THE EPIDEMIOLOGY OF DISAPPEARING MALARIA IN THE SOLOMON ISLANDS

(The work of the Malaria Eradication Programme in the Solomon Islands from 1970 to 1975)

A thesis submitted for the approval of the Faculty of Medicine in the University of Sheffield in accordance with the regulations pertaining to the Degree of Doctor of Medicine

by

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This work was carried out whilst the author was Government Malariologist and later Chief Medical Officer (Community Health) in the Solomon Islands between 1968 and 1976

June 1977

THEN ....

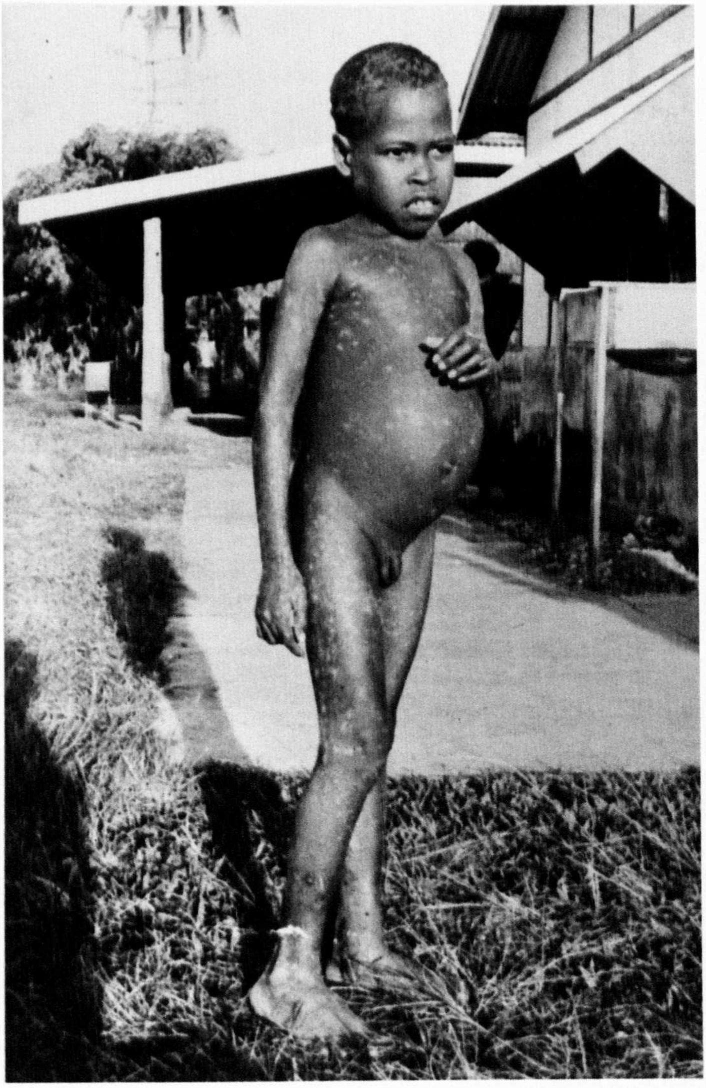

Plate 1. A boy with a big spleen.

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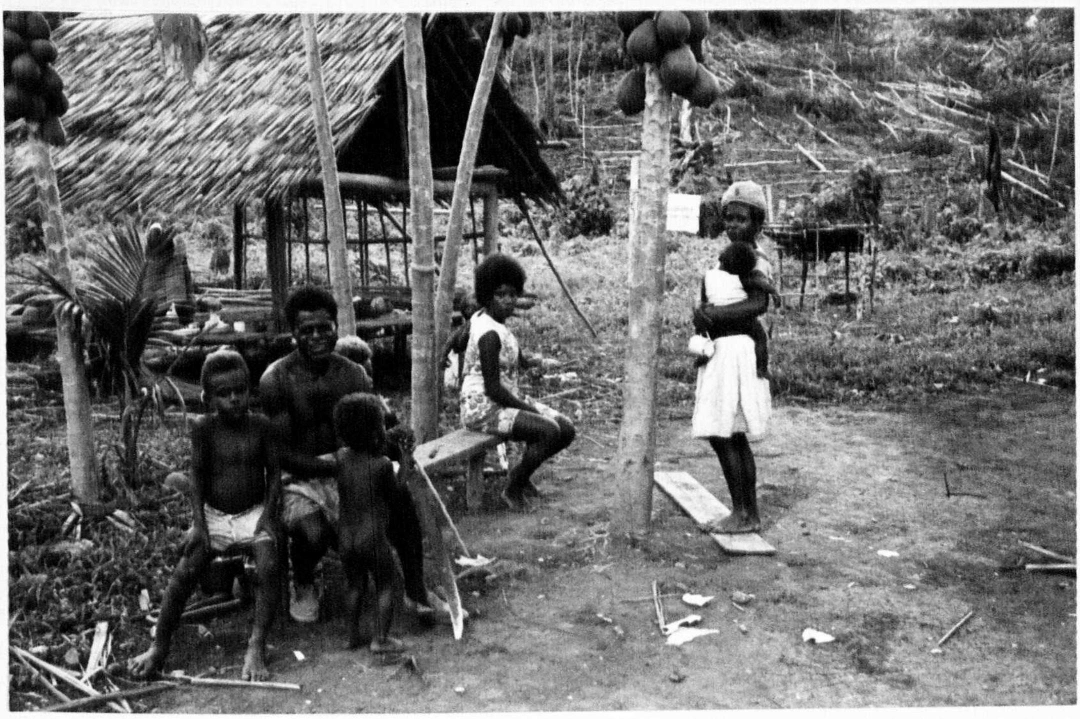

Plate 2. A healthy family in a Guadalcanal village.

"After forcing my way for some hours through a tangled forest, sweltering under the oppressive heat, I have suddenly emerged from the trees on the weather coast where the invigorating blast of the trade in a few moments restores the equilibrium of mind and body."

H. B. Guppy

Surgeon, H.M.S. 'Lark', 1887

in "The Solomon Islands and their Natives".

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PREFACE

On the 1st January 1970 there commenced in the Solomon Islands a special project for the eradication of malaria. This full Malaria Eradication Programme followed on from a Pilot Project which started in 1962 and a Pre-Eradication Programme which started in 1965.

These widely scattered islands have been notoriously malarious at least since the days of the early explorers and probably long before that. In more recent times infants and children have certainly died in their hundreds and most of the people have been weakened with persistent infections.

In the late 1950's, following on from the successful eradication of yaws, the Government and the World Health Organisation turned their attention to the possibilities of eradicating malaria. These early efforts have already been described by Dr. J.D. Macgregor in his M.D. thesis entitled "Malaria in the Island Territories of the South West Pacific".

This present thesis expands that work, concentrating particularly on the years 1970-75 which were the first six years of the full Malaria Eradication Programme.

CHAPTER 1

INTRODUCTION

Were the explorer Alvaro de Mendaña* to find himself on the shores of the Solomon Islands today, he would notice many changes. Perhaps not least would be the virtual absence of malaria. No doubt he, with his bitter memories, would be in a better position than most to appreciate the effect that the removal of malaria has had on the islands. The people have their memories too of feverish nights and dying children but, unlike polio and yaws, malaria leaves no deformities to act as a constant reminder. Often its ravages are all too easily forgotten.

For those of us deeply involved in the immediate daily problems there is much to be gained by a review of the efforts of our predecessors. The historical records described in Chapter 2 provide convincing testimony to the scourge of malaria in former years. They also provide a salutory insight into some of the problems that were very similar to our own today.

Since the Solomon Islands are relatively unknown the topography of the country has been outlined in Chapter 3. Certain physical features having an important influence on the epidemiology of malaria have also been described. A number of other geographical factors of relevance to the transmission and dissemination of malaria have been mentioned since these have a bearing on what can or cannot be

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* A Spaniard, Mendaña was the first European to discover and record the presence of the Solomon Islands in 1568. He died, probably of malaria, at Graciosa Bay in the Eastern Outer Islands in 1595 during his second expedition launched to set up a Pacific Island Colony.

done to eradicate the disease. A description of each inhabited island group has been made so that the malaria problems in any one locality may be fully appreciated.

Malaria may well be the most important health problem in the Solomon Islands but there are several other important diseases some of which may be affected by antimalaria operations. The extent of the malaria problem and its relation to other diseases is covered in Chapter 4.

Many lessons may be learned from a study of early efforts at control or prevention, so in Chapter 5 all of the major efforts have been reviewed. During the 1930's several attempts were made at ground control whilst in World War II massive and heroic efforts were made by the U.S. Forces to keep malaria in check. Once the yaws eradication campaign of the late 1950's was shown to be successful the way was paved for an early start to a Malaria Eradication Pilot Project followed in a few short years by a Pre-Eradication Programme.

Having decided to start a Malaria Eradication Programme the Government was still faced with many policy decisions. These and various other aspects of organisation and management are described in Chapter 6. Details follow of all the technical aspects of the Programme. Most of the methods used in the Solomon Islands follow a classical Malaria Eradication approach modified by local circumstances. Particular attention has been given to the methods of evaluation since failures in these may well mean a widespread resumption of the transmission of malaria.

On superficial acquaintance it might be thought that malaria, being almost at the end of its geographical distribution, could easily be eradicated from the Solomon Islands. That this is far from true may be seen in Chapter 7 where the results of entomological and parasitological surveys and assessment are presented. Although the surveys of anopheline distribution and behaviour were necessarily limited the parasitological surveys were very wide ranging. When it came to rooting out the residue of cases the surveillance agents experienced many trials and tribulations in trying to cover such a scattered archipeligo. Since each island is different, analysis of all results has been made on a district and island basis. A review has been made of progress on each island and special problems have been highlighted where necessary.

Besides specifically affecting malaria, a Malaria Eradication Programme also has an effect on many other diseases, especially those associated with insect vectors. Chapter 7 continues by examining these effects and the changes that the operations brought about in population dynamics, in the environment and on the economy.

Serious doubts are often raised about the validity of carrying out an ambitious eradication programme in a highly malarious country with only limited resources. The discussion in Chapter 8 examines these doubts and their relevance to the Solomon Islands. The numerous technical problems, their solution and the possible use of alternative methods are also discussed. Some emphasis is given to the need for political and public support and to the prime importance of building up the Rural Health Services to a standard capable of maintaining the gains already made.

The importance of the various other effects of the programme are also brought into perspective. Final discussion centres on those factors militating against success. The consequences of failure are examined and a note is made of the options open for work during the next few years.

CHAPTER 2

HISTORICAL BACKGROUND TO THE MALARIA PROBLEM

2.1 Historical and anthropological records

Malaria has probably existed in the Solomon Islands ever since man first settled there some ten thousand years ago. This assumption is based on the known high endemicity of malaria in south-east Asia and the probable origin of the Melanesians from those parts.

The first proof that malaria was present in the Solomons before the advent of the Europeans is in the records of the intrepid Spanish explorer Alvaro de Mendaña (Amherst & Thompson 1901). In 1567-68 during the first of his two voyages of discovery there was much fever and sickness among the crew. There were also several deaths from fever during visits to Santa Isabel, Guadalcanal and Makira. The expedition was eventually called off when, after eight months in the islands, more than half of the party had become ill. Twenty seven years later Mendaña made his second expedition. An attempt at colonisation was made at Graciosa Bay in the Santa Cruz group. This was abandoned after forty seven of the total complement of two hundred and ten had died from fever in a period of four weeks (Beaglehole 1947). Mendaña himself died only thirty seven days after the first landing. It is possible that some of the men may have died from scrub typhus since this is known to occur sporadically at Graciosa Bay. The balance is, however, in favour of malaria (Macgregor 1966).

Quiros, the Chief Pilot of Mendaña's second Expedition, returned briefly to the Solomon Islands in 1606 calling at Duff Islands and Tikopia. No mention was made of fever on this visit but very little contact was made with the natives (Beaglehole ibid). Nearly two hundred years passed before the next contact was made by Europeans with the islands. Thereafter visits became much more frequent but actual landings were rare due to the hostility of the natives (Jack-Hinton 1969). When missionaries, traders and labour recruiters followed, the islands soon became notorious for malaria and headhunting (Fox 1962).

The overwhelming influence of sickness on the lives of the people is mentioned in many of the accounts by anthropologists. Although often getting only a passing comment, malaria is frequently mentioned as a major cause of the ill health of the community. A few examples of beliefs in different islands will serve to illustrate the importance of mythology in the explanation of sickness. In Nggela sickness and death sprang from either the displeasure of an ancestral ghost or from sorcery (Penny 1888). As an alternative, some ill wisher may have called a ghost to bring sickness upon a person (Codrington 1891). The beliefs of the Arosi of Makira were extensively studied by Fox (1924). Malaria was caused by possession by an adaro or ghost and the remedy was to drive this out by working a charm with a dracera leaf. After shaking the leaf over the patient it was carefully taken outside and disposed of with the adaro hanging to it.

In Toambaita in North Malaita every disease had associated with it one or more magical systems. Hogbin (1939) noted that every system of magic had both harmful and curative spells. If someone fell ill the relatives would send for a man who knew the spells of that particular disease. The natives' belief in the efficacy of their magical systems remained unshaken because their health was so bad. There were many unpleasant tropical diseases for most of which there was no known remedy except magic. In Malaita and Ulawa, Ivens (1927, 1930) commented that the ravages of hookworm went unchecked. Yaws claimed victims everywhere amongst the children. Everyone suffered from malaria or ulcers and the cemeteries were full of children. The relative good health of the Lau people on the artificial islands was also noted. Here births were much more numerous than deaths and the distance of the islands from the mainland prevented the malaria mosquito from reaching them. Amongst the Kaoka of Guadalcanal a person who became ill took it for granted that he must have been bewitched (Hogbin 1964). The usual course of treatment was to seek the advice of one of the men who knew the curative rules for the disease. Parents were always prepared to accept the death of a child under the age of five.

Although these descriptions have been put in the past tense, many of them apply just as much today with varying degrees of dilution depending on the influence of the church and schools. None of these records so far provides absolute proof that malaria was in these islands before European man came. Further evidence of malaria being present long before European contact is the use of a native name for the disease in many of the Solomons languages. In Kwara'ae, the largest language group, it is called 'matai'. In Roviana, the second largest,it is called 'moko'. In only a few of the remote outer islands is there no local name. This is probably because of the more recent introduction of the disease to those islands.

On most of the islands of the Solomons the older people all testify to the constant ravages of malaria prior to eradication operations. Many describe the loss of babies or small children due to malaria. Others mention the frequent bouts of fever and sickness experienced by their children. They also comment on their own weakness and lassitude and on the distended abdomens to be seen in so many of the people in the past.

2.2 Medical Records

Apart from a handful of prevalence surveys (see Chapter 7) the most useful record of malaria in the Solomons is that from various medical reports. Since the Annual Reports contain many interesting references to malaria, some pertinent extracts have been made from these in order to put the problem in perspective. Although the Protectorate was proclaimed in 1893, the first Annual Medical Report did not appear until 1913. Since that date the records are complete except for 1916, 1924 and the World War II years. In spite of the gaps, retrospective data is still available from subsequent reports to complete the record for 1916 and 1924. The years 1941-45 are missing due to the absence of a civilian administration during World War II.

Over the years the reports build up a detailed and fascinating story of malaria in the Solomon Islands. They also tell of the gradual development of the Health Services. The statistical record which was meagre at first, steadily improved with the most consistent reports coming from hospital records. From 1913-1940 these were taken from the hospital at Tulagi, the centre of administration until World War II. From 1946 to 1957 the records were from the Central

Hospital at the new capital Honiara. From 1958 onwards the records also included most of the other government and church hospitals. For most years details were given of hospital admissions, deaths and out-patients due to all causes and due to malaria. These returns are summarised in Table 1 which also shows the relative priority of malaria in relation to other diseases requiring admission. The admissions are also represented graphically in Figure 1.

Invariably malaria was one of the leading causes of admission. In the early years it was not infrequently superseded by dysentry and influenza. In the years 1930 to 1950 yaws also held a prominent place but once the eradication campaign of 1956-59 had taken effect this disappeared from the lists. From 1958 until 1969 malaria was the leading cause of admission to hospital. During the very early years in Tulagi most of the people seeking medical aid from the hospital were either expatriates or locally employed indigenes. Consequently, the returns did not give a true reflection of disease in the village community. By the early 1920s however, reasonable numbers of people were coming into Tulagi hospital. Some value may, therefore, be placed on the figures as providing a reasonably accurate measure of the true incidence of severe malaria within a few miles radius of Tulagi up to 1940. The same applies around Honiara from 1946-57. From 1958 onwards we have a more accurate picture of the incidence of malaria throughout the Solomons due to the inclusion of the peripheral hospitals in the records. Even these figures were an under-estimate since these fourteen widely scattered 'hospitals' still only provided a service for their immediately surrounding populace. Malaria admissions rose steadily in parallel with total admissions

TABLE 1

Totals of Hospital Admissions, Deaths and Outpatients due to All Causes and due to Malaria. Solomon Islands. 1913-72.

Year	Admissions			Deaths			Outpatients		
	All causes	Malaria [1]	% due to Malaria	All causes	Malaria [1]	% due to Malaria	All causes	Malaria	% due to Malaria
1913	16	NA [2]	*	1	NA	*	NA	NA	*
1914	60	9(2) [3]	15.0	9	0	0	NA	NA	*
1915	185	10(3)	5.4	24	0	0	NA	NA	*
1916	160	NA	*	7	NA	*	NA	NA	*
1917	194	7(5)	3.6	20	2	10.0	NA	NA	*
1918	198	15(3)	7.6	16	1	6.3	5195	NA	*
1919	520	24(5)	4.6	30	0	0.0	3042	NA	*
1920	399	59(2)	14.8	24	2	8.3	4436	NA	*
1921	581	58(2)	10.0	24	2	8.3	7394	NA	*
1922	450	99(1)	22.0	18	2	11.1	6207	NA	*
1923	597	122(1)	20.4	26	1	3.8	2575	NA	*
1924	691	47(4)	6.8	20	1	5.0	NA	NA	*
1925	494	52(2)	10.5	20	1	5.0	NA	NA	*
1926	497	70(1)	14.1	20	0	0.0	NA	NA	*
1927	662	138(1)	20.8	22	0	0.0	NA	NA	*
1928	848	179(1)	21.1	19	2	10.5	NA	NA	*
1929	630	125(1)	19.8	44	2	4.5	NA	NA	*
1930	665	135(2)	20.3	23	3	13.0	NA	NA	*
1931	523	80(2)	15.3	22	2	9.1	NA	NA	*
1932	417	48(2)	11.5	22	2	9.1	NA	NA	*
1933	484	45(3)	9.3	12	0	0.0	NA	NA	*
1934	700	86(2)	12.3	17	1	5.9	NA	NA	*
1935	643	99(2)	15.4	19	1	5.3	NA	NA	*
1936	692	38(4)	5.5	13	1	7.7	NA	NA	*
1937	700	59(3)	8.4	24	1	4.2	NA	NA	*
1938	763	82(2)	10.7	24	2	8.3	NA	NA	*
1939	831	99(2)	11.9	17	2	11.8	NA	NA	*
1940	722	79(2)	10.9	17	0	0.0	NA	NA	*
				16	1	6.3	3137	155	4.9
1941-1945	No records available.			(World War II)					
1946	852	100(2)	11.7	17	NA	*	NA	*	*
1947	NA	NA	*	NA	NA	*	NA	*	*
1948	1439	348(2)	24.2	30	NA	*	6834	577	8.4
1949	1512	274(1)	18.1	35	NA	*	6807	600	8.8
1950	1376	NA	*	16	NA	*	7281	NA	*
1951	1659	NA	*	54	NA	*	11122	1443	12.9
1952	1643	239(2)	14.5	31	2	6.5	13277	2074	15.6
1953	1519	142(2)	9.3	28	4	14.3	24132	2146	8.9
1954	766	117(1)	15.3	47	6	12.7	6773	943	13.9
1955	1297	195(1)	15.0	30	5	16.7	8541	1262	14.1
1956	1714	232(1)	13.5	46	3	6.5	5571	789	14.2
1957	1498	223(2)	14.9	26	0	0.0	5649	1532	27.1
1958	5836	1374(1)	23.5	78	10	12.8	48922	9794	20.0
1959	7340	1864(1)	25.4	96	12	12.5	56308	10591	18.8
1960	8674	2188(1)	25.2	185	38	20.5	79671	15860	19.9
1961	11981	2755(1)	23.0	182	31	17.0	99596	23304	23.4
1962	11045	2874(1)	26.0	197	24	12.2	107948	18091	16.8
1963	7729	1935(1)	25.0	71	11	15.5	76347	18915	24.8
1964	8243	1513(1)	18.4	73	11	15.1	78436	18578	23.7
1965	7597	1235(1)	16.3	53	3	5.7	80275	15696	19.6
1966	8388	1481(1)	17.7	109	11	10.1	67035	14580	21.7
1967	7639	1281(1)	16.8	109	12	11.0	87957	15485	17.6
1968	8832	1064(1)	12.0	87	7	8.0	88920	13429	15.1
1969	7277	1116(1)	15.3	138	6	4.3	96936	14733	15.2
1970	1933	49	2.5	82	1	1.2	129721	NA	*
1971	3931	NA	*	NA	NA	*	119367	6901	5.8
1972	11754	NA	*	208	0	*	NA	NA	*

Notes

[1] Malaria cases and deaths include those due to blackwater fever.

[2] NA means data not available.

[3] The figure in brackets after the number of cases is the relative position of malaria in the number of admissions. For example in 1914 malaria was the second in order in the number of cases.

4. The data in these reports was obtained from the following sources:-
1913-40 Tulagi Hospital, Nggela. 1946-57 Central Hospital Honiara.
1958-69 and 1972. All or some of the 14 'hospitals' in the Solomon Islands.
1970-71 Admissions and deaths from Central Hospital only.
All data was published in the British Solomon Islands Medical Dept. Annual Reports.

5. Population data for the census years shows:
1931 - 94,066
1959 - 124,076
1970 - 160,998

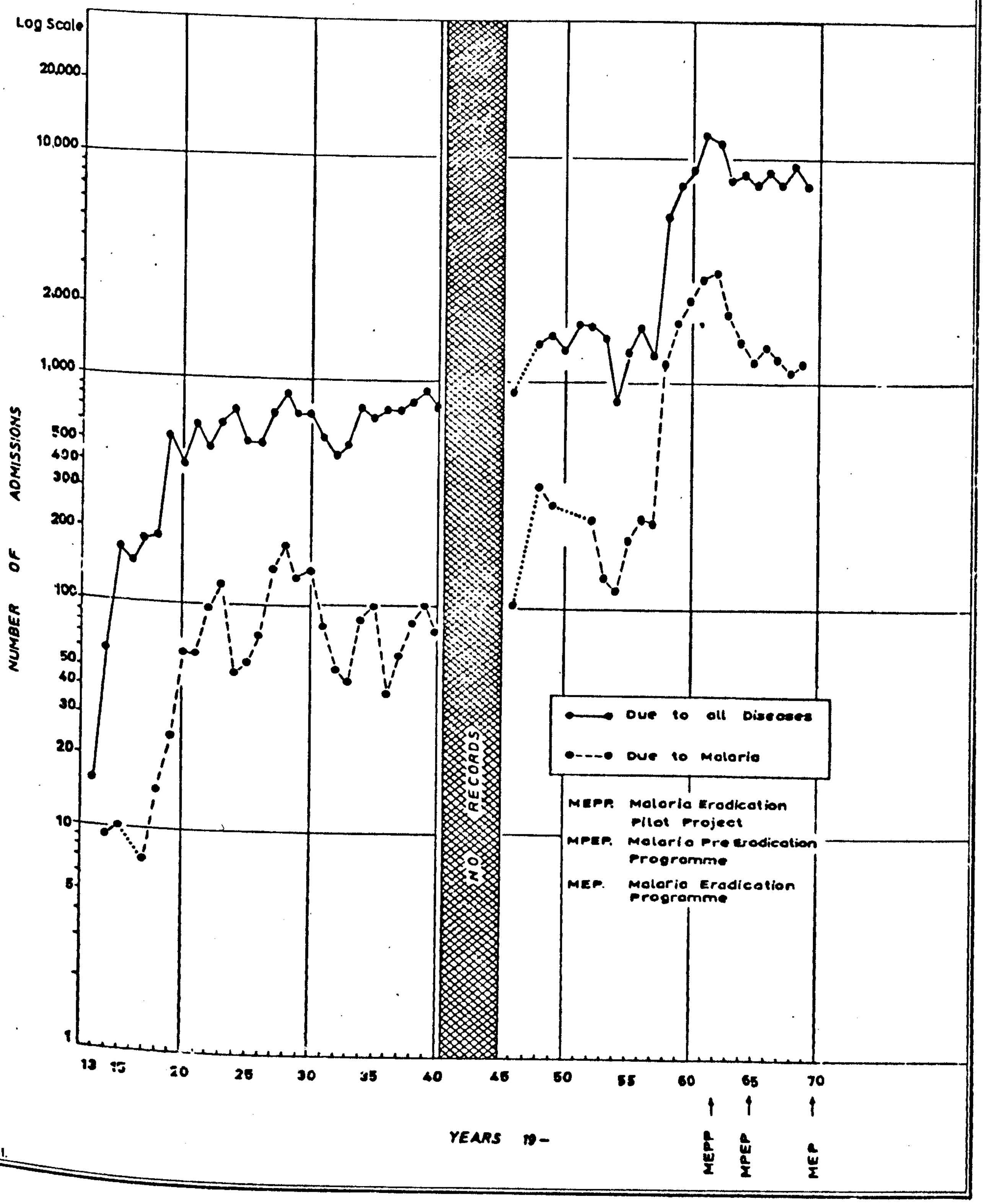
from 1958 to 1961 (Figure 1). This was due to an improved reporting system and an increasing awareness by the people of the facilities available. With the start of the Malaria Eradication Pilot Project in 1962 there was an immediate fall in both total admissions and in malaria admissions. From 1963 onwards there was an overall fall in malaria cases whilst admissions due to all causes remained steady. Overall from 1913 to 1962 some long term variations may be seen in the malaria case incidence with peaks at 3-4 year intervals.

Between 1920 and 1957 malaria usually accounted for more than 10% of the admissions per annum. From 1958 until 1963, during the time when records were becoming better established but prior to eradication operations, malaria accounted for at least 20% of all admissions. This is probably a better reflection of the true incidence of malaria seen in hospitals. From 1963, following the start of the Pilot Project, the percentage of admissions per annum due to malaria showed a fluctuating decline. Outpatients figures showed similar trends but with somewhat wider fluctuations.

Figures for deaths in hospitals due to malaria also varied accounting for between 12.2% and 20.5% of all deaths during the years 1958 to 1964. From 1965 onwards there was a marked fall in the percentage of deaths due to malaria.

In 1970 there was a change in the medical records system. This was unintentionally coincidental with the launching of the full Malaria Eradication Programme. The continuous and longstanding record of admissions, deaths and outpatients was disrupted and regrettably this data was not obtainable from other sources. Detailed totals of malaria and other diseases were also recorded for

Fig. 1. ANNUAL ADMISSIONS AND MALARIA ADMISSIONS, ALL HOSPITALS, SOLOMON ISLANDS 1913 – 1969.



individual hospitals in Annual Reports between 1958 and 1962. Then, paradoxically, at the start of the Pilot Project, when these figures would have been of most value, the records were also discontinued. For this reason, no further analyses were made of these records.

2.3 Medical literature

A further source of useful comment on the state of malaria in the Solomon Islands is the published writings of short term visitors and resident medical staff. Although few in number, these reports contain frequent comment on the severe and widespread nature of the disease. The earliest report in the medical literature is that of Crichlow(1921[a,b])reporting on the common occurrence of blackwater fever in expatriates in Tulagi. This was followed by a report by Sayers (1928) who noted that nearly every inhabitant of Roviana in New Georgia was infected with malaria in infancy. A patient of any age without a palpable spleen was uncommon. Malaria was the main factor producing the high infant mortality. In older children and adults malaria was unusual. This paper by Sayers also contained the first report of quartan malaria in the Solomon Islands (see Chapter 7). A year later Crichlow (1929) made a survey of prevalent diseases in the islands. He reported that malaria was widespread. The spleen rate of the under twelves was 80 whilst over twelve it was 40. Malaria parasites were found in 80% of the children. The species prevalence of these parasites was P. vivax 70: P. falciparum 20: mixed infections 10. The disease was one of the greatest factors in the high death rate amongst infants and children.

During his Pacific wide anti-hookworm campaign, Dr. S.M. Lambert also carried out other disease surveys (Lambert 1928, 1934).

He claimed that the medical problems of the Solomon Islands were stupendous. He also reported that little was known of the interior of the island of Malaita due to the hostility of the natives. Soon after this James (1939) reported on malarial nephritis and Sayers (1943) made a review of 741 slide positive malaria cases in New Georgia. Reflecting on eight years of service in the Solomon Islands between 1927 and 1934, Sayers considered that the total of misery and debility due to malaria was almost impossible to assess.

Several reports on malaria in the Solomon Islands followed on just after World War II. The disease was the greatest hazard experienced by American troops during that war according to Simmons (1947). It attacked approximately 100,000 men of the armed forces in the South Pacific. The threat of malaria to the success of the campaign was more serious in the Pacific than in any other theatre of war or at any other time. Malaria reached epidemic proportions amongst troops in Guadalcanal where there was a peak case incidence of 5 per 1,000 per day (Downs, Harper & Lisansky 1947). Later outbreaks occurred at Tulagi, Russells and Munda. They did not occur in the Treasury Islands (Mono) in the Western Solomons as good control had been established by the time troops were stationed there. Parasitiological surveys reported by Perry (1949) had previously found malaria to be of primary importance on Mono Island.

In a review of the problem of malaria in Pacific Territories, Ford (1950) thought that the disease was largely beyond control. The high endemicity, primitive civilisation and meagre economic facilities made the task appear to be beyond practical solution. After surveys in various parts of Melanesia, including the Solomon Islands, Black (1952, 1955[a] & 1956) confirmed that the control of malaria would be very difficult in this area. This was endorsed by Colbourne (1962).

Some very pertinent statements were made in a review of the Health Services of the Solomon Islands by Norman-Taylor (1961). Once again malaria was considered to be the most important disease in the territory. Mention was also made of the effects of inertia and absenteeism on the economy. A practical recommendation of relevance to a future eradication programme was that a Senior Medical Officer (Health) be appointed. There were also suggestions that Districts should function as autonomous Health Units and that the responsibility for Rural Health Services should be with local Councils. It was not until thirteen years later that these recommendations started to become reality.

A further source of information in addition to the statistical records already quoted is the commentary in the Annual Reports (BSIP 1913-1973). The very first report (BSIP 1913) stated that malaria was responsible for much of the sickness that did appear in Europeans. This could be expected to continue until sanitary conditions improved. In 1917 malaria was reported as being still very prevalent among Europeans, Non-natives and Natives. Whether Government official, trader or missionary the European in the Solomon Islands was constantly exposed to malaria. If he took inadequate doses of quinine he always had a high risk of dying from blackwater fever. In the early years the death rate in Europeans and Asiatics was often nearly as high as that in indentured labour. Almost every year one or two Europeans died of malaria.

It was not until 1931 that the importance of malaria in the village community was documented. In that year it was said that no person escaped periodical attacks of fever. Malaria probably accounted for more temporary disability and loss of time than did any other disease (BSIP 1931). The majority of patients admitted for any cause were found to have enlarged spleens due to malaria. These comments were repeated throughout the 1930s,it being claimed on many occasions that malaria was endemic throughout the islands.

After World War II the reports continued to emphasise the overwhelming influence of malaria on the lives of the people. In 1949 it was stated that the sequelae resulting from chronic malaria remained the primary incapacitating factor amongst the native population (BSIP 1949). The disease was the main cause of morbidity especially in the young. Secondary anaemia and splenomegaly were common and there was no malaria control in the villages (BSIP 1953). Malaria was also reported to frequently complicate other diseases (BSIP 1957). In addition to being the largest single cause of hospital attendance in the Protectorate, it was a contributory factor in many of the other diseases encountered. (BSIP 1958).

Some predictions of future problems in public co-operation may be seen from various reports. After conducting a leprosy survey in four of the large islands Innes (1938) was of the opinion that widespread illiteracy was a severe obstacle to the progress of any public health exercise. Some ten years later the Annual Report claimed that the people of Guadalcanal were backward and unco-operative (BSIP 1948). When the anti-government Marching Rule movement (see Glossary) became established in Malaita and Makira the people were prevented from deriving optimum benefit from the medical services (BSIP 1949, Allan 1951). In contrast, at the same time the people of the Western Solomons were reported to be more advanced and more receptive to medical propaganda. They were making a definite attempt to improve their living standards. A few years later general living conditions were still poor on Malaita(BSIP 1952). It was suggested that the incidence of disease would not fall there until these were improved. Meanwhile, in contrast to the earlier reports from the Tadhimboko district of Guadalcanal, the Chief Vouza was most co-operative. No trouble was experienced in assembling the villagers for the trial yaws campaign. (BSIP 1953). At this time the people of Malaita remained completely indifferent to injections even when they were brought to their door. Lack of parental control of children made the process even more difficult. A year later Malaita was still unco-operative with surveys and investigations but more willing to take advantage of quick acting injections (BSIP 1954).

The 1958 report marked a major milestone. It considered that the successful yaws campaign was of great importance to the health of the Solomons. This was because it greatly increased the confidence of the people in the activities of the Medical Department (BSIP 1958). The same report was, however, more cautious when mentioning the former Marching Rule stronghold of Kwaio in Malaita. Here the people were still primitive and their housing and sanitary conditions very poor. Love for their pigs was greater than that for their families and children. Many of the women refused to have injections because of pregnancy and menstruation taboos. It was clear from these reports that public co-operation was variable and that great care would have to be taken in certain areas. It certainly appeared that Malaita would prove to be difficult whereas a good degree of co-operation could be expected in the Western Solomons.

These few historical highlights are but a glimpse of the full story of the ravages of malaria in the Solomon Islands in the past. They are nevertheless necessary for a better appreciation of the problem and for an understanding of the approach required to combat such a devastating scourge.

CHAPTER 3

GEOGRAPHICAL BACKGROUND TO THE MALARIA PROBLEM

From the historical background, it appears that malaria has probably been rampant in the Solomon Islands since man first arrived from south-east Asia. That this is no mere coincidence may be seen by a review of the environment in which man lives in the islands.

The topography and climate operate in many places maximally in favour of the anopheline vectors. Man, by living in close association with these vectors, provides optimum opportunities for the transmission of malaria parasites should they be present in the community. The various activities that man pursues have a further bearing on whether or not malaria will become established and be maintained. Several other geographical factors are also relevant to the transmission of malaria in any given locality. These include the flora and fauna, water supplies and sanitation and the methods of agriculture. Then, in order to determine what can or cannot be done about the malaria problem, it is necessary to consider a few details about administration, the economy, commerce and industry, communications, education and the state of the medical and social services.

3.1 Topography

The Solomon Islands are a scattered archipeligo of mountainous islands and low lying coral stolls to the east of New Guinea (Figure 2). Situated between latitudes 5°S and 12°S and longitudes 155°E and 170°E, the distance between the western and the eastern extremes is some 1500 km. The main group comprises a double chain of islands continuing

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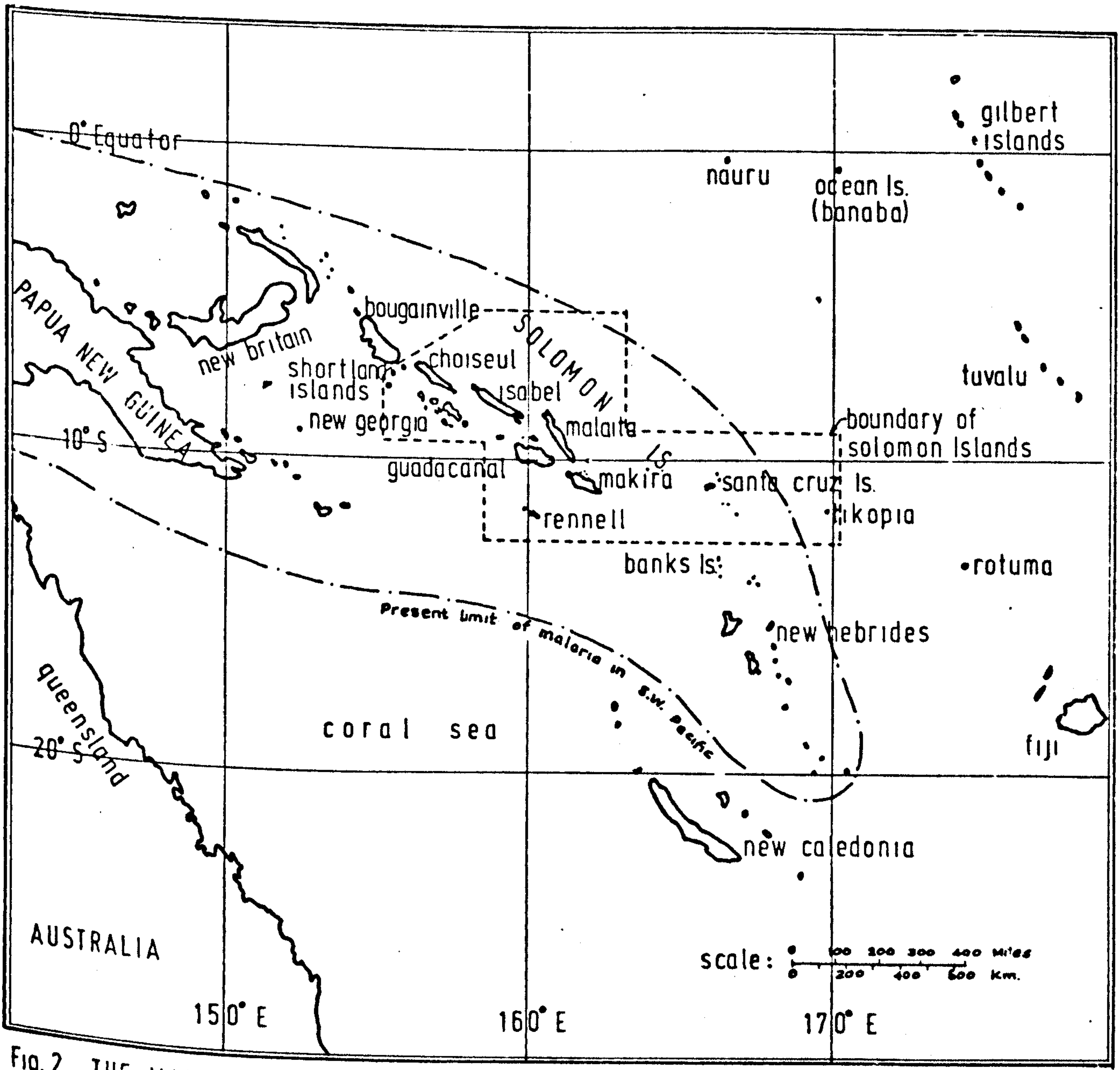


Fig. 2 THE MALARIOUS ISLANDS OF THE SOUTH-WEST PACIFIC

on from Bougainville which is administratively part of Papua New Guinea. In the east the Santa Cruz group is geographically more akin to the New Hebrides group than to the Solomons.

The majority of the Solomon Islands provide the ideal physical environment in which anopheline mosquitoes flourish. Several different types of island are to be found but the typical conditions which give optimum opportunity for the transmission of malaria are those that are found on the north coasts of the large islands. These coasts are usually on the easier northern slopes of the mountain chains (Figure 3). On Guadalcanal there is in addition an extensive plains area (Figure 4). On this large rivers tumble down from extensive mountain catchments to eventually meander into the sea. Frequent changes of course result in ox-bow lakes and other static accumulations of water. Minor tributaries wander sluggishly across the plains whilst other small creeks open direct into large expanses of estuarine water. Blocked by extensive sand bars at the mouth (Figure 5), these are regularly built up by wave action and only breached after heavy rains.

Prolonged dry spells leave subsidiary watercourses in the main channel to accumulate masses of small plants making an ideal habitat for anopheline larvae (Plate 3). Immediately behind the beach there is often a depressed swampy area at or below sea level (Figure 3). This easily becomes flooded after heavy rains, allowing renewed opportunities for anopheline breeding.

In the foothills the rivers flow rapidly. Even here the multitude of side streams are often blocked by debris resulting in stagnant pools.

Coastal villages tend invariably to be on the small fringe between beach and swamp. In recent years government and church persuasion

Fig. 3. CROSS SECTION OF GUADALCANAL, SOLOMON ISLANDS

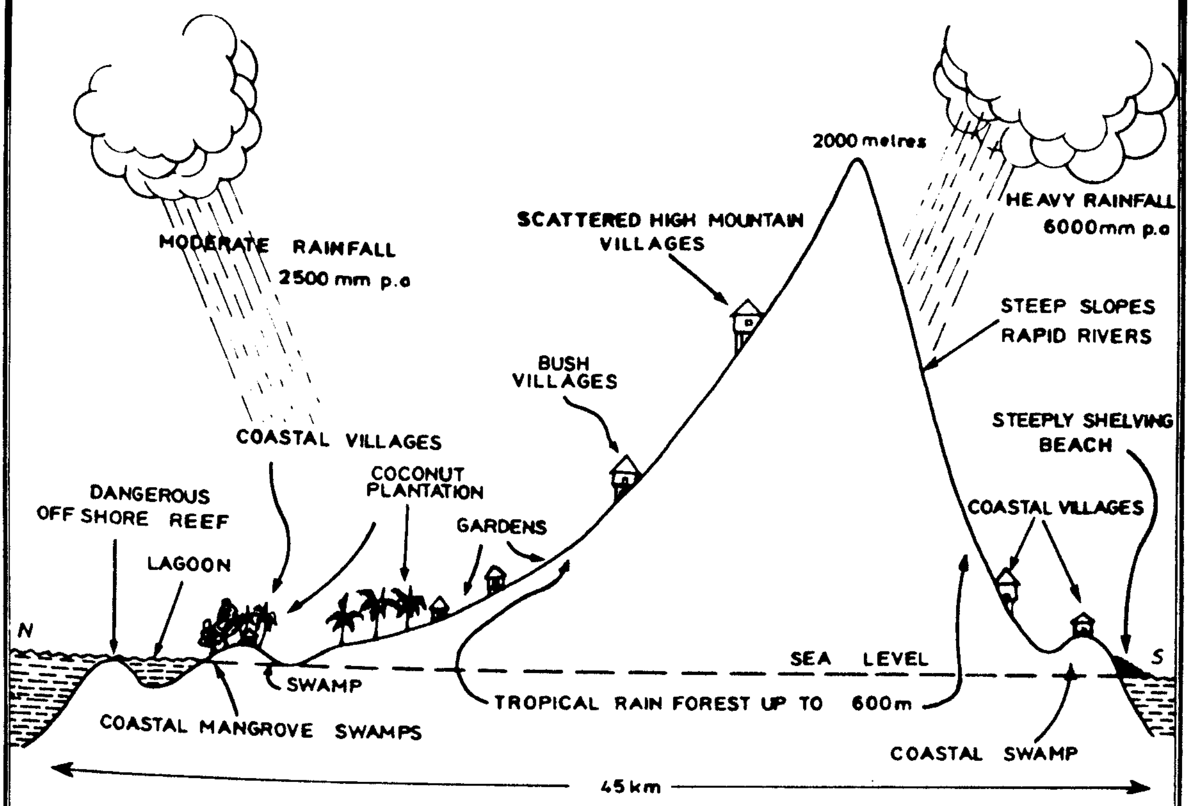
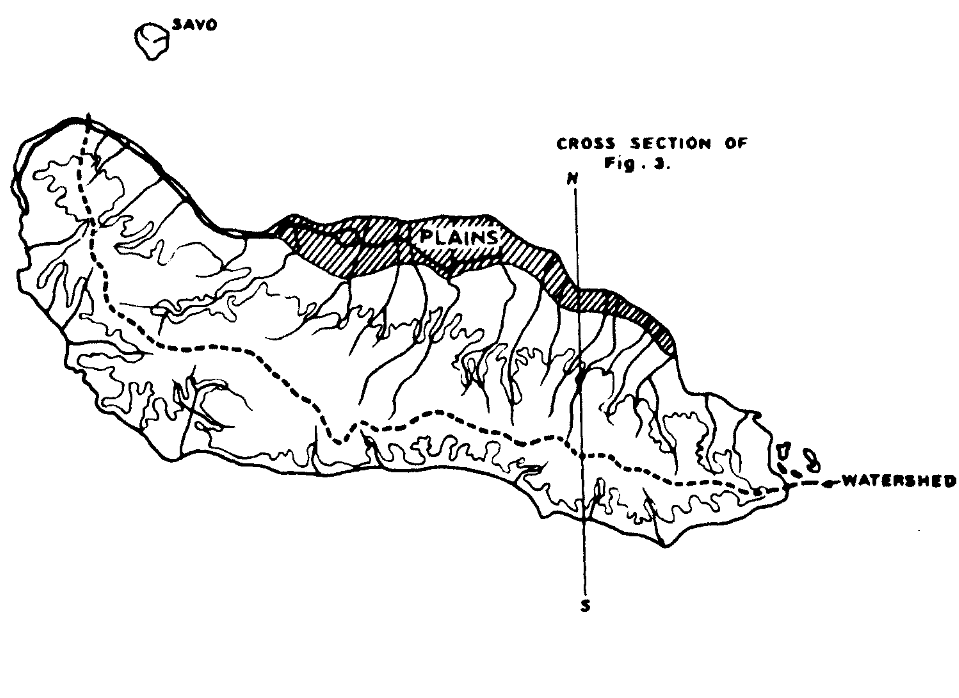
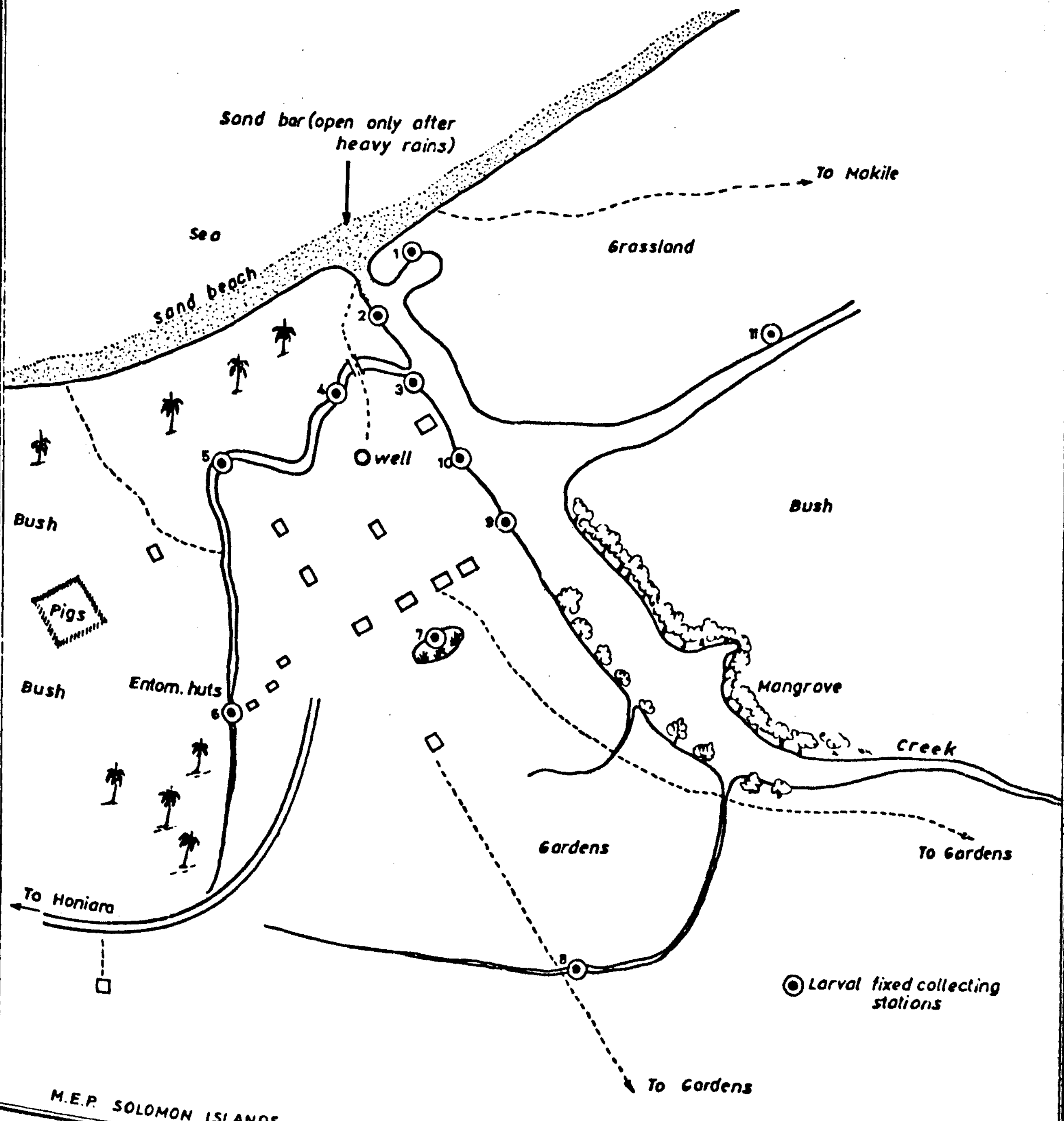


Fig. 4. PLAINS AREA, RIVERS AND MAIN WATERSHED, GUADALCANAL, SOLOMON ISLANDS.



M.E.P SOLOMON ISLANDS

Fig. 5. SPOT MAP OF GILUTAE VILLAGE, TADHIMBOKO, NORTH GUADALCANAL, SOLOMON ISLANDS.



M.E.P. SOLOMON ISLANDS.

has brought most people to the coast. Only a few small heathen communities remain in the hilly bush areas of the large islands, especially on Malaita.

The typical village is often within a few metres of easy breeding opportunities for anopheline mosquitoes (Plate 4, Figure 5). The sites for egg laying may be slow streams, creeks, sunlit pools, pig wallows or, especially on North Guadalcanal, wheel ruts and war time bomb holes.

The ease of transmission is compounded by the frequent celebration by pagans of traditional feasts and by christians of church festivals. In Nggela for example, every Saint on the Anglican calendar is celebrated by feasting in some village. These feasts are great gatherings. In true Melanesian style they often last for several days with people from villages far and wide intoxicated by the ritual chewing of betel nut. The small houses are grossly overcrowded with the overflow sleeping outside in the kitchens or canoe houses. Festive occasions indeed for anophelines as well as for man.

A minor variation of the typical island profile is that found on Malaita (Figure 6). Here the transinsular profile is very similar to Guadalcanal except that the coastal littoral is narrower. A unique feature is the villages on man-made artificial islands in the lagoons. Some doubt remains about their original purpose but it is probable that this was to allow the inhabitants to escape from both anopheline and human enemies (Ivens 1930).

In addition to the typical islands, a number of other variations exist in the Solomons group. On a few islands the terrain is unfavourable for anopheline breeding. One example is the volcanic island of which

Fig. 6. CROSS SECTION OF MALAITA, SOLOMON ISLANDS.

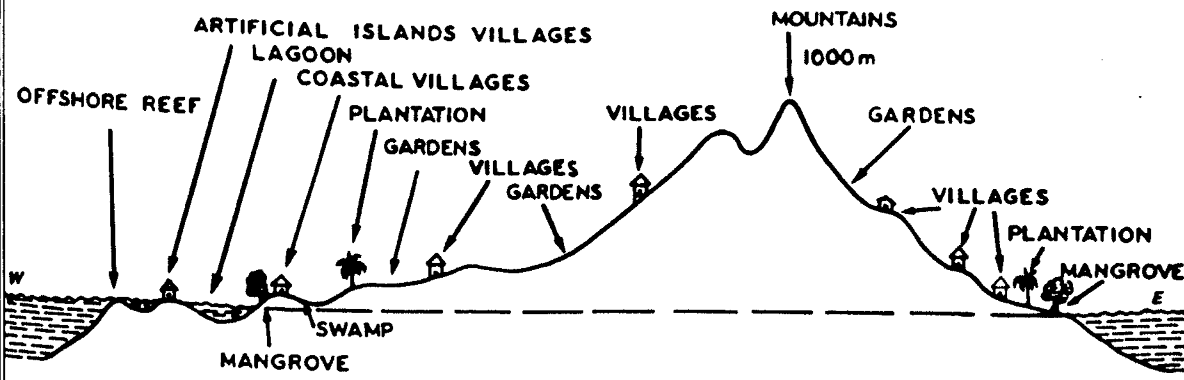
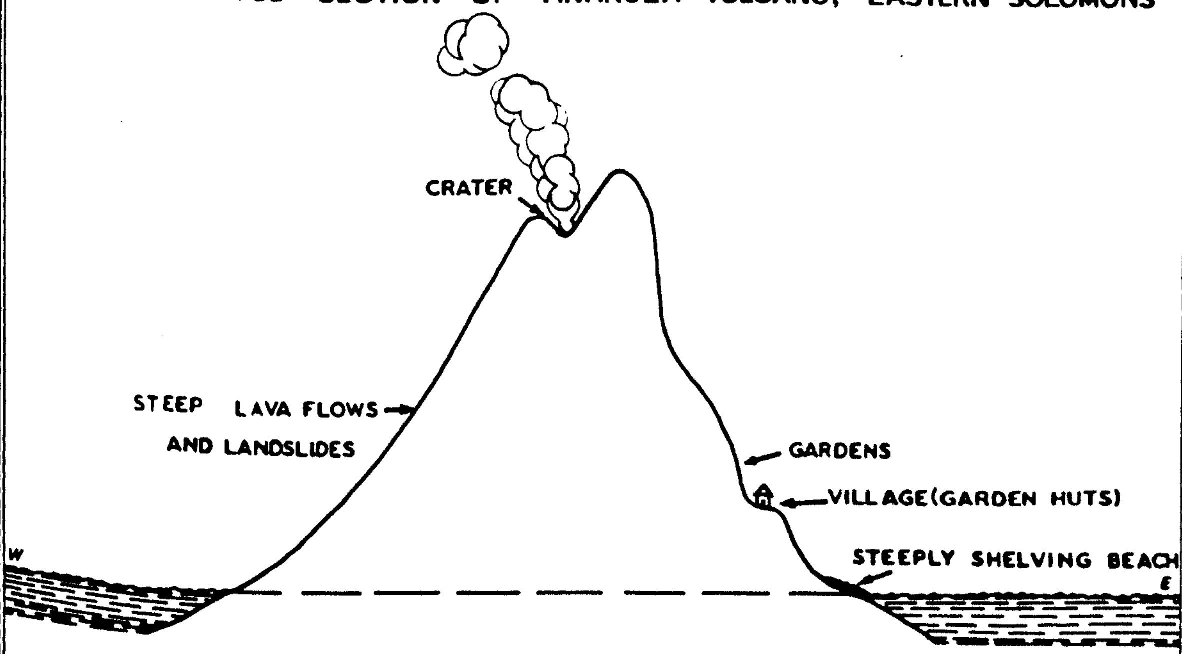


Fig. 7. CROSS SECTION OF TINAKULA VOLCANO, EASTERN SOLOMONS



M.E.P. SOLOMON ISLANDS

Plate 3. Anopheline breeding site in north Guadalcanal.

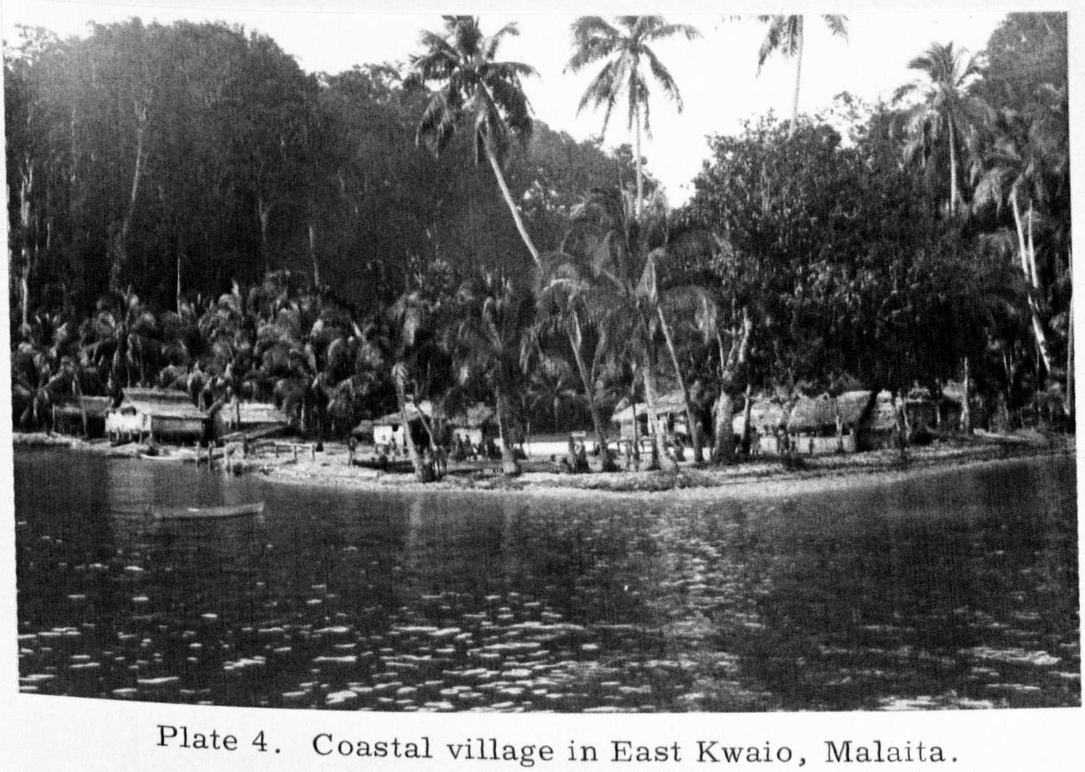


Plate 4. Coastal village in East Kwaio, Malaita.

the still active Tinakula (Figure 7) in the Santa Cruz Group is the best example. People from surrounding islands have traditionally used this island for gardens. They frequently spend several months at a time there in spite of the danger and the disapproval of the administration. Surface water is absent and no anophelines have ever been caught on the island. Two other extinct volcanic islands without anophelines are Anuta and Tikopia, the eastermost inhabited islands in the Solomons. A number of other islands are also extinct volcanoes, notably Duffs, Utupua, Vanikoro, Savo, Russells, Rendova, Ranongga and Kolombangara (see Maps, Figures 17, 21 & 25). All of these have sufficient surface water in small creeks and streams to allow easy anopheline breeding.

Different again are the Polynesian islands of Rennell and Bellona (Figure 8), the only examples in the Solomons of raised coral atolls. Both are elongated with a central depression. On Bellona there is no surface water and there are no anophelines. Rennell on the other hand has the large brackish water lake Te Nggano at the eastern end and swampy areas elsewhere. Anopheline adults and larvae have been found in low densities on this island (Maffi 1973).

Isolated coral stolls range from the very large Ontong Java to the relatively small Pileni and Matema in the Santa Cruz group. Others are Sikiana (Figure 9), Nupani and Nukapu (see Map, Figure 21). On the majority little running surface water is to be found but there is invariably a depressed swampy area in which swamp taro is cultivated. It is often difficult to find anopheline larvae in these swamps but night catches on several of the atolls have confirmed the presence of adults (Taylor 1974).

Fig. 8. CROSS SECTION OF BELLONA ISLAND, SOLOMON ISLANDS

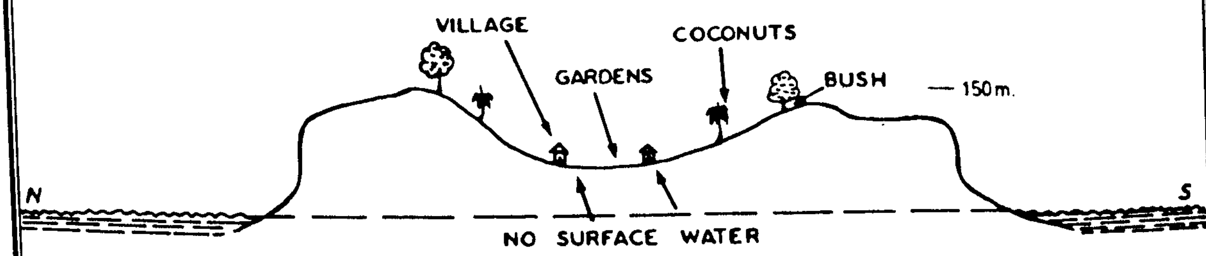


Fig. 9. CROSS SECTION OF SIKAIANA ATOLL, SOLOMON ISLANDS

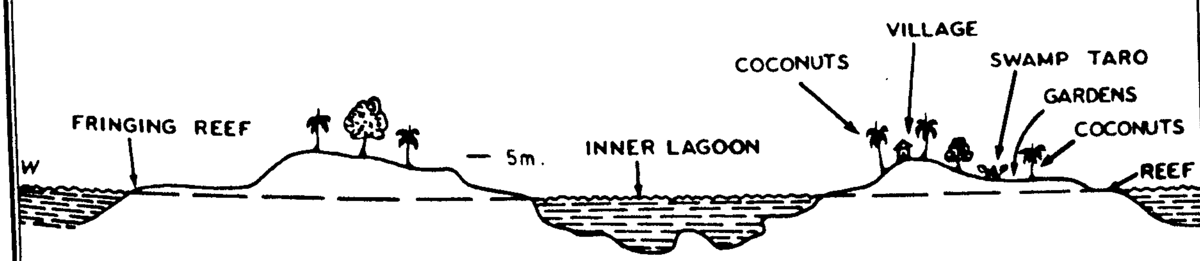
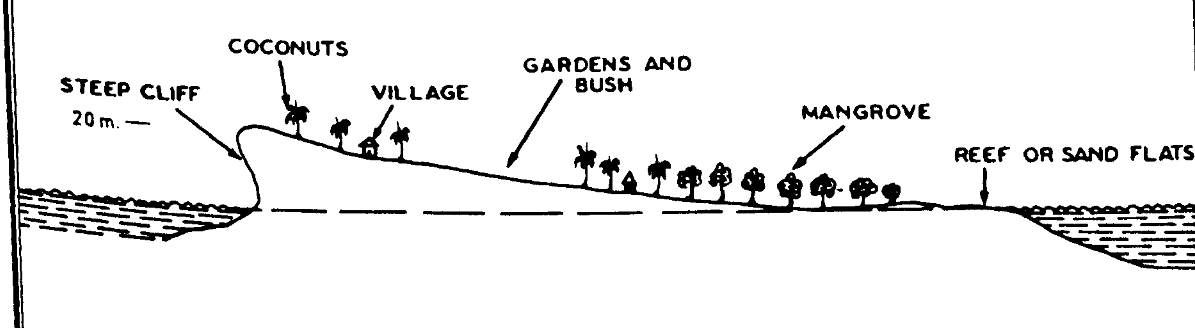


Fig. 10. CROSS SECTION OF LOMLOM ISLAND, REEF ISLANDS, EASTERN SOLOMONS.



M.E.P. SOLOMON ISLANDS

A final group is the Reef Islands in the Eastern Solomons. These are composed of raised coral reef (Figure 10). Each island has a maximum altitude of only a few metres above sea level. The usual feature is a tilting of the land mass with a steep eroded cliff on one side and tidally submerged area with mangrove swamps on the other. Surface water is seldom found except for the occasional brackish accumulation. The main breeding opportunity for anophelines is in the village water wells but it is possible that larvae may develop in crab holes. Anophelines are entirely absent from most of these islands, or else found only in very low densities (Maffi and Taylor 1974). The only other example of raised reefs in the Solomons Islands is the twin islands of Santa Ana and Santa Catalina to the east of Makira.

It is clear from this background that on many of the islands of the Solomons the anopheline mosquito is able to obtain a blood meal with comparative ease. Once replete there is no difficulty in finding good resting opportunities in the dark and humid leaf houses. In a day or two, having comfortably deposited her eggs on the nearest stretch of water, she obtains further protection from the abundant undergrowth surrounding the village. There she may remain for a day or two well protected from predators as well as from the wind and rain. Once darkness has descended the anopheline will soon be off again biting outdoors or waiting for her victim to settle into a deep sleep oblivious to the attentions of his sinister companion.

3.2 Climate

The climatic factors of greatest importance in maintaining the viability of anopheline mosquitoes are temperature, rainfall and humidity. Certain other factors like wind, cyclones and sunshine may exert an influence under exceptional circumstances.

Temperature

The ambient temperatures throughout the Solomon Islands are very conducive to anopheline survival and to the development of malaria parasites within these mosquitoes. Monthly mean maxima and minima seldom vary by more than a degree celsius. At Honiara for example, the range for the mean maximum daily temperature lies between 30.7^{o}C in November/December and 30.0^{o}C in July (Figure 11). The diurnal range is considerably greater, but this seldom shows much variation between a maximum of 32^{o}C and a minimum of 22^{o}C (Figure 12). These temperature ranges are comfortably within the optimum figures (Pampana 1969) for the development of all three species of malaria parasite found in the Solomon Islands and for the survival of the anopheline vectors. More extreme conditions are found above 500m where the night temperature may drop at least 4^{o}C below the lowest coastal figure (Taylor 1974).

Rainfall

An abundant rainfall in most of the Solomon Islands provides the regular supply of surface water that is required to maintain the anopheline breeding sites. On occasions an excess of rain may cause flushing out of the mosquito larvae whilst on less frequent occasions prolonged dry spells may cause the drying up of breeding sites. Most of the islands usually have a regular rainfall of at least 250mm (10") per month which is sufficient to maintain a regular supply of larvae and adults.

Wide variations exist in the availability and reliability of

Fig.11. TEMPERATURE RECORDS, HONIARA. 1949 - 73

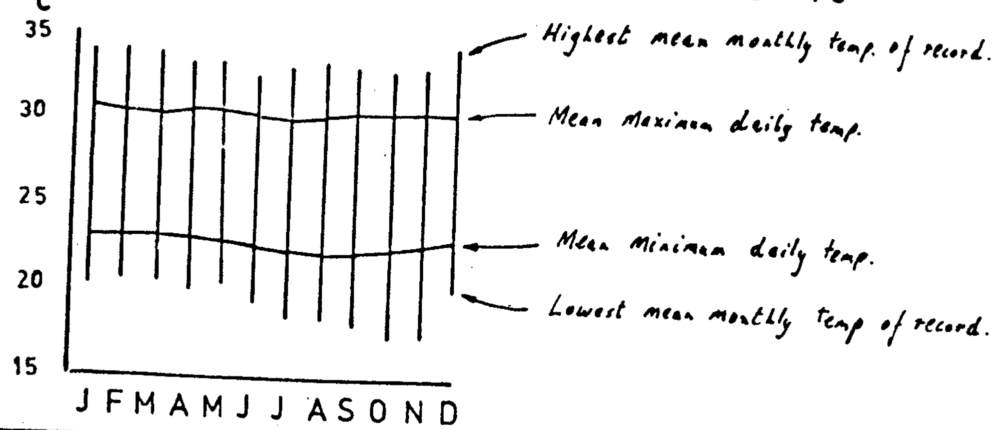
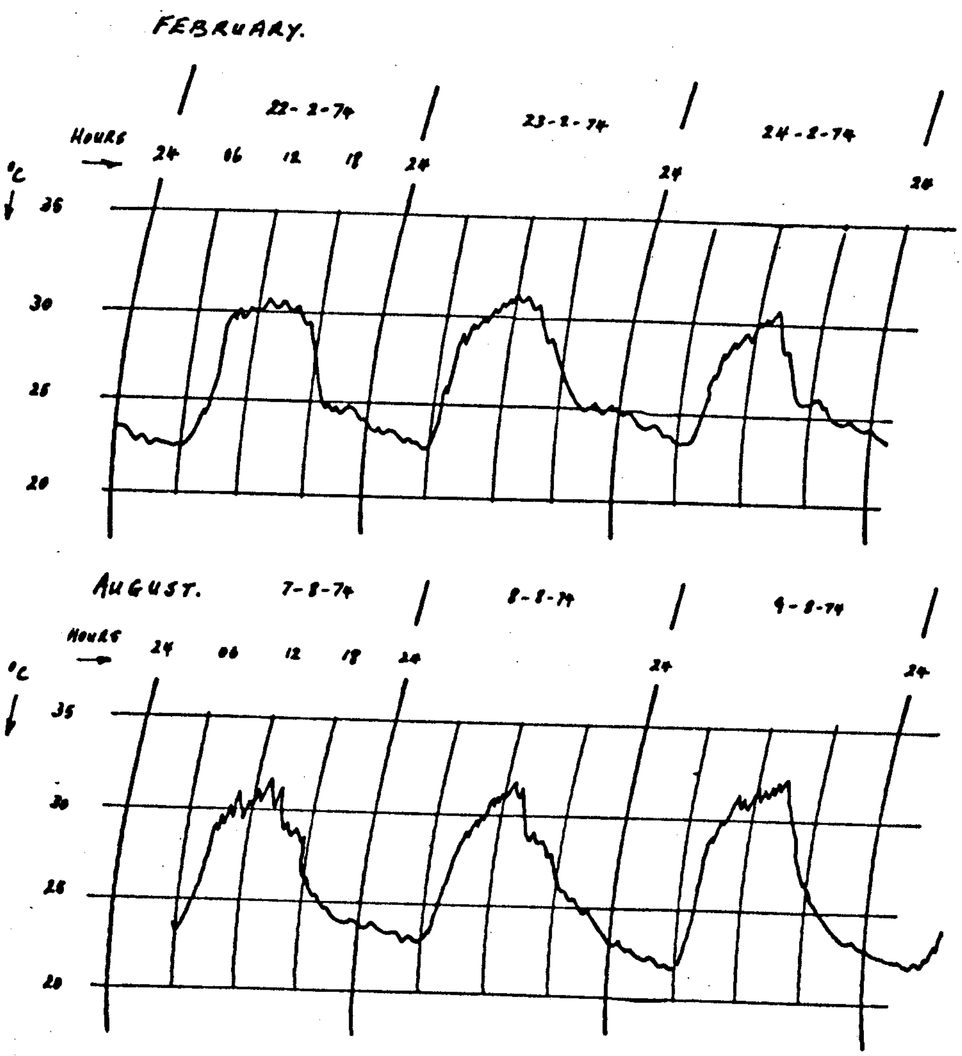


Fig.12. TYPICAL DIURNAL RANGE IN TEMPERATURE, HONIARA



Source. Honiara met. station.

rainfall data in the Solomon Islands. All known data up to the end of 1973 has been tabulated by Ash, Wall and Hansell (1974). Several of the outlying islands have no information and there are no regular records from bush stations at any altitude. The data from 33 selected stations has been taken from this work and shown as histograms in Figure 13. The data has also been interpolated into a rainfall distribution map in Figure 14.

Most of the islands experience a moderate to high annual rainfall of between 2500 and 5000 mm (100 to 200"). This is often distributed fairly evenly throughout the year. The only areas with a relatively low annual rainfall below 2500mm (100") are the north west coasts of Guadalcanal and (probably) Makira. A very high rainfall of over 5000mm (200") is found only on the south east coasts of Guadalcanal and Makira and on Vanikoro. Rainfall on all islands is influenced by the alignment of their mountain ranges to the prevailing north-west (November to April) and south-east (May to October) winds. Coasts directly exposed to the rain bearing south-east trade winds experience the highest rainfall. The driest areas are in the rain shadow in the lee of the high mountains which face the south-east winds. These low rainfall areas receive their heaviest rains during the north-west monsoon season. On the north coast of Guadalcanal there is a distinct dry season during the months of June to September when rainfall falls to around 100mm (3.9") per month.

