Technical Paper No. 125

STUDIES ON THE EPIDEMIOLOGY OF FILARIASIS ON CENTRAL AND SOUTH PACIFIC ISLANDS

ELON E. BYRD and LYLE S. St. AMANT

NOUMEA, NEW CALEDONIA
PRICE: 6/- STERLING

The South Pacific Commission

The South Pacific Commission is an advisory and consultative body set up in 1947 by the six Governments responsible for the administration of island territories in the South Pacific region (Australia, France, the Netherlands, New Zealand, the United Kingdom and the United States of America).

The Commission's purpose is to advise the participating Governments on ways of improving the well-being of the people of the Pacific island territories. It is concerned with health, economic and social matters. Its headquarters are at Nouméa, New Caledonia.

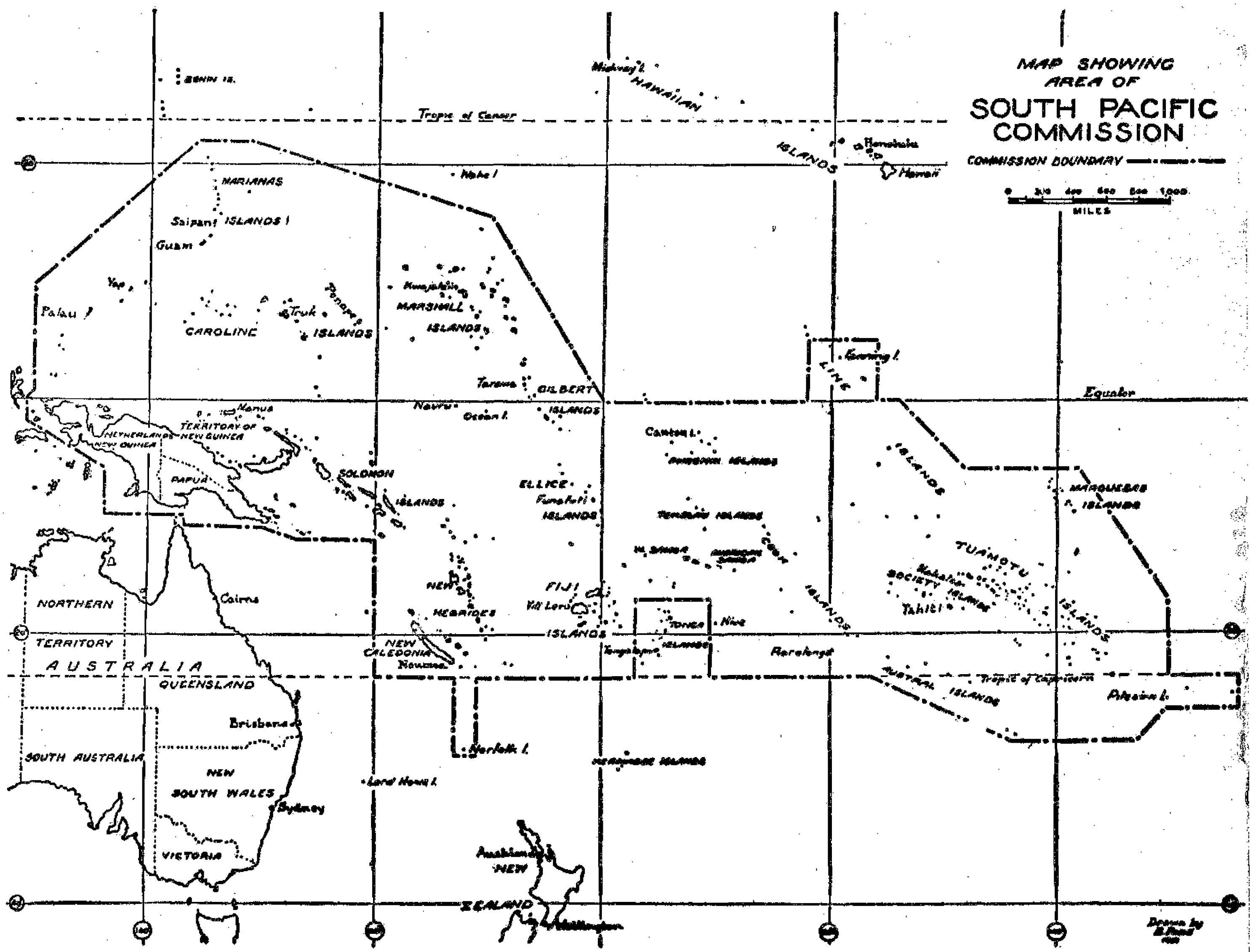
The Commission consists of not more than twelve Commissioners, two from each Government. It normally holds one Session each year. There are two auxiliary bodies, the Research Council and the South Pacific Conference.

There is a Research Council meeting once a year. This may be either a meeting of the full Council, or of one or other of its three main sections, specializing in the fields of health, economic development and social development. Members of the Research Council are appointed by the Commission. They are selected for their special knowledge of the questions with which the Commission is concerned, and the problems of the territories in these fields. The chief function of the Research Council is to advise the Commission on what investigations are necessary. Arrangements to carry out those that are approved are the responsibility of the Secretary-General and other principal officers.

The South Pacific Conference, which meets at intervals not exceeding three years, consists of delegates from the local inhabitants of the territories, who may be accompanied by advisers. The first Conference was held in Fiji in April 1950, and was attended by delegates from fifteen territories and from the Kingdom of Tonga. The second Conference was held at Commission headquarters in April 1953. The third Conference was held in Fiji in April-May 1956, and the fourth Conference in New Britain in April-May 1959.

The principal officers of the Commission are: Secretary-General, Mr. T. R. Smith; Executive Officer for Health (Acting), Dr. T. C. Lonie; Executive Officer for Economic Development, Dr. A. H. J. Kroon; Executive Officer for Social Development, Dr. Richard Seddon. The powers and functions of the Deputy Chairman, Research Council, are exercised by the Secretary-General.

Further particulars of the Commission's activities may be obtained from the Secretary-General, Nouméa, New Caledonia.



South Pacific Commission
Technical Paper No. 125

STUDIES ON THE EPIDEMIOLOGY OF FILARIASIS ON CENTRAL AND SOUTH PACIFIC ISLANDS

by

Elon E. Byrd

and

Lyle S. St. Amant

South Pacific Commission
Noumea, New Caledonia
September 1959

FOREWORD

The observations made by Drs. Byrd and St. Amant on filariasis in various island groups in the South Pacific during 1943-44 when the American Armed Forces were occupying the South Pacific Islands were presented by the authors in a 220-page official report to the Bureau of Medicine & Surgery, U.S. Department of Navy during 1945. This report has unfortunately so far remained unpublished.

One of the objects of the South Pacific Commission's project on mosquito-borne diseases is to obtain and disseminate precise information on the distribution and epidemiology of filariasis in the South Pacific region. Byrd and St. Amant's report contains important observations on filariasis in the several areas visited by them and its publication in the Commission's Technical Paper series would fit in well with the Commission's programme. On the recommendation of Dr. Iyengar, our specialist on mosquito-borne diseases, the Commission has pleasure in sponsoring the publication of this paper.

In spite of much other work on hand, Dr. Iyengar has undertaken the work of revising and condensing the report for publication. I wish to express my appreciation of the work done by Dr. Iyengar in this connection and thanks to Drs. Byrd and St. Amant for permission to publish.

T.C. Lonie

Acting Executive Officer
for Health

CONTENTS

		Page
1.	Introduction	1
2.	Methods	1
3.	Incidence of microfilarial infection	3
4.	Incidence of physical signs of filariasis	16
5.	Microfilarial periodicity	25
6.	Studies on mosquitoes:	29
	(a) American Samoa	29
	(b) Wallis Islands	52
	(c) New Hebrides	56
	(d) Solomon Islands	61
	(e) Experiments with Anopheles farauti and A. punctulatus	66
	(f) Habits of the principal vectors of filariasis	68
7.	Discussion	75
8.	Control of filariasis	83
9.	References	89

1. INTRODUCTION

This paper presents the results obtained by the special epidemiology unit sent to the Pacific area during 1943-44 by the Bureau of Medicine and Surgery, United States Navy, to investigate the filariasis problem. The areas investigated are American Samoa, Wallis Island, New Hebrides and Solomon Islands. This paper is based on an official report (yet unpublished) which was presented to the Preventive Medicine Section, Bureau of Medicine and Surgery, in July 1945. In editing this report for publication, no attempt has been made to include references to papers published since 1945.

Help received during this investigation from the members of the Filariasis Survey Unit as well as from Commander Leon Bromberg, Captains J.G. Dickson, R.J. Schlosser, M.M. Vincent and Lieut. R.J. Reiber is acknowledged with grateful thanks.

The authors wish to express their grateful thanks to the South Pacific Commission for accepting this work for publication in the Commission's Technical Paper Series, and to Dr. M.O.T. Iyengar for his encouragement of and painstaking interest in the revision and editing of the original report for publication. Without his help and insistence the report would not have been published.

2. METHODS

During this study attempts were made to obtain information on the epidemiology of filariasis in the islands mentioned above. This included:

1. Determination of the microfilaria rate based on the examination of a representative sample of the local native population.
2. Determination of the local mosquito vectors of filariasis, the incidence of natural infection in them, their transmitting efficiency, and studies on their breeding, feeding, resting, and flight habits.

From each of the persons examined during this survey a single 40 c.mm. sample of blood from a finger puncture was drawn into a standardized pipette and then discharged on a clean slide. A uniform sized smear was made on the slide by a rotary movement of the discharging pipette, air-dried at room temperature (several hours) and dehaemaglobinized in tap water. The smear was again air-dried at room temperature, fixed in absolute alcohol and hydrated through descending grades of alcohol to water. Harris' or Bullard's hematoxylin was the stain of choice. The smear was counterstained with eosin, cleared in acetone and xylol, and mounted in balsam.

In areas of the aperiodic filaria the blood sample was taken mostly during the afternoon hours. In the areas of the periodic filaria, the samples were taken between 19.30 and 24.00 hours. In some cases small groups of natives were selected for study both during daylight hours and at night.

In American Samoa each native examined was given a thorough physical examination at the time the blood smear was made. In the other islands this was not always possible, and hence, the survey relied on its ability to detect obvious physical manifestations of filariasis in evaluating the incidence of clinical filariasis.

On each island visited efforts were made to collect and dissect all mosquitoes encountered. Day-feeding mosquitoes were collected from likely resting places as well as from suitable bait. At all collecting stations some member of the party stripped to the waist and served as bait. Occasionally mosquitoes were captured while they fed on pigs, dogs, cattle and horses. In all collecting efforts the time of day, the number of collectors and the number of mosquitoes taken were recorded. From these data the density of a given species of mosquito was recorded as number of mosquitoes per man per hour.

Night-feeding mosquitoes were caught during the early morning hours from "huts" and other resting places within the village and adjacent to it. Where feasible, members of the unit and native volunteers were used as bait at night.

Captured mosquitoes were transported in well-shielded containers to the laboratory for dissection. After etherization, the body was separated into head, thorax and abdomen in Locke's solution on a glass slide. Each part was dissected with fine needles under a stereoscopic dissecting microscope and the preparation examined at 100 magnification. Positive preparations were fixed (Schaudinn's), stained and mounted.

In some instances wild caught mosquitoes were killed at 24-hour intervals for the purpose of observing the progress of the developing filaria larvae.

In American Samoa attempts were made to determine: (1) the density of the mosquito about the native village, (2) the incidence of infection in the locally caught mosquitoes, and (3) the flight range of the day-feeding _Aedes_ mosquito. Mosquito density was determined on the basis of number of mosquitoes captured per man hour of collecting time, with the collections being made at the centre of the village and at predetermined collection stations at 25 yard intervals along lines radiating from the centre of the village into the surrounding jungle. Several such radiating lines of collecting points were used.

The occurrence of developing filaria larvae in the mosquitoes captured from the different stations gave an indication of the distances travelled by the mosquitoes in seeking blood meal or in seeking shelter following engorgement.

Uninfected mosquitoes were raised from larvae collected from breeding sites. In a few instances adult mosquitoes were raised from eggs deposited in the laboratory. The adults so obtained were fed on a native Samoan having a microfilarial density in the peripheral blood of 1 to 3 microfilariae per c.mm. The experimentally fed mosquitoes were kept in a screened cage (approximately 2'x 2'x 2') covered with several layers of cheese cloth. The cheese cloth was sprayed with water two or three times daily so as to maintain a high humidity in the cage, and to supply moisture to the mosquitoes. Sugar-water was made available as supplementary food; for the first 10 to 12 days following the experimental feed mosquitoes were allowed to feed on blood (non-infected volunteers).

In following the developmental cycle of the filariae larvae in the mosquitoes, each day a number of mosquitoes was killed and examined until one was found harbouring developing larvae. Any dead mosquitoes found in the cages were removed twice daily and dissected for developing larvae.

3. INCIDENCE OF MICROFILARIAL INFECTION

During this survey, 2,155 individuals from South Pacific islands were examined for the presence of microfilariae in the peripheral blood. In addition, the writers were associated with other surveys. The results obtained through these independent or collaborated investigations have been reported elsewhere, mainly in summary reports by the officers in charge. Most of the data contained in the several reports are pertinent to the completeness of the present paper, and, for that reason, are included herein. Table 1 gives the results of surveys thus far completed on the islands visited by the authors. None of the five whites(French colonials) whose night blood samples were examined, proved to be positive for microfilariae, although one of them (40 years of age) was born on the island of Espiritu Santo (New Hebrides), while the other four had migrated to that island 9 to 20 years previously, one from France and the others from New Caledonia.

Although there was a rather large group of such colonials in the area covered, it is not possible to obtain blood smears from them for study. The sample of this population included in the survey is far too small to warrant discussing the filarious condition known to exist in these people. Certainly, one gets the impression from talking with these colonials that a fair number of them have the disease, and a few very frankly admitted that filaria larvae have been found in their blood at one time or another since their arrival in the area. The writers have observed evidence of elephantiasis in a few of the French and British colonials, and some of them freely discussed their elephantiasic condition with the investigators.

For further discussions on filariasis in colonial personnel in the Pacific area, see Bahr (1912) and O'Connor (1923).

TABLE 1

Incidence of microfilarial infection in 5,578 persons examined from South Pacific islands.

Race	Source	Home island or country	Number surveyed	Number positive	Percentage infected
Whites	Present report	France or possessions	5	0	..
Tonkinese	" "	Tonkin (Indochina)	520	43	8.3
Polynesians	Dickson 1943	Samoa	2,171	324	14.9
Fijians	Schlosser 1944	Fiji	146	29	19.9
Micronesians	Present report	Gilbert Islands	332	54	16.3
Melanesians	Vincent 1944	Solomon "	505	45	8.9
"	Schlosser 1944	" "	601	103	17.1
"	Present report	" "	902	211	23.4
"	" "	New Hebrides	396	86	21.7
	Total Melanesians		2,404	445	18.51
Total			5,578	895	16.05

The small group of Tonkinese surveyed (Table 1) showed a lower microfilaria rate than that observed in either Micronesians, Melanesians, Fijians, or Polynesians. Wuchereria malayi was the parasite harboured by the Tonkinese while W. bancrofti was the parasite involved in the other racial groups. The Tonkinese were imported labourers, serving on the plantations under contract for periods ranging from three to five years. Only young, healthy males and females were imported, in the ratio of one female to four males. Marriage was permitted after arrival in the area and, hence, children older than three or four years of age were not met with. Time did not permit the inclusion of these young children in the survey. A study of the transmission of W. malayi harboured by the Tonkinese would be highly desirable in view of the apparent rarity of known mosquito transmitters of W. malayi on the islands now occupied by these people. Of equal interest would be a study of the susceptibility of the Tonkinese, especially the offspring from their marriages, to the local filaria. In no case did the writers find a mixed infection in the group, nor were they able to obtain enough evidence to warrant expressing an opinion on the susceptibility of local pest mosquitoes to W. malayi.

The percentage incidence for blood microfilariae in the Micronesians, Fijians, Melanesians, and Polynesians is about the same. The slightly lower rate determined for the Polynesians might be because the greater majority of them come from an area where better sanitation prevails than in the case of the Melanesians.

It should be pointed out that the smaller groups of Fijians and Gilbert Islanders investigated do not represent as true a cross section of the population on those islands as does the larger group of Polynesians from American Samoa. The groups from Fiji and Gilbert Islands comprise young adult males recruited specifically for labour with the Armed Forces on Guadalcanal, an age-group recognized as having a higher index of infection than can be shown normally for the population as a whole. It seems probable that the microfilaria rate determined for them represents only the incidence of infection of a similar age-group on the home island rather than as giving an indication of this for even the adult male population of the entire island. Probably the overall filaria index for the home island will be slightly lower than the rate determined for the labourers, although the percentage recorded by Bahr (1912) for Fijian natives is considerably higher than this figure - 30.4 per cent for males of all age-groups and 23.8 per cent for females of all age-groups.

Stempien (1944) observed that 65 or 9.8 per cent of 666 Gilbert Islands natives examined by him had microfilariae in their peripheral blood. This group comprised 365 from the island of Apamama, 100 from Tarawa, and 201 from Makin. The natives surveyed came, as workmen, from the islands of Apamama, Tarawa, Nonouti, Makin, Marakei, Beru, Tapeteuea, Apaiang, and Nukunau in the Gilberts. Although the data on the incidence of infection in this group are not given according to home island, it is indicated that the infection rate was highest on Tarawa, slightly lower on Apamama, and practically nil on Makin. From evidence gained by the authors from the group of Gilbert islanders surveyed on Guadalcanal it is assumed that Stempien's survey was conducted during daylight hours since the overall percentage rate (9.8) for this group more nearly corresponds with the authors' daytime survey on a similar group of individuals from the same locations.

It has not always been possible to obtain accurate data on the incidence of microfilariae in the peripheral blood for the different age-groups.

This is especially true with regard to the Melanesians. Consequently, the individual Melanesian was classified as child or adult, the fifteenth year of life being selected as the crucial age at which to separate the two categories. This seemed to be the more desirable course to follow since the vast majority of the Melanesians have no conception of their age, and few of them speak more than a very rough pidgin English. In Samoa it was possible to obtain more accurate data on this point although even here many of the individuals were unable to give more than a rough estimate of their age. Tables 2 and 3 give the results of this phase of the study for the Melanesians and Polynesians, respectively.

TABLE 2

Incidence of blood microfilariae in Melanesian adults and children surveyed on the New Hebrides and Solomon Islands.

Island groups	Age groups	Males			Females		
		Number surveyed	Number positive	Percentage infected	Number surveyed	Number positive	Percentage infected
New Hebrides	Adult*	218	63	28.90	127	21	16.53
	Child**	33	2	6.06	18	0	0.00
Solomon Isl.	Adult	277	62	22.38	45	16	35.55
	Child	52	8	15.38	24	3	12.50
		Total adult males			495	125	25.25
		" " females			172	37	21.51
		" male children			85	10	11.76
		" female "			42	3	7.14

* Over 15 years of age
** Fifteen years old and younger

The data in Table 3, taken from Dickson 1943, depict the incidence of filarial infection for the various age-groups in the sample of Polynesians on American Samoa, although no explanation is offered as to the reason for the groupings employed. In the younger age-groups a three-year interval is employed and a five-year interval in the older age-groups. However, according to the incidence rates encountered in the numbers surveyed in each of the age brackets, the relative percentage incidence rate remains the same regardless of whether the three-year or the five-year interval is employed.

The more basic information contained in Table 3 is the trends in the incidence rate for this group of Polynesians. During the first 15 years of life the incidence of infection quickly attains a "childhood level", here

TABLE 3

Incidence of microfilariae in the peripheral blood
for the indicated age-groups in the Polynesian population on American Samoa*

Age group	Males			Females			Total		
	Number surveyed	Number positive	Infection rate	Number surveyed	Number positive	Infection rate	Number surveyed	Number positive	Infection rate
0-3	109	2	1.8	124	3	2.4	233	5**	2.1
4-6	121	7	5.8	115	6	5.2	236	13	5.5
7-9	110	2	1.8	105	5	4.8	215	7	3.3
10-12	97	2	2.1	81	8	9.9	178	10	5.6
13-15	55	3	5.5	68	4	5.9	123	7	5.7
16-20	110	22	20.0	98	7	7.1	208	29	13.9
21-25	136	24	17.6	82	8	9.8	218	32	14.7
26-30	144	42	29.2	63	13	20.6	207	55	26.6
31-35	78	22	28.2	48	9	18.7	126	31	24.6
36-40	95	37	38.9	52	7	13.5	147	44	29.9
41-45	68	21	30.9	25	3	12.0	93	24	25.8
46-50	45	17	37.8	26	2	7.7	71	19	26.8
50 & over	70	36	51.4	46	12	26.1	116	48	41.3
Total	1238	237	19.1	933	87	9.3	2171	324	14.9

* Table 1 from Dickson, 1943.
** All positives apparently three years of age.

roughly 5 per cent, and maintains this level throughout childhood and into early adulthood. The slight lag in the incidence rate in the very young can undoubtedly be explained on the basis of the individual's incubation period for the acquired infection. Throughout this early period (first 15 years) the incidence rate in the female equals or exceeds that in the male. Undoubtedly, it can be assumed that the incidence rate in the male and female Samoan is the same for the first six years of life, despite the earlier appearance of microfilariae in the blood of the female. After the sixth year of life the incidence of blood microfilariae reaches a much higher level in the female than in the male. The higher level is maintained throughout the remainder of childhood and puberty, after which the rate in the male attains a level again equal to that in the female. The rate in the male surpasses the female level during adolescence and maintains this higher level throughout the remainder of life. Between the ages of 26 and 35 and, to a certain extent, for the remainder of life, there is an unexplained increase in the relative incidence rate for the female. During this period the rate in the female more closely approaches that in the male than at any other period, exclusive of the early childhood years.

The differences in these incidence rates for the males and females can, in part, be explained on the basis of the habits of the two sexes. Undoubtedly, the Samoan, regardless of sex, is exposed to the bite of the transmitting mosquito to the same degree during the first few years of life. Although some attempt is made to keep the new born child covered for the first few months of life, none is made to keep clothes on the majority of the slightly older ones. Clothes, in general, are not worn until just before puberty, and during the early part of this period only the lower portion of the body remains more or less permanently covered. Thus, during the early years of life males and females alike are exposed to the bite of the mosquito vector throughout all daylight hours.

As will be shown later, the Samoan village must be considered to be a hyperendemic focus of infection, as evidenced by the high infection rate in the village population and in the mosquito vector. The infection rate in the vector drops off in almost arithmetic proportions at successive intervals away from the centre of the village until it reaches zero at a distance of approximately 150 yards from the periphery of the village. Now, just as soon as the Samoan male is of sufficient age to be trusted out of sight of the parent, he, like all young males, evades the proximity of the family household. Thus, for most of his childhood and adolescent years the male stays away from the village as much as possible. Once he is outside of the 150-yards limit the male is in a filaria-free environment and is no longer exposed to the infection to the same intensity as is the female who remains in the village. This tendency to wander about or to play away from the village is not observed to be the case with the female. However, on becoming of age, and with a consequential change in interest, the male Samoan becomes a regular village dweller. Thus, after puberty and adolescence the habit of the Samoan reverses itself to a large extent. Now the male remains in the village a greater part of the time and is clothed only in a short skirt-like loin-cloth, the "lava-lava". On the other hand, the female, in addition to child-bearing, becomes the principal food gatherer, spending a portion of her time away from the village, and her body is fairly generally protected by clothing from mosquito bites. The strain on the physiology of the female during the active child-bearing period possibly enhances her chances of acquiring some increase in the number of reproducing filaria worms.

Of equal interest is the proposition that the incidence rate as determined by the presence of microfilariae in the peripheral blood stream might just as well as not be the expression of the cumulative quantity of the filaria organisms within the body tissues of a given population. Certainly, in an area where the filaria parasite is endemic the population acquires the infection over a period of years and not overnight, so to speak, as is the case with many bacterial and protozoan infections. Then, just as an incubation period between infection and the appearance of blood microfilariae must elapse in the course of the disease within the individual, a group incubation period is required by the population before the incidence rate attains a level characteristic for the population as a whole for that focus. This incubation period requires between 15 and 20 years for its completion in the Samoan population, as is shown by the almost spectacular jump in the incidence rate from the childhood level (approximately 5 per cent) to the adult level (approximately 24 per cent) after the fifteenth year of life (see Table 3). Each generation must pass through this same cycle in building up the incidence rate characteristic for the adult population group.

During the first six years of life the microfilaria rate is the same for male and female. After the sixth year of life, however, the rate in the male lags behind that for the female until the adolescent years when it overtakes the female rate and even surpasses this during early adulthood. The higher rate is maintained by the male throughout the remainder of life. Undoubtedly, the protection clothing gives the female against the bite of the vector must retard the accumulation rate once clothing becomes a part of her regular habits. On the other hand, the worms accumulated by the male during his early years, plus the more casually acquired worms which come from less frequent contacts with the hyperendemic focus, must suffice to maintain his lower incidence rate until such time as he once again becomes a regular inhabitant of the village. Once this occurs his incidence rate quickly surpasses that of the more protected female and he maintains the higher level throughout the remainder of his life. Thus, the worm burden is built up over a period of years to a precipitous level as much through the accumulation of the parasite over a period of years as by the massive acquisition of additional organisms within a given short period. The importance of acquiring additional parasites for the maintenance of the blood microfilarial infection over long periods of time cannot be over-emphasized.

The youngest individuals (Table 3) found to harbour microfilariae were those included in the first age-group (1 to 3 years old), and here each positive individual was recorded as being three years of age. In a previous study (not recorded here), however, microfilariae were found in the blood of one child 18 months old. For the purpose of this paper, then, it is assumed that at least three years must elapse from the time of birth before microfilariae can be found in any appreciable numbers in the blood stream even in the indigenous population. This undoubtedly means that the native must be at least three years in continuous exposure to an efficient vector within a hyperendemic focus before a sufficient worm burden is acquired for a readable number of microfilariae to appear in the peripheral circulation. Under other conditions this may be delayed for years or may never occur. As is seen from Table 3, at least 15 years of continuous exposure within the hyperendemic area is required before more than 10 per cent of the population will be microfilaria-positive.

When we condense the data for the Polynesians (Table 3) into the two age-groups outlined for the Melanesians (Table 2) it is possible to compare the incidence of infection in the two races in relation to sex and age (Table 4).

TABLE 4

Comparative incidence of microfilariae in the peripheral blood of Polynesians and Melanesians included in the survey (Tables 2 & 3)

Race & Age-groups	Males			Females			Total		
	No. examined	No. positive	Infection rate	No. examined	No. positive	Infection rate	No. examined	No. positive	Infection rate
Polynesian									
Adult*	746	221	26.6	440	61	13.9	1,186	282	23.8
Child**	492	16	3.3	493	26	5.3	985	42	4.3
Total	1,238	237	19.1	933	87	21.5	2,171	324	14.9
Melanesian									
Adult*	495	125	25.3	172	37	21.5	667	162	24.3
Child**	85	10	11.8	42	3	7.1	127	13	10.2
Total	580	135	19.1	214	40	18.7	794	175	22.0

* Over 15 years of age
** Fifteen years old and younger

From the data in Table 4 it is seen that the overall incidence of microfilariae in the blood of Polynesians is roughly only two-thirds of that in the Melanesians. Only in the case of the adult male does the Polynesian surpass the Melanesian in the incidence rate. From the outset (in the first years of life) the infection appears to be more characteristic of the Melanesian population. Both the male and the female Melanesian show a higher rate than is true for the Polynesian, except for the adult males. In the younger age-group both the Polynesian and the Melanesian females show a comparable incidence rate although even here the rate in the Melanesian female is roughly one-third higher than that in the Polynesian female. In the older age-group the Melanesian female proved to have a rate almost double that of the Polynesian female. In the younger age-group the rate in the Melanesian male is almost four times that in the comparable Polynesian males. The differences between the incidence rates of Melanesians and Polynesians are even more striking when the Melanesians examined from Guadalcanal are used for the comparison (See Table 6).

As is seen from Table 4 the almost arithmetically proportionate incidence rate from young female to young male to adult female to adult male (7.1 : 11.8 : 21.5 : 25.3) is demonstrated for the Melanesian population. This is what one would expect among a group of individuals having a similar degree of susceptibility, and who have had identical conditions of exposure from the time of birth. The slightly higher incidence rate in the male members of the group probably suggests a higher degree of protection from the bite of the transmitting mosquito in the case of females in comparison with males, rather than as indicating a higher degree of susceptibility on the part of the male. This point, however, needs further study.

