J. trop. Med. publ. Hlth, 4, 179-183.

DESOWITZ, R.S. & SOUTHGATE, B.A. & MATAIKA, J.U. (1973) Studies on filariasis in the Pacific. 3. S.E. Asian J. trop. Med. publ. Hlth 4, 329-335.

DI IORIO, M. (1968) Assignment report of the Malaria Pre-eradication Programme. Wld Hlth Org., Manila, Phillipines.

EYRES, F.B. (1972) Tour report of Bellona, May 1972. Medical

- Department, Honiara, Solomon Islands (mimeographed).
- FIJI (1933) Annual Medical Report, Suva, Fiji, 1934.
- FOX, C.E. (1967) The story of the Solomons, Diocese of Melanesia Press, Taroaniara, B.S.I.P.
- HAIRSTON, N.G. & JACHOWSKI, L.A. (1968) Analysis of the Wuchereria bancrofti population in the people of American Samoa. Bull. Wld Hlth Org., 38, 29-59.
- HAIRSTON, N.G. & DE MEILLON, B. (1968) On the inefficiency of transmission of Wuchereria bancrofti from mosquito to human host. Bull. Wld Hlth Org., 38, 935-941.
- IYENGAR, M.O.T. (1954) Distribution of filariasis in the South Pacific Region. Sth. Pacif. Com., tech. Paper Ser., No. 65.
- IYENGAR, M.O.T. (1956) Annotated bibliography of filariasis and elephantiasis. Part 2. Sth. Parif. Com., tech. Paper Ser., No. 88.
- IYENGAR, M.O.T. (1957) Annotated bibliography of filariasis and elephantiasis. Part 3. Sth. Pacif. Com., tech. Paper Ser., No. 109.
- IYENGAR, M.O.T. (1959) Annotated bibliography of filariasis and elephantiasis. Part 4. Sth. Pacif. Com., tech. Paper Ser., No. 124.
- IYENGAR, M.O.T., DE ROOK, H. & VAN DIJK, W.J.O.M. (1959) Interruption of transmission of Anopheles-borne filariasis by indoor residual spraying in Netherlands New Guinea. Trop. geogr. Med., 11, 287-290.
- IYENGAR, M.O.T. (1959) A review of the literature on the distribution and epidemiology of filariasis in the South Pacific region. Sth. Pacif. Com., tech. Paper Ser., No. 126.
- IYENGAR, M.O.T. (1960) Annotated bibliography of filariasis and elephantiasis. Part 5. Sth. Pacif. Com., tech. Paper Ser., No. 129.

- IYENGAR, M. O. T. (1960) Summary data on filariasis in the South Pacific. Sth. Pacif. Com., tech. Paper Ser., No. 132.
- IYENGAR, M. O. T. (1965) Epidemiology of filariasis in the South Pacific. Sth. Pacif. Com., tech. Paper Ser., No. 148.
- JACHOWSKI, L. A., OTTO, G. F. & WHARTON, J. D. (1951) Filariasis in American Samoa. Loss of microfilaria in the absence of continual reinfection. Proc. helminth. Soc. Wash., 18, 25-29.
- KESSEL, J. F. (1957) Disabling effects and control of filariasis. Amer. J. trop. Med. Hyg., 6, 402-414.
- LAMBERT, S. M. (1928) Medical conditions in the South Pacific. Med. J. Aust., 2, 362-379.
- LAMBERT, S. M. (1934) British Solomon Islands Health surveys 1933. J. trop. Med. Hyg., 37, 85, 102 & 137.
- LEEUWIN, R. S. (1962) Microfilaria in Surinamese living in Amsterdam. Trop. geogr. Med., 14, 355-360.
- LEVER, R. J. A. V. (1933) Status of economic entomology in the British Solomon Islands. Bull. ent. Res., 24, 253-256.
- LEVINE, N. D. & HARPER, F. (1947) Malaria and other insect-borne diseases in the South Pacific Campaign (1942-1945). Amer. J. trop. Med., (Suppl.) 27, 119-128.
- MACDONALD, G. (1952) The Analysis of Equilibrium in Malaria. Trop. Dis. Bull., 49, 813-828.
- MACGREGOR, J. D. (1962) Malaria in the island territories of the South-west Pacific. University of St. Andrews, M.D. thesis.
- MAFFI, M. & McDONNELL, M. (1971) Malaria in the Eastern Outer Islands, British Solomon Islands Protectorate. Parassitologia, 13, 455-503.