Data is available from most stations on the number of days on which rain fell. Since rain falls everywhere almost daily with monotonous regularity this information is only of relevance at the low rainfall stations. Even during the dry season at these stations rain

Fig. 13. — SOLOMON ISLANDS — MONTHLY RAINFALL DATA AT VARIOUS STATIONS.

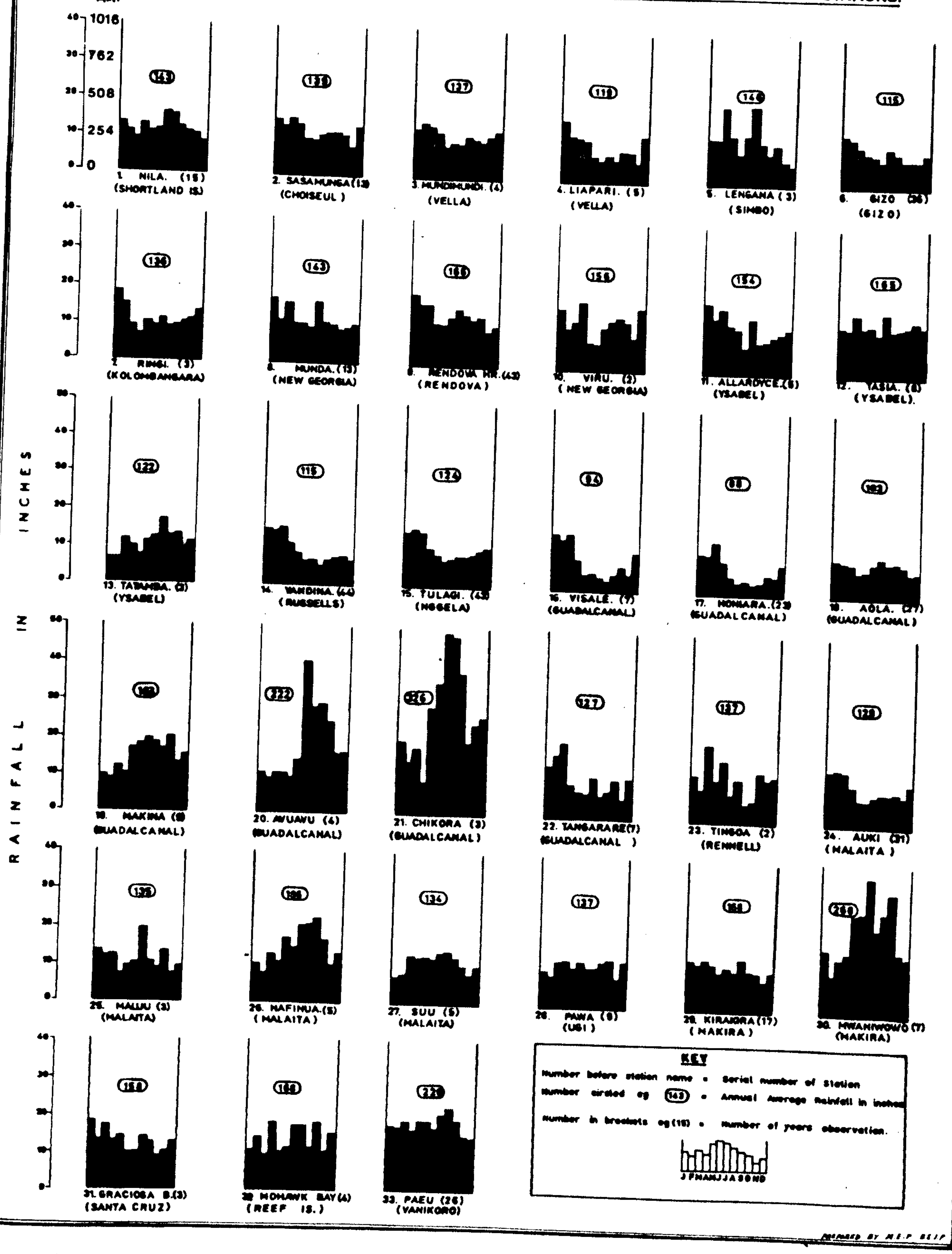
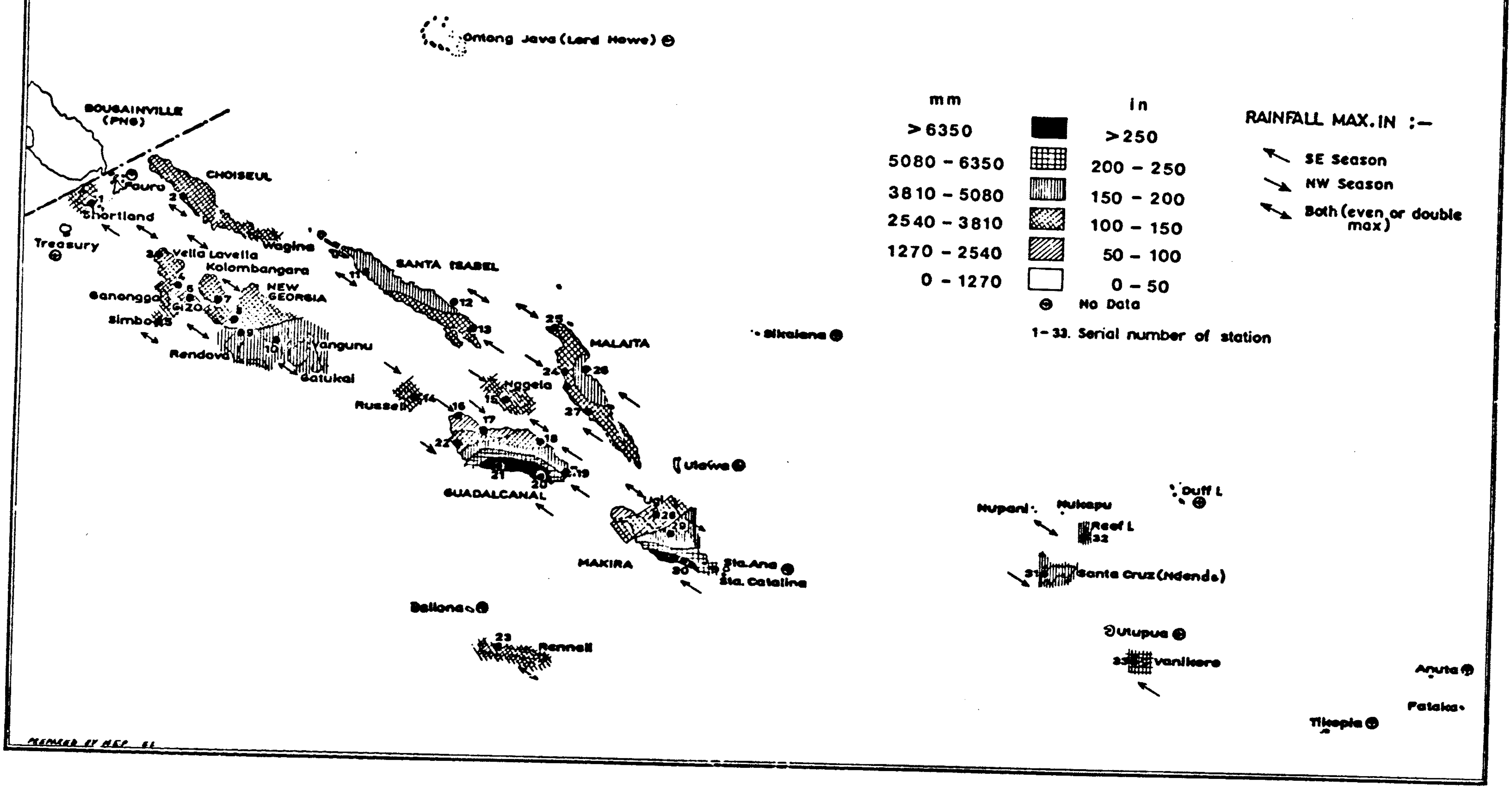


Fig. 14.

SOLOMON ISLANDS - MEAN ANNUAL RAINFALL



falls every few days and prolonged drought is very rare. For this reason no detailed analysis has been made of the days on which rain fell.

Relative humidity

The mean relative humidity for any set time of the day in the Solomon Islands shows remarkably little change throughout the year. The maximum humidity is found at the end of the wet season in March with an average of 90% at 0800 at Honiara. The minimum humidity occurs in Honiara at the end of the dry season with an average of 82% at 0800 in October. In effect, 'night is the winter of the tropics' so that there is a far greater diurnal range in humidity than a seasonal one (Figure 15). During an average 24 hour day humidity is at the maximum around midnight and minimum around noon. The anopheles is well adapted to these variations being most active during the night and resting during the day when it is more liable to dessication.

Other Climatological factors

Most other climatological factors are of little significance in either vector ecology or in the transmission of malaria in the Solomon Islands. Cyclones (tropical revolving storms) occur somewhat irregularly. There were twelve during the period 1966 to 1972, but then none during 1973-1975. The strong winds and heavy rainfall of these violent storms cause widespread destruction and disturbance. The potential for malaria transmission initially decreases due to the loss of vectors. Then within a few months the potential increases markedly due to a population explosion by the vectors and rapid rebuilding by the people. Immediately following a cyclone there is often a period of low rainfall and low humidity (Brookfield and Hart 1971).

Where surface water is constantly being replenished variations in the amount of sunshine are of no great importance in vector ecology. During the dry season on Guadalcanal, however, prolonged sunshine dries up a number of the well known anopheline breeding sites. This applies to small creeks and pond sites and to the man made wheel ruts which all dry out in the south-east trade wind season.

3.3 Flora and Fauna

The flora and fauna are influenced by the marked insularity of the islands, the majority of which are covered with dense rain forest. Some of the coastal plains are swampy and many lagoons and riverine areas have extensive mangrove swamps. Inland from these commercially useful hardwood may often be found interspersed with convolvulus, vines, canes and other dense undergrowth. At altitude the dense forest gives way along the ridges to smaller trees and bushes and eventually to brambles, ferns and montane scrub.

The northern coast of Guadalcanal along the plains and foot-hills is covered with thick kunai grass. This is thought to have become established only during the last few hundred years as a result of excessive slash and burn agriculture. The indigenous flora has been much modified by the activities of man. Along the coast and rivers many different varieties of palm may be seen. These may be in the regular coconut plantations for copra production or merely scattered around for domestic use. Much of the inland forest is now secondary growth recovering from the destruction of the primary forest by slash and burn agriculture. On many inland ridges old sites of villages may be seen. Around these sites and the newer villages pawpaw and banana mix in with root crops, sugar cane and other fruits and vegetables.

The indigenous land based mammalian life is restricted to a handful of mainly nocturnal species including tree rats, opossum, cuscus and bats (flying foxes). Dogs and pigs were already present at the time of the arrival of Mendaña in 1568. Most of the dogs are domesticated but timid. They are used for security and for hunting wild pigs. The more recent introduction of cats by Europeans has resulted in some becoming wild but prior to DDT spraying they thrived in many of the villages. The domestic rat is now a regrettable but inevitable companion in virtually all villages. It not only plunders food supplies and damages clothing and housing but also causes serious damage to coconut trees. The loss of cats has caused the inevitable increase in rats with all its serious sequelae. Cattle are now grazed extensively for commercial purposes and sheep and goats have also been tried on a few plantations. Most of the numerous land reptiles are harmless. Few of the snakes are of any great size or danger although some are venomous. The prolific toad Bufo maranus, introduced from North America, may be seen all along the coastal areas.

The rivers, lakes and lagoons and the seas around the islands contain abundant animal and plant life. Crocodiles and dugong may be seen occasionally in the mangrove swamps. In the lagoons and reef passages two species of turtle provide good sport for the local divers. The playful dolphin, although ritually hunted and driven ashore in North Malaita, seems nowhere near the threat of extinction faced by the whales.

Fish life is abundant in certain of the Solomons seas, but very sparse elsewhere. The formerly traditional line fishing by canoe for skipjack tuna has now turned into a major industry with Japanese catcher boats after almost every shoal.

Some 160 species of birds have been described. These range from the sea going frigate birds and boobies through to the many species of cockatoos and forest birds. A common and frequently irritating bird is the introduced Indian mynah often seen in built up areas and on plantations. One of the unique birds is the partly flighted megapode which incubates its eggs in hot sand on the seashore.

One of the most abundant forms of life in the Solomon Islands is the insects. A brief walk in the forests reveals a whole world of life ranging from the man biting mites and mosquitoes through to large and exotic butterflies and moths. Other irritants to man are the scorpions, centipedes and sandflies whilst the ubiquitous housefly abounds in many of the villages.

It is unlikely that any of the flora and fauna has any distinct bearing on the epidemiology of malaria in the Solomon Islands. The mosquito larvae do not appear to be attacked by many predators and it is only the introduced Gambusia affinis which appears to have any great liking for them. The abundant growth of algae and other plants in the slowly flowing rivers does much to encourage mosquito breeding. Likewise the dense undergrowth of the forest right up to the edge of the village provides ideal resting opportunities for the adult anophelines. Even the garden clearings have many large sheltering plants. The only areas which are not so favourable for the anopheline adults are the kunai grasslands. These are so hot and exposed that villages are only built near to the watercourses running through them.

No surveys have been made of mammalian malaria but there has never been any suggestion that any of the local species act as a reservoir of malaria for man. Neither do they act to any significant extent as an alternative host to the known vectors of human malaria. Even the most recently introduced cattle have little effect on human malaria except possibly by clearing plantation bush and so lessening the resting opportunities for mosquitoes. There is no doubt however that the antimalaria operations, and especially the use of DDT, have had some influence on the ecology. This will be discussed in more detail in Chapter 8.

3.4 The People, their Settlement and Subsistence

The migrations of a negroid race to the Solomon Islands are a relatively recent event in man's history (Ward 1972). Several migrations probably followed the initial invasion some 10,000 years ago. Some of these included seafarers with Polynesian or Micronesian characteristics. Many went right on into the central Pacific Islands but some may have stopped off in small enclaves especially on the outer islands. Within the last two or three hundred years some of the outer islands have been restocked by Polynesians migrating back again from the Eastern Pacific. The pattern of Melanesian settlement covering most of the islands was one of small hamlets scattered throughout the bush areas. Coastal areas were avoided probably because of the fear of malaria and of attack by hostile neighbours.

The population of the Solomon Islands was 160,998 in the official census of 1970. With a total land area of 27,421 km^2 the average population density in 1970 was thus 5.9 per km^2. All the large islands are inhabited by dark skinned negroid Melanesians (93.0% of the total population). The outlying coral stolls and volcanic islands are peopled by lighter skinned Polynesians (3.9%). A small group of Micronesians (1.5%) was settled in parts of the Western Solomons from the over populated Gilbert and Ellice Islands during the 1950's. The remaining 1.6% of the population is European, Chinese or other races.

A number of distinctive features readily identify the Melanesians from the different islands. The tall, lithe and dark skinned Shortland Islander of the Western Solomons is a marked contrast to the stocky, bronzed and blonde Malaita man. The short, wiry Guadalcanal bushman is equally quite a contrast to the fine featured, straight haired man from Santa Isabel. In temperament too there are many contrasts ranging from the quick tempered and truculent Malaita man to the cultured and courteous Westerner. If the Melanesians are remarkable for their diversity then the newly migrated Micronesians are striking for their similarities. The Polynesians also show many similarities though intermingling with Melanesians, as in the Rennell Islands, has rather confused the picture.

The annual growth rate of the population was 1.1% between 1931 and 1959 and 2.7% between 1959 and 1970 (Groenewegen, Groenewegen and Horton 1973). The provisional figure for the February 1976 census is a population of 196,708 (Dudley and MacFadden 1976). This gives an annual growth rate of 3.7% between 1970 and 1976. The only large town is the capital Honiara which had a population of 11,191 in the 1970 census and a provisional population of 14,993 in the 1976 count. In spite of the very rapid expansion of the main township and of the commercial enterprises, 90% of the people still live in scattered small villages.

The triad of man, anopheline and malaria parasite is required for the transmission of human malaria. Unfortunately man frequently does more to encourage transmission than to prevent it. In the tribal days malaria was probably kept in check by people living in isolation in the high bush. Coastal people found escape on artificial islands in the lagoons (Ivens 1930, Parsonson 1966, 1968). With the advent of missionaries and government everyone was encouraged to settle in large villages in the malarious coastal area. Church festivals, feasts and council affairs brought people together and malaria flourished. Later on the young men, especially from Malaita, were recruited for plantation work on other islands. The pool of malaria became even more enriched. The tendency to over populate the coastal areas led to blockage of natural streams with rubbish. Garden clearance in the upstream areas caused further opportunities for anopheline breeding (Laird 1955). Even the Marching Rule movement of post World War II years probably also helped to disseminate malaria (Allan 1951). The movement brought together many of the bush hamlets into larger stockaded villages. Communications were improved and free travel was allowed between villages. This was the main reason for the easy spread of polio in Malaita during the early 1950's according to Cross (1975).

The pig, for long a part of Melanesian culture, does not appear to offer much of an alternative bloodmeal to the Solomons anophelines. Neither did cattle or other domestic animals when they were introduced. Pig wallows and hoof marks do however, offer new breeding opportunities for the ubiquitous anophelines. Man made drainage channels on plantations made further tracts of breeding water. New ventures like lumbering and exploratory mining created even more breeding opportunities. Old workings and massive wheel ruts were found to teem with anopheline larvae on parts of Kolombangara and the Shortland Islands. With large scale clearance of the Guadalcanal Plains for cattle schemes, rice growing and oil palms, even more potential opportunities were created. The irrigation of the rice paddies created numerous irrigation channels and a back up of water in reservoirs for several kilometres behind the dams. Surprisingly these channels and reservoirs were not a source of breeding possibly due to the regular use of insecticides on the rice project. Here perhaps, man was at last turning the tide against the anopheline. Even this was not without its dangers due to the possibilities of larvae and adults developing resistance to insecticide used in suboptimal doses. In the Russell Islands where DDT was used for a while against the scopanes beetle, the dangers were even more serious.

With commercial development man tended to accumulate in even bigger villages or in labour lines especially on the Guadalcanal Plains. Housing was often of a poor standard providing easy day resting opportunities for the anopheline adults. Relatives and friends frequently visited from other islands. This allowed the reintroduction of more new strains of malaria and dissemination out to a wider area.

In the rather special case of World War II (see Chapter 2) man not only aggregated in large numbers but also created new breeding opportunities with wheel ruts and bomb holes.

And so, in the Solomon Islands malaria thrives in an almost perfect physical setting aided by an equable climate with abundant rainfall. On top of this man may be seen to have positively encouraged the transmission of the disease, none more so than during the last hundred years of active civilisation.

3.5 Water Supplies and Sanitation

The only reticulated mains water supplies are those in the major centres. During the last fifteen years W.H.O. sponsored schemes have brought well, spring or river supplies into many villages. Elsewhere the people rely on the abundant springs or on the nearby streams and rivers. Seldom is a village too far from water, even if this does mean some rather hard work in the evenings for the womenfolk. Roof catchments are also being used as more and more permanent buildings go up in the villages. On rare occasions the local water supply may be a source of anopheline breeding. Far more likely will be its suitability for culcine mosquitoes.

Sanitation remains crude in most areas, yet is seldom a serious health hazard. In the towns most of the sewage is disposed of in septic tanks. In the coastal villages oversea latrines may sometimes be used though often modesty precludes their use except in the hours of darkness. In inland villages pit latrines are sometimes seen. Water seal latrine building equipment is available but only a few villages along the roads have taken up the opportunity to construct such toilets. Culicine mosquitoes are often found in them especially when the concrete is cracked. A common means of faecal disposal is on the beach at the waters edge or even in the water usually after dark. Tidal scour frequently aids efficient disposal.

The major influence of water supplies on malaria vector ecology is the close proximity of many of the villages to breeding sites in streams and lakes. Man's insistence on performing ablutions and toilet in the early evening is highly conducive to malaria transmission since this is coincidental with the peak biting activity of the major vector A.farauti.

3.6 Economy

The traditional economy of the Solomon Islands is a subsistence one. The last decade has seen a very large expansion in commercial activity as shown in Table 2.

TABLE 2

Value of Imports and Exports, 1964, 1973-74. Solomon Islands.

In $A'000

	1964	1973	1974
Imports	5,465	11,256	16,988
Exports	4,072	9,553	18,305
Balance	- 1,393	- 1,703	+ 1,317

The Balance of Trade had always been in deficit until 1974 when a favourable balance was achieved.

The main export income in 1974 was from:-

Copra	$A	9,013,000
Timber	$A	4,283,000
Fish	$A	3,735,000
All Others	$A	1,274,000

Copra has always been the top revenue earner except for fish in 1973 and timber in 1972 (Solomon Islands Government, 1974).

No Gross National Product figure is produced but, on a per capita basis, this would be of the order of between $A 100-200. By world comparisons the Solomon Islands is still very much in the lower league of development.

In parallel with the commercial activity there have also been marked changes in government spending even allowing for the effect of inflation. Government Revenue and Expenditure more than doubled in the period from 1963 to 1973, as shown in Table 3.

TABLE 3

Government Revenue and Expenditure, Solomon Islands. 1963 & 1973

In $A'000

	1963	1973
Revenue	4,703	10,931
Expenditure	4,457	11,142

For many years around 50% of the total revenue has come from the United Kingdom aid funds of various kinds. The major source (41%) of the locally raised revenue in 1973 was from Customs and Excise duties. The expenditure was divided into $A 3,864,635 Capital and $A 7,277,410 Recurrent. The latter included a sum of $A 860,170 (11.8%) spent on Health Services. Since the end of the 1960's recurrent expenditure on Health has shown a relative decline from around 13% of the total compared with Education which has shown a steady rise from 13.3% in 1970 to 17.8% in 1973.

The National Development Plan for 1975/79 (Solomon Islands

Government, 1975) allows for considerable further expansion of the economy. Whilst all of the major export commodities are subject to the vagaries of world trade it is predicted that further expansion will provide reasonable stability in the future. The rapidly developing mining and cattle ventures should also help to offset variations in timber and fish production.

3.7 Commerce and Industry

The economy of the Solomon Islands is based almost entirely on primary production. The rendering of coconuts into copra for export to manufacturers in Europe, Japan and Australia has long been the mainstay of the export trade. It is only in very recent years that timber and fish products have made a serious challenge to the copra industry. Now a number of other activities like rice growing and market gardening are beginning to contribute to the local and even to the export economy. In the near future palm oil production and possibly bauxite and copper ore extraction may make a significant contribution to the economy. The bonanza following the discovery of good quality copper ore on neighbouring Bougainville has so far failed to hit the Solomon Islands.

There is no major heavy industry and the only secondary industry of any note is shipbuilding, tobacco, fibre glass, furniture and light clothing manufacture, mostly in Honiara. Fish canning and freezing is carried out at Tulagi and bread is baked in many villages throughout the islands.

Much of the day to day store trading in the main centres is carried out by the long established Chinese. This industrious group also engage in much of the shipping, especially the collection of copra in small cutter boats (Plate 5). Village stores owned by Solomon Islanders or by local co-operative groups are springing up rapidly even in quite inaccessible parts of the islands. Their viability is often seriously jeopardised by long delays in supplies, dubious accounting and continuous pressures by relatives for credit facilities.

A number of special commodities make a small but quite significant contribution to the economy. These include crayfish, exotic shells, trochus and pearl shells, crocodile skins, World War II salvage, postage stamps, shell jewellery and the sale of wood carvings and artefacts to tourists. Tourism itself was expanding quite healthily until the 1974 recession.

3.8 Agriculture and Rural Economy

The Sixth Development Plan (1970-75) recognised that the development of agriculture was of fundamental importance to the whole economy of the Solomon Islands. Since the majority of the inhabitants live off the land, supplemented by local fishing and hunting, the transition to a cash economy would not appear to be too difficult. But, given the ease with which the village man may subsist and his relative indifference to worldly goods, the problem becomes more apparent. Whilst copra can still be made more or less on inclination the more recent expansion into cattle and oil palms requires regular and intensive application. Nevertheless it is the policy of government to encourage smallholder copra and cattle production and to steadily develop the oil palm industry. Significant exports of beef and palm oil are expected in the early 1980's. Self sufficiency in rice production is also aimed for well before that time though problems with irrigation and insects have seriously hampered progress.

Numerous small crops like spices and cocoa will also continue to be encouraged. Problems of land tenure and inheritance still hamper progress in many areas but increasing registration and leasehold arrangements are allowing more land to be systematically developed.

Another industry experiencing land problems is the oil palm development started on Guadalcanal Plains in the early 1970's. Although the Commonwealth Development Corporation sponsored Solomon Island Plantations have now planted more than 2750 hectares of oil palms no progress has been made in local owner participation in this scheme.

The expansion of the various agricultural and rural economy activities may be seen by perusal of Table 4 showing production figures for selected years. Whilst copra and cocoa production has fluctuated considerably the figure for all other commodities shows a marked overall expansion during the decade 1964-74.

TABLE 4

Production of selected Commodities. Solomon Islands. 1964 & 1972-74

Commodity	Year			
	1964	1972	1973	1974
Copra (tons)	25252	20823	15832	28098
Cocoa (tons)	63	63	84	104
Rice Milled (tons)	0	0	NA	2800
Spices (tons)	0	16.85	72.55	40.09
Cattle (Census)	NA	15721	17206	21048
(Slaughtered)	NA	NA	NA	2300
Forestry Exports (Thousands of Cubic feet)	944	8414	8975	7458
Fish Skipjack (tons)	0	0	6500	10940

NA = Not Available

Source: Solomon Islands Annual Reports

The two other vital areas of rural economy are forestry and fishing. During the late 1960's and early 1970's there was a big expansion in the logging industry with large camps operating at six scattered sites in the Solomons. In 1972 a joint Government - Japanese commercial tuna fish cannery/freezing plant was set up on Tulagi in Nggela using the fish caught in Solomons waters. Another is being set up in Hathorn Sound in New Georgia. These fisheries will process and export the bulk of the fish caught in the Solomon Islands.

The Solomons has made a late entry into the mining field although several marginally commercial deposits of bauxite, copper, manganese and nickel exist. Plans for the opening of bauxite mines on Rennell and Vaghena have now reached an advanced stage. Small quantities of gold have been obtained by panning a few north Guadalcanal rivers for a number of years.

3.9 Administration

During the last decade the Solomon Islands have seen such rapid constitutional changes that even the most up to date commentary is out of date. From being a British Protectorate first set up in 1893, the country achieved Internal Self Government in 1975 and should proceed to Independence in 1977.

The present constitution,formulated in September 1974, allows for a Legislative Assembly with 24 elected members and three ex officio members. The elected members elect a Chief Minister who then chooses four to six Ministers to serve on his Council of Ministers. The Council is presided over by the Governor. The three ex officio members are the Deputy Governor, the Attorney General and the Financial Secretary.

The central administration of government is carried out by the public service under the direction of the Deputy Governor. The senior member of each of the six ministries is the Permanent Secretary who is responsible to his Minister and to the Deputy Governor.* The public service selection and regulation is in turn covered by the Public Service Advisory Board which has a Permanent Secretary and five members appointed by the Governor. It is a declared policy of government to appoint local officers to all posts as far as possible commensurate with the need to provide an effective public service.

Although the country is still divided into four administrative districts (Central, Eastern, Malaita and Western), it is the policy of government to progressively delegate more and more of the locally provided services to the nine local councils.

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* The six Ministries are:-

Agriculture and Rural Economy

Education and Cultural Affairs

Health and Welfare

Home Affairs

Trade, Industry and Labour

Works and Public Utilities

The nine local councils are:-

Central Islands (Bellona, Nggela, Savo, Rennell, Russells)

Eastern Outer Islands

Guadalcanal

Honiara Town

Makira (including Santa Ana, Santa Catalina, Three Sisters and Ugi)

Malaita (including Ontong Java and Sikaina)

Ulawa *

Western (all islands in Western District)

Isabel

Services which the councils have taken an increasing interest in since their reconstitution in 1974 include General Administration, Communications, Rural Health Services, Primary Education, Markets and Village water supplies.

Members of councils are elected by universal adult suffrage. Each council has a secretary and expert staff. Members of the public service staff have been seconded to the local councils in various fields where they still have not been able to recruit to full strength. Most councils are also advised by the Government Agent (formerly District Commissioner) and his staff (formerly District Officers). These still carry out their judicial duties as magistrates. Whilst it is proposed to hand over the Rural Health Services entirely to local councils it is still intended to keep the main district and rural hospitals under the jurisdiction of the Ministry of Health

* It is proposed to amalgamate Ulawa into Makira once agreements have been reached.

and Welfare. The Malaria Eradication Programme will also remain under this umbrella although in time it may also delegate some operations to local councils.

3.10 Communications

In spite of the wide dispersal of the archipeligo and the often sparse and scattered population, communications are reasonably good in the Solomon Islands. All neighbouring territories are in contact by regular jet flights and the internal airline, Solair, provides good services to the outlying islands. The twenty operational airfields, together with a few additional strips used by mission aircraft, provide a good coverage. A versatile float plane is operated from Honiara by the Missionary Aviation Fellowship (MAF). This may be used by the Ministry of Health and Welfare for emergency medical flights when required.

The shipping links between the main centres are operated on a scheduled basis by commercial enterprise. The most reliable services are the twice weekly one to Auki and the weekly services to Russells, New Georgia and Gizo. The government or local co-operatives also operate regular services round all the large islands. A typical feature of island communication is the oft over loaded 'cutter boat' (Plate 5). These trade from port to port on a casual basis picking up copra, carrying passengers and selling trade goods.

Road communications have shown a marked improvement in the last ten years. This has been due to the government policy to stimulate economic development. It has also been due to the activities of large commercial enterprises especially on Guadalcanal

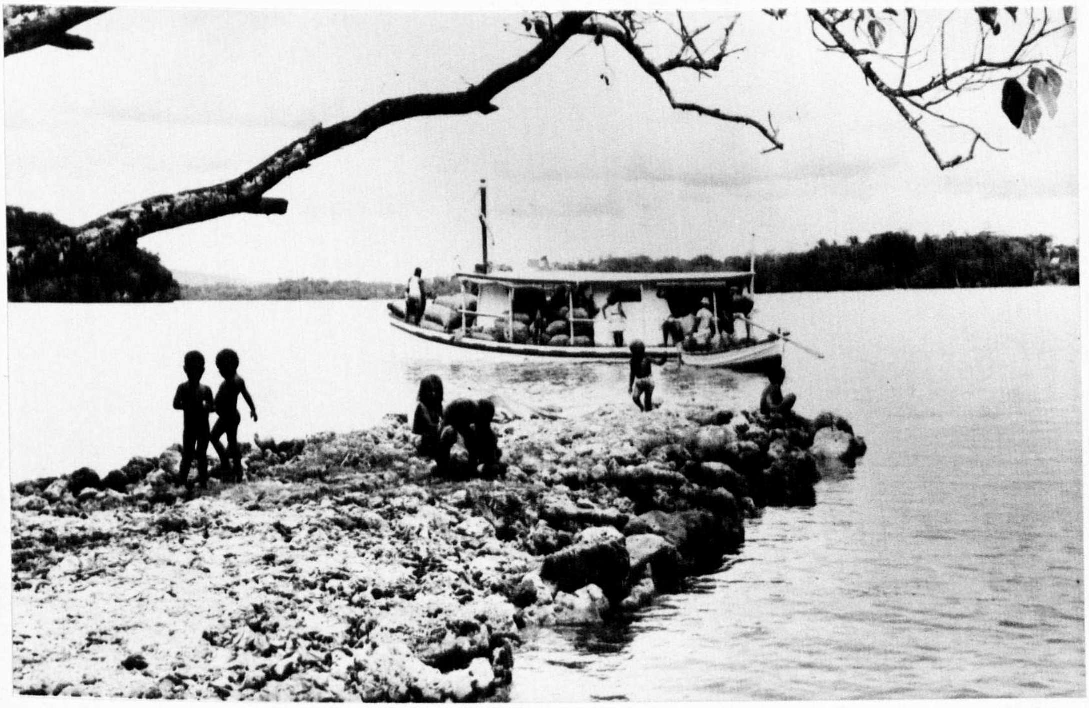


Plate 5. Cutter boat loading Copra, Roviana lagoon, Western Solomons.

Plate 6. Artificial island in Lau lagoon, Malaita.

and Kolombangara. The two major road systems are the 90 km. in North Guadalcanal and the 60 km. in North Malaita. There is also a rapidly expanding 35 km. of road in Makira and several small feeder roads on different islands. An attempt is being made to link two feeder roads in Central Malaita to form the first transinsular road in the Solomon Islands. The location of most of the feeder roads is shown on the individual island maps (Figures 17 to 27). The high rainfall makes road building and maintenance particularly difficult and expensive. On many occasions flash flooding of rivers has caused road blocks or carried away bridges.

For the average villager the most important means of communication is by canoe or on foot. In the lagoons of the Western Solomons and Malaita the real sign of increasing status is the ownership of a 20 or 33 h.p. Johnson outboard motor. Elsewhere the traditional paddle holds sway although the enterprising may sail before the wind with a palm frond or some sewn up copra sacks. All the large islands have an elaborate network of coastal and inland footpaths. These may be through coconut groves, along the beaches, up mountain ridges or criss-crossing endlessly through river valleys. For the bushman this is easy country, but for the uninitiated it is an agonising procession of halting steps through thick undergrowth or raging torrents.

A final and most important means of communication is through the radio network. Daily scheduled two way radio-telegraphy services maintain links between Honiara and the district centres. Similar links serve these centres and their outstations. The missions and commercial enterprises also have separate schedules.

Ship to shore communications allow government ships to be directed for emergencies if necessary. An experimental pedal radio link up has been made between Kirakira on Makira and two of the Rural Health Clinics on the south side of the island. If successful it is proposed to install radios in selected clinics elsewhere. Many agencies, including the Ministry of Health and Welfare, make great use of the service messages broadcast each evening by the Solomon Islands Broadcasting Service (SIBS). With the use of a simple transistor radio the nurse or health worker in a remote clinic or village can easily be forwarded a brief message. The method has proved invaluable for arranging movements of staff or for carrying out the rapid treatment of itinerant malaria cases.

3.11 Education

The Education Services experienced a rapid expansion during the 1970's. In a review dated 31st March, 1974, a total of 24,088 pupils were enrolled in 323 primary schools. (Solomon Islands Government, 1974) The six secondary schools had an enrolment of 1,566 (1174 males, 392 females). The total of 25,654 undergoing schooling represented 51.3% of the predicted number of around 50,000 in the school age group. In the census of 1970 (Groenewegen, Groenewegen & Horton 1973) only 10% of the Melanesian and 8% of the Polynesian population was found to have attained Standard 7 education. Three times more males than females attained this and there were marked regional variations. In the Western Solomons 25% of all Melanesian males aged 15 to 30 had reached Standard 7 education. In Malaita only 15%, and in the Eastern Solomons only 13% achieved this goal. A much higher proportion of the younger age groups had reached Standard 7 compared with the older age groups. Amongst the age group 15 to 20, 18% had achieved the goal whilst the figure was only 2% for those aged 45 and over.

Tertiary education has also expanded rapidly with 13 students achieving University degrees in 1974. There were 110 students in tertiary education overseas in that year and 597 doing full time courses at the Honiara Technical Institute.

An Education Policy Review published at the end of 1973 outlined plans for the provision of universal primary education and consolidation of the secondary education. Churches were to be encouraged to continue to provide for most of the primary education but government was to play an increasing role at the secondary and tertiary level. Vocational training was to be given a strong emphasis and every effort was to be made to provide sufficient number of young educated men and women to carry out the localisation policies of the government.

3.12 <u>Religion</u>

The people of the Solomon Islands are either Christian or heathen. The latter group numbering some 8,000 people is based mostly in the high bush areas of Guadalcanal and Malaita, on the artificial islands of Malaita or on the remote outer islands of Tikopia and Anuta. One third of the population was reported by the 1970 census to belong to the Anglican Church (Groenewegen, Groenewegen & Horton ibid). Most of the remaining two thirds have allegiance to the Roman Catholic Church, the South Seas Evangelical Church or the United Church. Small minorities belong to the Seventh

Day Adventist Church, the Christian Fellowship Church or a few other minority sects.

3.13 Employment

The majority of Solomon Islanders do not engage in any permanent employment. Typically a man will have a small plot of land for coconut palms, vegetables and, more recently, for cattle grazing. When tax demands or material needs call he merely cuts a few bags of copra or sells off some cattle. The younger men often make their way to Honiara or to the large commercial undertakings to work for a few months or years to earn their bride price. These cultural patterns are now changing with more and more settling in to permanent employment or to developing their own land holdings. The average number employed annually from 1970 to 1974 was around 14,000. In 1974 1,010 of these were expatriates and 1,381 were Solomon Islander women (Solomon Islands Government, 1974). Many of the employed males live in rudimentary labour lines provided by their employers. The proportion with families living in remains low but is beginning to rise.

3.14 Health and Social Services

The Health Services of the Solomon Islands have evolved steadily over many years whilst formal Social Services have only begun to take shape during the last ten years.

Traditionally treatment for ills was always provided by the local medicine man who was often able to effect cures with his spells and potions (see Chapter 2). Some ills recovered spontaneously, but many often went untreated. Prevention was virtually unknown although the building of artificial islands, settlement in small high bush hamlets and the observance of numerous taboos probably did much to prevent the spread of disease.

With the arrival of the missionaries and traders in the mid-nineteenth century a few rudimentary clinics were set up for treating expatriates. Once the missions became established in the early 1900's small hospitals were set up notably at Fauabu in Malaita and at Roviana in the Western Solomons. Today relatively extensive curative and preventive services are provided by both government and the churches. From its modest provision of a small hospital at Tulagi in 1910 government has gradually developed a network of hospitals and clinics throughout the islands. The churches have remained prominent to this day and continue to provide essential links in the overall network.

Hospital Services

The principal hospital is the Central Hospital which, in addition to being the district hospital for Central District, is the only one in the Solomons offering specialist services. It is, therefore, the referral hospital for a wide range of clinical conditions. With some 170 beds, including 18 in the mental hospital at Kukum, Central Hospital has an annual turnover of 3,500 in-patients, 40,000 out-patients, 1,500 operations and 1,000 deliveries.

Each district is served by a district hospital at the government administrative centre. These are Western District Hospital (46 beds) at Gizo; Malaita District Hospital (112 beds) at Kilu'ufi near Auki; and Eastern District Hospital (64 beds) at Kirakira. The government rural hospitals at Buala, Santa Isabel; Malu'u, North Malaita and Graciosa Bay, Santa Cruz, each have 32 beds. At least one Medical

Officer is based at each of the district hospitals together with nursing and laboratory staff. The Santa Cruz hospital is the base for the Medical Officer serving the Eastern Outer Islands.

The churches provide hospital facilities at Helena Goldie Hospital (52 beds) at Munda in New Georgia (United Church); the Adventist Hospital (91 beds) at Atoifi, Malaita (Seventh Day Adventist Church); the Catholic Mission Hospital, Buma Malaita (28 beds) and the Hospital of the Epiphany (130 beds including 30 for leprosy) at Fauabu, Malaita (Diocese of Melanesia). Medical officers are stationed at all except Fauabu.

Rural Health Services

Primary health care is provided outside the main centres by the Rural Health Clinics (RHC's) and church and commercial clinics throughout the islands. Central Government and local councils share the costs of running these clinics but in time they will be taken over entirely by local councils. A number of other Village Health Aid Posts (VHAP's) are maintained by councils. They are usually staffed by Village Health Aids all of whom have only a limited training in basic primary care skills. The churches provide the main coverage for the rural health services in some areas of Malaita and the Western Solomons. Government support for these services takes the form of subventions towards staff salaries and supplies of essential vaccines and drugs.

Most health institutions are regularly visited by the District Medical Officer and District Sister. They assist and supervise the clinic nursing staff who, in turn, carry out regular touring programmes within their defined clinic areas. In addition to general clinical services, these nurses are responsible for maternity and child health work, immunisations, tuberculosis and leprosy control and case detection for the Malaria Eradication Programme.

School health services are also in the hands of the district health staff but this still remains at an early stage of development. There is no Industrial Health Service although some of the larger Companies do provide clinics for employees and their families.

Distribution of Health Services

The original pattern of the hospitals in the islands was largely determined by poor communications. The virtual impossibility of referring a patient from one hospital to another dictated the establishment of at least one hospital per major island. More recently, with vastly improved communications, the picture has altered dramatically. It is now neither necessary nor desirable to provide comprehensive surgical facilities at all hospitals. The policy on the distribution of hospital and clinic services throughout the Solomons was clarified in the 1964 Government Policy Paper on the subject (BSIP 1964). This determined that some 60 permanent Rural Health Units would be provided each covering a population of about 2,500 people. Each unit was to be staffed by two fully trained nurses, one male and one female. The local councils and the churches would fill any gaps in coverage. At the end of 1975, 58 of the units (now called Rural Health Clinics) had been completed. Twenty two were fully staffed and most of the remainder had at least one qualified nurse at post (C. Acheson, personal communication).

Remote islands with small populations usually have a small clinic with a Village Health Aid (formerly called a Dresser). Smaller clinics are also established at some inaccessible bush areas in Guadalcanal and Malaita.

The sites of hospitals, rural health units, and clinics for each District are shown on the map at Figure 16. This map shows all Rural Health Clinics marked as Rural Health Units (RHU's). The map does not show the proposed Area Health Centres which are shown on the more detailed maps in the Description of Islands Section of this Chapter.

By world standards the Solomon Islands are comparatively well off for doctors, nurses and hospitals. With 2.3 doctors per 10,000 people the Solomon Islands are far better off than Papua New Guinea and most African countries (Table 5).

TABLE 5

Number of Doctors per 10,000 Population. Selected Countries

Country	Year of Survey	Number of Doctors per 10,000 population
Oceania		
Solomon Islands	1971	2.3
Australia	1972	13.9
Fiji	1971	4.8
Papua New Guinea	1972	0.9
Asia		
Indonesia	1973	0.4
Africa		
Zaire	1972	0.4
Nigeria	1972	0.4
Americas		
Colombia	1972	4.6
U.S.A.	1972	16.5
Europe		
England & Wales	1972	13.1
U.S.S.R.	1972	25.6

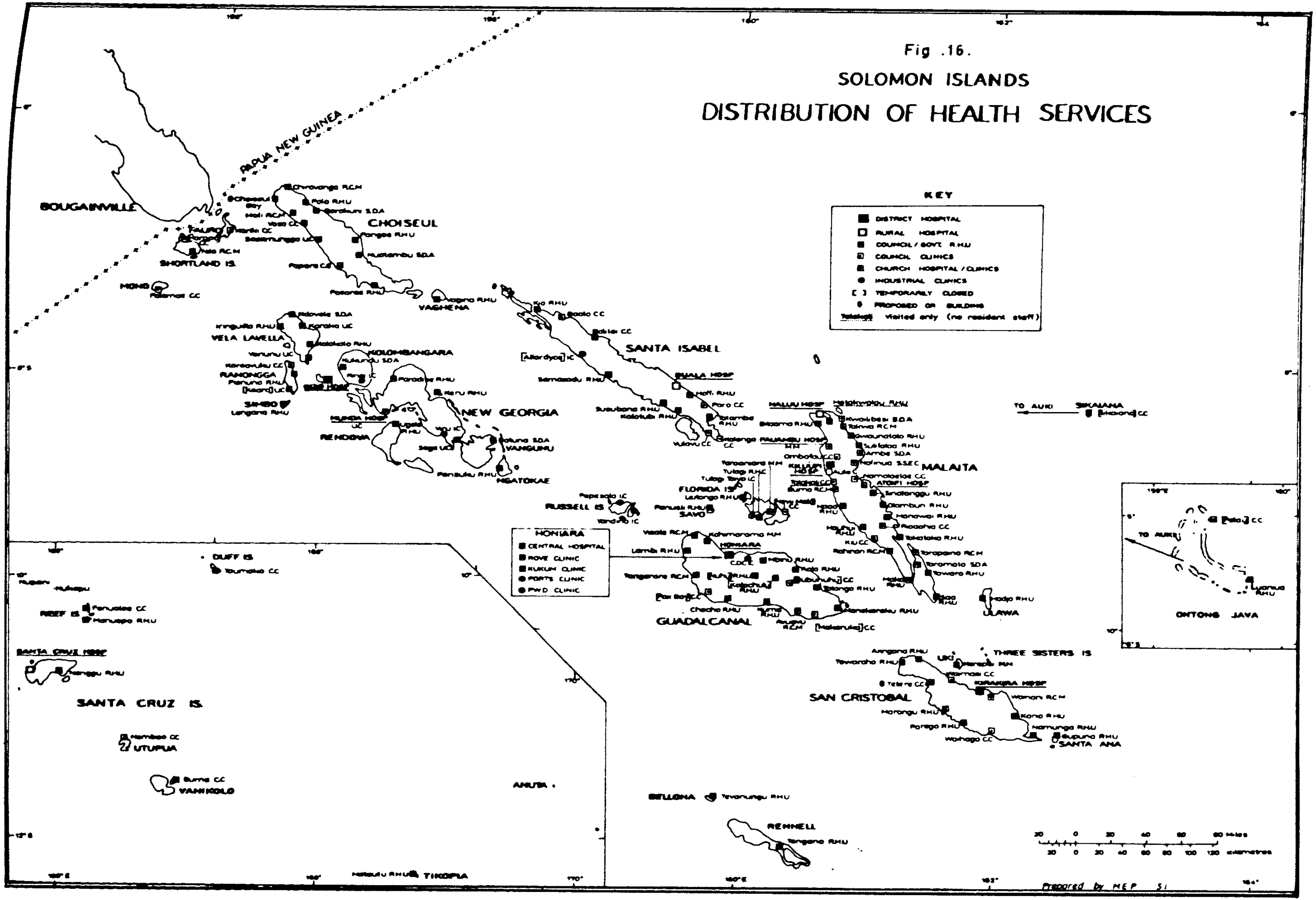


Fig .16.
SOLOMON ISLANDS
DISTRIBUTION OF HEALTH SERVICES
KEY
DISTRICT HOSPITAL
RURAL HOSPITAL
COUNCIL / GOVT. R.H.U
COUNCIL CLINICS
CHURCH HOSPITAL / CLINICS
INDUSTRIAL CLINICS
[ ] TEMPORARILY CLOSED
PROPOSED OR BUILDING
Visited only (no resident staff)
PAPUA NEW GUINEA
BOUGAINVILLE
SHORTLAND IS.
CHOISEUL
VAGHENA
VELA LAVELLA
KOLOMBANGARA
RANONGGA
SIMBO
NEW GEORGIA
RENDOVA
VANGUNU
NGATOKAE
SANTA ISABEL
MALAITA
FLORIDA IS.
SAVO
RUSSELL IS.
HONIARA
CENTRAL HOSPITAL
ROVE CLINIC
KUKUM CLINIC
PORTS CLINIC
PWD CLINIC
GUADALCANAL
ULAWA
THREE SISTERS IS
SAN CRISTOBAL
SANTA ANA
TO AUKI
SIKAIANA
ONTONG JAVA
BELLONA
RENNELL
DUFF IS
REEF IS
SANTA CRUZ IS.
UTUPUA
VANIKOLO
ANUTA
TIKOPIA
Prepared by MEP SI

Notes

1. For the purpose of these surveys a doctor includes a diplomate officer who has completed a recognised course in a medical school.

2. Source of data for Tables 5, 6 and 7 unless otherwise stated is W.H.O. Statistics Annual 1972, Volume III. Health, Personnel and Hospital establishments. Geneva: World Health Organisation 1976.

The country is also well endowed with registered nurses, having in 1975 no less than 16.8 nurses per 10,000 people. Again this compares favourably with many other countries (Table 6) even allowing for the later date of the Solomon Islands data.

TABLE 6

Number of Registered Nurses per 10,000 Population, Selected Countries

Country	Year of Survey	Number of Registered Nurses per 10,000 Population
Solomon Islands	1976	16.8[1]
Fiji	1971	16.0
Papua New Guinea	1972	6.0[2]
Indonesia	1973	2.2
England & Wales	1973	38.8

Notes

1. As at 1st January 1976. Source - Chief Nursing Officer, Solomon Islands.

2. Figure excludes midwives.

When comparisons are made between countries for the provision of hospital beds the Solomon Islands are still favourably placed with 85.2 beds per 10,000 population (Table 7).

TABLE 7

Number of Hospital Beds per 10,000 People, Selected Countries

Country	Year of Survey	Number of Hospital Beds per 10,000 Population
Solomon Islands	1971	85.2
Australia	1972	123.9
Fiji	1971	28.7
Papua New Guinea	1971	67.2
Indonesia	1971	6.9
Zaire	1970	31.4
Nigeria	1972	7.3
Colombia	1972	19.9
U.S.A.	1972	72.2
England & Wales	1972	89.2
U.S.S.R.	1972	112.9

Future Development of the Health and Social Services

With constitutional development proceeding at a steady pace many of the locally provided services are being handed over by Central Government to the local councils. This will require administrative re-organisation but the network of hospitals and clinics will remain much as before. The major change in the Rural Health Services will be the setting up of 15 or 16 Area Health Centres at strategic positions around the islands. These centres will act in a supervisory and referral capacity for a group of 2 to 6 Rural

Health Clinics. At the 'grass roots' village level it is also proposed to greatly increase the number of Village Health Aid Posts. These will be staffed by Village Health Aids (formerly called Dressers) who have undergone a six month basic training. They will probably serve all villages or groups of villages with more than 100-200 people.

Further major hospital development is not envisaged until the major Rural Health network is complete. In the long term a resiting and rebuilding of the 300 bed Central Hospital in Honiara may be required. Laboratory services will also require expansion particularly if they are to serve in a Public Health capacity.

Social Services

With the rapid urbanisation of Honiara and an increasing drift of partly educated people to the main centres demands for social services are steadily increasing. Some counselling and welfare services are already provided in addition to the hostel facilities for single girls. The service may be expected to expand considerably during the next few years. In the meantime the voluntary agencies and churches continue to carry out many of the social service tasks. An active women's interests section promotes and organises women's clubs in many of the villages.

3.15 Description of the Islands

In view of the relevance of the wide variety of geographical features to the epidemiology of malaria in the Solomon Islands, some detail is given of each major island or island group. Where smaller islands have special features these have also been included. Rainfall data for most of the islands may be found by referring back to Figures 13 and 14.

Central Solomons

This is a large and wide ranging group comprising, in the centre, Guadalcanal, Savo, Russells and Nggela. To the north lies Isabel and to the south Rennell and Bellona.

The areas and populations for these islands are shown in Table 8 and their topography is shown in Figures 17, 18 and 19.

TABLE 8

Central Solomons. Areas, Population and Population Densities

Island	Areas in km^2	Population	Population Density per km^2
Guadalcanal *	5564	35187	6.3
Savo	32	1352	42.3
Russells	207.3	2715	13.1
Nggela (Florida)	373.5	5351	14.3
Santa Isabel	3962	8653	2.2
Bellona	17	604	35.5
Rennell	528	900	1.7
Total:	10683.8	54762	5.1

Sources of Data: 1. Lands Division of the Ministry of Agriculture and Rural Economy.
2. 1970 Census

* Includes Honiara Population - 11,191

The people of the Central Solomons are predominantly Melanesian. The exceptions are Bellona and Rennell whose inhabitants have mainly Polynesian characteristics. Around the capital Honiara and at the main commercial centres representatives from all of the islands of the Solomons may be seen.

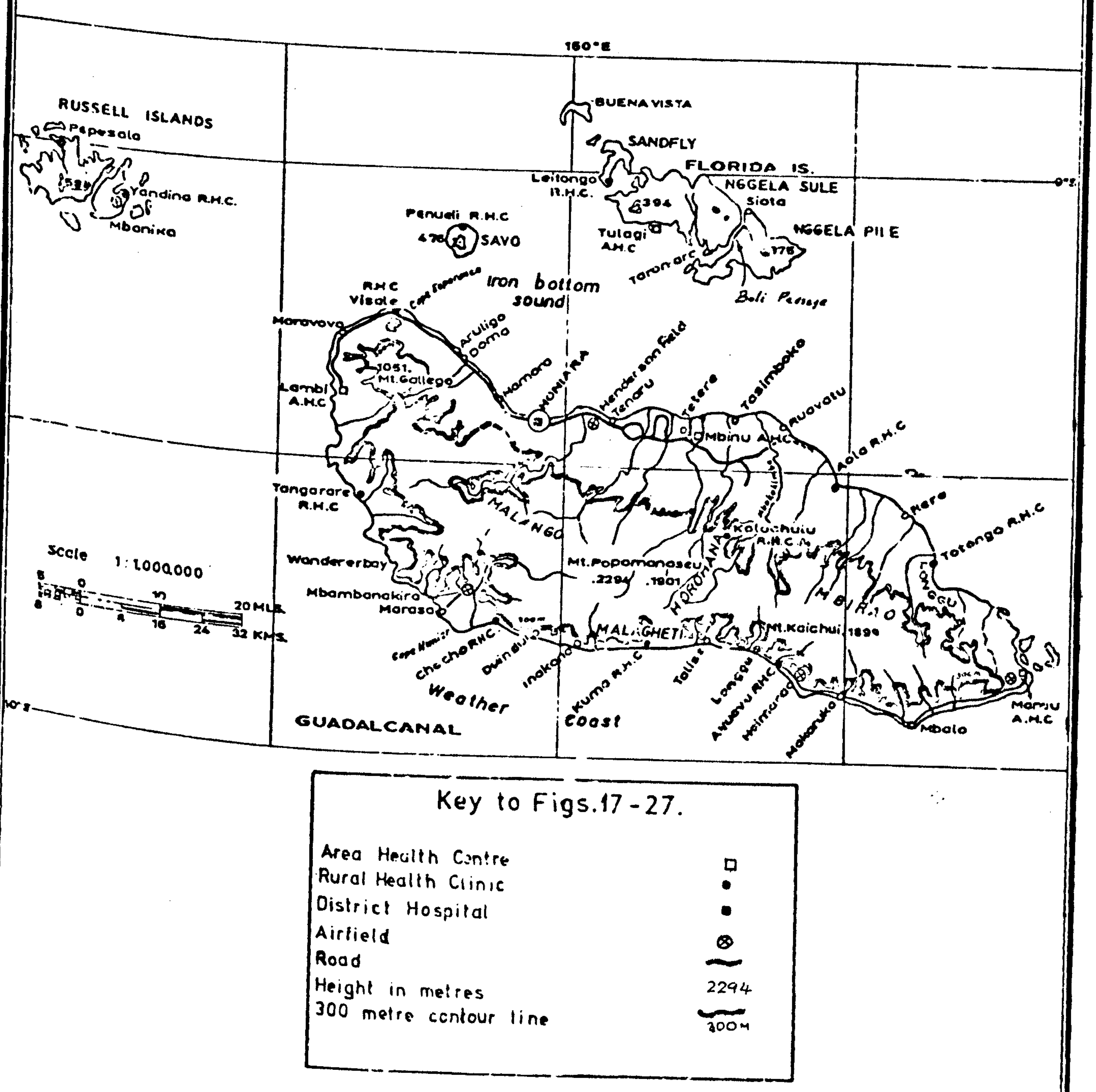
The central Solomons is divided administratively into four Councils. Honiara Town Council covers the urban area whilst the Guadalcanal Council, also based in Honiara, deals with the rest of the main island. The Central Islands Council based at Tulagi, covers Bellona, Rennell, Russells, Savo and Nggela. Buala is the base for the remaining council which is exclusive to the island of Santa Isabel.

Guadalcanal

Occupying a central position, this is the largest island in the Solomons group (Figures 3, 4 and 17). Much of the island is mountainous with Mount Popomanaseu at 2294 metres (7524 feet) being the highest in all the islands. The watershed is close to the south coast, so that steep and rapidly flowing streams, subject to massive flash flooding, are to be found on that side. On the north coast several large rivers cascade into the Guadalcanal Plains only to end up sluggishly meandering towards the sea. The plains, which extend fully 60 km (37 miles) to the east of Honiara, is the largest tract of flat land in the Solomon Islands. It is also the most important development area.

Apart from the capital at Honiara numerous commercial settlements and large villages are scattered over the Plains. Elsewhere most of the coastal strip is well populated especially around Malagheti and Makaruka on the southern coast. A significant enclave

Fig. 17. MAP OF GUADALCANAL, SAVO, FLORIDA AND RUSSELL ISLANDS. SOLOMON ISLANDS



of about 3700 people lives in the bush areas of Horohana and Mbirao in the Central highlands. Guadalcanal is the main centre for migrations from other islands.

A good dirt road extends out from Honiara as far as Lambi 50 km(31 miles) to the west and almost to Ruavatu 40 km(25 miles) to the east. Several other roads feed villages on the north coast. On the south east coast a much less used road currently leads from Marau to Avu Avu. Airfields at Marau, Haimarao and Mbambanakira provide quick air links to Honiara. Medical facilities appear to be well distributed with no less than ten Rural Health Clinics placed strategically around the island. The clinic at Mbinu has already been upgraded to the status of an Area Health Centre whilst Marau and Lambi are shortly to be improved for this purpose. The base hospital is the 170 bed Central Hospital at Honiara. This is also the specialist and referral hospital for all the islands.

Copra platations and cattle schemes may be seen all around the coast of Guadalcanal whilst gardening for the market in Honiara is carried out wherever communications are reasonable. The Guadalcanal Plains now support large irrigated rice and oil palm projects taking up formerly wasted grassland. Timber extraction has recently expanded well into the foothills to the south of the Plains. Honiara supports a large itinerant population looking for work and lodging with relatives. Several have jobs with the government and a few with commercial enterprises. The only town employment industries of note are tobacco manufacture, building, ship and canoe building, saw milling and furniture manufacture.

Savo

A small but distinctive quiescent volcano 15 km (9 miles) off the north west coast of Guadalcanal (Figure 17). The villages are scattered along the coast all round the island with a slightly greater concentration on the north and east sides.

The several hot springs are a useful reminder that this island is under constant threat of major volcanic activity. Numerous small fast flowing streams radiate down the slopes but these are often completely dry in the absence of rain. The Rural Health Clinic is at Panueli on the north of the island.

Russell Islands

This is the main centre for copra production in the Solomon Islands with the Lever Company plantations extending over all of Mbanika (Figure 17) and most of the northern part of the mainland. The remainder of the large island is hilly and forested. Extensive reef on the north side makes navigation particularly hazardous although there is a big ship wharf at the main centre of Yandina.

The plantation settlements house a wide cross section of labour from all over the Solomon Islands. Most are from Malaita but there are sizeable groups from the Eastern Solomons, Bellona and Rennell. The few indigenous Russell Islanders mostly live on the flat offshore islands working their own coconut platations. The Lever Company's Rural Health Clinic at Yandina serves both the plantation and private population. A smaller clinic at Pepesala serves a similar purpose.

Florida Islands (Nggela)

The Florida Island Group, which is usually called Nggela, lies some 30 km (19 miles) to the north of Guadalcanal (Figure 17). The main centre Tulagi, the capital of the Solomon Islands until 1942, is now a thriving ship repairing and fish processing centre. The islands are relatively low lying with gentle hills and extensive grassland lying in between the forested and garden areas. The several deep indentations into the islands include the Boli Passage which is navigable by small vessels. The people are scattered all around the islands mostly on the coast, but with a few villages a little inland. Frequent migrations take place between Nggela and neighbouring Santa Isabel, Savo and Guadalcanal.

Rural Health Clinics are located at Tulagi (due to become an Area Health Centre) and Leitongo. The Anglican 'hospital' at Taroniara has also served as a Rural Health Clinic for many years.

Santa Isabel

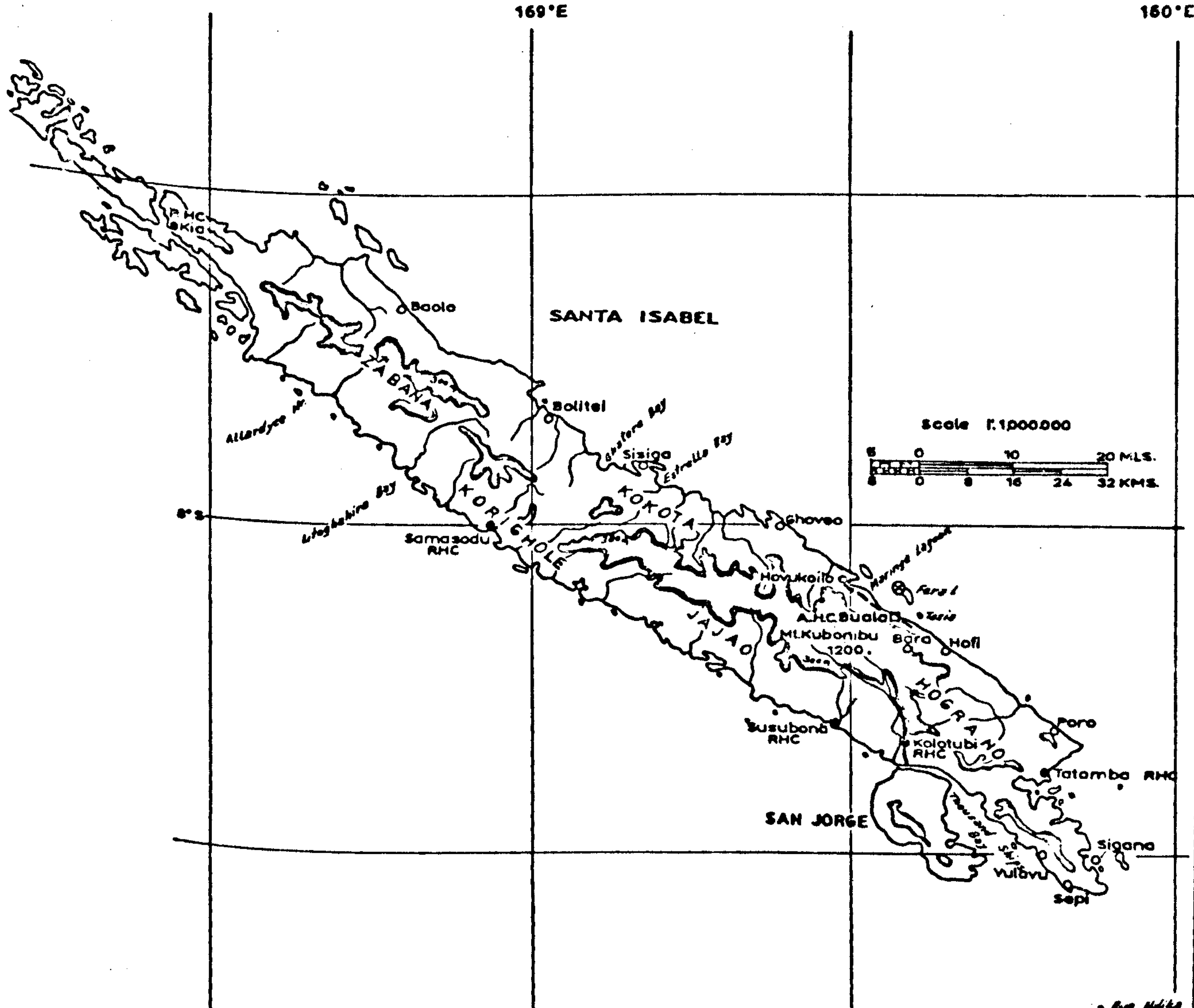
The fourth largest island in the Solomons, Santa Isabel lies midway between Choiseul and Malaita (Figures 2 and 18). It is rugged and mountainous in the centre and has several offshore reefs and islands especially at its north western end.

The main centre is at Buala on Maringe Lagoon where there is also a 32 bed Rural Hospital (soon to be designated an Area Health Centre). Five Rural Health Clinics are scattered around the coast concentrating on the more densely populated eastern side. A small number of bush villages are located behind Buala whilst Estrella Bay on the north coast is the site of the first point of contact of the modern discovery of the Solomon Islands by Alvaro de Mendaña in 1568.

Bellona

An isolated raised coral atoll situated some 150 km (93 miles) to

Fig.18, MAP OF SANTA ISABEL . SOLOMON ISLANDS.



Solomon Islands M.E.P.

the south of Guadalcanal (Figure 19). In profile the island is raised at both edges and depressed in the centre (Figure 8). In the absence of any recorded data it is assumed that the climate of Bellona is similar to that of Rennell. Surface water is seldom found on any part of the island. The eight villages are scattered along the island in the depression and there is an airstrip in the centre. Due to a thriving sale of carvings in Honiara the island is quite prosperous and several houses have corrugated roofs. The Rural Health Clinic is at Tevanungu.

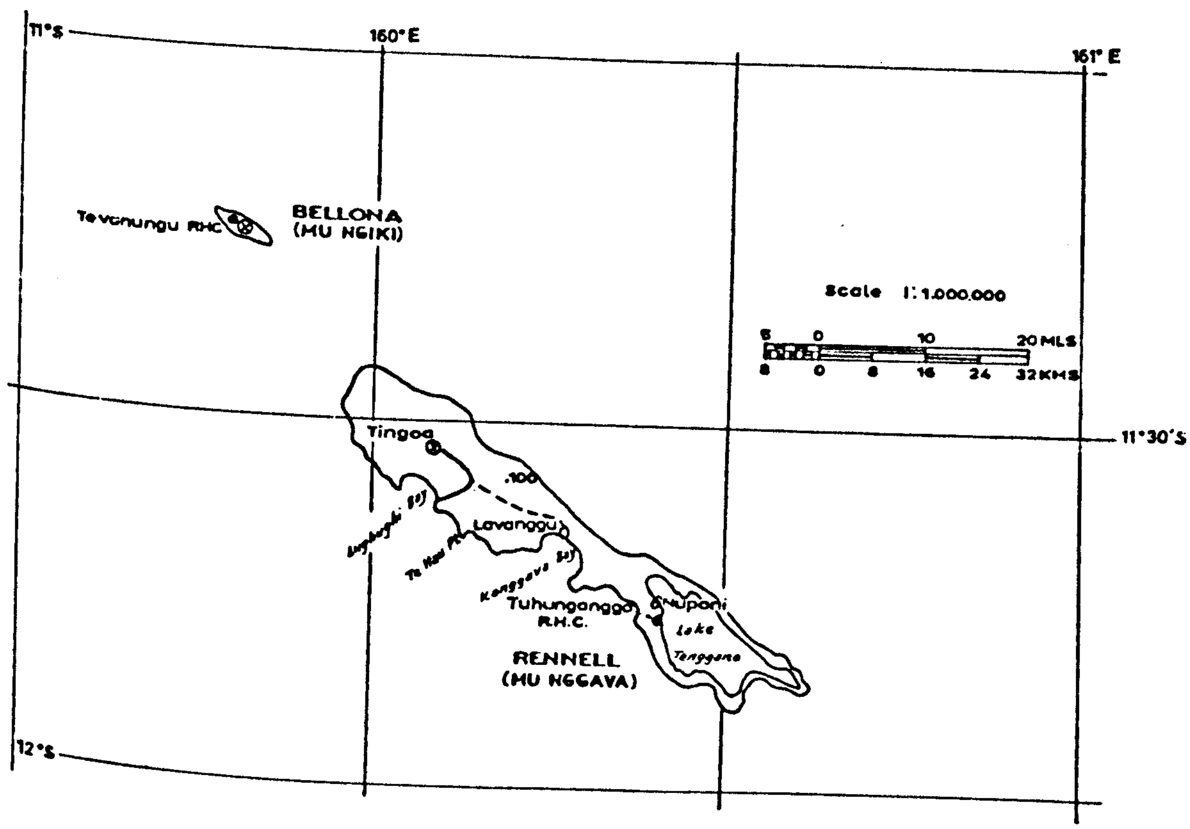
Rennell

A large isolated raised coral atoll 190 km (118 miles) to the south of Guadalcanal (Figures 2 and 19). In profile the island is similar to Bellona. The south coast has several inundations and two large bays. At Kangava Bay the cliffs are quite low, allowing relatively easy access to the interior.

In the east of the Island is the large brackish water lake Te Nggano. No surface streams exist but pools and swamps may occur in the centre of the island during heavy rain. Water is obtained from wells, limestone caves or roof catchments.

The 14 villages are scattered between the western edge of the lake and the new mining settlement at Tingoa. Frequent migrations are made by the inhabitants to Honiara and the Russell Islands. The present Rural Health Clinic is at Tuhunganggo but in the near future a mining company Clinic will be set up at Tingoa. The whole ecology of the island is likely to be radically disrupted within the next few years once mining starts on the rich bauxite deposits.

Fig. 19. MAP OF RENNELL, BELLONA, SOLOMON ISLANDS



Solomon Islands M.E.P.

Eastern Solomons - Eastern Inner Islands

This group, which is the inner part of the Eastern District, comprises the islands of Makira (San Cristobal), Santa Ana, Santa Catalina, Ugi, Three Sisters and Ulawa. The areas and population figures for these islands are shown in Table 9 and their topography is shown in Figure 20. The majority of the people are Melanesian, except for small enclaves of recent Polynesian migrants from the Eastern Outer Islands. Most villages are on or near the coast, the notable exception being a few hamlets in the bush behind Kirakira and Wainone on Makira. The Makira Council, based at Kirakira, currently covers all the group except for Ulawa which still retains its own small council.

TABLE 9

Eastern Inner Islands. Areas, Population and Population Densities

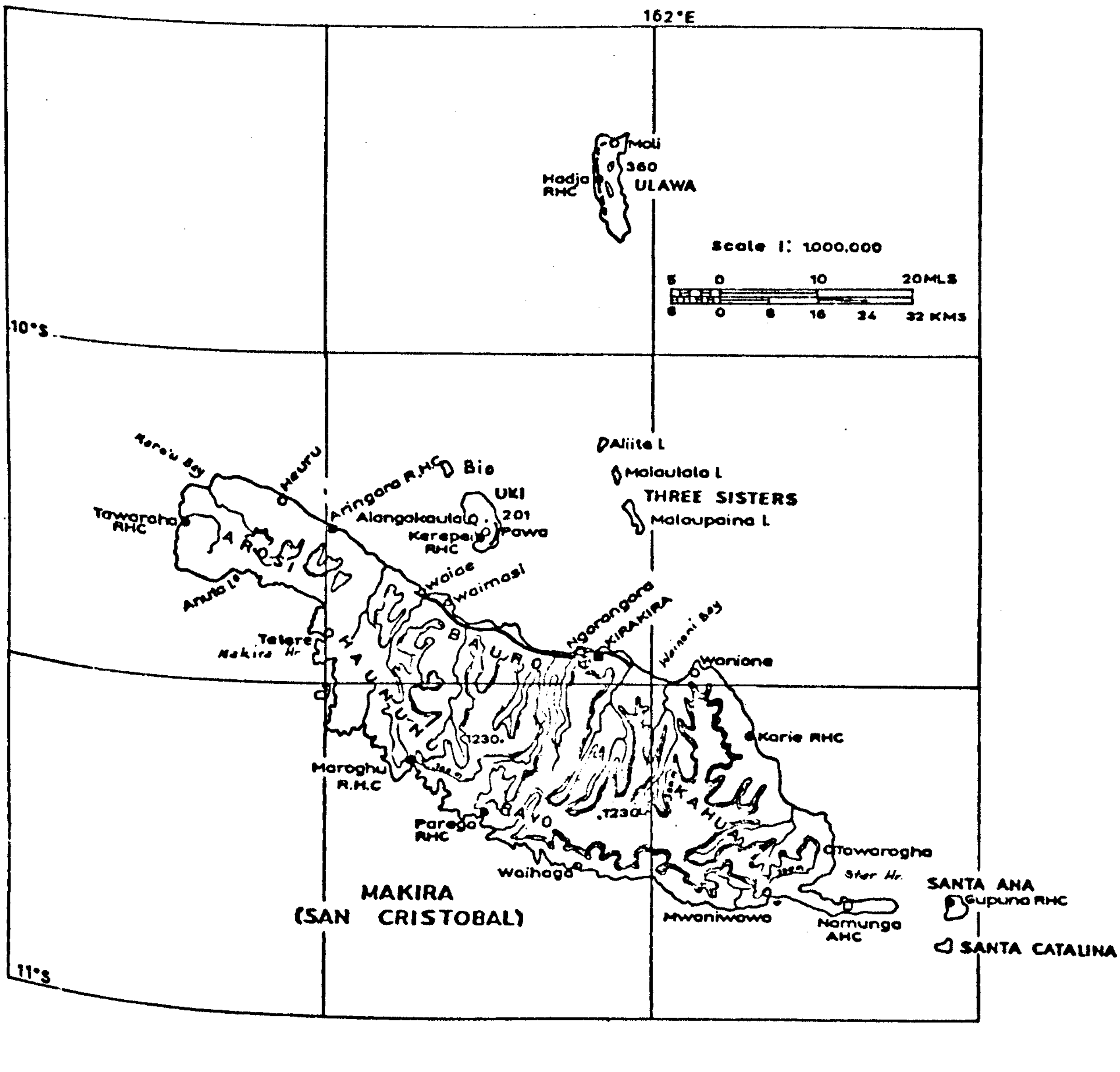
Island	Area in km^2	Population	Population Density per km^2
Makira	3370	9003	2.7
Santa Ana	13	756	58.2
Santa Catalina	5	345	69.0
Uki	42	817	19.5
Three Sisters *	(NA)	(60)	+
Ulawa	58	1469	25.3
Total:	3488	12390	3.6

Sources of Data

1. Lands Division of the Ministry of Agriculture and Rural Economy.
2. 1970 Census.

* Area and population data were included in with Makira in the 1970 Census.