The Melanesians and the Polynesians are, however, not subject to the same set of circumstances in regard to filarial infection. The infection is transmitted during daylight hours by the day-time feeding _Aedes_ mosquito in the case of the Polynesians while a night-feeding _Anopheles_ mosquito is responsible for the transmission of the parasite among the Melanesians. Hence, it becomes obvious that there is no escape for the Melanesians so long as they stay within the village at night. Certainly, as suggested above, if the Polynesians leave the village during the daylight hours they invariably enter a filaria-free area. To return to the village at night means to return to a highly dangerous area at the only safe period of the 24-hour day. The danger of such a procedure, however, is the possibility of building up of a focus of transmission outside of the village area when the same location is visited regularly during the daylight hours. The Melanesian, on the other hand, may roam the island at will during the daylight hours in complete safety from both the infection and from fear of establishing a focus of infection away from the village proper. On returning to the village at night, however, both males and females alike literally come home to the principal focus. The anopheline mosquito transmits the infection to the Melanesians under cover of darkness and while they are at home in the village. Undoubtedly, in the absence of protective night clothing and bed netting, this night transmission of the infection, in part, explains the higher overall rate of blood microfilariae among the Melanesians than among the Polynesians, as well as the almost arithmetic proportional rate between males and females for the two age-groups (see Totals, Table 4). Certainly, here the very young acquire the infection in the same relative proportions as regard to sex, and those proportionate rates are maintained into the adult ages.

In both of the New Hebrides and Solomon Islands the periodic strain of the parasite is the only one present, and only Melanesian and Tonkinese individuals, as more or less permanent residents, were available for study. In the Solomon Islands one small group of Gilbert islanders became available for study shortly after their arrival in the area. In the study on these two island groups the survey was more keenly interested in that part of the native population which lived or worked in the immediate vicinity of the Armed Forces although every effort was made to obtain as nearly a complete cross section of the general population as was possible within the short time available. In both areas, except for the Tonkinese population, the greater majority of natives living in the vicinity of the Armed Forces consisted of male workmen. As a consequence of this dearth of females and children among the workmen, the survey had to be taken beyond the occupied areas to get information relating to the general population.

On Espiritu Santo (New Hebrides), approximately 250 adult Melanesian and 800 Tonkinese labourers lived and worked in the immediate vicinity of the Armed Forces. From this group of plantation workmen we were able to get blood samples from 520 Tonkinese and 183 Melanesians. The remainder of the Melanesians included in the survey came from four locations, two villages on the mainland of Espiritu Santo and two small islands just off the mainland (see below). Of the workmen from the plantations only six natives from the island of Espiritu Santo were surveyed, the others coming from various islands within the New Hebrides group. Table 5 gives the results of the filaria survey from New Hebrides and Table 6 records the data on the group surveyed from the Solomon Islands.

The data presented in Tables 5 and 6 make no attempt to give a true picture of the relative incidence of blood microfilariae in these two groups of natives. Although special attention was given to those natives who were quartered within the occupied area of Espiritu Santo, the natives did not constitute an organized labour force such as that found on Guadalcanal. On Espiritu Santo the natives (Melanesians and Tonkinese) were employed by individual plantation operators, and these were scattered throughout the coastal area. The labourers from several of the islands within the group consisted of both males and females, as well as some children. The infection rate in these Melanesians is attributed to the home island since the labourers were employed on the plantations for only a six-month period. Just how long the majority of these labourers had been away from the home island or how many six-month periods they had been on Espiritu Santo could not be determined since there was a great deal of shifting from island to island and between the home islands and the ones on which they worked. However, the incidence

TABLE 5

Incidence of microfilarial infection in Melanesians surveyed from various islands in the New Hebrides group

Island	Age groups	Males			Females		
		Number surveyed	Number positive	Infection rate	Number surveyed	Number positive	Infection rate
Ambrym	Adult*	2	0	...	0	0	...
	Child**	0	0	...	0	0	...
Aoba	Adult	8	4	50.00	7	2	28.57
	Child	0	0	...	0	0	...
Araki	Adult	15	0	...	9	0	...
	Child	5	0	...	3	0	...
Banks Islands	Adult	38	15	39.47	39	12	30.77
	Child	3	0	...	0	0	...
Efate	Adult	8	0	...	0	0	...
	Child	0	0	...	0	0	...
Espiritu Santo	Adult	58	19	32.76	37	3	8.11
	Child	14	2	14.28	4	0	...
Malekula	Adult	28	13	46.43	1	1	...
	Child	0	0	...	0	0	...
Malo	Adult	0	0	...	1	1	...
	Child	0	0	...	0	0	...
Pentecost	Adult	30	9	30.00	6	2	33.33
	Child	0	0	...	0	0	...
Tangoa	Adult	21	0	...	26	0	...
	Child	13	0	...	11	0	...
Tanna	Adult	2	0	...	1	0	...
	Child	0	0	...	0	0	...
Torres Islands	Adult	5	2	40.00	1	1	...
	Child	0	0	...	0	0	...

	Number surveyed	Number positive	Infection rate
Total adults	343	84	24.49
" children	53	2	3.77
" males	250	64	25.60
" females	146	22	15.07

* Over 15 years of age

** Fifteen years old and younger

rates determined for those islands from which a representative number of natives came should give some indication as to the filarious condition existing on the home island, especially among the older age-groups.

TABLE 6

Incidence of microfilariae in the peripheral blood of Melanesians surveyed from the various islands of the Solomon Islands

Island	Age groups	Males			Females		
		Number surveyed	Number positive	Infection rate	Number surveyed	Number positive	Infection rate
Guadal- canal	Adult*	88	42	47.73	31	14	45.16
	Child**	21	5	23.80	15	3	20.00
Malaita	Adult	471	48	10.19	0	0	...
	Child	10	0	...	0	0	...
San Cristobal	Adult	243	99	40.74	0	0	...
	Child	1	0	...	0	0	...
Others	Adult	8	0	...	0	0	...
	Child	14	0	...	0	0	...
		Total adults			841	203	24.14
		" children			61	8	13.11
		" males			856	194	22.66
		" females			46	17	36.96

* Over 15 years of age
** Fifteen years old and younger

On Guadalcanal, on the other hand, an entirely different force was in operation. Here all natives indigenous to that island had been relocated at a safe distance from the occupied zone and only organized labour battalions were recruited from the general native population for work within this zone. These labourers worked for the Armed Forces solely, and were housed away from the majority of the service personnel. The labourers came from only three of the islands within the Solomon Islands, namely Guadalcanal, Malaita, and San Cristobal, with small groups of male labourers brought in from Fiji, Gilberts, and other islands as required. For this reason the data presented in Table 6 cannot be taken as a true picture of the filariousness in the area. In the first place, only males, usually between 13 and 40 years of age, were employed in the labour battalions and, secondly, they were selected with some consideration for their ability to work. Hence, the group studied consisted of the more select, healthy males. Especially is this true for all groups except those coming from the island of Guadalcanal.

Fortunately, the survey was conducted on Guadalcanal where special transportation was not required in taking a more liberal sample of the general population of that island. The more liberal was considered necessary for a more rounded survey of the Guadalcanal natives since only 26 of the males from the labour battalions came from that island. Table 7 gives the incidence of blood microfilariae in the labour battalions as opposed to the general population on Guadalcanal.

TABLE 7

Incidence of microfilariae in the peripheral blood of the Guadalcanal natives as compared with the rate found in males only of the labour battalions

Group	Number surveyed	Number positive	Infection rate
Labour battalion	751	151	20.11
Guadalcanal natives	129	59	45.74

When the data in Table 7 are compared with those in Table 6 it is seen readily that the incidence rate found in the labour battalions on Guadalcanal is due to the high rate in natives from the island of San Cristobal. Undoubtedly, those in charge of recruiting the labour battalions take cognizance of the general diseased condition of both the San Cristobal and Guadalcanal native in their selection of workmen for these battalions; hence, the proportionately larger number of natives from Malaita. We feel justified, from the data at hand, therefore, in assuming that the filarious condition among the natives on the island of Malaita (Table 6) is much lower than that among the natives on either Guadalcanal or San Cristobal, and that the natives on the two latter islands have about the same high microfilaria rate. Surveys by other workers confirm this view.

Among the Polynesians surveyed in American Samoa the microfilaria count ranged between 1 and approximately 1,000 per 40 c.mm. of blood. The average count was however very low. The microfilaria count in a unit volume of blood of a given population gives some indication of the extent of transmission of the infection which is possible by the vectors of that parasite. The effect of over-parasitism in the mosquito vector has been demonstrated on several occasions, and is confirmed for the *Aedes* vector in American Samoa (present paper). It has been shown that the optimum number of microfilariae per cubic millimeter of blood should be between one and five for the general transmissibility of the parasite. It becomes obvious, then, that the number of microfilariae in the blood stream of a given population greatly affects the extent of transmission of the infection. In cases in which the microfilaria count is constantly below the optimum level for transmission, too few mosquitoes will become infected for the maintenance of the infection in the human host over long periods of time, while a microfilaria count in excess of the optimum will cause a progressive mortality in the mosquito host in proportion to the number of larvae above the optimum, ultimately resulting in greatly reduced transmission. Thus, just as in the case of a very light infection, too heavy an infection materially reduces the transmissibility of the filaria parasite.

Table 8 gives the microfilaria counts per cubic millimeter of blood in the Melanesians and Tonkinese surveyed from the New Hebrides and Solomon Islands. It is seen that the highest microfilaria counts were observed among natives from the Banks Islands and from Guadalcanal. Even with such high counts the averages for the Melanesians from New Hebrides and Solomon Islands fall within the range of optimum numbers for infecting the mosquito vector. In contrast to American Samoa, where the number of microfilariae per 40 c.mm.of blood ranged from 1 to 1,000, the counts in the New Hebrides went up to only about 600, while a single record of 1,600 was from a Guadalcanal native. On Guadalcanal, in a like manner, one female child (six years of age) proved to have 440 microfilariae in 40 c.mm. of peripheral blood. With the exception of this female child, and one male child (14 years of age) who had as many as 130 microfilariae in 40 c.mm. of blood, all other children harboured larvae far below the 100 count level. Among the 54 Gilbert Islands natives showing microfilariae in the peripheral blood the counts ranged between 1 and 280 per 40 c.mm., while the highest count recorded for the Tonkinese was 150. Thus it is seen that, in a heavily infected population (the degree of infection judged from the demonstration of microfilariae alone), relatively few of the individuals harbour excessive numbers of the larvae, while the majority of the infected persons will carry these at a level more in accord with the number optimum for the maintenance of constant infection in the transmitting mosquito population.

4. INCIDENCE OF PHYSICAL SIGNS OF FILARIASIS

No case of elephantiasis was recorded among the Tonkinese on the New Hebrides Islands. This is not altogether surprising, despite the fact that these individuals were imported from an area where Wuchereria malayi is endemic, and each positive individual proved to carry larvae of that parasite only. The Tonkinese now in the New Hebrides Islands were imported into the area as young

TABLE 8

Total number of microfilariae counted in the 40 c.mm. blood sample, with the average number per cubic millimeter of blood, from the positive individuals from the New Hebrides and Solomon Islands

Race or Island	Males			Females			Both sex		
	Number infect -ed	Total number of micro- fila- riae	Aver- age number per c.mm.	Number infect -ed	Total number of micro- fila- riae	Aver- age number per c.mm.	Number infect -ed	Total number of micro- fila- riae	Aver- age number per c.mm.
Tonkinese	36	804	0.56	7	59	0.21	43	863	0.50
Gilbert Islands	54	1,505	0.69	..	...	....	54	1,505	0.69
Espiritu Santo	21	272	0.32	3	22	0.18	24	294	0.31
Banks Islands	15	2,041	3.40	12	1,329	2.77	27	3,370	3.12
Pentecost	9	497	1.38	2	132	1.65	11	629	1.43
Malekula	13	368	0.71	1	7	0.17	14	375	0.67
Aoba	4	84	0.52	2	63	0.78	6	147	0.61
Malo	..	...	....	1	3	....	1	3	0.07
Torres Islands	2	16	0.20	1	131	3.27	3	147	1.22
Malaita	48	1,039	0.54	..	...	....	48	1,039	0.54
San Cristobal	99	4,275	1.08	..	...	....	99	4,275	1.08
Guadalcanal	47	7,133	3.79	17	2,186	3.22	64	9,319	3.64
Total Melanesians, New Hebrides							86	4,965	1.44
" Melanesians, Solomon Islands							211	14,633	1.73
" Melanesians adults							287	18,938	1.65
" Melanesians children							10	660	1.65

adults for labour on the plantations. Presumably they are as select a group of this race as it is possible to obtain at the time of importation.

Although 43 or 8.27 per cent of the 520 Tonkinese surveyed proved to harbour W. malayi larvae in the peripheral blood at night (7.30 to 11.30 pm.) in no case was the microfilaria count large (150 being the maximum count in 40 c.mm.). This, however, does not preclude the likehood of elephantiasis developing, especially in view of the findings of workers in China, India, Malaysia, and the Dutch East Indies, where such manifestations are reported even among the very young. In these areas the incidence of elephantiasis not infrequently is reported to be as high as 80 per cent for local groups.

Of 398 Melanesians examined from the New Hebrides only six or 1.51 per cent had elephantiasis. Two of these were from among the six persons surveyed from the Torres group. In one of them the lower half of the left leg was involved; his night blood was negative for microfilariae. The other individual from the Torres Islands had an advanced hydrocele; he was positive for microfilariae (8 per 40 c.mm.). Of the remaining four individuals with obvious elephantiasis one was from the island of Malekula, one from the Banks group, and two from Espiritu Santo; none of these showed microfilariae in the night blood. One additional person was recorded as having deep abscesses; his night blood was negative for microfilariae. It is not possible to say whether these abscesses were a result of filarial infection or related to it in any way.

The Micronesians surveyed on Guadalcanal were recent recruits from the Gilbert Islands. Although 54, or 16 per cent, of the 332 surveyed (Table 1) proved to carry microfilariae in the peripheral night blood, only a single individual showed obvious elephantoid manifestations.

A total of 12 cases of elephantiasis and hydrocele was recorded among the Melanesians studied from the Solomon Islands. These were distributed among the three islands as follows: Guadalcanal, 5 cases (3.2 per cent of 155 surveyed, Table 6); Malaita, 4 cases (0.8 per cent of 481 surveyed); and San Cristobal, 3 cases (1.2 per cent of 244 surveyed). The parts of the body affected were as follows: left leg, 2 cases; right leg, 2 cases; right arm, 2 cases; left arm and leg, 1 case; both arms and legs, 2 cases; scrotum, 2 cases; breast (right), 1 case. Only 2 of the 12 cases of elephantiasis proved to have microfilariae in the night blood, 1 and 5 microfilariae respectively. The youngest individual with advanced elephantiasis was a male, 15 years of age, from the island of San Cristobal.

In the report on the survey of American Samoa, Dickson (1943) gives the following account of filariasis and filarial signs.

(a) "<u>Elephantiasis</u>

"Only 57 cases were found on the survey of 2,171 Samoans, an incidence for all ages of 2.6 per cent. This is probably less than the true incidence as not unlikely many cases stay away from such surveys through modesty. The condition was found in every possible combination with hydrocele and gross glandular enlargements. It is very interesting that no case of elephantiasis of the female breast was seen, nor has it been seen in the Samoan hospital during the past two years. Pictures of the condition (in Samoa) are prominently displayed in books published about 50 years ago. Its absence may well be related to the custom of covering the upper part of the female body. Likewise, no instance of elephantiasis of the female labia was found. However, only gross cases would have been found as the part of the body in question was not uncovered. However, it has not been seen, so far as is known, in recent years in the Samoan hospital.

"Age distribution: The youngest case (elephantiasis) seen was aged 24 years and the oldest 70. The incidence increases steadily with advancing age as shown by the following tabulations (where the numerator indicates the number with elephantiasis and the denominator the total number in the group). Age 21 to 30: 3/425 or 0.7%; 31 to 40: 16/273 or 5.9%; 41 to 50: 19/164 or 11.6%; 51 and over: 19/116 or 16.4%.

"Sex distribution: As seen from Table II*, the percentage incidence of elephantiasis is nearly twice as high in males as it is in females.

"Relation to positive filaria blood smears: As shown in Table II*, among males with embryos in the blood the incidence of elephantiasis is nearly twice as high as it is in males (of the same age group) showing a negative smear. Among females no significant difference is apparent, however, the number of cases is probably too small for proper comparison.

"Conversely, the correlation is also well shown by comparing the incidence of positive blood smears among those with elephantiasis with its incidence among those of the same age-group without elephantiasis**. There is a high degree of positive correlation among males, the incidence of positive blood smears being some 50 per cent greater among those with elephantiasis. Again, there is no significant variation, in this respect, among females.

"Relation to epitrochlear enlargement: Examination for such enlargement was recorded in 54 of the cases of elephantiasis. Enlargement was found in 40, an incidence of 74.1 per cent. Among all others over 20 (not showing elephantiasis) it was found in 472 of 924 individuals, an incidence of 51.1 per cent.

"Relation to gross enlargement of inguinal and femoral glands: Inasmuch as one or the other of these groups of glands is almost invariably

*Table 9 on page 22.
**Table 9a on page 22.

enlarged at all ages, it was extremely difficult to draw a line as to when such enlargement becomes significant. Only gross enlargements have been included. Among the 57 cases of elephantiasis the finding was recorded 13 times, an incidence of 22.8 per cent. Among all others over 20 (not showing elephantiasis) it was only found in 22 of 924, an incidence of 2.2 per cent.

"Relation to hydrocele: Of 44 males with elephantiasis 8, or 18 per cent, also had hydrocele. The incidence of hydrocele in all males above 15, not showing elephantiasis, was 70 among 702, or 10 per cent."

(b) "<u>Hydrocele</u>

"78 cases were found among 1,238 males of all ages, an incidence of 6.3 per cent. Its true incidence is probably considerably higher. In addition to the likelihood of many staying away from the surveys, small hydroceles can be readily missed as can post-operative cases (which were counted when found). Its true incidence may well be as high as 10 per cent. It was found in every combination with elephantiasis and epitrochlear, femoral and inguinal glandular enlargement.

"Age distribution: The youngest case seen was 16 and the oldest 69. Therefore, its incidence among the males of the affected age-group (746 individuals) was 10.5 per cent. Similar to elephantiasis, though less markedly, the percentage incidence increases with advancing age up to age 50: Age 16 to 20: 5/110 or 4.5%; 21 to 30: 17/280 or 6.1%; 31 to 40: 25/173 or 14.4%; 41 to 50: 19/113 or 16.8%; 50 and above: 10/70 or 14.3%.

"Relation to positive filaria blood smears: As shown in Table V*, hydrocele was much more frequent (by over 40 per cent) in those with positive blood smears than it was in those with negative smears. Conversely, the incidence of positive blood smears among those showing the condition was 37.2 per cent (29 of the 78 cases); whereas among 668 other males 16 years and older, without hydrocele, positive blood smears were found in 192, an incidence of 28.7 per cent.

"Relation to epitrochlear enlargement: 68 of the 78 cases of hydrocele also showed epitrochlear enlargement, an incidence of 87.2 per cent. Among 668 other males 16 years and older, without hydrocele, epitrochlear enlargement was found in 403, an incidence of 60.3 per centum.

"Relation to enlargement of inguinal and femoral glands: Among the 78 cases of hydrocele gross enlargement of these glands was found in 11, an incidence of 14.1 per cent. Among 668 other males of the affected age-group (16 and above), such enlargement was recorded in 34, an incidence of only 5.1 per cent."

*Table 12 on page 23.

(c) "Epitrochlear enlargements

"This has been largely covered under elephantiasis and hydrocele. Buxton claimed that there is a high degree of correlation between the incidence of such enlargement and the incidence of positive blood smears in Polynesia after childhood; that both yaws and filariasis cause such enlargement but that due to yaws is transient and mostly confined to childhood; that after childhood the epitrochlear rate is a good index of the amount of filariasis in an area. He emphasizes, however, that such is not the case in other parts of the world where the filaria is of the periodic type. In the present surveys, it was found that at all ages and in both sexes, epitrochlear enlargement is extremely common (42.3 per cent). The incidence is higher in each age-group among males. The combined incidence (all ages) is more than twice that found among females (54.6% vs. 25.9%). At times the degree of enlargement is very great, masses up to the size of a small orange being found at the site of the gland, the condition practically amounting to a small elephantiasis. Above the age of 20 the epitrochlear rate is usually, though not invariably, higher among those with positive blood smears, and invariably higher among males. Of 253 of both sexes above 20 with positive blood smears, 158 (or 62.4%) showed such enlargements; of 725 with negative blood smears epitrochlear enlargement was found in 354 (or 48.8%). The casual relationship to filariasis is also shown by comparing the incidence of positive blood smears among those showing such enlargement with the incidence of positive blood smears among those not showing epitrochlear enlargement. Among those over 20 the incidence of positive blood smears is usually, though not invariably, higher among those showing epitrochlear enlargement. Combined figures for all ages above 20 and both sexes show that 30.9 per cent of those showing epitrochlear enlargement also had positive blood smears, whereas only 20.4 per cent of all those over 20 without enlargement had positive smears."

Of 419 urines examined, persons 30 years or over, only one was found in which the typical "milky" condition of chyluria was observed.

In commenting on the findings of the survey Dickson (1943) draws attention to the following: "The increasing incidence of positive blood smears with advancing age is undoubtedly due to an accumulation of increasing numbers of adult worms in the body. No explanation can be offered for the lowered incidence among males of the age-group 7 to 9 or for the increased incidence among females of the group 10 to 12. The lower incidence among females (as compared with males) after the age of 16 seems to be explainable, at least in part, by the difference in dress which starts about the age of 13 or 14. The females, from puberty on, cover the breasts and the males do not. This must considerably reduce the number of inoculations suffered by the females.

TABLE 9

"Elephantiasis: Incidence among those 21 years and over, by sexes, with and without microfilariae in the blood and total incidence in the two sexes separately and combined."*

Condition of smear	Sex	Total examined	Elephantiasis	
			Number	Percentage
Microfilariae positive	Male	199	20	10.0
	Female	54	2	3.7
	Total	253	22	8.7
Microfilariae negative	Male	437	24	5.5
	Female	288	11	3.8
	Total	725	35	4.7
Microfilariae positive and negative	Male	636	44	6.9
	Female	342	13	3.8
	Total	978	57	5.8

* Table II from Dickson, 1943

TABLE 9a

"Incidence of positive Mf. blood smears among 57 cases of elephantiasis as compared with its incidence in all those over 20 who did not show elephantiasis."*

Sex	With elephantiasis			Without elephantiasis		
	Number	Number with microfilariae	Percentage	Number	Number with microfilariae	Percentage
Male	44	20	45.5	592	179	30.2
Female	13	2	15.4	329	52	15.8
Total	57	22	38.6	921	231	25.1

* Table II(a) from Dickson, 1943

"As the proof that elephantiasis is caused by filariasis is not considered absolute, it is well to summarize the evidence brought out above: (i) Elephantiasis, in Samoa, takes many years to develop. No cases were seen under the age of 20 when the percentage incidence of positive blood smears attains several times its incidence in childhood; (ii) The incidence of both elephantiasis and positive blood smears

TABLE 10

"Elephantiasis: Incidence among males and females of all ages".*

Sex	Total examined	Elephantiasis	
		Number	Percentage
Males	1,238	44	3.6
Females	933	13	1.4
Total	2,171	57	2.6

* Table III from Dickson, 1943

TABLE 11

"Elephantiasis: Anatomical distribution of 57 cases."*

Single		Paired	
Part affected	Number of cases	Part affected	Number of cases
leg	19	2 legs	10
arm	2	2 arms	1
scrotum	8	2 arms and 2 legs	2
Multiple			
1 arm, 1 leg	4	1 arm, 1 leg, scrotum	1
1 arm, 2 legs	2	1 arm, 2 legs, scrotum	1
1 arm, scrotum	1	2 arms, 2 legs, scrotum	1
2 arms, scrotum	2	2 legs, scrotum, penis	1
1 leg, scrotum	2		

* Table IV from Dickson, 1943

TABLE 12

"Hydrocele: Incidence among males 16 years and over with and without microfilariae in the blood and incidence among males of all ages."*

Condition of blood	Total examined (males)	Hydrocele	
		Number	Percentage
Mf-positive	221	29	13.1
Mf-negative	525	49	9.3
Total	746	78	10.5

"Incidence among all males (1,238): 6.3 per cent"
* Table V from Dickson, 1943

increases progressively with advancing age; (iii) The incidence of positive blood smears and the incidence of elephantiasis (in the affected age-group) are both much higher in males; (iv) The incidence of positive blood smears (in males) is about 50 per cent higher among those who show elephantiasis than it is in those who do not show the condition; (v) Glandular enlargements, (epitrochlear, inguinal and femoral) and hydrocele, commonly accepted as caused by filariasis, are all of much greater frequency among those with elephantiasis than they are among those without it.

"As with elephantiasis, the evidence that hydrocele is caused by filariasis is uniform and impressive, i.e., its greater frequency among those with positive blood smears as well as the greater incidence of positive blood smears among those with hydrocele, the greater incidence of glandular enlargements (epitrochlear, inguinal, and femoral) among those with hydrocele, and lastly, the greater incidence of hydrocele among those showing elephantiasis.

"The high degree of correlation of epitrochlear enlargement with positive blood smears, as well as with elephantiasis and hydrocele, leaves little room for doubt that, as claimed by Buxton, the condition (en masse) is causally related to filariasis. However, blood surveys would seem to be more accurate in determining the amount of filariasis in a community."

In regard to deep abscesses the report gives a brief account of "over 100 cases" treated in the Samoan hospital during the year. Two deaths resulted from these cases. It is believed that these abscesses "are caused by the implantation of pyogenic organisms, by way of blood or lymphatic channels, into lymphatic structures previously damaged by filarial blockage. The process starts as a phlegmon in a fascial space or as an acute lymphadenitis." Approximately 50 to 60 per cent of the cases are multiple and roughly 90 per cent go on to suppuration. Several such cases occurred among children. Smears from the vast majority of the abscesses showed staphylococci although one showed streptococci and another colon bacilli. It should be pointed out that the 100 or more cases of deep abscesses were not necessarily a part of the filaria survey, but should give some indication of the number of such cases reporting to the American Samoa hospital for medical care yearly.

The youngest individual in the Samoan Islands observed by the writers to have advanced elephantiasis was a lad of seventeen. Both legs and one arm were involved and one leg had developed the condition to about twice the size of a normal leg. The condition was of at least two, possibly three years' standing. The individual was a native of Wallis Island.

5. MICROFILARIAL PERIODICITY

Since its discovery the phenomenon of periodicity of the microfilariae has intrigued workers in the field of tropical medicine and been the subject of investigation and research. Such investigations soon led to the discovery by Thorpe (1896) and others that, in certain areas of the filarial belt, a strain of the parasite occurred in which the larvae failed to show the usual nocturnal periodicity in the peripheral blood, but which occurred in the blood in almost equal numbers both day and night. At the present time this aperiodic variety of the parasite is known to be the only strain occurring in the indigenous populations on the Ellice Islands, Samoa, Cook Islands, Tonga, Fiji, the Tuamotu Archipelago, the Marquesas, Australs, and Society Islands.

Dickson (1943) examined thick smears of approximately the same volume of blood collected during day-time from 352 residents of one village in American Samoa and found that 11.1 per cent were positive for microfilariae. On a second visit to the same village of 165 smears taken between the hours of 2300 and 2400, 21 (or 12.72 per cent) proved positive for microfilariae. No appreciable difference was noted in the numbers of microfilariae in night blood as compared to day-blood.

In the group of Gilbert Islanders surveyed, quite a different picture from that demonstrated in Samoa was obtained. Fifty-four of the 332 persons (16.3 per cent) proved to have microfilariae in the night-time circulation (Table 1). Twenty-six of the microfilariae positive individuals were examined between 1345 and 1430 hours, and fifteen (or 57.7 per cent) of these were found to be positive during the daylight hour (Table 13). A total of 1,202 microfilariae was counted in the night samples of blood while only 112 occurred in the daytime samples. The average night count was 46.15 microfilariae per 40 c.mm., or 1.16 larvae per cubic millimeter of blood, whereas an average of 4.31 larvae per host, or 0.11 larvae per cubic millimeter of blood, was observed in the daytime blood.

It is seen (Table 13) that in only three of these Gilbert Islanders did a sufficiently large number of microfilariae appear in the daytime blood for them to be considered as being "blood positive" by Samoan standards. Even here in only one of them (No. 7) did the daytime level of microfilariae approach the halfway level of the count observed for the night-time sample. With the possible exception of these three individuals the data in Table 13 conform more closely with what would be expected in an instance involving the typically periodic filaria.

Although the exact time is not given, it is assumed that the survey conducted by Stempien (1944) on Gilbert Islanders was made during daylight hours. If this be true, our own findings, in part, confirm this earlier record.