MAHONEY, L. E. Jr. & AIU, P. (1970) Filariasis in Samoan immigrants

to the United States. Amer. J. trop. Med. Hyg., 19, 629-31.

MATAIKA, J.U. (1965) A study of filariasis in the Solomon Islands

A report to the Medical Department, Solomon Islands (mimeographed).

McDONNELL, M. & MAFFI, M. (1969) A report on a malariometric survey in Choiseul and Vaghena islands. Western District.

Wld Hlth Org., Manila, Phillipines.

McDONNELL, M. (1970) Filariasis in Eastern District.

Eastern District Annual Medical Report, Kira Kira, B.S.I.P., 1970.

McDONNELL, M. & MAFFI, M. (1971) Malaria in the Eastern Outher Islands. British Solomon Islands Protectorate. Parassitologia, 13, No. 3, 455-503.

MORRIS, S. L. & MORRIS, K.A. (1975) Filariasis on Savo Island.

Medical Department, Honiara, Solomon Islands (mirceographed).

NEW GUINEA (1929) Annual Medical Report, Canberra, Australia 1930.

NEW GUINEA (1930) Annual Medical Report, Canberra, Australia 1931.

NORMAN-TAYLOR, W. (1961) Report on the public health services, B.S.I.P., Sth. Pacif. Com. 1961, page 13.

O'CONNOR, F. W. (1923) Researches in the Western Pacific.

London Sch. trop. Med., Res. Mem. Ser., 4, 1-57.

PERRY, W.J. (1946) Observations on the bionomics of the principal malaria vector in the New Hebrides-Solomon Islands. J. nat. Malar. Soc., 5, 127-139.

PERRY, W.J. (1949) The mosquito and mosquito borne diseases of the Treasury Islands. Amer. J. trop. Med., 29, 747-758.

PETERS, W.A. & STANDFAST, H. A. (1960) Studies in the epidemiology

- of malaria in New Guinea. II. Holoendemic malaria - the entomological picture. Trans. R. Soc. trop. Med. Hyg., 54, 249-2
- PICHON, G. (1974) Relations mathématiques entre le nombre des microfilaires ingérées et le nombre des parasites chez différents vecteurs naturels ou expérimentaux de filarioses. Cah. O.R.S.T.O sér. Ent. méd. et Parasitol. XII, No. 4, 199-216.
- PICHON, G. (1974) Quantitative Aspects in Filariasis (paper presented to the Fourth Joint SPC/WHO Seminar on Filariasis and Vector Control)
- PICHON, G., PERRAULT, G. & LAIGRET, J. (1975) Rendement Parasitaire chez les Vecteurs de Filarioses. WHO/FIL/75.132.
- SASA, M. (1967) Microfilaria survey methods and analysis of survey data in filariasis control programmes. Bull. Wld Hlth Org., 37, 629-650.
- SASA, M. (1974) Methods for estimating the efficiency of detection of microfilariae in various volumes of blood samples. S.E. Asian J. trop. Med. publ. Hlth., 5, No. 2, 197-210.
- SCHLOSSER, R.J. (1943 & 1944) Monthly Malaria Reports 20th Malaria Survey Unit, A.U.S. Aug. & Dec. 1943 and Jan. 1944. (Quoted in BYRD & ST. AMANT (1959) Sth Pacif. Com. tech. Paper Ser., No. 125).
- SCHLOSSER, R.J. & Reiber, R.J. (1945) Anopheles punctulatus found to mature both Plasmodium and Wuchereria on Guadalcanal. Newsletter Hdgrs. Mal. Epidem. Control, South Pacif. Area, May 1945, p. 4. (Quoted in BYRD & ST. AMANT (1959) Sth. Pacif. Com., tech. Paper Ser., No. 125).
- SCHLOSSER, R.J. (1945) Observations on the incidence of W. bancrofti larvae in the native population of the Solomon Islands area.