Fig. 20. MAP OF MAKIRA & ULAWA, SOLOMON ISLANDS.



Makira (San Cristobal)

This impressive mountainous island is the third largest in the Solomon Islands. Several long, wide and swiftly flowing rivers join the sea on the north coast. Here sand bars allow a build up of water at the river mouth providing ideal breeding opportunities for anophelines. On the south coast rivers are similar but shorter. Numerous indentations into the rocky coast provide superb sheltered anchorages for coastal vessels.

The main centre for the Eastern Inner Islands is at Kirakira with its neighbouring airfield at Ngorangora. A good dirt road extends some 35 km (22 miles) to the west of Kirakira and 8 km (5 miles) to the east. This is often impassable due to flooding. A reasonably reliable weekly shipping service operates to Honiara in addition to fortnightly trips around Makira and to the remaining Eastern Inner and Outer Islands. Copra production is the main economic activity.

With the opening of a new Rural Hospital (32 beds) at Santa Cruz in the Outer Islands, the small District Hospital (64 beds) at Kirakira now serves mainly the Inner Islands. Six Rural Health Clinics are also placed strategically around Makira. It is proposed that Namunga in Star Harbour will act as an Area Health Centre with supervisory functions over the south eastern clinics. Kirakira will act as the second Area Health Centre in addition to its District Hospital functions.

Santa Ana and Santa Catalina

Twin low lying islands situated some 8 km (5 miles) off the Eastern tip of Makira. There is little running surface water but Santa Ana has two small lakes full of *Tilapia* fish. No climatological data is available, but rainfall is reported to be abundant. A permanent Rural Health Clinic is based at Gupana on Santa Ana.

Uki

A small hilly island 12 km (7 miles) to the north of Makira. It has very few streams but several coastal swampy areas. The Rural Health Clinic based at Kerepei is readily accessible to most of the inhabitants. Neighbouring Bio island is uninhabited.

Three Sisters

A group of three low lying islands with extensive offshore reefs and little surface water. The fluctuating population is mainly composed of men employed by Levers for running the copra plantations. The rainfall pattern is very similar to Ugi.

Ulawa

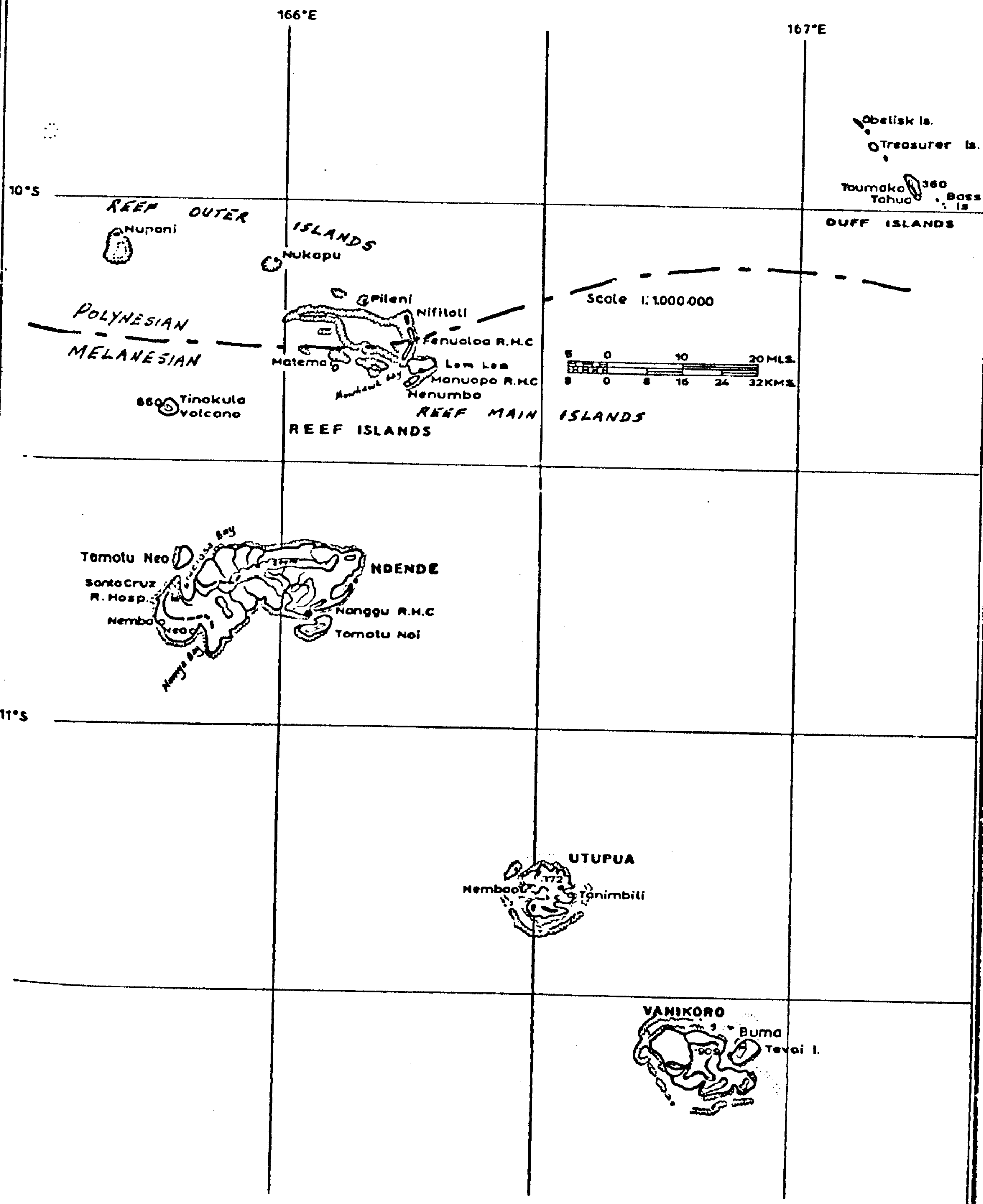
A rugged hilly island 70 km (43 miles) to the north of Makira. There are a few short, swiftly flowing streams and an area of mangrove swamps on the eastern side. No recorded climatological data exists, but rainfall is reported to be abundant. The permanent Rural Health Clinic is based at Hadja.

Eastern Solomons - Eastern Outer Islands

This distant group of islands, sometimes called the Santa Cruz Islands, is geographically more akin to the New Hebrides group than to the main Solomon Islands (Figure 2). The main island of Ndende is 380 km (236 miles) to the east of Makira.

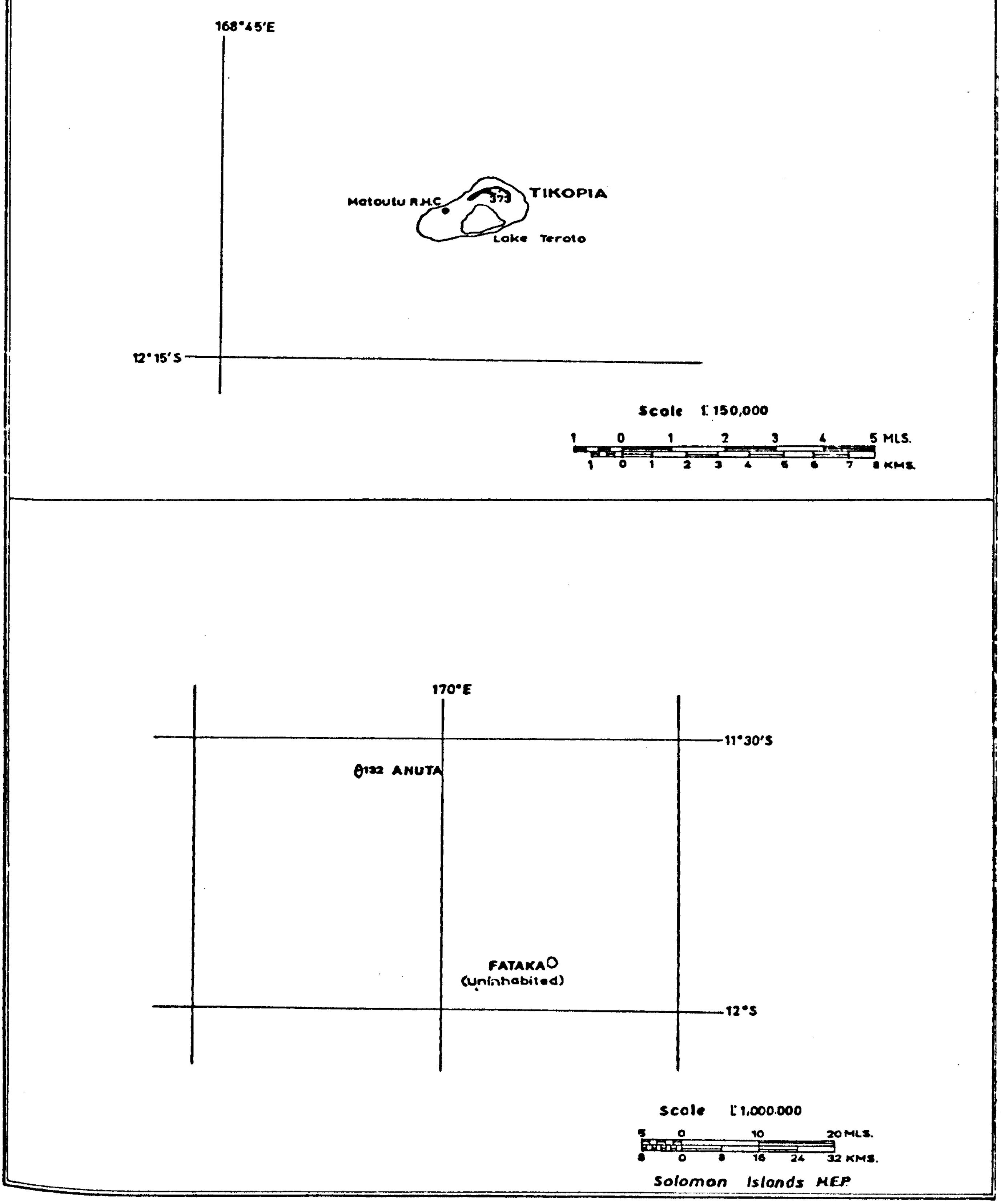
The inner group comprises Ndende and the raised coral atolls of the Reef Islands. The active volcano of Tinakula is also included in this group (Figure 21). The outer group of Utupua, Vanikoro,

Fig. 21. MAP OF SANTA CRUZ ISLANDS. SOLOMON ISLANDS



Solomon Islands M. E. P.

Fig.22. MAP OF TIKOPIA, ANUTA & FATAKA. SOLOMON ISLANDS.



Tikopia, Anuta, and Duff Islands spreads out in a wide arc to the east (Figures 21 and 22). The outermost inhabited island of Anuta situated 420 km (260 miles) from Ndende is equidistant between the capital Honiara and Fiji. The inhabitants of Ndende, Utupua, Vanikoro and the Reef Main Islands are predominantly Melanesian. Those of the Reef Outer Islands, Duff, Tikopia and Anuta are mainly Polynesian in culture. The traditional trading systems between Ndende and its immediate neighbours (Davenport 1964) have allowed some inter-marriage and mixing of cultures. In more modern times the Reef Islanders and the Tikopians in particular have migrated to many other parts of the Solomons.

The Eastern Outer Islands Council, based at the Santa Cruz government station on Ndende, serves all of the islands in the group. This nominally includes Tikopia and Anuta which have steadfastly maintained that their traditional chiefly system is adequate for their purposes.

The areas and population figures for these islands are shown in Table 10 and their topography is shown in Figures 21 and 22.

TABLE 10

Eastern Outer Islands. Areas, Population and Population Densities

Island	Area in km^2	Population	Population Density per km^2
Ndende	578	3433	5.9
Reefs. Main Island	15.3	2601	170.0
Reefs. Outer Islands	17.5	1239	70.8

continued -

Island	Area in km^2	Population	Population Density per km^2
Duff	10	213	21.3
Utupua	18	232	12.9
Vanikoro	42	163	3.9
Tikopia	5	1040	208
Anuta	1	157	157
Total:	686.8	9078	13.2

Sources of Data

1. Lands Division of the Ministry of Agriculture.
2. 1970 Census.

Ndende Island

A large rugged and mountainous island with extensive stands of kauri pine in the centre. To the west a raised coral plateau is separated from the mountains by the deeply incised Graciosa and Nemya Bays. There are two offshore islands Tomotu Neo and Tomotu Noi and also extensive lagoon and mangrove swamp areas around Nanggu. Several small streams and rivers on the north coast provide ideal breeding opportunities for anopheline mosquitoes but there is much less surface water on the coral plateau. One small road runs along the west side of Graciosa Bay, whilst another road reaches across to Nemya Bay. During 1973 the Allardyce Lumber Company set up a base and road system on the east side of Graciosa Bay with a view to extracting the valuable kauri timber. The 32 bedded Rural Hospital for the Eastern Outer Islands is at Graciosa Bay and there is also a Rural Health Clinic at Nanggu. Communications are maintained between Santa Cruz and Kira Kira and Honiara by weekly air flights and fortnightly shipping services. The Reef Islands are visited fortnightly by ship, whilst the remaining Outer Islands are usually visited monthly.

At the southern end of Graciosa Bay is the site of the first, and ill fated, attempt at European settlement in the Solomon Islands in 1595. This resulted in the death, probably from malaria, of the leader Alvaro de Mendaña (see Chapter 2).

Reef Main Islands

The group consists of several flat, low lying, raised coral atolls clustered around Mowhawk Bay. The largest of these is Lomlom (for profile see Figure 10). Villages are scattered along the seashore all round these islands.

Little surface water is to be found except for village wells and a few small streams near Nenumbo. A well established Rural Health Clinic at Manupo is within easy reach of the majority of the Reef Islanders.

Reef Outer Islands

These include all the small islands surrounding the Reef Main Islands. All are coral atolls or raised atolls except for Tinakula (Figure 7). This active volcano is at present uninhabited due to its unpredictability. In the past people from neighbouring islands spent long periods working gardens on the island on which there is no surface water.

The people of the northern atolls of Nupani, Nukapu and Pileni are renowned for their long inter-island trading voyages in 'te puke' outrigger canoes (Davenport ibid). All of these atolls have extensive and treacherous offshore reefs with difficult boat passages. They also have small brackish water lakes and inland swampy areas. Each has a variable population of between 60 and 80 inhabitants.

The remaining outer islands of Matema, Nimbanga Ndende, Nimbanga Temoa and Nifiloli are all raised atolls with 40-80 people on each. Fenualoa, which is also included in this group, had a population of 777 in the 1970 census. None of these islands has any surface water of note. The Reef Outer Islands are served by a Rural Health Clinic based on Fenualoa.

Duff Islands

A string of several extinct volcanic islands, of which only the largest Taumako is regularly inhabited. The largest village is on the artificial island of Tahua a mere two hundred metres off the coast of Taumako.

Rainfall is said to be abundant in spite of the absence of recorded climatological data. Although there is no surface water on Tahua,the neighbouring mainland has a large stream and several swampy areas ideal for anopheline breeding. A Village Health Aid is based on Tuhua. The Duff islanders were also participants in the traditional 'te puke' voyages.

Utupua

A solitary, rounded, extinct volcanic island with several deeply incised bays and extensive offshore reefs. The main village settlement overlooks an excellent and safe harbour at Nembao. Rainfall is reported to be abundant and there are numerous small streams and swampy areas. A Village Health Aid works from a small clinic at Nembao.

Vanikoro

A large, foreboding, extinct volcanic island, with a huge caldera on the east side. There are a number of swiftly flowing streams and extensive mangrove swamps and offshore reefs. The main settlement is at Buma where there is an anchorage and a Village Health Aid Post. Vanikoro once had valuable stands of kauri pine much of which was extracted by an Australian timber company between 1923 and 1965.

Tikopia

A very remote, extinct volcanic island some 350 km (215 miles) to the south east of Ndende. This is the most densely populated island in the Solomon Islands. During the 1950's there was a marked decline in the population due to famine, disease and migrations. Now many Tikopians live permanently in Honiara, or Makira or in the Russell Islands. In spite of many intrusions the Tikopians have steadfastly maintained several of the traditional customs described by Firth (1936).

There is no published climatological data, but rainfall is reported to be abundant and regular. A season of relatively dry weather occurs from June to August, but the large and attractive crater lake maintains regular supplies. All of the villages are on the south west side of the island, close to the permanent Rural Health Clinic at Matautu.

Anuta

A tiny and remote extinct volcanic island, the eastern most populated one of the Solomons group. Rainfall is reported to be reasonably abundant all the year round but there is very little surface water.

Malaita District

This district comprises the mainland of Malaita and the outlying islands of Ndai, Ontong Java and Sikaiana. The areas and population figures for these islands are shown in Table 11 and their topography is shown in Figures 23 and 24. One Council, based at Auki, covers the former administrative district.

TABLE 11

Malaita District. Areas, Population and Population Densities

Island	Area in km^2	Population	Population Density per km^2
Malaita Mainland	4047.5	50,659	12.5
Ndai *	NA	(60)	+
Ontong Java	5.0	873	174.6
Sikaiana	1.6	190	118.8
Total:	4054.1	51,722	12.7

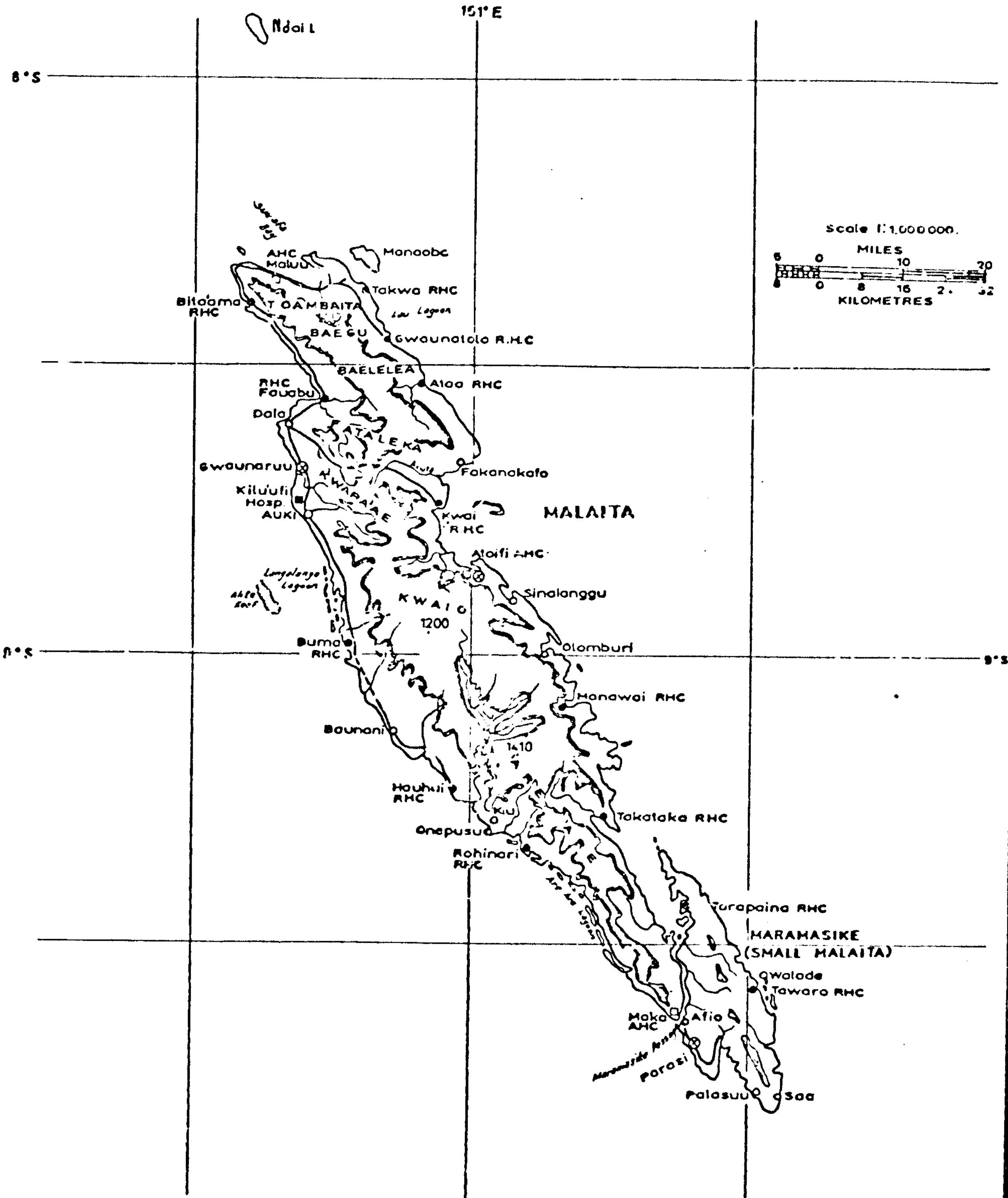
* The Ndai population was included in with the Malaita figures in the 1970 census.

Sources:
1. Lands Division of the Ministry of Agriculture and Rural Economy.
2. 1970 Census

Malaita Mainland

This is a rugged and mountainous island, the second largest in the Solomon Islands (Figures 6 and 23). The inhabitants are mainly Melanesian, living in coastal villages. More than half are concentrated in the northern third of the island. Some 7000 people live in small hamlets in the bush areas whilst another 4000 live on

Fig. 2.3. MAP OF MALAITA, SOLOMON ISLANDS



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the artificial islands of Lau and Langa Langa lagoons (Plate 6). Malaita people tend to migrate to other parts of the Solomons more than any other group.

The island has several large swiftly flowing rivers and numerous smaller ones. Tributaries, swampy areas, and streams blocked up by sand bars provide ideal anopheline breeding places throughout the island. Extensive mangrove swamps are to be found in many areas especially in the lagoons.

Many of the valleys and hill slopes have been over used in recent years for subsistence farming. In addition the extensive development of locally owned coconut plantations and cattle schemes has also brought pressure to bear on the land.

The main administrative centre is Auki. All weather airfields at Gwaunaruu near Auki, Parasi and Atoifi link with the rest of the Solomons. A good all weather road stretches north for 90 km (56 miles) from Auki to Gwaunatolo on the Lau lagoon. The southward section from Auki extends to Buma, but will soon link up with plantation roads to provide 60 km (37 miles) of road to Hauhui. A transinsular road covering the 30 km (19 miles) from Dala to Kwai is also expected to open in 1977. Amongst the small feeder roads is one in Small Malaita which is eventually expected to go all the way from Afio to Tawaro. Weekly or fortnightly shipping services call at most main centres round the island and there are regular twice weekly services to Honiara. There is also a service once every three months to the outer islands of Ndai, Ontong Java and Sikaiana.

The district hospital with 112 beds is based at Kiluufi near Auki. A rural hospital at Maluu (32 beds) and church hospitals at Fauabu

(130 beds) and Atoifi (91 beds) provide additional services. Fourteen Rural Health Clinics and several smaller clinics are placed strategically around the island. It is proposed to downgrade two of the hospitals to Area Health Centres and one to a Rural Health Clinic in the near future. It is also proposed to make the Maka Rural Health Clinic into an Area Health Centre.

Ndai Island

A low lying atoll some 50 km (31 miles) to the north of Malaita mainland (Figure 23). The only village is on the south west side and the people are entirely Melanesian. A large brackish water lake is regularly replenished by an abundant rainfall. There is no clinic on the island.

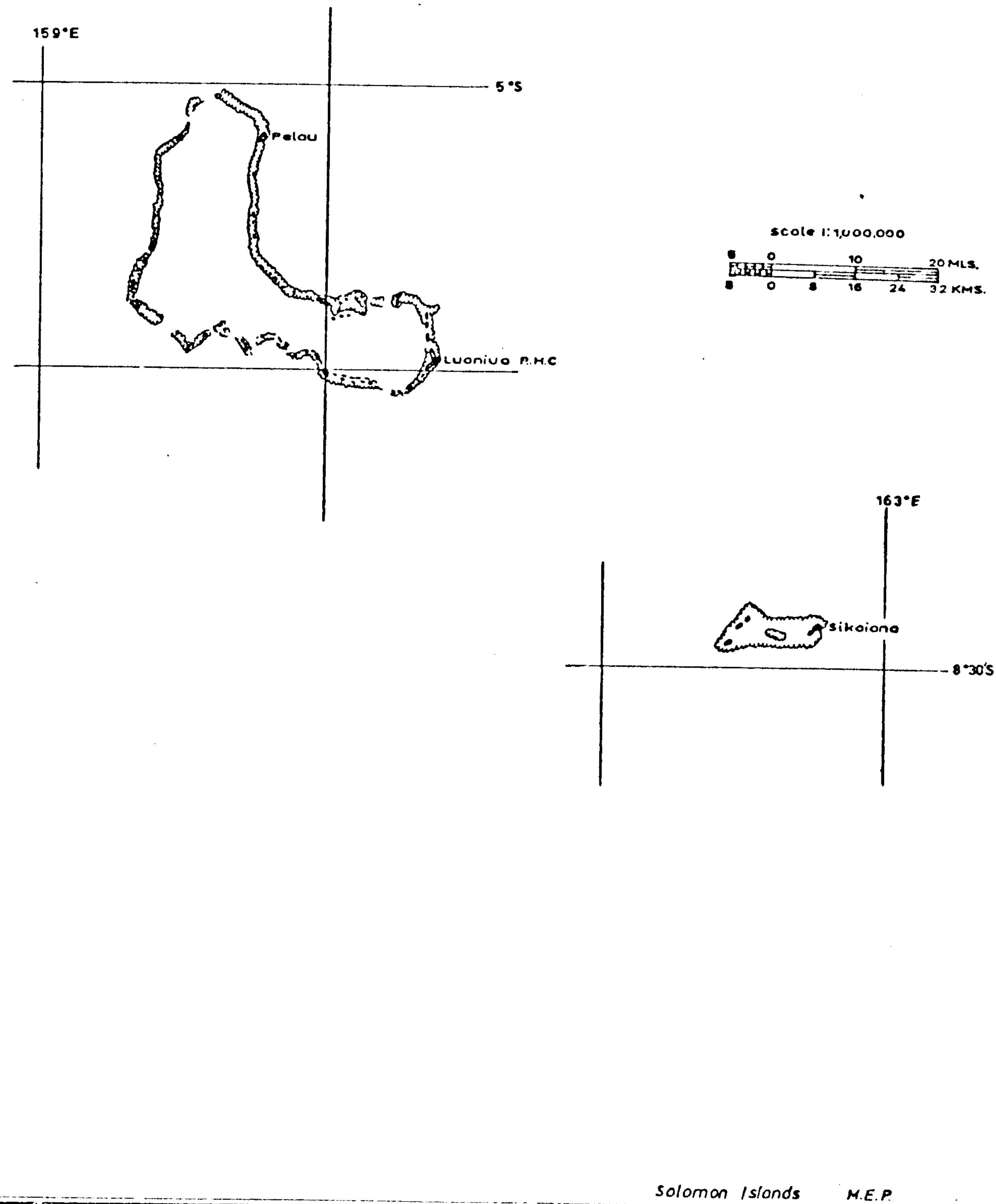
Ontong Java

A low lying extensive atoll some 320 km (200 miles) to the NNW of Malaita (Figure 24). Luaniua, the larger of the two settlements, is at the south east end. Although culturally Polynesian, many of the people have Micronesian physical features. Ontong Java suffered severe depopulation during the first half of the century falling from 5,500 in 1907 to 768 in 1954 (Hollins 1957). This was attributed to malaria and respiratory diseases introduced to a non immune population during missionary and trading expansion. The well established Rural Health Clinic at Luaniua has occasionally been augmented by a Village Health Aid Post at Pelau.

Sikaiana

A remote coral atoll 230 km (143 miles) to the east of Malaita mainland. A cross section of the island is shown in Figure 9 since this is a typical example of the coral atolls in the Solomon Islands.

Fig. 24. MAP OF ONTONG JAVA & SIKAIANA. SOLOMON IS.



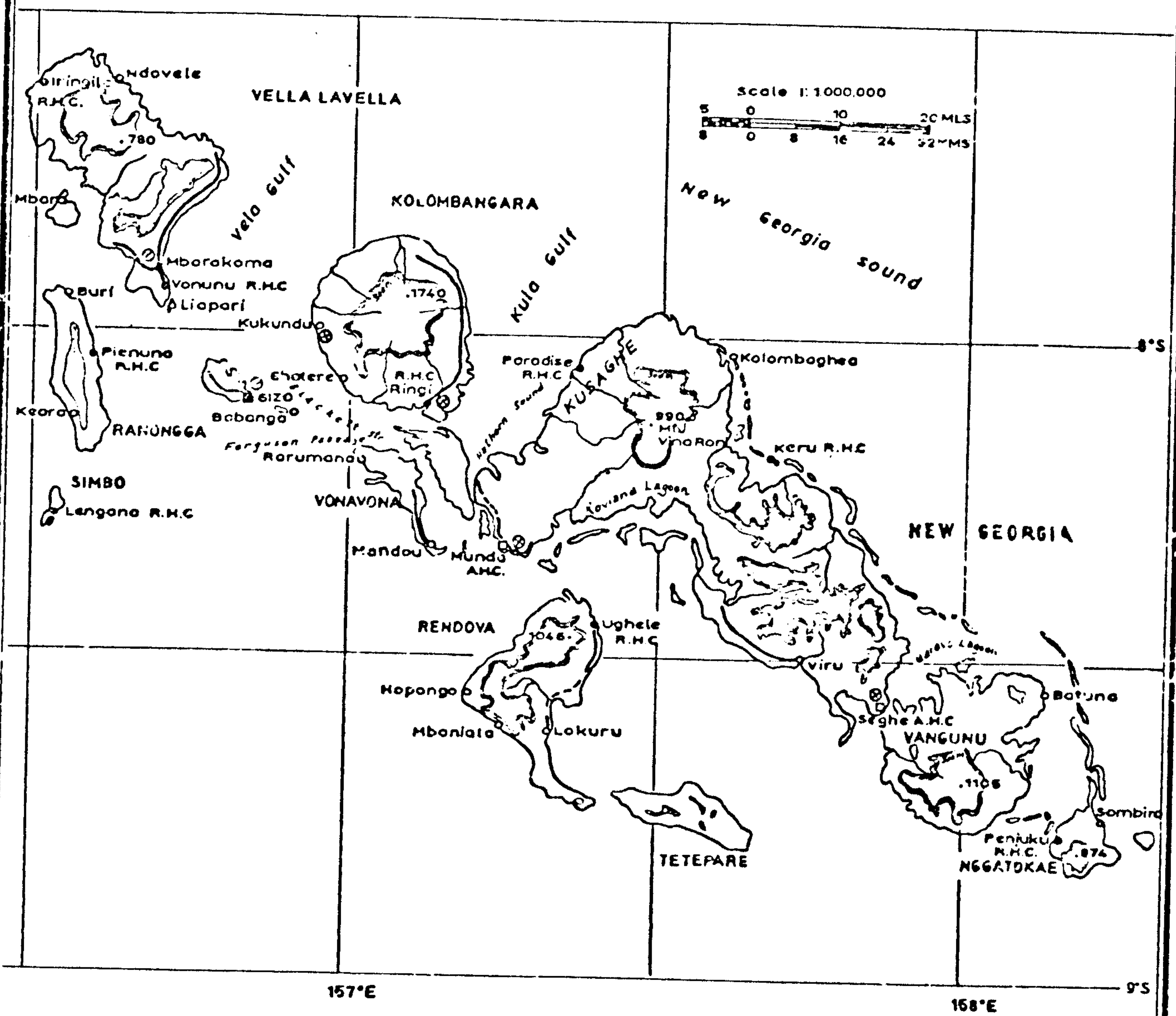
The entirely Polynesian population has shown marked fluctuation since the 1880's the highest recorded figure being the 340 counted by Lambert (1934). There is no climatological data but rain is reported to fall sporadically all the year round with occasional periods of drought. The small clinic is staffed by a Village Health Aid.

Western Solomons

This, the westernmost group in the Solomon Islands comprises the New Georgia Islands, the Shortland Islands, and Choiseul. The New Georgia Group consists of the mainland of New Georgia and the numerous nearby volcanic islands (Figure 25). The Shortland Islands group comprises Mono, Alu and Fauro, all very close to Bougainville in Papua Guinea (Figure 26). Choiseul also includes the separate island of Vaghena (Figure 27).

The areas and populations for these islands are shown in Table 12. The majority of the inhabitants are Melanesians, being differentiated from other parts of the Solomons by having a much darker skin colour. A more recent introduction into various parts of the Western Solomons has been the light skinned Micronesian Gilbertese relocated from the Gilbert and Ellice Islands in the mid 1950's and early 1960's. All of the Western Solomons are frequently visited by young men from Malaita and the Eastern Solomons looking for work. Often these men marry into Western families thereby acquiring local land for plantation development. Almost all of the villages in the Western Solomons are close to the seashore, except for a few scattered inland villages in Choiseul. The whole of the group comes under the care of the Western Council based at Gizo. This is also the site of the 46 bed Western District Hospital which is

Fig. 25. MAP OF NEW GEORGIA ISLANDS, SOLOMON ISLANDS.



Solomon Islands M.E.P.

the base hospital for the Western Solomons. It is also the Area Health Centre for the western islands of the New Georgia Group.

TABLE 12

Western Solomons. Areas, Population and Population Densities

Island	Area in km^2	Population	Population Density per km^2
New Georgia Group			
New Georgia	2240	5895	2.6
Vella Lavella	680.9	3792	5.6
Ranongga	148.9	2250	15.1
Simbo	13	950	73.1
Gizo	35.5	2235	63.0
Kolombangara	686	2323	3.4
Vonavona	181.0	1156	6.3
Rendova & Tetepare	531	1595	3.0
Vangunu	176.5	1304	7.4
Nggatokae	347	764	2.2
Shortlands Group			
Mono	75	309	4.1
Alu	243	1463	6.0
Fauro	96	178	1.9
Choiseul & Vaghena			
Choiseul	2972	7332	2.5
Vaghena	82	685	8.4
Total:	8507.8	32231	3.8

Sources of Data: 1. Lands Division of the Ministry and Rural Economy.
2. 1970 Census.

New Georgia Group -

New Georgia Mainland

This, the sixth largest island in the Solomon Islands, is set around two groups of extinct volcanoes. To the north there is the western part of the extensive Marovo Lagoon, whilst on the south side is the scenic Roviana lagoon. Both are full of treacherous reefs and are navigable only by canoes and small boats. The rivers, which are mostly only a few kilometres long, provide ideal anopheline breeding opportunities. Deep harbours provide good overseas ship anchorages at Viru and Hathorn Sound. Smaller inter island ships find haven at Munda and Seghe.

Communications are good with airfields at Munda and Seghe and embryo road systems around Munda. Weekly shipping services operate from Seghe, Viru and Munda to Gizo and Honiara, whilst less regular services ply around the island.

New Georgia is commercially more developed than any other island in the Solomons except Guadalcanal. Extensive locally owned plantations exist all around the island. These are encouraged particularly by the nativistic and enterprising Christian Fellowship Church led by their charismatic leader the 'Holy Mama' (Plate 7). Much of the south east side of the island has been stripped of the valuable hardwood timber by a Japanese owned Company operating from Viru. A newer venture with a fish canning and processing plant is currently being developed at a site on the Hathorn Sound. This will augment the recently established plant at Tulagi on Nggela to process all fish caught in the Solomons waters by the Solomon Taiyo Company.

Plate 7. The 'Holy Mama'.

At the main centre of Munda there is a small government sub-station and also a 52 bed hospital run by the United Church (formerly Methodist Church). It is proposed that this hospital will act as the Area Health Centre for Western New Georgia and the neighbouring islands. The eastern part of New Georgia will be served by the Seghe Area Health Centre. Additional Rural Health Centres are at Paradise and Keru.

Vella Lavella -

This hilly island is the most westerly of the New Georgia Group. An offshore reef on the north east side provides some shelter for lagoon navigation. Rivers are short usually ending in a depressed swampy area.

An airfield at Mbarakoma links the island twice weekly with Gizo, whilst a dirt road extending the whole length of the east coast provides a means of collecting copra. Rural Health Clinics at Vonunu and Iringila are accessible to the majority of the population. The exception is the Ndovele area which is served by a Seventh Day Adventist (S.D.A.) Church clinic.

Ranongga -

A long island with a range of low mountains running almost due north and south. The western side is precipitous but on the east there are many small streams and swamps. The greater bulk of the population is concentrated on the north east coast where there are three good harbours. There is no recorded rainfall data but the pattern is presumed to be midway between Vella Lavella and Simbo (q.v. Figure 13). The Rural Health Clinic is at Pienuna.

Simbo -

Standing sentinel like at the tip of Ranongga, this island was a landfall for ships bound from Sydney to China in the days of sail. Apart from the crater lakes and hot springs, very few regular stands of surface water exist. The island is the most densely populated in the Western Solomons and most villages are close to the wharf in the lagoon on the western side. A Rural Health Clinic at Lengana is within easy access of the whole island.

Gizo -

Centrally placed and much less hilly than the other islands, Gizo Island is the administrative and trading centre for the Western Solomons.

In spite of being bounded by reefs, Gizo Harbour is an excellent anchorage for overseas ships collecting copra. It is also the terminus for many inter-island steamers. The airfield at Nusatupe island two kilometres (1.2 miles) from Gizo has daily flights to Munda and Honiara. Little surface water is to be found except in a few swamps and rivulets on the south side. The town of Gizo with a population of about 1000 is on a small coastal strip on the eastern extremity of the island. Many of the villages are close to the swampy areas including those occupied by the recently resettled Gilbertese.

Kolombangara -

This distinctive island is a superb example of a blown out volcanic cone with a massive caldera in the centre. Numerous streams radiate out from the centre to end up sluggishly in swampy areas near the sea. Villages are concentrated mostly on the south side to the west of the large Lever Company timber camp at Ringi Cove. Communications are good with airfields at Ringi and Kukundu as well as several anchorages facing on to Blackett Strait. The Rural Health Clinic at Ringi serves surrounding villages although the west side of the island is mainly covered by the Seventh Day Adventist clinic at Kukundu.

Vona Vona -

This area is different from the remainder of the group. The Vona Vona is usually taken to consist of the Vona Vona Lagoon with its myriad of small islets bounded on the west by Vona Vona Island and on the east by Arundel Island. All of the islands are flat, low lying and virtually waterless yet several support quite large villages. There is no rainfall data for the Vona Vona, but it probably experiences falls similar to neighbouring Munda. A feeder road which runs north from Mandou will extend eventually to Rarumana. The nearest clinics are at Gizo, Ringi and Munda.

Rendova and Tetepare -

It was from their mountain hideouts in Rendova that the coast-watchers in World War II so successfully kept an eye on Japanese strategic movements (Horton 1970). This mountainous island has numerous small streams offering good anopheline breeding opportunities. The only good anchorages are on the north coast near the coconut and cocoa plantations.

As an aid to development a feeder road is now being built south from Ughele to Lokuru to serve the majority of the population. The

Rural Health Clinic at Ughele covers this area reasonably well but is too far, with present communications, from the two large villages on the south east coast.

Tetepare is uninhabited except for a small plantation at the western end. Most records for this island are included with Rendova.

Vangunu -

Separated from the mainland of New Georgia by a narrow passage of the Marovo Lagoon the island is completely surrounded by reefs or other islands. All round this island there are small streams and swampy areas providing good opportunities for anopheline breeding. No recorded rainfall data is available, but the island is assumed to have a moderate fall similar to neighbouring Viru. Sparsely populated except on the north east side, the island has extensive tracts of timber. Good coconut plantations also exist on the north and south coasts.

Vangunu is covered by the Seghe Area Health Centre on New Georgia and by the Penjuku Rural Health Clinic on neighbouring Nggatokae. A long established Seventh Day Adventist clinic at Batuna also covers much of the populous north east coast.

Nggatokae -

The eastern most island of the New Georgia Group, this island has a very exposed southerly coastline. The north side faces the shallow and only partly navigable Marovo Lagoon. Streams are mostly fast flowing except around Penjuku where anopheline breeding is easy. The Rural Health Clinic at this village is not easily accessible to the villages on the south and east coast due to the difficulty of the terrain.

Most of the records for Vona Vona, Vangunu and Nggatokae are included in with the New Georgia Mainland.

The Shortland Islands Group

Mono (Treasury)Island -

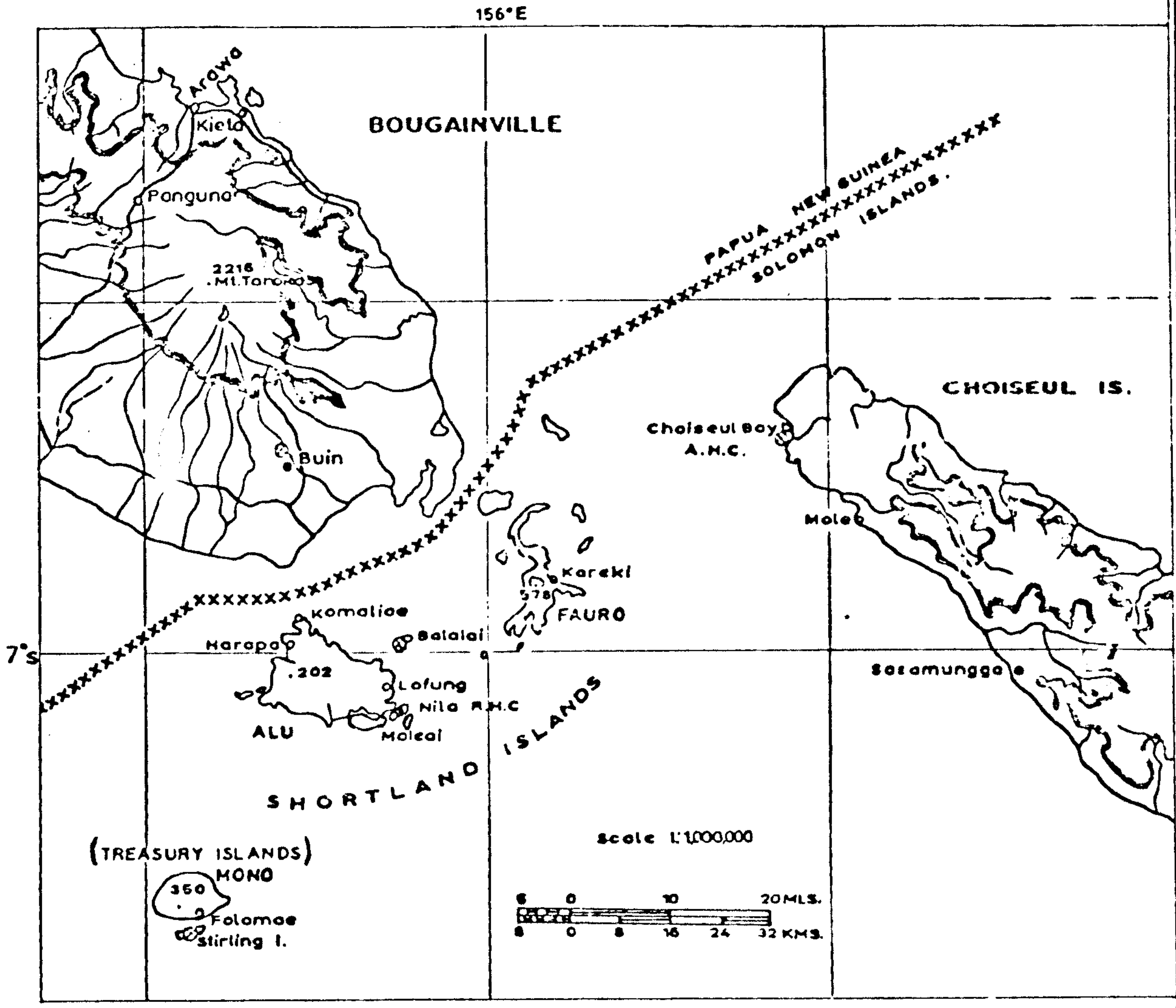
Lying some 30 km (19 miles) to the south west of Alu, hilly Mono has a genuine claim to being the legendary Bali Ha'ai of "South Pacific" fame (Michener 1947). The only settlement overlooks the natural harbour at Falamae. On the adjacent flat island of Stirling, the old World War II airfield has been maintained in reasonable condition. No climatological data is available and most streams are small and fast flowing. The people of Mono have a strong cultural association with Alu and with the Siwai of Bougainville.

Alu (Shortland) Island -

The main island of the Shortland group (Figure 26) is low lying with little surface water but with good stands of commercial timber in the centre. The coastal strips and several of the neighbouring islands support good coconut plantations. Earthquakes are more frequent in Alu than in any other part of the Solomon Islands.

The most densely populated part of Alu is on the shores of the boat passages around Nila. At Lofung there is a disused Japanese lumber camp, whilst the transmigrated Gilbertese are to be found settled mainly on the north west coast. This group makes frequent trips, not only to the easily accessible Bougainville, but also to their relatives throughout the Western Solomons and in Honiara. The indigenous Shortland Islanders are equally mobile with their frequent

Fig. 26. MAP OF SHORTLANDS ISLANDS, SOLOMON ISLANDS



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visits to relatives in Siwai on Bougainville.

A well equipped clinic run by the Roman Catholic Church at Nila serves the whole of the Shortland Group. The more remote areas at Harapa and also at Falamae in Mono and Kareki in Fauro have smaller Village Health Aid Posts. A police and customs station near Nila attempts to control and monitor the migrations to and from Bougainville. Weekly flights to Gizo and Honiara terminate at Balalai airfield 12 km (7 miles) by sea from Nila.

Fauro -

A hilly and sparsely populated island to the north east of Alu. No climatological data is available, but good anopheline breeding streams are situated near two of the three villages. The several good anchorages are seldom used though good stands of coconut are to be found.

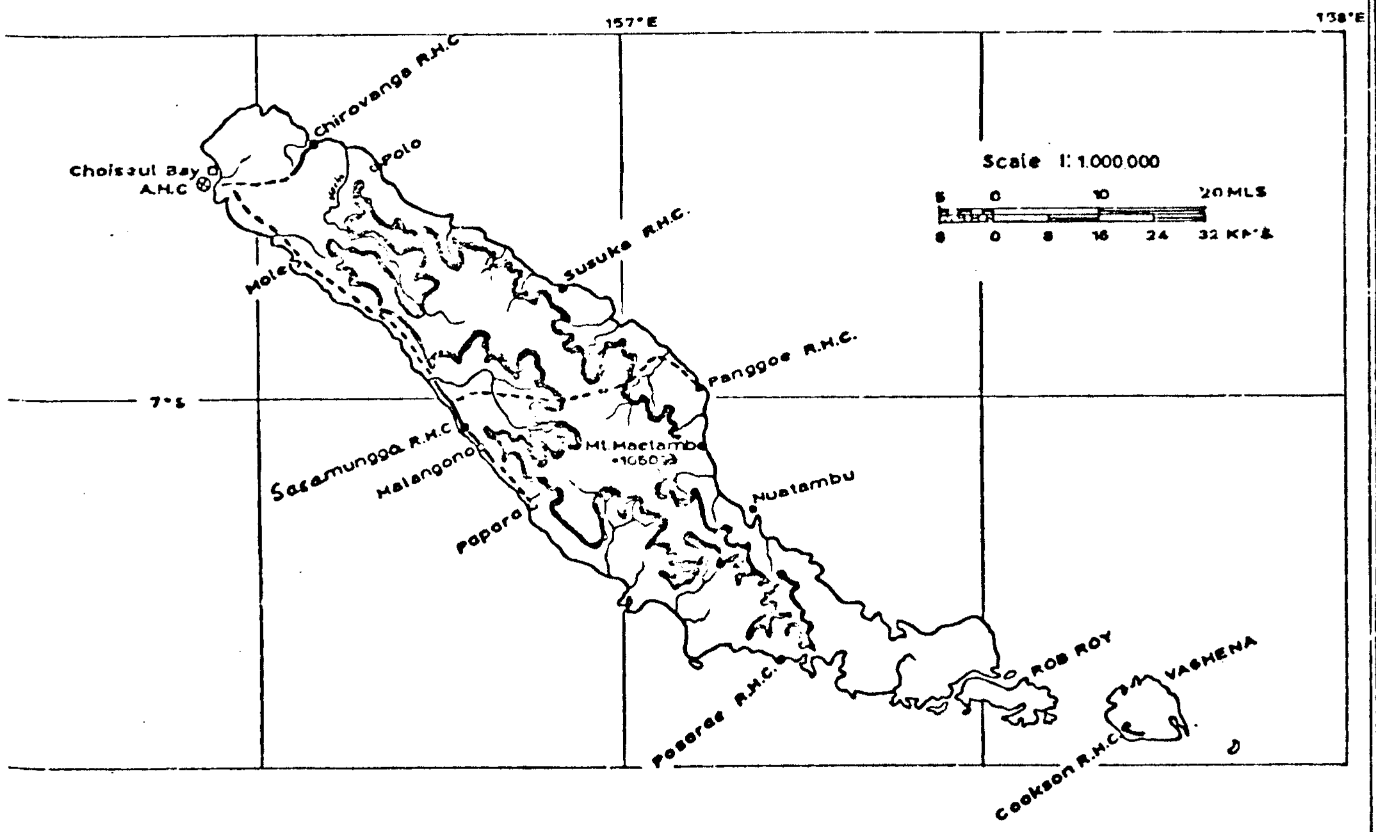
Choiseul and Vaghena

Choiseul -

This rugged and attractive island is the fifth largest in the Solomon Islands (Figure 27). Treacherous offshore reefs all along the coast frequently prevent access to the few good harbours and anchorages. The longest of several large rivers, the Vacho, discharges on the north east coast. Many of the smaller tributary streams on the island provide abundant scope for anopheline breeding.

Further development of the existing coconut plantations on Choiseul has been encouraged by the setting up of a Government sub district station and airfield on an island in Choiseul Bay. Feeder roads are also being developed from Sasamungga and Chirovanga to

Fig. 27. MAP OF CHOISEUL ISLAND, SOLOMON ISLANDS.



Solomon Islands M.E.P.

stimulate the cattle industry. An Area Health Centre is being developed at Choiseul Bay, whilst five Rural Health Clinics provide additional coverage in depth around the island.

Vaghena -

This swampy low lying island at the eastern extremity of Choiseul was once inhabited by Choiseulese.

In 1956 a small party of migrants from the overpopulated Phoenix Islands in the non malarious Gilbert and Ellice Islands was resettled in Vaghena. Soon more people came and the population rapidly expanded. Now the three large Gilbertese settlements are all on the south coast with ready access to coconut plantations, swamp taro beds and marine fauna. No climatological data is available but several small streams and the widespread cultivation of swamp taro provide easy anopheline breeding opportunities.

The valuable bauxite deposits,discovered on the island within the last few years,will certainly result in major social changes on Vaghena should mining ever start.

CHAPTER 4

MALARIA IN PERSPECTIVE

4.1 The extent of the malaria problem

The longstanding presence of malaria in many of the islands has been amply demonstrated in the historical record described in Chapter 2.. In Chapter 3 it has been further shown that the geographical environment is highly favourable to the transmission of malaria throughout many islands of the Solomons. Chapter 7 will outline the detailed results but, in the meantime, a brief review will be made of the overall malaria problem in the Solomon Islands.

Apart from the published hospital records (Chapter 2) perusal of the clinic records prior to anti-malaria operations showed a recording of 'fever' or 'malaria' for around 10-20% of all consultations. These cases were routinely treated with chloroquine and the majority quickly recovered. Most Rural Health Clinic staff readily recall the many cases of babies and young children who died from feverish illness. This regular experience dramatically changed following the introduction of DDT spraying thus providing good circumstantial evidence that these fever cases were indeed due to malaria.

When the results of all of the entomological surveys came to be analysed it was found that the major vector *Anopheles farauti* was widely distributed in coastal and riverine areas throughout many of the islands (see Chapter 7). The subsidiary vectors *A.koliensis* and *A.punctulatus* were found mostly on the larger islands. The malariometric surveys soon showed an equally heavy distribution of malaria in conjunction with the anophelines. Overall, most of the islands were classified as mesoendemic according to the Kampala classification (WHO 1951). Had the surveys been more extensive it is probable that more than a mere handful would have been classified in the hyperendemic range (Figure 28). There was even sufficient evidence on the northern coasts of Guadalcanal and Nggela to classify at least parts of these islands as holoendemic. At the other end of the scale a small number of islands had few vectors and little if any, malaria. These islands, along with some of the remote high bush areas of Malaita, were classified as hypoendemic. Bush areas elsewhere, like Guadalcanal and Makira, had quite high endemicities probably because of the frequent visits of their inhabitants to coastal villages.

Whilst subsequent surveillance returns found strong evidence of seasonal variations in malaria transmission on Guadalcanal and New Georgia the two pre-spraying incidence surveys proved inconclusive. These surveys, described in Chapter 7, were carried out for at least a year pre-spraying in Auki, Malaita and Kirkira, Makira. They gave some indication of a reduction in intensity of transmission during dry spells but the seasonal variation in rainfall is not as great at these localities as it is in North Guadalcanal (see Chapter 3).

Prior to eradication operations then, malaria was present on nearly all of the islands of the Solomons. In some areas this was of sufficient all the year round intensity to affect just about the whole population.

4.2 Malaria in relation to other diseases

Whilst there is no doubt about the prime influence of malaria on

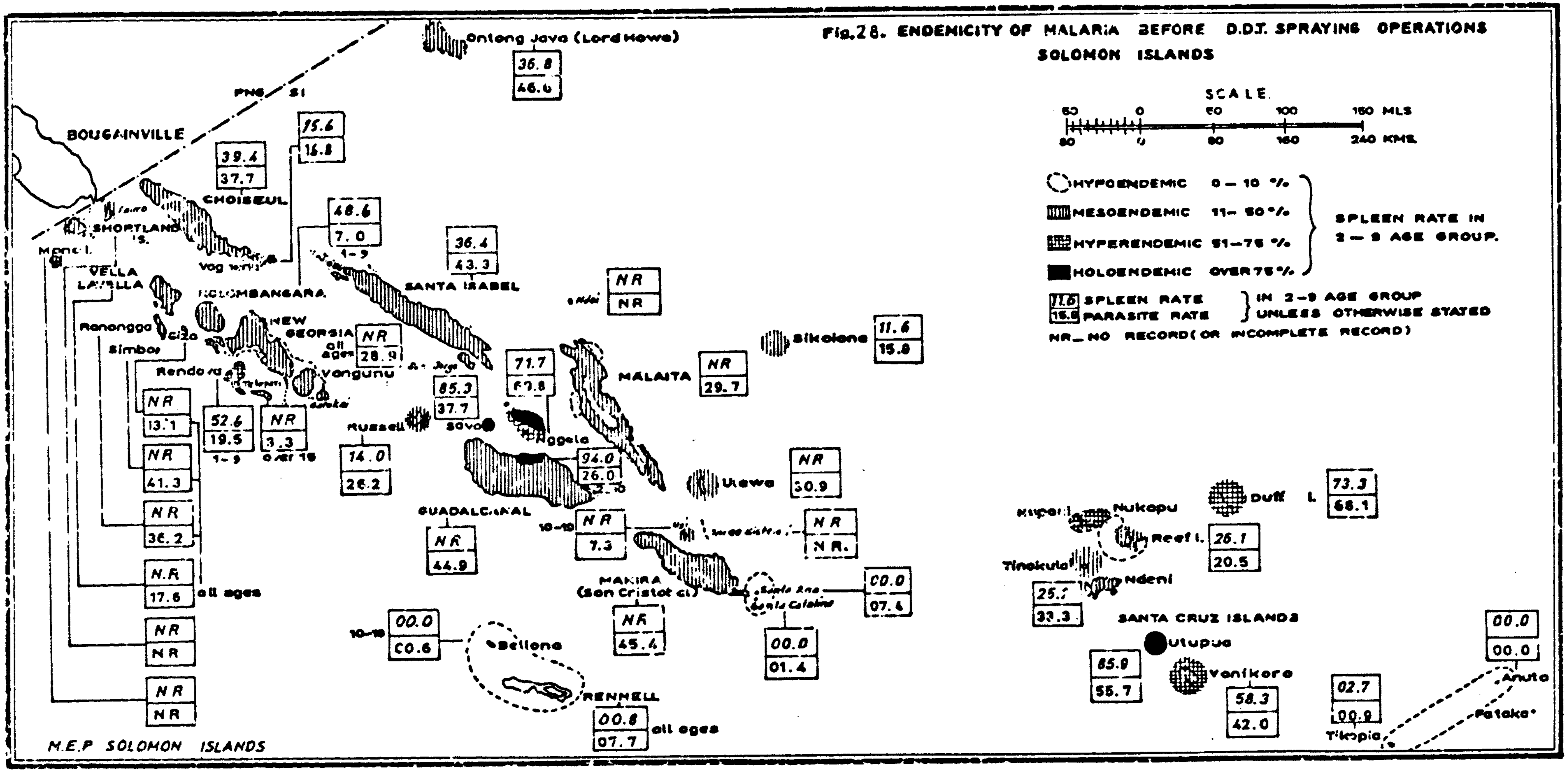


Fig. 28. ENDEMICITY OF MALARIA BEFORE D.D.T. SPRAYING OPERATIONS SOLOMON ISLANDS

the health of the people of the Solomons several other diseases have also taken their toll over the years. Perusal of clinic records show respiratory diseases like bronchitis and pneumonia to be high on the list of diagnoses. Apart from cuts, ulcers and sores, another common complaint is 'bakua' or ringworm.

When analyses of hospital records are made respiratory diseases appear second on the list, but accidents are the biggest diagnostic group. In 1972, for example (the last year for which detailed records are available), accidents accounted for 1505 (16.8%) of the 8948 non-obstetric discharges and deaths (BSIP 1972). Respiratory diseases accounted for 1166 (13.0%) and tuberculosis 973 cases (10.9%). When bed occupancy figures were calculated tuberculosis was found to account for 25.7% of beds, leprosy 8.6% and accidents 7.4% (the three leading bed occupiers). Tuberculosis accounted for 24.9% of all hospital deaths and respiratory diseases 16.2%. Only 2.5% of the deaths were due to accidents. The importance of respiratory disease in the community cannot be overemphasised although it is likely that much of it never presents for any kind of conventional medical treatment. Increasing urbanisation is now resulting in an alarming increase in road traffic, football and assault injuries.

A number of other diseases occur sporadically, but the islands are mercifully free from many of the parasitic diseases found in other parts of the tropics. Amongst the worm infestations Ascaris (round worm), Enterobius (thread worm) and Ancylostoma (hook worm) are common. Most of the other worms are rarely found as disease entities and seldom diagnosed in the laboratory. Scrub typhus has occurred sporadically in the Shortland islands and in

Ndendein the Eastern Outer Islands. Amoebiasis is very occasionally seen but some bacterial diseases are on the increase. The most notable is the big increase in gonorrhoea following commercial expansion. Venereal diseases, including syphilis, were present on some of the islands in the 1930's, but the 1950's and 1960's were reputedly free from all sexually transmitted diseases. Bacterial meningitis also presents quite regularly in hospital but the tuberculous form of this often fatal disease is now on the decline. Several cases of tetanus are still seen every year in spite of continuous efforts to achieve good immunisation coverage. Amongst other diseases preventable by immunisation, whooping cough and diphtheria are almost unknown. They are reported to have occurred in epidemic form in past years.

Epidemics of influenza regularly pass through the islands often taking a high toll in the elderly (1% of the population was reported to have died on Malaita in the 1973 epidemic). Measles also passes in waves every two to three years affecting the majority of non immune children. Severe complications and deaths seldom occur probably because of the overall good state of nutrition of the children. No evidence can be found of any epidemics of smallpox at least since the 1930's. Rubella and scarlet fever also appear to be unusual but it may well be that apparently minor exanthematous diseases have passed unknown in the past. Polio, on the other hand, has more than made its mark with numerous deaths and deformities following the several epidemics. The last major one (in 1951) resulted in paralytic lesions in at least 3% of the population (Cross 1975). A good coverage of most of the children with polio vaccine now ensures that severe epidemics of this crippling disease are less likely in the future.

Another serious disease, dengue fever (with its Pacific version of haemorrhagic fever) has also occurred in the past. It threatened again during the major Pacific epidemics of 1972-74 but did not get into the Solomons in spite of affecting all neighbouring territories. The only other viral disease of note is Viral Hepatitis of which the acute infective hepatitis form is the one most commonly seen. Viral meningitis is also seen on rare occasions.

A number of other important communicable diseases have had a considerable effect on the people. These include:-

Filariasis

Malaria and filariasis share as common vectors the Anopheles punctulatus group. The only form of filariasis in the Solomon Islands is that caused by the nocturnally periodic Wuchereria bancroftii. This was found to be focally distributed on several of the islands. All known surveys up to 1972 were summarised by Webber (1973) and are shown in Table 13. Later surveys are covered in Chapter 7.4.

No pre-spraying data was available from the Western Solomons and Santa Isabel, whilst the large islands of Guadalcanal, Malaita and Makira were all found to have high microfilaria and elephantiasis rates. Smaller islands like Nggela and Savo, along with several of the Eastern islands, were found to have high rates. Most Polynesian Outer Islands were relatively free from the disease. A surprising finding was the 5.2% microfilaria rate of non malarious Bellona in 1972. This was possibly due to an alternative vector or to acquisition

TABLE 13

Summary results of major filariasis surveys, Solomon Islands 1929-72

Island	Surveyor and date	Number Examined	Number Positive	Percentage Positive	Percentage with Elephantiasis
Central Solomons					
Guadalcanal	Various *	3035	762	25.1	1.02
	Mataika 1965	502	94	18.7	N.S.
Savo	Crichlow 1929	N.S.	N.S.	25.0	N.S.
	Vincent 1943	147 (By Day)	3	2.0	N.S.
Nggela	Mataika 1965	266	107	40.2	3.4
Bellona	Black 1952	230	0	0.0	
	Eyres 1972	251	13	5.2	
Eastern Solomons					
Makira	Various *	2654	662	25.0	1.02
Infected Eastern Islands (excluding Makira)	Various *	1624	227	14.0	1.9
Graciosa Bay	McDonnell 1970	N.S.	N.S.	9.5	N.S.
Malaita District					
Malaita	Various *	1260	126	10.0	0.8
Ontong Java	Black 1952	35 (By Day)	2	5.7	0.26
Sikaiana	Lambert 1933	49	1	2.0	-
	Black 1952	24	1	4.2	0.7

* Data from these islands is a summary of all known surveys over the period 1943-70. This has excluded data from daytime and adult male only collections, and those possibly affected by control.

Note: N.S. = Not Stated.

Source: Webber (1973)

of the disease on the mainland of Guadalcanal.

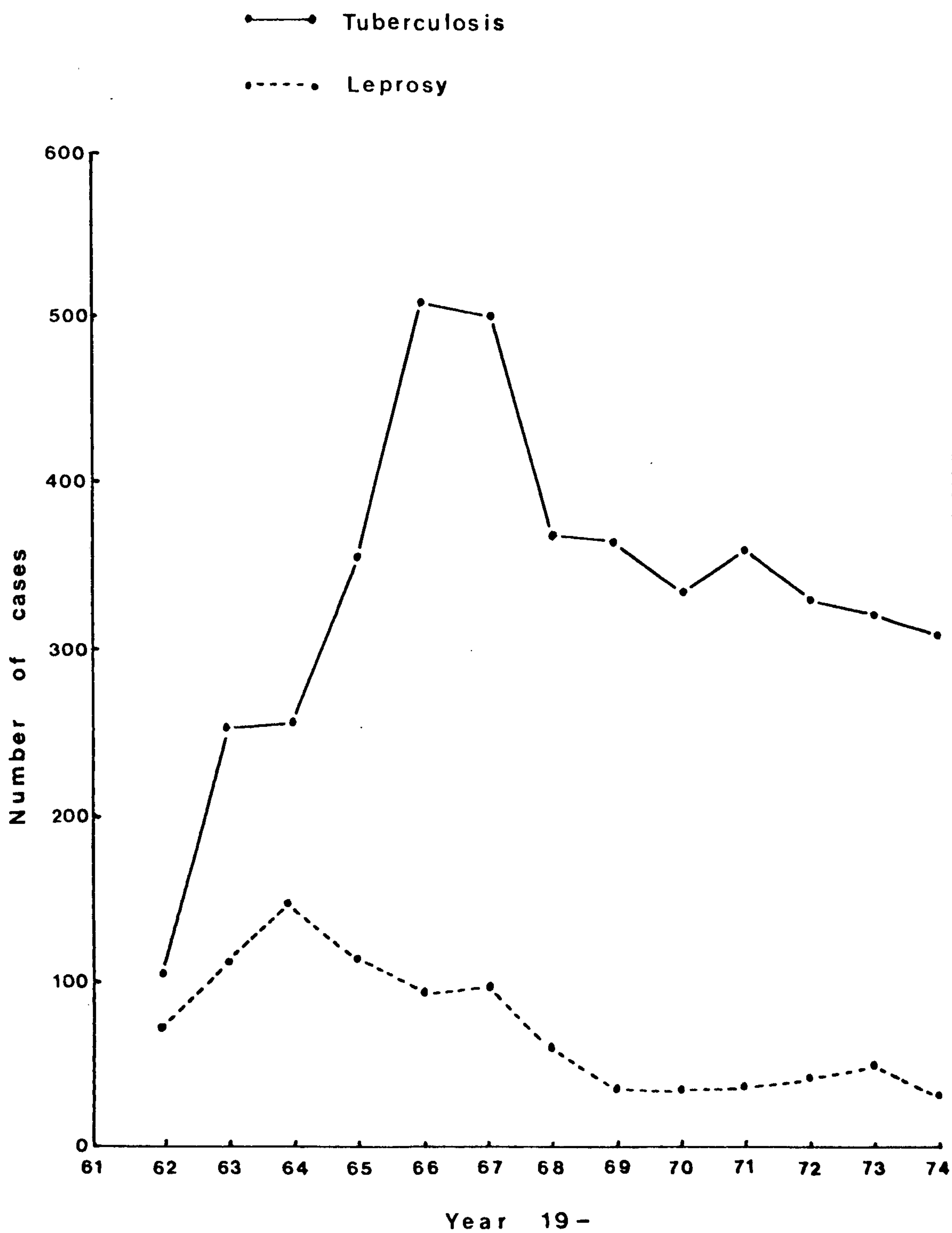
The presence of parasitaemia does not necessarily mean debility, but it is probable that many of the infected people are subjected to recurrent fevers and leg and chest pains due to filariasis. The final presentation of elephatiasis is but a small measure of the total morbidity.

Tuberculosis

Tuberculosis has long been regarded as the second most serious health problem in the Solomon Islands following malaria. For several years following the setting up of the register in 1961 the number of new notifications continued to rise (Figure 29). The turn of the tide was seen in 1966 when the effects of improved detection, treatment and contact tracing began to take effect. Some credit must also be given to the extensive whole population BCG campaign which started in the Eastern and Western Solomons in 1956 and later extended to the Central Solomons and Malaita.

The majority of tuberculosis cases are now hospitalised and stabilised for only 2-3 months. Following this domiciliary treatment is carried out by rural nursing staff. The disease is under good control in the Western Solomons but is still a serious problem elsewhere especially on Malaita. The BCG vaccination of newborn, improved case detection and follow up and improved rural health services may help the disease to come under good control within the next ten years. It is particularly noticeable that tuberculosis is rare in the Shortland Islands and Santa Isabel where most of the houses are large, light and airy.

Fig. 29. New Tuberculosis & Leprosy cases, Solomon Islands. 1962-74.



Source. S.I. Annual Reports

Leprosy

The importance of leprosy in the Solomon Islands was first outlined in detail by Innes (1938) who found an overall prevalence of 1.02% in 21,612 persons examined. For many years cases were treated at Fauabu hospital on Malaita and at Tetere on Guadalcanal. Soon after the setting up of a register in 1962 the totals of new cases began to decline (Figure 29). A small rise in new cases was then noted during 1972-73 after extensive field surveys by the W.H.O. Leprologist Dr. Lopez-Bravo. The surveys confirmed a total of 715 cases (505 tuberculoid), giving an overall prevalence rate of 0.4% in the Solomon Islands. The prevalence rate for the 38 new cases found in 17332 people examined was 0.2% (Data from report by Lopez-Bravo in Ministry of Health and Welfare, Solomon Islands).

The majority of active leprosy cases are under treatment with D.D.S. and a liberal domiciliary treatment is followed when supervision by rural health nursing staff can be guaranteed. A few cases still default and some others still escape detection until serious complications have developed. Two full time leprosy field workers are now active in Guadalcanal and Malaita searching out the final residue of cases. Rural staff are also active in Makira, the other main focus of leprosy. A decline has recently been seen in the notification of tuberculoid cases probably as a result of the widespread use of BCG vaccination. There are good prospects that this serious and debilitating disease can be brought under control within the next ten years.

Yaws

The early annual reports gave ample evidence that yaws was a widespread and serious problem in the Solomons up to the 1950's. In 1956 island wide surveys found 14.7% of the population to have active yaws (BSIP 1957). During 1956-59 a very successful eradication programme was carried out with the assistance of W.H.O. and U.N.I.C.E.F. This was the first successful disease control/eradication programme in the islands and was taken as a good augury for the future. Occasional residual active cases were seen during the early 1960's but, by the mid 1960's, it was clear that the total population exposure to long acting penicillin had been completely successful.

All health staff have instructions to keep a careful look out to prevent recurrence of this disfiguring disease.