TABLE 13

Microfilaria counts in 40 c.mm. of the daytime and night blood of 26 positive Gilbert Islanders

Serial number	Number in day blood	Number in night blood	Serial number	Number in day blood	Number in night blood
1	1	23	14	2	13
2	0	11	15	3	45
3	0	52	16	1	11
4	0	32	17	24	83
5	5	57	18	0	42
6	1	48	19	21	278
7	40	98	20	2	30
8	6	25	21	1	107
9	0	11	22	0	44
10	0	16	23	2	18
11	0	11	24	0	29
12	0	64	25	0	26
13	2	16	26	1	12

Total positive, night survey	26 or 100 per cent
Total positive, day survey	15 or 57.7 per cent
Total number of microfilariae, night survey	1,202 or 46.23 per individual
Total number of microfilariae, day survey	112 or 4.31 per individual

From these data it seems reasonable to assume that the filarial infection endemic in the Gilbert Islands is, for the most part, of the periodic variety and not an importation into the Gilberts from the Ellice Islands as is believed by Stempien (1944). Yet, when compared to the infection in the Melanesian a difference is observed for the daytime level of microfilariae: only 2.3 per cent of the total number of microfilariae counted in the night blood of the Melanesian appeared in the daytime sample (Table 15) while 9.3 per cent of the night count appeared in the day blood of the Gilbert islander (Table 13). On the other hand, almost equal numbers of microfilariae appear in the day and night blood in the case of the non-periodic filaria in Polynesia.

In the New Hebrides 46 Tonkinese and 28 Melanesians were tested for the periodicity of the microfilaria. Table 14 gives the results of the day and night surveys of these two groups.

TABLE 14

Incidence of infection in Tonkinese and Melanesians examined both during the day and the night

Race	Parasite involved	Hour of survey	Number surveyed	Number with microfilariae	Percentage infected
Tonkinese	Wuchereria	1300 to 1400	46	0	...
	malayi	1930 to 2030	46	6	13.04
Melanesians	Wuchereria	1300 to 1400	28	9	32.14
	bancrofti	1930 to 2030	28	15	53.57

From the data in Table 14 it would appear that the periodicity demonstrated for Wuchereria malayi in this group of Tonkinese is more sharply defined than is the case with W.bancrofti in the Melanesian. It is generally reported that this is not the case, however. On the other hand, the relatively high incidence rate for the daytime blood of the Melanesians could be misleading unless the actual number of microfilariae per unit volume of blood from both the day and the night blood samples was known. Table 15 records the data on the number of microfilariae per unit volume of blood (40 c.mm.) for the hours of the survey.

TABLE 15

Number of microfilariae per 40 c.mm. of day and night blood in each of the positive individuals indicated in Table 14

	Melanesian (W. bancrofti)			Tonkinese (W. malayi)	
Serial number	1300 to 1400 hrs.	1930 to 2030 hrs.	Serial number	1300 to 1400 hrs.	1930 to 2030 hrs.
1	0	58	1	0	56
2	0	3	2	0	37
3	11	527	3	0	52
4	0	8	4	0	1
5	1	107	5	0	1
6	0	76	6	0	2
7	0	1			
8	13	501			
9	1	131			
10	2	12			
11	16	71			
12	0	4			
13	12	549			
14	5	539			
15	1	72			

Although 9, or 60 per cent, of the 15 Melanesians with positive night blood proved to have microfilariae in the day blood (Table 15), only 62, or 2.3 per cent, of the total number of microfilariae (2,659) counted in the night samples of blood were encountered during daytime. The average night count of microfilariae was 177.3 per 40 c.mm. of blood while the average daytime count for the 15 persons studied was 4.1.

An average of 25 microfilariae per 40 c.mm. of blood was recorded in the night blood samples taken from the 6 Tonkinese but no microfilariae were seen in daytime samples.

The nocturnal periodicity of the microfilaria present in Solomon Islanders has been established by Schlosser (1944) and Vincent (1944). Their observations are furnished in Tables 16 and 17.

TABLE 16

Incidence of blood microfilariae in day and night blood from a sample of the general native population in the Solomon Islands

Observer	0700 to 1800 hours			2000 to 2400 hours		
	Number surveyed	Number infected	Percentage infected	Number surveyed	Number infected	Percentage infected
Vincent (1944)	335	24	7.2	170	21	12.4
Schlosser (1944)	484	20	4.1	409	100	24.4
Total	819	44	5.4	579	121	20.9

TABLE 17

Incidence of blood microfilariae in the same group of 398 Melanesians surveyed during daylight hours and again at night (from Schlosser, 1944)

Hour	Number surveyed	Number infected	Percentage infected
1400 to 1800 hours	398	17	4.3
2100 to 2400 hours	398	85	21.4

Schlosser (1944) also made microfilaria counts in ordinary thick blood smears taken at 2-hourly intervals over a 24-hour period from three microfilaria carriers and demonstrated the typical nocturnal periodicity of the microfilaria.

6. STUDIES ON MOSQUITOES

(a) AMERICAN SAMOA

(i) Natural infection in mosquitoes

Table 18 furnishes the results of examination of mosquitoes from American Samoa for the presence of natural infection with filaria larvae. Only three species were found infected, two of which, namely Aedes pseudoscutellaris* and Culex fatigans showed high natural infection rates of 10.7 per cent and 7.4 per cent respectively and carried developing filaria larvae in a sufficiently large number of individuals to be reckoned as of possible importance in the transmission of the parasite. Both the species are common in populated areas.

However, as shown later (page 31), C. fatigans does not enjoy as widespread a distribution in the Samoan area as does A. pseudoscutellaris. In many places the former species is replaced by the night feeding Aedes (Finlaya) samoanus, which is perhaps the second most common mosquito in American Samoa. All of the 251 specimens of Aedes samoanus proved to be free from filarial infection. None of them showed the presence of even a recently ingested microfilaria in the stomach (see page 44).

In order to determine the relative importance of the three species found infected in nature, a consideration of the age distribution of the filaria larvae found in them is necessary (Table 19). In the solitary infected specimen of Aedes aegypti, only recently ingested microfilariae were found in the stomach. This finding as well as the fact that A. aegypti is a rare mosquito on Tutuila (American Samoa) would show that it is of no importance in the transmission of filarial infection.

*The mosquito designated as Aedes pseudoscutellaris in the present paper conforms to the species, Aedes polynesiensis, described by Marks (Ann.Trop. Med.Parasit., 45: 137-140, 1951). In view of the findings of Rozeboom (J.Econ.Ent., 47: 383-387, 1954) and of Woodhill (Proc.Linn.Soc.N.S.W., 79: 19-20, 1954) who have shown that the two species, Aedes pseudoscutellaris and A. polynesiensis, are capable of producing fertile hybrid populations to F_2 and F_3 generations, it seems not yet certain whether the two species are specifically distinct.

TABLE 18

Incidence of natural infection with *Wuchereria bancrofti* larvae in mosquitoes examined from American Samoa

Species of mosquito	Number examined	Number positive	Percentage infected
Aedes pseudoscutellaris	4,293	458	10.7
Aedes samoanus	251	0	....
Aedes aegypti	122	1	0.8
Aedes vexans	3	0	....
Culex fatigans	1,063	79	7.4
Culex annulirostris	35	0	....

Note.- In addition to the above, the authors examined mosquitoes collected from Aitutaki (Cook Islands) for filarial infection. From a native village on that island the following mosquitoes were examined: 10 *Aedes pseudoscutellaris*, 13 *Culex fatigans*, and 1 *C. annulirostris*. Of the 10 specimens of *A. pseudoscutellaris* examined from this village, two were positive (respectively with one larva 12 days of age, and 7 larvae 8 days of age), giving an infection rate of 20 per cent; the other mosquitoes examined from this village gave negative results. None of 64 *Aedes pseudoscutellaris* collected from personnel camps on Aitutaki Island proved to be infected.

TABLE 19

Distribution in days of age* for developing filaria larvae from naturally infected mosquitoes in American Samoa

Species	Number of mosquitoes harbouring filaria larvae for the indicated day of developmental age													
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Aedes pseudoscutellaris	8	-	10	156		-	51	5	78	3	14	56	-	89
Aedes aegypti	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Culex fatigans	72	-	1	4	1	-	-	-	1	-	-	-	-	-

*Fourteen days being considered as the average time required for the complete development of the larva from microfilaria to the infective stage in the mosquito host.

The vast majority of the 79 infected specimens of Culex fatigans contained only recently ingested microfilariae while only 7 harboured filaria larvae in a more advanced stage of development than the microfilaria stage. It therefore seems highly improbable that this mosquito would play an important role in the transmission of the infection in American Samoa. Moreover it was not found to have a wide distribution over the entire area, although either the larvae or the adults of the species came from practically all of the larger villages. In no area was it the most common mosquito, and in but a few locations was it the most common night feeding variety. This rather limited distribution together with the dissection findings definitely indicate that it is only of minor importance in the transmission of the filaria. This conclusion is further supported by the findings of experimental infection carried out in the laboratory (see Table 25). Less than 30 per cent of laboratory bred C. fatigans picked up filaria larvae when fed on a carrier having 1.77 microfilariae per cubic millimeter of blood, and only one per cent of all exposed specimens developed the larva to the infective stage.

Aedes pseudoscutellaris, on the other hand, not only proved to be heavily infected in nature (10.7 per cent), and showed a distribution of developing larvae from recently ingested microfilariae to the infective stage (Table 19), but 87.9 per cent of the mosquitoes fed on a carrier picked up the infection (Table 26). More than 80 per cent of the experimentally infected specimens which survived long enough to permit complete development of the larva showed fully developed infective larvae on dissection. Further, the species has a wide distribution over the entire area.

In American Samoa, then, Aedes pseudoscutellaris alone appears to be the mosquito which transmits filariasis. The writers, however, do not doubt that an occasional specimen of Culex fatigans may develop the larva to infectivity in nature, and that the species may be responsible for a very minor part of the transmission which occurs, although the part played by C. fatigans would be negligible in comparison to that played by A. pseudoscutellaris. The relative importance of the two species as natural vectors of filariasis in Samoa is further demonstrated in Chart I.

For the purpose of the survey it seemed essential to divide the island of Tutuila (Samoa) into three sections for study: (1) Armed Forces camp areas (a safe distance from the native population); (2) camp-village areas (in which both Armed Forces personnel and natives were located an unsafe distance apart), and (3) purely native village areas. Table 20 gives the dissection records on A. pseudoscutellaris and C. fatigans collected from each of these three locations.

It should be pointed out that by the time the troops arrived at bases in American Samoa the urgency of the military situation was such that it was considered to be of the gravest importance that the area be occupied with a

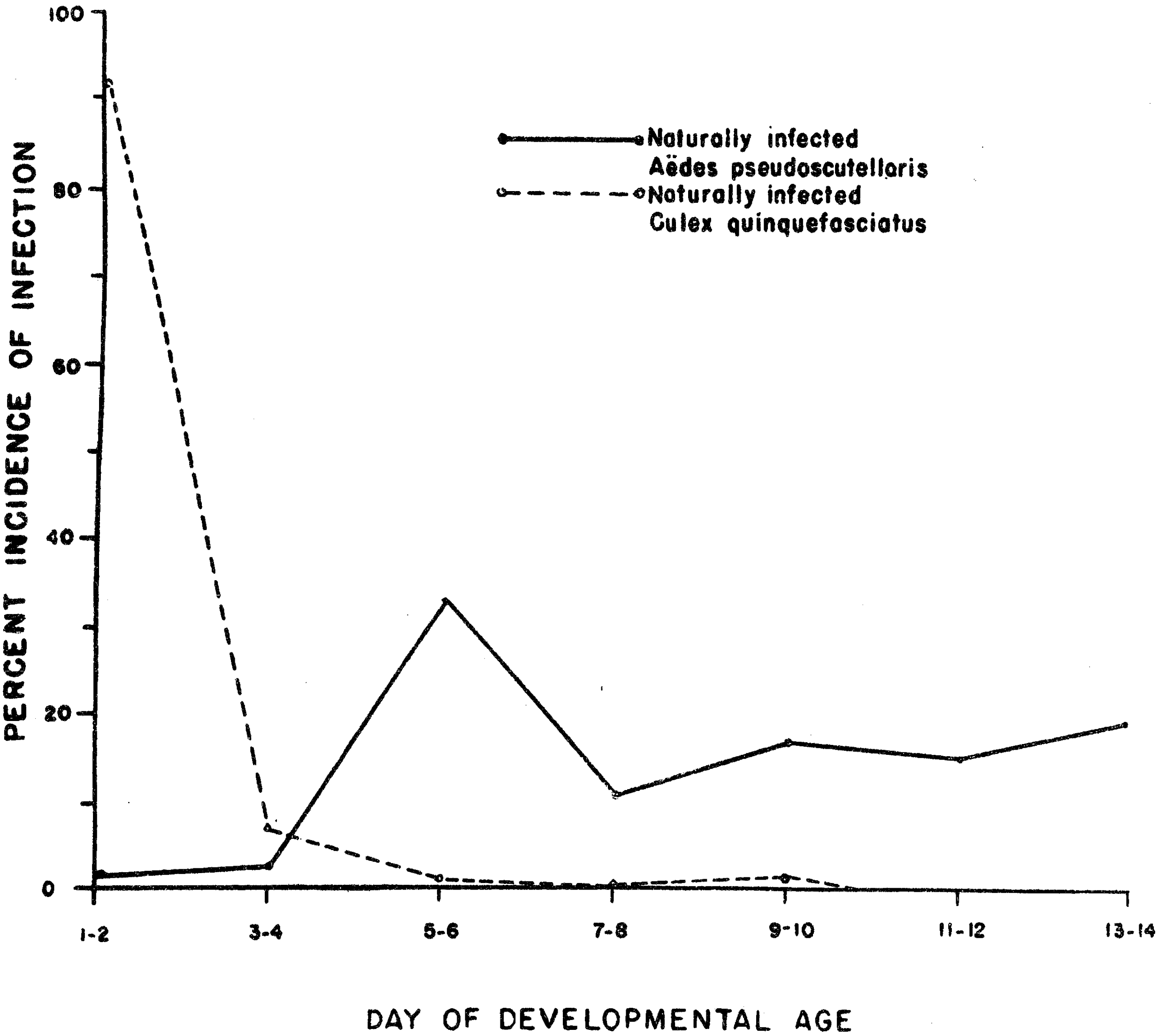


Chart 1. Observed incidence of filarial infection in naturally infected Aedes pseudoscutellaris and Culex quinquefasciatus (C.fatigans) in Tutuila (American Samoa). The percentage incidence is determined from the number of each species harbouring filaria larvae for the indicated days of larval development. The small number of A. pseudoscutellaris found infected with larvae of the 1-2 and 3-4 days of age is believed to be due to the high death rate in the host during the first few days of the infection and to failure of the recently engorged female to seek an additional blood meal (see page 45).

minimum of disturbance to the natural topography of the island, and a total defence organized within a minimum period of time. Thus, the troops were brought to the island and dispersed in accordance with the plan of defence. This plan of defence necessitated wide dispersal of troops to strategic points and, since the utmost care was exercised towards maintaining what natural concealment the island afforded, the troops unceremoniously moved into and established themselves in the only conveniently available locations within proximity of their areas of defence. It was unfortunate that practically every one of such favourable sites for camp location was already occupied by a native village group, with its filarial infection.

At the time of our arrival troops occupied quarters within, or at an unsafe distance from, more than two-thirds of the villages. In many of the villages currently occupied, ingenious schemes for camouflage had been devised and perfected. In a great many of the camp-village areas the personnel portion of the location was so well concealed by camouflage that no more than a fraction of the total number of buildings would have been seen by a stranger chancing to pass through the camp. Usually the more perfectly camouflaged camp areas were those which had been located to the immediate rear of the smaller native villages, in the narrow and shallow cove-like valleys. The camouflage practices being exercised in many of the camps undoubtedly increased both the breeding and resting places of the principal vector, thereby resulting in a local increase in the mosquito population.The area just to the rear of the native village provided ample breeding and resting places for the infected and uninfected specimens of the mosquito host alike and the establishment of camps in such areas undoubtedly brought the infected mosquito into a closer contact with the uninfected personnel.

Whatever condition of parasite-mosquito-human relationship the disturbance in the more or less static epidemiology, which had existed prior to the war, had attained by the time the authors arrived, those factors having a bearing on such disturbances had been at work for some months already and the relationship should have become as stable as the situation permitted. Thus, during the period of the investigation the data included in Table 20 can be taken as representative of the degree of infection in the mosquito host within the designated areas. This, however, does not mean that those conditions of mosquito density and infection rate were static throughout the entire period. During the initial phase of the occupation mosquito density within the camp areas undoubtedly was as high as that in the village. By density studies this was demonstrated to be the case in many of the camp-village areas. The data in Table 21 gives the overall (average) density of the principal mosquito vector for the entire island, as well as for the controlled (camp and camp-village) and the uncontrolled areas (village and unoccupied locations) on the island of Tutuila.

The average density (mosquitoes per man per hour) given in Table 21 represents a fair index of the density of <u>Aedes pseudoscutellaris</u> on the island

TABLE 20

Incidence of natural infection in Aedes pseudoscutellaris and Culex fatigans from the village, camp-village, and camp areas on the island of Tutuila (American Samoa)

Species	Village			Camp-village			Camp		
	Number dissected	Number positive	Infection rate	Number dissected	Number positive	Infection rate	Number dissected	Number positive	Infection rate
Aedes pseudoscutellaris	1,221	163	13.3	2,247	294	13.1	825	1	0.1
Culex fatigans	224	18	8.0	839	61	7.3	...	..	...

TABLE 21

Observed density of Aedes pseudoscutellaris for the controlled and uncontrolled areas on Tutuila over a period of nine months

Location	Number of catches	Number of mosquitoes caught	Average density*
Uncontrolled area	143	18,415	129
Controlled area	81	1,509	19
Total	224	19,924	89

* The average density represents the number of mosquitoes caught per man per hour.

of Tutuila. As will be shown later this species is a prolific breeder (page 68) and a vicious, though quiet biter (page 71). It breeds over the entire island but flies only a very short distance (page 69) in search of the blood meal. Thus, with a high incidence of blood microfilariae in the fairly stable village group and an efficient vector having a short flight range, the Samoan village becomes a hyperendemic focus for filariasis. This being so, the number of service personnel who contracted filariasis during the early phase of the occupation of the island can only be guessed at.

The amount of control work required to reduce the mosquito density from the uncontrolled level of 129 mosquitoes per man per hour (Table 21) to the controlled level of 19 mosquitoes per man per hour is surprisingly little (see page 85). This control work consisted of removing breeding places and of keeping the grass, weeds, and underbrush cropped to lawn length. By this process, the "camp beautiful" programme, the density of the vector was reduced in a matter of days to almost zero. Hence, the average of 19 mosquitoes per man per hour for the controlled area (Table 21) represents the average for the entire period of nine months and not the density attained by a single control effort.

Important as vector density is in the transmission of filarial infection, vector density only governs the amount of transmission (page 83). Thus, density is an invaluable adjunct to incidence of infection. The infection rate in the vector _per se_ is a poor criterion by which to judge the importance of a species in the transmission of the parasite (see Tables 18 and 19 for value of percentage infection in _Aedes pseudoscutellaris_ and _Culex fatigans_ on Tutuila). It becomes apparent, therefore, that for a mosquito to play a major role in the transmission of the filaria organism, the species must not only be able to pick up the microfilariae from the blood, but must survive the course of the developmental cycle of the parasite in a sufficiently large percentage of the individuals for the parasite to be passed on to the next susceptible human host. As is shown below (Table 26), _A. pseudoscutellaris_ fulfilled these requirements in the laboratory to the extent that 18.6 per cent of the experimental series survived long enough with a positive worm burden to have passed the parasite on to a susceptible host. In the field, however, this percentage survival rate for all mosquitoes is less striking, although it is sufficiently high to maintain a demonstrated 14 per cent incidence in the local native population (Tables 1 and 3). For the nine months of the study on Tutuila 2.6 per cent of all _A. pseudoscutellaris_ and 19.5 per cent of all positives had survived in the field long enough to develop the filaria to the stage infective to man. With the high survival rate in the _Aedes_ mosquito, the density factor has a profound influence on the amount of transmission in American Samoa. Table 22 gives the data on the incidence and survival rates in _A. pseudoscutellaris_ for each month of the survey on Tutuila.

Although the epidemiological studies which commenced in Samoa in May 1943, were terminated before a period of one year had been covered, the information on the monthly infection rates in the principal vector in the area is fairly complete for the period of the study.

From the information furnished in Tables 22 and 23 it is possible to detect certain variations and trends in the parasite-mosquito relationship within the two seasons and from season to season. From Table 22 it is seen that more than 9 per cent of all _A. pseudoscutellaris_ were infected for each month from May 1943 to January 1944, with high rates of over 15 per cent during

TABLE 22

Monthly dissection record on <u>Aedes pseudoscutellaris</u> from native populated places in Samoa, with the number of specimens carrying infective stage larvae and the percentage survival of mosquitoes harbouring this stage of the parasite

Month	a Number dissected	b Number positive	c Infection rate	d Number with infective stage larvae	e Percentage survival to infectivity	f Percentage of positives to survive to infectivity
May, 1943	134	19	14.2	6	4.5	31.6
June	392	72	18.4	17	4.3	23.6
July	550	62	11.3	13	2.4	21.0
August	349	61	17.5	14	4.0	23.0
September	678	61	9.7	11	1.6	18.0
October	476	60	12.6	10	2.1	16.7
November	231	29	12.6	8	3.5	27.6
December	422	66	15.6	7	1.7	10.6
January, 1944	286	27	9.4	3	1.0	11.1
Total	3,468	457	13.2	89	2.6	19.5

the months of June, August, and December 1943. Such high infection rates become less significant when compared with the survival rate to infectivity for <u>all</u> mosquitoes (the percentage of all mosquitoes to survive long enough for the filaria larva to complete its development within the host) and the percentage survival to infectivity for <u>positive</u> mosquitoes only. Although considerable fluctuation is seen in the rates (incidence and survivals), it should be noted that approximately twice as many mosquitoes permitted the full development of the larvae (monthly percentage survival to infectivity) during the dry months as did so during the first two months of the rainy season which followed.

One very marked exception to the above observation occurred during the course of the study. During the month of September (Table 22) only a 9.7 per cent incidence of infection was noted and a survival rate of 1.6 per cent of all mosquitoes. With these two marked drops in the rates expected it was difficult at first to explain why there was not a corresponding drop in the percentage survival for positive mosquitoes. This, we believe, is explained, in part at least, by the data recorded in Table 23.

TABLE 23

Climatological data for Tutuila, Samoa
for period of January, 1943, through May, 1944

Month	Mean temperature	Relative humidity (%)	Mean rainfall (inches)	Direction and mean wind velocity (knots per hour)	Percentage survival of all *Aedes pseudo-scutellaris* to develop infective stage larva
January, 1943	80.3	84	9	E. 5.6	
February	80.8	83	8	NNW. 5.6	
March	80.0	85	19	ESE. 5.2	
April	80.9	84	7	NNW. 4.9	
May	80.5	83	15	E. 6.4	4.5
June	79.1	77	2	SE. 10.1	4.3
July	78.7	82	3	E. 8.5	2.4
August	78.1	79	28	ESE. 9.8	4.0
September	76.4	81	6	E. 8.5	1.6
October	81.0	81	8	E. 8.0	2.1
November	81.1	81	5	E. 5.0	3.5
December	81.2	82	18	NW. 4.4	1.7
January, 1944	81.3	84	18	NW. 5.4	1.0
February	80.4	85	14	NW. 5.9	
March	81.2	86	7	NNW. 4.5	
April	80.7	86	9	E. 6.2	
May	80.9	85	8	ESE. 7.6	

When the data in Table 23 are analysed it is seen that 28 inches of rain fell during the month of August 1943, after a period of two months with practically no rain at all. It is obvious, therefore, that during the month of September large numbers of uninfected *Aedes pseudoscutellaris* were emerging from recently filled breeding containers to dilute the mosquito population. This is reflected in the lower infection rate (9.7 per cent) for September and in the 1.6 per cent survival of all mosquitoes for that month. On the other hand, the survival rate for positive mosquitoes shows but little change from the preceding month, a feature which is realized to be the normal when it is remembered that the parasite itself is the principal immediate factor governing the survival or death of the individually parasitized hosts.

The infection rates for October and November show a recovery from the lower rate of September. This is what one would expect to find in a population of mosquitoes as susceptible to filarial infection as the Aedes mosquito gives every indication of being. The infection rate was even higher during December than those recorded for October and November. It is observed, also, that during August there was a decided rise in the infection rate over that of the preceding month. Twenty-eight inches of rain fell during the month of August while there was only 18 inches of rainfall during the month of December.

From the low rate of survival (1.6 per cent) of all mosquitoes for the month of September, a steady increase is noted for October and November, until the 3.5 per cent level is reached. After this there is a decided drop in this rate to slightly above the one per cent level, at which level the rate was maintained for the remainder of the period of study. The drop from 3.5 per cent in November to 1.7 and 1.0 per cent respectively during December and January, coincides with the beginning of the rainy season. It is highly probable that the low incidence of infection (9.4 per cent) for A. pseudoscutellaris for the month of January (Table 22) is influenced by the rainy season (18 inches of rainfall during December 1943 as well as during January 1944, Table 23). Such a drop in the infection rate for January corresponds to the drop for the month of September, following the heavy rainfall during August (Table 22). However, during December 1943 and January 1944, a corresponding drop is experienced in the percentage survival to infectivity for all mosquitoes as well as for the survival of positive hosts. One explanation is apparent: the change from the dry to the wet season. The climatological factors, characteristic of the rainy season, undoubtedly play a major role in the physiology of both the mosquito host and the developing filaria. In the laboratory the mosquito passes through its developmental cycle to emerge as the adult much quicker (as much as by three or four days) during the season of higher temperature than is true for the opposite and the filaria's developmental time may be reduced by as much as 7 to 10 days from the maximum for the season of lower temperature. Certainly, the increased breeding of the mosquito host during the rainy season accounts for the dilution of the mosquito population by unfed recently emerged hosts and, hence, the lower infection rate. Increased temperature, high relative humidity, and heavy rainfall, with a corresponding acceleration in the physiology of both the mosquito and the parasite, in part explain the lowered survival rate to larval infectivity for the beginning of the rainy season (Table 22).

With the end of the rainy season in May 1943 (Table 23) the percentage survival rates (Columns e and f, Table 22) show a gradual falling off from the 4.5 and 31.6 per cent levels respectively as the dry season continues. It is probably indicated, therefore, that the low survival rates experienced at the beginning of the rainy season gradually recover during that season, and that the season of maximum filarial transmission is during the last half of the rainy and the first half of the dry periods. With certain variations the incidence of infection in the mosquito host should remain essentially the same for the months of both seasons.

The number of developing filaria larvae, as well as the number and nature of multiple infections, in naturally infected _Aedes pseudoscutellaris_ in American Samoa should be of some interest. In Table 24 information on the number of filaria larvae in the mosquito host is recorded for only the first, third, and fifth days prior to the first moult, the seventh day of developmental age. As will be shown later (experimental studies) these earlier stages in the developmental cycle of the parasite failed to show up in the general mosquito population because of (1) the feeding habits of the host (it will be remembered that only feeding mosquitoes were taken) and (2) the high mosquito mortality which occurs during the first few days of the infection. The relatively few specimens harbouring larvae of the eight day of developmental age, in addition to the fact that one of these harboured as many as 40 larvae, accounts for the high average count for this day of age. Wherever information is available, the worm burden per host is fairly uniform for the various days of the developmental cycle.

TABLE 24

Maximum and average numbers of developing filaria larvae for each day of developmental age in naturally infected _Aedes pseudoscutellaris_ in Samoa

Day of developmental age	Worm burden	
	Maximum number in one host	Average number per host
1	19	6.5
2	..	...
3	25	6.2
4	..	...
5	31	7.8
6	..	...
7	28	8.1
8	40	14.0
9	18	6.6
10	8	5.0
11	11	6.1
12	23	6.7
13	..	...
14	14	3.5

Number of single infections	448
Number of double infections	6
Number of triple infections	3

The vast majority (448) of the 457 naturally infected Aedes pseudoscutellaris from American Samoa harboured only a single developmental stage of the filaria parasite. Whether this can be taken as an indication of an immunity to superinfection in this host, it is impossible to say at the present time. It will be seen however that nine of the mosquitoes did carry more than a single developmental stage of the parasite, three of which carried triple infections. The number of mosquitoes with multiple infections is insignificant in comparison with the number carrying a single developmental stage, and could very well be taken as evidence of (1) an immunity to superinfection in the mosquito, or (2) a low survival rate for hosts carrying superimposed infections. As will be shown later this same degree of singleness of infection in the transmistting host was notencountered outside of the Samoan area.