- Amer. J. trop. Med., 25, No. 6, 493-496.
- SCHLOSSER, R.J. (1949) Photomicrographs of the developing larvae of Wuchereria bancrofti in a mosquito host of the South Pacific area. Amer. J. trop. Med., 29, 739-745.
- SHEFFLER, H.W. (1965) Choiseul Island Social Structure. University of California Press, Los Angeles, U.S.A.
- SOUTH PACIFIC COMMISSION (1954) Annotated bibliography of filariasis and elephantiasis. Tech. Paper Ser., No. 65.
- SOUTHGATE, B.A. & DESOWITZ, R.S. (1971) Comparative efficacy of the stained blood films, counting chamber and membrane filtration techniques in the determination of microfilarial rates and microfilarial densities. WHO/FIL/71.91 (mimeographed).
- SOUTHGATE, B.A. (1973) Studies on filariasis in the Pacific. Part 1. S.E. Asian J. trop. Med. publ. Hlth, 4, 172-178.
- TAYLOR, B. (1975) Observations on Malaria vectors of the Anopheles punctulatus complex in the British Solomon Islands Protectorate. J. Med. Ent., 11, No. 6, 677-687.
- THORPE, V.G. (1996) Filaria sanguina hominis in the South Sea Islands. Brit. med. J., 2, 922-924.
- VAN DIJK, W.J.O.M. (1958) Transmission of Wuchereria bancrofti in Netherlands New Guinea. Trop. geogr. Med., 10, 21-33.
- VAN DIJK, W.J.O.M. (1964) Control of Wuchereria bancrofti filariasis in West New Guinea. Trop. geogr. Med., 16, 54-60.
- VINCENT, M.M. (1943 & 1944) Monthly malaria reports. 15th Malaria Survey Unit, A.U.S. July, Aug., Sept. & Dec. 1943 and Jan., March and April 1944. (Quoted by BYRD & ST. AMANT (1959) Sth. Pacif. Com., tech. Paper Ser., No. 125).

WATSON, T.M. (1973) Malaria and Filariasis Survey, Graciosa Bay.

A report to the Medical Department, Solomon Islands (mimeographed).

WEBBER, R.H. (1973) Filariasis in the Solomon Islands and its reduction by vector control methods. University of London, D.T.P.H. dissertation.

WEBBER, R.H. (1974) Filariasis in the Solomon Islands (paper presented to the Fourth Joint SPC/WHO Seminar on Filariasis and Vector Control).

WEBBER, R.H. (1975) Vector Control of Filariasis in the Solomon Islands. S.E. Asian J. trop. Med. publ. Hlth (in press).

WEBBER, R.H. (1975) Theoretical considerations in the Vector Control of Filariasis. S.E. Asian J. trop. Med. publ. Hlth (in press).

WLD HLTH ORG. (1962) Expert Committee on Filariasis. Wld Hlth Org. techn. Rep. Ser., 233.

WLD HLTH ORG. (1967) Expert Committee on Filariasis. Second report.
Wld Hlth Org. techn. Rep. Ser., 359.

WLD HLTH ORG./STH PACIF. COM. (1968) Second joint seminar on filariasis. Wld Hlth Org., Manila, Phillipines.

WLD HLTH ORG. INTERCOUNTRY TEAM (1973) Report on Filariasis in the Solomon Islands. Wld Hlth Org., Manila, Phillipines.