Hookworm

Efforts were made by Lambert (1934) to eradicate hookworm from the Solomon Islands during the 1920's and 1930's. This was part of a Pan Pacific Campaign sponsored by the Rockefeller Foundation. It was probably successful as a temporary alleviation of this gut worm but it is also probable that a high proportion of the population soon became infected again. No serious efforts have been made to control the disease in recent years and it is generally considered to cause no serious problems unless other debilities are already present.

Trachoma

This blinding eye disease is common on certain islands. It is particularly prevalent on the artificial islands of Malaita where poor hygiene and dusty conditions are contributory. Whilst entropion and trichiasis are quite commonly seen the final complication of blindness is fortunately quite rare.

Other diseases

In common with most developing countries the communicable diseases still account for a major proportion of the morbidity and mortality. Nevertheless, some other diseases do merit attention. Mouth cancers, associated with the chewing of betel nut, are seen quite frequently. Most other cancers are rare. Burkitt's lymphoma and bone sarcomas appear from time to time but lung cancer is rare due to the low number of people smoking manufactured cigarettes. Bowel cancer is also rare probably because of the high fibre diet and lack of food contaminants.

The first recorded case of coronary heart disease occurred only a few years ago. Changing trends in heart disease were observed in the long term studies of the Harvard Solomon Islands Project (Page, Damon and Moellering, Jr. 1974). These surveys were made in the late 1960's in six cultural groups selected from Malaita in the Solomon Islands and from Bougainville in Papua New Guinea. No clinical evidence of coronary heart disease or atherosclerosis was found. However, serum cholesterol levels were higher in the three more acculturated groups (including the Lau of Malaita) than in the three less acculurated groups (including the Baegu and Kwaio of Malaita). The systolic blood pressure increased significantly with age in the women of the more acculturated groups. Analysis of electrocardiograms showed a lower frequency of abnormality than in any population previously recorded. Nevertheless, it was suggested that the small biologic differences between the different groups were the earliest antecedents of cardiovascular disease in these societies.

Nutritional deficiencies are very rare unless some special circumstances (e.g. twins or death of the mother) lead to neglect. The ease of cultivation of root crops, the abundance of land and adequate access to fruits, nuts, fish, pigs and poultry means that most Solomon Islanders have a well balanced and adequate diet (Jansen 1973).

Mental illness seldom causes serious problems. A few frank cases of schizoprenia and the occasional severely agitated patient are admitted to the small mental hospital at Honiara. Other cases of mental handicap and minor mental illness are usually well contained in their village environment. No accurate data is available on suicide but it is not as uncommon as the idyllic Pacific island environment might suggest.

A number of diseases are probably directly influenced by the severity and intensity of malaria. This particularly includes anaemia resulting from haemolysis caused by malaria infections. Low levels of haemoglobin were often recorded in cases admitted to hospital and in mothers presenting for delivery. This in turn led to an unnecessarily high number of ante- and post-partum haemorrhages. Other serious complications of pregnancy are rare except when delays occur in bringing cases in to clinics or hospital.

Nephritis due to malaria was first reported by Sayers (1928) from the Roviana lagoon. James (1939) later reported that the only effective treatment for his nephritis cases on Malaita was the use of intramuscular quinine. Nephritis is a rare cause for admission to hospital, but it was reponsible for six of the hospital deaths in 1972 (BSIP 1972). Cases of tropical splenomegaly syndrome are also known on most of the malarious islands. Not all of these have responded to antimalarial treatment.

CHAPTER 5

HISTORY OF ANTIMALARIA WORK

5.1 Early attempts at control and eradication

The eradication of malaria was of interest even to the earliest medical workers in the Solomon Islands. In the annual report for 1915 it was stated that swamps were left unfilled and undrained and collections of water left untreated (BSIP 1915). By 1917 it was realized that malaria would continue to be widely prevalent until measures were taken to reduce the number of mosquitoes and to treat the natives (BSIP 1917). The Annual Report of 1921 (BSIP 1921) explained that if any one of the triad of anopheline, parasite or non immune man could be removed malaria would cease to exist. Very few houses were screened and still little attention was paid to sanitation and drainage. In the 1920's efforts to control malaria continued to be applied almost exclusively to the government station at Tulagi. In most places the environment was highly anopheline favourable. Control measures then available were unlikely to make much impression on the incidence of malaria in the villages. In spite of the difficulties there was a lowering of the malaria rate in Tulagi by 1929 due to the use of more thorough anti-mosquito measures (BSIP 1929).

During the 1930's Tulagi remained comparatively free from malaria although there was little change in the methods used. Then in 1942 the somnolence of the islands was rudely shattered by the sudden appearance of Japanese and American military forces. The importance of malaria to the success of the land based campaigns became readily apparent (see Chapter 2). Nevertheless action was not taken by the American forces until malaria had reached epidemic proportions. The greatest source of widespread breeding of the vector A.farauti was in the innumerable man-made wheel ruts, ditches and foxholes (Oman & Christenson 1947). Every control method known at the time was used (Harper, Lisansky & Sasse 1947). This included ditching, dredging, flushing, larviciding, oiling, aerial spraying and the use of Gambusiae fish against the larvae. It included pyrethrum sprays, DDT residual spray and aerial spraying against the adult mosquitoes. Man himself was protected by special clothing, mosquito nets, repellents and the use of the drug quinacrine. At the peak activity in May 1944 the South Pacific Malaria and Insect Control Organization employed 4407 men concentrated mainly on Guadalcanal. (In contrast, the Malaria Eradication Programme in the Solomon Islands, at the peak of its activity in 1975, employed 350 men). The military malaria control teams were so effective that it was claimed by Simmons (1947) that their work did much to hasten the surrender of the Japanese. Harper et al (ibid) gave this even greater emphasis. They claimed that uncontrolled malaria, beri beri, and dysentry were among the decisive factors which lost the Japanese the Guadalcanal and Munda campaigns. A more detailed review of anti-malaria activities during the South West Pacific campaign has been made by Macgregor (1966).

After World War II the new capital of the Solomon Islands was set up at Honiara. Many of the buildings left behind by the American forces were utilised. The Honiara area continued to be sprayed aerially by the U.S. Army until the end of 1948. Regular oiling of all standing water with 2% DDT in fuel oil was also carried out. Ditches, waterways and mosquito breeding places were cleared. Residential quarters were sprayed with 5% DDT in kerosene as occasion demanded (BSIP 1948). These measures continued through the 1950's until the start of the Pilot Project in 1962. It was soon realized, however, that effective control was virtually impossible due to the large areas of water holding bush and swamp (BSIP 1952). District stations were later included but the high costs of labour and insecticide limited the extension of the work. Nevertheless, the clearing and elimination of obvious breeding sites was encouraged in villages (BSIP 1956).

In 1954 there occurred two events which heralded an increasing interest in the eradication of malaria from the Solomon Islands. The first was the drawing up of plans for the eradication of yaws. It was considered that a successful yaws campaign would result in a co-operative population. Lessons learned from this easier campaign could then be applied to the more difficult one against malaria (BSIP 1954). The second was an attempt at the eradication of malaria from the remote atoll of Ontong Java (Figure 30). This first attempt anywhere in the Solomon Islands was initially highly successful (BSIP 1955). The atoll of Ontong Java was found by Black (1952) to have both anopheline mosquitoes and hyperendemic malaria. These findings were confirmed in 1954 by Hollins (1957). The island was chosen because of its remoteness, limited breeding places, and the difficulty of return for anophelines once eradicated. Towards the end of 1954 an extensive anti-mosquito programme was carried out. The bush was cleared and breeding sites filled in. The swamps were

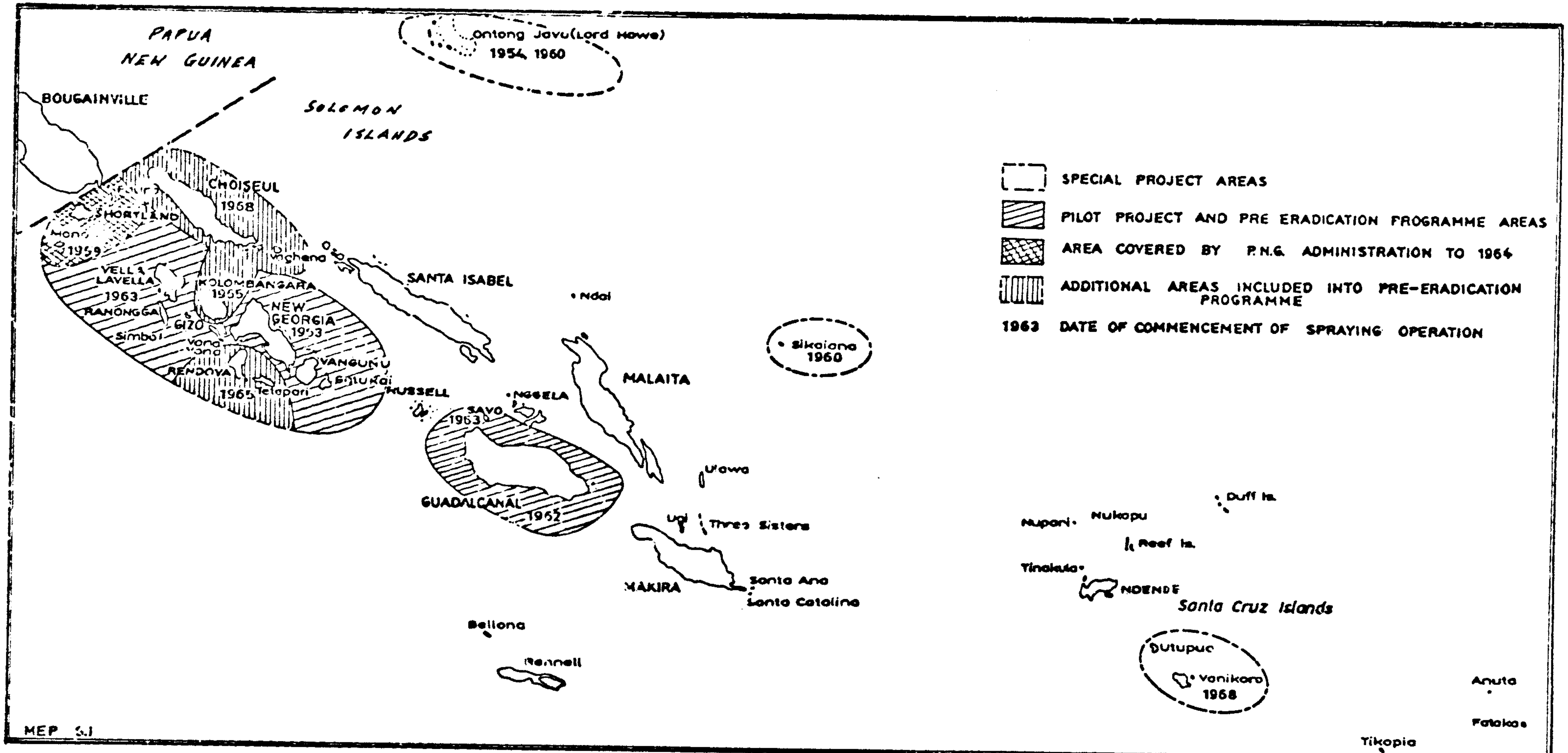


Fig. 30. Areas covered by malaria control & eradication operations, 1954 - 69.

sprayed with DDT in diesoline and Gambusiae fish were distributed in the taro pits. All the houses were sprayed with 5% DDT in kerosene mixture (BSIP 1954). Follow up visits in 1954 and 1955 found only a few anopheline larvae and no malaria cases (Hollins 1957). The Annual Report for 1955 (BSIP 1955) suggested that it should be possible to apply the lessons learned to other small islands. It also suggested that if further control measures could be undertaken it should be possible to eliminate the vector completely. It is clear from the subsequent Annual Reports (BSIP 1957-59) that this project had failed by 1957.

A second attempt at eradication on Ontong Java was started in May 1960. The method consisted of two cycles of house spraying using dieldrin 50% wettable powder applied at the rate of 0.5 g/m^2. In addition the whole population was treated for ten weeks with 'Lapaquine ICI' containing chloroquine 150 mg base and chloroproguanil 20mg adult dosage (BSIP 1960). Only one year after the completion of this exercise malaria had already returned to hyperendemic levels. In spite of explanations on several visits the people proved unco-operative during the second project which was therefore abandoned (BSIP 1961). There was also an unsuccessful project on Sikaiana (Figure 30) in 1960 (BSIP 1961).

5.2 The Malaria Eradication Pilot Project, 1962 - 1964.

During the time that the attempts were being made on the remote atolls the Medical Department was becoming increasingly interested in setting up an eradication programme. By 1960 the government had recognized that malaria was one of the main impediments to social and economic development in the country (BSIP 1960).

During 1960-61 a Plan of Operations for a Pilot Project was drawn up. A Colonial Development and Welfare (C.D. & W.) scheme was approved by Britain to cover the government commitments. WHO agreed to provide for the costs of equipment and supplies and for the employment of a malariologist and sanitarian (BSIP 1961; BSIP Government/ WHO, 1962). Meanwhile the Papua New Guinea Administration had already started (in 1959) to spray the Shortland Islands group. This was because of their close proximity to Bougainville which had come under spray cover in the same year.

The Malaria Eradication Pilot Project (MEPP) became officially operational on 1st March 1962. It was under the overall control of the Director of Medical Services assisted and advised by a WHO Malariologist and a WHO Sanitarian. Attached to the programme full time was a Fijian Assistant Medical Officer with training in entomology and a Solomon Islander Assistant Medical Officer with training in health education.

The areas chosen for the original Pilot Project were Guadalcanal and Savo in the Central Solomons and the New Georgia group in the Western Solomons (Figure 30). Arrangements were made for the continuation of spraying of the Shortland islands by the Papua New Guinea teams. The method used for the attack on the anopheline vector was DDT residual spraying of the inside surfaces of human dwelling places. The dosage was 2.0 g/m^2 applied once every six months. A trial was also made on the island of Savo of a combined approach with insecticide and mass drug administration. In all areas a system of case detection was set up. All microscopically proven malaria cases were administered a radical cure using

Chloroquine and Primaquine. The results of these operations have been described in detail by Macgregor (1966). On completion of the Pilot Project on 31st December 1964 four DDT Spray rounds had been completed in the whole operational area. Pre and post spraying malariometric surveys had been carried out in Guadalcanal/Savo and in New Georgia. Active and Passive Case Detection had been set up in most areas except for some of the remote bush villages.

The Pilot Project had proved that the interruption of the transmission of malaria was technically feasible certainly on some of the islands. The mass drug administration on Savo had shown that it was possible to obtain a clearance of the parasitaemia from the community using weekly Primaquine therapy. It had also shown that a twelve week administration gave a better guarantee of radical cure than an eight week one. The main problems of the project were breakdowns in transport, delays in supplies and the recruitment of suitable staff at all levels. The fears of non co-operation by the people had been proved to be totally unfounded. Credit for this must undoubtedly go to the extensive health education exercises that were carried out in most of the villages.

5.3 The Malaria Pre Eradication Programme, 1965 - 1969.

Following directly on from the Pilot Project the Malaria Pre Eradication Programme (MPEP) started on 1st January 1965. It concluded on 31st December 1969. A formal Plan of Operations was drawn up between the British Solomon Islands Protectorate Government and the World Health Organization (BSIP Government/WHO 1965). The objectives were 'to undertake the steady build up of the technical, administrative and operational facilities required for the launching in due time of a territory-wide malaria programme.' Included in this was the continued development of the Rural Health Services to provide a total of sixty Rural Health Units at the end of the Plan Period. It was expected that, once all the objectives had been fulfilled, the country would have reached the required operational maturity for the implementation of a full Malaria Eradication Programme.

Information on progress was reported in the annual addenda to the Plan of Operations, in the Quarterly Reports to WHO and in the Medical Department Annual Reports (BSIP 1965-69). Further information was also given in the Assignment Reports written by WHO officers on completion of their service (Tuazon 1967; de Iorio 1967; Sloof 1969; Maffi 1971; Lawrance 1973).

During the whole period of the MPEP, DDT spraying operations were continued on Guadalcanal and Savo. By the end of 1969 fourteen cycles had been completed in most zones. Ten of these cycles were completed during the five years of the MPEP giving an average of one cycle every six months.

The New Georgia group also continued spraying operations but with a timing slightly behind Guadalcanal. By the end of 1969 twelve cycles had been completed on most of the islands originally under spray cover. Eight of these cycles were completed during the five year period of the MPEP giving an average of one cycle every 7.5 months. The islands of Rendova, Tetepari and Kolombangara were included into the spraying operations in August 1965. The Shortlands group, including Mono and Fauro, was also brought into the Solomon Islands operation in September 1965. These islands had been regularly sprayed since 1959 by the Papua New Guinea Administration as part of their Bougainville operation. Finally, the inclusion of Choiseul in September 1968 brought the whole of the Western Solomons under spray cover during the MPEP.

During 1968 a combined DDT spraying and mass drug administration exercise was also carried out on Utupua and Vanikoro (Figure 30). These remote Eastern Outer Islands were chosen for a demonstration eradication project. The exercise was discontinued after two spray rounds because of difficulties in supplies and supervision (see Chapter 7).

Whilst the regular programme of DDT spraying was being carried out in the MPEP areas, entomological and parasitological surveys were being carried out in the other islands (see Chapter 7). Maps were prepared at a scale of 1 : 50,000 locating all villages and other topographical features. Equipment and supplies were procured and staff recruited and trained. Health education programmes were carried out especially in the island of Malaita where public co-operation was uncertain. This flurry of activity was all part of the big build up for the official launching of the full Malaria Eradication Programme in 1970.

With communications one of the major obstacles to success a detailed system of transport was set up. The difficult inter island communications required the use of three medium sized vessels (12 - 15 metres) for spraying operations. For surveillance, five smaller 'T' class vessels (Plate 8) were used. On the sheltered lagoons, canoes and outboard motors were the only suitable transport (Plate 9). On north Guadalcanal Land Rovers, VW Kombis

Plate 8. A "T" Class vessel used for government service.

Plate 9. A canoe and outboard motor used for lagoon work.

and Honda motorcycles were used. Many of the villages were covered by foot which was the only other means available. Considering the rough seas, treacherous reefs and difficult landings it is remarkable that the BSIP Marine Department was able to keep the teams on the move for most of the time. On land heavy rains, flooded rivers, poor roads and mechanical breakdowns caused many problems. In spite of these, spraying and surveillance teams nearly always kept to their schedules on time.

The malaria surveillance which was established during the Pilot Project continued on Guadalcanal/Savo and in the Western Solomons during the MPEP. Passive Case Detection agents continued to collect blood slides at their clinics and schools. The Active Case Detection Agents continued to visit all the villages once every fortnight. Bush villages and the south coast of Guadalcanal were particular areas where the coverage was inadequate on occasions. There were often long delays in locating cases and getting them under treatment. The results of malaria surveillance during the MEPP and MPEP period in Guadalcanal/Savo are shown in Table 28. Those for the Western Solomons are shown in Table 71. A more detailed review of progress in the eradication of malaria in these areas will be found in Chapter 7. In north Guadalcanal it became quickly apparent that the transmission of malaria had not been fully interrupted in all villages. This was considered to be due primarily to the excessive contamination by the large number of migrants from the highly malarious islands of Nggela and Malaita. In contrast, malaria was quite rapidly cleared from the south coast of Guadalcanal where there were few migrants. Another important factor was the very high density of anopheline mosquitoes which persisted on the north coast even after spraying. The vector Anopheles farauti also showed a strong tendency to bite earlier in the evening at the same time as the peak outdoor activity of man (see Chapters 7 and 8).

In the New Georgia group there was an initial rapid fall in malaria and good evidence that transmission had been interrupted in many villages. By 1966 however, cases were on the increase especially in Gizo and Roviana. This was due to the importation of cases from unsprayed Choiseul and also to steadily increasing migrations from Malaita. The increase in cases continued until the start of the full Malaria Eradication Programme in 1970.

As a further contribution to the build up towards the full eradication programme, the network of Rural Health Units continued to expand. A new target was set for sixty-two clinics. Fifty of these were to be full clinics, eight to be 'half' and four a 'quarter' only. These revisions were the result of improvements in communications notably in Malaita. This allowed for certain 'quarter' clinics to be visited only rather than to be staffed full time. The 'half' clinics were ones where no maternity services were to be provided because of objections for reasons of custom or taboo. The original target of sixty clinics was not achieved but reasonable progress was still made. By the end of 1969 thirty-nine full clinics and two half clinics were in use. There was, however, a shortage of fully trained nursing staff for many of them.

A notable event in late 1968 was the visit of the first WHO Independent Assessment Team to the Solomon Islands (Kranendonk and Ray 1969). This team considered that sufficient progress was being made to allow the country to proceed to a full eradication programme in 1970. They endorsed the work of the government Malaria Advisory Committee which had been set up in May 1968. The result of the deliberation of this body was the production of a White Paper (BSIP 1968) declaring the firm intention of government to go ahead with the eradication of malaria throughout the islands. The target date was set for starting on the 1st January 1970. This White Paper was passed by the BSIP Legislative Council in November 1968. From then on plans and preparations went steadily ahead for the expansion into an island wide programme (BSIP Government/WHO 1970).

5.4 Malaria Prophylaxis prior to eradication operations

The only other method used to control malaria in the period before full eradication operations was the use of prophylactic drugs. The value of these was appreciated as soon as formal medical services were set up in the Solomon Islands. At least as early as 1914 quinine was distributed to the expatriate staff in Tulagi (BSIP 1914). In spite of this malaria was reported as being very common amongst all groups of people including Europeans (BSIP 1920, 1921). After 1916 blackwater fever became comparatively common probably due to the injudicious use of quinine (BSIP 1920). The usual dosage for Europeans was 4-5 grains daily. By 1923 a medicine parade had been started for native policemen and prisoners (BSIP 1923). The administration of 10 grains of quinine twice weekly greatly improved their health.

During the 1920's and early 1930's quinine continued to be regularly in use. In 1934 'Atebrin' (Mepacrine) was tried. Many clinical cases relapsed within a week of completing a course of one tablet t.d.s. for 5 days (BSIP 1924).

After World War II 'Paludrine' (Proguanil) was widely used for both prophylaxis and treatment (BSIP 1949). Where this drug was in general use the incidence of malaria was greatly reduced. The dosage for prophylaxis was one tablet per day for Europeans and two per week for natives (BSIP 1950). Paludrine continued to be used during the early 1950's but soon a number of cases of clinical malaria occurred in people who were regularly taking it (BSIP 1954). No further attacks occurred when the patients were put on to Chloroquine. When the native population developed fever only modified therapy was given and no attempt was made to sterilise the infections (BSIP 1956).

Malaria proved troublesome for the newly arrived non-immune Gilbertese when they settled in Vaghena in the late 1950's (BSIP 1958). Control was achieved there towards the end of 1958 by the use of larvicides, chemoprophylaxis (drugs and dosage not stated) and the issue of mosquito nets.

By the time of the start of the Pilot Project in 1962 Chloroquine had become more widely used. This soon became the prophylaxis of choice although even during the 1970's people continued to arrive in the Solomon Islands having been advised to take Proguanil or Pyrimethamine (see Chapter 8).

CHAPTER 6

MATERIALS AND METHODS

6.1 Objectives and Policy

The objective of the Malaria Eradication Programme was to eradicate malaria from the Solomon Islands within a reasonable period of time commensurate with the resources available. The methods used were the standard ones laid down by the World Health Organisation allowing for some minor variations due to local circumstances. The basic theory was to interrupt the transmission of malaria from one man to another by reducing the life expectancy of the anopheline mosquitoes to such a level that they were no longer capable of developing sporozoites. This was achieved by the use of DDT insecticide sprayed on the resting surfaces of all dwelling places, the effect of this being to either kill or weaken the anopheline mosquito. In addition to the attack on the vector mosquito an attack was made on the malaria parasite in man by treating all proven cases with antimalarial drugs. These cases were those that had been detected by a system of surveillance aimed at regularly collecting blood slides from all persons suspected of having malaria.

6.2 Preparatory Work

The eradication of malaria is a theoretically simple task which in practice requires a high degree of organisation, management and technical skill. In many ways it is the Community Health exercise 'par excellence.' Not only do the staff have to maintain high standards but a great deal of co-operation is needed from other health workers, from community leaders and from the public.

Before any of the operations could be carried out, much preparatory work had to be undertaken. This included recruitment and training of suitable staff, budgeting, surveying, mapping, logistics planning and procurement of equipment and supplies. A most important aspect of this work was the regular publicising of activities in the media and the more specific health education of the public. Since the Solomon Islands is predominantly a rural society the main effort was by personal visits by MEP staff to villages. Informal meetings were held and discussions encouraged. Often these were held long into the night since Melanesian society traditionally only allows decisions to be made by consensus after careful deliberation.

6.3 Organisation and Management

The Malaria Eradication Programme (MEP) of the Solomon Islands was an autonomous unit within the Ministry of Health and Welfare. The Director of the programme, the Principal Malaria Eradication officer (PMEO), was responsible for the operation to the Chief Medical Officer (Community Health). The P.M.E.O. was assisted by a Senior Malaria Eradication Officer (SMEO) whose major responsibility was for field operations. There were also supervisors in charge of the three major support units of Geographical Reconnaisance, Microscopy and Entomology. The field work was carried out under the direction of four Field Operations Officers (FOO) based at the main district centres. Each FOO had an Assistant Field Operations Officer (AFOO). The responsibility of the FOO and AFOO was jointly for both spraying operations and surveillance with each one tending to take more responsibility for one or other branch.

A good deal of flexibility was required to allow for contingencies, leave, and absences in the field. At the Sub District or Regional level (see Glossary) the responsibility for all aspects of surveillance was with the Field Supervisor. He had a small team of Active Case Detection (ACD) Agents, Drug Administrators (DA) and Follow Up Spraymen (FUS) covering a population of between 5 - 15,000 people. The regular six-monthly cyclical spraying was carried out by teams of spraymen and their Squad Leaders and Senior Squad Leaders based on the main District centres. They covered a wide area staying in the villages by night and only returning to base at the end of the month for pay, recreation and supplies. The number of staff employed by the MEP at 1st January 1975 was 315. All malaria staff were employed full time on temporary terms at basic general rates appropriate for the job. They were also paid field allowances to compensate for overtime work and hardship.

The overall monitoring of the MEP was carried out by the Malaria Technical Operations Committee (MTOC) which met monthly. This body, chaired by the Chief Medical Officer (Community Health), included senior MEP staff and their World Health Organization counterparts. In addition to the minutes of the MTOC meetings Quarterly and Annual Reviews of progress were made. The WHO Team Leader also sent a monthly report to the WHO Western Pacific Regional Headquarters in Manila. The Field Operations officers were members of their respective District Health Teams.

On entry into the MEP, preferably with an education up to Form 2, all technical staff received a two weeks introductory training course. Following this they completed Job Specific Training the duration of which depended on the nature of the job. Most of this was carried out as a form of In Service Training. In addition, a Mobile Training Team periodically visited District and Regional Centres to carry out refresher training. The WHO officers were closely involved in all these training programmes.

A major facet of the organization and management of the programme was the procurement of equipment and supplies. This was the responsibility of the SMEO assisted as required by the Chief Administrative Officer of the Ministry of Health. The long distance from main manufacturing centres often caused problems and long delays in the procurement of basic equipment and supplies. This was further complicated by difficulties in internal communications so that peripheral field units sometimes went without essential supplies for several months.

Associated with the distribution of supplies was the transport system. With such a rugged terrain, rough seas, and treacherous reefs, reliance had to be placed on a variety of transport. In hilly bush country this could only be by foot. Elsewhere it could be by bicycle, motorcycle, mini moke or land rover. In the inshore lagoons canoes and outboard motors were often used (Plate 9). Once on the open sea the only safe and suitable means was by well found small ships. For spraying operations the rather larger outer island vessels of 12-15m were used. For surveillance the small 6-7m "T" class ships (Plate 8) usually sufficed. Breakdowns and rough weather sometimes caused delays with the smaller craft. On land breakdowns and flooded rivers were not unusual.

Finance was another matter of vital importance. The

Solomon Islands was fortunate for the first ten years since most of the programme was financed by British Colonial Development and Welfare (CD & W) funds. After 1972 it was financed as a special British Development Aid Project as part of the National Development Plan. Expenditure steadily rose from $A.177094 in 1970 to $A. 764725. in 1975. From 1976 onwards the expenditure was expected to gradually fall. A further valuable source of funds for the MEP was the International Agencies (UNDP, WHO, UNICEF). This expenditure was of the order of $US.80,000 per annum from the start of the MEP in 1970. It was allocated for payment of WHO staff, fellowships for MEP staff and advisory visits and for certain supplies like microscopes, outboard motors, canoes and drugs.

6.4 Geographical Reconnaissance (G.R.)

Where DDT spraying and malaria surveillance operations are being carried out it is essential to know whether or not a total coverage is being obtained of all the villages and of all of the population. The ideal procedure for this is to make detailed spot maps locating all houses and structures in every village. Details of the population are then maintained by house to house census registers, and all information is updated at regular intervals during visits by malaria staff.

The Solomon Islands used a modified form of classical G.R. The most important unit was the 1:50000 zone map. On this was plotted all villages with their population and the number of household units. Main topographical features were also marked in, including roads, paths, schools and clinics. These maps were fully revised and reissued every six months after spray rounds. They were kept up-to-date in the interval by the Field Supervisors. No village spot maps were made except for the special investigation of a problem. A head count was made during spray rounds and Active Case Detection but a detailed named census was only made when mass drug administration was being carried out.

Special maps at other scales were made as required, for example to show the distribution of malaria vectors or cases. Staff from the MEP Headquarters often went into the field to cross check the accuracy of the returns but there was no completely independent G. R. prior to spraying operations. All houses were, however, issued with a numbered house card. This was used for the purpose of recording all antimalaria operations carried out in that house.

6.5 Spraying Operations

The primary method of attack in the MEP in the Solomon Islands was on the indoor resting places of the vector anophelines with dichloro-diphenyl - trichloroethane (DDT) residual spray. The theoretical objective was for the mosquito to take in a lethal dose of insecticide whilst it was resting on the house wall after taking a blood meal. As long as the mosquito died within a period of ten days then no matter how many gametocytes it had ingested it would not live long enough to become infected with sporozoites. Some of the difficulties of this theory are discussed in Chapter 8. The inside and under surfaces of all dwelling houses were sprayed. Also included were any other buildings in which people might spend all or part of the evening. The under surfaces of furniture were also sprayed since this is a well known resting place of the Solomon Islands anophelines. The DDT was applied evenly at a dosage of 2.0 g/m^2 once every six months. In areas with a very high level of transmission the interval between spraying was cut down to once every four months. Another group of buildings included in the spray cycles was the garden houses. These were often as much as 2-3 hours walk away from the village.

The formulation of DDT for leaf structures was 75% technical grade water dispersible powder (w.d.p.) to WHO specifications (WHO 1967[a]). For permanent structures a 25% DDT emulsion concentrate was used. A combination of DDT 68.2% / Malathion 6.8% was also used when people complained of a severe bed bug problem.

Houses were not plotted or counted separately as an independent G.R. The percentage of structures sprayed was that counted by the Squad leader against the available structures at the time of spraying. Follow up teams attempted to spray the unsprayed houses within a week or so of the main cyclical spray round. Follow up spraying (FUS) was also carried out by teams under the Field Supervisor. These teams usually visited villages fortnightly with the ACD teams. The purpose of the FUS was to locate and spray all structures built or repaired since the last visit. The FUS team also resprayed any surfaces with excessive rub off. When a focus of malaria had been located a special team was usually sent in to carry out Focal spraying. This was usually a full re-spray up to the standards of the cyclical spraying operation. Where refusals were met to spraying operations, the senior Squad Leader or Field Operations Officer would make every effort to persuade the house owner to have his house sprayed. Only when refusals still persisted would the more drastic measures of court action be invoked. Friendly persuasion was much preferred to militant force.

A unique feature of spraying operations was the special arrangements that were made to avoid violation of customs and tambus in heathen villages in Malaita.

A specially painted red pump was used for the spraying of the women's menstruation hut or 'bisi' (Plate 10). After spraying these huts the man immediately left the village by a separate path and did not visit another heathen village until he and his equipment had been ritually cleansed. For the men's tambu house or 'beu' (Plate 11) a green pump was used. No man could spray any other houses in the same village after using these pumps.

The type of spraying operation was recorded on the house card by the Squad Leader. Village and zone summaries were then made and the final analysis of spray coverage completed in the Malaria H.Q. Frequent independent field checks were also made by Field Operations Officers and senior staff.

6.6 Evaluation

The purpose of evaluation was to compare the state of malaria after operations with the state prior to operations. Since the attack was being made on the vector and on the parasite in man these were the two areas in which measurement was required.

Entomological Evaluation:

Prespraying surveys of vector distribution

Since the habits of the *Anopheles punctulatus* group were already well known from studies in Papua New Guinea (Black 1955[b], Spencer 1964) and West Irian (Sloof 1964) the distribution surveys in the Solomon Islands concentrated on day resting collections. These were

Plate 10. Women's menstruation hut (bisi) in East Kwaio, Malaita.

Plate 11. Men's tambu house (beu) in East Kwaio, Malaita.

carried out on the inside surfaces of dwelling houses during the hours of daylight. Outdoor surveys of potential resting sites were soon abandoned as the vector proved extremely difficult to find by this method. During the surveys in Malaita in 1969-71 a record was also made of the type of locality and its altitude. In these surveys the level and type of surface on which the mosquito was resting was also recorded. Specimens were kept live in cardboard containers and identified on return to base using the keys prepared by Belkin (1962). Larval surveys were carried out from time to time in order to establish the types of breeding sites on different islands. Larvae were preserved in Macgregor solution and identified in the laboratory using the keys from Belkin (ibid).

Prespraying surveys of vector behaviour

There was very little detailed entomological work prior to the start of the Plot Project in 1962. A few more detailed studies were carried out during the period before the start of the full Eradication Programme in 1970. Most of the studies on vector behaviour pre-spraying were, however, carried out in Malaita and Makira during the period 1970-72. On both islands a series of night catches was carried out at a group of five fixed entomology stations. A team of entomology technicians carried out Indoor Man Biting (IM), Outdoor Man Biting (OM) and sometimes also Indoor Resting (IR) catches between the hours of sunset and sunrise. Originally three collectors rotated every half hour, the Indoor Resting collection being counted as a rest period. Collections started at 18.30 (approximate time of local sunset) and finished at 06.30 (local sunrise). For the collections in Makira there were twelve periods each of 40 minutes duration alternating with 20 minute rest periods. The first catching period started at 18.30 and the last period ended at 06.10. Collectors rotated venues and collecting places in order to even out possible variations in attractiveness as baits.

Post spraying surveys of vector behaviour

The same methods of IM and OM biting were used as in the pre-spraying surveys. The IS method was dispensed with as it was almost impossible to find any anophelines resting on sprayed indoor surfaces. Once the all night biting pattern had been established, night catches were reduced to cover the period of peak biting activity, i.e. from 18.30 to 21.00.

Tests for biting preference and insecticide susceptibility

A small number of tests were carried out to assess biting preferences both before and after DDT spraying. These tests, using the precipitin method with blood smears from day collections of *A. farauti*, were carried out through the courtesy of the World Health Organization at the Lister Institute, Elstree, England. The procedures for collection followed those recommended by Darsie and Ramos (1969).

Tests for the susceptibility of *A. farauti* to DDT were carried out periodically both pre and post spraying. It was intended to carry out these tests on every major island and to repeat them every six months where circumstances warranted. Often this was not possible because of a lack of sufficient numbers of vectors. For the same reason only one test was ever carried out on *A. punctulatus* and none at all on *A. koliensis*. During 1962, 1967 and 1973 tests were also made on susceptibility to dieldrin using A. farauti caught in north Guadalcanal and also in Santa Isabel. The standard W.H.O. test kits (World Health Organization 1970) were used for the purpose of insecticide susceptibility testing. For the purpose of assessing the quality of DDT spraying bioassay tests were occasionally carried out again using WHO test kits (World Health Organization ibid). The method was not used widely due to the difficulty in obtaining sufficient numbers of viable mosquitoes.

Dissections of mosquitoes

Prior to the original spraying programme on Guadalcanal a number of dissections were made on freshly caught unfed specimens of all three vector species. These specimens were caught biting at night and examined the next day for sporozoites using the methods described by Muirhead-Thomson (1963). The sporozoite rate was then calculated for each species from the results obtained. Dissections were also made for sporozoite rates on Nggela, Santa Isabel, Choiseul, Malaita and Makira. In all of these islands the numbers dissected were considerably less than on Guadalcanal. Soon after spraying started these dissections were discontinued due to the rapid disappearance of sporozoites from all specimens.

During the early years of antimalaria operations all anophelines, after identification, were also dissected for parity. This was done using the simple method outlined by Detinova (1962) for the examination of the tracheal system of the ovaries. These dissections were discontinued when the results varied considerably and were found to be inconclusive. A few calculations were made by Sloof (1969) on vectorial capacity but these were also discontinued when it was realized that little of practical value was accruing. The calculation merely confirmed the already obvious conclusion that the potential for transmission was high on Guadalcanal.

Experimental Huts

In order to study the behaviour of *A. farauti* before and after spraying, experimental huts were set up at Lunga on north Guadalcanal in 1965. These huts were also set up to test the residual effect of DDT w.d.p., DDT emulsion and Lindane w.d.p. Collections were made by outlet traps, morning searches for dead or resting mosquitoes and by Indoor and Outdoor Man Biting catches. Mortality was assessed after a 24 hour recovery period. These huts were abandoned in 1969 but a further three huts were set up in Gilatae, north Guadalcanal in 1972. The purpose of these was to assess DDT repellency but their use was discontinued in 1974. During the entomological studies carried out by Taylor (1975) in Makira, in the final attempt to assess vector behaviour pre and post spraying, some village houses were left unsprayed as 'experimental huts' for a brief period during 1972.

All of the methods used by the entomology staff in the MEP in the Solomon Islands were outlined in a Manual of Entomology in 1965 by the WHO Entomologist Dr. R. Sloof. This was the first malaria operational manual to be prepared specifically for the Solomon Islands.

Parasitological Evaluation:

Malariometric Surveys

Before the start of the Pilot Project in 1962 blood slides were collected from 42.6% of the whole of the population of Guadalcanal and 39.8% of the population of New Georgia. On the small island of Savo where a trial mass Drug Administration was carried out, nearly 95.8% of the population was surveyed. No spleen surveys were carried out on these islands (Macgregor 1966).

As the work expanded during 1965-70 into a Pre-Eradication Programme and then into an Eradication Programme, prespraying surveys were standardised to concentrate on the 2-9 year age group. Blood slides were taken from 10-100% of the 2-9 age group depending on the size of the island. On small islands usually all of the 2-9 age group was sampled. Spleen surveys were also carried out simultaneously but were missed out on several occasions due to the inexperience of the surveyors. Most surveys tended to concentrate on easily accessible coastal areas although genuine attempts were made to obtain an accurate survey by random selection of villages.

Once DDT spraying had started every effort was made to carry out serial blood surveys in the 2-9 year age group once every six months. The selection of villages and the numbers to be surveyed were made according to the methods of Swaroop (1966). Post spraying spleen surveys were carried out on only rare occasions when the failure to interrupt the transmission of malaria was suspected. The assessment of the interruption of the transmission of malaria was made from these surveys following the methods proposed by Macdonald and Göckel (1964) and detailed by the WHO

Expert Committe on Malaria (WHO 1964) and by Black (1968). It was always possible to apply the first criterion[1]. This was even allowing that the numbers sampled did not always fall within the confidence limits required by Swaroop (ibid) because of the small sizes of the population groups. Parasite densities were not recorded in most of the early post spraying surveys so that the second criterion could not be applied. Similarly the third criterion was not usually applied since the 0-1 year age group was only occasionally sampled. The other major malariometric surveys were the incidence surveys carried out in Malaita District Hospital, Auki and Eastern District Hospital, Kira Kira. These were carried out for several months prior to the start of spraying. They then continued thereafter as part of the routine Passive Case Detection element of surveillance. These surveys took blood slides from all fever cases of all ages presenting to out-patients in these hospitals during the survey period.

Surveillance

The purpose of malaria surveillance is to discover evidence of continuing transmission of the disease and to initiate such action as may be required to remove residual foci of malaria. The methods of surveillance in the Solomon Islands followed the strictly conventional lines detailed by Black (ibid).

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1. The criteria for the proof of the interruption of transmission of malaria are,that within one year:-
First criterion. That the parasite rate shall fall to a level of 16% and not more than 22% of the original rate in the 2-9 year age group.
Second criterion. That the ratio of heavy infections to light infections should not exceed 7:1.
Third criterion. That the parasite rate in the 0-1 age group (infants) should be zero. (WHO 1964, Black 1968)

Soon after spraying started Passive Case Detection (PCD) was set up on most islands. The main agencies were hospitals and Rural Health Clinics staffed by doctors and registered nurses. Blood slides were also collected by Village Health Aids (Dressers) with a less formal health training. In more remote areas where there was a lack of medical facilities slides were also collected by school teachers or community leaders. Blood slides were collected from all fever cases (temperature over 99°F or 37.2°C) presenting to these agencies. Slides were also taken from anyone else suspected of having malaria and from visitors from other islands.

At a slightly later stage after the commencement of spraying, perhaps after six months or a year, Active Case Detection (ACD) was set up. This was carried out by Active Case Detection Agents (AA's) employed by the M.E.P. These AA's were mostly recent school leavers who had received a two week intensive training before going into the field. Their duties were to collect blood slides (as in PCD) by visiting all villages in their area once every fortnight. During these visits AA's were required to visit every house and contact every person they could find. They also signed the House Cards to provide a record of their visit. AA's worked in teams of two to five men stationed at a Regional base under the direction of a Field Supervisor.

When taking blood slides all PCD and ACD Agents routinely administered a Presumptive Treatment consisting of:-

Chloroquine 600mg	}	adult dosage, pro rata
Primaquine 30mg		dosages for children

Originally only chloroquine was used in presumptive treatment but in early 1974, following the recommendation of a WHO Scientific

Group (WHO 1973[a]), primaquine was added. The purpose of the chloroquine was to provide an immediate clinical cure for the malaria attack. Further doses up to a total of 1500mg were occasionally used in semi-immunes over a 3 day period if the response was not satisfactory but malaria was still suspected. The chloroquine also acted as a gametocytocide for P. vivax and P. malariae infections. The purpose of the primaquine was to act as a gametocytocide for P. falciparum infections. In the consolidation areas, once the danger of P. falciparum infection had been removed, primaquine was withdrawn from the presumptive treatment.

A further important arm of surveillance was the collection of blood slides by surveys. These included the Mass Blood Surveys in the early assessment of spraying operations and later on in the investigation of foci of malaria. House contact surveys were routinely carried out in the immediate neighbourhood of new malaria cases. During the focal surveys presumptive treatment was administered, but in the assessment surveys this was not done.

Once a malaria infection was diagnosed in the microscopy laboratory the case was located as soon as possible. The ACD or PCD Agent or a specially trained Drug Administrator (DA) was then alerted to carry out a full Radical Treatment. The purpose of this was to achieve a complete clearance of all parasites from that case. The Radical Treatment for P. falciparum cases was for many years a 5 day administration of chloroquine and primaquine. In April 1975 this was reduced to 3 days following the findings of Clyde, McCarthy, Miller & Woodward (1974) that the Solomons (Nes) strain of P. falciparum from North Guadalcanal was equally susceptible to an adult dose of 1500mg of Chloroquine administered over a 3 day period. Primaquine was added to the radical treatment, as in the presumptive treatment, for the purposes of sterilizing gametocytes should they be present.

The definitive Radical Treatment for P. falciparum malaria was therefore, from April 1975:-

Day	Dosage of Antimalarials	Age over 15 years		Age			
		Weight over 60kg	Weight under 60kg	10-15 years	5-10 yrs	1-4 yrs	0-12 mths
1-3	Chloroquine 150mg tabs.	4	3-4	3	2	1	½
	Primaquine 7.5mg tabs.	4	3-4	3	2	1	½

These dosages were standardised for ease of administration so that each was identical with one dose of the Presumptive treatment.

Whilst the treatment of P. falciparum in the Solomon Islands was comparatively easy, that for P. vivax was quite the opposite. In the very early days of the Pilot Project the standard 5 and 14 day treatments were replaced by a weekly regime of chloroquine and primaquine for 8 weeks. Within a very short time, following the deliberations of the Third International Malaria Conference for the South-West Pacific, the weekly regime was extended to 12 weeks (Macgregor 1966). This was found to be very satisfactory in Savo Island but later reviews (Saint-Yves 1975[a]) showed that even this regime could not guarantee a radical cure in all cases. In view of the difficulties, further efforts were made during 1975 to utilise the 14 day treatment but with the dosage increased to 30mg daily.

The definitive treatment for P.vivax (and P. malariae) in the Solomon Islands was therefore decided in April 1975 to be:-

First choice - to be administered whenever feasible, always under close supervision and preferably as an In patient in hospital or clinic.

14 day Radical Treatment for P. vivax, P. malariae and mixed infections

Day	Dosage of Antimalarials	Age over 15 years		Age			
		Weight over 60 kg	Weight under 60kg	10-15 years	5-10 yrs	1-4 yrs	0-12 mths
1-3	Chloroquine 150mg	4	3-4	3	2	1	$\frac{1}{2}$
	Primaquine 7.5mg	4	3-4	3	2	1	$\frac{1}{2}$
4-14	Primaquine 7.5mg	4	3-4	3	2	1	$\frac{1}{2}$

Second choice - for those unable to have the first choice.

12 week Radical Treatment for P. vivax, P. malariae and mixed infections

Week	Dosage of Antimalarials	Age over 15 years		Age			
		Weight over 60kg	Weight under 60kg	10-15 years	5-10 yrs	1-4 yrs	0-12 mths
1-12	Chloroquine 150mg (or Amodiaquine 200mg)	4	3-4	3	2	1	$\frac{1}{2}$
	Primaquine 7.5mg	6	4-5	4	3	2	1

The Radical Treatment of the majority of cases was usually carried out under the close personal supervision of an ACD or PCD Agent or a Drug Administrator. On completion of treatment, all P. falciparum cases were followed up with a monthly blood slide for 6 months. P. vivax and P. malariae cases were followed up for 12 months. Presumptive treatment was not given on these occasions to avoid masking potential relapses or reinfection. Relapsing cases were immediately put on to the 14 day treatment under close supervision. Case Registers were kept by Field Supervisors and used for cross checking the accuracy of treatment and follow up.

When Mass Drug Administration (MDA) was utilised for the purpose of clearing up residual foci of malaria, a monthly presumptive treatment was used for 4-6 months for foci of P. falciparum. For foci of P. vivax the weekly treatment for 12 weeks was used. Every effort was made to ensure that the highest possible percentage of the population received the full treatment. This was done by taking a household census and recording each individual drug administration. During all drug treatments staff were required to observe, ask for, record and report any untoward side effects. All treatment dosages were recorded on printed treatment cards.

A last, but most important component of surveillance was the action taken once a malaria focus had been discovered. Action speedily and correctly taken would ensure the minimum spread of any outbreak and quick return to normal. Remedial measures were usually carried out under the Field Supervisor. In a large outbreak they were sometimes carried out by a special team seconded from the main District Centre. The action consisted of Focal spraying, Mass Blood Survey, Mass Drug Administration and possibly supplementary measures like ultra-low-volume spraying, larviciding or stream clearance.

Microscopy

The potential for success in a Malaria Eradication Programme depends on many factors. One of the most important of these is the quality of laboratory services. If the laboratory is incapable of accurately processing the required number of blood slides the whole system for surveys and surveillance is put in jeopardy. With this in mind an early effort was made to set up adequate laboratory facilities right from the start of the Pilot Project. Initially only the central diagnostic and reference laboratory was set up. Later, with the expansion of the programme, peripheral laboratories were set up at Gizo (Western), Auki (Malaita), Kira Kira (Eastern Inner Islands) and Graciosa Bay (Eastern Outer Islands). These provided adequate coverage for each District and also for the remote Eastern Outer Islands.

All malaria blood slides, correctly marked and documented, were channelled through one of these laboratories. After registration the slides were fixed and dehaemoglobinised, then stained in Giemsa. Fields stain was occasionally used for emergency requests. All slides were examined to cover 100 fields of thick film under oil immersion. Later refinements with manual counters allowed the parasite density per mm^3 to be measured. This refinement was only introduced in 1973 after all the major assessment surveys had already been completed. Microscopes used were the Olympus binocular model. All slides were sent in from Districts for cross checking. All positives, and 10% of negatives selected by a system of random numbers, were cross checked in the Central laboratory. Microscopy staff, male and female, were recruited direct from Form 2 school leavers or from the ranks of malaria field staff. They received three months in service training during which a high standard was expected. The accuracy of all microscopists was regularly analysed and defaulters dismissed if a definite improvement was not seen. A Manual of Microscopy was prepared by a Peace Corps Volunteer in 1975 and a Register was kept of all slides examined and cases detected (Gibson 1973).

Slides were taken in the field with a thick and thin film on the one slide. They were numbered according to a standard pattern. The person's name, age, sex, and village was then recorded on General Purpose forms. Slides were dried on the spot then stored in racks in field slide boxes. When ready for despatch to the laboratory they were wrapped inside the General Purpose forms and sent off. Most slides were inside the laboratory within 7-10 days of collection. After examination and cross checking in the laboratory slides were cleaned in detergent and then sent out to the field again in packages of ten. As soon as possible after receipt in the laboratory slides were fixed in methanol and stained in Giemsa which was buffered to a pH of 7.2. On examination a species diagnosis was always made if possible and the density recorded. The slide fields were also scanned for microfilariae which were recorded simply as MF Positive or Negative. Results of all positive slides were sent out to the Malaria Field Supervisor by the quickest possible means of communication. The results of negatives were usually sent by post. Confirmatory lists of all new cases were either sent to, or seen by, the Field Operations Officer at regular intervals.

The problem areas were also given closer entomological attention than elsewhere. In addition to routine catches, foci of malaria were investigated whenever possible. This often consisted of no more than a day larval survey and an early evening catch simply to measure the density of vectors present.

Note: Although this chapter has been written in the past tense, the present tense also applies since the majority of methods described are still in use.

Note on statistical evaluation.

For the purposes of evaluating the interruption of transmission by the use of malariometric surveys the sampling methods of Swaroop (1966) and the regression patterns of MacDonald & Göckel (1964) were considered to be adequate. In the case of analysis of routine surveillance the final objective was zero cases. Since even an absence of cases of any given species was not an absolute guarantee of interruption of transmission there was no point in applying sophisticated analytical techniques to the data. Where significance tests were applied those islands with a steady fall in cases showed significance levels of $P < 0.001$ giving every indication that the fall was due to measures being undertaken. The really important factor in surveillance is, however, to achieve the necessary coverage in space and time (Black 1968) rather than to provide statistically satisfying data which may still fail to show evidence of resumption of transmission of malaria.

Certain other statistical comment has been made in passing e.g. on Tables 19 and 20. On none of these occasions were statistical tests applied since the findings were for practical purposes rather than for statistical evaluation.

CHAPTER 7

RESULTS OF THE ANTIMALARIA OPERATIONS

7.1 Entomological

Early surveys

Classification and taxonomy of the vectors

Distribution of vectors

Capability of the *A.punctulatus* group as vectors

Susceptibility to insecticides

Behaviour of the vectors pre spraying

Behaviour of the vectors after DDT spraying

Behaviour of the vectors after cessation of spraying

Experimental studies

Summary of entomological findings

- Early surveys

Prior to World War II entomological surveys were a rarity. A re-examination of the material by Belkin (1962) concluded that most of the specimens previously found had been *Anopheles farauti*. It was not until strategic considerations required further study that U.S. Forces entomologists made more extensive collections. Following these the confused taxonomic status of the *Anopheles punctulatus* complex was soon clarified (Belkin, Knight and Roseboom 1945). These collections covered mainly North Guadalcanal, but also Malaita, Nggela (Florida Islands), Russells, New Georgia and Mono (Treasury Islands). *A.farauti* was to be found widely distributed whilst *A.punctulatus* and *A.koliensis* were found only on Guadalcanal.

After World War II several small surveys were carried out. These included those by Black (1952) on Guadalcanal, Savo and some of the Polynesian Outer Islands and by Laird (1955) in the mountainous interior of Guadalcanal. Most of these surveys found only A. farauti, but A. koliensis was reported from Guadalcanal and A. punctulatus from Savo. A report of a single female A. farauti from Bellona Island was also recorded in the summary made by Belkin (ibid) of all these surveys. The Eastern Outer Islands were surveyed in detail for the first time in 1956 resulting in A. farauti being found on several of the islands including Tikopia. This followed on from the collection of A. farauti larvae in the crater lake on Tikopia in 1955. The only other survey of note prior to the formal malaria eradication activities was the finding of A. farauti by Parsonson (1966, 1968) on Duff Islands, Vanikoro and Ndende, all in the Eastern Outer Islands. All of the pre spraying anopheline surveys of the Solomon Islands have been summarised by Taylor (1974). The more detailed surveys carried out by staff of the Malaria Eradication Programme and its precursors between 1962 and 1972 are covered later in this chapter. Some entomological information is also included for individual islands in Chapter 7.3 where this is relevant.

- Classification and taxonomy of the vectors

Of the seven species of anopheline mosquitoes in the Solomon Islands only three are vectors of malaria. The seven are classified as:-

Non Vectors — Bironella hollandii (Taylor 1934)

Anopheles (Cellia) solomonis (Belkin, Knight & Roseboom 1945)

	Anopheles (Cellia) lungae (Belkin and Schlosser 1944)		
	Anopheles (Cellia) nataliae (Belkin 1945)		
Vectors	*Anopheles (Cellia) farauti* (Laveran 1902)	}	The *Anopheles punctulatus* group
	Anopheles (Cellia) koliensis (Owen 1945)	}	
	Anopheles (Cellia) punctulatus (Dönitz 1901)	}	

The controversial taxonomy of the *punctulatus* group has now been clarified by Bryan (1973). In cross mating experiments carried out in the Ross Institute of Tropical Hygiene, London (using colonies reared from species collected in Papua New Guinea, Australia and the Solomon Islands) Bryan proved that there are four distinct species. Four colonies were reared each of which were reproductively isolated from the others. The four species now designated are:-

Anopheles (Cellia) punctulatus (Dönitz 1901)		
Anopheles (Cellia) koliensis (Owen 1945)		
Anopheles (Cellia) farauti No. 1 (Melanesia)	}	Provisionally
Anopheles (Cellia) farauti No. 2 (Australia)	}	

The final classification cannot be made until cross mating experiments are carried out with specimens from the *A. farauti* type locality on Efate in New Hebrides. Meanwhile *A. farauti* No. 2 (Australia) has not been found in the Solomon Islands.

- *Distribution of vectors*

When an overall review was made of the distribution of anophelines in the Solomon Islands, Taylor (1974) found that *A. farauti* was widely distributed on nearly all the inhabited islands (Figures 31 to 36). It was found in particularly high densities on the north coasts of all major islands. In some of the inhabited bush areas it

Fig. 31. DISTRIBUTION OF ANOPHELINE MOSQUITOES, WESTERN SOLOMONS

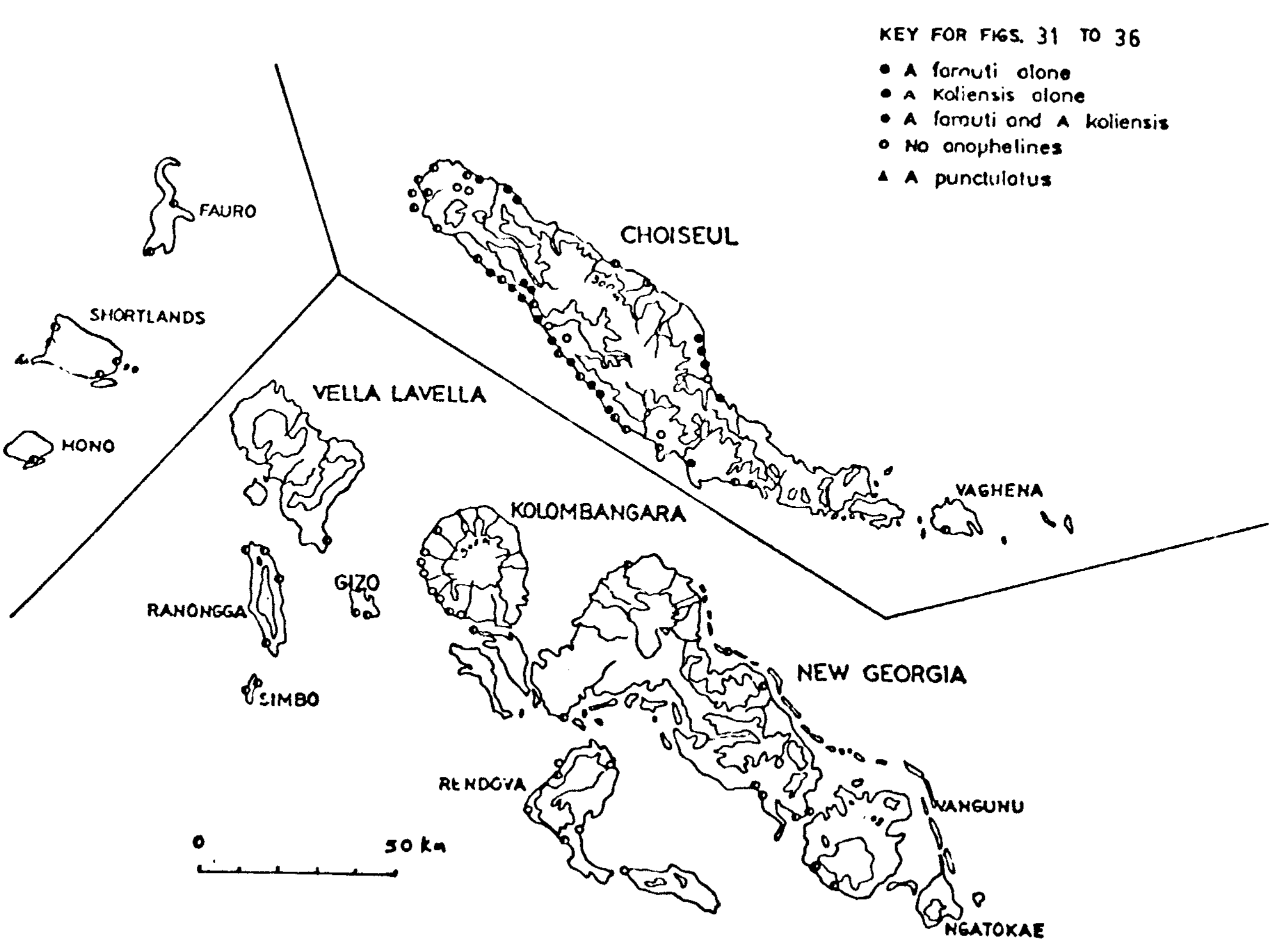
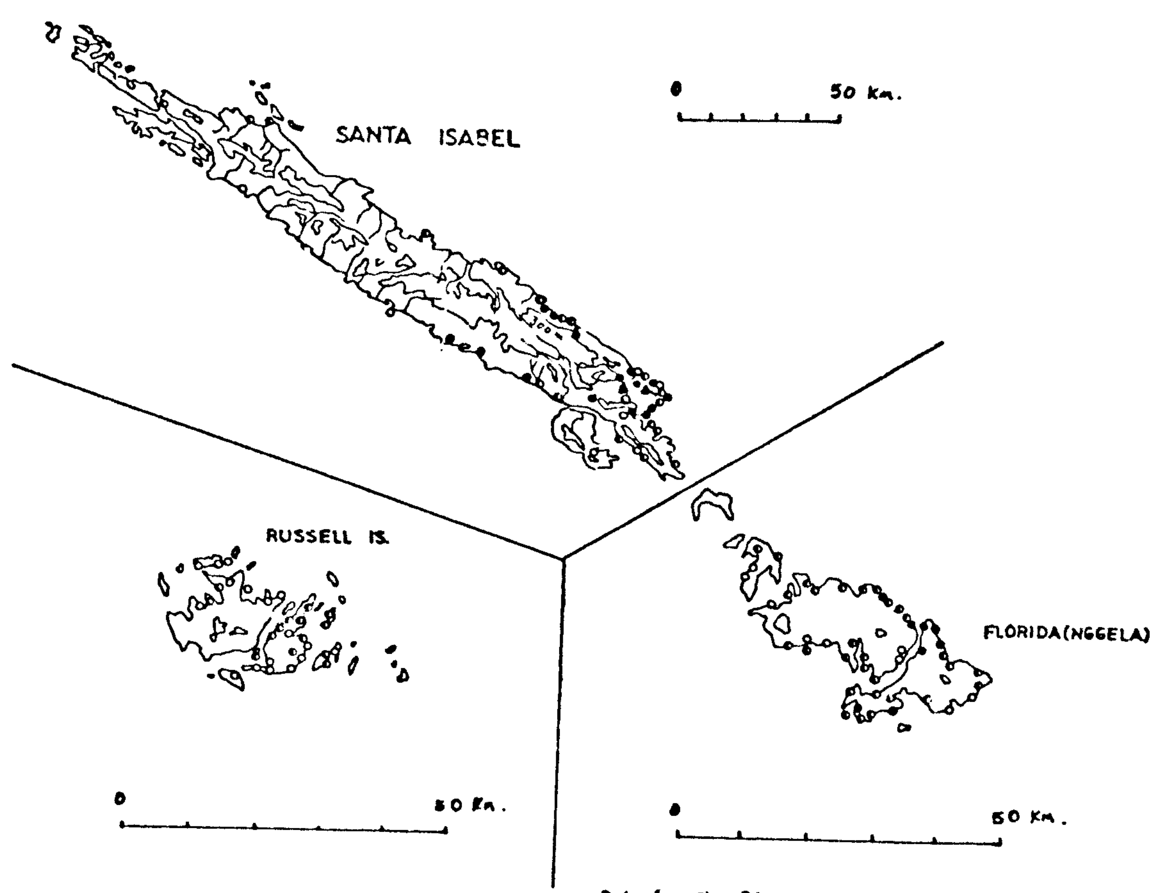


Fig. 32. DISTRIBUTION OF ANOPHELINE MOSQUITOES. SANTA ISABEL, FLORIDA, RUSSELL IS.



MEP SOLOMON ISLANDS

Data for Figs. 31 to 36 from Taylor (1974) with additions from MEP records.

Fig. 33. DISTRIBUTION OF ANOPHELINE MOSQUITOES. GUADALCANAL, SAVO, BELLONA RENNELL ISLANDS.

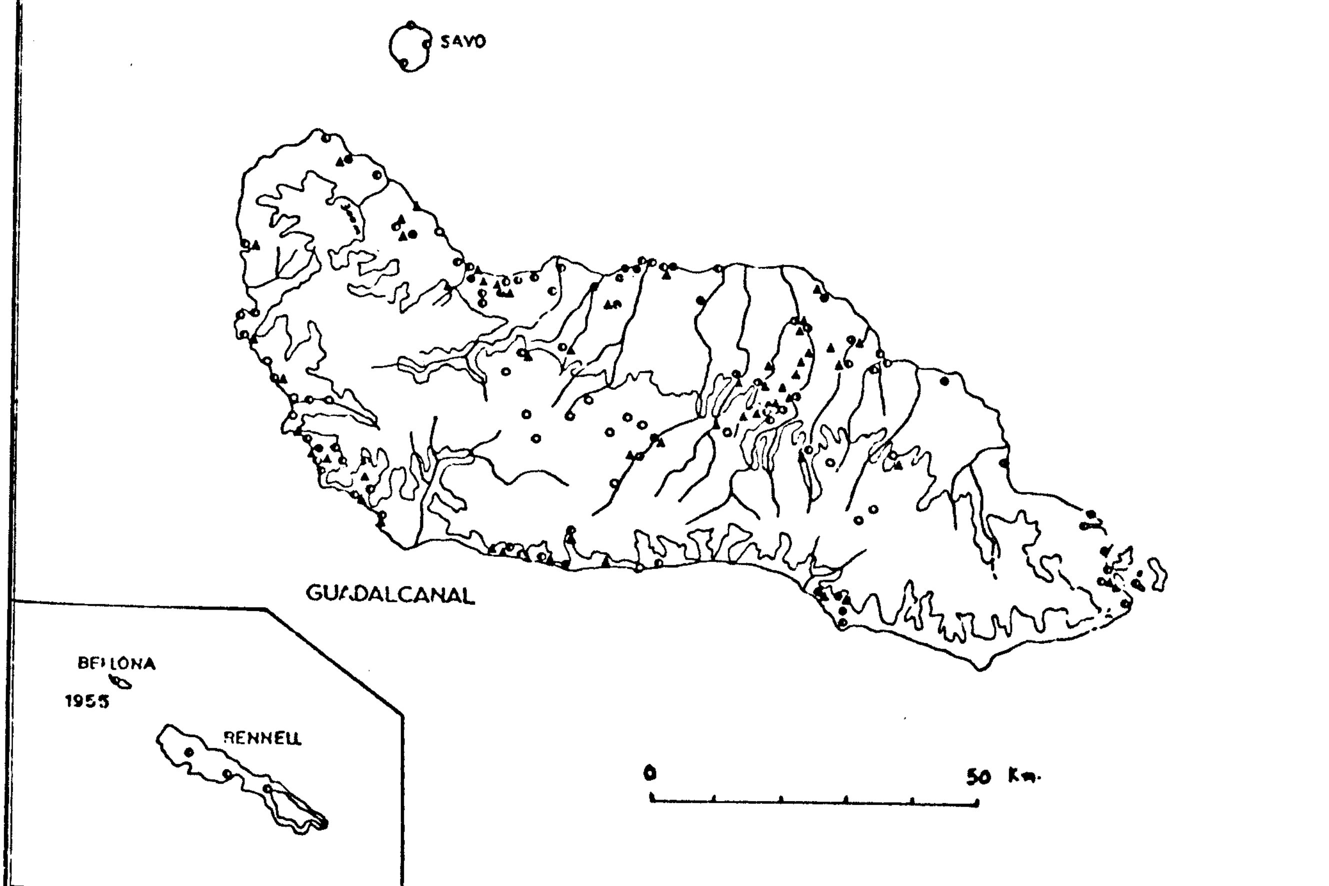
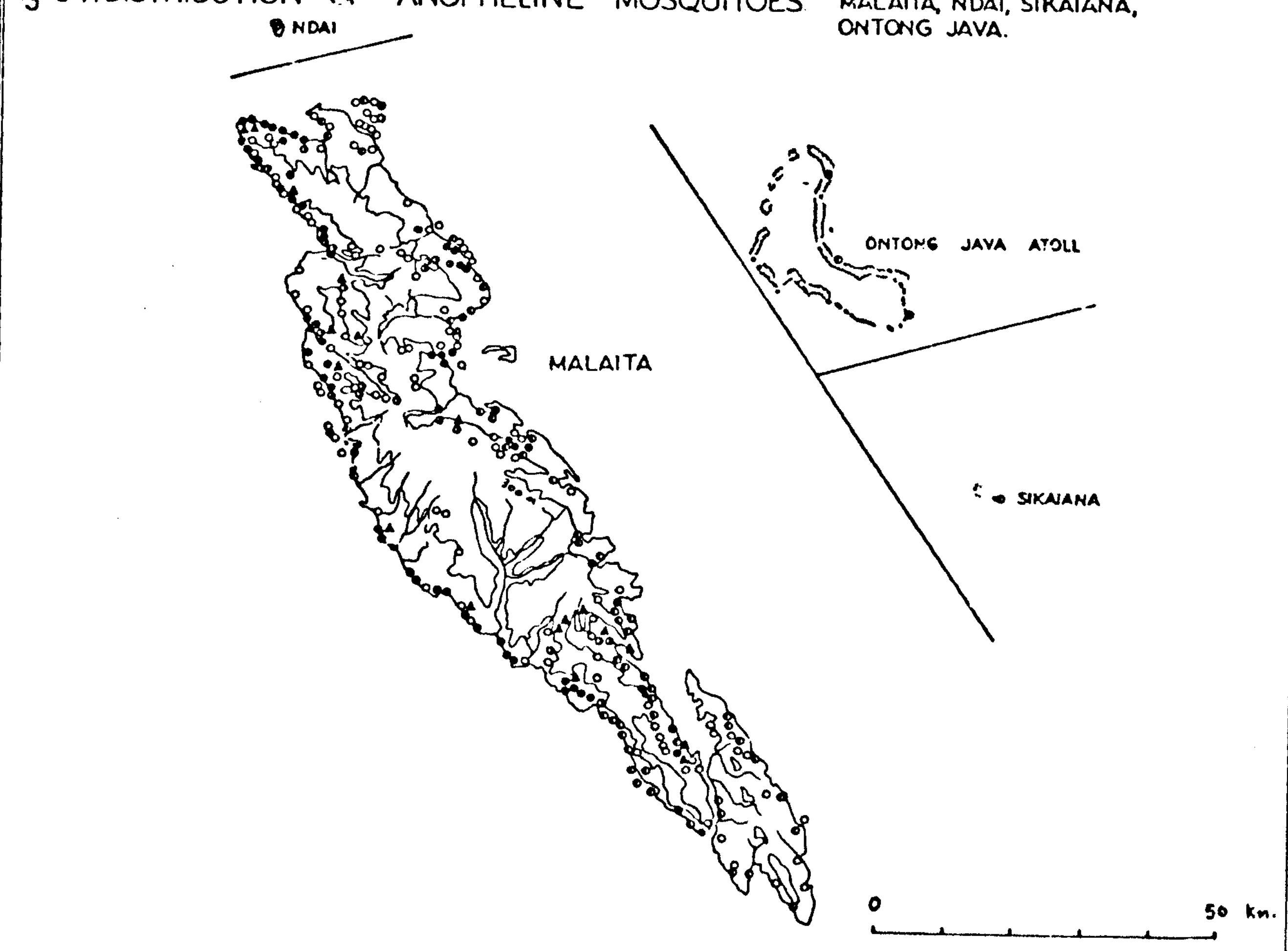


Fig. 34. DISTRIBUTION OF ANOPHELINE MOSQUITOES. MALAITA, NDAI, SIKAIANA, ONTONG JAVA.