(ii) Experimental infection of mosquitoes

The same native volunteer was used to infect all of the more common species of mosquitoes present on the island of Tutuila. In the earlier experiments adult mosquitoes bred in the laboratory were fed on a native volunteer one to four days after emergence. Engorged females were isolated in a cage in which ample food (sugar water) and a place for them to lay eggs were provided. After the infective blood meal the mosquitoes were given the opportunity to feed on microfilaria-free blood at least once each day. In the final experiment, Aedes pseudoscutellaris mosquitoes were given at least one feed on microfilaria-free blood before being fed on infective blood. The high mortality rate observed among young infected females suggested this procedure as a measure of protection against any untoward effect the ingestion of the first blood meal might have.

In the first few experiments only a fraction of the total number of fed mosquitoes were recovered from the cages, and all were dead within a very few days. Even with the reduced numbers of hosts being recovered from the experimental cages in the earlier tests, a definite clue as to the species involved in the transmission of the filaria parasite was obtained. In the first attempt 22 of the 48 Aedes pseudoscutellaris fed were recovered from the experimental cage; of these more than 50 per cent were infected. Of the 16 recovered from the second cage of 54 fed, 12, or 75 per cent, carried developing larvae and a single specimen of this lot survived for 14 days and contained 2 fully developed larvae. In a further experiment 83 per cent of the specimens recovered from a cage of 63 fed mosquitoes harboured developing larvae. One of these survived for as long as 11 days and contained 9 infective stage larvae. These nine larvae were distributed in the body as follows: 1 in leg, 2 in abdomen, 4 in thorax, 1 in head, and 1 in labium.

All the 12 Aedes vexans mosquitoes fed on infective blood proved to be negative for filariae on the fifth day. On the other hand, a single specimen out of 22 Aedes aegypti mosquitoes harboured larvae of four days of developmental age.

Twenty-five Culex annulirostris that took a full blood meal on a carrier with 71 microfilariae per 40 c.mm. of peripheral blood were isolated into a cage. On the second day (following the blood meal) two of the three dissected specimens contained normally developing larvae. Both specimens dissected on the third day contained developing larvae. On each of the next two days a single specimen harboured larvae while two of the five specimens dissected on the sixth day proved to be infected. A single larva was found in one of the specimens examined on the seventh day. This was the last positive to be found in this batch of mosquitoes although the experiment continued on through the thirteenth day.

In the first experiment with Culex fatigans all the 18 specimens were negative for developing larvae at the end of the eighth day following engorgement of the infective blood meal.

In a second experiment 101 Culex fatigans mosquitoes were fed on the native volunteer (having 71 microfilariae per 40 c.mm. of peripheral blood), and were treated in the same way as C. annulirostris above. Table 25 gives the results of this experiment.

TABLE 25

Infection in 101 experimental Culex fatigans in Samoa

Day after infective meal	Number dissected	Number positive
1	...	...
2	1	1
3	5	3
4	12	6
5	3	3
6	10	3
7	12	2
8	..	..
9	8	3
10	5	1
11	2	..
12	8	6
13	18	..
14 or more	17	1

Percentage positive 28.7
Percentage with infective stage larvae 1.0
Percentage positive to reach larval infectivity 3.5
Length of the experiment .... 16 days

Of 190 Aedes pseudoscutellaris mosquitoes that fed on the same native volunteer, 167 showed filarial infection (Table 26).

TABLE 26

Results obtained on 190 Aedes pseudoscutellaris experimentally infected with Wuchereria bancrofti in Samoa*

Species	Number positive	Percentage infected	Number negative	Percentage negative
Aedes pseudoscutellaris	167	87.9	23	12.1

Number to survive 14 or more days	38
Number with infective stage larvae	31
Percentage of positives to survive to larval infectivity	18.6
Length of the experiment	25 days

*See also Tables 27 and 29.

When the data contained in Tables 25 and 26 are compared with those recorded in Tables 18 and 19 (page 30) and Chart I, it is seen that laboratory tests confirm the findings on naturally infected Aedes pseudoscutellaris and Culex fatigans in American Samoa. In the case of C. fatigans an incidence of 7.4 per cent is reported for naturally infected specimens while no specimen was taken in the field in which larvae older than the ninth day of developmental age were observed (Table 19). In the laboratory 28.7 per cent of the specimens picked up larvae while only one per cent of these developed the larvae to the infective stage (Table 25). It should be pointed out, however, that six specimens of the species carried larvae in advanced stages (12 days of developmental age). It seems probable that some of these specimens would have survived to the completion of the developmental cycle of the larva had they been permitted to continue to the end of the experiment. Even had this been permitted, and assuming that all of the positive individuals would have survived to the complete development of the larva, only 7 per cent of the experimental host would have proved to carry the infective stage larvae at the termination of the experiment. As is evident from the data on the naturally infected host (Tables 18 and 19), fewer specimens of the species survived in nature than did so in the laboratory, indicating a longer survival period for the positive host in the more protected environment of the laboratory. Further, when it is remembered that all specimens of the species taken in nature were captured from native huts on the morning following engorgement the percentage incidence of natural infection for C. fatigans was obtained under more favourable circumstances than is true for A. pseudoscutellaris. Thus, specimens of C. fatigans taken in nature more nearly corresponded to the test made in the laboratory than is the case with the Aedes host. Yet, in the field no specimen of C. fatigans was taken in which larvae older than the ninth day of developmental age were observed.

In regard to Aedes pseudoscutellaris it will be remembered that no attempt was made in the field to take this host directly from the native hut. Captures were made at all hours of the day and from locations well away from native habitation, as well as from personnel camps and native villages. The 10.7 per cent incidence of infection reported for the species (Table 18), thus, represents the observed incidence in the host for the area covered. In a like manner, the 19.5 per cent survival (to infectivity for the filaria larva) in all positive mosquitoes of the species (Table 22) represents the survival rate for the host in nature over a period of nine months. The 87.9 per cent infection rate recorded in the experiment (Table 26) probably represents the true infection rate for all individuals of the species in Samoa which chanced to feed on infected persons having a number of microfilariae per cubic millimeter of blood comparable to that reported for the volunteer used in the feeding experiment. On the other hand, the 18.6 per cent survival (to infectivity) reported for the experimentally infected Aedes (Table 26) compares favourably with the survival level (19.5 per cent, Table 22) recorded for the naturally infected mosquito for the duration of the study.

The experiment involving Aedes pseudoscutellaris was carried onto the twenty-fifth day following the infective blood meal. On the last day of the experiment only 5 of the 190 fed females were still alive. It is important to remember that the mosquitoes in this experiment were offered a blood meal at least once daily for the first 11 days of the experiment. After that time fruit and sugar water were the only available food supply. Of the five specimens which survived to the twenty-fifth day four were positive for infective stage larvae.

In further experiments conducted with this mosquito, the native volunteer was transported to an area where the mosquitoes were previously determined to be free from filaria infection and engorged females were captured after they had fed on the volunteer. These experiments amply confirmed those conducted under laboratory conditions.

It is of some interest to analyse the data on the experimental host's ability to take up the microfilaria from the blood stream. The microfilaria count in a 40 c.mm. blood sample taken from the native volunteer ranged between 57 and 97. More consistently than not this number fluctuated around 70, and for each of the 3 experiments reported above the number was determined to be

71, or 1.77 microfilariae per c.mm. of blood. The average number of larvae for each day of developmental age and the maximum number in any one host in experimentally infected Aedes pseudoscutellaris are given in Table 27.

TABLE 27

Data on the number of Wuchereria bancrofti larvae taken up by Aedes pseudoscutellaris at a single blood meal from a Samoan native having 1.77 microfilariae per c.mm. of peripheral blood.

Day of developmental age	Mosquitoes dying during experiment		Mosquitoes killed during experiment	
	Maximum number in one host	Average number per host	Maximum number in one host	Average number per host
1	8	3.80	..	....
2	25	6.40	..	....
3	17	5.22	..	....
4	14	5.00	..	....
5	8	3.66	7	4.20
6	9	4.50	..	....
7	10	10.00	4	4.00
8	3	3.00	4	2.00
9	2	2.00	8	5.66
10	4	4.00	12	9.50
11	6	5.50	12	5.37
12	4	1.80	12	7.00
13	..	....	10	4.66
14	12	5.40	7	4.00
More than 14	6	3.10	5	4.20
Average	..	4.70	..	5.18

Average number of larvae per positive mosquito: 4.82

Stage and Yates (1936) working with Aedes vexans and A. aldrichi, reported that the mosquito is capable of imbibing as much as 1.99 c.mm. of blood at a meal. If this figure can be taken as the volume of blood withdrawn by Aedes pseudoscutellaris in Samoa, it is seen that the mosquito was able to find more larvae in the blood of the carrier than it was possible to demonstrate in an equivalent amount of blood by the sampling method employed. For all but four days of the developmental cycle the average number of larvae was more than twice the number demonstrated by the sampling method. This average number of larvae for all of the experimental mosquitoes was more than 60 per cent greater, while individually 40 per cent of the hosts were able to find two or more times as many larvae in the blood than the simple prick of the finger could produce. The greatest number of larvae found by any one mosquito was twenty-five.

Ashburn and Craig (1907), and others, pointed out this ability of the transmitting mosquito to find more microfilariae in the blood of the infected individual than could be shown by routine laboratory methods. The phenomenon appears to be fairly common among the so-called "good transmitters" of filariasis, although species which are not involved in the transmission of the infection often fail entirely to pick up even an occasional microfilaria from a heavily infected person. This fact was clearly demonstrated in Samoa by using specimens of Aedes samoanus, a common night feeding mosquito in the area. This species breeds extensively throughout the area, breeding in small accumulations of water in the axils of the Taro, Mat grass, and Pandanus plants. It is a vicious night feeder. Yet, not a single specimen of the species was taken in the field which proved to have even recently ingested microfilariae in the digestive tract, and many of the individuals were caught directly from natives known to have microfilariae circulating in the peripheral blood and from whom microfilaria-positive A. pseudoscutellaris had been taken earlier during the day. O'Connor (1923) reported the finding of a filaria larva in an arrested stage of development in the thorax of a closely related species, Aedes (Finlaya) kochi, from the Ellice Islands. In a personal communication Heydon (1944) reports Aedes (F.) kochi to be very susceptible to the nocturnal periodic W. bancrofti experimentally at Rabaul, New Britain. The evidence gained through dissections of specimens caught in nature in Samoa precluded any attempt on our part to experimentally infect A. (F.) samoanus on Tutuila.

In the laboratory, on the other hand, Aedes pseudoscutellaris was able to pick up as many as 25 larvae in the approximately 2 c.mm. blood meal from an individual demonstrated to have 1.77 microfilariae per c.mm. of circulating blood. Specimens caught in nature frequently carried 25 or more developing larvae, although the average number for all mosquitoes was much lower than this (6.78 worms per host, Table 28).

In the field Culex fatigans picked up an average of 6.47 microfilariae per meal per host although in the experimental series only 3.68 larvae (with a maximum of 20) per mosquito were acquired from a source in which 1.77 larvae per c.mm. of blood could be demonstrated. Table 28 summarizes the data on the worm burden observed in A. pseudoscutellaris and C. fatigans in Samoa.

From Table 19 it is seen that only incomplete data are available on the number of filaria larvae in the naturally infected Aedes pseudoscutellaris for

TABLE 28

Average and maximum numbers of filaria larvae picked up by naturally infected Aedes pseudoscutellaris and Culex fatigans from the blood stream of Samoans as compared with the number acquired from a known source of infection

Species	Naturally infected		Experimentally infected*	
	Average	Maximum	Average	Maximum
Aedes pseudoscutellaris	6.78	40	4.82	25
Culex fatigans	6.47	23	3.68	20

*Volunteer native carried 1.77 microfilariae per c.mm. of peripheral blood at the time of feeding.

several of the days of the developmental cycle. No data are available for the second, sixth, and thirteenth days. As a matter of fact, the data recorded in the Table take into account only 8 and 10 mosquitoes for the first and third days, respectively. When it is recalled that the data in Table 19 are the results obtained from 458 positive mosquitoes out of over 4,000 dissected (Table 18), and this is considered in the light of data in the experimentally infected host (Table 29), it becomes obvious that the greater majority of the hosts containing the younger stages in the development of the parasite were not available for study. Three factors are recognised as being responsible for this scarcity of the earlier developmental stages: (1) the authors' unfamiliarity with the developing larvae during the initial phase of the study; (2) the feeding habits of the mosquito host; and (3) the high mortality rate in recently infected mosquitoes.

With regard to the first of these factors it can be said that the criteria by which the filaria larvae are determined to be of a specific day of developmental age permit only a rough approximation. However, as one attains some skill in this capacity it is recognized that the specific day of developmental age of a larva refers only to its degree of development and not to any one of a set number of days. The development of the larva to full maturity requires from 11 to 17 days (in our experience), with an average of fourteen days. Thus, the 14-day period is taken as the basis by which to judge the age of any one larva, with no reference being made to the actual day of age the larva has attained. Certainly, therefore, with even a moderate amount of experience in the field one can be trained to estimate more or less accurately the degree of development the larva has undergone. Thus, we feel justified in claiming to have recorded a minimum number of errors in this regard.

With regard to the second factor it is observed (field and laboratory studies) that the mosquito host feeds regularly about every third or fourth day. In the laboratory recently engorged females will feed again the next day, although the number of feeding individuals will increase daily until the maximum number is reached. This occurs on the third or fourth day. Afterwards approximately equal numbers will feed daily. In the field, on the other hand, one seldom takes a specimen of Aedes pseudoscutellaris in which a partly engorged blood meal is in the stomach, as evidenced by the eight mosquitoes harbouring recently engorged larvae in the digestive tract (Table 19). As further evidence, a few of the Aedes mosquito harboured more than a single developmental stage of the parasite. In these mosquitoes (Table 24) the degree of development attained by the larvae attests to the feeding habits of the host. In one specimen, larvae one and three days of age were observed. In another, these were five and nine days of age. In two specimens larvae as old as 5 and 12 days of age were observed. In one the larvae were 7 and 14 days of age. In the triply infected mosquitoes one specimen carried larvae respectively 1, 12 and 14 days of age, while 5, 9, and 12, or 14 days of age were recorded for the larvae in two others. Thus, it is seen that from three to four days is the most frequent interval between feeding times for the Aedes mosquito in the field, as can be judged by the age of the successively acquired filaria larvae. In view of this interval between feeding times one would expect to capture a uniform sample of mosquitoes containing all stages in the developmental cycle of the parasite. This occurred only for those hosts harbouring the more advanced developmental stages. As is seen from Table 19 hosts containing the younger developmental stages were not available for capture in nature. Because of this disparity in the uniform occurrence of all the developmental ages of the larva, and because of the observed death rate in the experimental host, it is assumed that the absence of the younger developmental stages in naturally infected Aedes in the field is not a natural consequence of the feeding habits of the mosquito.

The data contained in Table 29 give the principal clue to the situation. In all of the experiments with Aedes pseudoscutellaris a very high mortality occurred within the first few days following the infective blood meal, reaching a peak on the third day of the infection, after which the number of deaths fell off very rapidly to a more or less uniformly lower level which maintained for the remainder of the period of experiment.

Table 29 summarizes the data on the death rate in the last lot of experimentally infected Aedes mosquitoes. More than one-half of the experimentally infected mosquitoes were dead by the end of the fifth day. This is true for negative mosquitoes as well as for the positive ones. However, it might be pointed out that all negative mosquitoes dying during the early days of experiment died on the second and third days; no further deaths occurred in this group of mosquitoes until the fourteenth day. The infected hosts continued to die throughout the experiment, but at a rate slower than that observed for the first five days. It will be recalled that no blood meal was given to the mosquitoes after the eleventh day; the death rate in the mosquito thereafter was undoubtedly influenced by the nutrition factor.

TABLE 29

Death rate in experimentally infected <u>Aedes pseudoscutellaris</u> in Samoa

Day of larval age	Number dead in cage*	Percentage death rate	Number positive	Percentage infected	Number negative	Percentage negative
1	5	2.63	5	100.00	..	...
2	18	9.46	15	83.33	3	16.66
3	68	35.79	55	80.88	13	19.12
4	11	5.79	11	100.00	..	...
5	6	3.15	6	100.00	..	...
6	2	1.05	2	100.00	..	...
7	1	0.52	1	100.00	..	...
8	2	1.05	2	100.00	..	...
9	1	0.52	1	100.00	..	...
10	1	0.52	1	100.00	...	...
11	3	1.57	3	100.00	..	...
12	5	2.63	5	100.00	..	...
13	..	....	..	....	..	...
14	7	3.68	5	71.43	2	28.57
15 to 25	23	12.1	19	82.61	4	17.39

Total dead for experiment	153
Percentage dead	80.53
Total dead first five days of experiment	108
Percentage dead first five days of experiment ..	56.84
Percentage positive for first five days of experiment	85.18
Percentage positive for developing larvae (entire experiment)	85.62

*All other mosquitoes in the experiment were killed by ether and examined

In the light of further observations, both in the field and in the laboratory (see Charts IV and VI), the writers are convinced that the death rate observed among experimentally infected <u>Aedes</u> mosquitoes, especially during the early days of the infection is not a factor peculiar to the laboratory experiment, but rather is a natural consequence of the infection in the mosquito. It is a response to the infection whether the host be in the laboratory or in the field. Thus, with the demonstrated high mortality rate in the experimentally infected <u>Aedes</u> in mind it became apparent why data on the worm burden for naturally infected mosquitoes (Table 24) were not obtained for many of the younger stages in the development of the parasite, and why so few of the mosquitoes carrying these stages were available for capture (Table 19). Confirmation of this evidence was forthcoming in the continuation of the work on two other island locations (New Hebrides and Solomon Islands). Here a night-feeding mosquito, Anopheles farauti, was demonstrated to be the principal vector. In this species approximately 70 per cent of the positives carried developing larvae five days of developmental age or younger, while 30 per cent harboured larvae older than this age (Tables 36 and 41). Thus, by the sixth day of larval development the potential 100 per cent rate in the infected host had dropped to a level which yielded only a 30 per cent infection for the older developmental ages.

With this knowledge in mind, it became evident that a proportionate number of the infected Aedes had not been captured in Samoa. Thus, with the evidence obtained from the experimental tests on A. pseudoscutellaris, and the supportive evidence demonstrated in the naturally infected night-feeding Anopheles, it was possible to compute the number of probable infected Aedes, especially those harbouring the one-to five-day old larval stages. The computations are based on the direct proportions of the death rate in the experimental host and the actual number of mosquitoes harbouring larvae in the indicated day of age-groups. Thus, if by the end of the fifth day of larval development only 43.16 per cent of the experimental mosquitoes were available for capture, the computation was a matter of proportions between the percentage available for the fourth and fifth day and the number actually captured for these days in nature.

Example:

46.32 per cent available on 4th day
43.16 per cent available on 5th day
156 specimens captured containing larvae 4 to 5 days of developmental age (Table 19)
46.32 + 43.16 = 89.48
43.16 ÷ 89.48 = 48.23 per cent, or 75 of positive specimens captured for 4th and 5th day belonged in the 5th day group.

Now, 43.16 : 75 :: 46.32 : x = 81 in the 4th day of age-group, etc.

The results of these computations are given in Table 30.

Once the number of mosquitoes harbouring the younger ages of the developing filaria larva has been computed, it becomes possible to compare the survival rate in the naturally infected host with that observed for the experimentally infected one. This comparison is shown in Table 30 and Chart II.

It is to be pointed out that in the experimentally infected Aedes the maximum number of deaths (68) occurred on the third day (Table 29).

TABLE 30

Distribution of _Wuchereria bancrofti_ larvae
in naturally and experimentally infected _Aedes pseudoscutellaris_ in Samoa

Aedes pseudo-scutellaris	Number of mosquitoes harbouring filaria larvae for the indicated day of developmental age													
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Natural infection*	170	154	91	81	75		51	5	78	3	14	56		89
Experimental infection (166 positives)**	166	161	146	91	80	69	67	64	60	56	53	42	34	31

*The number of hosts harbouring larvae for the first five days of developmental age has been computed on the basis of experimental evidence and the actual number of hosts infected with larvae for these days of age (see text).

**Numbers are based on the number of positive experimental hosts that would have been available for capture on the day of larval age (see survival curve, Chart II) for first 14 days of the developmental cycle.

Afterwards there occurs an almost precipitous drop in the number of deaths to well below the 10 per cent level, and this lower rate is maintained for the remainder of the experiment. The curve (Chart II, solid line) partly explains what occurs in nature in the naturally infected host. Certainly, the maximum percentage incidence of infection in the naturally infected mosquito occurs for the early developmental stages of the filaria larva. As the recently ingested larvae exsheathe, penetrate the wall of the digestive tract, and become established in the thoracic muscles the death rate in the infected mosquitoes increases in proportion to the severity of the host-parasite reaction. Once the larvae become established in moderate numbers, and a compatible host-parasite relationship is attained, the death rate drops off. The host death rate for the early days of the infection appears to be more the result of a shock reaction rather than a direct response to the number of larvae acquired. Within limits the actual number of larvae in a given host appears to influence the death rate only to a minor degree. This is evident from the average number of worms per host in the dead and in the killed mosquitoes in the experiment (Table 27), i.e., 4.70 worms per dead host as against 5.18 worms for those that were alive. In the field, on the other hand, the naturally infected _Aedes_ appears to be quite capable of supporting a heavier worm burden (6.78 worms per infected host, Table 28) than was observed for those experimentally infected (4.82 worms per host, Table 27).

In hosts having older developmental stages of the parasite a definite tissue reaction is observed in the gross dissection. A positive or negative status could be detected immediately on exposure of the thoracic muscles for dissection, expecially in hosts harbouring larvae older than the very young developmental stages.

In the laboratory, deaths among uninfected bred mosquitoes followed the same pattern as that shown in Chart II for infected mosquitoes; the peak of the death rate was however reached slightly later than that observed in infected mosquitoes, and the death rate was never as high as in the latter. Undoubtedly, the number of dead uninfected mosquitoes recorded in Table 29 for the second and third day of the infection represents the peak death rate in the uninfected recently emerged portion of the mosquitoes used in the experiment. (It will be recalled that an attempt was made to condition these hosts to blood and to laboratory conditions prior to the commencement of the experiment). After the third day no further deaths occurred among the purely negative hosts until well after the source of the blood meal was withdrawn from them.

Thirty-seven mosquitoes were killed during the course of the experiment, 31 between the 5th and 14th day, and five on the twenty-fifth day, the last day of the experiment. Since these mosquitoes were killed it is likely that they might have survived for the full 14 days or more. To include these mosquitoes in the normal death rate curve, it became necessary to compute their propor positions on the basis of the normal death rate. Chart II includes the individuals of the group in their determined positions on the curve.

It will be noted (Table 29) that 23 of the mosquitoes dying during the experiment survived for a period of more than 14 days. The daily number of deaths in this group of mosquitoes, from the fifteenth to the twenty-fifth day of the experiment, follows: 5, 7, 0, 3, 1, 3, 0, 1, 1, 2, 0. Of these 23 mosquitoes 19 were infected.

During the 12th to 16th day of the experiment a total of 24 mosquitoes died. Undoubtedly this slight acceleration in the death rate of the infected host corresponds to the period of larval migration within the body of the host. However, more important than this is the fact that of all the mosquitoes in the experiment 38 survived for more than 14 days; 31, or 81.38 per cent of these permitted the filaria larva to attain full development. If the results obtained from the experiment can be taken as an indication of what occurs in the field, it is seen that what may be termed a "backlog" of _infective_ mosquitoes is built up in nature. This backlog persists in the field despite the high mortality rate in the recently infected host. Some evidence in support of this view was obtained from the naturally infected _Aedes_ mosquito in Samoa. In the field infective stage larvae were demonstrated in a greater number of hosts than could be demonstrated for any other age-group after the fifth day of developmental age (Table 19 and Charts I and II).

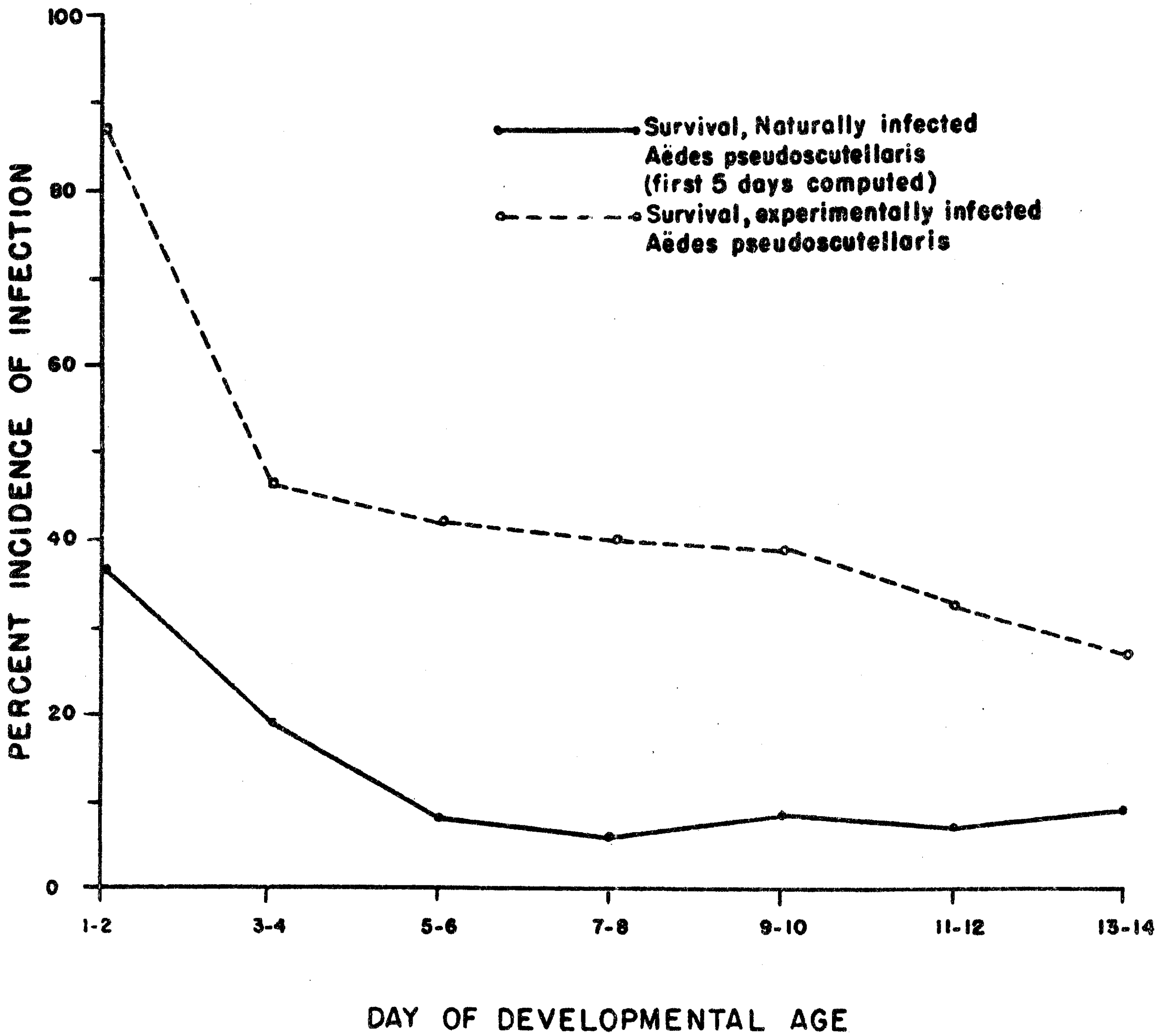


Chart II. Incidence of filarial infection (survival) in naturally infected Aedes pseudoscutellaris and the percentage of the 190 experimentally infected Aedes hosts which were available for study in the laboratory for the indicated days in the development of the larvae. The number of naturally infected specimens has been computed for the first five days of the developmental cycle (see page 48).

When the curve for the computed numbers of the naturally infected Aedes (Chart II) is compared with a survival curve of those experimentally infected, a striking similarity is observed in the behaviour of the two groups. The survival rate in experimentally infected mosquitoes drops in the same manner as that in naturally infected mosquitoes. Both curves continue to drop off almost precipitously until the 5 to 6 day of developmental age locus is reached. Beyond this day of age locus the curves become more or less stable. The second drop in the survival curve (experimental) occurring from the 9 to 10 day group to the 13 to 14 day locus represents a slight death rate in the host for the period of larval migration after full metamorphosis is attained.

In the experimentally infected mosquitoes the survival curve (Chart II, broken line) represents the actual percentage of infected mosquitoes surviving for the indicated days of larval development. The solid curve, then, must represent that portion of the available naturally infected Aedes which the survey should have been able to capture in the field had all infected mosquitoes been available for capture. The proportionately higher percentage of naturally infected mosquitoes harbouring larvae of the 3rd to 4th day of developmental age is an expression of the larger numbers of the host available for the first blood meal following the infective one. The rise in the curve at the 13 to 14 day locus (solid line), on the other hand, represents the "backlog" of naturally infected hosts carrying the infective stage larva.