APPENDIX I

Summary of Filariasis Surveys by Island from Various Sources

Source	Island	No. examined	% positive	Mf density	Elephantiasis No.	Percentage
Crichlow (1929)	Not specified	-	15	-	-	-
Schlosser (1944)	"	601	17.1	-	-	-
Vincent (1943)	Guadalcanal	114	14.0	-	-	-
Schlosser (1943)	(by day)	86	9.3	-	-	-
Schlosser (1945)	"	157	10.2	-	-	-
Byrd & St. Amant (1944)	"	26	15.4	-	-	-
Byrd & St. Amant (1944)	(adult m.)	155	40.6	-	5	3.2
Reiber (1945)	"	137	19.0	-	-	-
Levine & Harper (1947)	"	2,500	22.0	-	-	-
Yaws camp. (1953)	"	1,106	-	-	11	1.0
Mataika (1965)	"	502	18.8	53.6	2	0.4
WHO Intercountry Team (1973)	"	127	1.79	MFD 50 14.0	-	-

APPENDIX I cont.

Source	Island	No. examined	% positive	Mf density	Elephantiasis No.	Percentage
Vincent	Malaita	157	9.0	-	-	-
Schlosser (1943)	"	74	10.8	-	-	-
Schlosser (1945)	"	548	10.2	-	-	-
Byrd & St. Amant (1944)	"	481	10.0	-	4	0.8
Byrd & St. Amant (1944)	"	466	(adult m)	10.1	-	-
Schlosser (1943)	Malaita & Makira	398	21.3	-	-	-
Vincent (1943)	Makira	50	22.0	-	-	-
Schlosser (1945)	"	558	31.5	-	-	-
Byrd & St. Amant (1944)	"	244	40.5	-	3	1.2
Byrd & St. Amant (1944)	"	242	38.8	-	-	-
McDonnell (1970)	"	1,802	20.8	25.0	18	1.0
WHO Intercountry Team (1973)	"	186	26.31	(60 cmm)	53.68	(MfD ₅₀ = 20)
McDonnell (1970)	Ugi (Pawa sch.)	179	5.6	23.8	0	0
B.S.I.P. Med. Rep. (1949)	Santa Catalina	-	80.0	-	-	-
Fiji Med. Rep. (1933)	Santa Ana	41	12.2	-	-	-
Fiji Med. Rep. (1933)	Anuta	23	0	-	-	-
Fiji Med. Rep. (1933)	Reef Islands	72	4.2	-	-	-

APPENDIX I cont.

Source	Island	No. examined	% positive	Mf density	Elephantiasis No.	Percentage
McDonnell (1970)	Reef Islands	254	0	0	0	0
McDonnell (1970)	Duff Islands	68	20.5	9.2	0	0
McDonnell (1970)	Ndende (Santa Cruz)	1,196	13.0	11.6	23	1.9
Watson (1973)	" Graciosa Bay	830	2.7	-	2	0.24
McDonnell (1970)	Urupua	91	30.8	43.5	1	1.0
McDonnell (1970)	Vanikoro	49	10.2	11.8	1	2.0
Fiji Med. Rep. (1933)	Rennel	297	0	-	-	-
Black (1952)	Bellona	230	0	-	-	-
Eyres (1972)	"	251	5.2	-	0	-
Vincent (1943)	Ngella	37	2.7	-	-	-
Mataika (1965)	"	266	40.2	109 (MfD ₅₀ = 40)	9	3.4
Kiers (1968)	" (Big)	391	35	-	-	-
Eyres (1974)	" (Small)	214	21	-	-	-
Crichlow (1929)	Savo	-	25.0	-	-	-
Vincent (1943)	"	147	2.0	-	-	-
Morris (1975)	(by day) (Millipore)	186	3.8	(MfD ₅₀ = 11)	-	-
Lambert (1933)	"	49	2.0	63.3	-	-
Black (1952)	"	24	4.2	-	1	0.7

APPENDIX I cont.