MEP SOLOMON ISLANDS

Fig 35. DISTRIBUTION OF ANOPHELINE MOSQUITOES. EASTERN INNER ISLANDS

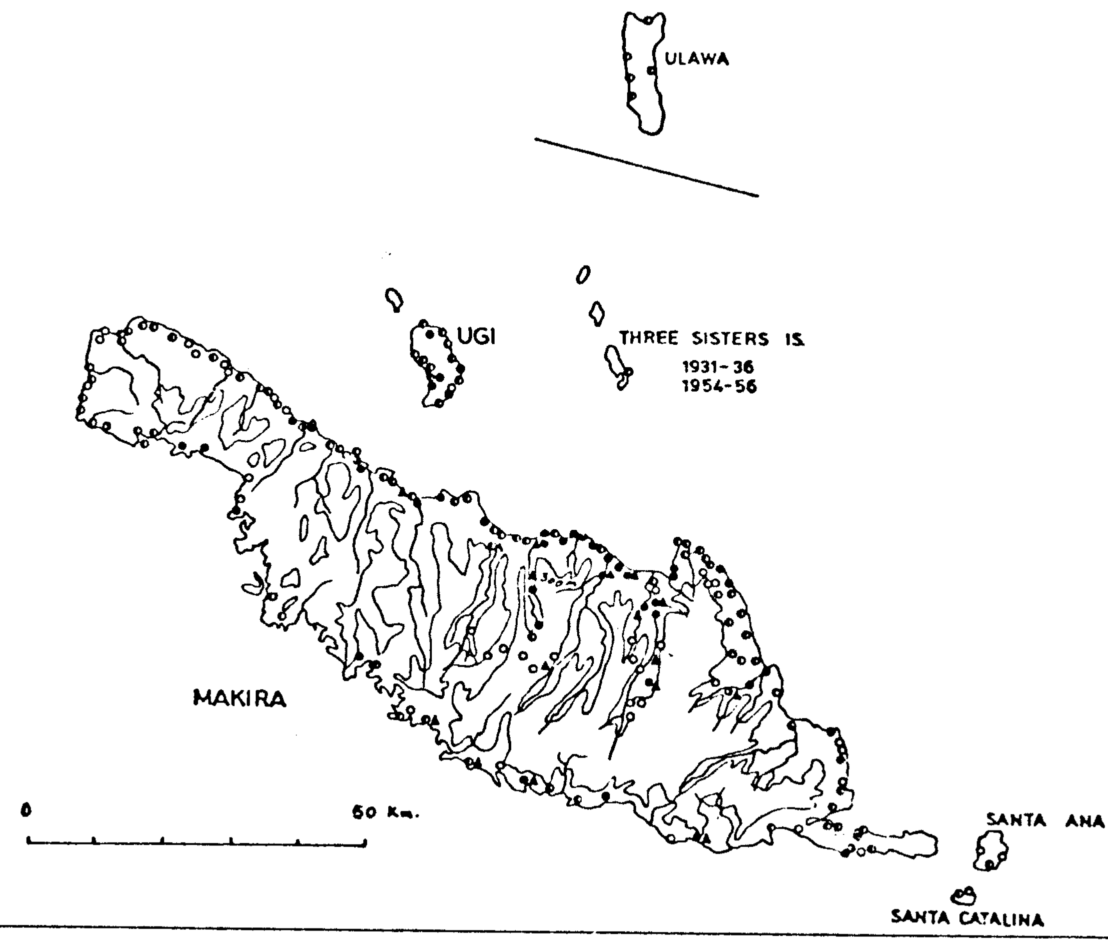
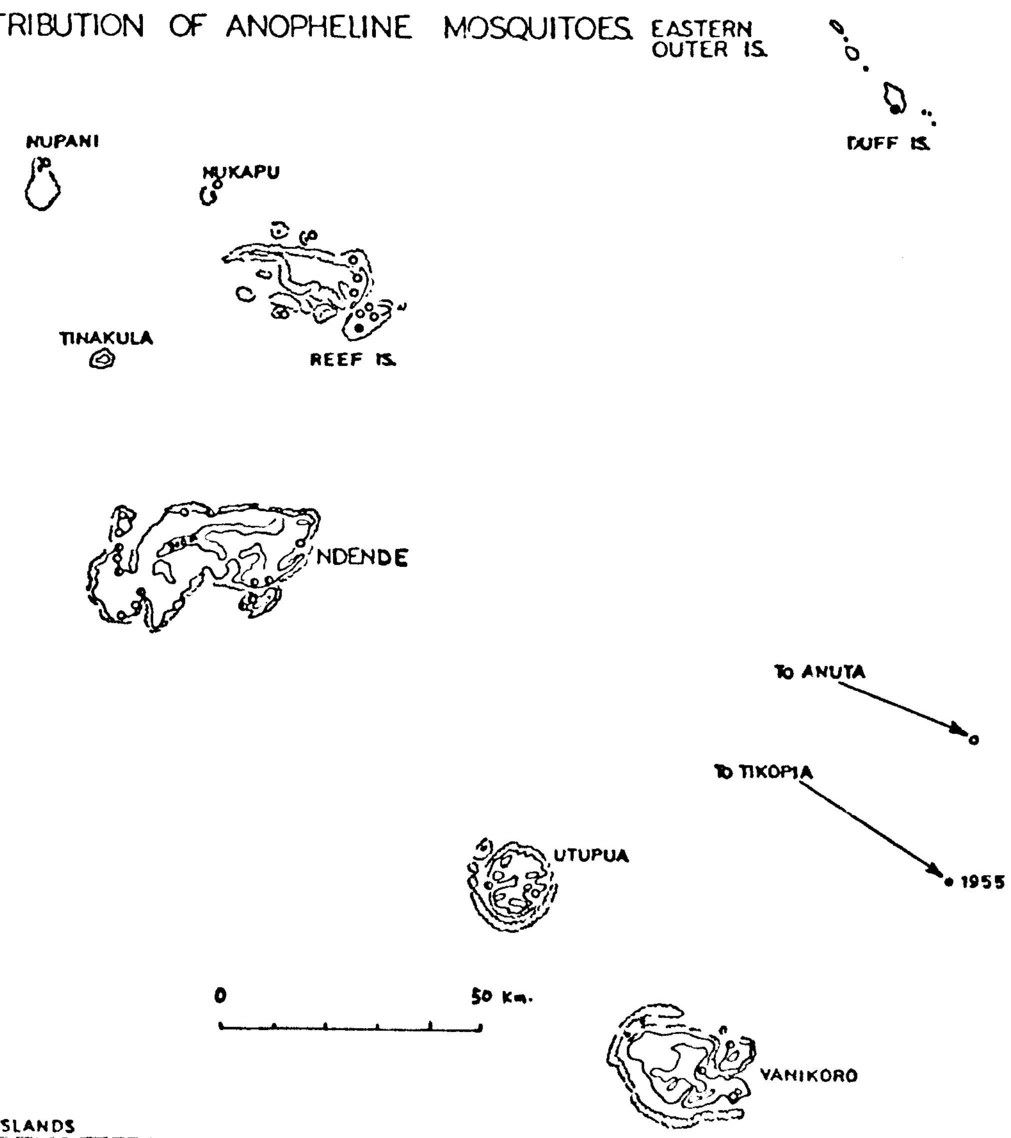


Fig. 36. DISTRIBUTION OF ANOPHELINE MOSQUITOES. EASTERN OUTER IS.



MEP SOLOMON ISLANDS

was found in lower densities along the river valleys. The high bush areas were found to be free from all anophelines. In several other coastal areas the major vector was easy to find, but in much lower densities than on the north coasts.

The subsidiary vectors A.koliensis and A.punctulatus were found to be much more restricted in their distribution. A.punctulatus was found on parts of Guadalcanal, Santa Isabel, Malaita and Makira. A.koliensis was also found on these islands and in addition, on Choiseul and Nggela. A.punctulatus tended to be quite localised in its distribution and was often found well inland along the river valleys. The earlier finding of A.punctulatus on Savo island could not be substantiated. A.koliensis preferred the coast but was also found occasionally up the river valleys. The maximum altitude at which A.farauti and A.koliensis was found was around 800 m. on Malaita. The maximum for A.punctulatus was the 580 m. recorded on Guadalcanal by Laird (1955).

No anophelines were found on Santa Catalina, on Anuta or on the Reef Outer Islands. On Bellona and Tikopia the earlier findings of A.farauti were not substantiated whilst on Rennell and Santa Ana A.farauti disappeared very soon after spraying started. No pre spraying survey was carried out on Three Sisters so the earlier findings of A.farauti on these islands could not be substantiated. Most of the islands of the Western Solomons, with the exception of Choiseul and Vaghena, were not surveyed in any detail pre spraying. It was only the subsequent surveys in malaria foci which found A.farauti in abundance. It is not known whether the subsidiary vectors were present in the New Georgia and Shortland groups before spraying.

- Capability of the A. punctulatus group as vectors

Malaria sporozoites have been found on several occasions in all members of the A. punctulatus complex throughout its geographical range e.g. in West Irian by Metselaar (1957) and in Papua New Guinea by Peters and Standfast (1960).

Few records exist of sporozoite dissections in anophelines in the Solomon Islands. The first detailed surveys were those carried out prior to the Malaria Eradication Pilot Project in 1962-63 (Mac gregor 1966). A summary of all known major dissections is shown in Table 14.

TABLE 14

Sporozoite rates in anopheline mosquitoes in the Solomon Islands

Date	Locality	Species of Mosquitoes	Number Dissected	Number with Sporozoites	Sporozoite Rate
Pre spraying					
(May 1962	Guadalcanal	A. farauti	3840	11	0.29
to	"	A. punctulatus	2730	10	0.37
Jan. 1963)	"	A. koliensis	405	9	2.20
Post spray					
1963-1964	Guadalcanal	A. farauti	6319	1	0.016
		A. punctulatus	22	0	0
		A. koliensis	12	0	0
Pre spray					
1968	Choiseul	A. farauti	265	2	0.8
	"	A. koliensis	18	0	0
1969	Russells	A. farauti	142	2	1.4
1969	S. Isabel	A. farauti	48	0	0
1969	"	A. koliensis	14	0	0

Sources: M.E.P. Field Reports, Alves (1965), Macgregor (1966).

Once spraying started further dissections consistently failed to detect sporozoites except for one report of a sporozoite positive

A. farauti caught out doors at Lunga near Honiara in November 1964 (Table 14). This was some 10 months after the start of spraying in that area.

In the early stages of the Pilot Project some calculations were also made on parity rates in order to try and determine the longevity of the vectors. In unsprayed Nggela in October 1964 78% of 142 specimens of A. farauti were found to be parous. At Koli in the sprayed North Guadalcanal, a range was found between 69 to 95% for 478 A. farauti dissected during the months May to November 1964. When it was seen that these results were inconclusive these particular studies were discontinued. After calculations by Sloof (1969) on vectorial capacity (after Garrett-Jones and Grab, 1964) these were also discontinued when it became clear that the potential for transmission was still high on North Guadalcanal. Since there was no doubt that transmission was still continuing in certain areas there appeared to be little jusitification in carrying out sophisticated entomological calculations. It was acknowledged however, that the information could have been useful had this been carried out regularly in North Guadalcanal in order to try and measure seasonal changes in longevity.

No studies were made on the extrinsic cycle for any of the species of malaria in any of the vectors. For practical purposes the figure for P. malariae (19 days in Papua New Guinea) was of little interest. With continuing transmission the figures for the other two parasites were certainly useful to know. These were taken to be the same as those found in the Sepik District of Papua New Guinea by Peters and Standfast (1960), namely P. falciparum - 11 days and P. vivax - 8 days.

- *Susceptibility to insecticides*

Although DDT was used as a larvicide and residual insecticide on Guadalcanal during World War II (Harper, Lisansky and Sasse 1947) its use did not become widespread until the start of the Pilot Project. Shortly after the war DDT applied to the walls of native houses in southern Papua was shown to reduce the transmission of malaria for a four month period (Bang, Hairston, Maier and Roberts 1947). In Espiritu Santo in the New Hebrides, Yust (1947) was able to free the environment from *A. farauti* for a period of three months by the use of DDT on breeding sites.

These initial successes were not followed up immediately as many malariologists considered that the exophilic habits of the *A. punctulatus* complex would not allow sufficient contact between vector and insecticide. In spite of these reservations (Ford 1950) considered that DDT residual spraying offered the most advantages as a control method in New Guinea. Pilot projects were set up in holoendemic areas around Hollandia in West Irian (Metselaar 1957) and at Wewak and Maprik in the Sepik District of Papua New Guinea (Peters and Standfast 1958, 1960). In both of these projects residual spraying with DDT wettable powder at $2 g/m^2$ resulted in high mortalities of anophelines. The effect lasted for three to four months and there were also falls in spleen and parasites rates. Dieldrin emulsion at $0.5 g/m^2$ also produced similar results. Although good control was achieved in these projects it appeared that the longevity of the anophelines was not sufficiently reduced to allow complete interruption of transmission. This was thought to be due to the people sleeping in garden huts, spending the early part of the evening outdoors and moving frequently between villages.

The nearest geographical locality in which resistance by anophelines to DDT has occurred is Java in Indonesia (WHO 1976[b]). On this island and also in Sabah and the Phillipines the vectors are also resistant to dieldrin.

The members of the A. punctulatus complex have not yet developed any true resistance to DDT. However in experiments in West Irian Sloof (1964) did show that DDT at a dosage of only 1.0 g/m^2 had a less repellent effect and resulted in a lower mortality for the group than DDT at 2.0 g/m^2.

Several susceptibility tests were carried out in the Solomon Islands both pre and post spraying. The results of most of these are summarised in Table 15 whilst selected tests have been plotted on the regression diagram in Figure 37. The majority of the tests have confirmed that there is no resistance by A. farauti or A. punctulatus to the standard dosage of DDT at 2.0 g/m^2. Four tests gave a hint of incipient resistance at the discriminating dose of 4.0% DDT. There was also some sign of vigour tolerance or possible seasonal change in susceptibility as shown in Figure 37. Whilst these findings in no way suggest a need for a change of insecticide they do indicate that a reduced dosage would be very risky. The lack of specimens precluded tests on A. koliensis.

The few tests with A. farauti for susceptibility to dieldrin all confirmed resistance to this insecticide. Since dieldrin is less repellent than DDT for the A. punctulatus group it had been hoped at one time that this insecticide could have been used to give a better guarantee of contact with a lethal dose.

TABLE 15

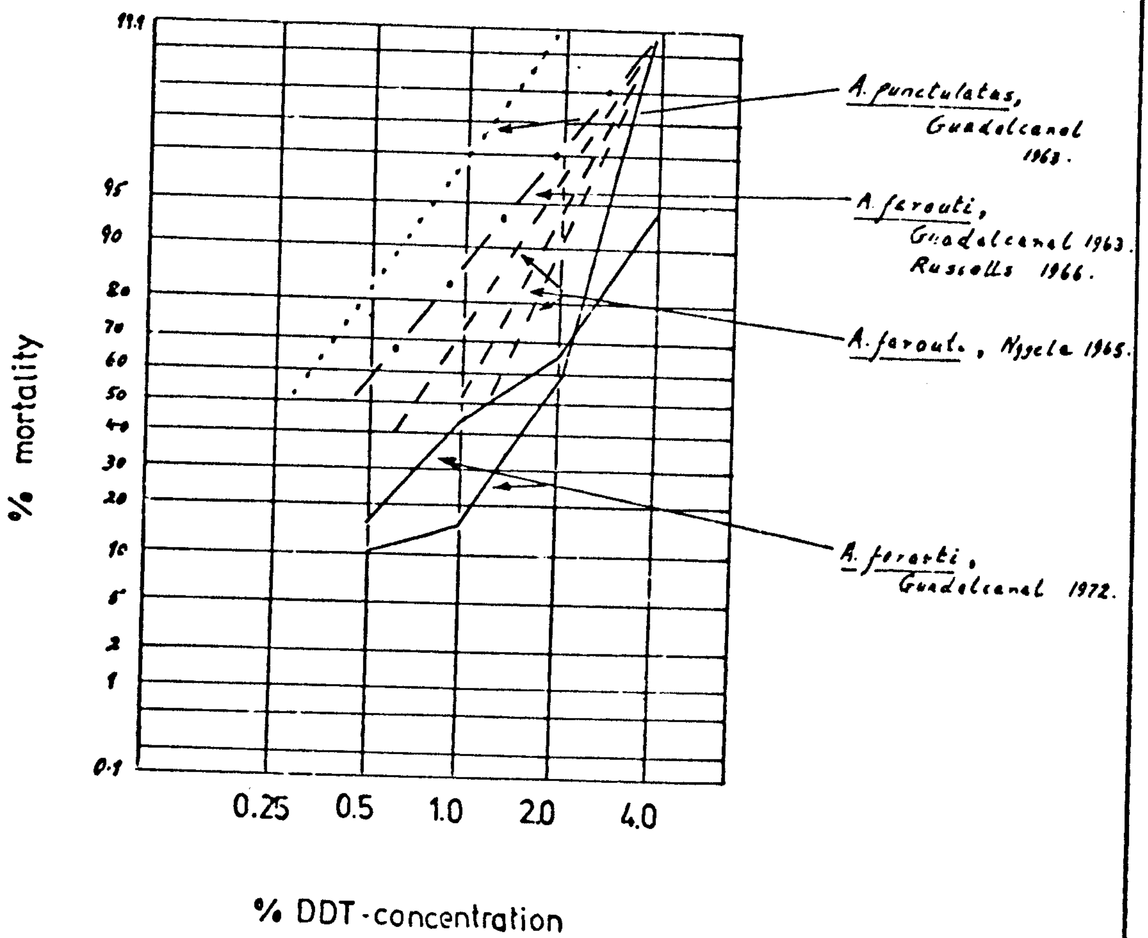
Summary of insecticide susceptibility tests in the Solomon Islands

Date 19-	Locality	Anopheline Species f, p, k	Number Tested	Years of Exposure to Insecticide	LC 50	LC 100	Comment
Insecticide - DDT					% DDT Concen-tration		
Sep. 62	Honiara, Guadalcanal	f	195	Nil	0.45	4.0	
Jan. 63	Vura, Guadalcanal	p	NS	Nil	0.30	2.0	
Feb. 63	Koli, Guadalcanal	f	NS	Nil	0.42	4.0	
Oct. 63	Koli, Guadalcanal	f	NS	6 months	0.53	2.0	
Dec. 63	Lunga, Guadalcanal	f	NS	8 months	-	2.0	
Jun. 64	Lunga, Guadalcanal	f	NS	1 yr/1 mth	-	4.0	2% not tested
Nov. 64	Namavalu, Guadalcanal	f	NS	1 yr/7 mth	-	4.0	
Nov. 64	Tasmania, Savo	f	NS	1 yr/7 mth	-	4.0	
Nov. 64	Ilu, Guadalcanal	f	NS	1 yr/7 mth	-	>4.0	1 Survivor in 52 @ 4% DDT
Apr. 65	Tavulea, Nggela	f	NS	Nil	0.79	4.0	
May 65	Siarara, Nggela	f	NS	Nil	1.00	4.0	
May 65	Bungana, Nggela	f	NS	Nil	1.30	4.0	
Dec. 65	Takavali, Nggela	f	NS	Nil	1.10	4.0	
Jan. 66	Lunga, Guadalcanal	f	NS	2 yr/9 mth	1.0-2.0	4.0	
Mar. 66	Lunga, Guadalcanal	f	NS	2 yr/11 mth	0.92	4.0	
Mar. 66	Lever Pt. Russells	f	NS	Nil	0.44	4.0	
May 66	Sipisai, Choiseul	f	NS	Nil	0.70	4.0	
Nov. 66	Lunga, Guadalcanal	f	NS	3 yr/7 mth	-	4.0	
Jul. 67	Samasodu, Isabel	f	NS	Nil	0.80	4.0	
Nov. 67	Suagi, Guadalcanal	f	NS	4 yr/7 mth	-	2.0	
Apr. 68	Ilu, Guadalcanal	f	NS	5 yr.	NR	>4.0	1 Survivor @ 4% DDT
Aug. 69	Tambea, Guadalcanal	f	NS	6 yr/4 mth	1.0	>4.0	3 Survivors @ 4% DDT
Jul. 70	Tadhimboko, Guadalcanal	f	61	7 yr/3 mth	2.1	4.0	
Jan. 71	Tamboko, Guadalcanal	f	145	7 yr/ 9 mth	1.4	4.0	
Feb. 72	Koli, Guadalcanal	f	315	8 yr/10 mth	1.3	>4.0	4 Survivors in 70 @ 4% DDT
Feb. 72	Lunga, Guadalcanal	f	182	8 yr/10 mth	1.8	4.0	
Mar. 73	Kukum, Guadalcanal	f	129	8 yr/1 mth	0.9	4.0	
" 74	Nth Guadalcanal	f	NS	9 yrs	NR	4.0	
" 75	Nth Guadalcanal	f	NS	9 yrs	NR	4.0	
Insecticide - Dieldrin							
Oct-Nov. 73	Gilutae, Guadalcanal	f	350	10 yr/6 mth	0.9	>4.0	
Jan. 74	Lunga, Guadalcanal	f	240	10 yr/9 mth	1.5-2.2	>4.0	5 survivors in 241 @ 4% DDT
Aug-Nov.74	Burn's Creek, Guadalcanal	f	540	11 yr/6 mth	1.1-2.3	>4.0	

f. - A. farauti p. - A. punctulatus NS - Not Stated NR-No Record No tests made on A. koliensis

Sources: Sloof (1969), van Seventer (1972) and MEP field reports.

Fig. 37. DDT SUSCEPTIBILITY REGRESSION LINES, 1963-72.



The rarely carried out Bio-Assay test using DDT or DDT/ malathion always resulted in a 100% kill of _A. farauti_ 24 hours after a one hour exposure to routinely DDT sprayed surfaces.

- Behaviour of the vectors pre spraying

Since the major problems are caused by _A. farauti_ most of the attention will be paid to this vector. Several earlier studies, summarised by Taylor (1974), have described the behaviour of _A. farauti_ in the Solomon Islands. This hardy and ubiquitous vector prefers the coastal littoral and the immediate foothills. Its favoured breeding site is at the side of partially sunlit, gently flowing streams where there is an abundance of vegetation. It also breeds close to the beach at the edge of estuaries blocked by sand bars. In addition to these sites _A. farauti_ is very capable of breeding in a wide range of other habitats notably small sunlit pools and man made water accumulations. This was seen most markedly during World War II (Oman and Christenson 1947) when the vector bred prolifically in wheel ruts, drainage channels and bomb craters on the Guadalcanal Plains. It continues to do so to this day.

Once deposited, the eggs of _A. farauti_ mature within 2-3 days. The larval stage lasts 3-7 days and the pupal stage 1-3 days. Adults may thus emerge from 6-13 days after oviposition. The precise mating habits are not known, but fertilisation is assumed to occur within one to two days after emergence. The female soon seeks a blood meal usually from man. Once replete she will then rest indoors and depart the house at daylight. Some bloodfed females may rest inside all day and only depart on the following morning. _A. farauti_ females also rest under bushes and plants, in tree holes or under fallen tree trunks by day but are often very difficult to find. In the late afternoon and possibly in the early morning the gravid females search for the nearest suitable breeding site and deposit their eggs. Soon after they seek out another blood meal and within two days have oviposited once again (i.e. the gonotrophic cycle is 2 days).

The day resting habits of anophelines are of some importance in deciding on spraying strategy. A few indoor surface (IS) collections were made in the early surveys but these were widely extended for the later surveys. In Malaita for example, 81.4% of 853 anophelines of all three vector species caught between 1967 and 1969, were found resting at heights of between 0-6 feet (0-2 metres). The remainder were found under furniture or in the roof and other less accessible sites (MEP entomology records). The pre spraying night biting pattern of A. farauti was one of continuous all night biting indoors and outdoors, but with a quick build up early in the evening followed by a progressive decline in activity (Figure 38). Outdoor biting densities were almost identical with the indoor ones. The Kira Kira surveys of 1971-72 showed a peak of biting indoors around midnight. Earlier surveys by Sloof on Nggela had suggested a more even distribution of night biting with a peak between 2100 and 0100. Biting by day was rarely experienced but Alves (1965) reported collecting 193 A. farauti biting human bait between 0830 and 1030 and 498 A. farauti resting outdoors at Lunga in Guadalcanal in November 1964 (i.e. post spraying).

The bionomics of A. farauti in the Solomon Islands are similar to many of the findings described by Black (1955[b]) and Spencer (1970,

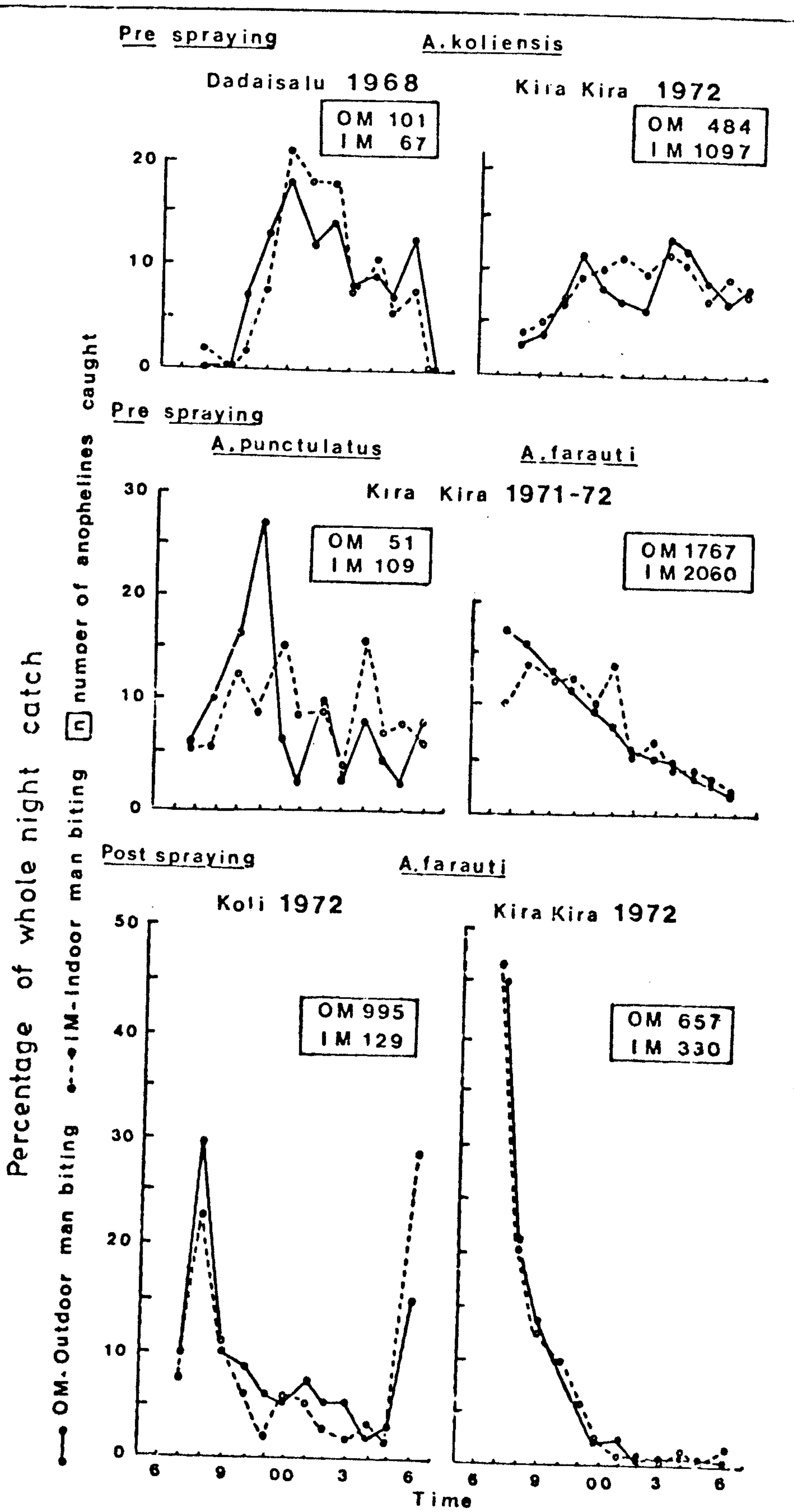


Fig. 38. Nocturnal biting patterns of anopheline mosquitoes, pre & post spraying, Solomon Islands.

1971) for coastal Papua New Guinea and by Sloof (ibid) for West Irian.

It seems unlikely that the same seasonal factors for survival and longevity operate in highland Guadalcanal as have been described for the highlands of New Guinea (Peters and Christian 1960). In contrast to the plains the high bush areas of Guadalcanal are reputed to have continuous all year round rainfall (see Chapter 3.2). Nevertheless it may be possible in exceptional circumstances for prolonged dry periods to occur.

The biting preferences of the A. punctulatus group were tested only during the early stages of the anti-malaria work. The only test on A. punctulatus found only 8 of the 21 specimens to have taken human blood (Table 16). In contrast A. koliensis was found to be strongly anthropophilic. The tests for A. farauti showed a wide range of results but with generally a strong preference for human blood. There was no indication from the small number of tests that any change occurred in biting preferences after spraying. There was also no sign when cattle came to be used more widely that A. farauti was using these as an alternative host. On 4th February 1972 van Seventer (1972) was unable to catch any anophelines from three penned cows at Koli during the peak biting time of 1900 to 2230.

The preference of A. farauti for human blood confirmed the findings of Black (1955[b]) and Spencer (1964) in Papua New Guinea and Sloof (ibid) in West Irian. Sloof claimed however, that the human preference may have been simply because of lack of alternative hosts since anophelines have also been found in abundance in uninhabited villages in New Guinea.

TABLE 16

Results of Precipitin Tests on Anopheline Mosquitoes, Solomon Islands 1962-67.

Date	Site	State of Spray-ing	Species f - A. farauti k - A. koliensis p - A. punctulatus	Mosquito Collection Site	Number Collected	Positive for						Human Blood Index
						Man	Bovid	Dog	Pig	Bird	Not Stated	
1962	North Guadalcanal	Pre	f.	Outdoor	54	23	0	23	8	0	0	0.43
1962	North Guadalcanal	Pre	k.	NS	19	16	NS	NS	NS	NS	NS	0.84
1962	North Guadalcanal	Pre	p.	NS	21	8	NS	NS	NS	NS	NS	0.28
1964	North Guadalcanal	Post	f.	NS	60	48	NS	NS	NS	NS	NS	0.80
1965	Lunga, Guadalcanal	Post	f.	Outdoor	73	36	NS	NS	NS	NS	NS	0.49
1965	Tavulea, Nggela	Pre	f.	House	50	39	0	8	0	0	3	0.78
1965	Koli, Guadalcanal	Post	f.	Outdoor	12	3	NS	NS	NS	NS	NS	0.25
1966	Mango, Choiseul	Pre	f.	House	46	45	NS	NS	NS	NS	NS	0.98
1967	Lunga, Guadalcanal	Post	f.	Outdoor	52	44	NS	NS	NS	NS	NS	0.85

NS - Not Stated

Sources: Alves (1965), Macgregor (1966), Sloof (1969) and M.E.P. Field Reports.

Little information was obtained on the subsidiary vector A. koliensis since it was only found in low numbers and densities pre spraying. It was found breeding in ditches or temporary collections of water often slightly inland from the coast. This anopheline was found pre spraying to bite all through the night at Dadaisalu in Malaita with a peak of both IM and OM between 2200 and 0130 (Figure 38). The pattern was similar in the villages near Kira Kira on Makira except that the outdoor pattern had two peaks one at 2200 and another 0200.

A. punctulatus was more often found a little inland in the river valleys. It had fairly restricted breeding preferences for small temporary sunlit pools, part shaded rainwater pools or for areas of recent disturbances by man or animals. These sites were usually quite close to human habitation. This vector was found by Oman and Christenson (1947) to retreat to the foot hills on Guadalcanal during the dry season. A. punctulatus was also found to proliferate after heavy rains and was stated by Taylor (1974) to be found mainly in the vicinity of alluvial soils or limestone.

The only record of night biting patterns was the pre spraying collections from villages near Kira Kira. These involved only small numbers and showed a number of fluctuations for both IM and OM, but with biting going on all through the night (Figure 38).

No parity rates were calculated for A. koliensis or A. punctulatus due to the low numbers caught. Nor could post spraying biting patterns be established due to the rapid disappearance of these vectors once spraying started.

At no time during any of the mosquito catches was there any suggestion that alternative vectors were of any importance in the transmission of malaria. *A. lungae*, *A. nataliae* and *A. solomonis* have been known to bite man occasionally but their contact is so infrequent as to be of no concern. *B. hollandii* has never been caught biting man in the Solomon Islands.

- Behaviour of the vectors after DDT spraying

On Guadalcanal *A. koliensis* and *A. punctulatus* appeared to completely disappear after only two rounds of DDT residual spraying (Macgregor 1966, Sloof 1969). The same was true in Choiseul, Nggela, Santa Isabel and Malaita as they came under spray cover. In Makira, however, both subsidiary vectors persisted in small numbers in night catches for a few months following the first spray cycle. This was partly due to two villages being left unsprayed in order to continue studies on pre spraying night biting activities. In the absence of any worthwhile numbers of *A. punctulatus* and *A. koliensis*, it was not possible to reach any conclusions on the effect of DDT on their behaviour. The DDT certainly appeared to be remarkably effective in killing these vectors.

The behaviour of *A. farauti* after spraying was the subject of some confusion and controversy. The change in biting pattern to one of an early peak of outdoor biting confirmed similar findings in Papua New Guinea (Spencer, Spencer and Venters 1974) and West Irian (Sloof ibid). The typical pattern (Figure 38) was one of voracious biting during the first two to three hours of darkness followed by a long period of sporadic biting and a small subsidiary peak of activity before dawn. The findings in KiraKira showed a greater peak of activity early in the evening and less of a subsidiary peak at dawn. The densities by outdoor man biting were nearly always greater than by indoor biting although sometimes only marginally so.

The effect of DDT spraying was generally to markedly reduce the densities of mosquitoes biting at night. In Choiseul, New Georgia, Russells, Savo, south Guadalcanal, Santa Isabel and Malaita all of the vectors appeared to almost completely disappear following spraying. Subsequent investigations in Choiseul and Malaita, however, confirmed the presence of A. farauti in moderate numbers in numerous foci. On north Guadalcanal during the Pilot Project there was a remarkable drop in overall densities (Table 17) but they still remained very high during some of the catches (Alves 1965). In the early stages there was some indication of an increase in densities about four months after spraying. This was followed by a fall in densities following the next spray round. These trends became less obvious in later years but there was an overall increase in densities from 1963-64 to 1965-68 (Table 17). Seasonal trends were also indistinct although at certain periods there were high and low trends in keeping with the wet and dry seasons. Low densities were particularly noticeable during the dry seasons (July to October) of 1965, 66 and 67. Analysis of later surveys on North Guadalcanal during 1970-75 (Figure 47, Chapter 7.3) showed some peaks of very high densities but these did not necessarily correlate with high rainfall. Low densities were generally seen in the 'dry' season but again there were numerous anomalies.

A marked fall in densities of anophelines was also seen in the five survey villages near Kira Kiraon Makira following the first DDT spray round (Figure 42, Chapter 7.2). This was offset by a big increase in densities two months after cyclone Ida. In turn this was followed by several months of low rainfall (characteristic after cyclones - see Chapter 3.2) during which time densities of A. farauti reached levels as much as four times higher than the pre spraying figures. After further fluctuations during 1973 the densities steadily fell during 1974 and catches were discontinued in July.

Indoor surface collections were abandoned in all areas soon after the start of spraying. The two subsidiary vectors were never found by this method and A. farauti only rarely found. The longest they persisted to any degree was on Nggela when small numbers of A. farauti were still found on indoor surfaces up to about 6 months after the first cycle.

TABLE 17

Numbers of A. farauti caught per man hour at Koli, 1963-68, North Guadalcanal

Date	Months after Start of Spraying	Human Bait Collection		Indoor Surface (IS) Collections
		Outdoors (OM)	Indoors (IM)	
Early 1963	Pre Spray	107 (51)	95 (54)	NS
April 1963 - Nov.1964	Post Spray	2.4 (196)	0.5 (200)	NS
Jan. 1965- Jun. 1968	2yrs - 5½yrs	7.9 (NS)	1.7 (NS)	0.3
		(Monthly range varied from 1.5 - 17.0)	(Monthly range varied from 0.0 - 8.0)	

Notes: Figures in brackets ( ) are number of man hours spent on catches.
NS - Not Stated.

Sources: Alves (1965), Sloof (1969) and M.E.P. Records.

It is still not possible to say conclusively why A. farauti was found to change its biting pattern. This may have been due to repellency by the DDT or to the emergence of a stronger, mainly exophagic, early evening biting anopheline or to some other factors as yet undiscovered.

In studies in experimental huts in West Irian Sloof (1964) found that entry into DDT sprayed huts was much less than entry into unsprayed huts (excito - repellency). This resulted in less indoor and more outdoor biting. Sloof also found that the feeding and resting behaviour of A. farauti within a sprayed hut was affected by the restlessness of the host under biting attack and by irritation of the tarsi when mosquitoes rested on the wall. Anophelines entering sprayed huts were only half as successful in obtaining a blood meal as those which entered unsprayed huts. Mosquitoes tended to bite earlier and leave earlier in sprayed huts. In spite of these findings Sloof concluded that longevity was not sufficiently affected for adequate control of malaria to be achieved. In further experimental hut studies during his WHO assignment to the Solomon Islands Sloof (1969) confirmed some of his West Irian findings but was unable to reach any more definitive conclusions. Similarly, in a short term WHO consultancy, van Seventer (1972) made no further comment on behaviour except to conclude that the problem lay in man's close relationship to the early evening biting pattern of the vector.

The last opportunity to study the behaviour changes pre and post spraying was in Makira between 1971 and 1973. This was the last of the large islands to come under spray cover and an effort was made to carry out reasonable longitudinal surveys pre and post spraying. In a detailed analysis of these results (Taylor 1975) made a number of important observations relevant to the control of the vector. He suggested that the apparent changes in biting patterns were due to the persistence of an exophagic[1] fraction of the A. farauti population following DDT spraying. The formerly dominant endophagic[2] fraction was seriously reduced due to the deterrent (repellent) effect of DDT on this group. Since A. farauti is mainly man biting the endophagic fraction would tend to feed later at night when man is asleep. The exophagic fraction would tend to feed earlier in the evening when man is still active outdoors. The reduction in the endophagic fraction would therefore lead to an apparent change in observed biting patterns. Although the evidence for two fractions was very strong Taylor was unable to determine whether they were both present before spraying. He noted, however, that the post spraying indoor and outdoor biting patterns were identical (Figure 38). Pre spraying they were different. There was also a reduction of entry into houses, a shifting of the times of peak biting and a reduction in overall densities for A. farauti.

Apart from man being able to carry malaria parasites over wide areas by migration his detailed movements within the village during the hours of anopheline biting were also of great importance. Prior to DDT spraying, when anophelines were biting indoors and outdoors all through the night, evening movements were of no great significance. When A. farauti changed its habits after spraying to early evening outdoor biting, personal movements became very important. A

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1 Exophagy - preferring to take blood meals outdoors.

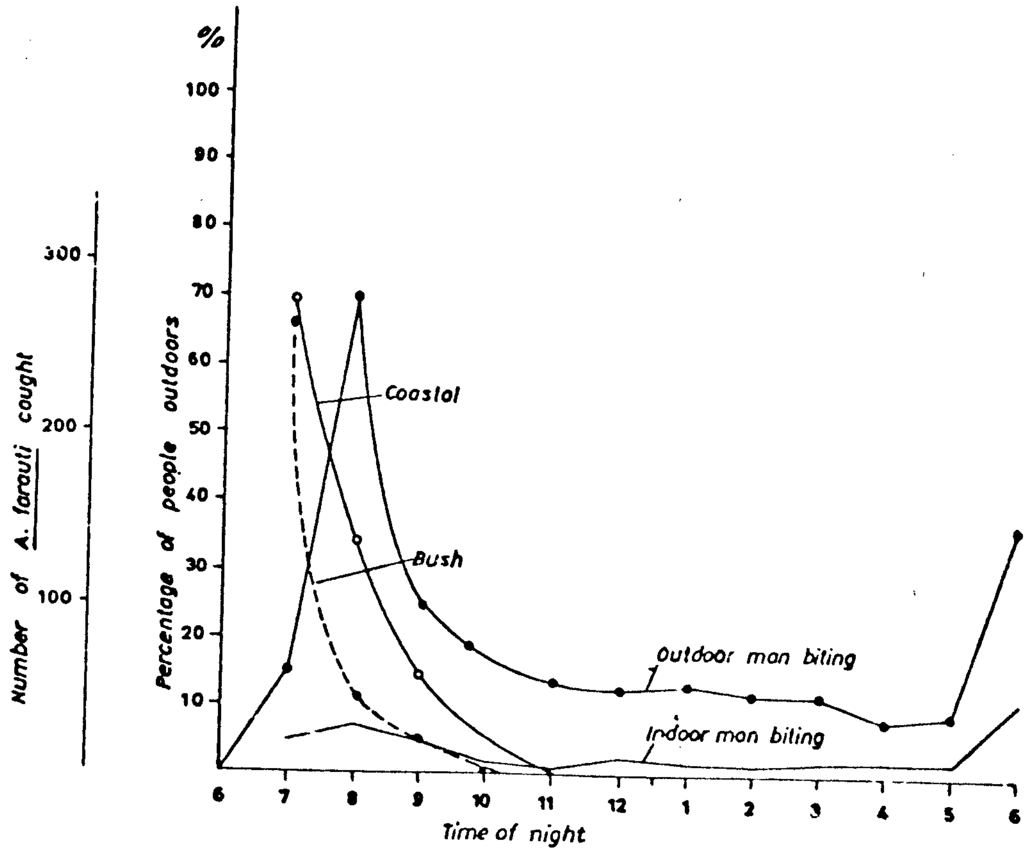
2 Endophagy - preferring to take blood meals indoors.

similar problem was noted in West Irian by Metselaar (ibid) and Sloof (ibid). In traditional villages in the Solomons the people tended to go indoors soon after dusk. As development proceeded they tended more and more to spend the early evening outdoors. After food preparation in open kitchens and a supper outdoors people congregated in the open walled church. Mothers with babies often stayed outside. Later on people still stopped outside talking and listening to the radio. Children often fell asleep outside when the weather was fine. In Nggela some of the people slept on the beach or in newly built unsprayed garden huts because of the irritation of bedbugs. During January to May 1975 MEP staff surveyed the indoor/outdoor activities of villagers around Kolosulu in central Guadalcanal bush and in coastal villages on north Guadalcanal. A count was made of all people indoors and outdoors at hourly intervals to 2100 on the coast and 2200 in the bush. The findings are shown in Figure 39. The peak of outdoor biting activity of A. farauti at 2000 came at a time when around 34% of the coastal people were still outdoors. The near coincident peak of man's evening outdoors activities with that of outdoor biting by A. farauti would appear to offer the anopheline maximum opportunity for obtaining a blood meal.

- Behaviour of vector after cessation of spraying

There was no opportunity to make a systematic study of the resurgence of vectors. DDT spraying was discontinued in the high bush areas of Guadalcanal and Malaita in 1972. The decision was made on parasitological grounds although a few casual surveys by senior staff had failed to locate any anophelines. In Malaita a few bush

Fig. 39 . POST SPRAYING NIGHT BITING ACTIVITY OF A . FARAUTI IN RELATION TO OUTDOOR ACTIVITY OF MAN, NORTH GUADALCANAL.



(Entomological data after van Seventer 1972)

M.E.P. SOLOMON ISLANDS.

transits during 1974 and 1975 failed to find any anophelines except in the river valleys. In the bush areas of Guadalcanal A. punctulatus larvae and adults were found at several sites during 1973 only 12 months after spraying had been stopped. These findings were mostly in the river valleys even as far as 18 km inland but A. punctulatus was also found in early 1975 at Kolosulu well above 300 m. During the same survey A. farauti was also found 25 km inland. Without more prolonged and systematic studies it was not possible to say how long it had taken for A. punctulatus to emerge after the withdrawal of spraying. From the very limited evidence available from Guadalcanal it appears that it may take only about twelve to eighteen months before the subsidiary vector re-establishes itself in sufficient numbers to be capable of causing malaria transmission.

When the islands of the New Georgia group went into consolidation in 1974 it was decided to carry out limited entomological surveys at fixed stations. Without baseline data comparisons were again difficult but early impressions were that A. farauti had become well established within a year after the cessation of spraying. These studies were unfortunately discontinued when the entomology staff were required for investigations into focal outbreaks.

- Experimental studies

In addition to the studies carried out by van Seventer and Taylor on the night biting pattern of A. farauti, some studies were made, mainly by Sloof (1969), using experimental huts. These were set up at Lunga near Honiara and later at Koli and Gilutae on the Guadalcanal Plains. The purpose of these experiments was to study the behaviour of A. farauti before and after spraying and to test the residual effect of DDT. The biting pattern of A. farauti was found to be very similar to that found when Sloof (1964) made his earlier studies in West Irian. Post spraying there was a tendency to bite earlier in the evening both indoors and outdoors. In the first month after spraying the mortality after a 24 hour recovery period was as high as 77.5%. By the fourth month this had fallen to 29.5% at which level it remained until further spraying. After the second spray the mortality again rose, but this time only to 50.8%. After four months it again fell this time to 30.2% and then remained static. These findings suggested the effect of DDT on mortality was considerably reduced after four months. The effects of DDT on feeding and on reducing entry, i.e. those effects thought to be due to repellency, were also noticeable immediately after the first spray round. In this case however, there was no wearing off in the effect at four months.

- Summary of entomological findings

In the coastal area of the Solomon Islands the main vector A. farauti has no difficulty in breeding and in obtaining blood meals. Such is the environment that within 8-10 days this vector will develop sporozoites if gametocytes have been taken up from an infected person. A. farauti is found in high densities in many areas and bites indoors and outdoors all through the night. It bites with more persistence in the early evening. This hardy and ubiquitous vector is susceptible to DDT but changes in its biting pattern following spraying do cause problems. The early evening peak biting coincides with a peak in man's outdoor activities which may be the reason for continuing transmission in areas with high densities of A.farauti. The aquatic stages of the life cycle are less amenable to control and a high standard of DDT coverage every 4-6 months remains the best attack on the vector at present.

The subsidiary vectors A.koliensis and A.punctulatus are less widely distributed. They tend to bite more in the middle of the night. They are highly susceptible to DDT and appear to present no great problems once spraying has started. A possible exception is A.punctulatus which may reappear in high riverine areas once the pressure of spraying has been removed for a few months.

7.2 Parasitological

- By serial surveys
- By surveillance

- By serial surveys

The results of the major spleen and parasite prevalence surveys, both pre and post spraying, are included in the next subsection of this chapter. These have been classified on a district and individual island basis.

The other series of results which have a distinct bearing on the epidemiology of disappearing malaria in the Solomon Islands are the incidence surveys. Regrettably only very limited information is available since few longitudinal pre spraying incidence surveys were carried out. Whilst the majority of the islands experience an even climate certain rain shadow areas do have marked seasonal changes in rainfall (Chapter 3.2). An early attempt at noting seasonal trends was made by Sayers (1943). He reported that between the years 1927 and 1934 in Roviana and Vella Lavella in New Georgia, the most malarious months were April, May and June. This was following on from the rainy season. There are occasional references to seasonal variations in malaria in the Medical Department Annual Reports (Chapter 2.2) but none with any specific details.

When the Pilot Project was started in 1962 it was realised that information on the seasonal incidence of malaria was lacking. Blood slides were collected from the Central Hospital, Honiara for a short period prior to the start of spraying operations. This information is unfortunately no longer available but it was never analysed in any detail.

Prior to the start of spraying on Nggela in 1970, an analysis was made of the monthly admissions of fever cases to the Anglican Hospital at Taroniara near Tulagi. This analysis showed that over the period of 1965-69 a greater number of fever cases occurred during the rainy season (Figure 40) than during the relatively dry season.

The most detailed analyses of seasonal trends in malaria were those made prior to DDT spraying operations in Malaita and Makira. Blood slides were collected from all fever cases presenting to Malaita District Hospital, Kilu'ufi, Auki from July 1968 until the start of spraying. Collections continued thereafter as part of routine surveillance. The monthly trends in malaria cases are shown in Figure 41. There are signs from this data of seasonal high peaks of malaria from October to May and of seasonal lows from June to September. Unfortunately the records did not continue for long enough to allow for more accurate analysis. The records have not

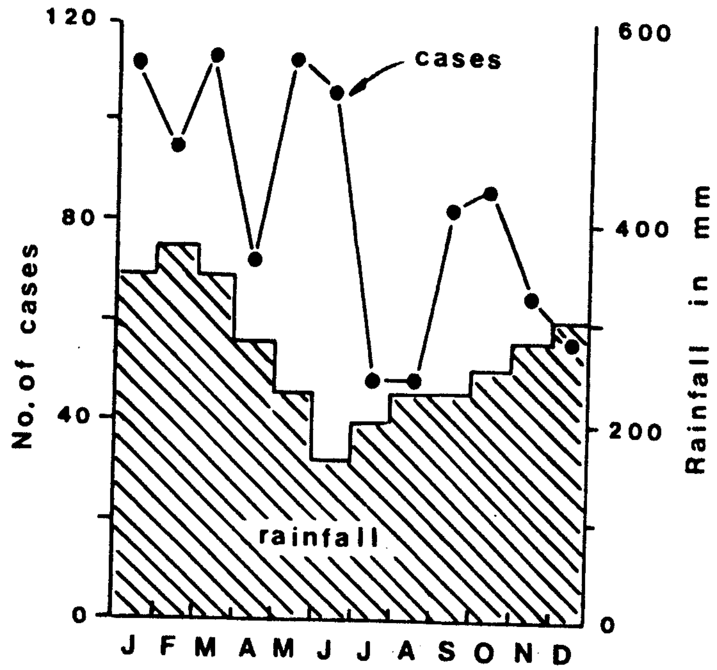


Fig. 40. Average monthly number of fever cases admitted to Taroniara hospital 1965-69

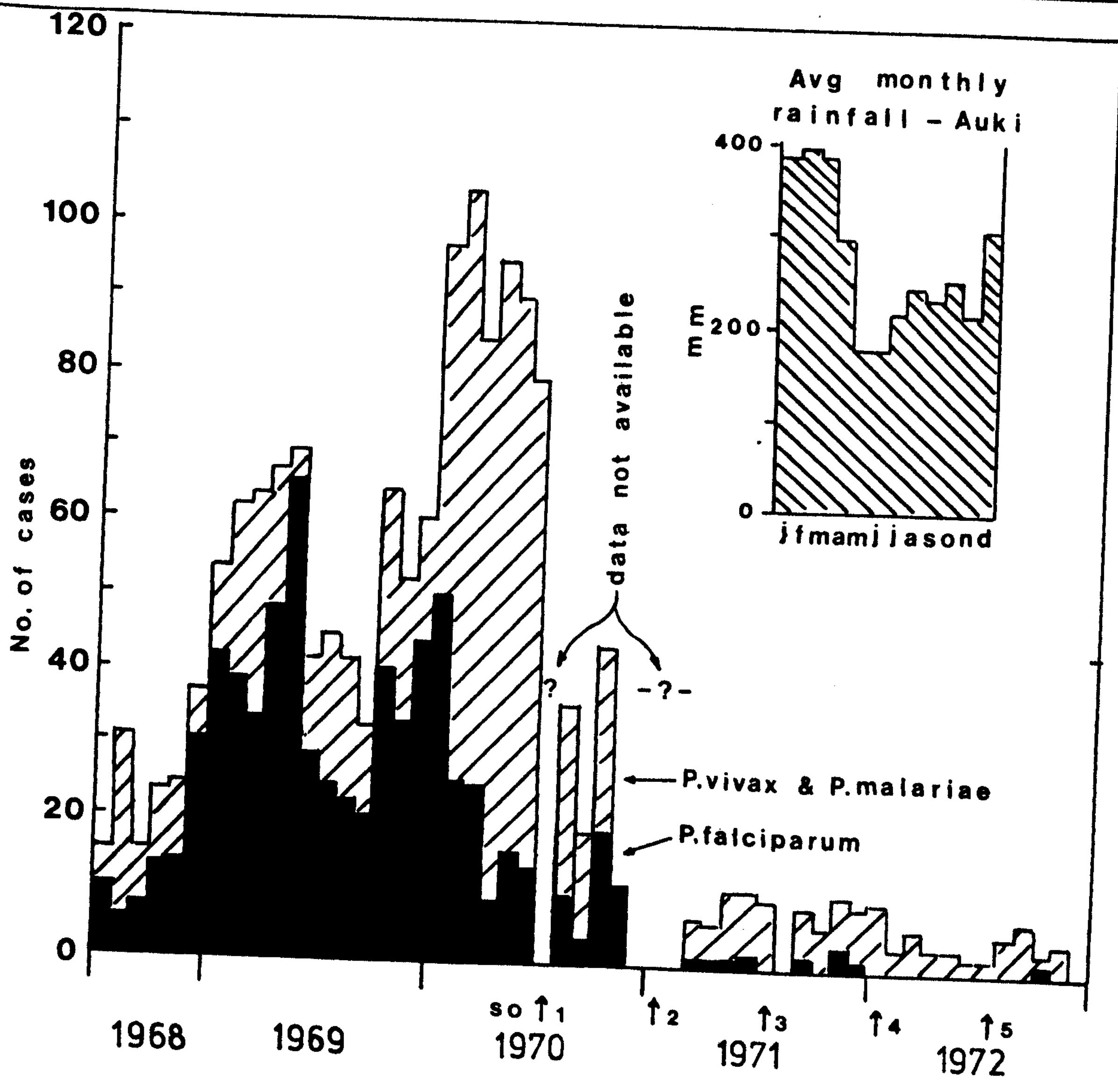


Fig.41. Monthly totals of malaria cases, Kilu'ufi hospital, Malaita. 1968-72.

been correlated with the detailed monthly rainfall data for Auki for the same period but the average rainfall in Auki does show a marked rise during the months of December to April (see inset, Figure 41). The seasonal increase in malaria cases in Auki therefore did appear to coincide with a seasonal increase in rainfall.

More detailed analysis was made of the 649 malaria cases detected at Kiluufi during 1969 (Table 18). The 1-9 age group accounted for 54.7% of all the malaria cases whilst 40.4% of the slides examined from this group were found to be malarious. P. falciparum accounted for 66.2% of the infections in the 1-9 age group and 66.0% in the all ages group. The overall parasite rate for all ages was 29.5%. A further item not listed in the tables was that only 7.2% of slides examined from the 0-3 months age group proved to be infected. It cannot be proved with any certainty that this was due to transplacental immunity since no serological studies were carried out.

When plans were being made for the expansion of the DDT spraying operations to the Eastern Solomons further efforts were made to obtain baseline longitudinal data. Blood slides were collected from fever cases presenting at Kira Kira Hospital from June 1969 until the start of spraying in October 1971. Collections continued thereafter as part of routine surveillance. During the last 8 months of this period night catches were also made for anopheline mosquitoes. Rainfall data was obtained from the meteorological station at the airfield. All of this information is shown in Figure 42.

The overall conclusion from the longitudinal studies in Kira Kira was that there was no clearly defined influence of rainfall on anopheline

TABLE 18

Analysis of all malaria cases detected at Kiluufi hospital, 1969.

Age Group	Number Examined	Number Positive	Parasite Rate %	Species of Positives f.	v.	m.	mx.	Percentage of total
0-1	298	70	23.5	46	12	10	2	10.8
1-4	554 } 878	229 } 355	41.3 } 40.4	137	46	37	9	35.3 } 54.7
5-9	324 }	126 }	38.9 }	88	16	16	6	19.4 }
10-14	146	41	28.1	27	6	6	2	6.3
15-19	117	35	29.9	22	8	3	2	5.4
Over 20	764	148	19.4	88	32	18	10	22.8
Total	2203	649	29.5	408	120	90	31 NS	100.0

Parasite Formula		f.	v.	m.
	1-9 age group	66.2	18.2	15.6
	All ages group	66.0	19.4	14.6

Mixed infections not included in the Parasite formula as they were not specified in the survey data. NS - Not Specified.

Source: Laboratory records, Kiluufi Hospital.

TABLE 19

Analysis of all malaria cases detected at Kira Kira hospital, 1970.

Age Group	Number Examined	Number Positive	Parasite Rate %	Species of Positives f.	v.	m.	mx.	Percentage of total
0-1	NA	82	NA	26	50	0	6 fv	9.9
1-4	"	393	"	121	244	3	24 fv 1 vm	47.5)
5-9	"	134	"	71	57	1	4 fv 1 vm	16.3))63.8
10-14	"	64	"	41	19	2	2 fv	7.7
15-19	"	30	"	17	12	0	1 fv	3.6
Over 20	"	124	"	62	58	1	3 fv	15.0
Total	2181	827	38.0	337	441	7	42 fv 2 vm.	100.0

Parasite Formula		f.	v.	m.
	1-9 age group	39.5	59.4	1.1
	All ages group	43.4	55.6	1.0

NA - data not available.

Source: Malaria case registers, Kira Kira Hospital.

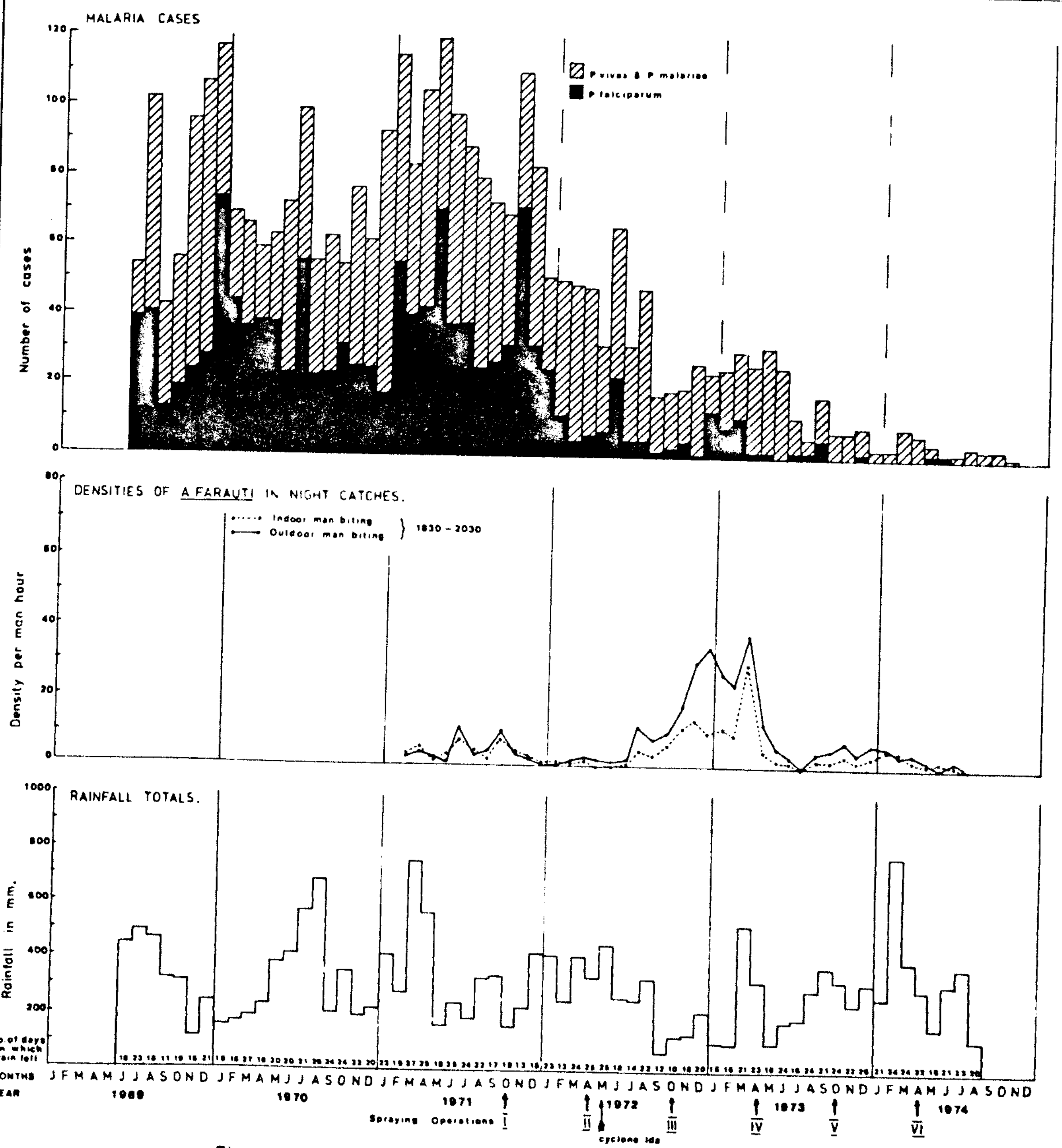


Fig 42 Monthly incidence of malaria cases, anopheline densities and rainfall in Kira Kira —— Solomon Islands, 1969 - 74

densities nor of either on malaria cases. There were however, trends which tended to show an increase in malaria cases following on shortly after increases in rainfall. Generally less malaria cases occurred during periods of low rainfall. There is a high annual rainfall in Kira Kira averaging 4267 mm annually. This is normally evenly distributed with only slightly higher falls at the beginning of the year. The years 1969-71 saw unusually large swings in monthly totals whilst 1972 had a prolonged relatively dry spell following cyclone Ida. It is probable that in periods of very heavy rainfall anopheline aquatic stages are stranded or swept out to sea and that adult densities may actually fall. It is also probable that during the periods of relative drought there is still ample rain to maintain most of the breeding sites.

An analysis of the 827 cases detected at Kira Kira during 1970 (Table 19) makes interesting comparison with the analysis for Kiluufi in Malaita. In spite of a higher all ages parasite rate of 38.0% the parasite formula showed P. vivax to predominate in the 1-9 and in the all ages groups. In the over 10 age groups however, P. falciparum just predominated. The figures for the 1-9 age group are in contrast to Malaita where P. falciparum predominated. We were unable to find any explanation for this reversal of roles of P. falciparum and P. vivax in Makira. In Kira Kira, as in Malaita, the 1-9 age group accounted for a large proportion of the cases. In Kira Kira it was 63.8%. In the prevalence surveys in both Makira and Malaita P. vivax was easily the major species (Tables 32 & 57).

A review was also made in the Kira Kira surveys of the sex distribution of malaria cases. This has not been recorded in the

Table since there was no significant difference between the sexes except for P. vivax infections in the 0-1 group. In this group females were infected more than twice as often as males.*

The post spraying surveillance returns for several islands showed seasonal trends in malaria often for several years after spraying (Chapter 7.3). This was probably due to a resumption of transmission when the potential was at its highest. It was seen for example in Choiseul and New Georgia and in Makira (Figure 42) and it was marked in Guadalcanal (Figures 46 & 47).

On the limited evidence available perennial transmission was the rule in the Solomon Islands. There were however, seasonal variations in some islands. These became more marked where there were definite differences in rainfall. On these occasions an increase in cases was often associated with an increase in rainfall. It was unlikely that transmission actually ceased during the low rainfall seasons except on those islands with very low levels of malaria.

- By surveillance

The detailed results for the surveillance returns for each of the major islands groups are shown in the various sections of Chapter 7.3. It has already been mentioned in Chapter 2 that a review of the records of malaria cases admitted to hospitals was discontinued from 1970 onwards. Nevertheless it was estimated by Tewari and Colbourne (1973) that perhaps 114 940 malaria cases would have occurred in the Solomon Islands in 1973 had there been no eradication operations. These authors then went on to estimate from the existing surveillance returns that probably 92 240 cases of malaria were prevented in 1973.

* Significance testing not possible due to loss of data on numbers examined.

The sum total of malaria cases recorded in the surveillance returns is still an under recording of the total cases although by 1975 it could be said that several islands were picking up most of the cases that existed. This is particularly true of the Eastern and Western Solomons.

Before moving on to the island returns a review has been made of the productivity of the various methods of surveillance. A review has also been made of the classification of malaria cases. For each of the years 1973-75 the most productive method of slide collection in every district was Passive Case Detection (PCD) (Table 20). Whilst on several occasions PCD was twice as effective as Active Case Detection (ACD) this should not underrate the importance of ACD in seeking out cases in more remote localities. The Table also shows how the 'other' sources also became relatively more important as the Slide Positivity Rate fell.

TABLE 20

The percentage of slides found positive by various methods of surveillance, by Districts, Solomon Islands. 1973-75

	1973			1974			1975		
	ACD	PCD	Others	ACD	PCD	Others	ACD	PCD	Others
Central	11.1	11.7	6.0	5.7	7.2	2.9	3.3	5.1	2.0
Eastern Inner Islands	10.8	14.8	9.4	2.5	3.3	2.7	0.6	1.1	1.0
Eastern Outer Islands	8.9	9.9	9.3	2.9	5.6	4.5	0.6	1.4	1.3
Malaita	3.0	5.0	3.1	0.7	2.8	3.4	1.7	4.7	1.6
Western	1.0	2.0	1.3	0.2	0.7	0.2	0.2	0.3	0.3
All Islands	6.3	8.5	5.8	2.4	4.4	2.1	1.6	3.3	1.6

ACD - Active Case Detection PCD - Passive Case Detection

Others - Case Follow up, House Contacts, Surveys.

Source: Data extracted from surveillance returns in MEP records.

The population coverage by one ACD agent (Table 21) is very low in the Solomon Islands when compared with international standards.

TABLE 21

Average population covered by one Agent, by Districts, Solomon Islands, 1974

District	Population (1974 MEP Figures)	Population Density per km2	Number of ACD Agents	Average Population per ACD Agent
Central	64016	6.0	51	1255
Eastern +	21774	5.2	12	1815
Malaita	55019	13.6	22	2500
Western	25679	4.2	24	1486

+ Several islands have no ACD.

According to Black (1968) the average population coverage for monthly visits by one agent should be about 7000 for a population density of below 50 per km^2. The low population coverage by the Solomon Islands ACD agents is explained by a number of factors. Population densities are generally very low and the terrain very difficult even using transport by sea. The population is highly mobile and often away in the gardens necessitating wide detours. Most villages are also visited fortnightly which further reduces the number that can be covered by one agent. Most ACD agents are also multi-purpose workers who do case treatment, investigation, follow up and remedial measures. Finally Solomon Island customs do not normally permit haste in social contacts and language or cultural barriers may also result in further delays.

A review has not been made of the classification of cases before 1974 because the numbers involved were not sufficient to merit detailed analysis. During 1974 and 1975 case investigation steadily improved in all Districts. In Central and Eastern Districts as the case load fell so the investigation coverage improved (Table 22). In the Western Solomons ever maturing surveillance investigated 94 out of the 101 cases in 1975. In Choiseul in 1975 all nine cases were fully investigated.

A breakdown of the 1975 investigations into island groups in the Western Solomons (Table 22), showed that 8 (36.4%) of the cases investigated in the Shortland Islands were classified as imported. Five (3 P. falciparum, 2 P. vivax) of the eight cases were from neighbouring Bougainville and several of the indigenous cases also had a recent history of visits to Bougainville. The remaining three cases (all P. vivax) were from New Georgia, Guadalcanal and Malaita.

In New Georgia 21 (33.3%) of the 63 investigated cases in 1975 were imported. Ten (all P. vivax) came from elsewhere in the Western Solomons and eight (all P. vivax) were from Guadalcanal. The remaining cases were two (1. P. falciparum, 1. P. vivax) from Malaita and one P. vivax from Papua New Guinea.

A detailed breakdown has not been made of imported cases in other Districts since their operations have not yet reached the same stage of advancement. In passing it should be noted that the Eastern District has already experienced a number of imported cases. The same district also found 18.2% of its investigated cases to be relapsing. These are further indicators of the maturity of the operation in that district.

TABLE 22

Classification of malaria cases, Solomon Islands, 1974 and 1975. By Districts.

Year	District	No. of cases	Species f.	Species v.	Species m.	Species mx.	Number investigated	Percentage investigated	Classification Indigenous/Introduced	Classification Relapsing	Classification Imported	Classification Not traced
1974	Central	2533	804	1696	7	26 fv	250	9.9	189	48	13	2283
	Eastern	544	35	460	48	1 fv	33	6.1	26	7	0	511
	Malaita	503	221	268	14	0	72	14.3	61	8	3	431
	Western	101	4	97	0	0	85	84.2	74	6	5	16
1975	Central	2195	305	1896	7	13 fv	684	27.0	579	54	51	1511
	Eastern	170	0	167	3	0	132	77.6	100	24	8	38
	Malaita	1088	737	345	2	4 fv	386	35.5	360	8	18	702
	Western	101	7	92	1	1 fv	94	93.1	60	5	29	7

By Island Groups in the Western Solomons.

Year	District	No. of cases	Species f.	Species v.	Species m.	Species mx.	Number investigated	Percentage investigated	Classification Indigenous/Introduced	Classification Relapsing	Classification Imported	Classification Not traced
1974	New Georgia	41	2	39	0	0	36	87.8	30	1	5	5
	Shortlands	34	2	32	0	0	28	82.4	28	0	0	6
	Choiseul	26	0	26	0	0	23	88.5	18	5	0	3
1975	New Georgia	66	5	60	1	0	63	95.5	41	1	21	3
	Shortlands	26	2	23	0	1	22	84.6	13	1	8	0
	Choiseul	9	0	9	0	0	9	100.0	6	3	0	0

Source: Data extracted from M.E.P. surveillance returns.

7.3 Progress by Islands

This Chapter contains the summary results of all malariometric surveys and surveillance returns for all of the major islands. These have been classified according to the four original Districts and sub-divided into islands or island groups. Some of the smaller and more remote islands have been included separately because of their unique character. The sequence of islands follows the same format as that outlined in Chapter 3.15, namely:-

- Central Solomons
    - Guadalcanal
    - Savo
    - Russell Islands
    - Nggela (Florida) Islands
    - Santa Isabel
    - Bellona
    - Rennell
- Eastern Solomons
    - Eastern Inner Islands
        - Makira
        - Santa Ana and Santa Catalina
        - Uki
        - Ulawa
        - Three Sisters
    - Eastern Outer Islands
        - Ndende
        - Reef Main Islands
        - Reef Outer Islands
        - Duff Islands
        - Utupua
        - Vanikoro
        - Tikopia
        - Anuta
- Malaita
    - Mainland
    - Ndai
    - Ontong Java
    - Sikaiana

- Western Solomons

  - New Georgia group
    - New Georgia mainland
      - Roviana (including Vona Vona)
      - Marovo (including Vangunu, and Nggatokai)
    - Vella Lavella
    - Ranongga
    - Simbo
    - Gizo
    - Kolombangara
    - Rendova - Tetepare

  - Shortlands Islands group
    - Mono
    - Alu
    - Fauro

  - Choiseul group
    - Mainland
    - Vaghena

These island commentaries also contain basic information on entomological findings and progress in spraying operations. They also highlight certain special features where these are relevant and comment on prospects for eradication. Finally they comment on receptivity and vulnerability to the reintroduction of malaria.

- Central Solomons

In this, the largest and most populous of the four districts, the progress in the eradication of malaria has been the least satisfactory. Nevertheless, if Guadalcanal is excluded, progress has actually been very good in all of the remaining islands. The overall progress may be seen from the results of the pre and post spraying malariometric surveys (Tables 23-27) and also from the results for surveillance from the whole district (Table 28) and from individual islands(Tables 29-31).

The Slide Positivity Rate (SPR) for the whole district fell from 13.8% in 1970 to 4.0% in 1975. The Annual Parasite Incidence (API)

TABLE 23

Results of pre spraying spleen surveys, Central Solomons.

Date	Surveyor	Age group	Number Examined	Number Positive	Spleen Rate %
Guadalcanal (35187)					
1944	Levine/ Harper	All ages	253	NS	73
May 1952	Black	2-10	50	47	94.0
Savo (1352)					
1951	"AMO"	All ages	248	NS	36
May 1952	Black	2-10	76	65	85.3
Russells (2715)					
March 1966	de Iorio	2-9	420	119	28.3
Feb. 1970	Maffi	2-9	178	25	14.0
Nggela (5351)					
Jan. 1966	de Iorio	2-9	399	343	85.9
Aug. 1969	Maffi	2-9	546	389	71.7
Jan. 1970	Maffi	2-9	159	79	50.3
Santa Isabel (8653)					
Aug. 1966	de Iorio	2-9	132	NS	9.9
April 1969	Maffi	2-9	NS	NS	36.4
Bellona (604)					
June 1952	Black	All ages	180	7	3.9
		2-10	33	2	6.1
April 1966	de Iorio	2-9	97	13	13.4
May 1969	Maffi	10-18	58	0	0.0
Rennell (900)					
June 1952	Black	All ages	245	47	19.2
		2-10	42	10	23.8
April 1966	de Iorio	2-9	127	20	15.7
Feb. 1970	Maffi	All ages	374	3	0.8

Note: Figure in brackets after island name is population in 1970 census.