Based on the number of experimentally infected Aedes mosquitoes which would have been available for capture in the field on a given day of larval development the data in Table 30 compare the number of captured naturally infected hosts in Samoa with the experimentally infected ones. Of the 166 positive mosquitoes in the experimental series 31 survived beyond the full development of the larvae, some for as long as 11 days after full larval development had been attained. In nature this survival of the host beyond the full development of the larva is cumulative, and accounts for the building up of the "backlog" of infective hosts. Hu (1935) reported Culex pipiens var. pallens to be capable of surviving with infective stage larvae of W. bancrofti for as long as 79 days following the infective blood meal. In nature, however, it is improbable that even the more efficient mosquito vectors will survive with a positive worm burden for more than a few weeks. Yet, it cannot be assumed that all infective stage larvae will be discharged onto the skin of the human victim at the first feeding of the host following larval infectivity. In the experimental host in American Samoa we were never able to demonstrate more than three or four infective stage larvae in the labium of the mosquito at one time. Even when such mosquitoes were allowed to feed and the discharged larvae washed onto a clean slide, no more than 5 larvae were recovered. The greater majority of the recently fed positive hosts could be demonstrated to be still infected by infective stage larvae immediately after feeding. It is to be assumed, therefore, that the entire worm burden is not lost at a single feeding, except in lightly infected hosts.

(b) WALLIS ISLANDS

Topographically, Uvea, the main island of the Wallis Islands, is intermediate between the mountainous volcanic island and the coral atoll. It is about six miles in length, and four miles in greatest breadth. A central plateau of from 50 to 700 feet in height forms the greater part of the island. A narrow coastal strip of only a few hundred yards in greatest depth almost completely surrounds it. The native population lives in an almost continuous village along the eastern, southern, and southwestern coastal area. There is little habitation on the central plateau.

Brochard (1910) showed that the microfilaria in the Wallis Islands exhibited no periodicity. In the absence of other suitable transmitting mosquitoes, and as the filaria was of the aperiodic variety, the present writers assumed the infection here to be transmitted by Aedes pseudoscutellaris, by far the most common mosquito on the island. Only five species were found to occur commonly, namely, Aedes pseudoscutellaris, A. aegypti, A. samoanus, Culex fatigans, and C. annulirostris.

The distribution of Culex fatigans is limited to a few foci within the inhabited coastal area, and its breeding incidence is not high. Aedes aegypti is also spotty in its distribution, and only on certain occasions does its breeding become extensive. The other species mentioned above are more or less generally distributed throughout the island. Aedes pseudoscutellaris is the only species with a breeding and adult density considered to be sufficiently great for it to play a major role in the transmission of filarial infection. Of 2,645 specimens of A. pseudoscutellaris examined from Wallis, 7.3 per cent were found naturally infected (Table 31). As in Tutuila, there occurred a more uniformly distributed sample of the more advanced developmental stages of the larval filaria. However, on Wallis, there was a piling up of the number of mosquitoes harbouring larvae three to five days of age, and a scarcity of infective stage larvae. These differences in the distribution of developing larvae in the same mosquito host from the two separate islands are believed to be due to a slightly different emphasis being placed on that part of the survey which dealt with the personnel camp areas. On Wallis, the same contiguity of troop-native habitation did not exist as that which occurred on Tutuila. At the time of our arrival in Wallis Islands, at least 75 per cent of the service personnel were quartered at a safe distance from the native population. Large groups of natives were however employed as labourers in most of the camps. Even when natives were not actually employed in the camps it was not uncommon to find large groups loitering within the camps for one or more hours each morning and afternoon in passing to or from nearby villages and farms. Because of the employment and the loitering of these native groups in the personnel areas the survey made a special effort to determine what effect this practice had on the incidence of infection in the mosquito population in these camps. Table 32 records this information.

TABLE 31

Incidence of infection and observed distribution of developing <u>Wuchereria bancrofti</u> larvae in 2,645 <u>Aedes pseudoscutellaris</u> from Wallis.

Number dissected	Number positive	Infection rate
2,645	193	7.3

Distribution in days of developmental age* of the filaria larvae in the mosquito host

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
0	1	51	79		20	5	20	3	14	1	4	1	2

*Fourteen days being considered as the average time required for the complete development of the larva from the microfilaria to the infective stage in the mosquito host.

TABLE 32

Incidence of natural infection in <u>Aedes pseudoscutellaris</u> captured from the village, camp-village, and camp areas on Wallis Island

Location	Number dissected	Number positive	Infection rate
Village	770	94	12.20
Camp-village	755	64	8.48
Camp	1,120	35	3.12

A lower rate of infection prevailed in the mosquito within the camp-village than in the village on Wallis, or in a similar location on Tutuila (Table 20). This is to be contrasted with the almost identical infection rate for the mosquito host in the Samoan and Wallisian village. On the other hand, the infection rate for the mosquito from the camp area on Wallis is many times higher than that determined for the same type of location on Samoa. Undoubtedly, the more intensive study in the personnel portion of the camp-village combination on Wallis resulted in the lower infection rate for the vector at this location. This more concentrated study seemed demanded since on Wallis the personnel camp was only rarely located directly in the village. The camp-village set-up on Wallis, then, was not as compact a unit as on Tutuila, demanding thereby that attention be paid to the mosquito vector in the personnel part of the area.

The higher rate of infection for the host within the camp area is due entirely to the employment of native labourers and to permitting loitering. This is demonstrated to be true since: (1) six of the 15 camps studied which did not employ native labourers nor permit loitering were entirely free from infected mosquitoes; (2) mosquitoes collected from outside of native habitation or native frequented areas were entirely free from infection; and (3) when native traffic into some of the camps was discontinued the infection in the mosquito host disappeared completely.

It should be pointed out that the incidence of infection in Aedes pseudoscutellaris was not uniform throughout the native inhabited areas on Wallis. Within the purely native village the infection rate ranged from 5.79 to 23 per cent, the incidence rising as high as 38 per cent in certain sections of the villages. In the camp-village areas infection rates in the mosquito ranged from 2.56 to 19.05 per cent. The same variation in the incidence of infection was noted in the mosquito host within these areas as that noted in the villages. Likewise, the infection rate in the mosquito ranged from 1.14 to 6.21 per cent for those camp areas in which natives were permitted daily. It seems highly probable that the preponderance of the younger developmental stages of the parasite, as well as the scarcity of the infective stage larvae, met with in the dissections made in Wallis, might be a direct result of the more intensive study in the purely camp areas. Certainly, filarial disease is rampant on Wallis Island as is evidenced by the large number of cases which developed in the Armed Forces at this base, and by the demonstrated incidence of infection in the transmitting mosquito.

Dense vegetation does not occur on Wallis Islands in anything like the same degree as on Tutuila. This results in a greater exposure of the mosquito population to the prevailing environment, and a reduction in the number of favourable breeding places. From Table 33 (mosquito density studies on Wallis) it is seen that, although almost identical densities prevailed in the controlled (camp) areas on Wallis as those found in Samoa (Table 21), the overall density as well as the density for the uncontrolled area fall below the figures given for Samoa. This is expressed as 66 mosquitoes per man per hour for the island of Wallis (89 for Samoa) and 96 for the uncontrolled areas (129 for Samoa).

Comparative data on the average number of developing filaria larvae per naturally infected mosquito on Uvea (Wallis Islands) and on Tutuila are furnished in Table 34. Chart III combines the computed data on the incidence

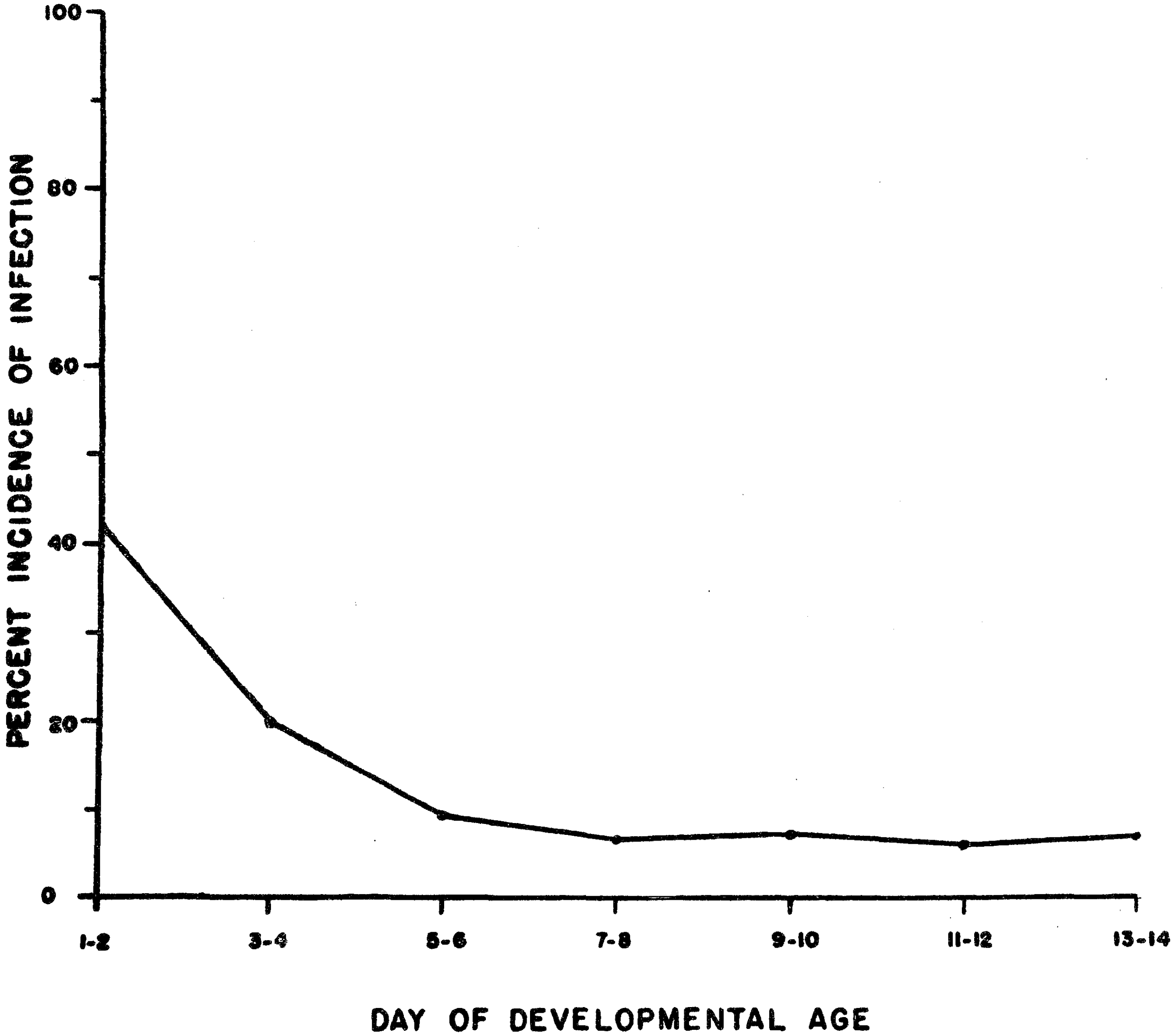


Chart III. Incidence of filarial infection in naturally infected Aedes pseudoscutellaris from Tutuila and Wallis Island. The percentage infection has been computed for the first five days of the developmental cycle of the filaria larva (see page 48). Compare with Chart II.

TABLE 33

Density of <u>Aedes pseudoscutellaris</u> for the island of Wallis over a period of approximately two months

Location	Number of catches	Number of mosquitoes caught	Average density*
Uncontrolled area	121	11,653	96
Controlled area	78	1,382	18
Entire island	199	13,055	66

*The average density represents the number of mosquitoes <u>caught</u> per man per hour.

TABLE 34

Comparative data on the maximum and average numbers of developing filaria larvae for each day of developmental age in naturally infected <u>Aedes pseudoscutellaris</u> from Samoa and Wallis Islands

Day of developmental age	Wallis Island		Samoa		Both Islands	
	Maximum number in one host	Average number per host	Maximum number in one host	Average number per host	Maximum number in one host	Average number per host
1	...	...	19	6.5	19	6.5
2	2	2.0	..	...	2	2.0
3	19	4.3	25	6.2	25	4.6
4	13	4.3	..	...	13	4.3
5	25	6.5	31	7.8	31	7.6
6	16	5.6	..	...	16	5.6
7	10	5.0	28	8.1	28	7.8
8	10	4.3	40	14.0	40	6.3
9	4	3.3	18	6.6	18	6.5
10	12	4.3	8	5.0	12	4.4
11	4	4.0	11	6.1	11	6.0
12	5	2.5	23	6.7	23	6.5
13	1	1.0	..	...	1	1.0
14	25	15.5	14	3.5	25	3.8

of natural infection in <u>Aedes pseudoscutellaris</u> from Wallis with that in the same host from Tutuila. Except for the lowering of the rate for infective stage larvae the curve remains essentially the same as that determined for Samoa (Chart II).

It might be pointed out that only in eight mosquitoes on Wallis did a multiple infection occur. The days of age for the larvae in these eight infections were respectively: 3 and 8; 3 and 8; 4 and 8; 4 and 10; 5 and 10; 6 and 10; 6 and 14; 8 and 12.

(c) NEW HEBRIDES

Results of the examination of mosquitoes collected in the New Hebrides are furnished in Table 35.

TABLE 35

Incidence of infection with developing Wuchereria bancrofti larvae in mosquitoes dissected in New Hebrides

Species of mosquito	Number examined	Number positive	Percentage infected
Anopheles farauti	1,239	170	13.72
Aedes hebrideus	377	13	3.45
Aedes vexans	127	16	12.59
Aedes aegypti	5	1	20.00
Aedes funereus ornatus	91	6	6.59
Culex fatigans	70	9	12.85
Culex annulirostris	117	5	4.27
Culex sitiens	6	0	...
Culex pacificus	1	0	...

Seven of the nine species of mosquitoes examined were found to harbour developing filaria larvae, the infection rates ranging from 3.45 per cent for Aedes hebrideus to 20 per cent for A. aegypti. Here, as in Samoa, the percentage rate of infection in the individual species would not correctly indicate the importance of the species in filaria transmission which could only be judged by the degree of development that the filaria larva attains within the host. Table 36 more accurately indicates the species responsible for the transmission of the filaria in this area.

From this Table it is seen that in Anopheles farauti alone was it possible to demonstrate complete larval development in naturally infected mosquitoes. In this species all stages in the developmental cycle of the parasite comparable to those observed in naturally and experimentally infected Aedes pseudoscutellaris in Samoa were demonstrated. In only a single specimen of Culex fatigans

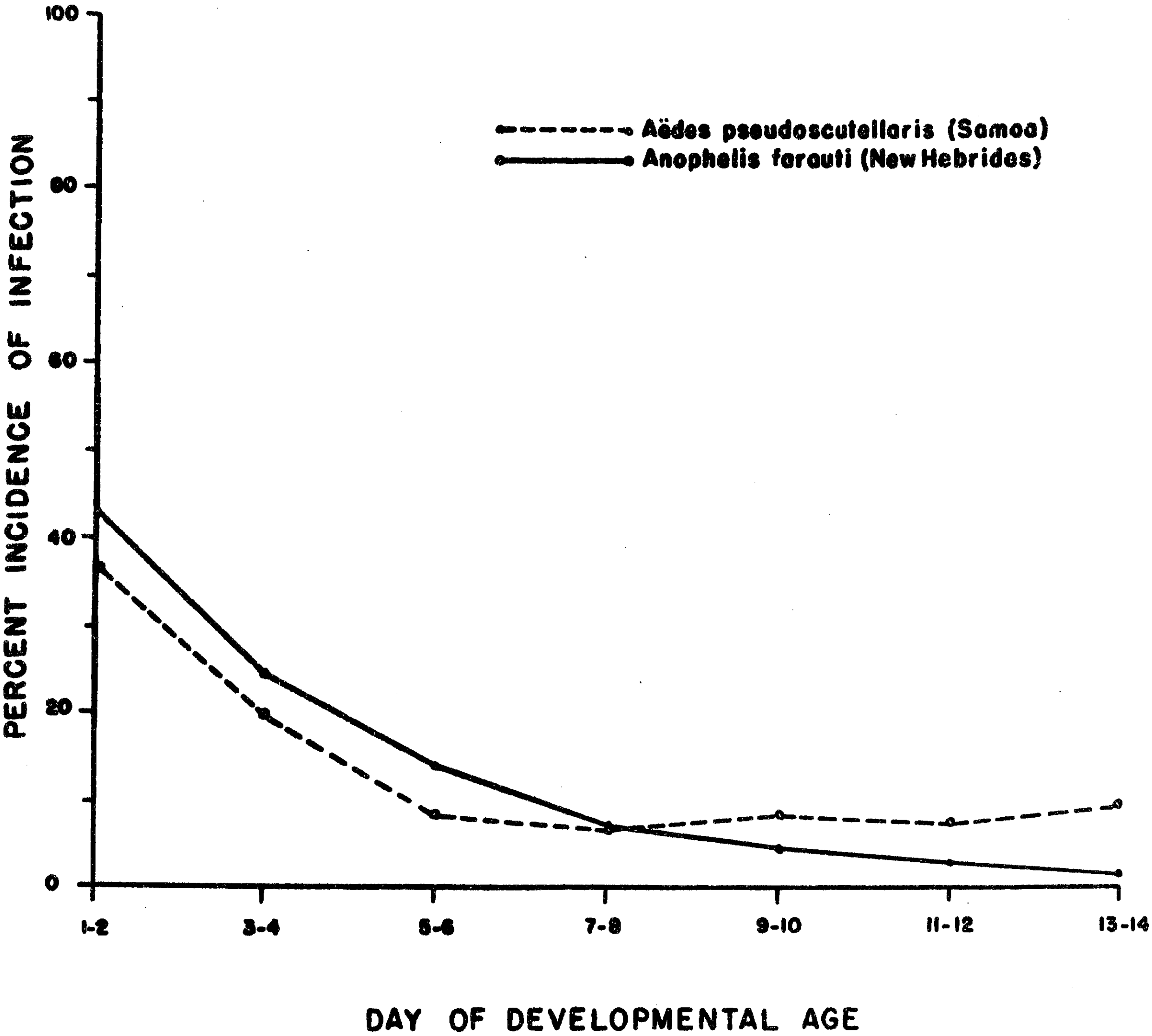


Chart IV. Comparative incidence of filarial infection in naturally infected Aedes pseudoscutellaris from American Samoa and Anopheles farauti from New Hebrides.

TABLE 36

Distribution in days of age* for developing filaria larvae in naturally infected mosquitoes from New Hebrides

Species	Number of mosquitoes harbouring filaria larvae for the indicated day of developmental age*													
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Anopheles farauti	58	25	15	33	16	12	8	5	5	5	1	6	1	2
Culex fatigans	8	1	1					1						
Aedes hebrideus	9	2	1	1										
Aedes vexans	16													
Aedes funereus ornatus	6													
Culex annulirostris	5													
Aedes aegypti	1													

*Fourteen days being considered as the average time required for the complete development of the larva from microfilaria to the infective stage in the mosquito host.

did filaria larvae as old as the eighth day of developmental age occur; in two others larvae two and three days of age respectively were recorded. All the other infected specimens of this species harboured only recently ingested microfilariae. Larvae older than the fourth day of developmental age were not recovered from Aedes hebrideus; two specimens of this species carried larvae of two days of developmental age and a single specimen contained larvae of the third and fourth days of age respectively. All other species of mosquitoes harbouring filaria larvae proved to have only recently ingested microfilariae in the digestive tract, some of which had exsheathed, but none had penetrated the gut wall. It is concluded, therefore, that Anopheles farauti is the transmitter of filariasis in the New Hebrides.

Chart IV compares the distribution of filaria larvae (in days of developmental age) in Anopheles farauti from New Hebrides with that in Aedes pseudoscutellaris (computed) from Samoa.

The presence of malaria in the native population of the New Hebrides necessitated a vigorous mosquito control programme at this location. By the time the authors arrived on the island of Espiritu Santo a mosquito control programme directed against larval as well as adult Anopheles, was well in hand and covered all the occupied areas on this island and adjacent islands of the group. The control measures also included the spraying of each hut within the controlled area with freon-aerosol (pyrethrum) once a week. Thus, soon after our arrival it became apparent that very little knowledge concerning the transmission of filariasis could be obtained through examination of mosquitoes caught within this controlled area. Hence, the major portion of the work in the New Hebrides was done at the periphery of the controlled area or entirely outside of it. Table 37 gives the results of our studies on Anopheles farauti from the controlled and uncontrolled areas in the New Hebrides.

TABLE 37

Dissection records on Anopheles farauti
from controlled and uncontrolled areas of Espiritu Santo
(New Hebrides)

Area	Number dissected	Number positive	Percentage infected	Number of single infections	Number of double infections	Number of triple infections
Controlled	493	60	12.17	59	1	
Uncontrolled	746	110	14.74	93	13	4

It is seen (Table 37) that: (1) the infection rate in Anopheles farauti captured from within or at the fringe of the controlled area was only slightly lower than that for the outside area, and (2) the number of multiple infections in the mosquito was markedly lower within the controlled zone. The efficacy of the control programme is further seen from the data in Table 38.

The data in Table 38 only projects the trend in the mosquito control programme. Since the majority of Anopheles mosquitoes captured from the controlled area on Espiritu Santo actually were caught from the periphery of the controlled zone, the data in Table 38 do not represent the density picture for any other section. The data on the density prevailing in the uncontrolled zone of Espiritu Santo are more accurate since at least five villages were visited, and in several of the huts visited a density of more than 500 mosquitoes per man per hour prevailed.

The distribution of the developing filaria larva in accordance with the day of their developmental age in the mosquito host is revealing for the

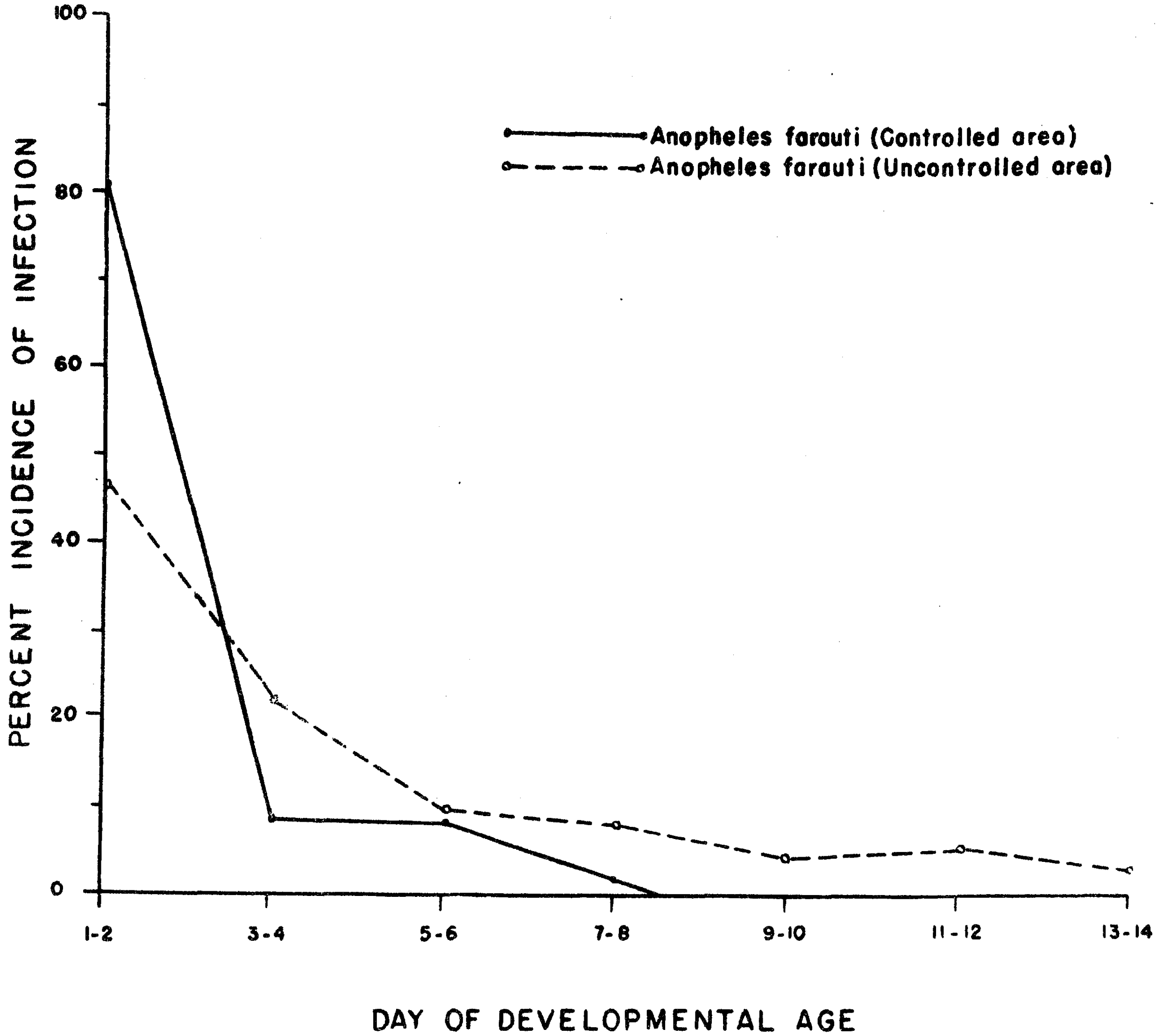


Chart V. Incidence of natural infection with filaria larvae in Anopheles farauti from the controlled and uncontrolled areas of Espiritu Santo (New Hebrides). The control of filariasis trans-transmission has been accomplished in the controlled area (solid line) through the weekly adult mosquito spray-killing phase of the malaria control programme (see page 57).

TABLE 38

Density of <u>Anopheles farauti</u>
in the controlled and uncontrolled areas of Espiritu Santo

Location	Number of catches	Number of mosquitoes caught	Average density*
Uncontrolled area	9	746	62
Margin of controlled area	26	493	14

*The average density represents the number of mosquitoes <u>caught</u> per man per hour.

controlled and uncontrolled areas of Espiritu Santo. Chart V depicts this information.

Within the controlled area, and due principally to the activity of the adult mosquito spray-killing teams, mosquitoes harbouring filaria larvae older than the eighth day of developmental age (Chart V) were not captured in 34 hours of collecting time.(This is true despite the fact that mosquitoes from the periphery of the area are included in the data). It thus appears that the adult mosquito spray-killing programme within and at the margin of the controlled area partly answers the question of why the number of service personnel developing filariasis at this base was extremely low, or entirely nil. However, just outside of the controlled zone filariasis is rampant, especially in the coastal areas of the islands.

In two villages on the island of Espiritu Santo, namely Wailapi, a coastal village, and Narango, atop of a 700-foot high ridge and no more than five or six miles from Wailapi, the prevalence of filariasis differed markedly. In Narango only one out of 40 persons examined proved to have microfilariae in night peripheral blood. <u>Anopheles farauti</u> was plentiful within the village (up to 500 mosquitoes per man per hour for some of the huts), but only 6, or 7.1 per cent, of 84 dissected carried the filaria larva. In all cases the microfilariae found in these mosquitoes were still in the digestive tract and only a few of them had exsheathed, while the majority were already dead at dissection (the morning following capture). In the village of Wailapi, on the other hand, a density of <u>A. farauti</u> similar to that observed at Narango prevailed, and 72, or 34.3 per cent, of over 200 mosquitoes dissected harboured developing filaria larvae (Table 39). It was further demonstrated that 14, or 31.1 per cent, of 45 inhabitants of Wailapi harboured microfilariae in night peripheral blood.

TABLE 39

Distribution in days of age (with maximum and average number per host) of Wuchereria bancrofti larvae in naturally infected Anopheles farauti from the village of Wailapi and for New Hebrides

Day of developmental age	Village of Wailapi			New Hebrides group		
	Number of infected hosts	Maximum number of worms in one host	Average number of worms per host	Number of infected hosts	Maximum number of worms in one host	Average number of worms per host
1	22	28	4.7	58	96	8.6
2	20	12	3.0	25	28	4.1
3	8	5	2.3	15	45	7.0
4	10	28	6.0	33	50	8.0
5	7	7	2.9	16	52	7.8
6	1	2	2.0	12	12	4.7
7	4	12	4.3	8	12	5.1
8	1	1	1.0	5	12	6.0
9	1	3	3.0	5	14	6.8
10	..	..	...	5	11	5.5
11	..	..	...	1	1	1.0
12	5	14	5.8	6	14	6.8
13	1	7	7.0	1	7	7.0
14	1	2	2.0	2	2	1.5

Average number of worms harboured by A. farauti: 6.74

In contrast to the conditions found at Narango and Wailapi, not a single case of filariasis was discovered in a total of 104 inhabitants of two small islands just off the mainland of Espiritu Santo. One of these islands, Tangoa, lay no more than a few hundred yards off the mainland while the other, Araki, was as much as three or four miles off shore. Two and one cases of filaria infection appeared in the groups examined from the two islands, respectively. On further enquiry it was learned that each of these infected persons came from a coastal village on the mainland. A search for Anopheles mosquitoes on these two islands failed to reveal any breeding, and only five adult A. farauti could be found on the island of Tangoa, none of which was infected.