Source	Island	No. examined	% positive	Mf density	No. elephantiasis	Percentage
B.S.I.P. Med. Rep. (1928)	Ontong Java	-	-	-	4	-
Black (1952)	" "	35 (by day)	5.7	-	2	0.26
Perry (1949)	Mono	-	0.7	-	-	-
Norman-Taylor (1961)	Shortland Islands	500 (by day)	0.4	-	-	-
Webber (1970)	"	218	0	0	1	0.46
Webber (1970)	Fauro	158	0.6	0.6	6	3.8
Webber (1975)	"	112 (Millipore)	0	0	-	-
Webber (1970)	Choiseul	1,385	15.0	9.4(MfD ₅₀ = 3.7)	11	0.8
	"	" (corrected to 60 cmm)	29.2	27.9(MfD ₅₀ = 12.2)		
Webber (1974)	"	300	21.75	13.0(MfD ₅₀ = 5.4)	-	-
Webber (1975)	"	351	9.2	6.3(MfD ₅₀ = 3.0)	-	-
Webber (1975)	New Georgia	575	0	0	0	0
Webber (1974)	Gizo(Gilbertese)	100	0	0	0	0
New Guinea Med. Reports (1929 & 1930)	Bougainville	-	-	-	Present	-
	Bouka	-	-	-	Present	-

SUMMARY OF INFECTED AREAS*

Island	No. examined	No. positive	% positive	Elephantiasis %
Guadalcanal	3,035	762	25.1	1.02
Malaita	1,260	126	10.0	0.8
Makira	2,654	662	25.0	1.02
Ngella	266	107	40.2	3.4
Infected Eastern Islands	1,624	227	14.8	1.9
Solomon Islands, adjusted for population			16.1	0.97

* Excludes data from daytime and adult male only collections, and those possibly affected by control

APPENDIX II(a)
Choiseul 1970

Age groups	No. examined		No. positive		Positive by age group		Population <i>f</i>		% population	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
0-4	90	95	1	0	1.11*	0	690	644	18.7	17.7
5-9	102	107	4	8	3.94	7.45	601	590	16.4	16.4
10-14	104	96	7	11	6.8	11.5	549	470	15.0	13.0
15-19	86	75	11	10	12.7	13.4	294	350	8.0	9.6
20-24	52	58	5	9	9.8	15.5	194	259	5.2	7.1
25-29	45	47	15	8	33.2	17.0	235	270	6.2	7.4
30-34	59	36	13	5	22.0	14.0	173	200	4.7	5.5
35-39	34	35	10	4	29.5	11.4	189	211	5.2	5.8
40-44	32	17	10	4	31.2	23.5	133	134	3.6	3.7
45-49	29	25	13	6	35.0	24.0	154	137	4.2	3.7
50-54	33	23	8	5	24.2	21.8	104	94	2.8	2.6
55-59	14	10	6	5	43.0	50.0	72	84	2.2	2.3
60-64	25	21	8	10	32.0	48.0	104	75	2.8	2.0
65-69	12	9	5	2	41.8	22.2	82	61	2.3	1.7
70-74	10	7	3	2	30.0	28.6	49	38	1.3	1.0
75-84	6	0	0	0	0	0	46	21	1.2	0.6
85+	0	1	0	1	0	(100.0)*	15	4	0.4	0.1
Totals	723	662	119	90	16.4	13.6	3684	3640	100	100
	1385		209		15%		7324			