NS - Not Specified.

TABLE 24

Results of pre and post spraying malaria parasite surveys of Guadalcanal

Population: 35187 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Pre spraying surveys										
1942-44	*	Levine/ Harper	All	1114	490	44	60	18	12	10
Aug.73	*	Laird ✱	All ages	100	15	15.0	0	6	9	0
May 52	*	Black ●	2-10	50	13	26.0	6	5	2	0
Nov. 62	*	Macgregor	1-9	3597	1612	44.8	773	392	247	75 fv. 62 fm. 48 vm. 15 fvm.
Post spraying surveys[1]										
1st Jul. 63	9	Macgregor	1-9	2781	377	14.0	126	118	58	47 fv. 6 fm. 19 vm. 3 fvm.
2nd Jan. 64	15	Macgregor	1-9	3439	218	6.3	18	89	98	1 fv. 2 fm. 10 vm.
Nov. 66	3½ yrs.	Avery-Jones ✱	2-9	162	25	15.4	1	14	9	1 vm.
Nov. 66		" " ●	2-9	94	17	18.1	3	10	4	
May 69	6 yrs.	Davidson●	2-9	206	32	15.5	16	?	?	?
Jan. 71	8 yrs.	Gibson +	2-9	766	5	0.7	NA	NA	NA	NA
Jan. 71	8 yrs.	Gibson +	All	1165	13	0.6	3	5	5	0

1st CSO - October 1962

Note: SO - Spraying Operation.
NA - Not Available.

✱ Central highlands
● Tadhimboko area
\+ South coast

[1] Note: Some figures in these surveys have been adjusted following corrections to the original data quoted by Macgregor (1966).

TABLE 25

Results of pre and post spraying malaria parasite surveys of Nggela (Florida) Islands

Population: 5351 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number Exam-ined	Number Posi-tive	Para-site Rate %	Species f.	Species v.	Species m.	Species mixed
Pre spraying surveys										
Mar. 65	*	de Iorio	2-9	762	429	56.3	239	103	59	7 fv. 13 fm. 6 vm. 2 fvm.
June & Aug. 69	*	Maffi & Eyres	2-9	589	410	69.6	56	307	16	24 fv. 2 fm. 5 vm.
Jan. 70	*	Maffi	2-9	159	86	54.1	18	61	1	6 fv.
Post spraying surveys										
1st Apr. 71	12	Gibson	2-9	711	169	23.8	64	103	11	8 fv. 1 vm.
2nd Oct. 71	18	Gibson	2-9	800	241	30.1	37	181	19	3 fv. 1 fm.
3rd May 72	25	Gibson	2-9	781	237	30.3	95	113	19	7 fv. 2 fm. 1 vm.
4th Dec. 72	32	Gibson	2-9	827	78	9.4	6	68	4	0
5th Sep. 73	41	Alexander	2-9	656	41	6.3	10	31	0	0
6th Nov. 74	55	Paitahua	2-9	420	6	1.4	1	5	0	0

Note: SO - Spraying Operation.

TABLE 26

Results of pre and post spraying malaria parasite surveys of Santa Isabel
Population: 8653 (1970 census)

Date	Months after 1st S.O.	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Pre spraying surveys										
Aug. 66	*	de Iorio	2-9	132	NS	13.5	Not specified			
Jul. 67	*	Davidson	2-9	NS	NS	53.2	Not specified			
Jul. 69	*	Davidson	2-9	NS	NS	50.8	Not specified			
Nov.68-Apr. 69	*	Maffi	2-9	1041	444	42.7	130	264	83	19 fv. 14 fm.
Post spraying surveys										
1st Mar. 71	12	Harrison	2-9	299+	58	19.4	4	44	10	0
2nd Sep. 71	18	Gibson	2-9	793	111	14.0	4	85	25	1 fv. 2 fm.
3rd May. 72	26	Gibson	2-9	876	8	0.9	2	4	2	0

1st SO December 1969.

Note: SO - Spraying Operation.
NS - Not Specified.

+ North east coast only.

TABLE 27

Summary results of pre and post spraying parasite surveys in the 2-9 year age group, by selected islands, Central Solomons.

Island	Population (1970 census)	Pre spraying survey Parasite Rate	Post spraying survey Parasite Rates 1st	2nd	3rd	4th	5th	1st SO	Date of surveys
Savo+	1352	61.6 (219)	0.4 (963)	4.1 (973)	1.0 (1018)	0.0 (1066)	1.1 (1074)	Jan. 1963	1963-64
Russells	2715	26.0 (361)	13.7 (306)	6.8 (576)	1.5 (646)	*	*	Aug. 1970	1970-72
Bellona	604	3.7 (82)	0.6 (156)	*	*	*	*	None	1969-72
Rennell	900	7.6 (144)	←	None			→	Feb. 1970	1970

Note: Number in brackets under Parasite rate is number examined.

SO - Spraying Operation.
\+ - all post spraying surveys in Savo are in the All ages group.

TABLE 28

Results of malaria surveillance, Central District +, 1963 - 75.

Population:
1964 - 20130 (MEP estimates)
1966 - 25000 (" ")
1970 37439 (Census)
Population under surveillance only
1971 - 57504 (MEP estimates)
1972 - 60937 (" ")
1973 - 65346 (" ")
1974 - 64016 (MEP estimates)
1975 - 66827 (" ")
1976 - 70695 (Census)

+ includes Savo 1963-75, plus Guadalcanal 1964-75, plus Rennell 1970-75, plus Bellona, S. Isabel, Russells, Nggela 1971-75

	Year	Number of slides collected by				ABER by PCD+ ACD	Total cases by				Species				SPR% by PCD+ ACD	API‰ by All Sources
		ACD	PCD	Other Sources	All Sources		ACD	PCD	Other Sources	All Sources	f.	v.	m.	mixed		
MEPP	1963	187	0	NA	187	19.4	8	*	*	8	0	6	1	1 fv.	4.3	NR
MEPP	1964	4195	3657	NA	7852	39.0	402	433	*	835	386	NA	NA	NA	10.6	NR
MPEP	1965	5197	5565	NA	10762	48.9	NA	NA	*	1403	780	425	207	2vm (11)NS	13.0	NR
MPEP	1966	5276	11103	NA	16379	65.5	NA	NA	*	1004	634	255	129	1 fv. (15)NS	6.1	NR
MPEP	1967	8863	19765	NA	28628	102.2	NA	NA	*	2118	1414	467	267	(30)	7.4	NR
MPEP	1968	10110	18891	NA	29001	93.5	NA	NA	*	2848	1496	1257	188	2 fv (95)	9.8	NR
MPEP	1969	18486	18688	NA	37174	106.2	NA	NA	*	4322	2022	2292	113	3 fv (108)	11.6	NR
MEP	1970	14986	18926	NA	33912	90.6	2185	2509	*	4694	1963	2771	108	(148)	13.8	NR
MEP	1971	14272	14876	NA	29148	50.7	NA	NA	*	2061	560	1495	39	(33)	7.1	NR
MEP	1972	19760	16718	NA	36478	59.9	NA	NA	*	2109	646	1437	32	(7) 1 fv.	5.8	NR
MEP	1973	20963	14920	8571	44454	54.9	2332	1750	511	4593	2126	2418	7	42 fv.	11.4	70.3
MEP	1974	20178	14649	11115	45942	54.4	1157	1058	318	2533	804	1696	7	26 fv.	6.4	39.6
MEP	1975	24464	14864	30697	70025	58.9	818	752	625	2195	292	1883	7	13 fv.	4.0	32.8

TABLE 28 - continued

Notes:

ACD	-	Active Case Detection.
PCD	-	Passive Case Detection.
ABER%	-	Annual Blood Examination Rate.
SPR%	-	Slide Positivity Rate per hundred slides.
API‰	-	Annual Parasite Incidence per thousand population.
NA	-	Data Not Available.
NR	-	Data Not Relevant.
*	-	No Record or Not Established.
NS	-	Not Specified.

Other Sources include Case Follow up, House Contracts and Surveys.

Species - Mixed infections are specified where known. Where the number is in brackets the species was not specified in the returns. On these occasions the total of mixed species has been subtracted from the total of the other species (i.e. total infections) to give the total cases.

fell from 70.3‰ in 1973 to 32.8‰ in 1975. Results of progress by quarters since 1970 may be seen in Figure 46.

- Guadalcanal

The largest of the Solomon Islands, Guadalcanal was the one in which the new series of eradication operations was first launched. It was not long before it came to be realised that this island also presented the largest and most difficult malaria problem.

A number of entomological surveys were carried out prior to the Pilot Project in 1962. These have been summarised by Taylor (1974). Most surveys concentrated on the coastal areas of north Guadalcanal and had no difficulty in finding all three vectors. In the only recorded bush surveys, in August 1953, Laird (1955) found *A. punctulatus* 26 km. inland in Guadalcanal at an altitude of 580 metres. Immediately prior to the Pilot Project Mataika carried out an extensive round the island survey. All three vectors were found to be widely distributed around the island (Figure 33) although *A. farauti* was relatively uncommon in the bush areas. *A. punctulatus*, by contrast, was present a long way up several of the large river valleys. *A. koliensis* was frequently found in coastal and foothill areas.

During World War II Levine and Harper (1947) and Harper, Levine and Leibow (1949) recognised the serious influence of malaria on Guadalcanal. These workers found an all ages parasite rate of 44% in 1114 natives examined on the island (Table 24). The parasite rate in the 0-5 age group was as high as 91%. The spleen rate was also high being 73% in 253 of the all ages group. In May 1952 Black

(1952) carried out a brief survey in the Tadhimboko area of north Guadalcanal. The spleen rate of 94.0% in 50 children in the 2-10 age group allowed this particular area to be classified as holoendemic. The parasite rate was only 26.0% (Table 24) but 6 of the 13 cases were P. falciparum. Another brief survey was that of Laird (ibid) in the Betilonga bush. This found an all ages parasite rate of 15.0% but had only P. vivax and P. malariae present.

The major pre spraying parasitological survey of Guadalcanal was the one by the malaria team under Macgregor (1966) and his W.H.O. advisers in November 1962. This survey covered nearly 50% of the population but tended to concentrate more on the coastal areas. No spleen survey was carried out, but the 1-9 parasite rate of 44.8% is an indication that a spleen rate of over 50% would have been a distinct possibility. Using the parasite rate alone, however, the whole island has been classified in the high mosendemic range. The part of the north coast surveyed by Black (ibid) has been classified as holoendemic.

The survey by Macgregor found decreasing parasite rates in age groups as follows:-

Age	%
Under 1	69.0
1 - 4	63.1
5 - 9	30.6
10 - 14	29.2
Over 15	16.7

These trends confirmed the earlier findings of Harper et al (ibid). The loss of records from the early blood slide collections at Central hospital (see Chapter 7.2) means that no information is available on the seasonal incidence of malaria for Gualdalcanal. Subsequent surveillance returns gave clear indications of seasonal increases during the wet season on both the north and south coasts of the island.

Apart from the efforts of the U.S. Forces in World War II (see Chapter 2) and some ground control around Honiara, no antimalaria activities were carried out on Guadalcanal prior to 1962. DDT cyclical spraying started in October 1962. It continued at intervals of approximately 6 months (with occasional intervals as long as 8 months) so that, by the end of 1975, a total of 26 cycles had been completed. Public co-operation was excellent in early years but it gradually deteriorated so that less than 90% coverage was recorded for several areas in the mid 1970's. In the third cycle of 1975 on north Guadalcanal the coverage was only 84.6% (M.E.P. Annual Review 1975). Whole cycles were missed out in the bush areas during 1968-69 and on parts of the south coast during 1972. This was due to operational delays and DDT shortages. Spraying was discontinued in the high bush areas in early 1973 on the grounds that the vector could not be found in bush villages. It was resumed again in 1975 when parasitological evidence indicated that transmission had been renewed in some of these villages. In mid 1973 the whole of the north coast of Guadalcanal was changed to a 4 month cycle involving 3 spray rounds per annum. This was part of the combined effort to try and interrupt the long-standing transmission in this area.

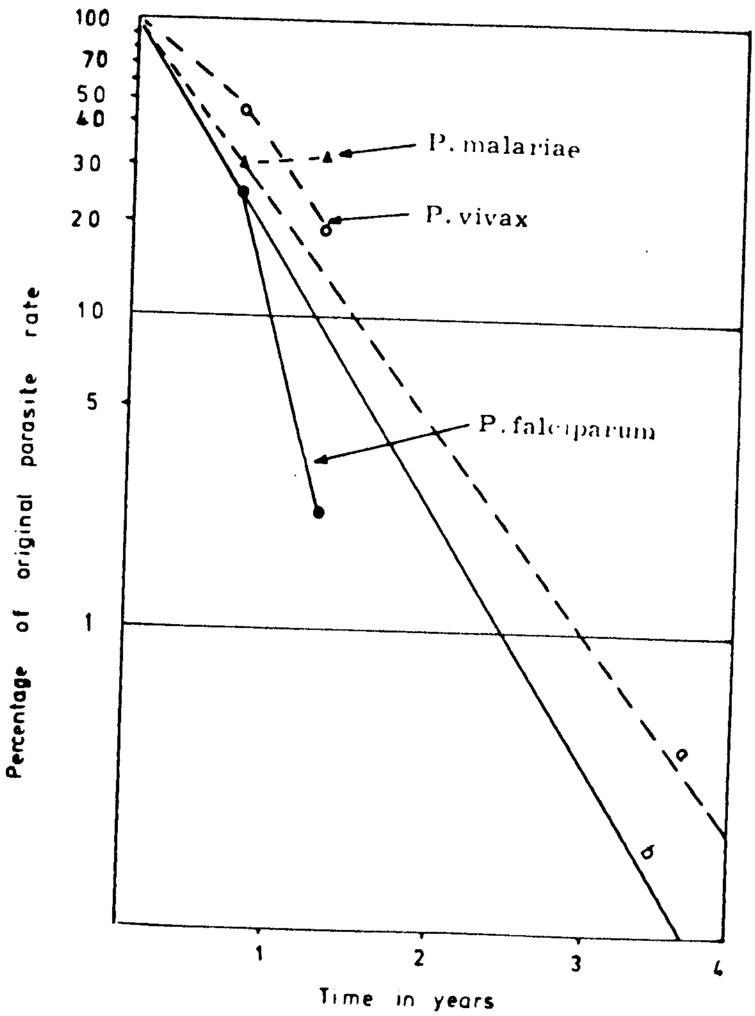
Several entomological fixed stations were set up around

Guadalcanal at which periodic night catches were made. Most of these were discontinued during the late 1960's due to the low catches but those around Honiara continued their activities. The results of these catches have already been covered in the entomological section of this Chapter.

The two post spraying parasitological surveys that were carried out during 1963-64 (Table 24) confirmed that the transmission of P. falciparum had been interrupted (Figure 43). The regression for P. vivax followed a characteristic pattern which was later confirmed by surveys on other islands. Even though the first criterion laid down by the World Health Organisation (W.H.O. 1964) was not satisfied it was felt by Macgregor (1966) that the pattern may still have been sufficient to confirm interruption of transmission for this particular strain of P. vivax malaria. The second criterion of zero infections in the 0-1 age group was satisfied for P. falciparum and P. vivax, but not for P. malariae. Even though transmission clearly was resumed subsequently, there is good evidence that it was interrupted during these early surveys.

Two minor surveys were carried out at later dates for assessment purposes. In November 1966 Avery-Jones found a 2-9 parasite rate of 15.4% in the Kolochulu bush area 32 km. to the south east of Honiara. In the same month he found a 2-9 parasite rate of 18.1% in Tadhimboko coastal villages. Then in May 1969, again in the Tadhimboko area where transmission was clearly continuing, Davidson found a 2-9 parasite rate of 15.5%. A more extensive survey was carried out by Gibson on the south coast of Guadalcanal in 1971. This found a 2-9 parasite rate of 0.7% in 766 slides examined.

Fig. 43. Fall in malaria parasite rates in the 1 - 9 age group following DDT spraying in Guadalcanal during 1962 - 64



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

The collection of blood slides for fever cases was started in Central Hospital in early 1962. Analysis of this was not undertaken in any detail until the setting up of Passive Case Detection (PCD) posts elsewhere on Guadalcanal in mid 1964 (Macgregor, ibid). An analysis of 3657 slides taken from fever cases in Central Hospital in 1964 found 433 (11.8%) positive including 144 P. falciparum. Meanwhile Active Case Detection (ACD) was also being set up around most of the island. The Annual Blood Examination Rate (ABER) for Guadalcanal was always very high right from the start of surveillance (Table 29). From 1966 onwards it was well over 60%. The Slide Positivity Rate (SPR) showed wide fluctuations with high peaks over 13% in 1965, 1970 and 1973 (Table 30). The figure of 5.3% in 1975, although still very high, was the lowest for the whole surveillance period. The annual totals of malaria cases (Table 31) also showed wide variations with a peak of 4586 cases in 1970. Encouraging trends were seen in 1971-72 with a big fall in cases especially in P. falciparum. This was followed by a serious relapse during 1973 when transmission was clearly resumed widely throughout much of north Guadalcanal. A reappraisal of operations with an increase in spray rounds and an intensive attack on foci saw further reduction in cases during 1974-75. Once again there was a big fall in P. falciparum but, at the end of 1975, several small foci remained. As the past had so frequently shown, these were all capable of spreading and fusing into widespread activity. The quarterly data in Figure 46 shows the seasonal trends more clearly. Although this is for the whole of the Central Solomons it largely reflects the pattern in Guadalcanal which was easily the major contributor to the totals of cases. A more

TABLE 29

Annual blood examination rate (%) by Islands, Central Solomons, 1963-75.

Island	Year 19- Population (1970 census)	63	64	65	66	67	68	69	70	71	72	73	74	75
Guadalcanal	35187	*	40.7	48.7	66.1	107.1	98.4	114.1	93.1	72.9	72.5	61.9	61.3	64.3
Savo	1352	17.5	8.9	46.4	42.9	21.1	37.5	52.2	71.1	49.6	44.8	26.5	31.2	45.1
Russells	2715	*	*	*	*	*	*	*	*	4.3	5.7	27.9	30.1	31.8
Nggela	5351	*	*	*	*	*	*	*	*	7.2	52.6	49.0	41.9	74.7
Santa Isabel	8653	*	*	*	*	*	*	*	*	7.7	33.4	42.8	47.9	57.0
Bellona	604	*	*	*	*	*	*	*	*	3.7	1.7	3.7	2.7	3.8
Rennell	900	*	*	*	*	*	*	*	19.1	30.7	54.2	60.3	14.9	10.2

TABLE 30

Slide positivity rate (%) and Annual parasite incidence (‰) by Islands, Central Solomons, 1963-75.

Year 19- Island	Slide Positivity Rate													Annual Parasite Incidence		
	63	64	65	66	67	68	69	70	71	72	73	74	75	73	74	75
Guadalcanal	*	10.8	13.4	6.1	7.5	9.8	11.6	14.0	7.0	5.5	13.6	7.9	5.3	93.2	54.8	47.7
Savo	4.3	1.0	6.4	5.5	1.6	10.7	10.9	11.0	3.5	1.9	2.4	2.9	3.8	6.3	9.2	23.8
Russells	*	*	*	*	*	*	*	*	5.2	2.6	1.1	0.1	0.1	3.0	0.3	0.3
Nggela	*	*	*	*	*	*	*	*	26.4	13.0	11.3	4.1	1.3	69.4	20.7	6.9
Santa Isabel	*	*	*	*	*	*	*	*	4.7	2.2	1.8	1.1	0.4	10.0	6.5	3.3
Bellona	*	*	*	*	*	*	*	*	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0
Rennell	*	*	*	*	*	*	*	1.1	3.1	0.4	0.0	1.4	0.0	0.0	2.1	0.0

— Islands which satisfy the Solomon Islands criteria for entry into consolidation (see Chapter 8.5 - Discussion)

TABLE 31

Annual totals of malaria cases in individual islands, Central Solomons, 1963-75.

	Guadalcanal	Savo	Russells	Nggela	Santa Isabel	Bellona	Rennell
1963	*	8(1)	*	*	*	*	*
64	834(386)	1	*	*	*	*	*
65	1369(759)	34(21)	*	*	*	*	*
66	976(617)	28(18)	*	*	*	*	*
67	2114(1410)	4(4)	*	*	*	*	*
68	2800(1479)	48(19)	*	*	*	*	*
69	4251(1995)	71(30)	*	*	*	*	*
70	4586(1930)	106(32)	*	*	*	*	2(1)
71	1877(496)	22(1)	6	114(55)	33(4)	0	9(4)
72	1576(415)	11(7)	4	446(217)	68(8)	2	2
73	3984(1706)	9(6)	8(3)	494(355)	98(59)	0	0
74	2305(644)	13(4)	1	148(117)	64(41)	0	2
75	2075(289)	35(1)	1	51(4)	33(11)	0	0

Notes: Figures in brackets ( ) are P. falciparum cases.

Cases for 1963-72 from ACD and PCD only.

Cases for 1973-75 from All Sources.

* No Surveillance.

detailed review of rainfall data, anopheline densities and malaria cases in Tadhimboko, north Guadalcanal is shown in Figure 47.

Soon after spraying started it was noted by Macgregor (ibid) that there was a marked difference in the SPR for slides collected by ACD on the north coast compared with those collected on the south coast. In 1964 the rate was 11.7% in the north, but only 3.9% in the south. Similar differences were noted during 1965-66. Thereafter the rate remained generally low on the south coast whilst rising on the north coast. In south Guadalcanal the SPR rose during 1969, fell in 1970-71, rose again in 1973-74, but fell once more in 1975. From 1970 onwards trends were similar in both sections except that seasonal increases were seen in November to May on the north coast and in June to October on the south coast. The urban area of Honiara and its satellite villages has generally remained malaria free since the early 1970's apart from occasional small foci.

In view of the clear evidence of continuing transmission on the north coast, and also in foci elsewhere from time to time, serious thought was given to the use of supplementary measures. Mass drug administration was tried using either monthly treatments or the full twelve week treatment. In small foci this proved satisfactory but on the Guadalcanal plains it appeared to have little effect. During 1974-75 minor efforts were made with the use of *Gambusia affinis*, stream clearance and abate larvicide but none gave conclusive proof of efficacy. A final resort was the use of ultra low volume malalthion in and around the villages. This was with a view to knocking out the anophelines on the wing in the early evening. Once again entomological and parasitological evaluation could provide no conclusive proof that these methods were worthwhile but, by the end of 1975, the method still had not been given sufficient trial. The problems of the supplementary measures and their relative merits are discussed in more detail in Chapter 8.5.

Guadalcanal holds the key to the success of the whole malaria eradication programme. The north coast is not only the most malarious part of the Solomons (along with Nggela) but it is also the focus of migratory activity and the centre of major development. Even if malaria is eradicated the north coast will remain highly receptive to malaria due to the prolific opportunities for anopheline breeding. As the main meeting point it will also be highly vulnerable to reinfection. The north coast will always remain the area from which malaria may be easily disseminated again all round the islands. The south coast is far less receptive and yet such large centres as Makaruka may easily create additional anopheline breeding opportunities by man's activities. This particular area is also highly vulnerable due to frequent migrations to the pagan activities from all over Guadalcanal.

- <u>Savo</u>

This was the first island in the Solomon Islands on which a 'knock out' of malaria was attempted during the current eradication operations.

The first record of an anopheline being found on the island was the collection by Perry (quoted by Taylor, 1974) of <u>A.farauti</u> in 1950. This was followed by the finding of a single <u>A.farauti</u> adult and two <u>A.punctulatus</u> larvae by Black (1952). More detailed pre spraying surveys by Mataika in 1962-63, reported by Macgregor (ibid), confirmed the presence of *A. farauti*, but not *A. punctulatus*. During his visit Black also found a 2-10 spleen rate of 85.3% (Table 23) and a 2-10 parasite rate of 21.1% in which *P. vivax* was just predominant over *P. falciparum*. Black also quoted the visit of an unnamed Assistant Medical Officer (AMO) who found an all ages spleen rate of 36% in 688 examined in 1951. The major pre spraying survey by Macgregor (ibid) in February 1963 found a 2-9 parasite rate of 61.6% (Table 27). The parasite formula was *falciparum* 49.1, *vivax* 14.8, *malariae* 36.1. Even though the Black survey was carried out some years previously this very high spleen rate, along with the high parasite rate found by Macgregor, was sufficient to classify the island in the holoendemic range.

DDT spraying started in January 1963 as part of the Pilot Project. Spraying continued with near total coverage at regular six monthly intervals (maximum interval eight months) until, at the end of 1975, a total of 25 cycles had been completed. Since Savo was isolated and apparently infrequently visited it was decided to go for an early 'knock out'. This was done by exposing the whole population to the eight week radical treatment for *P. vivax* malaria as recommended by Alving *et al*.(1960). The exercise was carried out starting with the first spray round in January 1963 and finishing in March 1963. It was claimed by Macgregor (ibid) that 97% of the population received the full treatment using chloroquine 400 mg, primaquine 45 mg. and pyrimethamine 33 mg. weekly. Immediate success was seen from this treatment in a survey in April 1963 (the 1st survey in Table 27) which found only four malaria cases in 963 slides examined.

This early elation was tempered by the July survey (the 2nd survey in Table 27) which found 74 cases in 964 examined. Since it was clear that the eight week regime was not sterilizing all infections it was decided to increase the length of treatment to twelve weeks (see Chapter 8.5). With this treatment no relapses were experienced after at least six months follow up and a survey in May 1964 (the 4th survey in Table 27) found no parasites in 1066 slides examined. Even this optimism was not justified for the survey of August 1964 (the 5th survey in Table 27)found twelve positives in 1074 examined. Since five of these were due to P. falciparum it is distinctly possible that these infections were brought in from neighbouring Nggela or Guadalcanal. If this was so then it merely served to demonstrate the ease with which transmission could be resumed on Savo.

Post spraying entomological surveys were also carried out between 1965 and 1968 at three fixed stations on the island. Two of these stations always reported low densities or nil returns, but very high densities of A. farauti were occasionally recorded from Reko. Later casual surveys in the 1970's nearly always found low densities, but the occasional resurgence of malaria on this island is an indication that it probably experiences big explosions in its anopheline population from time to time. This is almost certainly associated with the filling up of breeding sites after heavy rain.

Both active and passive case detection were set up at an early stage in 1963. A resident ACD agent allowed easy access to all villages and, from 1965 onwards, more than 20% of the population was sampled every year. The SPR showed considerable fluctuation during the period 1963-75 usually in parallel with variations in the number of cases (Tables 30 and 31). It is clear that transmission was resumed on numerous occasions and was probably continuous during the period 1968-70. It is probably more than coincidence that the number of cases did begin to fall once neighbouring Nggella came under spray cover in April 1970. Even this was not enough for the frequent contact with north Guadalcanal (where transmission was certainly still continuing) allowed regular reintroduction of infection. During the first six months of 1975 only three cases were detected, but then, in the third quarter, 30 P. vivax cases were detected around Panueli. Transmission had occurred once again on the island although it is likely that the index case picked up the infection whilst at a feast on north Guadalcanal. This particular outbreak was attacked with a thorough respray of all houses and a 14 day radical treatment of the people in all the affected villages. Only two further cases occurred during the last quarter of the year.

In spite of the apparent lack of anophelines Savo is highly receptive to the reintroduction of malaria. It is also highly vulnerable due to the regular migrations of its inhabitants to the (formerly) highly malarious Nggela and Guadalcanal.

- Russell Islands

These plantation islands were long regarded as being only moderately malarious. Extensive entomological surveys carried out by Sloof (1969, 1972) in 1965 and 1966 found generally low densities of A. farauti around the islands (Figure 32). The one exception was the very high densities found at Lever Point near Yandina at the site close to some of the plantation labour lines.

A review of the fever cases in Yandina hospital (Rural Health Clinic) during the years 1968-69 showed a peak of over 600 cases in January and a low of around 150 cases in May to July. These corresponded closely with the seasonal high and low rainfall figures respectively (see Chapter 3.2).

In the two pre spraying malariometric surveys that were carried out the island was classified in the low mesoendemic range. In 1966 de Iorio found a 2-9 year spleen rate of 28.3% (Table 23) and a 1-9 year parasite rate of 11.0% with P. vivax as the predominant species. The official baseline survey by Maffi in 1970 found a 2-9 year spleen rate of 14.0% and a 2-9 year parasite rate of 26.0% (Table 27). The parasite formula in this survey was falciparum 26.7; vivax 68.3; malariae 5.0.

DDT spraying started in August 1970 and continued thereafter at approximately 6 monthly intervals. By the end of 1975 ten cycles had been completed. The three post spraying malariometric surveys (Table 27) gave good evidence of the interruption of transmission of all parasites. The final survey of May 1972 found only ten P. vivax parasites.

Passive Case Detection was set up at Yandina and Pepesala in 1971 followed a year later by fortnightly Active Case Detection. The population coverage steadily improved so that during 1974 and 1975 more than 30% of the population was sampled by ACD/PCD. The SPR steadily declined from 5.2% in 1971 to 0.1% in 1975 (Table 30) whilst the API declined from 3.0‰ in 1973 to 0.3‰ in 1975. During 1974 and 1975 only two cases (both P. vivax) were detected. The island was therefore already qualified to enter into consolidation under the conditions laid down by the WHO Independent Assessment Team (see Chapter 8.5).

The Russells remain moderately receptive to malaria since anophelines may still be found at certain sites. They also remain very vulnerable due to the high rates of inward migrations from malarious areas. For this reason it was decided to continue DDT spraying during 1976.

- Nggela (Florida) Islands

It was no surprise to find that this, the most malarious group in all the Solomon Islands, was also one of the most difficult from which to clear malaria.

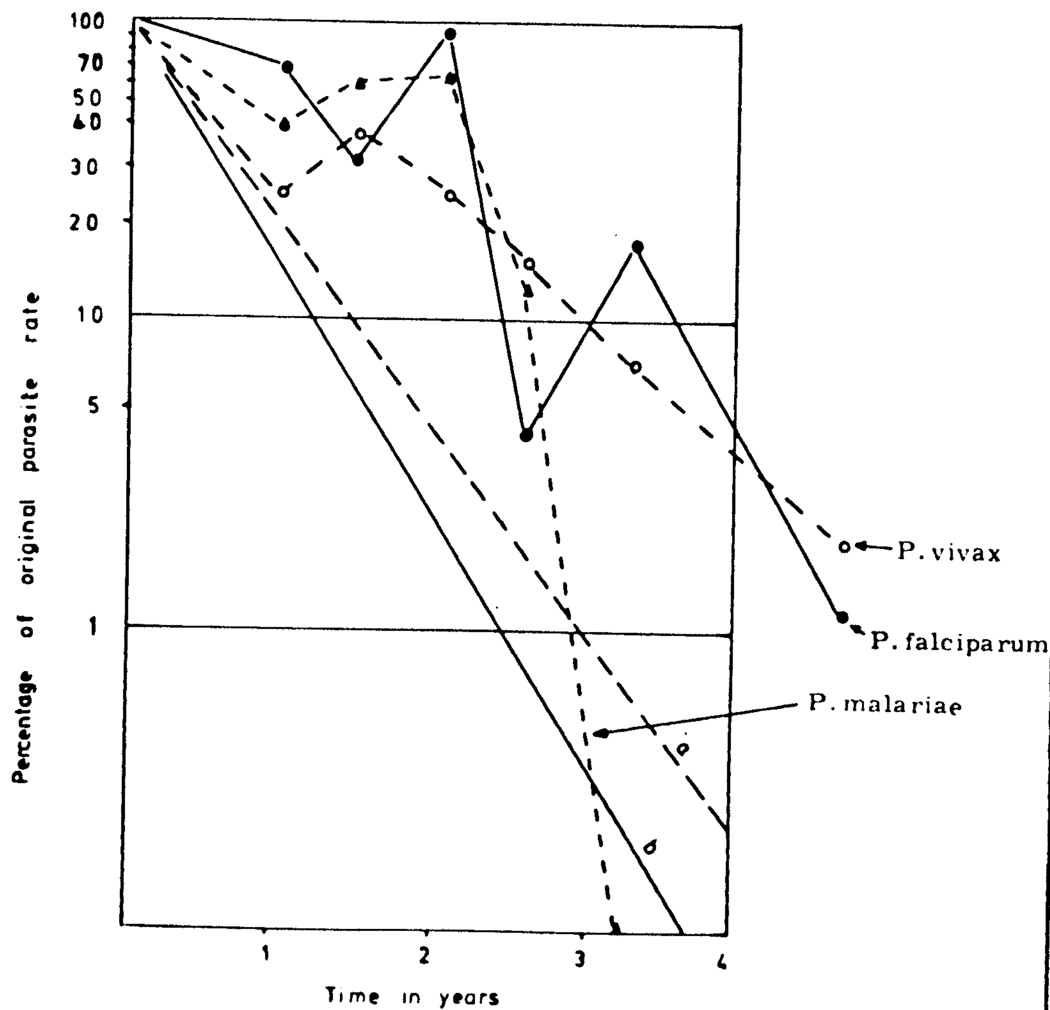
Although only a few entomological or malariometric surveys were carried out prior to the mid 1960's it soon became clear that a very large malaria problem existed. Round island entomological surveys in 1965 found *A.farauti* in abundance at almost every site (Figure 32). *A.koliensis* was also found with some ease on the north coast (Taylor 1974).

The earliest malariometric survey, by de Iorio in March 1965, found a 2-9 year parasite rate of 56.3% (Table 25). This was followed in January 1966 by the finding of a spleen rate of 85.9% (Table 23). These high rates were confirmed by Maffi in August 1969 with a 2-9 spleen rate of 71.7%. In the northern part of Nggela spleen rates in villages were also well over 80% whilst those on the south coast and Buena Vista were only in the 30-50% range. The north coast therefore qualified for the holoendemic classification. Surveys by Maffi and Eyres in June and August 1969 were combined to provide the base line parasite rate of 69.6% thus classifying Nggela in the high mesoendemic range. The parasite formula for these surveys was falciparum 18.6; vivax 76.2; malariae 5.2. A further survey by Maffi in January 1970 (Tables 23 and 25) was not considered as the base line survey since this covered only five villages.

DDT spraying started in April 1970 and continued at six monthly intervals until the completion of the seventh cycle in April 1973. When it became clear that transmission was still continuing the interval between operations was reduced to four months. Mass drug administration was also introduced to all villages with malaria cases towards the end of 1973. Entomological surveys were also carried out for a time at fixed stations along the north coast showing moderate densities of A. farauti on most occasions. These surveys also gave some evidence of an increase in densities about four months after the previous DDT spray round. Larval surveys also found anophelines with some ease. In 1972 van Seventer(1972) carried out a series of all night catches at the same sites. These showed a pattern of night biting with quite high densities all night but with subsidiary peaks at midnight and again before dawn. These findings were in contrast to the post spraying early evening peak in Guadalcanal, but more in line with the pre spraying pattern found in Makira (see Results - Entomological in this Chapter).

Several post spraying malariometric surveys were carried out. At no time did these give sufficient evidence to confirm the interruption of transmission except for P. malariae in the later stages. (Table 25 and Figure 44). The survey findings were not fully confirmed by the surveillance records shown in Tables 30 and 31. A generous

Fig. 44. Fall in malaria parasite rates in the 2 - 9 age group following DDT spraying in Nggela during 1969 - 74



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

coverage of the population from 1972 onwards (Table 29) allowed some confidence to be put in the fall in the SPR from 26.4% in 1971 to 1.3% in 1975 and the API from 69.4‰ in 1973 to 6.9‰ in 1975. It is clear that initially there were many villages in which transmission had not been interrupted. However, once the reduced spraying interval and mass drug administration had taken effect during 1974 and 1975 there was a rapid reduction in malaria. This island is a good example of the value of an intensive effort when basic methods have failed. Prior to the final mass drug administration effort of November 1973 to September 1974 two previous efforts had made some impact but had clearly not been applied intensively enough. The final effort covered more than 90% of the target population during the period July to September 1974 using a monthly administration of chloroquine 600 mg and primaquine 45 mg adult dosage. Following on from this small treatments were confined just to a few limited foci. No P. falciparum cases occurred after March 1975 and there was a considerable reduction in the total cases during 1975 (Table 31).

This island cannot in any way be considered to be clear of malaria and it remains highly receptive to reintroduction of the disease. It is equally vulnerable due to the high levels of migrations from Guadalcanal and Malaita. Nggela is also a potential disseminator of malaria to other parts of the Solomons.

- Santa Isabel

From the time of the visit of Mendaña in 1568 to the late 1960's little was recorded on the state of malaria on Isabel. Any doubt that may have existed was soon dispelled by the pre spraying surveys. Between August 1966 and March 1969 entomological surveys were carried out in 48 localities (Taylor 1974). A.punctulatus was found in three localities on the north east coast whilst A.koliensis was more widely distributed at the eastern end of the island. A.farauti was spread throughout the coastal area although it was very sparse in the western half (Figure 32).

A review of the pre spraying malariometric surveys justified a classification of high mosoendemicity for Santa Isabel. In a small survey of 132 children in the 2-9 years age group at Kia in 1966 de Iorio found a spleen rate of only 9.9% and a parasite rate of 13.5% with P.vivax predominating. Subsequent surveys confirmed that this western part was the least malarious of all the island. In 1969 Maffi, during part of his pre spraying baseline surveys, found a 2-9 year spleen rate of 36.4% on the west coast (Table 23). The 2-9 parasite rate in the more extensive part of this survey was 42.7% (Table 26) with a parasite formula of falciparum 30.0; vivax 52.1; malariae 17.9. A small round island sample survey by Davidson in 1967 had previously found a 2-9 parasite rate of 53.2%. A later survey in 1969 by the same worker covering three bush villages confirmed that these were little different from the coast with a 2-9 parasite rate of 50.8%. Davidson also made a review of the outpatient register at Buala hospital over a one year period July 1968 to June 1969 and found no obvious seasonal trend.

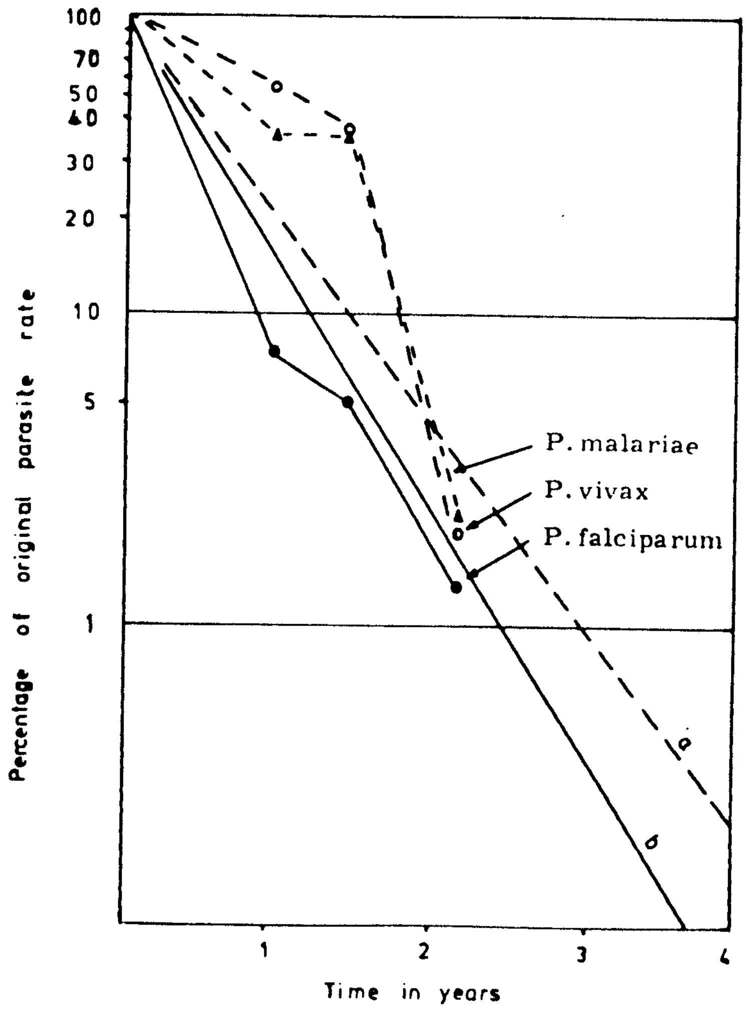
Santa Isabel was the first of the islands to be brought under spray cover under the full MEP expansion having started DDT spraying in December 1969. By the end of 1975 a total of 12 cycles had been completed at six monthly intervals although there was one gap of ten months during 1972. Public co-operation was of a very high order with nearly 100% coverage being achieved. For assessment some entomological fixed stations were set up at the east coast but sampling was discontinued towards the end of 1971 when densities were found to be consistently low.

The three post spraying malariometric surveys (Table 26 and Figure 45) confirmed the interruption of transmission of P. falciparum. The regression patterns for P. vivax and P. malariae followed almost identical lines. That of P. vivax showed an earlier drop to the minimum acceptable rate than that seen on other islands.

The setting up of PCD and ACD in early 1971 was a little later than the usual short period following the start of DDT spraying. Long distances around the islands and from Honiara meant that, even in 1975, some areas were not being regularly covered. Nevertheless, overall, a respectable coverage of the population was achieved with over 30% being sampled by ACD/PCD from 1972 onwards. The SPR fell steadily from 4.7% in 1971 to 0.4% in 1975 whilst the API fell from 10.0‰ in 1973 to 3.3‰ in 1975. A more detailed review of the surveillance returns, however, showed that several foci of transmission of P. falciparum malaria occurred during 1971-75 (Table 31). These were particularly around Buala on the north coast and Susubona on the south coast. A seasonal pattern also emerged with an increase in cases towards the end of the year, i.e. during the north west monsoon season. A general improvement during the latter half of 1975 finally resulted in the knocking out of most of the residual foci.

Santa Isabel has almost achieved the eradication of malaria but remains highly receptive with abundant anopheline breeding sites all

Fig.45. Fall in malaria parasite rates in the 2-9 age group following DDT spraying in Santa Isabel during 1969-72



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

around the island. It is not too vulnerable however, since most of the population tend to migrate to and from less malarious areas.

- Bellona

The only record of an anopheline on this island is the single adult female A. farauti caught by Brown in 1955 (Belkin 1962). Numerous other surveys reviewed by Maffi (1973), all failed to find any anophelines. Culcines, on the other hand, are represented by at least 8 species. One or more of these may possibly be vectors of filariaris as several cases have been recorded on the island (see Chapter 4.2).

The occasional malariometric surveys, including that of Black (1952), all found spleen and parasite rates at zero or very low levels. Most of the infections were accounted for by recent migrations. An indication of increasing travel to the mainland was seen when de Iorio found a 2-9 spleen rate of 13.4% in 1966. Only two slide positive cases (1. P. vivax, 1. P. malariae) were found in 454 all ages slides examined. In 1969 Maffi found a zero spleen rate in teenagers (Table 23) but a parasite rate of 3.7% in the 2-9 age group (Table 27). Twelve P. vivax cases were found in 189 all ages slides examined and two of these were reported never to have left the island.

No DDT spraying was carried out but several efforts were made to set up Passive Case Detection. The generally poor response to these is reflected in the low ABER shown in Table 29. This may not be of so much concern since an extensive survey by Eyres and Williams in May 1972 (MEP records) found only one P. vivax case in 156 slides examined from the 2-9 age group.

Bellona is technically in the maintenance phase of eradication and it is assumed that transmission has seldom, if ever, occurred on the island. The Bellonese, being largely non immune, are highly susceptible to severe malaria infections should they be suitably exposed.

- Rennell

This island was regarded for many years as being anopheline free until Black (1952) hatched out adult A. farauti from larvae collected at lake Te Nggano. A number of later surveys, summarised by Maffi (1973) also found low densities of A. farauti. A total of twelve culcicine species have been noted but it is not known if any of these are vectors of disease.

A number of malariometric surveys were carried out over the years on Rennell, the earliest of which were summarised by Black (ibid). The baseline pre spraying survey has been taken as that of Maffi in 1970 who found eleven positive slides (3. P. falciparum, 8. P. vivax) in 144 slides in the 2-9 age group. This gave a parasite rate of 7.6% (Table 27). Earlier spleen surveys (Table 23) and Black's parasite survey of 1952 (2-10 parasite rate of 14.3%) had suggested mesoendemicity but Maffi's spleen rate of 0.8% in all ages in 1970 confirmed his parasitological findings of hypoendemicity.

The presence of low density vectors was nevertheless sufficient for the island to be put under DDT spray cover in February 1970. By March 1971 the final of three rounds had been completed. Post spraying entomological surveys by Maffi (1973) and by Taylor (1974) failed to find any anophelines although culcines remained abundant.

Later surveys in 1974 and 1975 confirmed these findings. No post spraying malariometric surveys were carried out, but the surveillance returns soon gave a good indication that malaria had been eradicated from the island. Active Case Detection was carried out for a period of just over four years between 1970 and 1975 and Passive Case Detection was carried out from 1971 onwards. The ABER for Rennell steadily improved to cover 60.3% of the population in 1973 but then deteriorated as ACD activity decreased (Table 29). The SPR and API both remained low during the period and reached zero in 1973 and 1975 (Tables 30 and 31).

Rennell effectively went into consolidation in March 1971 and into maintenance in early 1975, being the first island in the Solomons to achieve these goals. Prospects for maintaining eradication are good and the absence of anophelines makes the island non receptive to malaria at present. This may be changed drastically, however, when full scale bauxite mining operations start and many more man-made breeding opportunities are created. The importation of labour from all over the Solomons will then greatly increase the risk of reintroduction of malaria if anophelines should become re-established.

- Eastern District

Eastern Inner Islands *

This group comprising Makira and its neighbouring islands has made more rapid progress in the eradication of malaria than any other district in the Solomon Islands.

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* Note: For administrative purposes the Eastern District is one of the four Districts in the Solomon Islands. For the purpose of malaria operations and epidemiology the Eastern District has been divided into Inner and Outer Islands.

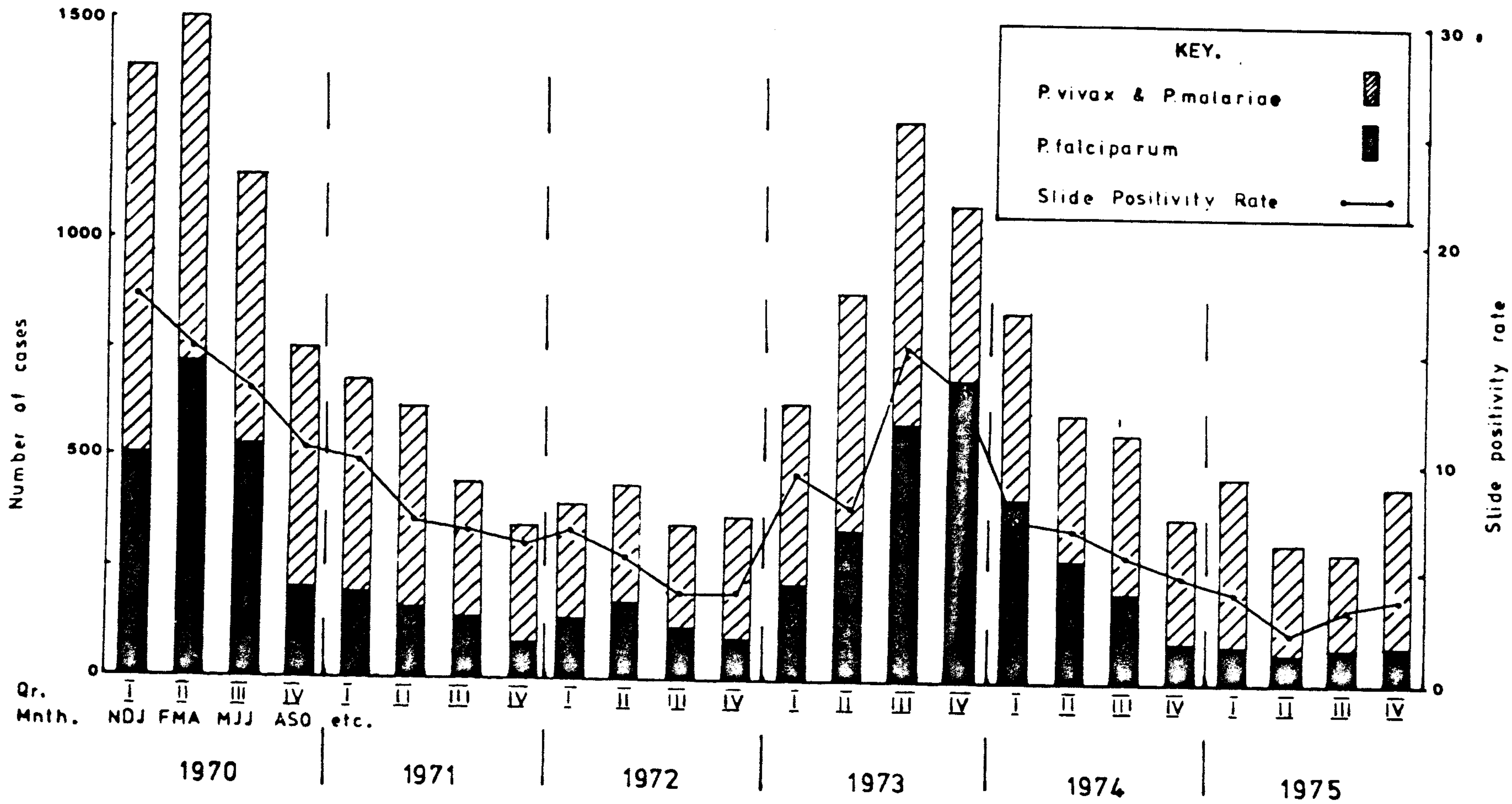


Fig.46. Quarterly totals of malaria cases detected by Active & Passive Case Detection in the Central Solomons, 1970 - 75

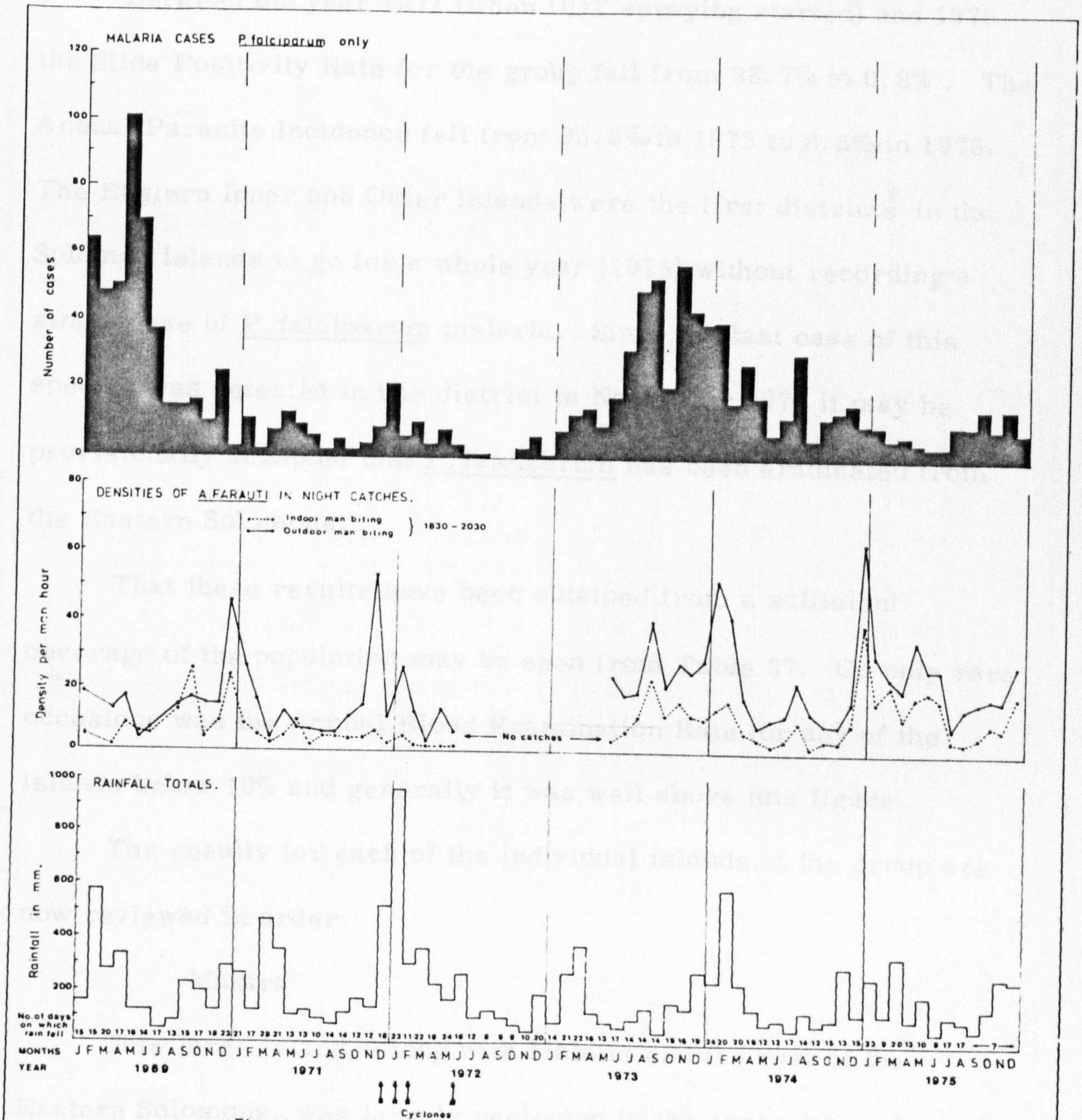


Fig. 47. Monthly incidence of malaria cases, anopheline densities and rainfall in West Todhimboko, Solomon Islands. 1970-75.

This progress may be seen from the results of the pre and post spraying malariometric surveys for Makira and Ulawa (Tables 32 and 33) and also from the results of surveillance for the whole group (Table 36) and for individual islands (Tables 37-39).

Between the year 1971 (when DDT spraying started) and 1975 the Slide Positivity Rate for the group fell from 38.7% to 0.8%. The Annual Parasite Incidence fell from 95.8‰ in 1973 to 8.5‰ in 1975. The Eastern Inner and Outer Islands were the first districts* in the Solomon Islands to go for a whole year (1975) without recording a single case of P. falciparum malaria. Since the last case of this species was detected in the district in November 1974 it may be provisionally accepted that P. falciparum has been eradicated from the Eastern Solomons.

That these results have been obtained from a sufficient coverage of the population may be seen from Table 37. On only rare occasions was the Annual Blood Examination Rate for any of the islands below 10% and generally it was well above this figure.

The results for each of the individual islands of the group are now reviewed in order.

Makira

This large island, along with Malaita and the rest of the Eastern Solomons, was largely neglected in the early entomological surveys. Prior to the surveys immediately pre spraying, the only known collection of anopheline mosquitoes on Makira was that by Brown who found A. farauti between 1954 and 1956 (Taylor 1974). Extensive surveys were carried out by malaria staff during 1970-71 when A. farauti was found to be widely distributed with A. koliensis

TABLE 32

Results of pre and post spraying malaria parasite surveys of Makira Island, Solomon Islands

Population: 9003 (1970 census)

Date 19-	Months after 1st S. O.	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Pre spraying survey										
Jul. 71	*	Gibson	2-9	645	293	45.4	102	163	19	9 fv.
Post spraying surveys[1]										
1st Jun. 72	6	Gibson	2-9	711	249	35.0	19	189	31	6 fv. 4 fm.
2nd Dec. 72	12	Paik/ Tapoa	2-9	650	224	34.5	66	205	8	5 fv.
3rd Jun. 73	18	Peabody	2-9	867	113	13.0	11	88	14	0
4th Apr. 74	28	Horoto	2-9	933	45	4.8	1	42	2	0
5th Jul. 74	31	Horoto •	2-9	328	0	0.0	-	-	-	-

Notes: SO - Spraying Operation. • W. Bauro & N. Arosi only.

1 - These surveys included Uki, Santa Ana and Santa Catalina.

TABLE 33

Results of pre and post spraying malaria parasite surveys of Ulawa, Solomon Islands

Population: 1469 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Pre spraying surveys										
Jun. 69	*	McDonnell	2-9	356	110	30.9	19	86	3	2 fv.
Post spraying surveys										
1st Mar. 71	6	Avery	2-9	171	55	32.2	0	53	0	2 fv.
2nd Aug. 71	11	Gleadhill	2-9	269	53	19.7	2	50	1	0

Note: SO - Spraying Operation.

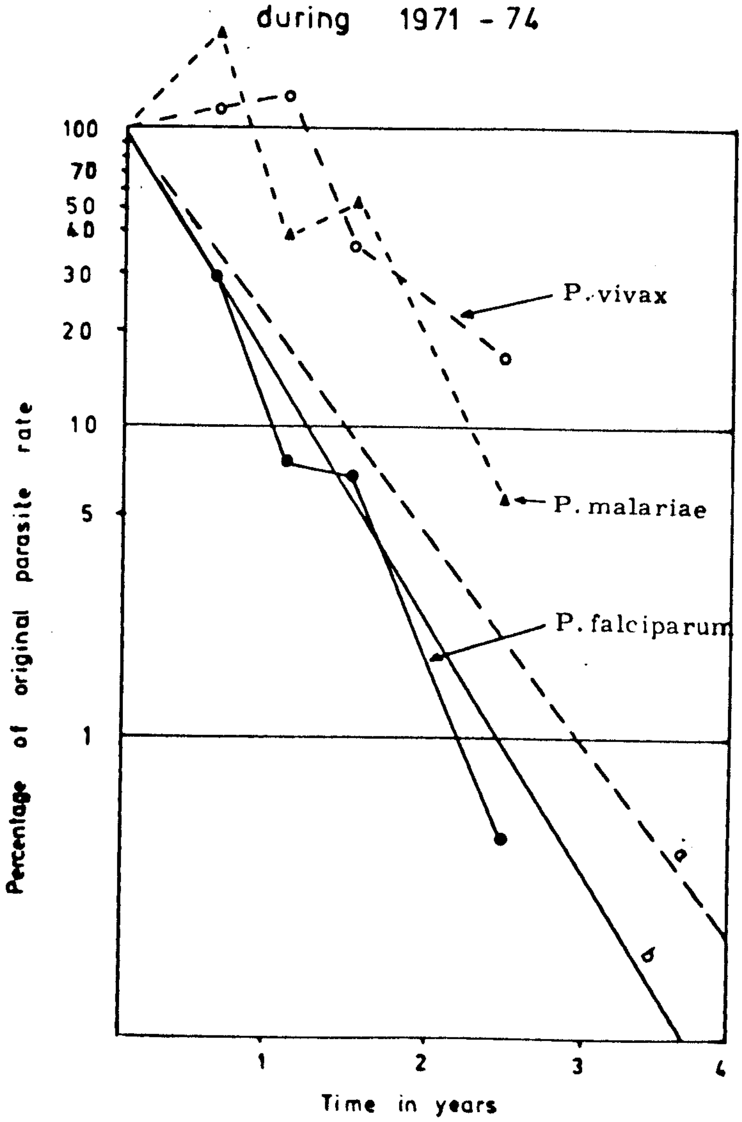
less so. A.punctulatus was much more restricted in distribution being confined to the coastal and riverine areas of Bauro with a few scattered collections on the south coast (Figure 35). The studies which were made on anopheline behaviour pre and post spraying are described in more detail in Chapter 7.1.

Makira was also neglected in malariometric surveys prior to the major pre spraying one by Gibson in July 1971. Innes (1938) found an all ages spleen rate of 80.8% during leprosy surveys in 1938 and McDonnell and Maffi separately found spleen rates of over 60% in Bauro bush in 1969 and 1970. The absence of further more detailed spleen surveys nearer the time of spraying made the spleen rates of no value in the classification of endemicity. This was done on the survey by Gibson which found a parasite rate of 45.4% in the 2-9 age group (Table 32). The parasite formula was falciparum 36.7 ; vivax 57.0 ; malariae 6.3 . The island was therefore classified as high mesoendemic but it is very likely that it would have been found to be hyperendemic had more extensive spleen surveys been carried out. The malaria incidence survey carried out at Kira Kira hospital from 1969 to 1971 is described in Chapter 7.2.

No antimalaria activities were carried out prior to the full eradication operations with Makira being the last major island in the Solomons to come under spray cover. DDT spraying started in October 1971. Spray rounds continued regularly every 6 months so that by the end of 1975 a total of 9 rounds had been completed.

The four post spraying parasitological surveys showed a steady regression in the parasite rate (Table 32) and proof of the interruption of transmission of P.falciparum malaria (Figure 48). The regression

Fig. 48. Fall in malaria parasite rates in the 2-9 age group following DDT spraying in Makira during 1971 - 74



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

pattern for P.vivax followed the typical pattern of that for other islands. P.malariae was erratic in its disappearance although by the last survey in April 1974 only two cases were found in the 933 slides examined.

Passive Case Detection (PCD) started even before the start of spraying whilst Active Case Detection (ACD) started, also very early, in May 1972. Surveillance soon became well established throughout the island so that in the years 1973-75 more than 60% of the population had blood slides taken by ACD or PCD each year. The Slide Positivity Rate (SPR) fell from 45.2% in 1971 to 1.5% in 1975 (Table 38), whilst the Annual Parasite Incidence (API) fell from 123.4‰ in 1973 to 11.0‰ in 1975. P.falciparum rapidly disappeared from the returns during 1974-75, but there was evidence during 1973 of the resumption of transmission of P.falciparum and P.vivax malaria in several foci in Makira. This was clearly shown in the monthly field returns, in the quarterly reviews (Figure 50) and in the longitudinal study (Figure 42).

During early 1974 a mass drug administration was carried out in West Bauro and North Arosi. The purpose of this was to clear up small persistent foci and accelerate the operation. In West Bauro a weekly treatment with chloroquine 600 mg and primaquine 45mg adult doses was carried out for twelve weeks. In Arosi a monthly treatment with similar doses was used for six months. Both treatments proved effective in clearing the residual infections and in preventing any recurrence of malaria.

By the end of 1975 only a few small residual foci of malaria remained on Makira. These were mainly in the Star Harbour and Wainone areas. The prospects for eradication of malaria during 1976 were very good providing the high standards could be maintained and the splendid co-operation of the people continued. Makira is highly receptive to malaria due to the abundance of anophelines still to be found all round the island. It is also moderately vulnerable to re-infection due to regular migrations to and from the still malarious areas of Guadalcanal.

Santa Ana and Santa Catalina

Only two records exist of anophelines being found on these twin islands (Taylor 1974). In 1970 a few A. farauti larvae were found by Maffi on Santa Ana whilst in 1971 malaria staff found a few A. farauti adults on both islands. The islands have long been regarded as non malarious, but the people frequently experienced fever ('matoaroa') in the past when they went to the mainland of Makira. In the two recorded pre spraying surveys Maffi found spleen rates of less than 1% on both islands. He also found very low parasite rates (Tables 34 and 35). P. vivax was the predominant species but five adults from Santa Ana were found to have P. falciparum infections in 1970. It is probable that all these infections were acquired on the mainland.

In view of the potential for transmission of malaria due to the presence of small numbers of A. farauti it was decided to include the islands in with the DDT spraying of Makira. The first spray round was in September 1972 but in August 1973, after only three rounds had been completed, spraying was discontinued. This was because night catches and larval surveys had failed to find any anophelines. Several post spraying surveys had also failed to detect any parasites in the small number of slides examined.

Passive Case Detection was started at the Gupuna Rural Health

TABLE 34

Results of pre spraying spleen surveys, Santa Ana and Santa Catalina Solomon Islands

Population: S. Ana - 756, S. Catalina - 345 (1970 census)

Date 19-	Surveyor	Age group	Number Examined	Number Positive	Spleen Rate %
Santa Ana					
Oct. 67	Maffi	All	239	1	0.4
Santa Catalina					
Oct. 67	Maffi	All	150	1	0.7
Oct. 70	Maffi	2-9	71	0	0.0

TABLE 35

Results of pre spraying malaria parasite surveys of Santa Ana, Santa Catalina and Uki, Solomon Islands

Population: S. Ana - 756, S. Catalina - 345, Uki - 817 (1970 census)

Date -19	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Santa Ana									
Oct. 70	Maffi	All	363	21	5.9	5	16	0	0
Santa Catalina									
Oct. 70	Maffi	2-9	71	1	1.4	0	1	0	0
Uki									
Oct. 70	Maffi	10-19	479	83	17.3	32	36	13	2 fv.

Note: Post spraying survey results were included in with Makira (Table 32).

TABLE 36

Results of malaria surveillance, Eastern Inner Islands+, Solomon Islands, 1971-75.

Population: 1970 - 12390 (Census)
1971 - 12886 (MEP estimates)
1972 - 13401 (" ")
1973 - 13901 (" ")
1974 - 13282 (MEP estimates)
1975 - 13745 (" ")
1976 - 14873 (Census)

Year	Number of slides collected by				ABER by PCD+ ACD	Total cases by				Species				SPR% by PCD+ ACD	API‰ by All Sources
	ACD	PCD	Other Sources	All Sources		ACD	PCD	Other Sources	All Sources	f.	v.	m.	mixed		
1971	303	2323	NA	2626	20.4	NA	NA	NA	1017	511	546	28	(68)	38.7	NR
1972	500	4530	NA	5035	37.5	NA	NA	NA	1220	218	884	128	(10)	24.2	NR
1973	3600	3792	4067	11459	53.2	389	560	383	1332	219	1024	79	8 fv. 2 vm.	12.8	95.8
1974	4572	2631	4501	11704	54.2	116	88	123	327	18	262	47	0	2.8	24.6
1975	5497	2925	5456	13878	61.3	32	33	52	117	0	114	3	0	0.8	8.5

+ includes Makira, Santa Ana, Santa Catalina, Uki, Three Sisters and Ulawa.

Notes:
ACD - Active Case Detection.
PCD - Passive Case Detection.
ABER - Annual Blood Examination Rate.
SPR - Slide Positivity Rate per hundred slides.
API - Annual Parasite Incidence per thousand population.
NA - Data Not Available.
NR - Data Not Relevant.

Other Sources include Case Follow up, House Contacts and Surveys.

Species - Mixed infections are specified where known. Where the number is in brackets the species was not specified in the returns. On these occasions the total of mixed species has been subtracted from the total of the other species (i.e. total infections) to give the total cases.

Clinic in May 1972 a few months before the start of spraying. Monthly Active Case Detection was started in May 1973. In 1972 only 6.7% of the population had blood slides examined by routine surveillance, but by 1975 the figure had risen to 13.6% (Table 37). The Slide Positivity Rate fell from 12.5% in 1972 to 0.6% in 1975, whilst the Annual Parasite Incidence fell from 8.0‰ in 1973 to 0.9‰ in 1975 (Table 38). No P.falciparum cases were detected during any of the post spraying surveys or case detection activities and only one malaria case (P.vivax) was detected during 1975.

Santa Ana and Santa Catalina may now be declared malaria free. Receptivity is very low, but vulnerability remains moderate due to frequent migrations from (potentially) malarious islands. The islands entered into Consolidation in August 1973 when spraying was discontinued.

Uki

No antimalaria activities were carried out on this island prior to eradication operations. An exception was the weekly chloroquine prophylaxis administered to most of the children at the two large boarding schools. Surveys in 1971 found both A.farauti and A.koliensis in abundance all round the island (Taylor 1974).

The only recorded malariometric survey is that of Maffi who found a parasite rate of 17.3% in 479 children of the 10-19 age group in October 1970 (Table 35). In spite of their being on prophylaxis, 34 of the 83 proven cases had P.falciparum infections.

DDT spraying operations started on Uki in February 1972. These continued regularly every six months so that, by the end of 1975, a total of 8 rounds had been completed. PCD commenced in May 1971 even

TABLE 37

Annual blood examination rate (%) by Islands, Eastern Inner Islands, Solomon Islands, 1971 - 75.

Year 19- Island	Population (1970 Census)	Annual Blood Examination Rate %				
		71	72	73	74	75
Makira	9003	23.7	42.3	62.6	64.1	75.2
Santa Ana/ Santa Catalina	1101	*	6.7	12.5	13.5	13.6
Uki	817	9.5	14.4	30.7	36.6	15.7
Ulawa	1469	26.6	47.0	41.5	34.2	34.3
Three Sisters	(60) approx.	*	13.3	*	6.1	52.9
Eastern Inner Islands	12390	20.3	37.5	53.2	54.2	61.3

TABLE 38

Slide positivity rate (%) and Annual parasite incidence (‰) by Islands, Eastern Inner Islands, Solomon Islands, 1971-75.

Year 19- Island	Slide Positivity Rate					Annual Parasite Incidence		
	71	72	73	74	75	73	74	75
Makira	45.2	28.2	14.0	3.1	1.5	123.4	31.8	11.0
Santa Ana/ Santa Catalina	*	12.5	5.1	2.0	0.6	8.0	2.7	<u>0.9</u>
Uki	18.8	20.8	11.9	2.6	2.2	42.2	10.6	4.5
Ulawa	9.0	6.8	4.5	0.7	0.2	29.4	5.0	<u>1.2</u>
Three Sisters	*	12.5	*	0.0	0.0	*	<u>0.0</u>	<u>0.0</u>
Eastern Inner Islands	38.7	24.2	12.8	2.8	0.8	95.8	24.6	8.5

__ Islands which satisfy the Solomon Islands criteria for entry into consolidation (see Chapter 8.5 - Discussion) before spraying started whilst monthly ACD started in April 1973. No post spraying parasitological surveys were carried out but occasional entomological surveys showed A.farauti to be still present in high densities. During 1973-1975 more than 15% of the population was sampled each year by ACD/PCD (Table 37). The Slide Positivity Rate fell from 20.8% in 1972 to 2.2% in 1975. The Annual Parasite Incidence fell from 42.2‰ in 1973 to 4.5‰ in 1975 (Table 38). With such good progress the island was expected to go into consolidation during 1976 or 1977.

Uki remains highly receptive to malaria, but only moderately vulnerable due to its relative isolation.