The authors feel reasonably certain that every positive mosquito reported herein was infected with Wuchereria bancrofti acquired from the Melanesian population of the islands, and not Wuchereria malayi, acquired from the Tonkinese. This conclusion is based on the following observations:

(1) very few of the mosquitoes dissected came directly from Tonkinese quarters; (2) the Tonkinese occupy cleaner (white-washed) and more modern huts than do the Melanesians which are less conducive to mosquito resting; and (3) all the Tonkinese occupied quarters within the controlled area on the island of Espiritu Santo. Although no attempt was made to determine the possibility of A. farauti serving as the intermediate host of W. malayi, almost invariably the two groups of people occupied quarters well separated from each other, and usually no anopheles could be found resting in or about Tonkinese huts. On the few occasions in which mosquitoes collected from the Tonkinese and Melanesian quarters were examined separately no infection was observed in mosquitoes captured from Tonkinese quarters.

(d) SOLOMON ISLANDS

Altogether 1,494 mosquitoes from Guadalcanal, Solomon Islands, consisting of 10 species were examined: the results are given in Table 40.

TABLE 40

Incidence of infection with developing Wuchereria bancrofti larvae among mosquitoes from Guadalcanal (Solomon Islands)

Species	Number dissected	Number positive	Percentage infected
Anopheles farauti	655	340	51.90
Anopheles koliensis	351	17	4.84
Anopheles punctulatus	64	0	.....
Mansonia (Mansonioides) uniformis	385	90	23.37
Aedes imprimens	25	0	.....
Armigeres breinli	1	0	.....
Culex fatigans	5	2	40.00
Culex annulirostris	1	0	.....
Culex hilli	3	0	.....
Tripteroides quasiornata	4	0	.....

It should be pointed out at the outset that there were no natives within the occupied area of Guadalcanal. At the beginning of the Guadalcanal campaign the native population withdrew into the hills where they remained until most of the island was secured. Subsequently a portion of the indigenous population returned to their old village sites, but remained there for only a short time before the military relocated them entirely away from the occupied area. Thus, for the greater part of the occupancy of Guadalcanal relatively few natives were in close proximity to the service personnel. By the time the authors arrived on the island approximately 2,000 native labourers occupied three camps on the periphery of the zone in which a constant and vigorous anti-mosquito programme was maintained. During the 3½ months the authors spent on the island no more than one or two anopheles mosquitoes were caught within the controlled area. Hence, all of the work done by the survey had to be conducted on the margin of the controlled area or entirely outside of it. The data included in Tables 40 to 43 are compiled from information gained through a study of that portion of Guadalcanal which was not occupied by service personnel.

When it is remembered that the survey made every attempt to take any and all mosquitoes which came out to feed or which were found resting in or about human habitation, it will be seen that the data in Table 40 give some indication of the relative abundance of the different species on Guadalcanal.

Two of the five specimens of Culex fatigans captured contained recently ingested microfilariae only; this species is of such rare occurrence on the island as to be of no importance whatsoever in the transmission of filariasis. Aedes imprimens was taken more from the jungle than from about human habitation; all specimens of this species examined proved to be negative for developing larvae. Four of the species listed, then, give promise of being abundant enough to constitute a filaria hazard. Of these four species, Anopheles punctulatus alone was found to be entirely free of the infection. An infection rate of 51.90 per cent was demonstrated for A. farauti while A. koliensis showed a 4.84 per cent infection rate. An infection rate of 23.37 per cent is recorded for Mansonia (Mansonioides) uniformis; this is the first time that this species has been incriminated in the transmission of Wuchereria bancrofti in the islands of the Pacific area. The age distribution of the developing filaria larvae for the species showing positive infection is given in Table 41.

Of 351 specimens of A. koliensis collected near a labour camp, 17 proved to harbour W. bancrofti larvae. Two of the positives harboured larvae of two different days of age while all other positives harboured but a single developmental stage. Fourteen of the 17 infected specimens harboured only recently ingested microfilariae and one specimen harboured larvae for each the second, fourth, seventh, thirteenth, and fourteenth days of development. The presence of infective stage larvae in one specimen out of the small number of infected specimens of this species probably indicates that the mosquito is capable of developing the larva to maturity. The small number of positives out of the total dissected, on the other hand, suggests: (1) the source of the infection to be low, or (2) a comparatively low susceptibility to the infection. From data obtained on A. farauti collected from the same camp area, and elsewhere on the island, the first proposition appears to be the more correct one. Nine, or 13.6 per cent, of

TABLE 41

Distribution in days of age* for developing Wuchereria bancrofti larvae from naturally infected mosquitoes on Guadalcanal (Solomon Islands)

Species	Number of mosquitoes harbouring filaria larvae for the indicated day of developmental age*													
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Anopheles farauti	168	75	74	42	43	31	14	28	9	18	6	26	1	27
Anopheles koliensis	14	1		1			1						1	1
Mansonia uniformis	86		1		2			1		2		1		
Culex fatigans	2													

*Fourteen days being considered as the average time required for the complete development of the larva from microfilaria to the infective stage in the mosquito host.

36 A. farauti from the same camp area were infected as against a 51 per cent infection rate for the species from other locations. Unfortunately, the native labourers within the camp were not surveyed for blood microfilariae at the time.

The specimens of Mansonia (Mansonioides) uniformis were collected mostly from a labour battalion in which 28.8 per cent of the individuals were microfilaria-positive in the night blood. Although 23.4 per cent of the specimens were found to be infected, only 1.56 per cent of all M. uniformis mosquitoes dissected from Guadalcanal harboured larvae older than the recently ingested microfilaria; two specimens contained larvae as old as the tenth day of age while one contained three larvae as old as 12 days of developmental age (Table 41).

The 51 per cent infection rate reported for Anopheles farauti from Guadalcanal is the highest determined for any species during this survey. 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 filaria larvae. Eight of the infected mosquitoes carried infective stage larvae within the labium.

In view of the unusually high incidence of infection demonstrated for both the native population (Table 6) and the principal mosquito vector (Table 40) on Guadalcanal it is not surprising to find an unusually large number of the positive specimens of A. farauti harbouring more than a single developmental stage of the parasite. Table 42 records the data on the single and multiple infections in the positive mosquitoes from Guadalcanal.

TABLE 42

Incidence of single and multiple infections in different species of mosquitoes found infected with W. bancrofti on Guadalcanal

Species	Anopheles farauti	Anopheles koliensis	Mansonia uniformis	Culex fatigans
Total number positive	340	17	90	2
Number with:				
one stage	210	15	87	2
two stages	83	2	3	-
three stages	27	-	-	-
four stages	15	-	-	-
five stages	5	-	-	-

In many specimens of A. farauti the infection was so heavy that neither the exact age of the larvae could be estimated nor the total number of worms ascertained. The exact number of days required for the complete development of the filaria larva in A. farauti could not be determined because the authors were unable to obtain sufficient numbers of uninfected mosquitoes for experimental infection studies. The estimated day of developmental age of the larvae was therefore based on experience gained through experiments with Aedes pseudoscutellaris. Whether or not such experience permits even an approximation of the larval ages in Anopheles farauti it is impossible to state. Yet, the morphological development attained by the larvae in A. farauti corresponded in every respect to a given day of age in the Aedes host, and such an attainment was the basis for making the determination. As stated earlier, it is extremely difficult to determine the age of the larva in naturally infected mosquitoes to more than one or two days of its actual day of age. In the laboratory, however, the filaria larva did develop macroscopically at the same rate in naturally infected Anopheles farauti as was observed for the larva in experimentally infected Aedes pseudoscutellaris.

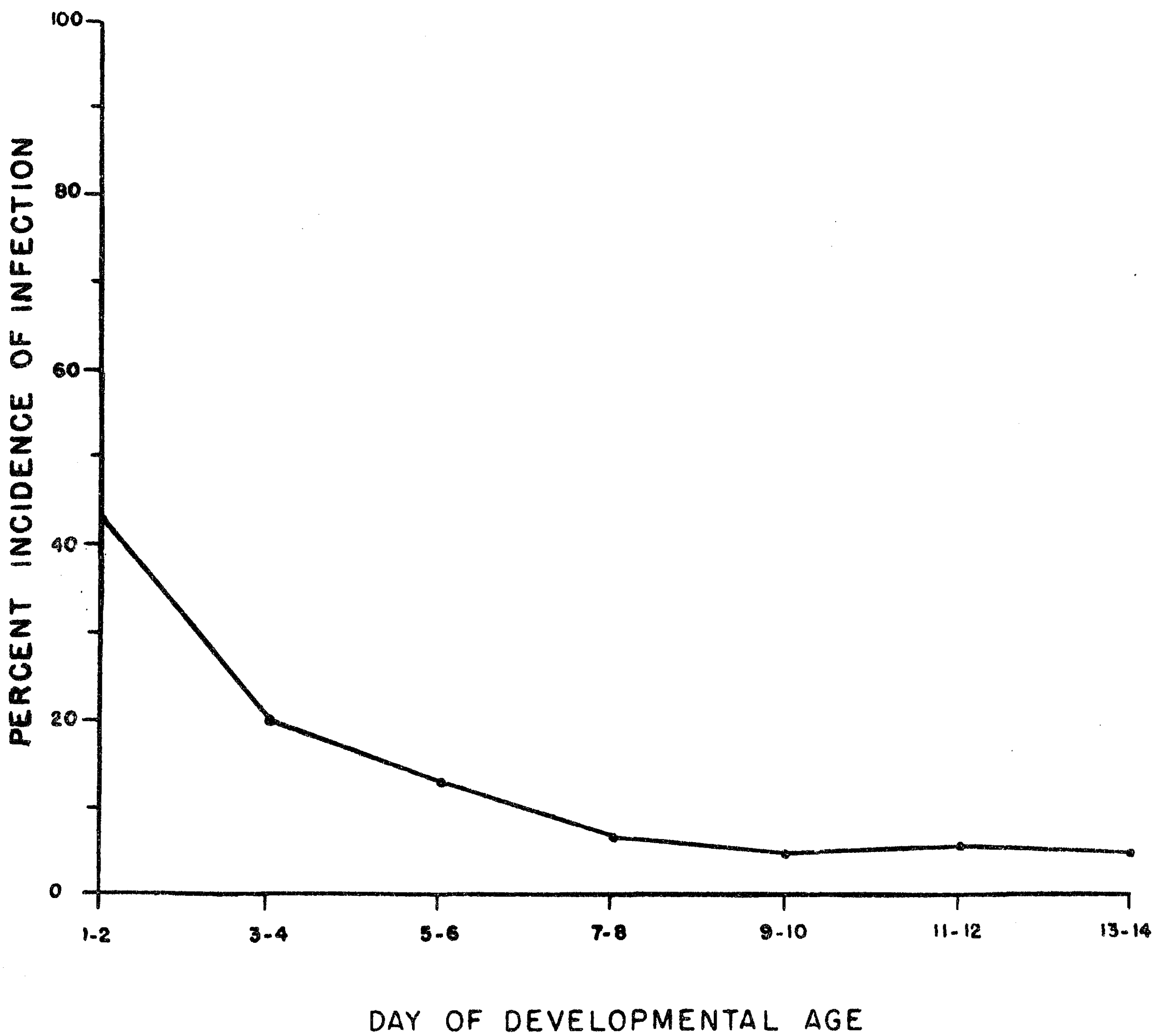


Chart VI. Incidence of filarial infection in naturally infected Anopheles farauti from Guadalcanal (Solomon Islands). The percentage incidence is determined from the number of mosquitoes harbouring filaria larvae for the indicated days of larval age.

Throughout the survey the question of whether or not all larvae within a single host developed to the same degree each day until the infective stage is reached was one of considerable interest. In the case of the experimental Aedes this was the case. It should be pointed out, however, that although each worm is a single host specimen developed macroscopically at the same rate, some hosts developed the worms at a more rapid rate than did others. In the experimental series in Samoa the infective stage larva appeared as early as the eleventh day, although the majority of the hosts took longer than this. If, therefore, conditions of larval development in the experimental Aedes can be applied to naturally infected Anopheles farauti on Guadalcanal, it may be assumed that the data presented in Tables 41 and 42 are approximately correct.

Table 43 summarizes the information on the observed worm burden in the infected mosquitoes from Guadalcanal. It is seen that both Mansonia uniformis and Anopheles koliensis appear to be as efficient as A. farauti in picking up microfilariae from the blood stream of the carrier upon whom they fed. Despite this ability to find the microfilariae in the blood neither of the two species is as efficient as A. farauti in developing the larvae to the infective stage.

Of 340 positive A. farauti only 27, or 7.94 per cent, harboured infective stage larvae as compared to the 19.47 per cent of A. pseudoscutellaris harbouring infective stage larvae in Samoa (Table 22). However, it must be remembered that A. pseudoscutellaris is a day-feeding mosquito and all specimens of the species were caught while they attempted to feed on the human bait, and before they had an opportunity to lose some of the infective larvae. This is not so in the case of A. farauti. Specimens of this mosquito were collected from in and about native habitations, and the great majority of them had engorged a blood meal the previous night. It must be concluded, therefore, that some of the A. farauti examined by us had got rid of infective stage larvae prior to the time of their capture. It is very probable that under more favourable circumstances of making captures a much higher percentage of A. farauti would prove to carry larvae of this stage of development.

Chart VI gives the survival curve of naturally infected Anopheles farauti from Guadalcanal.

The majority of the specimens of Anopheles punctulatus dissected during the survey on Guadalcanal came from two localities, and by far the greater majority of these came from the same camp location from which all of the specimens of Anopheles koliensis were taken. Since a definite percentage of specimens of both A. farauti and A. koliensis from this camp proved to harbour developing larvae while even microfilariae failed to appear in recently engorged A. punctulatus, it is assumed that the latter species did not serve as a host to Wuchereria bancrofti within this camp. Schlosser and Reiber (1945), however, record a 15 per cent infection rate in A. punctulatus from a village on Guadalcanal.

TABLE 43

Maximum and average numbers of *Wuchereria bancrofti* larvae for each day of developmental age in naturally infected mosquitoes from Guadalcanal (Solomon Islands) and in *Anopheles farauti* from New Hebrides and Solomon Islands

Day of developmental age	*Anopheles farauti*		*Anopheles koliensis*		*Mansonia uniformis*		*Culex fatigans*		*Anopheles farauti* from New Hebrides and Solomon Is.	
	Maximum number in one host	Average per host	Maximum number in one host	Average per host	Maximum number in one host	Average per host	Maximum number in one host	Average per host	Maximum number in one host	Average per host
1	107	12.8	210	24.8	540	25.3	4	3.0	107	11.8
2	98	12.0	1	1.0	4	4.0	..	...	98	10.0
3	53	13.0	..	...	4	4.0	..	...	53	11.8
4	81	11.6	2	2.0	..	...	..	...	81	10.0
5	23	7.2	..	...	5	4.5	..	...	52	7.2
6	78	13.1	..	...	..	...	..	...	78	10.8
7	52	18.1	3	3.0	..	...	..	...	52	13.4
8	46	11.6	..	...	1	1.0	..	...	46	10.7
9	17	6.1	..	...	..	...	..	...	17	6.4
10	24	8.4	..	...	2	1.5	..	...	24	7.8
11	25	12.0	..	...	..	...	..	...	25	11.7
12	30	9.3	4	4.0	6	6.0	..	...	30	8.5
13	6	6.0	..	....	..	...	..	...	7	6.5
14	10	3.3	5	5.0	..	...	..	...	10	3.4

(e) EXPERIMENTS WITH ANOPHELES FARAUTI AND A. PUNCTULATUS

On Guadalcanal an experiment was carried out to test the ability of *Anopheles farauti* and *A. punctulatus* to pick up and to nurture the larvae of the Gilbert Islands strain of *W. bancrofti*. At the times of the experimental feeds (two evenings) the carrier, a Gilbert Islander, showed 54 and 78 microfilariae per 40 c.mm. of peripheral blood. Feeding commenced at 2030 hours and ran for about half an hour. Table 44 records the results of the experiment.

TABLE 44

Experiment to determine the ability of _Anopheles farauti_ and _Anopheles punctulatus_ to pick up and to nurture the microfilariae of the Gilbert Islands strain of _Wuchereria bancrofti_

Day following feeding	Record of dissection for the indicated day following the feeding experiment			
	Anopheles farauti		_Anopheles punctulatus_	
	Number dissected	Number positive	Number dissected	Number positive
1	9	3	68	5
2	2	0	72	12
3	5	0	15	0
4	2	0	19	0
5	..	..	24	0
6	6	1	41	0
Total	24	4	239	17

Total number of microfilariae picked up by _Anopheles farauti_ 5
Total number of microfilariae picked up by _Anopheles punctulatus_ 26

Neither _Anopheles farauti_ nor _A. punctulatus_ appeared to be a good host for the filaria present in the Gilbert Islander. Of the four specimens of _A. farauti_ which contained larvae at dissection only one had developed the larva to the sixth day of developmental age. The fact that a single specimen did develop the parasite to the sixth day of developmental age probably indicates that the species might serve as a vector under ideal conditions in nature. The four positive individuals picked up a total of only five microfilariae from the blood stream, probably indicating its inability to find more larvae of the strain per unit volume of blood than can be shown by the 40 c.mm. sample method.

With regard to _Anopheles punctulatus_, no larvae were found in the experimental host after the second day. Altogether 26 larvae were picked up by the 17 positive mosquitoes, although only 3 larvae were observed to be still alive in the mosquitoes at dissection. In no case had the larvae left the digestive tract, and about half of them failed to wriggle free of the sheath.

(f) HABITS OF THE PRINCIPAL VECTORS OF FILARIASIS

In passing from Polynesia to Melanesia considerable differences in the habits of the mosquito vectors are noted. Many of these observations and studies seem to be worth recording.

(i) Aedes pseudoscutellaris

In Samoa, and to a large extent in Wallis and Ellice Islands (Funafuti), rather large concentrations of the native population live in compact village groups. The village is generally built encircling an open area, the "village green", or along one side of it. The village green is kept closely cropped or even devoid of all vegetation except for fruit trees, flowering shrubs, and ornamental plants. The houses are of the open type, and are built on mounds of coral or lava rock. Beyond the huts is the jungle. Crowded into the area just beyond the huts are dense groves of banana plants, breadfruit, papaya, and coconut trees, and occasionally variously sized patches of taro, yam, and sugar-cane. These grade directly into the jungle and all are traversed by many trails leading out to pig sties or farm areas. Amid the vegetation at the jungle's edge in the immediate rear of the village is a conglomerate of refuse accumulated over years of refuse disposal. On visiting the village one is impressed with the apparent cleanliness of the area and the absence of mosquitoes so long as only the village green is visited. To go beyond the fringe of huts, a different story is to be told. In this litter-studded "backyard" mosquito density is high and ample breeding places are to be found close at hand.

The important breeding places of Aedes pseudoscutellaris in and around villages are (1) discarded tin cans, (2) coconut shells, (3) rot holes in trees, and (4) rain water barrels, troughs, and cisterns. In most cases the breeding places were in deep shade or had become completely covered over by luxuriant vegetation. Rarely was Aedes pseudoscutellaris observed to be breeding in open containers in direct sunlight.

On the island of Funafuti, Ellice Islands, because of the acute water shortage, several thousands of steel drums were used as water containers and hundreds of these bred mosquitoes prior to the initiation of the mosquito control programme. This type of breeding place was far in excess of all others for the Aedes mosquito on that island.

To collect Aedes mosquitoes for dissection or for experimental purposes one has only to go out into the jungle at any place and beat the grass, vines, and underbrush for a moment to have mosquitoes flying about in abundance. One often finds the adults resting in the grass and other vegetation, near the breeding places. Not uncommonly the adults rest directly within a breeding container or a potential one.

Frequently the eggs are deposited in a completely dry or only moist container, where they have but a few days to await the rain. The adult was never observed to lay eggs directly on water, but always on the moist area just above the water level. When heavy rains come and flood an area containing large numbers of breeding containers those larvae and eggs which are washed overboard do not appear to survive for more than a day or so. Usually one could find no larvae in the puddle of water although large numbers of partly submerged cans and bottles will contain many larvae. Several dozens of larvae can survive to emergence in no more than half a teacupful of water.

In studies on the incidence of infection in the Aedes mosquito it was observed that in certain sections of a native village, a high incidence of infection (up to 35 per cent or more) prevailed in contrast to a much lower infection rate among mosquitoes collected from adjoining sections of the same village. The infection rate was always higher among mosquitoes collected from a village than in those from the adjacent camp area. Further, it was observed that few or no mosquitoes came out to feed so long as one remained on the village green within the village, but that just as soon as one reached the edge of the adjoining jungle the density of the mosquito increased many times and one was put hard to it to avoid being bitten.

These observations led to an investigation of the flight range of the Aedes mosquito. The first location at which this feature was investigated was an inland village. Prior to the investigation, the incidence of filarial infection had been determined for both the native and the mosquito populations of the village. Thirty-four, or 20.6 per cent, of 165 of the inhabitants carried microfilariae in the daytime blood and 20.2 per cent of the mosquitoes dissected harboured developing larvae. By further study it was determined that 28 per cent of the Aedes host taken from the village green and near the huts were infected. Once this infection rate was established, mosquitoes were captured in lots of approximately 100 specimens at successive intervals of 25 paces up to 150 paces away from the outer fringe of huts. At the 25-pace interval the infection rate dropped to 22 per cent, and at 50 paces only 3.6 per cent of the mosquitoes proved to be infected. A single infected mosquito came from each of the 75- and 100-pace intervals. Beyond this point no infected mosquitoes were taken. As the work progressed it was seen that the first trial had taken the leeward side of the village from which to collect mosquitoes. In mosquitoes captured from the windward side of the village only 9.3 per cent of mosquitoes caught at 25-paces from the outer huts were infected, and only a single infected specimen came from each of the catches at the 50- and 75-pace intervals. Beyond this point entirely negative results were obtained. As one passes around the village from the windward to the leeward side the positive hosts gradually range outward from the village, becoming increasingly more frequent as one approaches the village concentration. Chart VII illustrates a cross section of the determined incidence of infection in Aedes pseudoscutellaris to windward and leeward of this Samoan village.

At a second village, located directly on the coast, only 8 per cent of the mosquitoes from the village itself were infected whereas 35 per cent of mosquitoes captured at 25-paces to the rear of the outer huts carried developing larvae. This village was selected for study because of: (1) the strong prevailing wind which swept the village-green, and (2) the proximity (250 yards) of a personnel camp to the immediate rear. A foothpath led from the village to the camp and troops and natives alike made frequent use of the trail daily. A 3 per cent incidence of infection was demonstrated among mosquitoes within the camp, and a 6 per cent incidence occurred in mosquitoes captured from the pathway, midway between the camp and the village.

In many instances similar conditions were shown to exist for the villages on the islands of Tutuila and Wallis, although extensive studies were not always undertaken in each village. In most cases the incidence of infection in the mosquito was determined from two or three locations within the village and from samples of mosquitoes taken from entirely outside of the village areas. In all cases, mosquitoes taken at 150 yards away from the village showed very low infection rates or were totally free from the infection. In several catches involving 300 to 400 mosquitoes from one camp area from which natives were excluded except for the period of the evening movie all but a single mosquito were negative for filaria larvae. The one positive specimen came from the immediate vicinity of the outdoor movie.

Frequently as many as 300 to 400 mosquitoes per man per hour could be counted from almost any area within the camp. The high density of the Aedes mosquito here, as well as for other locations on the island, is due to the presence of innumerable breeding places and the dense unkempt vegetation in the immediate environs, the vegetation serving to conceal the breeding places and as mosquito resting areas.

Two areas within this camp were selected for determining the number of coconuts on the ground. In the first of these, a plot approximately 60 by 70 feet, a total of 153 coconuts was counted. Fifty-six of these had holes in them, rendering them suitable for breeding mosquitoes. Twelve of the nuts were breeding mosquitoes at the time the count was made, four of which had been opened by man, and the rest had been gnawed by rats or coconut-crabs. On the second plot, approximately 100 feet square, 101 coconuts were found, of which 52 were suitable for Aedes breeding. Aedes pseudoscutellaris was breeding in 8 of the nuts at that time.

Practically every nut on the ground in the area was completely covered over by dense grass, vines and other vegetation. For counting the number of coconuts on the ground in the two plots it was necessary to walk over every square foot of surface so as not to overlook the nuts. These counts do not take into account the numerous tin cans and other breeding sites that were

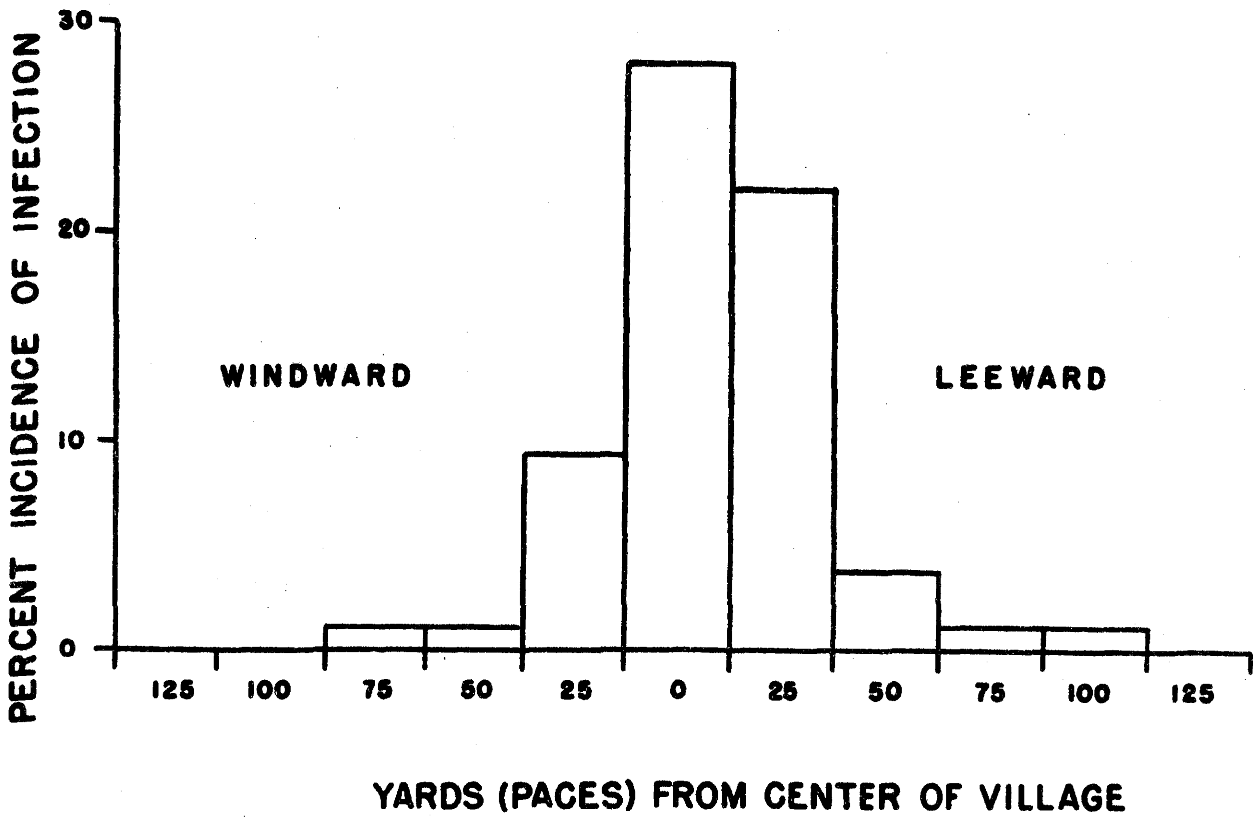


Chart VII. Flight range of Aedes pseudoscutellaris in Tutuila, as determined from the incidence of natural filarial infection in the mosquito from locations at various distances away from the source of the infection.

present and, hence, no attempt was made to estimate the total number of potential breeding sites within each of the two areas. It should be pointed out that this study was made during the so-called dry season. With the advent of the rainy season, when all these potential breeding places get filled in with water, the number of actual breeding places is something enormous and the density of Aedes mosquitoes very high.

Aedes pseudoscutellaris feeds during daylight hours. It is most active at twilight and at dusk, although it feeds actively at any hour of the day and occasionally even in bright sunlit places swept by strong wind. In shade and on cloudy days this mosquito may be particularly troublesome throughout all daylight hours.