* Excluded from graph % population examined : 19%

f 1970 census

APPENDIX II (b)
Shortlands, 1970

Age groups	No. examined		No. positive		% positive		Population		% population	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
0-4	27	41	0	0	0	0	133	151	16.0	21.2
5-9	31	34	0	0	0	0	124	116	15.0	15.7
10-14	19	19	0	0	0	0	104	98	11.6	13.3
15-19	12	17	0	0	0	0	79	44	9.5	5.9
20-24	8	13	0	0	0	0	52	53	6.2	7.2
25-29	10	11	0	0	0	0	58	45	6.8	6.1
30-34	13	10	0	0	0	0	51	41	6.2	5.5
35-39	7	4	0	0	0	0	49	38	5.9	5.1
40-44	7	5	0	0	0	0	21	28	2.5	3.8
45-49	5	7	0	0	0	0	36	32	4.3	4.3
50-54	9	7	0	0	0	0	35	24	4.3	3.25
55-59	7	4	0	0	0	0	18	18	2.2	2.4
60-64	10	10	1	0	10	0	15	13	1.8	1.75
65-69	5	6	0	0	0	0	26	7	3.1	0.94
70-74	2	8	0	0	0	0	9	16	1.1	2.2
75-84	3	4	0	0	0	0	21	14	2.5	1.9
85+	1	0	0	0	0	0	5	0	0.6	0
Totals	176	200	1	1	0.57	0.57	836	738	100	100
	376		1	1	0.27%	0.27%	1574			

% Population examined: 23.2%

APPENDIX II (c)
Elephantiasis Cases, 1970

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Age group	Choiseul						Shortlands					
	No. examined	No. positive		% positive		No. examined	No. positive		No. examined	No. positive		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
0-4	90	95					27	41				
5-9	102	107					31	34				
10-14	104	96					19	19				
15-19	86	75	1		0.73	0	12	17				
20-24	52	58					8	13				
25-29	45	47					10	11	1			
30-34	59	36	1	1	1.52	3.8	13	10				
35-39	34	35	1	1			7	4				
40-44	32	17					7	5				
45-49	29	25					5	7				
50-54	33	23	2		3.2	0	9	7				
55-59	14	10	2		5.1	0	7	4				
60-64	25	21					10	10				
65-69	12	9					5	6				
70-74	10	7					2	8				
75-84	6	0	1		16.6	0	3	4				
85+	0						1	0				
Total	723	662	7	4	0.97	0.6	176	200	2	5	1.14	2.5
Totals	1385		11		0.8		376	7			1.87	

APPENDIX III

Percentage of Elephantiasis Cases Compared with the Proportion Positive
and Density of Microfilaraemia in Different Areas of the Pacific

Modified from Kessel (1957)

Island	Per cent elephantiasis	% population positive microfilaria	Density of microfilariae pos. 20 cmm
Hitiaa	9.9	43.6	110
Society Islands	7.0	32.0	110
Maiao	5.0	27.0	127
Ngella(Solomons)	3.4	40.2	109
Marquesas	3.0	33.7	58
Apia, West Samoa	1.6	22.6	46
Maupitit	1.0	26.0	46
Kandavu, Fiji	1.0	25.3	36
Mau, New Caledonia	1.0	33.0	20
Makira(Solomons)	1.0	20.8	25
Choiseul "	0.8	15.0	9.4
Tikehau	0.5	29.2	22
Austral Islands	0.3	30.0	40
Labasa, Fiji	0.3	9.0	10

APPENDIX IV
Choiseul, 1970

Village Distribution of Microfilaria positive and Elephantiasis Cases

Villages	Population	No. examined	% positive	No. elephantiasis	% elephantiasis
Sangigae, Ngarione, Salakana, VOZA, Gazekeo	357	199	21.0	5	2.5
Kuku, Pimandara	105	69	1.5	0	0
MOLI, Leva Leva, Vundataru, Nukiki	427	138	11.6	0	0
Choiseul Bay, Poro Poro, Rabakela Liu Liu, Malevanga, Barakakasa	281	179	5.0	0	0
Venga, Vurango, Mundo-Mundo	685	119	15.0	0	0
Enara, POLO, Lokapakoma	245	141	15.0	1	0.72
Bobokuana, Sariana, OGO	291	220	23.0	5	2.3
Voru Voru, Bangara, Tutu	347	239	16.6	0	0
Totals	2819	1385	15.0	11	0.8