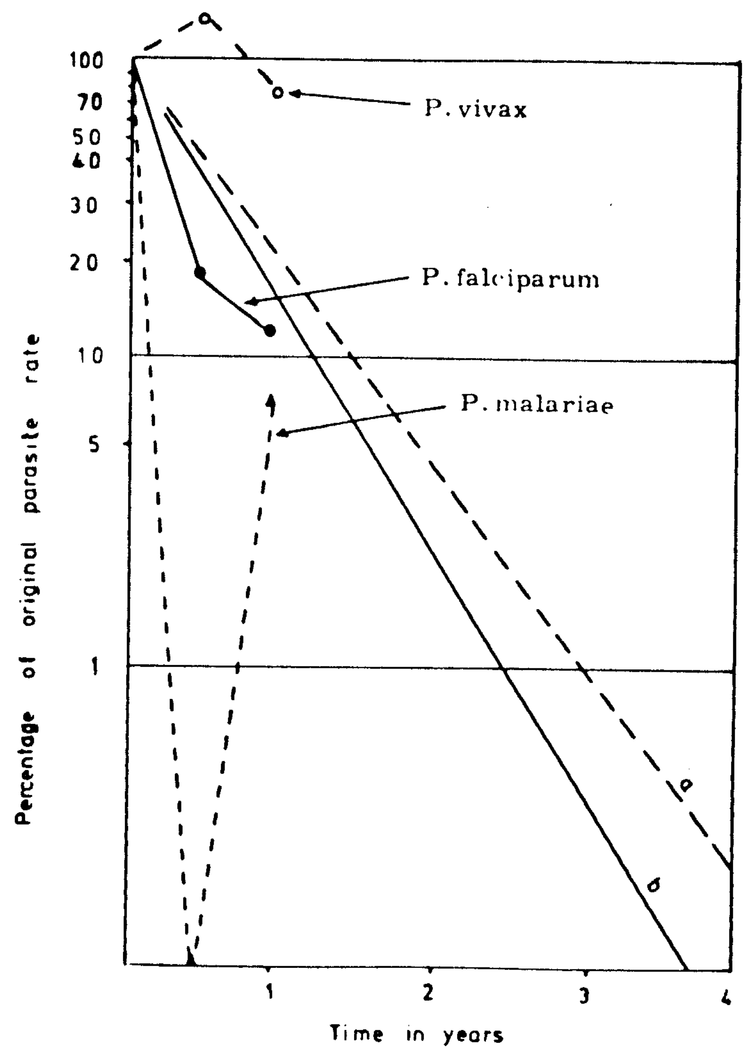
Ulawa

This hilly island had no antimalaria activities prior to eradication operations. The only pre spraying entomological survey (in September 1969) found A.farauti at 6 of the 8 localities surveyed. Early evening night catches found very low densities of this vector. A review of the records from Hadja Rural Health Clinic for the period 1962-68 showed an average of 210 fever cases every month with a slight tendency towards peaks in March to May. The pre spraying parasite rate was 30.9% in the 2-9 age group, but no spleen survey was made. The predominant species was P.vivax (Table 33).

DDT spraying operations started in September 1970. These continued regularly every 6 months until by the end of 1975 a total of 11 cycles had been completed. Surveillance by both active and Passive Case Detection started in May 1971.

The two post spraying parasitological surveys (Table 33 and Figure 49) showed that the transmission of malaria was interrupted on

Fig. 49. Fall in malaria parasite rates in the 2 - 9 age group following DDT spraying in Ulawa during 1969 - 71



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

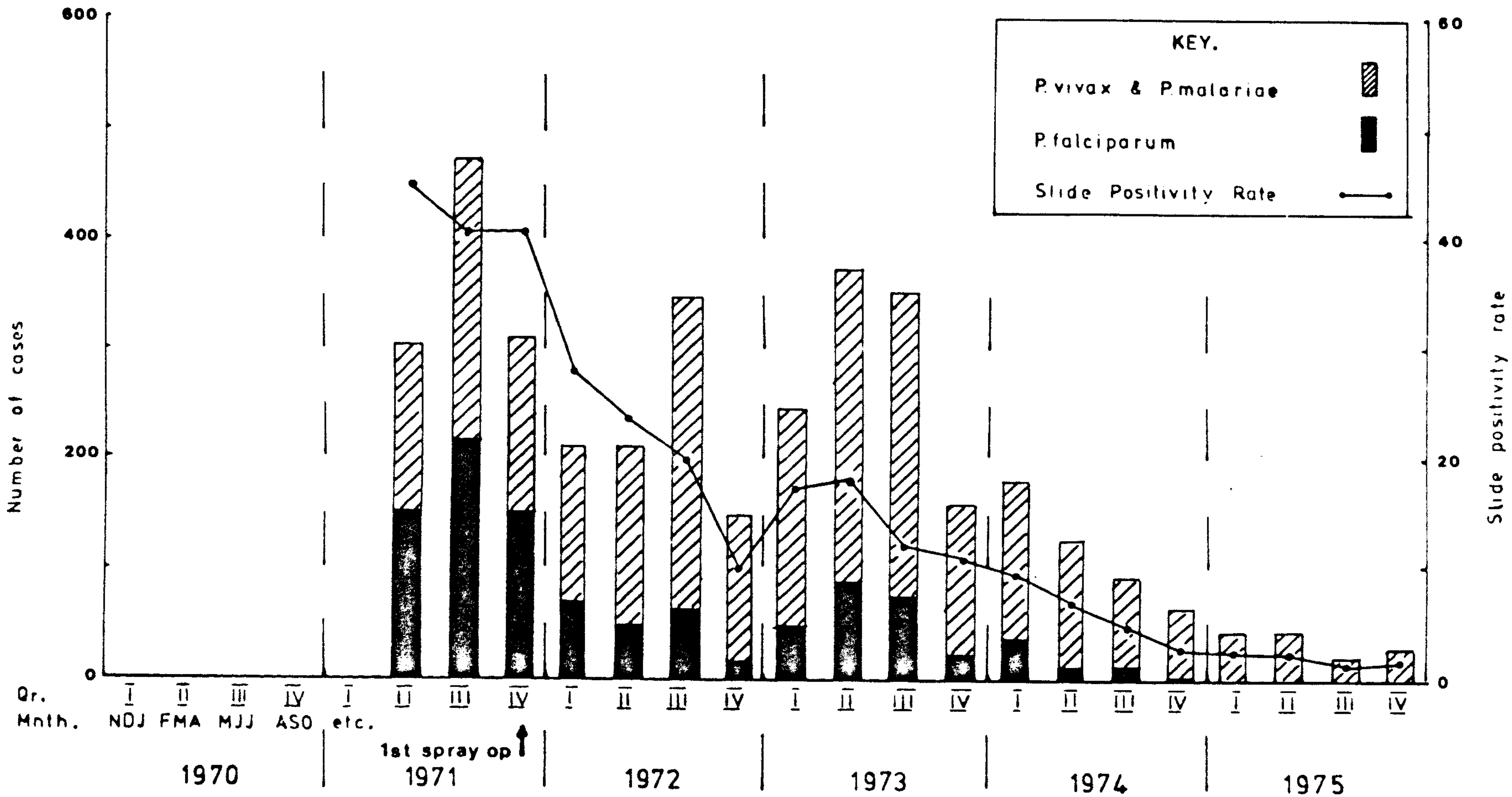


Fig.50. Quarterly totals of malaria cases detected by Active & Passive Case Detection in the Eastern Solomons, 1970 - 75

TABLE 39

Annual totals of malaria cases in individual islands, Eastern Inner Islands, 1971 - 75.

	Makira	Santa Ana & Santa Catalina	Uki	Ulawa	Three Sisters
1971	965(500)	*	15(8)	37(3)	*
1972	1132(204)	10	26(9)	51(5)	1
1973	1234(210)	10	38(3)	50(3)	*
1974	307(17)	3	9(1)	8	0
1975	110	1	4	2	0

Notes: Figures in brackets ( ) are P. falciparum cases.

Cases from 1971-72 from ACD and PCD only.

Cases from 1973-75 from All Sources.

* No surveillance.

Source - MEP Surveillance returns.

Ulawa during the early Attack phase.

During the years 1972-75 surveillance coverage of the island was very good. At least 30% of the population was sampled by ACD/ PCD each year (Table 37). The Slide Positivity Rate fell from 9.0% in 1971 to 0.2% in 1975 (Table 38). The Annual Parasite Incidence fell from 29.4‰ in 1973 to 1.2‰ in 1975. By the end of 1975 the island was ready to go into Consolidation, the small residual foci in the north east of the island having been satisfactorily cleared up.

Receptivity is moderate since the vector is still present. Vulnerability is low since there are only small number of movements between Ulawa and the (potentially) malarious areas.

Three Sisters

A.farauti was caught on these plantation islands in the 1930 's and again in the 1950's (Taylor 1974). The pre-spraying mosquito surveys of the Eastern Solomons in 1971-72 unfortunately missed out Three Sisters and no parasitological surveys were ever made. The group was included into DDT spraying operations purely on the basis of the previous presence of A.farauti.

Spraying operations started in February 1972. They continued regularly at 6 monthly intervals to complete 9 cycles by the end of 1975. There is no official health agency on Three Sisters but a voluntary PCD agency was set up in conjunction with the start of spraying. The agent has collected very few blood slides due to the absence of fever cases. Monthly ACD was introduced at the end of 1974, but even this produced only a minor improvement in population coverage.

No malaria cases have been detected on the island since the one P.vivax case in 1972. Malaria has almost certainly been eradicated and the island is due to go into Consolidation in 1976 or 1977. Three Sisters is of low receptivity and low vulnerability to malaria.

Eastern Outer Islands

This group, scattered widely around the main island of Ndende, has made progress every bit as good as that in the Eastern Inner Islands. The results of the pre and post spraying surveys show that Ndende and the Reefs made quick progress in the reduction of malaria following the start of DDT spraying in September 1971. The highly malarious Duffs, Utupua and Vanikoro however, each had a relapse detected during the post spraying surveys. In spite of this it was not long before the interruption of transmission was fully established on all of these islands. This was amply demonstrated by the surveillance returns shown in Table 40. Apart from some minor resumption of transmission in Ndende and Duff Islands the eradication of malaria proceeded well for the whole group during the period 1972-75.

The surveillance coverage was well above the minimum 10% in Ndende and Utupua showing a steady improvement over the years (Table 41). The other islands were more sporadic in their returns reflecting the communications and supervisory difficulties of those islands. In the two most remote Polynesian islands of Tikopia and Anuta surveillance was never really satisfactory in spite of several attempts to stimulate it. The Slide Positivity Rate for the Eastern Outer Islands fell from 24.0% in 1972 to 0.8% in 1975 whilst the Annual Parasite Incidence fell from 40.7‰ in 1973 to 6.1‰ in 1975 (Table 42).

The results for each of the individual islands of the group are

TABLE 40

Results of malaria surveillance, Eastern Outer Islands+, 1972 - 75.

Population:

1970 - 9078 (Census)
1972 - 9260 (MEP estimates)
1973 - 9330 (" ")
1974 - 8492 (MEP estimates)
1975 - 8945 (" ")
1976 - 10850 (Census)

Year	Number of slides collected by				ABER by PCD + ACD	Total cases by				Species				SPR% by PCD+ ACD	API‰ by All Sources
	ACD	PCD	Other Sources	All Sources		ACD	PCD	Other Sources	All Sources	f.	v.	m.	mixed		
1972	390	880	NA	1270	13.7	NA	NA	NA	305	41	256	8	0	24.0	NR
1973	348	1047	2624	4019	15.0	31	104	245	380	43	320	11	6 fv.	9.7	40.7
1974	1819	1494	1822	5135	39.0	52	83	82	217	17	198	1	1 fv.	4.1	25.6
1975	2975	1176	1489	5640	47.5	18	16	19	53	0	53	0	0	0.8	6.1

+ includes all islands in Eastern Outer Islands group.

Notes:

ACD - Active Case Detection.
PCD - Passive Case Detection.
ABER - Annual Blood Examination Rate.
SPR - Slide Positivity Rate per hundred slides.
API - Annual Parasite Incidence per thousand population.
NA - Data Not Available.
NR - Data Not Relevant.

Other Sources include Case Follow up, House Contacts and Surveys.

now reviewed in order. The annual totals of malaria cases in the individual islands are shown at the end of the section in Table 55.

Ndende

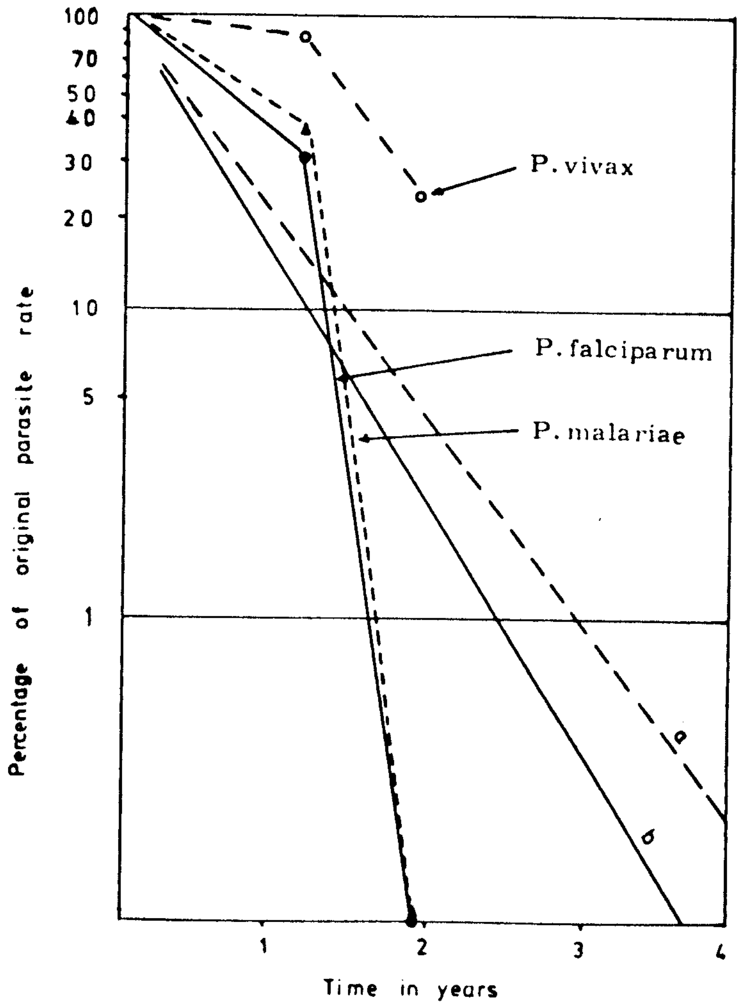
The vector *A.farauti* was found on several occasions on Ndende between 1926 and 1971 mostly from the Graciosa Bay area (Maffi and Taylor 1974). The vector was also found around Nanggu but was sparse on Temotu Neo and at Nemya Bay. No subsidiary vectors were found.

The small number of malariometric surveys carried out on Ndende (Tables 43 and 44), reported by Maffi and McDonnell (1971), allow the island to be classified as mesoendemic. All of these surveys missed out important malarious villages especially on the north coast. Had these been included higher spleen and parasite rates would undoubtedly have been recorded. The predominant species was *P.vivax*. No data is available on seasonal variations in malaria on Ndende.

Prior to the full eradication operations no antimalaria activities were carried out. DDT spraying operations commenced in October 1971. They continued at approximately six monthly intervals so that by the end of 1975 nine rounds had been completed. Refusals were very rare during this period. Passive Case Detection was started in January 1972 and Active Case Detection in July 1972.

The first of the two post spraying parasitological surveys showed that transmission of *P.falciparum* malaria had not been interrupted (Table 44 & Figure 51). The second confirmed that the transmission of *P.falciparum* had been interrupted in the Graciosa Bay area. The regression pattern for *P.vivax* was similar to that found elsewhere in

Fig. 51. Fall in malaria parasite rates in the 2 - 9 age group following DDT spraying in Ndende during 1969 - 73



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

the Solomon Islands. During casual post spraying entomological surveys A.farauti was found in abundance on the north coast, but only rarely found elsewhere on Ndende.

During the period of surveillance the Annual Blood Examination rate by ACD and PCD exceeded 20% on all occasions (Table 41). The Slide Positivity Rate fell from 28.4% in 1972 to 0.7% in 1975 (Table 42). The Annual Parasite Incidence fell from 50.2‰ in 1973 to 9.6‰ in 1975. The main residual foci of malaria during this period were on Tomotu Neo and on the north coast. These cases often persisted because of the frequent migrations to and from the Reef Islands. It is probable that many people came to Ndende before transmission had been fully interrupted. On departure to the Reefs they defaulted treatment only to return to reinfect others. Relapsing P.vivax cases were also very common. In a review of 30 P.vivax cases which occurred in the village of Otmogi in 1974 it was found that 10 had relapsed and 15 had returned to the Reef Islands at some stage. In view of these problems of recurrent malaria a 12 week mass drug administration was carried out on the north coast of Ndende between September and November 1975. By the end of the year very few cases were being detected anywhere on the island.

Prospects for the eradication of malaria from Ndende are excellent. However, receptivity is high due to the abundance of anophelines especially on the north coast. Vulnerability is also high due to the frequent migrations from malarious islands.

TABLE 41

Annual blood examination rate (%) by Islands, Eastern Outer Islands, 1972-75.

Year 19- Island	Population (1970 Census)	72	73	74	75
Ndende	3433	21.3	21.2	62.9	80.8
Reefs	3840	12.2	11.5	15.8	9.3
Duffs	213	*	*	22.0	9.2
Utupua	232	11.9	18.9	55.7	76.6
Vanikoro	163	24.0	2.4	18.4	37.9
Tikopia	1040	2.4	2.2	0.7	0.9
Anuta	157	*	*	*	*
Eastern Outer Islands	9078	13.7	15.0	39.0	47.5

TABLE 42

Slide positivity rate (%) and Annual parasite incidence (‰) by Islands, Eastern Outer Islands, 1972-75.

Year 19- Island	Slide Positivity Rate				Annual Parasite Incidence		
	72	73	74	75	73	74	75
Ndende	28.4	10.5	4.1	0.7	50.2	34.3	9.6
Reefs	11.1	8.1	3.1	2.8	16.3	15.1	3.0
Duffs	*	*	5.9	4.5	253.5	34.5	4.2
Utupua	51.6	7.5	4.1	0.5	71.4	87.1	7.3
Vanikoro	27.1	0.0	0.0	0.0	24.0	14.1	<u>0.0</u>
Tikopia	0.0	0.0	0.0	0.0	*	<u>0.1</u>	<u>0.0</u>
Anuta	*	*	*	*	*	<u>0.0</u>	*
Eastern Outer Islands	24.0	9.7	4.1	0.8	40.7	25.5	6.1

— Islands which satisfy Solomon Islands criteria for entry into consolidation (see Chapter 8.5 - Discussion).

TABLE 43

Results of pre spraying spleen surveys, Ndende

Population: 3433 (1970 census)

Date 19-	Surveyor	Age group	Number Examined	Number Positive	Spleen Rate %
Feb. 56	Hollins	All	1289	322	25.0
Feb. 56	Hollins	0-9	497	178	35.8
Jul. 67	McDonnell	2-9	52	33	63.5
Nov. 67	Maffi	2-9	166	46	27.7
Mar. 68	Bourke	2-9	101	32	31.7
Nov. 69	Avery	2-9	131	34	26.0
Jul. 70	Maffi	2-9	34	17	50.0

TABLE 44

Results of pre and post spraying malaria parasite surveys of Ndende, Solomon Islands.

Population: 3433 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number		Parasite Rate %	Species			
				Examined	Positive		f.	v.	m.	mixed
Pre spraying surveys										
Mar. 68	*	Bourke	2-9	91	56	61.5	5	29	12	4 fv. 6 vm.
Nov. 69	*	McDonnell	School 5- over 20	90	18	20.0	1	14	3	0
Jul. 70	*	Maffi Sukea	School 5- over 20	219	55	25.1	25	30	0	0
Nov. 69 & Sep. 70	*	Avery McDonnell	2-9	220	73	33.2	9	54	7	2 fv. 1 vm.
Post spraying surveys										
1st Nov. 72	13	Avery Silibasi	2-9	309	81	26.2	5	72	4	0
2nd Jul. - Sep. 73	22	Watson Silibasi Mazzur	All	830	53	6.4	0	53	0	0

Classification - Mesoendemic

Note: SO - Spraying Operation

Reef Main Islands

This low lying group has long been considered to be non malarious. The recorded mosquito surveys of the Reef Islands were summarised by Maffi and Taylor (1974). Adult anophelines have never been found and larvae of A.farauti found on only two occasions. These were in a very small number near Manupopo Rural Health Clinic in 1969 and near Nenumbo in 1970.

The small number of pre spraying malariometric surveys indicated a state of low mosoendemicity (Tables 45 and 46). The highest spleen and parasite rates were found in Nenumbo. In most other villages the rates were zero or near zero.

No antimalaria operations were carried out on the Reef Islands group prior to eradication. Although all the available evidence suggested that malaria transmission was only taking place in very limited foci it was decided to spray the three main islands. The first round was in February 1972. Spraying continued at approximately 6 monthly intervals until, at the end of 1975, nine rounds had been completed. Only one post spraying assessment survey was made this being at twelve months after the start of spraying (Table 46). It showed a very low parasite rate of 2.2%, with all the infections being due to P.vivax. Meanwhile three post spraying entomological surveys failed to find any sign of anopheline larvae or adults.

Passive case detection was started at Manuopo Rural Health Clinic simultaneously with the start of spraying. It was also included in Fenualoa clinic when this opened in late 1974. There has been no regular Active Case Detection. During the period 1972-1974 slightly more than 10% of the population was sampled in each of the years,

TABLE 45

Results of pre spraying spleen surveys, Reef Main Islands.

Population: 3840 (1970 census)

Date 19-	Surveyor	Age group	Number Examined	Number Positive	Spleen Rate %
Feb. 56	Hollins	0-9	83	1	1.2
Nov. 67	Maffi	2-9	155	39	25.2
Feb. 68	Bourke	2-9	34	12	35.3
Nov. 69	Avery	2-9	166	5	3.0
Jul. 70	Maffi	2-9	73	19	26.0

TABLE 46

Results of pre and post spraying malaria parasite surveys of Reef Main Islands, Solomon Islands.

Population: 3840 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number		Para-site Rate %	Species			
				Exam-ined	Posi-tive		f.	v.	m.	mixed
Pre spraying surveys										
Nov. 67	*	Maffi	2-9	77	10	13.0	4	4	2	0
Feb. 68	*	Bourke	2-9	34	16	47.1	3	8	5	0
Nov. 69	*	Avery	2-9	63	5	7.9	0	4	0	1 fv.
Post spraying surveys										
1st Feb. 73	12	Silibasi	2-9	414	9	2.2	0	9	0	0

Classification - Low Mesoendemic

Note: SO - Spraying Operation.

whilst in 1975 this fell to 9.3% (Table 41). The Slide Positivity Rate fell from 11.1% in 1972 to 2.8% in 1975 whilst the Annual Parasite Incidence fell from 16.3‰ in 1973 to 3.9‰ in 1975 (Table 42). The group was under serious consideration for entry into Consolidation during 1976 or 1977.

The Reef Islands are of very low receptivity to malaria but of moderate vulnerability due to the high rate of migration from (potentially) malarious areas. The easy access to and from Manuopo and Fenualoa clinics should allow a good standard of surveillance to be maintained. The prospects are excellent for achieving and maintaining malaria eradication in the Reef Islands.

Reef Outer Islands

The islands of Matema, Nimbanga Ndende, Nimbanga Temoa, Fenualoa and Nifiloli are all non malarious (Tables 47 and 48). Anophelines have never been found on any of them. The small number of malaria cases that have been found mostly acquired their infections during visits to Ndende.

The northernmost Polynesian islands of Nupani, Nukapu and Pileni were all considered to be non malarious in earlier surveys. During the early 1970's however, each island was found to have increasing parasite rates (Table 49) even though the vector could not be found on any of them. In view of the risk that transmission may have been occurring on these islands they were brought under DDT spray cover in 1972 (Nukapu and Nupani) and 1974 (Pileni). Spraying continued to the end of 1975 but the absence of further malaria cases qualified them all for entry into Consolidation in 1976. Nukapu had

TABLE 47

Results of (pre spraying) spleen surveys, Reef Outer Islands.

Date 19-	Surveyor	Age group	Number Examined	Number Positive	Spleen Rate %
Fenualoa					
1963	Savou	All	78	15	19.2
Nov. 67	Maffi	All	124	3	2.4
Tinakula					
May 67	McDonnell	All	41	6	14.6
Nov. 67	Maffi	All	41	5	12.2
Nupani					
1962	Savou	All	120	0	0.0
Nov. 69	Avery	2-9	14	8	57.1
Nukapu					
Nov. 69	Avery	2-9	13	1	7.7
Nov. 72	Avery & Silibasi	2-9	15	9	60.0
Pileni					
Nov. 69	Avery	2-9	32	5	15.6

TABLE 48

Results of (pre spraying) malaria parasite surveys of unsprayed Reef Outer Islands.

Date 19-	Surveyor	Age group	Number Exam-ined	Number Posi-tive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Matema									
Sep. 70	Sukea	All	32	2	6.3	0	1	1	0
Mar. 74	Sukea	All	37	1	2.7	0	1	0	0
Nimbanga Ndende*									
Sep. 70	Sukea	All	40	3	7.5	1	2	0	0
Nimbanga Temoa *									
Sep. 70	Sukea	All	71	5	7.0	0	5	0	0
Fenualoa									
Oct. 70	McDonnell & Moare	All	499	21	4.2	3	17	1	0
Feb. 73	Silibasi	2-9	125	3	2.4	0	3	0	0
Nifiloli									
Feb. 73	Silibasi	2-9	15	0	0.0	-	-	-	-

Note: All islands remained unsprayed.

* Population included in with Reef Main Islands.

TABLE 49

Results of pre and post spraying malaria parasite surveys of sprayed Reef Outer Islands.

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number		Parasite Rate %	Species			
				Examined	Positive		f.	v.	m.	mixed
Pre spraying surveys										
Nupani										
Nov. 69	*	Avery	2-9	14	5	35.7	2	3	0	0
Jul. 70	*	Maffi	2-9	5	1	20.0	1	0	0	0
Jun. 72	*	Lee	2-9	8	4	50.0	1	3	0	0
Nükapu										
Sep. 70	*	McDonnell	All	58	8	13.8	2	6	0	0
Nov. 72	*	Avery & Silibasi	2-9	15	12	80.0	1	11	0	0
Pileni										
Sep. 70	*	Sukea	All	91	9	10.0	2	7	0	0
Feb. 73	*	Silibasi	2-9	20	2	10.0	0	2	0	0
Sep. 73	*	Silibasi	2-9	33	2	6.1	0	2	0	0
Mar. 74	*	Avery & Silibasi	2-9	27	3	11.1	1	2	0	0
Post spraying surveys										
Nupani										
1st Nov. 72		Avery & Silibasi	2-9	9	2	22.2	0	2	0	0
2nd Apr. 74		Silibasi	All	8	0	0.0	-	-	-	-
Nukapu										
1st Sep. 73		Silibasi	2-9	35	10	28.5	1	9	0	0
2nd Mar. 74		Avery & Silibasi	2-9	21	12	57.1	1	11	0	0

Note: SO - Spraying Operation.

Note for Tables 47-49:

The total population of the Reef Outer islands in the 1970 census was 1239. This comprised Fenualoa - 777, Nupani, Nukapu & Matema - 227 and Nifiloli & Pileni - 235. Tinakula was not inhabited in 1970.

shown a further increase in malaria in 1974 but field reports indicated that the island was clear of the disease in 1975.

Due to their remoteness none of the Reef Outer Islands was covered by regular surveillance. The Rural Health Clinics at Manuopo on Lom Lom and at Fenualoa in the Reef Outer Islands provide adequate Passive Case Detection cover albeit at some distance away. Their staff also carry out a form of Active Case Detection on their patrols around the islands. These patrols are not very regular, however, due to shipping difficulties and treacherous seas.

The absence of surface water has made malaria transmission impossible on the volcanic island of Tinakula.

All of the Reef Outer Islands are of very low receptivity and vulnerability to malaria, yet it should not be forgotten that at least three of them acquired malaria in recent years.

Duff Islands

Malaria is thought to have been present for many years on the Duff Islands. Pre spraying surveys easily established the presence of *A.farauti* larvae on the mainland of Taumako and of adults on the mainland and on Tahua (Maffi and Taylor 1974). The island of Tahua was chosen by Parsonson (1966, 1968) to endorse the thesis of Ivens (1930) that the artificial islands were built specifically by the people to escape the ravages of malaria. Unfortunately none of the most recent evidence supports this thesis for Tahua although there is a stronger case for the Malaita islands (see Chapters 2 & 3).

Most of the pre spraying malariometric surveys found spleen and parasite rates high enough to classify the island as hyperendemic (Table 50). The official pre spray survey of Maffi in 1970 showed a slight predominance of P.falciparum over P.vivax with only one P.malariae being found. It is probable that seasonal factors are very important on Duff Islands but this was not proved in any of the surveys.

DDT spraying operations commenced in September 1971. They continued regularly thereafter at intervals of 5-7 months. By the end of 1975 a total of 9 cycles had been completed. No Active Case Detection was started until a Village Health Aid was posted to Tahua in August 1974. During 1974,22.0% of the population was sampled by Passive Case Detection but during 1975 this figure fell to 9.2% (Table 41). The Slide Positivity Rate fell from 5.9% in 1974 to 4.5% in 1975 and the Annual Parasite Incidence fell from 253.5‰ in 1973 to 4.2‰ in 1975 (Table 42).

It was hoped to be able to measure the true regression pattern of P.vivax on Duff Islands since this was an isolated and uncontaminated island with no medical facilities. The experiment was unfortunately invalidated by the resumption of transmission of both P.falciparum and P.vivax during 1973. During the parasitological surveys night catches were also made for A.farauti. Anopheline densities were over 20 per man per hour on occasions showing the greatest fluctuations with changes in wind direction. On the one occasion when an onshore wind was blowing no anophelines were caught. Whenever the breeze was blowing from the land anopheline densities were high.

Following the resumption of transmission in 1973 monthly mass drug administration was carried out on Duff Islands from September 1973 to January 1974. Surveys in 1974 (Table 50) and the surveillance returns (Tables 42 and 55) showed a marked reduction in malaria during 1974 and 1975. By the end of 1975 there were good prospects

TABLE 50

Summary results of malariometric surveys, Duff Islands.

Population: 213 (1970 census)

Date 19-	Surveyor	Age group	Spleen Rate (No Exd)	Parasite Rate (No Exd)	Parasite species			
					f.	v.	m.	mixed
Pre spraying								
1954	Dawea	All	54.0 (50)	-	-	-	-	-
Feb. 56	Hollins	0-9	59.3 (59)	-	-	-	-	-
1962	Savou	2-9	21.7 (120)	-	-	-	-	-
Nov. 67	Maffi	2-9	46.5 (43)	32.6 (43)	8	1	5	0
Jul. 68	Sloof	2-9	-	57.5 (40)	2	7	8	2 fv. 3 vm. 1 fv.
Nov. 69	Avery	2-9	31.9 (69)	14.5 (69)	3	5	2	0
Jul. 70	Maffi	2-9	73.5 (49)	68.2 (44)	15	14	0	1 fm.
Dec. 70	McDonnell	2-9	-	58.3 (36)	10	9	1	1 NS
Sep. 71	Gleadhill	2-9	-	44.4 (36)	4	10	1	1 fv.
Post spraying - selected surveys								
Feb. 72(5)	Lewis	2-9	-	30.1 (73)	5	17	0	0
Oct. 72(13)	Lee/ Silibasi	2-9	-	29.0 (62)	1	10	7	0
Jan. 73(16)	Silibasi	2-9	-	53.0 (83)	15	?	?	? +
Jun. 73(21)	Turner	2-9	-	48.8 (82)	12	22	4	2 fv.
Mar. 74(30)	Avery/ Silibasi	2-9	-	12.1 (33)	0	4	0	0

Classification - Hyperendemic

Notes: NS - Not Specified.

\+ details of other species lost from records.

Number in brackets after post spraying dates is the month after first spraying operation.

that the island would be able to go into Consolidation later in 1976.

Prospects for the eradication of malaria from Duff Islands are excellent. Receptivity remains high but vulnerability is low due to the infrequent migrations from (potentially) malarious areas.

Utupua

On this highly malarious island A.farauti adults and larvae have been found on several occasions in recent years (Maffi and Taylor 1974). The pre spraying malariometric surveys (Table 51), summarised by Maffi and McDonnell (1971), classified the island as holoendemic.

In the parasite surveys of February 1968 all three species were well represented with a slight predominance of P.vivax. A survey by Maffi only a few months earlier however, showed an almost exclusive predominance of P.falciparum.

In February to July 1968 a special malaria eradication operation was carried out on Utupua and Vanikoro. All villages were sprayed with DDT and as many people as possible treated weekly with chloroquine 600 mg and primaquine 45 mg for adults (pro rata doses for children) for 12 weeks. The DDT spraying operation was repeated in July 1968. On review of the operations in Utupua it was found that several houses had not been sprayed and several people had not taken their full drug treatment. There was no change in the parasite rate (Table 51) but the parasite formula had changed to a predominance of P.vivax with the virtual disappearance of P.falciparum. The exercise was abandoned at this stage due to the disproportionate amount of time being spent by senior staff for such small returns. Within two years P.falciparum had returned almost to its former importance.

TABLE 51

Summary results of malariometric surveys, Utupua island.

Population: 273 (1970 census)

Date 19-	Surveyor	Age group	Spleen Rate (No Exd)	Parasite Rate (No Exd)	Parasite species f.	v.	m.	mixed
Pre spraying								
Feb. 56	Hollins	0-9	54.5 (44)		-	-	-	-
Nov. 67	Maffi	2-9	86.9 (46)	30.4 (46)	12	0	1	1 fm.
Feb. 68	Bourke	2-9	-	55.7 (61)	10	13	9	2 fv.
Post special experimental eradication operation								
Jul. 68	Sloof	2-9	-	53.2 (62)	2	30	0	1 vm.
Nov. 69	Avery	2-9	34.0 (50)	57.1 (70)	4	33	0	3 fv.
Jul. 70	Maffi	2-9	61.1 (36)	60.4 (53)	6	20	0	6 fv.
Dec. 70	McDonnell	2-9	-	58.6 (29)	13	4	0	0
Feb. 72	Avery	2-9	32.1 (84)	56.6 (83)	11	33	1	2 fv.
Post spraying								
Nov. 72(9)	Avery & Silibasi	2-9	-	39.7 (78)	3	28	0	0
Mar.72 (13)	Silibasi	2-9	-	48.0 (25)	0	12	0	0
Oct. 73(20)	Silibasi	2-9	-	9.8 (41)	0	4	0	0
Mar. 74(25)	Avery & Silibasi	2-9	-	28.8 (52)	0	15	0	0

Classification - Holoendemic.

Note: Number in brackets after post spraying dates is the months after first spraying operation.

Parasite rates remained consistently high at over 50%.

In February 1972 Utupua was included into the Eastern Outer Islands DDT spraying operations. These continued once every six months until by August 1975 a total of 8 cycles had been completed. Four post spraying serial surveys were carried out between 1972-74 (Table 51). These showed fluctuating parasite rates in the 2-9 age group and some evidence that transmission was not fully interrupted. P.falciparum infections were however, absent from all but the first survey.

Passive Case Detection was also started in February 1972 at the Rural Health Clinic (Village Aid Post) at Nembao. The collection of slides was sporadic at first but during 1974 and 1975 more than 50% of the population was sampled each year (Table 41). The Slide Positivity Rate fell from 51.6% in 1972 to 0.5% in 1975 (Table 42) whilst the Annual Parasite Incidence fell from 71.4‰ in 1973 to 7.3‰ in 1975 after rising to 87.1‰ in 1974. P.falciparum was absent from all returns from 1973 onwards. The dramatic reduction in malaria during 1975 made the island a candidate for entry into consolidation during 1976 or 1977.

Prospects for the eradication of malaria on Utupua are excellent notwithstanding its formerly highly malarious state. The island remains highly receptive to malaria due to the continuing presence of anophelines proved in occasional post spraying surveys. It is of low vulnerability due to the infrequent migrations from (potentially) malarious areas.

Vanikoro

This large volcanic island has a long history of malaria. A.farauti was found in moderate densities on a number of occasions

(Maffi and Taylor 1974). The major surveys of 1967-68 (Table 52), reported by Maffi and McDonnell (1971), classify the island as hyper-endemic. The predominant species was P. vivax in the 1968 survey but in the 1967 survey there was a clear predominance of P. falciparum.

During 1968 a special malaria eradication operation was carried out identical to the one on Utupua (q.v.). This also missed out the spraying of some houses and treatment of some people. Following this the parasite rate actually increased (Table 52), but P. falciparum completely disappeared from the community. Subsequent surveys showed that the spleen rate had fallen to zero. The parasite rate first of all fell and then rose again. P. falciparum reappeared in the later surveys.

In February 1972 Vanikoro was included into the Eastern Outer Islands spraying operations. These continued every six months until by August 1975 a total of 8 cycles had been completed. Four post spraying serial surveys were carried out between 1972-74 (Table 52). These showed low but fluctuating parasite rates and a complete absence of P. falciparum infections.

Passive Case Detection was set up at the Village Health Aid Post at Buma in August 1971, actually before spraying started. Collections of blood slides during the ensuing years were sporadic, but in 1974 and 1975 more than 18% of the population was sampled by PCD each year (Table 41). The Slide Positivity Rate fell from 27.1% in 1972 to zero from 1973-75 (Table 42). The Annual Parasite Incidence fell from 24.0‰ in 1973 to zero in 1975. Only one P. falciparum case was detected by surveillance, this being in 1972. Progress was so good that the island qualified to enter into Consolidation

TABLE 52

Summary results of malariometric surveys, Vanikoro Island

Population: 163 (1970 census)

Date 19-	Surveyor	Age group	Spleen Rate (No Exd)	Parasite Rate (No Exd)	Parasite Species f.	v.	m.	mixed
Pre-spraying								
Nov. 67	Maffi	2-9	58.3 (36)	25.0 (36)	6	1	2	0
		All	46.5 (99)	13.1 (99)	9	2	2	0
Feb. 68	Bourke & Sloof	2-9	*	42.0 (50)	6	14	1	0
		All	*	28.7 (167)	17	28	2	1 fv.
Post special experimental eradication operation								
Jul. 68	Sloof	2-9	*	56.4 (55)	0	31	0	0
		All	*	31.9 (163)	0	52	0	0
May 69	McDonnell	Children	36.4 (22)	*	*	*	*	*
Nov. 69	Avery	2-9	0.0 (47)	16.7 (48)	0	8	0	0
		All	0.0 (106)	8.2 (110)	0	9	0	0
Jul. 70	Maffi	2-9	0.0 (15)	26.1 (46)	3	9	0	0
		All	5.2 (38)	16.4 (110)	4	14	0	0
Feb. 72	Avery	2-9	0.0 (58)	57.1 (42)	0	23	0	1 fv.
		All	0.7 (137)	*	*	*	*	*
Post spraying								
Nov. 72 (9)	Avery & Silibasi	0-1	*	0.0 (5)	*	*	*	*
		2-9	*	10.7 (56)	0	6	0	0
Mar. 73 (13)	Silibasi	2-9	*	7.7 (26)	0	2	0	0
Oct. 73 (20)	Silibasi	2-9	*	6.7 (60)	0	4	0	0
Mar. 74 (25)	Avery & Silibasi	2-9	*	9.4 (32)	0	3	0	0

Classification - Hyperendemic

Note: Number in brackets after post spraying dates is the months after first spraying operation.

in 1976.

Prospects for the eradication of malaria from Vanikoro are excellent. Receptivity is, however, high due to the continuing presence of A.farauti. Vulnerability is quite low due to infrequent migrations from malarious areas.

Tikopia

The presence of anopheline mosquitoes on Tikopia was long suspected by Firth (1936) and confirmed by the Robinson Peabody expedition in 1956 (Maffi and Taylor 1974). Subsequent surveys failed to find anophelines although culcines were abundant. Tikopia was considered to be malaria free up until the early 1950's (Black 1955[a]). Following two epidemics of influenza and dysentry in the 1950's it became apparent that malaria was present on the island (Maffi and McDonnell 1971) (Table 53). Houses were sprayed with BHC, breeding sites oiled and patients treated. Malaria was considered to be the main source of ill health during the 1960's (Maffi 1967, Field Trip Report) but,by the end of the decade,the parasite and spleen rates were showing a steady decline (Table 53). It has always been difficult to carry out malariometric surveys on Tikopia due to the reticence of the people. A reasonable coverage was finally obtained, however, by Alexander in June 1974. In this survey only one P.vivax case was detected in 287 slides examined from all ages.

No DDT spraying operations have been carried out on Tikopia. Passive case detection started in February 1972 but the annual coverage of the population has been below 3% (Table 41). No malaria cases were detected on Tikopia by PCD during the period 1972-75. The island has a low receptivity and low vulnerability to malaria.

TABLE 53

Summary results of malariometric surveys, Tikopia island.

Population: 1040 (1970 census)

Date 19-	Surveyor	Age group	Spleen Rate (No Exd)	Para-site Rate (No Exd)	Parasite Species			
					f.	v.	m.	mixed
Sep. 55	Tabua	0-9	26.1 (138)	*	*	*	*	*
Feb. 56	Hollins	0-9	72.2 (281)	*	*	*	*	*
Nov. 67	Maffi	2-9	17.6 (34)	8.8 (34)	2	0	1	0
Nov. 69	Avery	2-9	2.7 (73)	13.6 (22)	1	1	0	1 fv.
Jul. 70	Maffi	All	*	3.2 (62)	9	2	0	0
Dec. 70	Paik	All	*	1.9 (52)	0	1	0	0
Jun. 74	Alexander	2-9	*	0.9 (113)	0	1	0	0
Jun. 74	"	All	*	0.3 (287)	0	1	0	0

Classification - Hypoendemic

No Spraying Operations.

Anuta

Anopheline mosquitoes have never been found on this lonely island although two culcicine species have been recorded (Maffi and Taylor 1974).

The most recent malariometric surveys found no enlarged spleens in the all ages group in 1969 and 1970 and 2-9 parasite rates of 7.1% in 1970 and zero in 1974. The all ages parasite rate was 12.0% in 1970, but zero in 1974 (Table 54).

There has been no DDT spraying on the island. There is no medical agency and no malaria surveillance has been carried out apart from the surveys. The island is considered to be free from malaria. It is neither receptive nor vulnerable to the disease in the future.

- Malaita District

This group comprising the main island of Malaita (including Small Malaita), and the outlying Ndai, Ontong Java and Sikaiana had initially spectacular success in the reduction of malaria. This was followed by a breakdown in operations and resumption of transmission in several foci during 1973-75.

The overall progress may be seen from the results of the pre and post spraying malariometric surveys on Malaita island (Table 57) and the outlying islands (Tables 63 and 64). A further review of progress may be seen in the results of malaria surveillance for the whole of Malaita District (Table 61) and in the quarterly progress chart for 1970-75 in Figure 53. The Annual Blood Examination Rate for

TABLE 54

Summary results of Malriometric surveys, Anuta island

Population: 157 (1970 census)

Date 19-	Surveyor	Age group	Spleen Rate (No Exd)	Para-site Rate (No Exd)	Parasite Species			
					f.	v.	m.	mixed
Jul. 33	Lambert	2-9	5.0 (20)	*	*	*	*	*
Nov. 67	Kiers	5-9	16.7 (12)	*	*	*	*	*
Nov. 69	Avery	2-9	0.0 (22)	4.3 (23)	0	1	0	0
Nov. 69	"	All	0.0 (102)	8.8 (102)	0	9	0	0
Jul. 70	Maffi	2-9	0.0 (18)	7.1 (28)	0	2	0	0
Jul. 70	"	All	0.0 (83)	12.0 (83)	5	5	0	0
Jun. 74	Alexander	2-9	*	0.0 (18)	*	*	*	*
Jun. 74	"	All	*	0.0 (86)	*	*	*	*

Classification - Hypoendemic

No Spraying Operations.

TABLE 55

Annual totals of malaria cases in individual islands, Eastern Outer Islands

	Ndende	Reff Main Islands	Reef Outer Islands	Duff Islands	Utupua	Vanikoro	Tikopia	Anuta
1972	241(28)	35(4)	*	*	16(8)	13(1)	0	*
1973	241(26)	30(1)	12(1)	71(21)	20	6	0	*
1974	148(13)	21(4)	13(1)	8	23	3	1	0
1975	43	7	0	1	2	0	0	*

Notes: Figures in brackets ( ) are *P. falciparum* cases.

Cases in 1972 from ACD and PCD only.

Cases for 1973-75 from all sources.

* No surveillance.

the mainland reached a very reasonable figure for each of the years 1972-75 (Table 59) but it was rather variable for the outer islands. The Slide Positivity Rate and Annual Parasite Incidence fell to low levels for all the outer islands during 1971-75 (Table 60). On the mainland there was a remarkable fall in the Slide Positivity Rate from 39.6% in 1970 (Table 61) to 1.5% in 1974 (Table 60). Unfortunately this rose again to 3.1% in 1975 as a result of the resumption of transmission in certain parts of the island. The Annual Parasite Incidence showed a similar fall from 1973 to 1974 with an increase again in 1975 (Table 60). The annual totals of malaria cases for each island are shown in Table 62.

Malaita Island

This large and foreboding island had very few malariometric surveys carried out prior to the recent operations. The only known anopheline surveys (U.S. Forces 1942-45, Brown 1954-56 and M.E.P. staff 1967-70) have been summarised by Taylor (1974). During 1968-70 M.E.P. staff visited 320 of the 1643 villages subsequently reported on during the first spray round. Anopheline mosquitoes were found in 188 of the villages. The altitudinal distribution of these is shown in Table 56.

The major vector A.farauti was found to be widely distributed (Figure 34, Chapter 7.1) though generally confined to coastal areas. A.koliensis was more patchily distributed whilst A.punctulatus was found in only a small number of scattered localities. A.koliensis and A.punctulatus were also found in some inland riverine localities. Both A.farauti and A.koliensis were found up to an altitude of 800 metres,

TABLE 56

Altitudinal distribution of the Anopheles punctulatus group on Malaita island. Sept. 1968 - Sept. 1970

Locality	Total No. of localities visited	Anophelines present	Percentage with anophelines present
Artificial or offshore island	22	6	27.3
Coastal	145	104	71.7
Inland 0-200m	66	47	71.2
200-400m	19	8	42.1
400-600m	19	7	36.8
600-800m	9	3	33.3
Over 800m	3	0	0.0
Unlocated on map (Probably relocated since survey)	37	13	35.1
TOTAL	320	188	58.7

Source: Summarised from Taylor (1974).

this being a record for the Solomon Islands. A.punctulatus was not found above 400 metres. Taylor (personal communication) noted that in only one of the six largest villages on Malaita could the vector be found. These villages each had a population of over 400. Four of them were on artificial or offshore islands. Villages with less than 30 people comprised 67.9% of all villages but accounted for only 20.9% of the total population of the island.

Malaita was rather badly neglected by malariometric surveys probably because of the expected hostility of the people (see Chapter 2). The earliest record is that of Innes (1938) who found during his leprosy surveys a spleen rate of 77.2%. Nearly thirty years later, in a survey of accessible coastal villages during 1967, Davidson found a parasite rate of 44.3% in the 2-9 years age group. Nearer to the time of spraying Kirimaoma in a series of spot surveys in villages in 1970, found 2-9 years spleen rates of over 50% in many coastal and low bush villages. In the only known high bush survey Kirimaoma (in 1970) found a 2-9 year spleen rate of 45.0% in the Alasaa group of villages near Auki. Spleen rates on most of the artificial islands were much lower at between 10-20%. Two further parasite surveys carried out in 1969 and 1970 were combined to provide the baseline data for future assessment. These were the surveys of Maffi in March 1969 in Small Malaita and of M.E.P. staff in Big Malaita in March 1970. The combined survey resulted in a 2-9 parasite rate of 29.7%, the predominant species being <u>P. vivax</u> (Table 57). Malaita was therefore classified as mesoendemic even though earlier surveys had certainly given some indicationsof hyperendemicity. The malaria incidence surveys carried out at Kilu'ufi Hospital, Auki, have already been covered in Chapter 7.2. They showed that the incidence of malaria on the west coast of Malaita did appear to fall during the dry season.

The Malaita anti-malaria operations were regarded from the beginning as being potentially the most difficult. Much of the transportation was by sea yet there were numerous bush villages which could only be reached by foot along rough mountain tracks. The island was well known for the truculent nature of the indigenes and the strict adherence to custom by the pagan bush people. These were expected to make spraying and blood taking difficult.

The first DDT spray round started in July 1970 with excellent

TABLE 57

Results of pre and post spraying malaria parasite surveys of Malaita Island

Population: 51722 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	Species v.	Species m.	Species mixed
Pre spraying surveys										
Aug. 67	*	Davidson	2-9	585	259	44.3	Data incomplete			
Mar. 69 } Mar. 70 }	*	Maffi MEP staff	2-9	2174	645	29.7	126	453	31	29fv. 3fm. 2vm. 1fvm
Post spraying surveys										
1st Apr. 71	7	Gibson	2-9	870	325	37.4	33	264	20	7fv. 1fm.
2nd Sep. 71	12	Avery/ Paik	2-9	920	242	26.3	11	211	19	1fv.
3rd Apr. 72	19	Paik	2-9	1178	217	18.4	10	183	24	0
4th Sep. 72	24	Avery/ Peabody	2-9	1278	163	12.8	3	152	6	1fv. 1fm.
5th Mar. 73	30	Turner	2-9	1664	83	5.0	22	60	1	0
6th Nov. 73[1]	38	Alexander	2-9	632	4	0.6	0	4	0	0

Classification - Mesoendemic

Note: SO - Spraying Operation

1 - Small Malaita only

public co-operation all round. This remained good for the first two years but then deteriorated during 1973-75 (Table 58).

TABLE 58

Percentage of structures unsprayed during DDT spraying operations, Malaita Island, 1970-75

Year	Cycle 1	Cycle 2
1970[1]	0.8	
1971	2.2	3.4
1972	5.2	6.3[2]
1973	9.3	12.1[2]
1974	10.5	11.5
1975	14.5	12.6

Notes:
1 There was only one round in 1970.

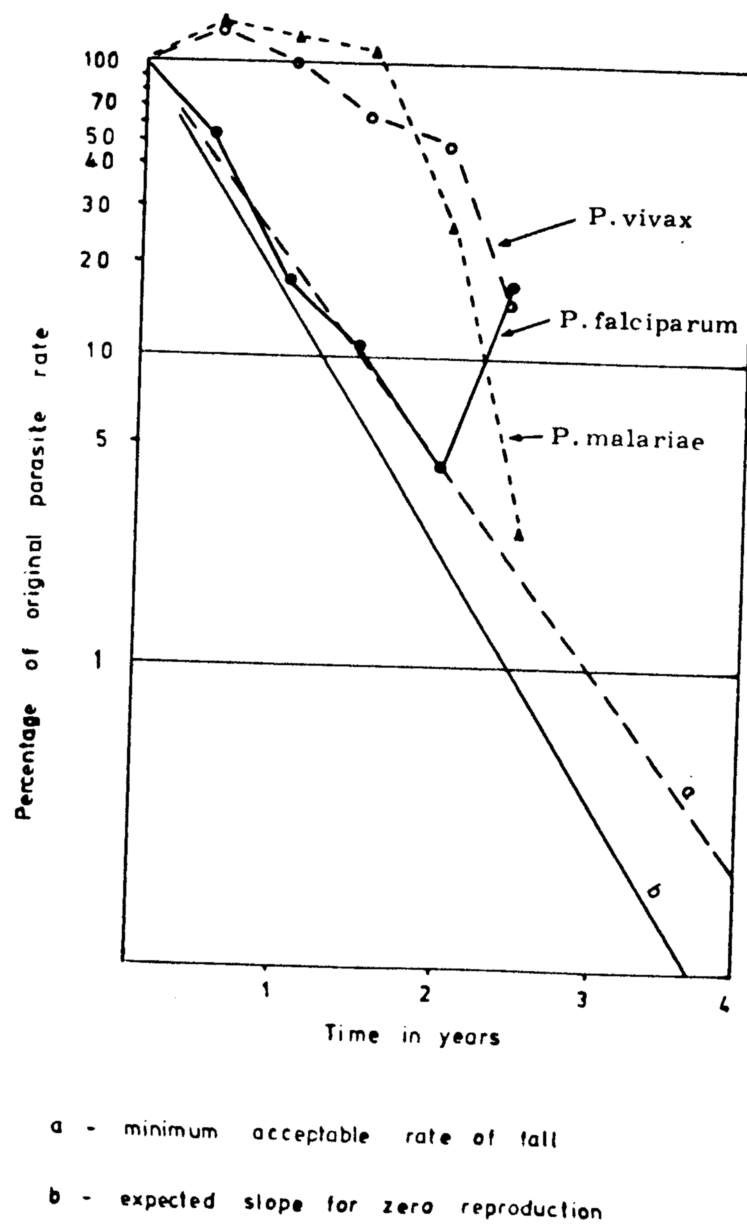
2 These figures are a % of the zones actually sprayed. Some zones were missed out completely due to DDT shortages.

The first three rounds were completed with an interval of six months between cycles but in 1972-73 there were gaps of 8-10 months in several zones and some were even missed out completely. This was due to DDT shortages, increasing lack of co-operation and indifferent field organisation. A marked improvement was seen in 1974-75 with the spray rounds returning to their former 6 monthly intervals. The actual spray coverage, however, still remained poor. An intensive Health Education programme through the local Council Area Committees finally resulted in some improvement in overall spray coverage in the latter half of 1975. Most of the bush and artificial islands were excluded from spraying operations from 1972 onwards. This was after only three rounds since there was no entomological or parasitological evidence that transmission was going on in these areas. However, the difficulty in interrupting transmission elsewhere prompted senior staff to seriously consider bringing these areas back under spray cover during 1976.

If the pre-spraying surveys were inadequate this was certainly made up for by the post spraying parasitological surveys. Five surveys were made at six monthly intervals. These showed a steadily decreasing parasite rate (Table 57) even though the first survey actually resulted in a higher parasite rate than the original surveys. The P.falciparum parasite rate twice fell within and twice just outside, the limits for the minimum acceptable rate of fall (Figure 52). On the last island wide survey however, in March 1973, there was an increase in the P.falciparum rate and a clear indication that transmission had not been effectively interrupted in all areas. The regression pattern for P.vivax on the other hand (Figure 52), whilst not falling anywhere near the acceptable limits (see Chapter 6.6), nevertheless followed the typical Solomon Islands pattern. P.malariae was only detected in small numbers after the third survey.

For some time prior to and immediately following the start of DDT spraying, anopheline night catches were made at five fixed stations near Auki. This was with a view to confirming the findings on the changes in vector behaviour that were seen earlier in Guadalcanal. However, A.farauti fell to such low densities that no adequate study was possible. The two subsidiary vectors A.koliensis and A.punctulatus disappeared completely. Occasional surveys in the investigation of foci during 1972-75 located moderate densities of A.farauti in some areas but a number of bush surveys failed to locate any vector above 200 metres. A surprising finding was the collection of seven A.punctulatus

Fig. 52. Fall in malaria parasite rates in the 2 - 9 age group following DDT spraying in Malaita during 1970 - 73



in the early evening in a village in south-east Malaita in February 1973. This was near to one of the collection sites of this vector in the original surveys.

Soon after the start of spraying an effort was made to set up an island wide network of Passive Case Detection agencies. Kilu'ufi (Auki), Fauabu and Malu'u hospitals continued with the collections they had already started before spraying. By February 1971 there was already an excellent coverage of the island. Active Case Detection started in February 1972 gradually expanding all round. Even by the end of 1975 however, some of the bush areas were not being regularly visited by ACD agents. Meanwhile, most coastal villages were getting fortnightly visits. During the period 1972-75 there was an Annual Blood Examination Rate each year of well over 40% of the population (Table 59).

TABLE 59

Annual blood examination rate (%) by islands, Malaita District, 1971-75

	Year 19- Population (1970 census)	-71	-72	-73	-74	-75
Malaita Island	50,659	10.2	41.8	43.6	50.8	48.7
Ndai	(60)[1]	3.3	83.3	76.7	0.0	11.7
Ontong Java	873	26.7	19.7	9.7	31.0	47.3
Sikaiana	190	25.0	101.4	64.0	106.0	0.0

[1] Ndai population was included in with Malaita in the census.

In spite of some of the setbacks, the Slide Positivity Rate fell from 16.4% in 1971 to 1.5% in 1974. It then increased to 3.1% in 1975 (Table 60). The Annual Parasite Incidence fell from 21.0‰ in 1973 to 9.3‰ in 1974 but increased again to 19.6‰ in 1975. The Quarterly

TABLE 60

Slide Positivity Rate (%) and Annual Parasite Incidence (‰) by islands, Malaita District, 1971-75

	Slide Positivity Rate					Annual Parasite Incidence		
	71	72	73	74	75	73	74	75
Malaita Island	16.4	5.6	4.3	1.5	3.1	21.0	9.3	19.6
Ndai	100.0	0.0	0.0	*	0.0	<u>0.0</u>	*	<u>0.0</u>
Ontong Java	7.3	1.4	0.0	0.0	0.0	<u>0.9</u>	<u>0.0</u>	<u>0.0</u>
Sikaiana	7.0	0.7	0.0	2.8	*	<u>0.0</u>	30.1	<u>0.0</u>

___ Islands which satisfy Solomon Islands criteria for entry into consolidation (see Chapter 8.5 - Discussion).

Malaria returns are shown in histogram form in Figure 53. These returns showed an overall fall in malaria and a marked fall in the Slide Positivity Rate. They also showed an increase in malaria and in the Slide Positivity Rate in mid 1973, late 1974 and again in early 1975. The crude annual and quarterly figures do not reflect the monthly field reports which confirmed the survey of March 1973 that transmission had already been resumed in some areas at that time. Sporadic outbreaks continued to occur during 1973. By early 1974 remedial measures appeared to have brought these setbacks under control resulting in the almost complete disappearance of P.falciparum from the returns. Then in May 1974 a small outbreak occurred in the Olomburi area of E.Kwaio. This was duly contained only to break out again with even greater morbidity in November 1974. Soon malaria had spread up and down the coast reaching as far south as north Small Malaita and also spreading across the mountains to the west coast (Figure 54). During the first six months of 1975 more cases were reported on the island than in the whole of Malaita in 1974. The reasons for this serious

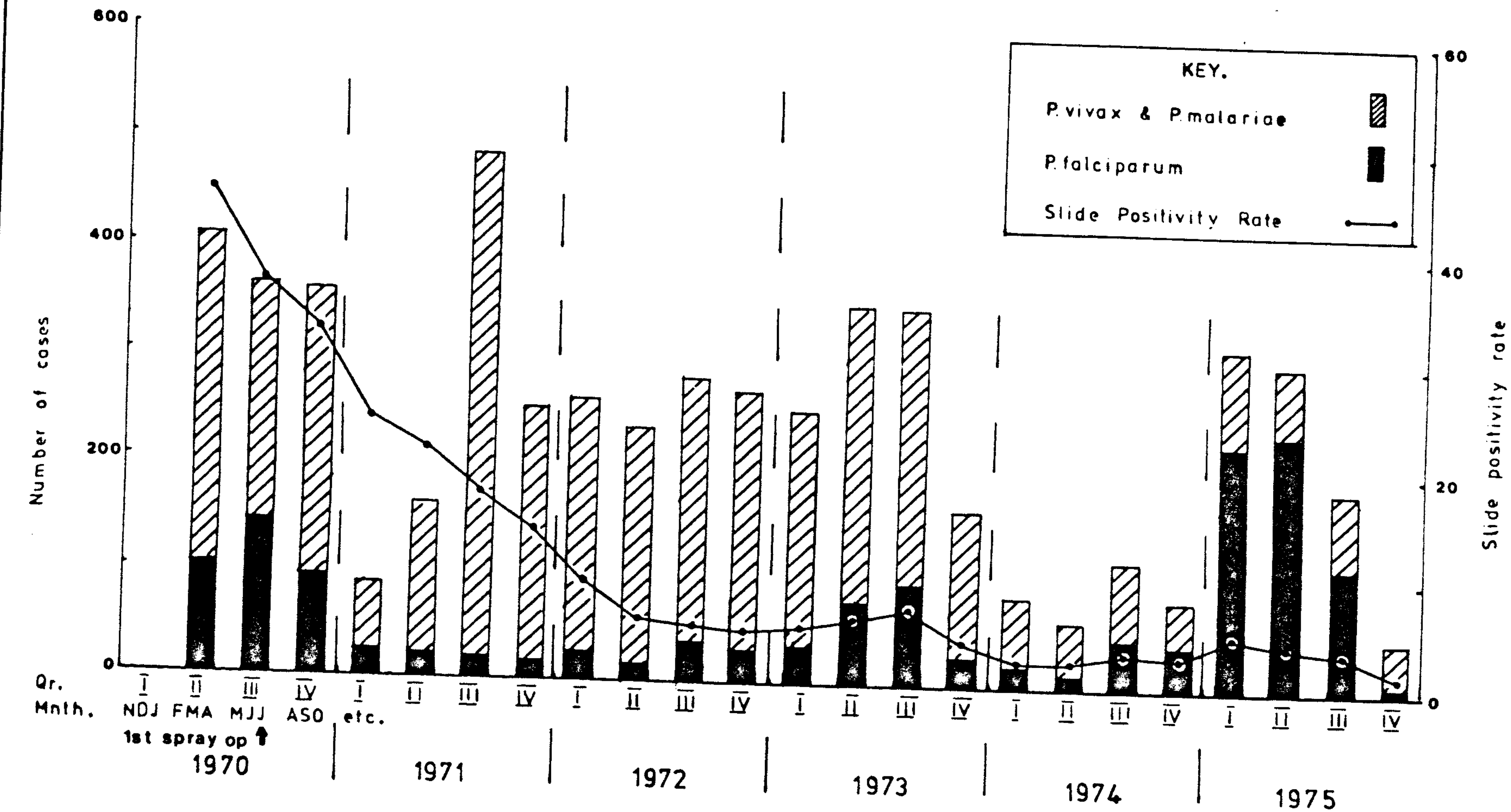
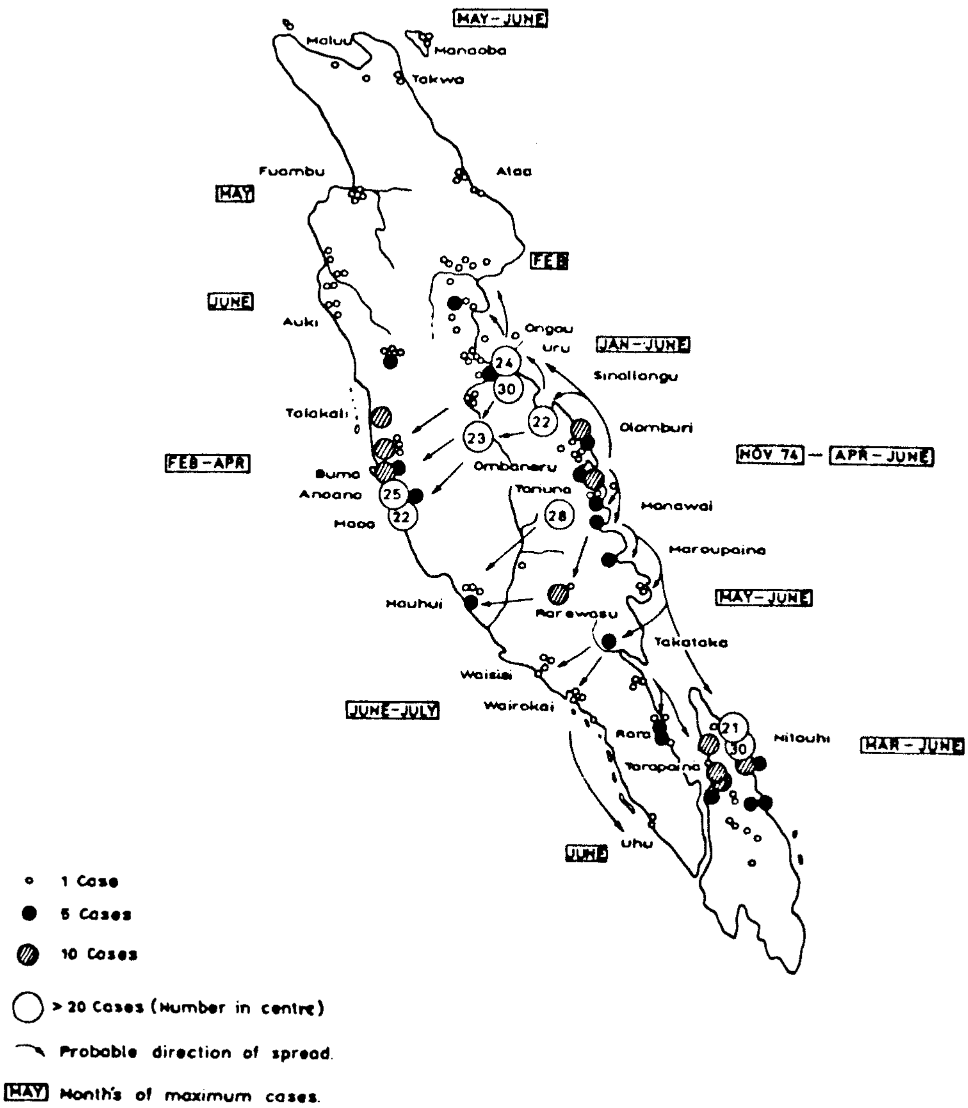


Fig.53. Quarterly totals of malaria cases detected by Active & Passive Case Detection in Malaita District, 1970 - 75

Fig . 54 .

DISTRIBUTION OF 499 MALARIA CASES MALAITA ISLAND
JAN – JUNE 1975

NOTE *A total of 786 cases of malaria were detected in Malaita between January and June 1975. The 287 cases not marked on the map were mostly from villages with known cases but which were not fully recorded in the case registers. 61 of these cases were from villages which could not be located on operational maps.*



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setback and the remedies taken are discussed in more detail in Chapters 8.5 and 8.7. Fortunately by the end of 1975 there were distinct signs of an improvement and there was a marked fall in the number of cases being reported (Figure 53).

Prospects for the eradication of malaria from Malaita mainland are not good at the present time. Even the malaria free areas remain very vulnerable to reinfection from Guadalcanal or from neighbouring villages. The Rural Health Services already have a good coverage of most of the island if and when the question of consolidation and maintenance arises in the future.

Ndai

This remote atoll has had few malaria surveys of any kind. A. farauti (stage not specified) was found by M.E.P. staff in 1969 and 1970 (Taylor 1974). No pre spraying malariometric surveys were made but the people reported frequent fevers on the island. DDT spraying started in September 1970 and continued at approximately 6 monthly intervals until the end of 1975. The absence of a medical agency has precluded satisfactory surveillance on Ndai island. Blood slides are collected only sporadically during brief ship visits. During 1971 the two slides collected both proved to be P. vivax. During 1972 the 50 slides from Ndai were all negative. Similar results were found with the 46 slides in 1973 and the seven taken in 1975. Unfortunately no slides were collected in 1974 so that we cannot say with absolute confidence that there is no malaria on Ndai island.

The probable absence of malaria and the absence of anophelines (in the one post spraying entomological survey in February 1973) mean

TABLE 61

Results of malaria surveillance, Malaita District+, 1970 - 75.

Population:

1970 - 51722 (Census)
1971 - 52756 (MEP estimates)
1972 - 53812 (" ")
1973 - 54936 (" ")
1974 - 55019 (MEP estimates)
1975 - 56944 (" ")
1976 - 59970 (Census)

Year	Number of slides collected by				ABER by PCD+ ACD	Total cases by				Species				SPR% by PCD + ACD	API ‰ by All Sources
	ACD	PCD	Other Sources	All Sources		ACD	PCD	Other Sources	All Sources	f.	v.	m.	mixed		
1970	0	3663	NA	3663	7.1	*	1451	*	1451	449	NA	NA	NA	39.6	NR
1971	42	5305	NA	5347	10.1	NA	NA	*	871	45	817	35	(26)	16.3	NR
1972	2470	19838	NA	22308	41.5	NA	NA	*	1220	91	1086	43	0	5.5	NR
1973	9535	14062	4150	27747	43.0	287	706	129	1122	212	877	31	2 fv.	4.2	20.4
1974	17345	10498	3688	31531	50.6	120	295	88	503	221	268	14	0	1.5	9.1
1975	14500	13111	14392	42003	48.5	241	612	235	1088	737	345	2	4 fv.	3.1	19.1

+ includes Malaita mainland, Small Malaita, Ndai, Ontong Java and Sikaiana. 1970 covered Malaita mainland only.

Notes:

ACD - Active Case Detection.
PCD - Passive Case Detection.
ABER - Annual Blood Examination Rate.
SPR - Slide Positivity Rate per hundred slides.
API - Annual Parasite Incidence per thousand population.
NA - Data Not Available.
NR - Data Not Relevant.
* - No Record or Not Established.

Other Sources include Case Follow up, House Contacts and Surveys.

Species - Mixed infections are specified where known. Where the number is in brackets the species was not specified in the returns. On these occasions the total of mixed species has been subtracted from the total of the other species (i.e. total infections) to give the total cases.

TABLE 62

Annual totals of malaria cases in individual islands, Malaita District.
1970 - 75.

	Malaita mainland	Ndai	Ontong Java	Sikaiana
1970	1451(449)	*	*	*
1971	863 (45)	2	3	3
1972	1216 (90)	0	3 (1)	1
1973	1121(214)	0	1	0
1974	498(217)	*	0	5 (4)
1975	1088(741)	0	0	0

Notes: Figures in brackets ( ) are *P. falciparum* cases.

Cases from 1970-72 from ACD and PCD only.

Cases from 1973-75 from All Sources.

* No Surveillance.

that this island was qualified to enter into Consolidation during 1976. Receptivity and vulnerability to malaria are both low.

Ontong Java

The only pre spraying entomological surveys on this large atoll were those by Black in 1952 and M.E.P. staff in 1969 and 1970 (Taylor 1974). Anopehlines have never been found at Pelau but Black (1952) found a few larvae of A. farauti in the former settlement of Avaha. There is only one record of a single A. farauti adult being found at Luaniua this being in June 1970. No larvae have been found at Luaniua in spite of the presence of abundant swamp taro beds.

The early malariometric surveys of Ontong Java were summarised by Hollins (1957). Spleen rates well in excess of 50% were found by Price in 1928, Black in 1952 and Hollins in 1954. The only parasite survey in that period was by Black who found a rate of only 10.1% in the 2-10 age group (Table 63). In 1960, after a second mass drug administration and spraying operation (see Chapter 5.1), an Infant Parasite Rate of zero was reported (BSIP 1960). Only three years later many P. falciparum and P. vivax cases were found in a survey (BSIP 1963). By 1968 a survey by Maffi found a spleen rate of 43.9% and a parasite rate of 50.8% in the 2-9 year age group (Table 63). In the final survey prior to spraying Kirimaoma found a spleen rate of 36.8% and a parasite rate of 46.6% in the 2-9 years age group. The Parasite formula was falciparum 60.6; vivax 39.4; malariae 0. The final classification of Ontong Java was therefore high mesoendemic although earlier surveys found good evidence of hyperendemicity.

Starting in September 1970 DDT spraying continued at approximately

TABLE 63

Summary results of malariometric surveys, Ontong Java

Population: 873 (1970 census)

Date 19-	Surveyor	Age group	Spleen Rate (No Exd)	Parasite Rate (No Exd)	Parasite Species f.	v.	m.	mixed
Pre spraying								
Oct. 28	Price	All ages	88.8 (167)	-	-	-	-	-
1941	Crichlow	?	25 - Luaniua 21 - Pelau	-	-	-	-	-
Jun. 52	Black	2-10	82.2 (79)	10.1 (79)	3	3	1	1NS
Jul. 54	Hollins	0-9	62.4 (286)	-	-	-	-	-
1960*	?	0-1	-	Infant Parasite Rate - 0				
1962*	Alves & Gurney	?	-	"Many P.f. and P.v. cases"				
1968	Maffi	2-9	44.0 (132)	50.8 (132)	51	10	0	6 f.v.
Sep. 69	Kirimaoma	2-9	36.8 (133)	46.6 (135)	37	23	0	3 f.v.
Post spraying								
Jul. 71(10)	Gibson	2-9	-	0.0 (162)	-	-	-	-
Feb. 72(17)	Peabody	2-9	-	0.0 (117)	-	-	-	-
Aug. 72(23)	Harvard University	All ages	-	0.0 (640)	-	-	-	-

Classification - High Mesoendemic

Notes: NS - Not Specified.