In the undisturbed condition A. pseudoscutellaris does not feed at night. On one occasion a density of 300 to 400 mosquitoes per man per hour was determined for an area at about midafternoon. From 9 pm. to midnight of the same day, between 200 to 300 specimens of Aedes samoanus were captured per man per hour when they fed on natives at the same location; but not a single A. pseudoscutellaris appeared. After nightfall at a second location, an out-of-doors movie which was attended by both troops and natives, among mosquitoes attempting to feed on persons in attendance at the movie, Aedes pseudoscutellaris occurred in the ratio of one to every four specimens of other species. During daylight hours, A. pseudoscutellaris was the only species captured from this location.

On several occasions collections were attempted at night. Immediately upon arrival at the selected location small numbers of A. pseudoscutellaris came out to feed. So long as the collecting party remained motionless the feeding fell off to nil within a few minutes, and very few mosquitoes actually landed and drew blood. Each time the collecting party moved about in the area considerable numbers of the species could be seen flying about on being disturbed, although very few of them made any attempt to feed. The same feeding behaviour was observed for the species in the laboratory. Large numbers of the species would feed at any hour of the day while no more than a few bites were experienced when an arm was exposed at night. When the beam of a flashlight was not used to observe the number of feeding mosquitoes, fewer mosquitoes fed than when the flashlight was used.

Aedes pseudoscutellaris is a voracious feeder. In our experience very little nervousness is exhibited on the part of the species in its feeding habits. There is but little flying around as it approaches the victim, and once it alights feeding usually begins immediately. Occasionally a specimen can be seen to walk over the surface of the body, making several stabs at the skin before actually feeding. A moist shirt, especially when adhering to the body, offers little interference to the mosquito's feeding. This immediate attack on the victim together with its noiseless flight and almost painless bite often enables the species to feed unobserved on the exposed surface of the body. In Samoa, it was not uncommon to see two men occasionally slapping mosquitoes on each other's face as they stood about to talk, neither being aware of being bitten until one or the other chanced to see the feeding mosquito. Several minutes after the blooded mosquito is gone a small, itching wheal may appear on the skin of the allergic individual.

(ii) Anopheles farauti

Anopheles farauti, the principal vector of filariasis in the New Hebrides and Solomon Islands, on the other hand, breeds almost entirely in water directly on the ground. The species breeds in practically any and all still water, especially in ditches, impoundments, wheel ruts, borrow pits, hoof prints, and along stream banks where there is ample emergent or floating vegetation. Less frequent breeding places include, open fox holes, slit trenches, oil drums, tin cans, buckets, rot holes in trees, and canvas covers. Apparently open sunlight for at least a part of the day renders an area more suitable for breeding than is the case with Aedes pseudoscutellaris.

Anopheles farauti is more or less a sporadic feeder, feeding chiefly after nightfall. On one or two occasions the mosquito was observed to feed in deep jungle during daylight hours, and before nightfall on dark rainy days. In one village on Espiritu Santo many specimens of this mosquito came out to feed on the natives during a rain storm about two hours before night set in. The period of feeding lasted for about an hour, after which none was observed to feed until about 9.00 pm. In this village "flashlight catches" yielded more than 500 mosquitoes per man per hour in several huts before the first feeding was observed. On another occasion Anopheles farauti was observed to feed on the legs of a native as early as 9.30 am. On this occasion several collectors were in the hut making catches and the native sat idly by observing the process. In all probability the feeding activity was brought on by the fact that the mosquitoes were disturbed from their resting places. In the laboratory, when sufficient specimens of the species were available for tests, some feeding was observed to occur at all hours of the day, with only a slight increase in the number of bites after nightfall.

Very few specimens of Anopheles farauti were observed to rest away from human habitation. When found resting out in the open the species usually selects abandoned buildings, bridges, stream banks, and trees as resting places. In all cases the greater majority of the individuals are observed to rest close to the ground or a foot or two above the water level. In the New Hebrides the native huts are made mostly by weaving a rough mat of bamboo strips and uprighting these as walls. The ground serves as the floor and the walls of the huts extend up to the roof. In such huts A. farauti is most frequently found resting on the darker strips of the bamboo, on objects (rocks, sticks, sacks, and clothing) on the floor, and on clothing hung on the wall. Invariably the greater numbers of the mosquito will be seen to rest near the floor, and often on objects directly on the floor. There seems to be a preference for certain areas within the hut. It is not uncommon to find many mosquitoes in one corner of the hut or along one wall and few or none in other parts of the hut.

The native hut on Guadalcanal is of a different type from that seen on Espiritu Santo. Here the huts are more permanent structures, and, although made mostly of bamboo, coconut fronds, or a similar material, are constructed more on the order of the European house. Usually there is a central portion of the house and this is surrounded on three sides by a shed. The sheds may or may not be walled in. Occasionally the central portion is floored and the floor is one or more feet above the ground. The side walls of the central portion generally are left open for a space about two feet wide just under the roof. Less often another open portion, about one foot wide, is left open about one foot above the floor. Although A. farauti is found resting in the same types of situations in the huts on Guadalcanal as those observed on Espiritu Santo, fewer mosquitoes are found resting in the broken-walled huts than in those having continuous walls.

In both the New Hebrides and Solomon Islands the natives use a considerable number of stones, about the size of unhusked coconuts, for cooking purposes. When not in use these stones are generally piled up in one corner of the hut. Almost invariably large numbers of the Anopheles mosquito were found resting on such stones. It did not seem to matter how many specimens were taken from a given resting place within a hut nor how much disturbance was wrought in the original appearance of the location; one could return to the same site the following morning and find just as many resting mosquitoes as on the day before.

Because of the danger of contracting malaria, members of the survey took every precaution to avoid being bitten by Anopheles farauti, hence the nature of the bite was not studied outside of the laboratory. Although the Melanesian native did not seem to be the least bit perturbed by having a dozen or more specimens biting him about the ankles at one time, the authors were conscious of a single feeding specimen in the laboratory.

At both of these island locations it was generally assumed that Anopheles farauti is the principal vector of malaria. Certainly it is the only anopheline mosquito with a sufficiently wide distribution to play a major role in the transmission of either malaria or filariasis. Hence, in both island groups a vigorous mosquito control programme was already in operation by the time the authors arrived. The programme more or less accepted the thesis that the mosquito flies no more than one mile in search of the blood meal and, hence, the occupied area, with the usual mile safety zone about the perimeter, was under constant surveillance. Due to (1) close watch over the breeding sites of the mosquito by the malaria control personnel, (2) the fact that few cases of filariasis are known to have developed among service personnel from these island bases, and (3) the remarkable reduction in the number of initial malaria cases within the controlled area, it was not considered necessary to investigate the flight range of the species.

(iii) Other species of mosquitoes

The other two species of *Anopheles* considered in this paper breed and rest in the same situations as those observed for *A. farauti*. In one camp area only did all three species occur together; on seven collecting trips to the area the three species averaged 51 *A. koliensis* : 9 *A. punctulatus* : 7 *A. farauti* for each trip. At all other locations *A. farauti* was the most common species or the only anopheline found. In two or three selected areas *A. punctulatus* could be found resting in considerable numbers about the large buttress-like roots of certain trees. The camp (mentioned above) was the only location on Guadalcanal from which the species was taken from human habitation.

Of the two species of *Mansonia* which occur on Guadalcanal *M. uniformis* was the only one taken in large numbers. The majority of these came from one camp area, although a few specimens came from practically every location visited on the island. More specimens of the species were taken from tents than from regularly constructed huts.

Only one pupa and two fourth instar larvae of a *Mansonia* mosquito were taken in the field. The specimens came from an impounded river mouth where water-hyacinth was abundant. The larvae were collected by carefully washing the roots of the water-hyacinth into a pan after the plants had been transported to the laboratory. All other attempts to collect the larvae of the species failed.

There was no water-hyacinth in the immediate vicinity of the camp in which larger numbers of adult specimens were taken regularly every morning. Although several attempts were made, no *Mansonia* larvae were taken from the small river which ran through the camp area nor from the swamps less than one mile from the camp.

No specimens of any species of the *Aedes scutellaris* group were taken from Guadalcanal, although one or more species are known to occur on the island. *Aedes hebrideus*, a close relative of *Aedes pseudoscutellaris*, was quite common in certain parts of Espiritu Santo, and filaria larvae as old as the fourth day of developmental age were recorded from this species. The species was observed to be breeding prolifically in tin cans and coconut shells. Occasionally larvae were taken from rot holes in trees and from gnawed cacao pods. The mosquito was decidedly more nervous in its feeding habits than A. pseudoscutellaris. Often it was necessary to allow the species to imbibe a portion of a blood meal before it could be captured by the method employed. It was flighty, often circling the body many times before coming to rest, and not infrequently attempts to feed were delayed for sometime after alighting.

7. DISCUSSION

In the light of our present knowledge there is no single and simple method of making the diagnosis of filariasis. The diagnostic methods now employed, then, will do no more than give a moderately fair indication of the total number of individuals harbouring the filaria parasite within a given endemic area. On the basis of various diagnostic procedures many authors have estimated that from 60 to 80 per cent of the natives within the area covered by the present survey harbour or have harboured the parasite at one time or another during their lives. Perhaps this estimate is too low. Data from blood studies and from dissections of the probable and principal mosquito vectors, as well as from personal observations, convince us that filariasis is one of the more important diseases of man in the South and Southwest Pacific areas. Certainly, the demonstrated frequency with which blood microfilaria occurs in that group of the population surveyed from Samoa, New Hebrides, and Solomon Islands attests to the prevalence of the infection here (Tables 1, 2, 5 and 6).

In any endemic area it is just as important to know the species of mosquito responsible for the transmission of the filaria as it is to know the incidence of blood microfilaria in the general native population. The most practical means by which the vectors of filariasis can be determined for a given area is through the dissection of mosquitoes and actually observing the developing larvae within the tissues of the host. As pointed out earlier (pp. 31 and 56) the infection rate in a given species of mosquito is no criterion whereby the importance of the species to filaria transmission can be judged. Yamada (1927), Newton, et al. (1945), and others, have shown that a mosquito might be very efficient in picking up the larva from the blood stream (even nurturing the parasite during the first few days of the metamorphic cycle) but fail altogether to complete the development and, hence, never serve as a transmitter. Still other mosquitoes might permit the complete development of the larva in such a low percentage of the individuals as to be of minor or secondary importance in the propagation of the infection in the community. A good vector of filariasis must permit complete development of the larva in a sufficiently high percentage of the specimens to maintain at least a constant percentage incidence of infection in the human host.

Just how high the percentage incidence for infective stage larvae in the mosquito host must be in order to maintain the estimated 60 to 80 per cent infection in the human population is a problem not yet solved. However, some general idea of this requirement is offered. For Samoa (Tutuila) 2.56 per cent of all Aedes pseudoscutellaris (Table 22) taken from and about the native village harboured the infective stage larva. On Wallis, on the other hand, only a 0.19 per cent incidence for the infective stage larva was demonstrated in the mosquito from similar locations. When the combined records of all A. pseudoscutellaris dissected from these two islands (on which there is every reason for believing the incidence and epidemiology of filariasis to be about the same) are considered it is observed that 1.3 per cent of the mosquitoes had completed the development of the larval filaria (compared with the 9.38 per cent incidence of infection for the hosts from these two locations). In conformity with this, Anopheles farauti shows the same variation from island to island as was shown for Aedes. In the uncontrolled area of New Hebrides only 0.40 per cent of A. farauti developed the larva through its complete metamorphosis. On Guadalcanal, however, 4.27 per cent of the host harboured the infective stage of the parasite. A combined figure of 1.6 per cent is obtained when all data for A. farauti are taken into consideration (compared with the 27.81 per cent incidence of infection in this host for the two island locations). For Tutuila, then, 2.56 per cent of all A. pseudoscutellaris must carry the infective stage larva for the host to maintain the readily demonstrated 14.9 per cent (Dickson, 1943) incidence of blood microfilariae in the Polynesian inhabitants. On Guadalcanal, on the other hand, an incidence of 4.27 per cent for the infective stage larva is required for A. farauti to maintain a 40 per cent microfilaria rate in the inhabitants of that island.

In the Solomon Islands only one other species of mosquito, Anopheles koliensis, developed the filaria larva to full maturity in nature. Even here only a single specimen of the species was determined to harbour this stage in the metamorphosis of the parasite. On the other hand, however, several other species of mosquitoes within the areas were found to harbour developing larvae, some specimens of which had developed the larvae to the twelfth day of developmental age.

From the results of the present investigation it is shown further that in every case where the incidence of infection for both the native and the mosquito population in the uncontrolled condition was determined a higher percentage rate of infection occurred in the principal vector than was shown for blood microfilaria in the human population by the methods employed. Thus, in ten Samoan villages an incidence of blood microfilaria of 11.60 per cent was demonstrated for 1,400 individuals. In these same villages 19.23 per cent of the specimens of Aedes pseudoscutellaris harboured developing filaria larvae, an incidence of 7.63 per cent infection in the mosquito in excess of that shown for the native population from the same locations. In each of the ten villages the infection rate in the mosquito vector was higher than the microfilaria rate in the native population, the excess of the former over the latter in the ten villages being respectively: 2.05, 3.27, 3.43, 4.16, 4.47, 6.68, 7.63, 11.47, 12.26, and 17.15. Likewise, in the New Hebrides and Solomon Islands the infection rate in the mosquito vector was higher than the microfilaria rate; the excess in six locations surveyed were respectively: 3.42, 3.67, 4.64, 6.56, 8.24 and 12.73.

In two locations on the fringe of the controlled area on Espiritu Santo, on the other hand, the infection rate in the vector, Anopheles farauti, was lower than the microfilaria rate in the human population. Thirty-three and 46 per cent of the Melanesian population from the two villages, respectively, were found to harbour microfilariae in the blood stream, while only 12.5 and 15.1 per cent of the vector mosquito, respectively, were found to carry developing filaria larvae. Both locations were on the periphery of the controlled area; in addition to the mosquito larva control programme being carried out to one side of each location, each hut in the villages was sprayed with freon-aerosol (pyrethrum) at least once each week as a control measure against the adult mosquito. Although 71, or 14.79 per cent, of the 480 mosquitoes from the two locations were found to be positive for developing filariae, approximately 82 per cent of these contained only recently engorged microfilariae and none of the mosquitoes harboured larvae older than the eighth day of developmental age (Chart V). It would appear, then, that the adult mosquito spray-killing programme carried out here for the control of malaria was 100 per cent effective against the transmission of filariasis. Such a spray-killing programme against the adult vector will undoubtedly prove to be as valuable an adjunct to any control programme instituted against the house-resting filaria transmitting mosquito as that reported by Russell and Knipe (1939) for the control of malaria in India.

In the area where Aedes pseudoscutellaris is the principal vector it is observed that the incidence of infection in the mosquito varies from location to location within the same village. Many of the Samoan villages follow the coast for considerable distances and may be but a few huts in depth. Thus, collections of mosquitoes could be made regularly from sections of the village without too much intermingling of the inhabitants having occurred since the time of previous collections. Frequently, it was noted that an area of a village no more than 25 yards square proved to have a mosquito population showing 35 to 40 per cent infection for developing larvae, while mosquitoes from an adjoining section of the same village showed a much lower incidence of infection. This same condition exists from day to day and from week to week with never more than a very slight fluctuation being noted in the infection rate in the mosquito population. Often several sections of a village could be shown to have higher infection rates in the mosquito vector than adjoining sections. No attempt was made to show that the areas having high infection rates in the mosquito host corresponded to those in which the native inhabitants had a high incidence for the blood microfilaria. This was assumed to be the case and, after the short flight range of the vector was demonstrated, the explanation for the condition was evident.

In the area of the Anopheles vector (New Hebrides and Solomon Islands) this spotty distribution of the higher incidence rate in the mosquito host is not so evident. Due entirely to the method used in capturing A. farauti, much higher rates of infection for the recently ingested microfilariae are noted from hut to hut. This, however, only indicated the presence of a larger number of inhabitants within the specific huts harbouring the blood microfilaria. When the older stages in the developmental cycle of the parasite are taken into consideration the infection rate in the vector from the entire village is fairly uniform from section to section. Major differences in the infection rate in the vector are noticed from village to village, although when villages are fairly close together the infection rates in mosquitoes from adjoining villages vary but little.

With the exception of a few areas in New Hebrides discussed previously (page 59) which were inherently free of the disease, in all other locations investigated by us filariasis is endemic, the highest incidence demonstrated being 80 per cent for the native and 87 per cent for the mosquito vector in one village on Guadalcanal.

Just as it was true in the case of Culex fatigans in Samoa, the method of capturing Anopheles farauti and other night feeding species of mosquitoes in the New Hebrides and Solomon Islands undoubtedly gives a more accurate index of the infection rate in naturally infected individuals of the species than can be claimed for Aedes pseudoscutellaris. In Polynesia, for example, the Aedes mosquito was captured only as it attempted to feed in the field whereas the night-feeding species were taken as they rested in and about native habitation following the blood meal. Even here all the specimens taken had not fed recently although the majority of them had done so. Thus, in the case of the night-feeding mosquitoes, records on the dissections of the recently engorged individuals are more comparable to an experimental test than it would be under other conditions, such as those outlined for A. pseudoscutellaris.

As it was not possible to maintain a colony of Anopheles farauti in the laboratory, and attempts to keep specimens alive under experimental conditions met with failure within a few days, tests similar to those devised for A. pseudoscutellaris and C. fatigans were not possible for the Anopheles host. On several occasions, however, a colony of sufficient size for short term experiments could be built up from larvae caught in nature, or large numbers of the naturally infected host could be kept for a few days in laboratory cages. The observed death rate in these naturally captured individuals was extremely high, just as it was in the recently emerged specimens kept in the laboratory. In two tests, involving 266 adult A. farauti captured in nature, a 11.88 and 15.75 per cent infection, respectively, was determined from the dead mosquitoes. One batch of 101 individuals died at the rate of 1, 5, 13, 19, 32, 8, 12, 6, 1 and 4 mosquitoes for the successive days they were kept under observation. All of the positive individuals died during the first five days in the laboratory, at the rate of 2, 1, 4, 3, and 2 mosquitoes per day. In a second batch of 165 specimens deaths occurred as follows: 7, 33, 112 and 13 for successive days. The positives died during the first three days - 3, 5, and 18 specimens, respectively. In both tests, however, the filaria larvae present underwent development comparable to the corresponding day of developmental age in the Aedes host.

In nature, on the other hand, it was seen that the majority of the naturally infected Aedes host harboured larvae four to five days of age in the younger age-groups (Table 19 and Chart I) while the majority of the Anopheles host were infected with larvae younger than this (Tables 36 and 41, and Charts IV and VI). Such a difference in the percentage rate of infection for the different ages in the developmental cycle of the parasite is explained solely on the method of capturing the two different species of hosts. Unless one is constantly aware of this discrepancy, the higher overall percentage rate which can be demonstrated for the naturally infected Anopheles or Culex mosquito is likely to give the wrong impression. It was for this reason, fully substantiated by experimental data, that it became necessary to compute the number of naturally infected Aedes mosquitoes which died in the field because of the infection before captures could be made (Table 30 and Chart II). Even when the computed figure is taken as the true incidence of infection for the Aedes host in Samoa the infection rate comes to only 18.14 per cent as compared with 51.90 per cent for Anopheles farauti on Guadalcanal. However, it is believed that the computed infection rate for the Aedes mosquito more nearly corresponds to the actual than does the observed. This opinion is based on the observed infection in the experimental Aedes as well as the observed infection for the Anopheles vector from both the New Hebrides and Solomon Islands.

Regardless of the demonstrated infection rate in the general mosquito population, the more important point is the number of each vector harbouring the infective stage larva. The number of the host harbouring such larvae is conditional, and will be found to depend on (1) the ability of the host to nurture the larva through its complete metamorphic cycle and (2) the number of the host specimens which survive the initial stages of the infection.

Within the area covered by the survey only 2 of the 14 species of mosquitoes found to harbour the filaria larva developed the infective stage in sufficient numbers for them to play a major role in the transmission of the infection. One other species developed the larva to infectivity in the laboratory and one was shown to contain this stage in a single specimen in the field.

All other mosquitoes harboured only recently ingested microfilariae, with a few of the species developing the larva to various stages in its developmental cycle, but not to the infective stage. For the area covered, then, only Aedes pseudoscutellaris in Samoa and Wallis, and Anopheles farauti in New Hebrides and Solomon Islands, can be considered as principal vectors.

From the standpoint of the infection in the two vectors, however, only 45.45 per cent of the naturally infected Aedes host harboured larvae five days of developmental age or younger while 72.81 per cent of Anopheles farauti did so. On the other hand, 58.4 per cent of the experimental Aedes mosquito died on or before the fifth day of the developmental cycle of the larval parasite. In nature 54.55 per cent of the infected Aedes harboured larvae older than the fifth day of development, and only 27.19 per cent of A. farauti contained the older developmental stages. When the computed figures for the number of A. pseudoscutellaris harbouring larvae for the younger age-groups are used (Table 30), 65.86 per cent of the naturally infected mosquitoes contained larvae five days of age or younger while only 34.14 per cent harboured larvae older than the fifth day. It would seem therefore that the computed infection rate for A. pseudoscutellaris is more nearly the true incidence rate for the species, and that comparable results were obtained for the two hosts. Again, the method of making the captures will not permit making too close a comparison for the incidence of infection in these different and unrelated mosquitoes.

On the basis of the number of infected individuals harbouring the infective stage larva alone it would appear that but little difference can be seen in the ability of the two hosts, Aedes pseudoscutellaris and Anopheles farauti, to develop the larva to the infective stage. For the former species 1.3 per cent of all the naturally captured individuals developed the larva through the complete cycle while 1.6 per cent of the latter species completed the development cycle. On the other hand, A. farauti appears to be more efficient in picking up the microfilaria than A. pseudoscutellaris (Tables 34 and 43), as well as to carry a larger number of multiple infections (Tables 24 and 42).

Filariasis is primarily a disease of the community. The prevalence of the disease within the community is conditioned by: (1) community sanitation and (2) community stability.

In general the native community on the islands surveyed is a small congregation of individuals who carve out a site for themselves from the dense jungle and remain at the location as long as conditions are highly favourable to their existence. Certainly, the majority of the villages are more or less permanent, although it is not uncommon, among the Melanesians particularly, for the inhabitants of a village to have an alternate, even two or three, locations with more or less permanent houses already set up for occupancy. As a result the group is never in one place for more than a few months, often for only a few days, at a time. Usually one of the locations will constitute the pivot about which the group rotates, and rarely will the principal village be completely vacated. Occasionally two or more groups will alternate in the secondary villages and frequently no more than a foot-path will lead directly to the door of these temporary villages. Often solitary huts can be found in the dense jungle, and no more than a few yards of the jungle cleared away from about the dwelling. Undoubtedly, the semi-nomad type of life is a response to the food needs, for only one or two varieties of food seem to be grown at any one location. As the need for other food arises most or all of the village inhabitants move into another area for varying lengths of time. Most of the principal villages are arranged along the coast although a so-called "bush native" confines most of his activities to the hills.

Even in the principal village very little by way of sanitation is accomplished. A few of these villages are located directly on the coast, with the jungle cleared away between the huts and the sea, although it is not at all uncommon to find the coastal jungle interrupted by only a trail which leads back into the "bush" for a few yards to the village site. Here a fair sized village will be located, with no more of the jungle cleared away than is necessary for the creation of a dozen or more "native" houses. Where possible the village is located in the proximity of a source of fresh water, usually a stream.

In Polynesia, on the other hand, the village is more or less a permanent dwelling place, although it is not uncommon for the inhabitants of the smaller villages or groups from the larger ones to visit another village for one, two, three, or more weeks at a time. When the food supply in the village being visited is exhausted the visitors return home to serve as hosts to visitors from that or another village group.

The village green is usually kept at lawn conditions, often appearing as a park area. Along the coast the Polynesians generally clear away all low vegetation and grass from the area between the houses and the sea than is the case with the Melanesians, and usually such an area is quite extensive, depending on the available land space. Inland from the sea the village green consists mostly of an area central to a circular fringe of houses.

In either case, Melanesian or Polynesian, the area immediately surrounding the village is left to the jungle. In such an area the mosquito vector finds ample breeding places within a short flight range of the native population. As the development of the parasite is completed in the mosquito host within two weeks or less, the native has only to occupy a permanent or temporary village site for this short period of time for transmission to be continued. Once transmission begins, its continuance is dependent upon the usual concepts of insect-borne disease transmission, namely: (1) a constant source of the infection for the insect vector; (2) the presence of an efficient insect transmitter; (3) the density of both the infected human host and the transmitting insect; (4) a free intercourse between the vector and the human host; and (5) a susceptible human population to whom the infection can be transmitted.

The only source of the infection for the mosquito vector is the native population. As was demonstrated in Samoa the centre of the infection is the native village. Within the native village the incidence of infection for the native and mosquito alike can be demonstrated readily to be 10, 20, 30 per cent or more. Twenty-five yards away from the perimeter of the village the infection in the mosquito may be only one-half that shown for the host within the village proper, and entirely absent in the host at a distance of 150 yards from the village. The village in the endemic area, then, must be regarded as a hyperendemic focus of infection. To reside in or even be closely associated with such a focus of infection almost assures the estimated 60 to 80 per cent infection for the native population. Except for the assumed longer flight range of <u>Anopheles farauti</u> the same hyperendemicity of the native village on the islands of the New Hebrides and Solomon groups prevails. Here, however, because of the longer flight range of the vector, the hyperendemicity of a focus may become contiguous with that of an adjacent one, with the intensity of transmission in the intervening area being inversely proportional to the distance away from either focus.

As was shown above (p.54 and Table 32) a temporary focus of infection may be built up in the <u>Aedes</u> mosquito outside of the village area by infected natives who visit an area daily in pursuit of work or for food gathering. Such extraneous foci of infection are less likely to occur in the case of the night-feeding <u>Anopheles</u> since working parties are less likely to be bitten in strong light and because the natural human tendency is to return home at nightfall.

Within the hyperendemic focus the incidence of infection in both the native and mosquito populations is fairly constant. Minor fluctuations in the infection rate are noted from day to day, or from month to month. Such variations, however, fluctuate about a relatively stable percentage value. An increase or a decrease in the density of the vector in such a focus affects the general incidence value only temporarily, there being a quick return to the normal in either case. In many locations we were able to demonstrate a 15 per cent infection in the mosquito host, for example, when the density of the vector was shown to be 100 mosquitoes per man per hour. The incidence of infection may be found to be two or three per cent lower following recent emergence of large numbers of the host (density count jumped suddenly to 300 mosquitoes per man per hour), or as much as 18 per cent when the density fell to half its original level. Such fluctuations as these return to the normal (15 per cent) within a very few days regardless of which way the density count goes. Thus, within the focus a sufficient number of individuals harbouring microfilariae was distributed throughout the area for at least 15 per cent of the local vector to feed on infective blood regardless of how many mosquitoes happened to be in the vicinity at a given time. Within a given area the larger the number of individuals harbouring blood microfilariae the higher the percentage of infection in the mosquito vector will be. For the area covered by the survey the infection rate in the mosquito host was always slightly higher than the demonstrated infection rate in the human host (p. 76).

The rate of transmission of filarial infection, then, is not conditioned only by the infection rate in the transmitting insect. When the infection rates in the human and mosquito hosts are constant the rate of transmission is dependent upon the density of the vector. As is shown above the infection rate remains fairly constant in the mosquito vector regardless of the density of the vector. This being the case, the density of the vector conditions the amount of transmission. To take a hypothetical case, in a location where 10 per cent of the vector harbour developing larvae and where the vector density is 100 per man per hour, only one in ten mosquitoes will ever be able to transmit the infection. When the density is increased to 250 mosquitoes per man per hour, the infection rate in the mosquito remaining the same, the density of infected mosquitoes increases by two and one-half times, in direct proportion to the increased total density. In a like manner an area having a low density count for the vector but a high incidence of infection is much less dangerous to the casual visitor than is a location having a low incidence of infection and a high density count. For example, when the density count is 500 mosquitoes per man per hour and the infection rate is 10 per cent for a given location, the extent of transmission here is equivalent to that of another location with a density of 100 mosquitoes per man per hour and an infection rate of 50 per cent. Transmission, then, is in direct proportion to the density of the vector in an area where the incidence of infection in both the human and mosquito host is constant.

8. CONTROL OF FILARIASIS

As is the case with so many insect-borne diseases the control of filariasis resolves itself into the control of the insect vector. The measures for the control of filariasis would vary according to the breeding, flight, and feeding habits of the transmitting mosquito. These habits vary with the vector species, and from location to location.

In Polynesia the transmitting mosquito, *Aedes pseudoscutellaris*, confines its breeding to small accumulations of water such as will always be found in innumerable receptacles within the rain forest on the majority of the islands in the area. The rapid growth of vegetation, the heavy rainfall, strong steady trade wind, and the lassitude of the native population which prevail in the tropical climate, do not lend themselves to the eradication of the vector or vectors of the disease. On the volcanic islands particularly the native populations live in relatively small, well isolated locations, usually at the mouth of some stream, along the coast. It is not infrequently that relatively high ridges come down to the sea, forming well protected but isolated cove-like valleys, in which are located village groups of various sizes. Most of the villages are shallow in depth but may become contiguous with adjacent ones when the terrain is suitable. In the larger principal villages, some sections appear to be well sanitated and cleared of the jungle growth. The jungle encroaches upon all areas and crowds in to reclaim these with the first show of negligence on the part of the inhabitants.

On the coral atoll, on the other hand, the amount of vegetation may be no more than is required for the bare necessities of existing human life. On the larger atolls the overall general conditions are favourable for the propagation of filariasis, many of which are supported in part by current farming practices. On the larger volcanic islands or the larger atolls the grazing of cattle and horses on the coconut plantations is often enough to keep the undergrowth in excellent control once the area is cleared for farming. Such a measure is essential to the recovery of a maximum crop, and is an invaluable adjunct to the control of the mosquito vector within the location. When the area or the island is of insufficient size or fertility to support this additional animal life, the control of the undergrowth is left to the initiative of man.

The eradication of <u>Aedes pseudoscutellaris</u> is possible only on a small scale in Polynesia as for example on the smaller atolls. O'Connor (1923) has demonstrated how this vector was eradicated on the islet of Funafulla: "It is obvious from this account of its habits and breeding-places, that measures for the control of the insect (<u>A. pseudoscutellaris</u>) would not, particularly in the coral islets, be difficult to formulate. Periodic cutting and burning of bush and burning of husks of coconut (if these cannot be used for coir) would do much, and the use of very dilute cresyl for water-holes that are not used for drinking and the employment of aquatic natural enemies in those that are, would also tell. But, of course, the success of any measures would depend upon the wisdom of the inhabitants and their response to instruction. It is not difficult to imagine a determined and intelligent people keeping the insect at a safe distance, with very little assistance.

"That the insect can be exterminated from a single islet by one determined effort I myself proved by an experiment with the islet of Funafulla, an islet from 75 to 120 yards broad and about a mile-and-a-quarter long, that forms a part of the atoll of Funafuti (Ellice Islands).

"Fifty men armed with hatchets or choppers and formed in line like beaters marched right down the island and cut all the bush to the ground. The work was completed in a single day. Next day the ground was again traversed and everything combustible was conveniently stacked and set on fire. At the same time all holes in trees were trimmed or drained. The result was that all adult insects were burned or smoked out, and during the week that I remained on the islet afterwards, only three could be found." (O'Connor, 1923, page 16).

During the present survey eradication of Aedes pseudoscutellaris was achieved on another island of the Ellice group. The island was the largest in the atoll of Funafuti, and measured approximately four miles in length by no more than half a mile in greatest width. Because of the exigencies of war the entire native population relocated itself on another island, a considerable distance from the one in question. Due to this fact alone the island was considered to be free of filariasis within a few weeks following the wholesale emigration of the native population. However, the presence of a sufficient number of service personnel to utilize practically every square yard of the island's livable surface resulted in a complete destruction of the underbrush and the establishment of a thorough sanitation programme. The complete disruption in the normal routine of the island was accomplished within a very short time so that within a matter of days Aedes pseudoscutellaris completely disappeared.

Due to the fact that fresh water for so large a body of men could not be obtained on the island except by distillation and the employment of numerous rain barrels, breeding of all mosquitoes was reduced to the absolute minimum except in these temporary, essential water containers. Aedes aegypti was the only mosquito which survived the campaign to breed in any numbers under the vigorous control programme maintained on the island. The density of the adult A. aegypti varied so sharply from month to month that a constant effort in the control programme had to be directed against this species alone.

On the volcanic island, on the other hand, the control of Aedes pseudoscutellaris, at best, can be accomplished only locally. On this type of island the control seeks only to reduce the density of the adult mosquito to a level sufficiently low to render it negligible as a pest and impotent as a vector of filariasis. Such a reduction in the density of the species can be accomplished readily within limited areas and this can be maintained as long as desired.

On the islands of Wallis and Tutuila, where the major part of the control work was undertaken, the density of the vector was reduced from the overall density level of 96 and 129 mosquitoes per man per hour, respectively, to practically zero by but a single control effort. This marked reduction in the number of mosquitoes within the controlled areas was accomplished mainly by removing all breeding and resting places of the vector from within and for a distance of 100 yards about the periphery of the area to be controlled. In certain localities a second campaign, or even a third or a fourth, was necessary to bring the density to zero. Once the area was gone over and the breeding and resting places of the mosquito removed or destroyed, very little effort was required to maintain the area in a mosquito-free condition. Density counts both before and after such a "clean-up" programme for a few specific locations should suffice to illustrate the results obtained. These follow (where the density figures represent the number of mosquitoes per man per hour).

Area I

Collecting stations	Mosquito density before clean-up programme	Mosquito density after clean-up programme
1	54	0
2	20	0
3	80	0
4	96	3
5	210	7
6	170	2
7	312	36
Average	134.6	6.9

Area II

1	24	0
2	72	7
3	72	9
4	120	9
Average	72.0	6.3

Area III

1	456	8	-	2
2	36	0	-	0
3	336	20	-	0
4	110	0	-	0
5	615	36	-	18
Average	310.6	12.8	-	4.0

Area IV

Collecting stations	Mosquito density before clean-up programme	Mosquito density after clean-up programme
1	40	0
2	62	2
3	180	10
4	200	0
Average	120.5	3.0

Area V

1	60 - 75	0 - 0 - 0
2	360 - 320	10 - 0 - 0
3	240 - 240	0 - 0 - 0
4	470 - 400	22 - 2 - 0
5	456 - 440	8 - 0 - 0
6	336 - 360	6 - 0 - 0
7	110 - 90	0 - 0 - 0
8	80 - 80	0 - 0 - 0
Average	264.0 - 250.6	5.8 - 0.3 0

In one area a control programme was put into effect, maintained for several weeks, and then abandoned because of consolidation of camp areas. Density counts in this area before, during, and after abandonment of clean-up work, run as follows:

Area VI

Collecting stations	Mosquito density prior to control work	Density during active control	Density after abandonment
1	380	20 - 0	460
2	400	10 - 0	380
3	160	0 - 0	210
4	60	0 - 0	40
Average	250.0	7.5 - 0.0	272.5

Control work in many other locations gave similar results to those outlined above. In many areas the vector completely disappeared when its resting and breeding places were removed for only a few yards about the area. When the "clean-up" programme was extended for as much as 100 yards beyond the periphery of the village or camp the density invariably fell off to such a low level that often two or three hours were required to find but a single mosquito at stations where previously 30 to 40 or more specimens could be taken in a period of only ten minutes.

As the control programme progressed in and about the camp locations, the general sanitation of the native villages improved. In many of the purely native villages the density of the Aedes mosquito was seen to drop off until it was extremely difficult to obtain enough infected mosquitoes to demonstrate the developing larvae to interested persons. For this show of industry on the part of the native populace the interest the island government took in the control programme was mainly responsible.

Since Aedes pseudoscutellaris breeds but rarely in water directly on the ground and because of its habits of breeding in small, usually well-concealed containers, the usual spray-oiling programme is ineffective against this species. The small water containers in which it breeds must be sought out and destroyed. By removing the grass, vines, and other low vegetation from an area the breeding places are exposed for disposal and the resting places are eliminated at the same time. Tree-holes must be filled with sand, gravel, or other suitable filler, or opened to allow immediate draining. These should be trimmed or filled in such a way as to prevent future collections of water.

In the area of the night-feeding Anopheles vector of filariasis a well organized and vigorously prosecuted anti-mosquito programme was already in operation by the time the authors arrived. In the case of the anopheline vector, or any mosquito normally breeding on the ground, a more extensive programme of control will be required in the control of filariasis than that which proved to be sufficient for the control of the Aedes mosquito. Such a programme as that normally used against the malaria vectors will be most satisfactory. The efficiency of such a programme in controlling filariasis on Espiritu Santo, (pages 58-59, Tables 37 and 38, and Chart V), and Guadalcanal, (page 62) has been well demonstrated. At these two locations a sufficient number of the principal vector could be obtained only from the margin of the controlled area or from entirely outside of that area. Here the principal effort of the control programme was aimed at the control of malaria and dengue, while only those pest mosquitoes which bred and rested in association with the vectors of these two diseases were controlled equally as well. Species which did not breed or rest in the same habitats as the malaria or dengue vectors, were not affected by the control measures employed, as for example Aedes hebrideus. Large numbers of Aedes hebrideus could be captured from almost any location within the controlled area on Espiritu Santo. Although some development of the filaria larva took place in A. hebrideus no specimen was taken which harboured larvae older than the fourth day of developmental age. For this reason no control measures were instituted against it. The control of this species would vary but slightly from measures against A. pseudoscutellaris.

The only other mosquito in the two island locations which gave some promise of being of importance to the transmission of filariasis, and which in all probability would not be effectively controlled by measures now in use against the vectors of malaria, was Mansonia (Mansonioides) uniformis. In so far as the survey was able to determine, larvae of the Mansonia mosquito attach themselves to the water-hyacinth for breathing purposes. Where the Mansonia mosquito is common, the drainage of flood or impounded water together with the removal of the "host" plant from such bodies of water should be of material aid in the control of the species.

REFERENCES

Ashburn, P.M. & Craig, C.F. 1907 Observations upon Filaria philippinensis and its development in the mosquito. Philipp. J. Sci., (B), 2 : 1-14.

Bahr, P.H. 1912 Filariasis and elephantiasis in Fiji. London Sch. Trop. Med., Res. Mem. Ser., 1 (1) : 1-192.

Brochard, V. 1910 Recherches sur une microfilaire humaine des iles Wallis. Bull. Soc. Pat. Exot., 3 : 138-142.

Dickson, J.G. 1943 Annual sanitary report of the Public Health Department of American Samoa with an appendix. 48 typed pages.

Hu, S.M.K. 1935 Preliminary observations on the longevity of infective larvae of Wuchereria bancrofti Cobbold in Culex pipiens var. pallens Coquillett. Chinese Med. J., 49 : 529-536.

Newton, W.L., Wright, W.H. & Pratt, I. 1945 Experiments to determine potential mosquito vectors of Wuchereria bancrofti in the Continental United States. Amer. J. Trop. Med., 25 : 253-261.

O'Connor, F.W. 1923 Researches in the Western Pacific. London Sch. Trop. Med., Res. Mem. Ser., 4 : 1-57.

Russel, P.F. & Knipe, F.W. 1939 Malaria control by spray killing adult mosquitoes. First season's results. J. Malar. Inst. India, 2 : 229-237.

Schlosser, R.J. 1944 Monthly Malaria Reports, 20th Malaria Survey Unit, A.U.S. Aug. & Dec. 1943, and Jan. 1944.

Schlosser, R.J. & Reiber, R.J. 1945 Anopheles punctulatus found to mature both Plasmodium and Wuchereria on Guadalcanal. Newsletter, Hdqrs. Mal. Epidem. Control, South Pacif. Area, May 1945, p. 4.

Stage, H.H. & Yates, W.W. 1936 Some observations on the amount of blood engorged by mosquitoes. J. Parasit., 22 : 298-300.

Stempien, S.J. 1944 Filariasis in the Gilbert Islands. A report of survey, 1944. Report by Epidemiology Team on Apamama, Gilbert Islands. Accession No. 9522, 7 typed pages.

Thorpe, V.G. 1896 Filaria sanguinis hominis in the South Sea Islands. Brit. Med. J., 2 : 922-924.

Vincent, M.M. 1944 Monthly malaria reports. 15th Malaria Survey Unit, A.U.S. July, Aug., Sept. & Dec. 1943, and Jan., Mar. & April 1944.

Yamada, S. 1928 An experimental study of twenty-four species of Japanese mosquitoes regarding their suitability as intermediate hosts for Filaria bancrofti Cobbold. Sci. Repts Govt. Inst. Infec. Dis., Tokyo, (1927), 6 : 559-622.

(Continued from outside back cover)

102. Index Of Social Science Research Theses On The South Pacific. April 1957. (4/- stg., 5/-A., 4/6F., $0.60, 2G.)

CO-OPERATIVES

1. The Co-operative Movement in the Gilbert and Ellice Islands. H. E. Maude. February 1949.
42. The Co-operative Movement in Papua and New Guinea. Prepared by the Registry of Co-operative Societies, Port Moresby. February 1953.
51. A Bibliography of Co-operation in the South Pacific. December 1953.
75. Catalogue of the Commission's Co-operative Library (Bibliography of Co-operation). January 1955. (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
120. A Guide to the Marketing of Copra in Primary Co-operative Societies. C. G. Joannides. January 1959.
121. Catalogue of the S.P.C. Co-operative Library January 1959. (Revised edition of T.P. 75.) (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
123. Co-operatives in the South Pacific. (Report of the SPC Technical Meeting on Co-operatives held at Port Moresby July 21-A.gust 1, 1958.) February 1959.

COMMUNITY DEVELOPMENT

2. Community Development. March 1950.
11. Interim Reports on the Moturiki (Fiji) Community Development Project. Howard Hayden, Director of Education, Fiji. May 1951.
26. Further Education in the Cook Islands. P. F. Henderson, Officer for Further Education, Cook Islands. July 1952.
35. The Purari Delta—Background and Progress of Community Development. November 1952.
45. The Nimboran Community Development Project. Dr. J. van Baal, Director of the Bureau of Native Affairs, Netherlands New Guinea. June 1953.
46. The Koror Community Centre. Reports supplied by the High Commissioner, Trust Territory of the Pacific Islands. August 1953.
74. Educational Aspects of Community Development. R. Thomson. January 1955. (4/- stg., 5/- A., 4/6F., $0.60, 2G.)
84. The Communities Project Approach to Economic Development. H. Belshaw. July 1955.

EDUCATION

3. The Village Library. April 1950.
14. Educational Broadcasts to Samoan Village Schools. Department of Education, Western Samoa. May 1951.
15. Libraries for Beginners. Dr. and Mrs. Kenneth Todd, Kwato Mission, Eastern Papua. July 1951.
Types of Organization in Adult and Mass Literacy Work. D. B. Roberts, Organizer of Island Literature, South Pacific Commission. August 1952.
44. The Use of the Vernacular in Teaching in the South Pacific. G. J. Platten. June 1953.
47. Central Vocational Training Institution. F. J. Harlow. August 1953. 5/- stg.; plans available sep. (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
72. Literacy Teaching for Adults. Karel Neijs. November 1954. (5/- stg.)
73. Educational Evaluation—A Documentary Survey. J. C. Nield. December 1954.
99. Education In The Pacific Islands—A Selective Bibliography. C. Wedgwood. November 1956. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
114. An Experimental Course in Adult Literacy. Karel Neijs. January 1958.

OTHER SUBJECTS

6. A Preliminary List of Economic Plants of New Caledonia. J. Barrau, Director of Agriculture, New Caledonia. July 1950.
7. A Preliminary List of Plants Introduced into Tahiti. July 1950.
16. Some Notes and Suggestions Regarding Conservation of Important Archaeological Sites and Archives in South Pacific Territories. F. M. Keesing. August 1951. (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
25. Report of Fisheries Conference, Noumea. May 1952.
28. Coral as a Building Material. July 1952.
30. Bibliography of Cargo Cults and other Nativistic Movements in the South Pacific. Ida Leeson. July 1952.
41. Social Problems of Non-Maori Polynesians in New Zealand. Rev R. L. Challis, Pastor of the Pacific islanders' Congregational Church in New Zealand. February 1953.
49. The Social and Cultural Position of Micronesian Minorities on Guam. R. R. Solenberger. October 1953.
53. Reclamation of Tidal Mud Flats in Tonga. W. Straatmans, Head of the Department of Agriculture, Nuku'alofa, Tonga. March 1954.
70. A Linguistic Survey of the South-Western Pacific. Dr. A. Capell. November 1954. (20/- stg., 25/-A., 22/6F., $3.00, 10G.)
76. A Bibliography of Tropical Housing. January 1955.
93. Clearing House Service for Broadcast Recordings—Information and Catalogue. July 1956.
103. How to Make Your Own Posters. Nancy Phelan. May 1957. (2/6 stg., 3/3A., 2/9F., $0.40, 1.25G.)
108. Practical Aspects Of Weed-Killing By Chemicals In Tropical Crops. E. J. E. Lefort. July 1957.
111. A Selected Annotated Bibliography of Trochus. R. Gail and L. Devambez. January 1958. (2/6 stg., 3/3A., 2/9F., $0.40, 1.25G.)
112. Film and Filmstrip Catalogue. (Revised edition of T.P. 71). January 1958. (3/- stg., 3/9A., 3/6F., $0.45, 1.50G.)
122. Social Development in the South Pacific. (Report of the Ninth Research Council Meeting.) February 1959.

PRINCIPAL COMMISSION PUBLICATIONS

- The *SPC QUARTERLY BULLETIN* features articles on activities in the Commission's three main fields of operation: economic development, health and social welfare.

SUBSCRIPTION RATES

PRICE	*STG.*	*AUST.*	*FIJI*	*U.S.$*	*N.G. GUILDERS*
Single copy	2/–	2/6	2/3	0.30	1.00
One year ..	8/–	10/–	9/–	1.15	4.00
Three years	20/–	25/–	22/6	2.80	10.00

- *TECHNICAL PAPERS:* See list above.
- *OFFICIAL RECORDS: Proceedings of Sessions of the South Pacific Commission* (First to Nineteenth); *Annual Reports of the South Pacific Commission (1948 to 1958); Reports on the First, Second and Third South Pacific Conferences.*
- *EXPERT REPORTS:* The Oxford University Press is publishing a series of Expert Reports in book form for the Commission. Four have been issued to date:

VOCATIONAL TRAINING IN THE SOUTH PACIFIC. By R. A. Derrick, M.B.E., A.M.I.S.E., F.R.G.S. Mr. Derrick's report consists of a survey of the facilities for professional and technical training in the whole of the South Pacific, and of recommendations for future development.
Price in Australia ***30/-A.***

MOTURIKI: A PILOT PROJECT IN COMMUNITY DEVELOPMENT. By Howard Hayden. A fully documented, copiously illustrated report on a pilot project in community development carried out under Commission sponsorship on the island of Moturiki by the Government of Fiji.
Price in Australia ***42/-A.***

SOCIAL ANTHROPOLOGY IN MELANESIA: A Review of Research by Dr. A. P. Elkin, Professor of Anthropology in the University of Sydney. In this report Dr. Elkin reviews past, present and future anthropological research in Melanesia, designed to advance native welfare.
Price in Australia ***27/6A.***

SOCIAL ANTHROPOLOGY IN POLYNESIA: A Review of Research by Dr. Felix M. Keesing, Professor of Anthropology, Stanford University. This is a parallel study to Professor Elkin's report on anthropological research in Melanesia.
Price in Australia ***27/6A.***

- *BIBLIOGRAPHY:* The following bibliography has been published for the Commission by Oxford University Press:

A BIBLIOGRAPHY OF BIBLIOGRAPHIES OF THE SOUTH PACIFIC: Compiled by Miss Ida Leeson, former Mitchell Librarian. A basic catalogue arranged by area and subject.
Price in Australia ***15/-A.***

- *OTHER PUBLICATIONS:*

The Construction of Literacy Primers for Adults: By Dr. K. Neijs .... *5/-Stg.*
How to Make Your Own Filmstrips: By Nancy Phelan. *2/6Stg.*

The above volumes are obtainable through leading booksellers.

ENQUIRIES TO SOUTH PACIFIC COMMISSION, G.P.O. BOX 5254, SYDNEY, AUSTRALIA.

Printed by Bridge Printery Pty. Ltd., 117 Reservoir St., Sydney.

South Pacific Commission Technical Papers

Copies of Technical Papers, which are published both in English and French editions, may be procured from the South Pacific Commission, Nouméa, New Caledonia, or G.P.O. Box 5254, Sydney, Australia. Except where otherwise stated, price per copy, post free by surface mail, is 2/- stg. (2/6 Aust., 2/3 Fijian, 30 cents U.S., 1 New Guinea guilder)*.

NUTRITION

18. Report on Nutrition Investigations by the South Pacific Commission in 1950. November 1951.
22. Chemical Composition of the Milk of New Hebridean Mothers. F. E. Peters, biochemist, South Pacific Commission. February 1952.
23. Nutrition Research Conducted in New Hebrides during 1951. Sheila Malcolm, nutritionist, South Pacific Commission. April 1952.
50. Nutrition Investigation in New Caledonia. Sheila Malcolm. October 1953.
63. Diet and Nutrition in American Samoa. Sheila Malcolm. August 1954.
83. Diet and Nutrition in the Trust Territory of the Pacific Islands. Sheila Malcolm. July 1955.
85. Etudes sur la Nutrition et l'Alimentation dans les Etablissements Francais de l'Oceanie (Summary and Conclusion in English). Sheila Malcolm. April 1955.
95. Bibliography of the Nutritional Aspects of the Coconut (revised edition of T.P. 58). F. E. Peters. September 1956.
100. Chemical Composition of South Pacific Foods—An Annotated Bibliography. F. E. Peters. January 1957. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
106. Some Food Problems in The Pacific Islands. H. S. McKee. May 1957.
113. The Diet of Mothers and Children on the Island of Guam. Sheila Malcolm. January 1958.
115. The Chemical Composition of South Pacific Foods. F. E. Peters. January 1958.
118. Nutrition and the Papuan Child. H. A. P. C. Oomen and S. H. Malcolm. April 1958. (8/- stg., 10/-A., 9/-F., $1.20, 4G.)

PUBLIC HEALTH

12. Tuberculosis Investigations by the South Pacific Commission in 1950. May 1951.
24. A Survey of Leprosy on the Island of Nauru. Dr. C. J. Austin, Director, Makogai Leprosy Hospital, Fiji. April 1952.
27. A Survey of Leprosy in the British Solomon Islands Protectorate. Dr. C. J. Austin. July 1952.
56. Leprosy in Netherlands New Guinea. Dr. Norman R. Sloan. April 1954.
57. Leprosy in the Trust Territory of the Pacific Islands. Dr. Norman R. Sloan. April 1954.
62. Leprosy in American Samoa. Dr. Norman R. Sloan. July 1954.
64. Dental Conditions in School Children of American Samoa. Dr. Raymond G. Neubarth. August 1954.
67. Ophthalmological Survey of the Trust Territory. Dr. H. E. Crawford. September 1954.
69. Leprosy in Western Samoa and the Cook Islands. Dr. Norman R. Sloan. October, 1954.
96. Health Education In The South Pacific. G. Loison and L. L. Keyes. September 1956.

MOSQUITO-BORNE DISEASES

17. Conference of Experts on Filariasis and Elephantiasis, Tahiti: Summary of Proceedings. September 1951.
33. A Survey of Malaria in the British Solomon Islands Protectorate. Dr. R. H. Black, School of Public Health and Tropical Medicine, University of Sydney. November 1952.
60. Some Aspects of Malaria in the New Hebrides. Dr. R. H. Black. May 1954.
61. Malaria in the Trobriand Islands. Dr. R. H. Black. May 1954.
65. Annotated Bibliography of Filariasis and Elephantiasis. September 1954. (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
66. Distribution of Filariasis in the South Pacific Region. Dr. M. O. T. Iyengar. September 1954. (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
68. Malaria in the Torres Straits Islands. M. Josephine Mackerras and Dorothea F. Sandars. October 1954.
80. Malaria Control and Research in Netherlands New Guinea. Dr. R. H. Black. March 1955.
81. Malaria in the South-West Pacific. Dr. R. H. Black. March 1955.
86. Distribution of Mosquitoes in the South Pacific Region. Dr. M. O. T. Iyengar. 1955. (8/- stg., 10/-A., 9/-F., $1.20, 4G.)
88. Annotated Bibliography of Filariasis and Elephantiasis. Part 2. Dr. M. O. T. Iyengar. Jan. 1956. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
104. Developmental Stages Of Filariae In Mosquitoes. Dr. M. O. T. Iyengar. May 1957.
105. An Investigation On Filariasis In The Berau Region. H. de Rook. May 1957.
109. Annotated Bibliography of Filariasis and Elephantiasis. Part 3. Dr. M. O. T. Iyengar. July 1957. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
110. Enquete epidemiologique et entomologique sur la Filariose de Bancroft en Nouvelle-Caledonie et dependances. M. Lacour et J. Rageau. (With Summary in English). August 1957.
117. La repartition geographique des moustiques en Nouvelle-Caledonie et dependances. J. Rageau. Mars 1958. (Available in French only).
119. Enquete entomologique sur le Paludisme aux Nouvelles-Hebrides, Jean Rageau et Guy Vervent. Janvier 1959. Available in French only. (25 francs CFP.)
124. Annotated Bibliography of Filariasis and Elephantiasis. Part 4. Dr. M. O. T. Iyengar. July 1957. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)

TROPICAL CROPS

31. Cocoa Plantation Management in Western Samoa. D. R. A. Eden, General Manager, New Zealand Reparation Estates, and W. L. Edwards, Assistant General Manager. October 1952.
36. Cocoa Growing in Fiji Islands. D. H. Urquhart, former Director of Agriculture, Gold Coast. December 1952.
37. Cocoa Growing in Netherlands New Guinea. D. H. Urquhart. January 1953.
38. Coffee Growing in New Caledonia. D. H. Urquhart. January 1953.
39. Cocoa Growing in Western Samoa. D. H. Urquhart. January 1953.
40. Cocoa Growing in New Hebrides. D. H. Urquhart. January 1953.
48. The Management of Coconut Plantations in Western Samoa. D. R. A. Eden. September 1953.
82. The Manufacture of Copra in the Pacific Islands. W. V. D. Pieris. July 1955. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
87. L'agriculture vivriere autochtone de la Nouvelle-Caledonie, par Jacques Barrau; precedee de l'organisation sociale et coutumiere de la population autochtone, par Jean Guiart. Janvier 1956. Available in French only. (20/- stg., 25/-A., 22/6F., $3.00, 10G.)
94. Food Plants of the South Sea Islands. Dr. E. Massal and Jacques Barrau. September 1956. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
97. Rice Production In The South Pacific Region. R. Watson. October 1956.

PESTS AND DISEASES OF PLANTS AND ANIMALS

9. Report of Plant and Animal Quarantine Conference, Suva. April 1951.
34. Rhinoceros Beetle Control in the Kingdom of Tonga. L. J. Dumbleton, Plant and Animal Quarantine Officer, South Pacific Commission. November 1952.
77. A List of Diseases and Parasites of Animals Recorded in the South Pacific Territories. Bilingual. December 1954.
78. A List of Plant Diseases Recorded in South Pacific Territories. Bilingual. December 1954.
79. A List of Insect Pests Recorded in South Pacific Territories. Bilingual. August 1955. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
101. Parasites And Predators Introduced Into The Pacific Islands For The Biological Control Of Insects And Other Pests. L. J. Dumbleton. March 1957.
107. The Rhinoceros Beetle In Western Samoa. R. A. Cumber. June 1957. (4/- stg., 5/-A., 4/6F., $0.60, 2G.)
116. Contribution a l'Etude des Cochenilles d'Interet Economique de Nouvelle-Caledonie et Dependances, par F. Cohic. Fevrier 1958. Available in French only.

ECONOMIC CONDITIONS

54. The Pacific Islander and Modern Commerce. V. D. Stace, Assistant Economist, Reserve Bank of New Zealand. March 1954.
89. Small-Scale Industry for the South Pacific—Preliminary Papers. Cyril S. Belshaw. March 1956. (4/- stg., 5/-A., 4/6F., $0.60, 2G.)
90. Industrial Activity in Selected Areas of the South Pacific. K. H. Danks. March 1956. (5/- stg., 6/3A., 5/6F., $0.75, 2.50G.)
91. Western Samoa—An Economic Survey. V. D. Stace. June 1956. (6/- stg., 7/6A., 6/9F., $0.90, 3G.)
92. Economic Aspects of the Coconut Industry in the South Pacific. E. J. E. Lefort. September 1956. (4/- stg., 5/-A., 4/6F., $0.60, 2G.)

CURRENT RESEARCH

29. Current Research in the South Pacific in the Field of Economic Development. July 1952.
43. Research in Queensland in Tropical Plant and Animal Industries. Jacques Barrau, Technical Officer, South Pacific Commission. May 1953.
98. Social Science Research In The Pacific Islands. November 1956. (4/- stg., 5/-A., 4/6F., $0.60, 2G.)

* Abbreviations used in the above list for the currencies quoted are: stg. (sterling); A (Australian); F (Fijian); $ (United States dollars); G (New Guinea guilders).