Number in brackets ( ) after post spraying dates is the months after first spraying operation.

* after special eradication operation.

six monthly intervals. Eight rounds were completed by the end of 1975. During some of 1973 and 1974 there were delays of up to ten months in spraying operations. Three post spraying surveys were carried out at intervals of 10, 17 and 23 months after the start of spraying. Not a single parasite was found on any of the surveys including the 640 slides examined by the M.E.P. for the Harvard University Bio-medical Expedition in August 1972 (Table 63).

Passive Case Detection started at Luaniua Rural Health Clinic in July 1971 and was also carried out for a while at Pelau when the clinic was staffed. Active Case Detection was started with a resident agent in January 1973 but this did not prove satisfactory due to problems of supervision. Although erratic, the population coverage by ACD/PCD was reasonable except in 1973 when only 9.7% was sampled (Table 59). The Slide Positivity Rate fell from 7.3% in 1971 to zero from 1973 onwards (Table 60). Post spraying entomological surveys at Luaniua and Pelau in July 1972 and February 1973 failed to find any anophelines. With this convincing evidence in favour of eradication, Ontong Java was eligible to go into Consolidation in 1976.

In view of the past history of two abortive attempts at eradication the island must be considered moderately receptive and vulnerable to malaria.

Sikaiana

The few entomological surveys carried out on remote Sikaiana (by Lambert in 1933, Black in 1952 and M.E.P. staff in 1969 and 1970) had no difficulty in finding A.farauti adults and larvae (Taylor 1974). Malaria was probably introduced to both Ontong Java and Sikaiana by missionaries in the late 1890's. The major pre spraying malariometric

TABLE 64

Summary results of malariometric surveys, Sikaiana

Population: 190 (1970 census)

Date -19	Surveyor	Age group	Spleen Rate (No Exd)	Parasite Rate (No Exd)	Parasite Species			
					f.	v.	m.	mixed
Pre spraying								
May. 63	Lambert	Children	55.0 (80)	-	-	-	-	-
1947	Dovi	All ages	6.6 (165)	-	-	-	-	-
Jun. 52	Black	2-10	19.4 (31)	6.5 (31)	0	2	0	0
1961*	McCririck	Children	2.0 (NS)	-	-	-	-	-
1963*	Gurney	Children	2.0 (NS)	-	-	-	-	-
1968	Maffi	2-9	16.1 (31)	55.0 (31)	13	4	0	0
Sep. 68	Kirimaoma	2-9	11.6 (43)	15.9 (44)	0	7	0	0
Post spraying								
Jul. 71(10)	Gibson	2-9	-	5.1 (39)	0	1	1	0

Classification - Low Mesoendemic

Notes: NS - Not Specified.

Number in brackets ( ) after post spraying date is the months after the first spraying operation.

* after special eradication operation.

survey in 1968 classified the island as low mesoendemic (Table 64). Several earlier surveys found varying spleen and parasite rates mostly in the mesoendemic range. Two surveys in the early 1960's found very low spleen rates probably due to the brief spraying and drug treatment exercise carried out in 1960 (see Chapter 5.1).

Full DDT spraying operations started in September 1970. Spraying was then carried out at 6 monthly intervals until mid 1973 which was followed by two long intervals of around ten months. The final round of September 1975 completed a total of 8 rounds for the island. The only post spraying parasitological survey (Table 64), made ten months after the start of spraying, found two cases (1 P. vivax and 1 P. malariae).

Passive Case Detection started at the Rural Health Clinic in July 1971. The only Active Case Detection was occasional house visits made by visiting malaria supervisors. Although the slide collection was erratic it was still far better than on all of the other Polynesian islands. During each of the years 1972-74 well in excess of 50% of the population was sampled (Table 59). During 1973 no cases were detected and the island appeared to be free from malaria (Tables 60 and 62). Then in early 1974 a priest and his family returned to the island from Guadalcanal. Shortly afterwards five cases were detected (4 P. falciparum, 1 P. vivax). Four of these infections were acquired on the island yet the only post spraying entomological survey (in July 1972) had failed to find any anophelines. The cases occurred before the reported delays in spraying and there is no doubt that the vector had re-established itself. After Remedial Measures had been taken, including a thorough focal spraying, no further cases occurred during 1974. No slides were collected by PCD during 1975 but the 42 survey slides were all negative. With the island considered to be malaria free during 1975 it was thought safe to enter into Consolidation in early 1976. Due to its bad malaria history Sikaiana must be regarded as moderately receptive and vulnerable to malaria.

- Western Solomons

This scattered district comprising the New Georgia, Shortland and Choiseul groups has reached the most advanced stage in the eradication of malaria of all the districts in the Solomon Islands. Progress has been so good that many of the islands have already entered into the consolidation phase of eradication and others are due to follow in the near future.

Parts of New Georgia were included in the original Pilot Project which started DDT spraying in 1963. The Shortland Islands had come under cover even earlier when the Papua New Guinea administration sprayed them in 1959 in order to protect their own operation in Bougainville.

No pre spraying entomological or malariometric surveys were carried out in the Shortlands Group, but the new Georgia group did have reasonable malariometric surveys on most islands. The Choiseul group had a good coverage with both entomological and malariometric surveys. The results of pre and post spraying assessment surveys are shown in Tables 65 to 70. Surveillance returns, which started to come in during 1964, showed an initial fall in the Slide Positivity Rate (SPR) to 2.9% (Table 71). By 1967 this had risen to 10.7% but from then on it steadily fell over the years to reach 0.2% in 1975. The more sensitive Annual Parasite Incidence (API) fell from 8.4‰ in 1973 (when it was first measured) to 2.8‰ in 1975. Although the API for 1975 was identical with that for 1974 the 101 cases recorded were from a considerably larger range of blood slides (Table 71). The overall progress by quarters, from the start of the full eradication programme in 1970 until 1975, is shown in Figure 55. This shows a regular seasonal increase in malaria in the Western Solomons every year during the second or third quarters from 1971 onwards. Monthly field trip reports showed even more seasonal variations and minor outbreaks from island to island. The surveillance results were obtained from a more than adequate coverage of the population over the whole district (Table 71) and on individual islands (Table 72). Once surveillance was fully established the Annual Blood Examination Rate (ABER) was always well above the required 10% often well in excess of 50%.

The results for each of the main individual islands of the Western Solomons are now reviewed in order.

New Georgia Group

The original spraying of the Pilot Project started in early 1963. The islands included were New Georgia mainland (including Roviana, Marovo, Vonavona, Vangunu and Nggatokae), Vella Lavella, Ranongga, Simbo and Gizo. The islands of Rendova, Tetepare and Kolombangara were brought under cover in 1965. Spraying continued at approximately six monthly intervals, with occasional lapses to 8 or 10 months, to complete 19 rounds by mid 1973. At this point the majority of this group ceased spraying and went into consolidation having fulfilled the

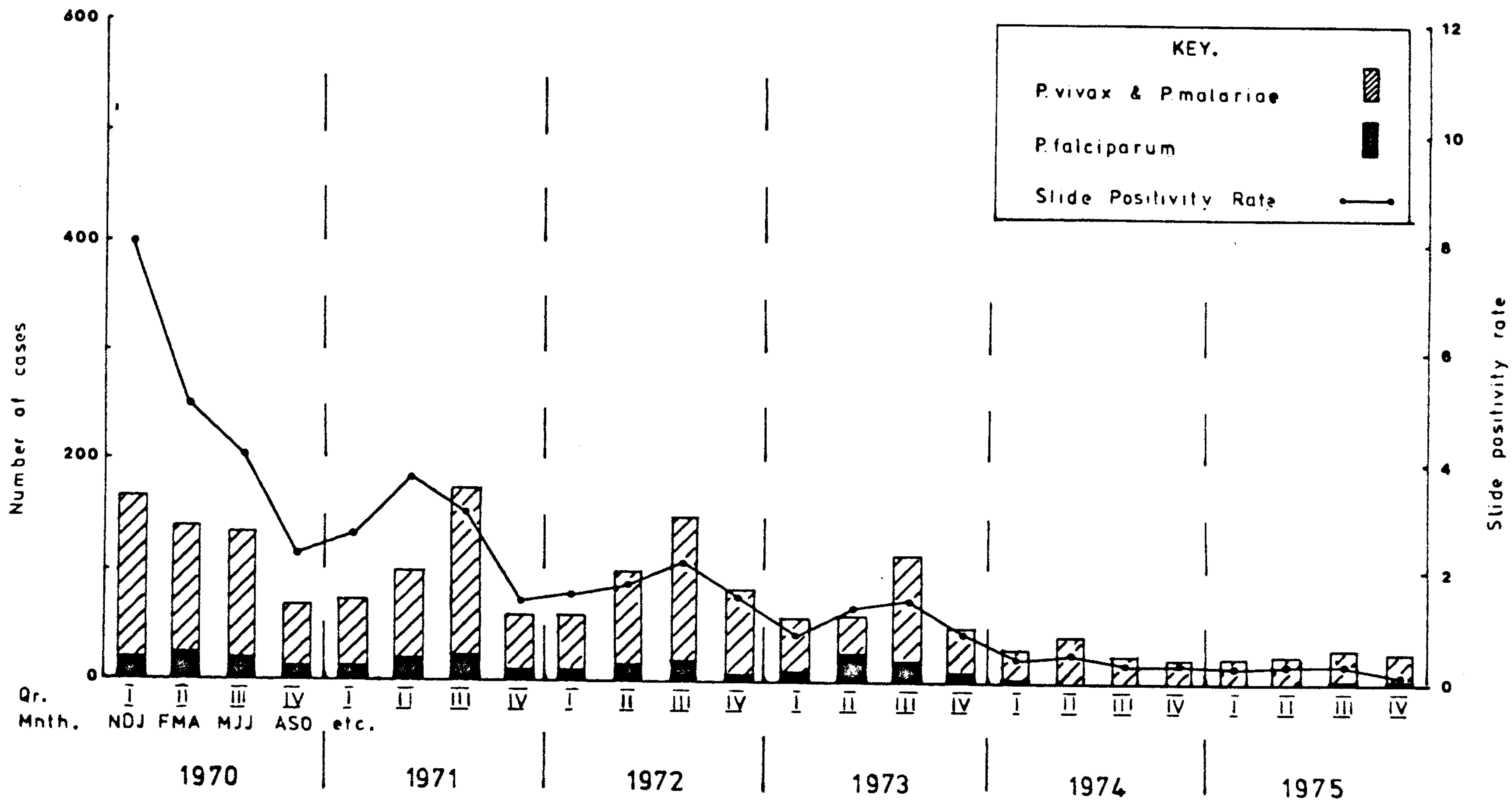


Fig. 55. Quarterly totals of malaria cases detected by Active & Passive Case Detection in the Western Solomons, 1970 - 75

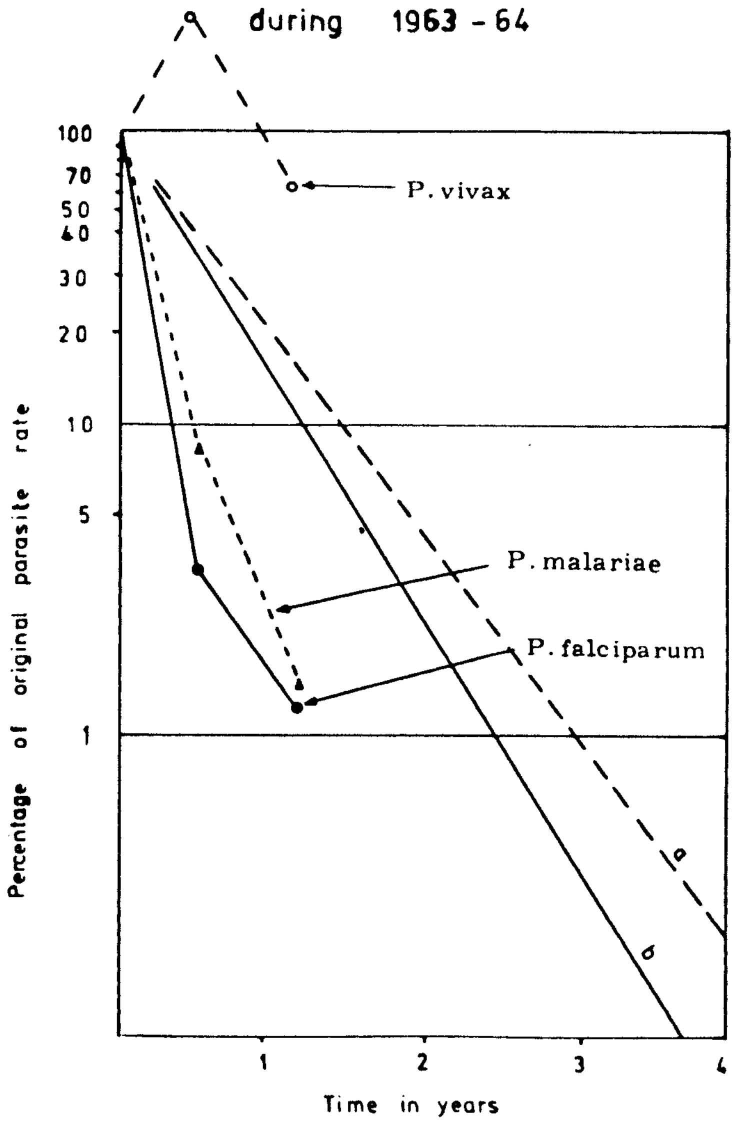
criteria (see Chapter 8.5) recommended by the W.H.O. Independent Assessment Team (Tewari and Colbourne 1973). Meanwhile the small foci which had a history of malaria cases within the previous year continued spraying. These included parts of Vella Lavella, Ranongga, Kolombangara and Gizo.

In the original assessment of operations in New Georgia only two post spraying surveys were carried out. These confirmed a rapid fall in the All ages parasite rates for the group (Table 66) and for all the individual islands surveyed (Table 67). The fall in P.falciparum and P.malariae rates satisfied the first criterion for the interruption of transmission laid down by Macdonald and Göckel (1964) as seen in Figure 56. The fall in P.vivax was nowhere near the minimum acceptable rate, but it did follow the characteristic pattern (Macgregor 1966) which was later found to be the typical pattern for regression of P.vivax in the Solomon Islands (see Chapter 8.5). These patterns have been plotted realising that there may have been some over diagnosis of P.malariae instead of P.vivax on the pre spraying survey.

Slide Positivity Rates for New Georgia have been consolidated for the whole group for the years 1964-72 (Table 73) but subdivided into the main islands for 1973-75. After an initial fall in 1965 the SPR rose to a peak of 10.8% in 1967. It then fell steadily to reach 0.1% in 1974 but rose again to 0.2% in 1975, mainly due to small foci in Ranongga and Kolombangara (Tables 73 and 74).

During the period 1973-75 the API for New Georgia remained below the 2‰ recommended by the WHO Independent Assessment Team.

Fig. 56. Fall in malaria parasite rates in the All ages age group following DDT spraying in New Georgia during 1963 - 64



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

Several individual islands fulfilled this criterion for entry into Consolidation but Ranongga, Gizo and Kolombangara noticeably failed to get below 2‰ at any stage (Table 73).

All of the islands of New Georgia are moderately receptive to the reintroduction of malaria due to the widespread distribution of anopheline breeding sites. Limited entomological surveys carried out 6-18 months after the cessation of spraying proved the presence of A.farauti in abundance at several sites. The group is also highly vulnerable to malaria due to the frequent influx of migrants from Guadalcanal and Malaita and, to a lesser extent, from Papua New Guinea.

The individual islands of the New Georgia group are now briefly described since progress was different in each depending on local circumstances.

New Georgia Mainland

Roviana (including VonaVona)

In the only recorded pre spraying malariometric survey for the whole island of New Georgia,a parasite rate of 34.9% (Table 67) in the all ages group suggested a classification of high mesoendemicity. If allowance is made for the probable misdiagnosis of P.malariae then P.vivax was the predominant species over P.falciparum. Post spraying surveys, which separated off Roviana from Marovo, showed a rapid disappearance of P.falciparum and an only slightly slower removal of P.malariae in both localities. Subsequent surveillance returns (Table 74) showed a greater number of cases (mostly P.vivax) for Roviana during the period 1966-71 but then a reverse trend with more cases for Marovo from 1972-75.

Many of the cases detected in the 1970's in Roviana proved to be recent arrivals from Malaita and Papua New Guinea. There were also some puzzling cases in indigenes on small islands with very little surface water and no evidence of the presence of anophelines. Nevertheless these were thought to be due to transmission rather than to relapses of a long standing infection.

Marovo (including Vangunu and Nggatokae)

The major contrast between the more eastern Marovo and the more western Roviana was the quite definite resumption of transmission of both P. falciparum and P. vivax in Marovo. This occurred either in old well established villages close to sluggish streams or in totally new villages built on bad swampy sites. On all occasions vigorous respraying and drug treatment knocked out the foci but there was a tendency for others to break out elsewhere within a short time. The rapid development of New Georgia with a considerable immigration of malaria carriers has meant that the potential for explosive epidemics remains very high.

Vella Lavella

This large island had a long history of malaria dating at least from the days of the mission hospital at Vonunu (Sayers 1928). The only recorded pre spraying malariometric survey is the parasite survey in December 1962 (Table 67).

On the results of this survey the island was classified as mesoendemic but it is very likely that this was an under estimate. There was a nearly equal distribution between the three parasite species, the high prevalence of P.malariae being similar to the findings on neighbouring islands. The two post spraying surveys showed a rapid fall in the parasite rate with a big drop in P.falciparum and P.malariae. Surveillance returns over the years showed a fluctuating number of cases (Table 74) with a big increase in P.falciparum during 1968. From 1970 onwards there was a general fall in cases culminating in only 2 P.vivax cases being detected in 1975.

Ranongga

Although the only pre spraying malariometric survey (Table 67) classified the island as high mesoendemic subsequent results suggest a higher rating. This was one of the few islands in the Solomons to have P.falciparum predominant. This species was slow to clear on the first survey, but thereafter made a rapid disappearance. P.vivax persisted in its typical way and P.malariae, initially very scanty, was also slow to disappear. On several occasions during the next few years there were small outbreaks of P.vivax malaria notably on the north east coast (Table 74). An occasional problem was the return of infected Seventh Day Adventist missionaries from Papua New Guinea. This was eventually controlled by testing this group on arrival and radically treating all proven cases.

Simbo

The only recorded pre spraying survey classified this small volcanic island at the upper range of mesoendemicity (Table 67). P.vivax was the predominant species, whilst P.falciparum and P.malariae rapidly disappeared after spraying according to the two post spraying surveys. These showed a rapid fall in the parasite

P.falciparum with only one case of P.vivax being detected in some 657 slides examined. As with Choiseul (q.v.) it was subsequently thought that P.malariae was misdiagnosed for P.vivax.

No post spraying surveys were carried out and surveillance returns showed fluctuating results with evidence of resumption of transmission on at least three occasions (Tables 73 and 74). A further small outbreak of P.vivax around Ringi in 1975 confirmed the importance of that large timber centre as a potential malaria focus.

Rendova - Tetepare

Although Rendova just qualified for the classification of hyperendemicity (Table 65), it had a parasite rate nearly three times that of Kolombangara (Table 67). In this island P.vivax just

TABLE 65

Results of pre spraying spleen surveys, Western Solomons.

Date	Surveyor	Age group	Number Examined	Number Positive	Spleen Rate %
Kolombangara (2323)					
1965	de Iorio	1-9	218	106	48.6
Rendova (1595)					
1965	de Iorio	1-9	232	122	52.6
Shortlands (1463)					
Sep. 1965	de Iorio	2-9	231	31	13.4
Mono (309)					
Sep. 1965	de Iorio	2-9	74	7	9.5
Choiseul (7332)					
Feb. 1966	de Iorio	2-9	761	300	39.4
Vaghena (685)					
Nov. 1965	de Iorio	2-9	263	41	15.6

Note: The figure in brackets ( ) after the island name is the population in the 1970 census.

TABLE 66

Results of pre and post spraying malaria parasite surveys, of the New Georgia Group +

Population: 18346 (1970 census)

Date -19	Months after 1st S.O.	Surveyor	Age group	Number		Parasite Rate %	Species			
				Examined	Positive		f.	v.	m.	mixed
Pre spraying surveys										
Nov-Dec. 1962	*	MEP staff	All	6257	1889	28.9	531	235	999	124NS
Post spraying surveys										
1st Aug.-Nov. 1963	6	MEP staff	All	7806	728	9.3	27	581	89	31NS
2nd Feb.-Apr. 1964	14	" "	All	9816	269	2.7	12	228	23	6NS

Classification - Mesoendemic

1st SO - February 1963

Notes: SO - Spraying Operation.

NS - Not Stated.

\+ included New Georgia mainland (Roviana, Marovo, Vona Vona, Vangunu, Nggatokae), Vella Lavella, Ranongga, Simbo & Gizo.

TABLE 67

Summary results of pre and post spraying malaria parasite surveys in the 2-9 years age group, by Islands, New Georgia Group

Island	Population (1970 census)	Pre spraying survey Parasite Rate	Post spraying Parasite surveys Parasite Rate 1st	2nd	3rd	4th	5th	Date of 1st SO	Date of Surveys
New Georgia group									
(Roviana)	9119	34.9• (3258)	10.7• (1645)	2.4• (2450)	*	*	*	1963	1962-64
(Marovo)		⊕	7.0• (1780)	3.1• (1959)	*	*	*		
Vella Lavella	3792	17.6• (1115)	14.1• (1584)	2.5• (2293)	*	*	*	1963	1962-64
Ranongga	2250	36.2 (417)	21.4 (421)	10.3 (505)	2.6• (1514)	*	*	1963	1962-64
Simbo	950	40.2• (264)	8.6• (720)	2.0• (758)	*	*	*	1963	1962-64
Gizo	2235	13.1• (563)	4.2• (566)	1.4• (842)	*	*	*	1963	1962-64
Kolombangara	2323	7.0° (186)	*	*	*	*	*	1965	1965
Rendova	1595	19.5° (232)	*	*	*	*	*	1965	1965
Tetepare	included in Rendova	3.3x (30)	*	*	*	*	*	1965	1965

Notes: Number in brackets under Parasite rate is number examined. • all ages
o - 1-9 years age group. ⊕ - included with Roviana. x - over 15. SO - Spraying Operation.

predominated over *P. falciparum* with *P. malariae* insignificant. Again there were no post spraying surveys but few malaria cases were detected except for a short period of resumed transmission during 1969-71 (Table 74). Apart from a small outbreak of *P. vivax* in 1974 only two indigenous cases were detected during 1973-75.

Shortland Islands Group

This group first came under DDT spray cover in 1959 when the Papua New Guinea administration covered these islands in order to protect their own effort on Bougainville. The only record of any pre spraying malariometric surveys in the group is that of Perry (1949) during World War II on Mono. This recognised the presence of malaria but did not give specific details of parasite or spleen rates. The report also recorded *A. farauti* on Mono but it is only pre-spraying record of anophelines in the group.

In 1964 the Solomon Islands administration took over spraying of the group. Malariometric surveys were carried out on Alu and Mono. These confirmed continuous low grade transmission on both islands. The findings were amply substantiated by further surveys during 1969 (Table 68) which also found possible low grade transmission on Fauro.

The frequent and uncontrolled migrations from all of the Shortlands group to Bougainville has meant an ever present threat of reintroduction of malaria from that source. This was complicated in the early 1960's by the settlement of non-immune Gilbertese on north west Alu. Their migrations proved to be even more frequent and more widespread than those of the indigenous Shortland islanders.

TABLE 68

Results of post spraying malaria parasite surveys of the Shortland Islands

Date -19	Surveyor	Age group	Number		Parasite Rate %	Species			
			Examined	Positive		f.	v.	m.	mixed
Alu (Shortland) (1463)									
Sep.65	de Iorio	1-9	254	3	1.2	0	2	1	0
May 69	Avery	2-9	174	33	19.0	0	33	0	0
Jul.69	Watson	2-9	109	13	11.9	1	12	0	0
Oct.69	Watson	2-9	92	15	16.3	3	12	0	0
Mono (309)									
Sep.65	de Iorio	1-9	92	1	1.1	0	1	0	0
May 69	Avery	2-9	69	13	18.8	2	10	0	1fvm.
Jul.69	Watson	All	25	2	8.0	0	2	0	0
Oct.69	Watson	2-9	20	1	5.0	1	0	0	0
Fauro (178)									
May 69	Avery	2-9	27	2	7.4	1	1	0	0
Jul.69	Watson	All	40	3	7.5	0	3	0	0
Oct.69	Watson	All	33	2	6.1	1	1	0	0

Notes: The figure in brackets ( ) after the island name is the population in the 1970 census.

Months after first spraying operation is not relevant due to long time span (5 years).

From the take over in 1964 until August 1976 a total of 19 DDT spray cycles had been completed in the Shortlands group. These were mostly at six monthly intervals with occasional gaps as long as 10 or 11 months. The coverage was invariably of a high order with outright refusal almost unknown.

Passive Case Detection was established at the main (Catholic)

Rural Health Clinic at Nila in February 1966 and at the small clinics at Falamae, Mono and Kariki, Fauro in August 1969. Active Case Detection using canoes and later, also the small "T" class vessels (Plate 8), started on Alu in November 1966. Nearly three years elapsed before this activity became fully established in Mono, the main purpose of the fortnightly visits being to collect the PCD slides. The Annual Blood Examination Rate by ACD and PCD in Alu has been well above 50% since 1968 (Table 72) whilst that for Mono and Fauro has been over 30% since 1971.

Mono

During the whole surveillance period from 1968-76 only two malaria cases (both P.vivax) were detected by routine surveillance on Mono Island (Table 11). The danger of relying on this method was amply demonstrated in a survey carried out in May 1969 soon after the start of passive case detection (Table 68). The all ages parasite rate of 15.2% clearly confirmed recent transmission which had not been picked up due to indifferent PCD. A.farauti was found biting in the early evening although breeding sites were difficult to find. Improved spray coverage and closer supervision soon cleared the outbreak and no further cases occurred except for one P.falciparum and one P.vivax in 1973 in young men recently returned from Bougainville.

Alu

The erratic progress in the eradication of malaria from this island is shown in Tables 73 and 75. On several occasions during the years 1966-75 there was clear evidence of the resumption of transmission. This was sometimes due to P.falciparum in the indigenous villages or in the lumber camp at Lofung but more often due to P. vivax in the Gilbertese villages of Harapa and Komaliae. Transmission in this group was made easy by the cultivation of swamp taro near the villages (ideal for anopheline breeding) and by the traditional use of roll up wall matting (difficult to spray) in the houses. Dissemination of the disease was aided by itinerancy and indifference to drug taking. A. farauti was found with ease in many of the villages.

In 1973-75 a concentrated effort was made to break the transmission cycle in the Gilbertese. This was simultaneous with the attack on the Gilbertese settlements elsewhere in the Western Solomons. The roll down matting was carefully sprayed with DDT and the people encouraged to keep it down in the early evening. Taro beds were treated with Abate larvicide. The whole Gilbertese population was twice administered a full 12 week radical treatment with chloroquine and primaquine. On both occasions more than 90% of the population was recorded as having taken the full treatment. In June 1975 an even more extensive mass drug administration covered 1210 of the 1346 population of the Shortlands. On this occasion the 14 day treatment was used without any serious side effects. The latter half of 1975 saw a marked reduction in cases and a distinct chance of a permanent breakthrough in the cessation of transmission.

Fauro

For several years sporadic cases, often P. falciparum, have been picked up on this sparsely populated island (Table 75). A recent visit to Bougainville has usually been the reason but some cases have had to be classified as indigenous.

All of the islands of the Shortlands group are vulnerable to reinfection due to their close proximity to neighbouring Bougainville. Alu is also suspect due to the frequent movements of its Gilbertese inhabitants around the other Gilbertese settlements. Alu is more receptive to malaria due to the abundance of anophelines but A.farauti has also been found with ease on Mono and Fauro.

Whilst it may be possible to stop spraying on Mono and Fauro in 1977 there is no prospect of this yet on Alu. A very high standard of surveillance is required in the whole group. This includes the taking of blood from, and the presumptive treatment of, all new arrivals from Papua New Guinea.

Choiseul Group

This group includes the main island of Choiseul and the small low lying island of Vaghena at its eastern extremity.

Choiseul

This large mountainous island achieved a marked degree of success in eradicating malaria between 1968 and 1975. No anti-malaria activities were carried out prior to 1968 apart from routine treatment of suspect malaria cases.

Pre spraying entomological surveys in 57 localities during 1966 and 1968 detected A.farauti at many sites all around the island (Figure 31). A.koliensis was also found to be widely distributed on the south coast and present at scattered sites on the north coast (Taylor 1974). Numerous anopheline breeding sites were found all round the island. The malariometric surveys classified Choiseul as mesoendemic (Tables 65 and 69) but several areas, notably on the

TABLE 69

Results of pre and post spraying malaria parasite surveys of Choiseul Island

Population: 7332 (1970 census)

Date-	Months after 1st S.O.	Surveyor	Age group	Number		Parasite Rate %	Species			
				Examined	Positive		f.	v.	m.	mixed
Pre spraying surveys										
Feb.66	*	de Iorio	1-9	1680	281	16.7	75	35	163	2fm. 6vm.
Jul.-Sep.68	*	MEP staff	2-9	494	186	37.7	37	131	2	11fv. 5vm.
Post spraying surveys										
1st Feb.69	5	Maffi McDonnell	2-9	1120	364	32.5	10	338	11	3fv. 2vm.
2nd Sep-Nov.69	13	MEP staff	2-9	813	221	27.2	3	212	6	0
3rd May 70	20	Tobia	2-9	305	37	12.1	1	36	0	0
4th Feb.71	29	Davidson	2-9	1503	133	8.8	2	131	0	0

Classification - Mesoendemic.

1st SO - Sept. 1968

Note: SO - Spraying Operation

north east coast, had much higher spleen and parasite rates.

Spraying operations began in September 1968. They continued at approximately six monthly intervals (with gaps of 8-10 months in 1969 and 8 months in 1972-73) to complete a total of 14 cycles by August 1975. Due to DDT shortages part of the south east coast omitted one whole cycle in early 1973. On the other hand, due to continuing transmission, the north west coast had cycles reduced to intervals of four months during 1973-74 resulting in the completion of one extra cycle for that area.

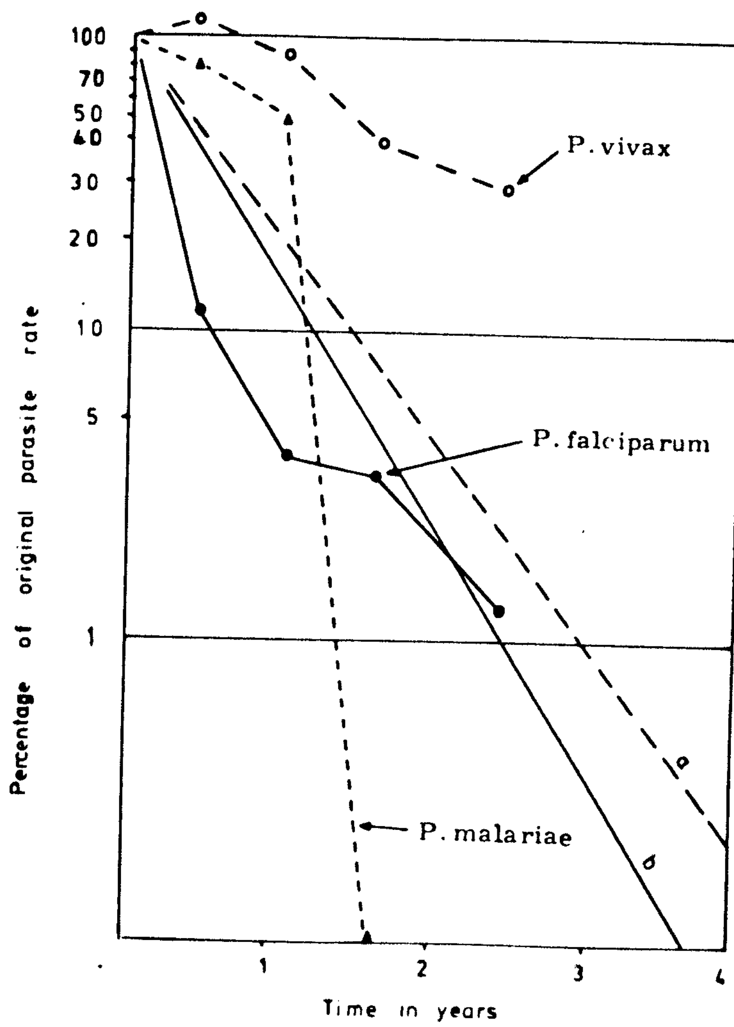
In the post spraying entomological monitoring that was carried out at fixed stations near Sasamunga A.koliensis was found to disappear rapidly. A.farauti fell to such low densities that these surveys were soon discontinued. Later surveys to investigate continuing transmission during 1972-74 found moderate to high densities of A.farauti notably on the north west coast.

The pre-spraying malariometric survey utilised for baseline assessment purposes was the survey of July-September 1968 (Table 69). The survey of de Iorio in January-February 1966 was not utilised because of the high prevalence of P.malariae. This bore no relation to subsequent surveys in Choiseul or elsewhere in the Solomons and it was suspected that P.malariae was mis-diagnosed for P.vivax. Nevertheless the 1-9 age group spleen rate of 39.4% (Table 65) was used to classify the island as mesoendemic.

The results of the four post spraying surveys are shown in Table 69 whilst the regression patterns are shown in Figure 57. The fall for P.falciparum was within the minimum acceptable limits confirming that transmission of this parasite had been interrupted. This was corroborated by slides taken from the 0-1 age group which, from February 1969 onwards, were all negative for P.falciparum.

The regression pattern for P.vivax followed the typical pattern found by Macgregor (1966) in Guadalcanal and New Georgia and found subsequently in several other islands in the Solomons. The assumption that this may have confirmed the interruption of transmission of P.vivax was not substantiated by the slides taken from the 0-1 age group. In these there were still two P.vivax infections in 75 slides examined twenty nine months after the start

Fig.57. Fall in malaria parasite rates in the 2-9 age group following DDT spraying in Choiseul during 1968 - 71



a - minimum acceptable rate of fall

b - expected slope for zero reproduction

of spraying.

Passive Case Detection started on Choiseul in January 1970 at the many Rural Health Clinics and schools around the island. Surveillance expanded to include Active Case Detection a year later. The activities steadily expanded so that from 1972 onwards well over 70% of the population was being sampled each year (Table 72). Although the Slide Positivity Rates steadily fell during 1970-72 (Table 73) the rising numbers of P. falciparum cases indicated that there was some resumption of transmission. Surveillance records showed that this was notably on the north west coast. A seasonal tendency towards an increase in cases during the months of April-June had been noted ever since surveillance started. Communications problems, both around the island and to the District centre at Gizo, made treatment and remedial measures very slow. In conjunction with the intensified spray rounds in 1974-75 surveillance was also improved. This was further speeded up by stationing a temporary team in the problem area. A monthly mass drug administration using chloroquine and primaquine was commenced in October 1973 to cover the 3,450 people in this area. This achieved an average of over 90% coverage during each month and was concluded after four rounds. The procedure was so successful that during 1974 there was a total of only 24 cases (all P. vivax) compared with 148 in 1973 (Table 75). In 1975 there was a total of only 9 (all P. vivax) cases.

Spraying was stopped in August 1975 but full surveillance continues with the island technically in Consolidation from August 1975.

Choiseul remains moderately receptive to the reintroduction of malaria due to the abundance of breeding sites all round the island.

It is less vulnerable than the other Western Solomons islands due to its relative isolation.

Vaghena

In spite of numerous difficulties this low lying swampy island, inhabited exclusively by migrant Gilbertese, has seen excellent progress in the eradication of malaria. Prior to spraying a limited collection of A.farauti adults and larvae was made at Cookson (Taylor 1974).

Spraying was not carried out when the non immune Gilbertese first settled on Vaghena in the early 1960's. They were however, put on chemoprophylaxis with chloroquine and pyrimethamine.

The pre spraying survey of de Iorio and Davidson (Tables 65 and 70) confirmed clinical impressions that malaria transmission was common in the community, an impression confirmed beyond any doubt by later survey and surveillance returns. The infections were almost exclusively P.vivax if allowance is made for the anomalous survey of de Iorio. The island has been classified as mesoendemic although the true pattern of transmission was confused by the widespread use of drugs.

DDT spraying commenced on Vaghena in September 1968. It continued at approximately six monthly intervals until 1973 when this was shortened to four months. The shortened interval was continued during 1974 but reverted to six monthly again in early 1975. The final cycle was completed in July 1975 making a total of 15 cycles during the seven years of operation.

Passive Case Detection was started at the Vaghena (Cookson) Rural Health Clinic in September 1969 following on a few months after

TABLE 70

Results of pre and post spraying malaria parasite surveys of Vaghena

Population: 685 (1970 census)

Date 19-	Months after 1st S.O.	Surveyor	Age group	Number Examined	Number Positive	Parasite Rate %	Species f.	v.	m.	mixed
Pre spraying surveys										
Nov. 65	*	de Iorio	1-9	296	38	12.8	1	22	15	0
Sep. 68	*	Davidson	2-9	155	26	16.8	1	25	0	0
Post spraying surveys										
1st Feb. 69	5	Maffi & McDonnell	2-9	181	21	11.6	0	21	0	0
2nd Oct. 69	13	MEP staff	2-9	148	18	12.2	1	16	0	1 fv.
3rd Feb. 71	17	Davidson	2-9	199	2	1.0	0	2	0	0

Classification - Mesoendemic

1st SO - Sept. 1968.

Note: SO - Spraying Operation.

the commencement of Active Case Detection in June 1969. Generous collections of slides were made so that in each of the years 1969-75 more than 60% of the population was sampled by combined ACD or PCD (Table 72).

Initial returns from surveillance showed a decline in the S.P.R. (Table 73) but by mid 1972 the monthly returns showed that there was clearly widespread resumption of transmission of P. vivax. By this stage a seasonal pattern had also emerged on Vaghena with a peak of transmission in May to July. In spite of this anophelines were found only in low densities.

In addition to intensifying the spraying operations a programme of Mass Drug Administration was commenced in October 1972. Initially only the five day regime with chloroquine and primaquine was used knowing that some relapses would probably occur. A careful census was taken on each occasion and a coverage of well over 90% obtained. The five day treatment was repeated in January 1973 and again in March 1973 but by May 1973 there were signs that transmission had been resumed or that relapses were occurring. Although there were good signs in late 1973 that case detection and radical treatment alone were taking care of the problem,it was decided to go for a "knock out" in November 1973. This consisted of a full 12 week treatment for the whole population. It is a remarkable testimony to a people, already over exposed to an excess of anti malaria activities, that 56.5% of the population took the full 12 week treatment and 93.7% completed at least eight weeks of the treatment.

During the whole of 1974 surveillance picked up only two P. vivax cases whilst in 1975, no cases were proven. The progress was so good that it was decided to stop spraying in August 1975 after ensuring that adequate surveillance coverage was maintained.

Due to the very high intinerancy of the Gilbertese group (total population in Western Solomons approximately 2000) the remaining members of the group in Shortlands, Gizo and Kolombangara were all subjected to the 12 week Mass Drug Administration during 1974. Even after this residues of infection still remained in 1975 in the Shortlands' Gilbertese.

Receptivity and vulnerability are both high due to the abundance of breeding sites, poor living conditions and frequent migrations to

TABLE 71

Results of malaria surveillance, Western Solomons[+], 1964-75

Population:

1964	-	7600	(MEP estimates)
1967	-	18000	(" ")
1970	-	32321	(Census)
1971	-	33359	(MEP estimates)
1972	-	34527	(" ")
1973	-	35575	(MEP estimates)
1974	-	35679	(" ")
1975	-	36326	(" ")
1976	-	40320	(Census)

1964 and 1967: Population under surveillance only

+ includes New Georgia 1964-75, plus Shortlands 1966-75, plus Vaghena 1969-75, plus Choiseul 1970-75.

Year	Number of Slides collected by				ABER by ACD +PCD	Total cases by				Species				SPR by ACD/ PCD %	API by all sources ‰
	ACD	PCD	Other sources	All sources		ACD	PCD	Other sources	All sources	f.	v.	m.	mixed		
1964	1335	0	NA	1335	17.6	59	0	-	59	NA	NA	NA	NA	4.4	NR
1965	3519	53	NA	3572	29.8	104	0	-	104	16	51	35	2vm	2.9	NR
1966	1762	2109	NA	3871	25.8	62	247	-	309	46	165	65	10fv 15fm 8vm	8.0	NR
1967	2059	2368	NA	4427	24.6	133	341	-	474	115	327	45	(13)	10.7	NR
1968	2470	3465	NA	5935	26.1	176	384	-	560	176	363	40	(19)	9.4	NR
1969	6649	4696	NA	11345	47.1	464	328	-	792	126	655	23	(12)	7.0	NR
1970	6620	4869	NA	11489	35.6	317	252	-	569	49	517	4	(1)	5.0	NR
1971	10564	5552	NA	16116	48.3	NA	NA	-	418	37	368	12	1fv	2.6	NR
1972	17259	7604	NA	24863	72.0	NA	NA	-	451	41	400	10	0	1.8	NR
1973	16204	5081	3096	24381	59.8	156	102	40	298	50	244	4	0	1.2	8.4
1974	18810	6021	8721	33552	69.6	46	41	14	101	4	97	0	0	0.4	2.8
1975	22279	11216	8858	42353	92.2	41	32	28	101	7	92	1	1fv	0.2	2.8

TABLE 71 - continued

Notes:

ACD	-	Active Case Detection.
PCD	-	Passive Case Detection.
ABER	-	Annual Blood Examination Rate.
SPR	-	Slide Positivity Rate per hundred slides.
API	-	Annual Parasite Incidence per thousand population.
NA	-	Data Not Available.
NR	-	Data Not Relevant.
*	-	No Record or Not Established.

Other Sources: include Case Follow up, House Contacts and Surveys.

Species - Mixed infections are specified where known. Where the number is in brackets the species was not specified in the returns. On these occasions the total mixed species has been subtracted from the total of the other species (i.e. total infections) to give the total cases.

and from other formerly malarious Gilbertese settlements.

Bougainville

The state of malaria control in Bougainville, Papua New Guinea (Figure 26) has a direct effect on the state of malaria in the Shortland Islands group. The high rate of migration to and from the malarious Bougainville is such that malaria may easily be reintroduced into the Shortland Islands.

During 1974 no cases of malaria were confirmed as having been imported into the Shortland Islands from Bougainville. During 1975 there were 5 confirmed cases (3. *P.falciparum*, 2. *P.vivax*). The movements of some other Shortland Islands cases in 1974-75 gave strong circumstantial evidence that they too,had acquired their infections in Bougainville.

In recent years the traditional population movements have been increased by the attraction of work at the copper mines at Panguna (Figure 26). These mines employ people from all over Papua New Guinea, some of whom frequently make overnight visits to the Shortlands. Since border control is inadequate it is impossible to accurately quantify the population movements. Malaria surveillance staff take blood slides from new visitors almost daily but details of numbers taken are not available as these slides are classified under the general heading 'Other Sources'.

The threat of importation of malaria from Bougainville is quite considerable. A survey in 1960 just prior to the commencement of spraying operations recorded a parasite rate of 21.8% for the island (Parkinson 1974). Spleen rates were much higher, justifying a

TABLE 72

Annual Blood Examination Rate (%) by islands, Western Solomons, Solomon Islands, 1964 - 75.

Island	Year 19' Population (1970 census)	64	65	66	67	68	69	70	71	72	73	74	75
New Georgia[o]	9119	17.6	29.8	25.9	24.8	24.7	40.5	42.3	43.0	62.3	46.7	60.7	90.8
Vella Lavella	3792	+	+	+	+	+	+	+	+	+	34.9	51.2	49.4
Ranongga	2250	+	+	+	+	+	+	+	+	+	56.5	50.9	75.8
Simbo	950	+	+	+	+	+	+	+	+	+	51.2	46.8	86.4
Gizo	2235	+	+	+	+	+	+	+	+	+	99.2	102.2	163.8
Kolombangara	2323	+	+	+	+	+	+	+	+	+	51.3	83.3	105.1
Rendova[x]	1595	+	+	+	+	+	+	+	+	+	60.2	76.6	78.9
Mono	309	*	*	*	*	4.0	56.3	12.6	57.8	33.9	78.1	49.3	63.3
Alu	1463	*	*	24.6	21.7	58.2	117.6	63.2	67.1	108.9	67.3	114.5	110.3
Fauro	178	*	*	*	*	2.4	70.0	22.5	49.5	35.2	50.9	111.9	84.6
Choiseul	7332	*	*	*	*	*	*	8.5	53.9	89.5	83.0	70.6	91.3
Vaghena	685	*	*	*	*	*	102.1	60.3	106.5	148.4	129.7	146.9	93.5

Notes:
o - includes Roviana (with Vona Vona) and Marovo (with Vangunu and Nggatokae)
x - includes Tetepare
+ - included in with New Georgia
* - No Surveillance

TABLE 73

Slide Positivity Rate (%) and Annual Parasite Incidence (‰) by islands, Western Solomons, 1964 - 75.

Year 19'	Slide Positivity Rate												Annual Parasite Incidence		
Island	64	65	66	67	68	69	70	71	72	73	74	75	73	74	75
New Georgia[o]	4.4	2.9	8.3	10.8	9.3	6.3	4.4	2.4	0.8	0.3	0.1	0.2	1.5	0.8	1.8
Vella Lavella	+	+	+	+	+	+	+	+	+	0.8	0.2	0.1	2.9	1.0	0.1
Ranongga	+	+	+	+	+	+	+	+	+	0.5	0.7	0.6	3.5	3.5	4.4
Simbo	+	+	+	+	+	+	+	+	+	0.4	0.0	0.0	2.0	0.0	0.0
Gizo	+	+	+	+	+	+	+	+	+	2.1	0.2	0.2	24.7	3.2	3.9
Kolombangara	+	+	+	+	+	+	+	+	+	0.5	0.2	0.6	3.2	2.3	8.3
Rendova[x]	+	+	+	+	+	+	+	+	+	0.0	0.5	0.1	0.0	3.5	1.1
Mono	*	*	*	*	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	5.8	0.0	0.0
Alu	*	*	3.7	9.2	10.7	5.5	1.3	2.5	1.7	0.6	1.8	0.6	3.8	25.4	17.1
Fauro	*	*	*	*	0.0	3.4	2.5	3.8	2.3	0.0	0.5	0.8	0.0	3.5	10.2
Choiseul	*	*	*	*	*	*	4.3	2.8	1.8	1.8	0.4	0.1	17.7	2.8	1.0
Vaghena	*	*	*	*	*	20.9	27.8	4.3	13.3	3.1	0.2	0.0	36.2	2.0	0.0

o - includes Roviana (with Vona Vona) and Marovo (with Vangunu and Nggatokae)   x - includes Tetepare

+ - included in with New Georgia as data not amenable to analysis.

* - no surveillance.

— - Islands which satisfy Solomon Islands criteria for entry into Consolidation (see Chapter 8.5 Discussion).

TABLE 74

Annual totals of malaria cases in individual islands, New Georgia group. 1964 - 1975

	Vella Lavella	Ranongga	Simbo	Gizo	Kolombangara	Rendova-Tetepare	Roviana	Marovo	New Georgia group	
1964	5 (1)	25 (NA)	3 (NA)	10 (4)	NR	NR	14 (1)	2 (1)	59 (7)	Records collected for part year only
1965	29 (6)	21 (2)	9 (2)	23 (5)	NR	NR	22 (1)	included in Roviana	104 (16)	
1966	3 (1)	4	10	252 (59)	NR	NR	30 (6)	included in Roviana	299 (66)	
1967	8 (1)	14	3 (2)	300 (70)	18 (4)	4	61 (24)	42 (13)	450 (114)	
1968	36 (22)	12	44 (28)	227 (35)	31 (11)	5 (2)	84 (30)	40 (21)	479 (149)	
1969	26 (7)	26 (1)	5 (0)	253 (20)	72 (12)	13	93 (39)	66 (13)	554 (92)	
1970	27 (7)	18	0	189 (10)	49 (7)	11 (3)	85 (10)	40 (10)	419 (47)	
1971	12	11	4 (2)	95 (9)	19 (1)	8 (1)	49 (3)	40 (1)	238 (17)	
1972	7	12 (2)	0	40 (1)	12	7	15	26 (2)	119 (5)	
1973	12	9	2	61 (1)	7	0	7 (2)	8 (1)	106 (4)	
1974	4	10	0	8	5	6	4 (1)	4 (1)	41 (2)	
1975	2	14	0	10 (2)	19	2 (2)	5 (1)	14	66 (5)	

Notes: Figures in brackets are _P.falciparum_ cases.
Cases from 1964-72 from ACD and PCD only
Cases from 1973-75 from all sources
NR - No Record, Surveillance not yet started.
NA - Data not available.

TABLE 75

Annual totals of malaria cases in individual islands. Shortlands and Choiseul groups, 1966 - 75.

	Mono	Alu	Fauro	Choiseul	Vaghena
1966	NR	10 (5)	NR	NR	NR
1967	NR	24 (1)	NR	NR	NR
1968	0	81 (27)	0	NR	NR
1969	0	91 (30)	4 (1)	NR	143 (3)
1970	0	12	1 (1)	22 (1)	115
1971	0	25	4 (1)	114 (20)	37
1972	0	26 (2)	2 (1)	126 (33)	178
1973	2 (1)	5 (1)	0	148 (44)	37
1974	0	33 (2)	1	24	2
1975	0	23 (2)	3 (2)	9	0

Notes: Figures in brackets ( ) are *P.falciparum* cases.

Cases from 1966 - 72 from ACD and PCD only.

Cases from 1973 - 75 from all sources.

NR - No Record.

classification of hyperendemicity. Spraying operations with DDT started throughout Bougainville in 1959-60. They continued at six-monthly intervals thereafter. The Papua New Guinea administration also sprayed the Shortlands group between 1959 and 1964.

Spray coverage for the whole of Bougainville in the years 1972-75 ranged between 85 - 94% per cycle. The coverage for the Buin Sub-District (the area closest to Shortlands) of Bougainville during the years 1973-75 ranged from 78% to 93% per cycle. Refusal rates as high as 20% were experienced in Bougainville during early 1974 but there are now encouraging signs that the spray coverage is improving. Experience has shown in the Solomons, however, that a coverage of anything less than 95% will usually result in continuing transmission.

During the earlier years of spraying operations in Bougainville a single dose mass drug administration was carried out for all people during the spray rounds. The drug used was a combination of chloroquine 150 mg and pyrimethamine 25 mg. In addition a 10% sample blood survey was carried out in each village concentrating on infants and toddlers. Passive Case Detection was started soon after the commencement of spraying whilst Active Case Detection started in the Buin Sub-District in October 1975 (Tavil, personal communication).

The results of malariometric surveys and surveillance returns show fluctuations in the prevalence and incidence of malaria. The 10% sample surveys for the whole of Bougainville showed an overall fall in the parasite rate from 3.8% in 1970 to 1.5% in 1974. Then,in the first half of 1975, there was a marked rise to 3.3%. The surveys for the Buin Sub-District showed considerably lower parasite rates. These fell to zero in the first half of 1974, but subsequently rose to 0.2% in the first half of 1975. Passive Case Detection returns showed a fall in the Slide Positivity Rate for Bougainville from 33.9% in 1970 to 14.0% in 1973. Following this there was a rapid rise to reach 31.2% in 1975. In the Buin Sub-District the figure for 1975 was 6.4%.

From these records it appears that the best control of malaria was obtained on Bougainville in 1973 and early 1974. The effects of increasing refusals were seen with a rise in parasite rates in 1974 and 1975.

It must be concluded that a moderate degree of transmission still continues in parts of Bougainville and possibly also in Buin. Health staff in the Solomon Islands will therefore need to keep the very closest surveillance on all new arrivals from that island. There is no easy solution to the problem of importation. It is both physically impossible and politically unacceptable to have tighter border control. Fortunately, the people of the Shortlands are most co-operative in informing malaria staff about new arrivals.

A desirable solution to the whole problem is for Bougainville to achieve a high degree of malaria control. The Health Department in Papua New Guinea has already given this some considerable attention. The objective of good malaria control has been the subject of official and informal communications between the respective Health departments. It was also recommended as a high priority in the report of the Independent Assessment Team which visited Papua New Guinea in early 1975 (Macgregor and Farid 1975).

Meanwhile the Solomon Islands Malaria Eradication Programme will keep the Shortlands group under a perpetual state of attack with six monthly spraying operations and regular surveillance. This expensive operation will continue until the threat of importation of malaria from Bougainville no longer exists.

<u>Note</u>: Spraying and surveillance data on Bougainville was taken from Quarterly and Annual Reports of the Malaria Control Branch of the Department of Health, Papua New Guinea.

7.4 Effects on other diseases

In addition to having a direct influence on malaria and its vectors the Malaria Eradication Programme has had a number of other effects. Whilst none of these is specifically related to the epidemiology of disappearing malaria their importance is such that they deserve mention in passing. These effects are outlined in the remaining parts of this Chapter, i.e. 7.4 to 7.8.

The Malaria Eradication Programme may make a reasonable claim to have directly or indirectly affected the status of a number of other diseases in the Solomon Islands. This particularly includes those diseases in which the work has influenced a vector or parasite host. It also includes diseases where the removal of general debility has created a less favourable environment for them to develop in.

Filariasis

Within a few years of starting DDT spraying people were reporting that no new cases of 'big leg' were being seen. They also claimed that some of those who had started to develop swollen legs had already shown improvement. In addition to these clinical impressions a few parasitological surveys confirmed the influence of DDT spraying on the disease.

The only detailed assessment of a fall in microfilaria rates in the Solomon Islands was that made by Webber (1973, 1975 and personal communications) in selected villages on the north west of Choiseul island. In this study there was a fall in the microfilaria rate, as measured by the 60 mm^3 measured blood film technique, from 21.8% in 1974 to 5.5% in 1976 (Table 76). An earlier survey in 1971 (two and a half

TABLE 76

Summary results of filariasis surveys in areas of DDT spraying, Solomon Islands

Island (Year of first DDT spraying)	Surveyor and date	No. Exd.	No. Positive	% Positive	M.F. density per mm^3	mfD_{50}	Elephantiasis rate
North west Choiseul (1968)	1968	-	-	-	-	(16.4)[1]	-
	Webber 1970	1385	209	15.1	27.9	12.2[2]	0.8
	Webber 1974	300	62	21.8	13.0	5.4	NS
	Webber 1975	351	32	9.2	6.3	3.0	NS
	Webber 1976	200	11	5.5	7.4	NS	NS
Shortlands & Fauro (1959)	Webber 1971	376	1	0.27	NS	NS	1.87
Fauro	1959	-	-	(30.0)[1]	-	-	-
	Webber 1975	112	0	0.0	NS	NS	NS
Savo (1963)	Morris & Morris 1975	186 (over 15 yrs)	7	3.8	63.0	11.0[2]	NS
Nggela(Big)	Mataika 1965	266	NS	40.2	5.2	40.0	3.4
" (Small) (1970)	Kiers 1968	391	NS	35.0	NS	*	NS
	Eyres 1974	214	NS	21.0	NS	*	NS
Graciosa Bay (Ndende) (1971)	McDonnell 1970	450	43	9.5	NS	*	NS
	Watson 1973	830	22	2.7	NS	*	0.24
"	Merrill 1976	800	1	0.1	NS	*	NS

Sources: Webber (1973, 1975, 1976 personal communication)
Merrill (personal communication)

1. Theoretical retrospective calculation.

2. Calculated in retrospect from available data.

years after the start of spraying), covering a wider spectrum of the island, had found a microfilaria rate of 15.1%. This lower rate was probably due to the wider range of the survey taking in some non-infected areas. This survey only used 20 mm^3 for each film so may well have missed some low density parasitaemias. In smaller surveys on Fauro island of the Shortland group, first sprayed in 1959, Webber found no microfilaraemia in 1975 using the more searching membrane filtration technique. An earlier survey in 1971 of Fauro and part of Shortland island, using 20 mm^3 blood films, had found a microfilaria rate of 0.27%, but an elephantiasis rate of 1.87%. Webber concluded from these surveys that the original microfilaria rate on Fauro may well have been of the order of 30% and that, after 15 years, filariasis had disappeared from the island.

Further evidence of a fall in microfilaria rates came from a survey by Watson in 1973 in Graciosa Bay. This showed a substantial drop from the 9.5% rate found by McDonnell in 1970. This was further substantiated by Merrill (personal communication), who found only 1 microfilaria positive slide in 800 examined in Graciosa Bay in late 1976. Less conclusive evidence came from Savo in 1975 when Morris and Morris (personal communication), using the membrane filtration technique, found a microfilaria rate of 3.8%. This was after 12 years of DDT spraying, but is perhaps not surprising considering the originally high endemicity (Table 13). In addition the people of Savo have very close contacts with the highly malarious and filarious Guadalcanal and Nggela and there has been evidence of resumption of malaria transmission on several occasions on Savo.

Strong evidence supporting the effect of DDT spraying on filariasis also came from the regular inspection of all malaria blood slides for filaria parasites. From the time when these were first routinely examined in 1973 until 1975 there was a steady drop in the filaria parasite rate in each district (Table 77). These rates reached very low levels in the Western District which was the one longest and most fully under spray cover. Even in Central District (including Guadalcanal which had then been under spray cover for 12 years), the rate was very low in 1975. This may represent interruption of filariasis transmission even though it is known that malaria transmission was not interrupted in all areas.

From the evidence presented it is clear that DDT spraying has had a profound influence on the incidence of filariasis in many parts of the Solomon Islands. There are distinct possibilities that the disease may have been eradicated from certain parts of the Western Solomons. Now that spraying has ceased in some of these islands there is also high probability that the disease will make a resurgence (see Chapter 8.6).

Other vector borne diseases

Other diseases where mosquito vectors are involved include dengue haemorrhagic fever, viral encephalitis and Burkitt's lymphoma. The latter is often found in association with holoendemic malaria and is thought to be an abnormal reaction between the causative Epstein-Barr virus, *P. falciparum* parasites and lymphoid tissue (Burkitt 1969, O'Conor 1970). The virus itself is probably not transmitted by mosquitoes, the association with anophelines being due to the malaria parasite. In Papua New Guinea Wilkey (1973[a]) has shown that Burkitt's lymphoma occurs more frequently in the malarious

TABLE 77

Annual incidence of filariasis cases detected during malaria surveillance, by Districts, Solomon Islands. 1973-75.

Year	Number of Slides Examined	Number Microfilaria Positive	Percentage Positive
Central District			
1973	44319	57	0.13
1974	45942	45	0.10
1975	70025	50	0.07
Eastern District			
1973	15478	123	0.79
1974	16839	141	0.84 +
1975	19518	41	0.21
Malaita District			
1973	27747	62	0.22
1974	31531	39	0.12
1975	42003	40	0.10
Western District			
1973	24381	18	0.07
1974	33552	8	0.02
1975	42353	5	0.01

\+ Rate increased by the inclusion of night surveys carried out in Eastern Outer Islands.

Source: M.E.P. surveillance records.

lowlands than in the highlands. It also occurs less frequently in those areas with more effective malaria control. In the Solomon Islands between the years 1966-74 six histologically proven cases were recorded (Cross, personal communication). These were from widely scattered localities and it is not possible to say at this stage whether the DDT spraying has had any influence on this cancer.

No case of dengue haemorrhagic fever has been proven in the Solomon Islands in recent years in spite of widespread epidemics in every neighbouring territory. The vector Aedes aegypti is present in small foci in the capital Honiara but very difficult to find elsewhere. It is possible that the DDT residual spraying of houses has kept numbers down but it is more likely that this has been due to routine ground control. Viral encephalitis occurs sporadically but no culicine vector has yet been incriminated. As with dengue fever, it is possible that the overall level of mosquito control may have kept the disease at bay.

One of the more adverse influences on health was the increase in bed bugs (Cimex lectularius) and cockroaches. These insects caused much irritation and were certainly responsible for an increase in skin infections and sores amongst children. Even this effect was offset by the relief obtained from head lice whenever the DDT spray teams came round.

An unusual example in which a non insect vector of a disease may be affected by DDT spraying is toxoplasmosis. The definitive host for this protozoan is now considered to be the domestic or wild cat (Wallace 1973). Soon after DDT spraying cats disappeared from virtually all villages and did not return again until spraying ceased. Unfortunately no routine tests were carried out on patients for the presence of Toxoplasma gondii. In the absence of routine notification of deaths or handicaps it is not possible to say for example, how many cases of congenital abnormality were prevented by the possible disappearance of toxoplasmosis. The only known surveys for toxoplasma antibodies were the small surveys of Malaita in 1966 and Ontong Java in 1972 (Wallace

1976). The Malaita survey, which was pre spraying, found 80% of the people positive for toxoplasma antibodies in 191 all ages tested. The rate increased with age. The Ontong Java survey produced similar results with a rate of 89% in 152 all ages examined. This survey was conducted only two years after the first spray round so was too early to show any overall changes. In neighbouring New Guinea, Wallace, Zigas and Gajdusek (1974) found rates of 14-34% in areas where cats were numerous. In areas where the people had no contact with any kind of felid the toxoplasma antibody rates were less than 2%.

Since there was a distinct possibility that toxoplasmosis could have disappeared following such a widespread loss of cats we considered undertaking blood surveys to try to detect the parasite or antibodies to it. Regrettably, this could not be given a high priority within the resources available so that the possible favourable influence of antimalaria operations on this disease remains to be proven. Now that cats have made a rapid resurgence in the Western Solomons following the cessation of spraying there are theoretical possibilities of a resumption of transmission of this clinically rare disease.

Diseases associated with malaria

Two diseases which have a close pathological association with malaria are the tropical splenomegaly syndrome and nephritis. In Papua New Guinea Crane, Hudson and Hudson (1973) found a decline in tropical splenomegaly in areas where spleen rates were low and gross splenomegaly rare. Earlier findings by Schofield, Parkinson and Kelly (1964) had shown malaria control to have little effect in areas where gross splenomegaly was common.

Clinical impressions suggest that there has been a decline in tropical splenomegaly and nephritis in the Solomon Islands. This cannot be substantiated from the annual Medical Reports which show that in 1972 nephritis/nephrosis was not in the list of principal causes of bed occupancy. In spite of this six deaths were recorded from these diseases in that year. In the early 1960's, when comprehensive lists of admission were compiled, nephritis/nephrosis accounted for around 30 cases each year. Deaths were less than 1972 with 1960-5, 1961-1 and 1962-1. In 1969, when spraying was well established in Guadalcanal and the Western Solomons, there were 17 admissions and 1 death. Unfortunately a continuous record is not available during the transition pre spray to post spray so no accurate assessment can be made of a change in the pattern of nephritis/nephrosis following spraying. Tropical splenomegaly is not classified separately in the published disease returns. It now remains to be seen whether future data can confirm the clinical impressions of a decline in these diseases.

Bacterial diseases

Apart from the effect of antimalaria operations on disease vectors it is reasonable to claim that several other diseases have also been indirectly affected. For a number of diseases the overall improvement in the health of the people created in turn a more favourable environment for a reduction in the disease. This was then enhanced by the improved standards in health care which followed on from the requirements of the M.E.P. to set up rural Passive Case Detection agencies. It is likely that the incidence of tuberculosis was much influenced by the antimalaria work. From 1966 onwards the number of new cases notified steadily decreased (see Chapter 4, Table 29). In spite of this the deaths in hospital from tuberculosis actually increased from 36 (12.9% of hospital deaths) in 1969 to 49 (24.9%) in 1972. This was not really surprising since improved detection had by then begun to search out some of the more severe and terminal cases. It is not possible to say how much effect the removal of malaria has had on the transmission and development of tuberculosis. Nevertheless, since this disease thrives in debilitated individuals, some modest claim is certainly justified.

The number of newly registered leprosy cases showed a steady decline from a peak of 144 cases in 1966 to only 26 cases in 1974. This disease may also have been affected by the improved state of health. An interesting speculation is now allowed following the findings by Kircheimer (1975) that live leprosy bacilli can be taken up by mosquitoes. The bacilli are then capable of causing leprosy lesions after being injected by the mosquito into the footpad of a mouse. Could the control of anopheline mosquitoes in most of the Solomons have so affected the transmission of leprosy that this disease is rapidly becoming a less serious problem ? The major objection is that most leprosy cases are located in the remote mosquito free bush areas. Whatever the cause there has certainly been a dramatic fall in the incidence of leprosy in the Solomon Islands since the introduction of DDT spraying.

A state of malnutrition is sometimes thought to lead to greater susceptibility to malaria. On the other hand Jose and Good (1972) have argued that malaria may itself lead to malnutrition due to changes in immune response and absorbtion. The question is largely academic in the Solomon Islands since the state of nutrition is remarkably good (see Chapters 3.4 & 4.2). There is no evidence that the nutrition has markedly changed since DDT spraying except adversely in that increased cash prosperity has led to increased consumption of rice and refined carbohydrates. In the long term this may well have adverse effects on the state of health of the country.

A final important group of diseases that may be affected by the state of malaria in the community is the respiratory diseases. Asthma, bronchitis and pneumonia are all grouped together under this heading although clearly they often do have different causative agents. Whilst pneumonia may easily become established in a person debilitated with the disease, it is also thought that malaria itself may cause oedema and pneumonitis in the lungs. For many years prior to and following the M.E.P. respiratory disease was always in the top three causes of morbidity and mortality in hospitals in the Solomons (BSIP Annual Medical Reports). In Papua New Guinea respiratory tract infections are the leading cause of hospital admissions and deaths even in the presence of malaria (Riley 1973).

It was not possible from a review of the Solomon Islands annual hospital returns to confirm any reduction in morbidity or mortality due to respiratory diseases following DDT spraying. On the contrary these returns showed an increase in total cases of respiratory disease (excluding influenza and tuberculosis) and of deaths due to these diseases over the period 1962 to 1972. This was not necessarily due to greater take up of services since, during the same period, total hospital admissions actually declined. These records remain difficult to interpret due to inconsistencies in reporting. It is still possible that overall, the incidence of respiratory diseases other than tuberculosis and influenza, did actually decline. This has been claimed by Saint-Yves (1975b) in a different interpretation of the annual returns.

The examples quoted of the influence of antimalaria operations on other diseases should suffice to show that the favourable effects have been far more widespread than just those on malaria.

7.5 Effects on man's general state of health

In a number of areas we were able to show that the activities of the Malaria Eradication Programme had a measurable effect on the state of health of the community. The particular areas where information was obtainable were child mortality, stillbirth rates, birth weights, prematurity rates and haemoglobin levels.

Child Mortality

No precise data was available on Child or Infant Mortality since deaths are not notifiable. We knew however, from clinic records and reports of nursing staff, that many more babies and toddlers were surviving once spraying started. We also know more recently from a retrospective analysis of the birth notifications which started in 1967, that the Child Mortality Rate (deaths under 5 years old) showed a slow decline at least from 1958 onwards. These analyses, made by Sheila Macrae (personal communication) as part of a detailed study of child mortality in the Solomon Islands, showed a greater rate of decrease for Malaita (first sprayed in 1970) than for the 'non malarial' areas of the Solomon Islands (i.e. those areas first sprayed in 1963). The calculations showed that for 1958, 23.7% of the babies born in Malaita had died by the age of 5 years. The corresponding figure for the 'non malarial' areas of Guadalcanal, Savo, New Georgia and Shortlands was 13.1%. By 1970 these figures had been reduced to reach 9.7% for Malaita and 8.4% for the 'non malarial' areas. It should be noted that these calculations were made from the birth returns completed by the midwives after questioning the mothers about the outcome of their previous pregnancies. The proportions dying are given for birth cohorts and the experience of the malarial environment is that related to the five years following the date of birth. Children born in Malaita started to experience a 'non-malarial' environment from mid 1970 onwards whereas those born in Guadalcanal, Savo, New Georgia and Shortlands started to experience this environment from 1963 onwards. Therefore children born in Malaita from 1958-1965 experienced a wholly malarial environment whilst those born in the Guadalcanal group experienced a theoretically 'non malarial' environment from 1963 onwards. The trend in the decline in Child Mortality for the period 1958-70 was reasonally uniform for both groups with the figure for Malaita nearly approximating those for the Guadalcanal group by 1970. There was no evidence in either group that there was any change in the rate of decline that could be attributed to the effects of anti-malaria spraying. It appears from these analyses that the decline in Child Mortality had started in all parts of the Solomon Islands sometime before the start of spraying. It is possible that the yaws eradication campaign of 1956-59 so improved the health of the people that this was the starting point in an acceleration in population growth. Future studies of the births from 1970 onwards may show more clearly to what extent malaria has influenced child mortality and hence population growth.

A useful estimate of Infant Mortality was the figure of 73.4 per 1000 live births for the whole Solomon Islands calculated from the 1970 census returns (Groenewegen, Groenewegen & Horton 1973). This contrasts with an earlier report by Wrightson (quoted by Macgregor 1966) that 50 out of the 111 children born on Savo island between 1948 and 1950 had died at birth or in very early childhood. Allowing that at least half of these would probably have died in the first year of life we may interpolate an Infant Mortality Rate of about 250 per 1000 at that time. The Child Mortality Rate would have been of the order of 450 per 1000.

The crude evidence from Savo, the analysis of the 1970 census and the review of the birth returns all indicate that there was a substantial drop in Child and Infant Mortality in the Solomon Islands in the years 1950-70.

Stillbirths

The only information available on stillbirths is the provisional analysis that has been made of the birth returns by Macrae (ibid). These returns included information on stillbirths from which it was possible to calculate a Stillbirth Rate (as % of all still + live births) of 2.55%, for 'malarial' Malaita in 1969. The figure for 'non malarial' Malaita in 1972 was 1.77% but this rose slightly to 2.12% in 1973 possibly as a result of the resumption in transmission already mentioned in Chapter 7.3. Prior to the 1973 increase the Malaita figures were showing signs of approaching the lower figures already obtained for the 'non malarial' areas of the Solomons. These decreased from 1.64% in 1969 to 0.95% in 1973. These figures are close to those obtained in many developed countries and it is possible that there was some degree of failure by mothers to recall all stillbirths. Analysis has not yet been made of the figures for 1974 onwards.

Birth Weights and Prematurity Rates

Direct evidence of influence on health was obtained from a further analysis of the birth records. By 1968, the standard of notification had become good enough to allow a complete analysis of birth weights. This showed an average difference of 147g between the birth weights of babies born on the highly malarious island of Malaita and those born on islands in which malaria had been well controlled. By 1971, an estimated 69% of all births were being notified. Further analysis (Macgregor and Avery 1974) showed that on the island of Malaita (first sprayed in July 1970) the mean birth weights of all babies born showed a net gain of 165g between 1969 and 1971 (Table 78).

TABLE 78

Birth weights of all babies born in Malaita Island, 1969 - 72.

	1969	1970	1971	1972
No. of babies	970	1073	1162	1469
Mean Birth Weight in g. (± S.D.)	2869±530.2	2909±530.4	3034±488.4	2994±500.9
No. (%) < 2500g	199(21)	212(20)	137(12)	209(14)

The improvement was even more striking in babies born to Primigravidae. In these the net gain was 253g (Table 79). Perhaps of even greater importance, in view of the great risks of prematurity to life (Fitzhardinge & Steven, 1972), was the drop in the numbers of premature infants. These fell from 21% of all births in 1969 to 12%

TABLE 79

Births weights of babies of primigravidae born in Malaita Island, 1969 - 72

	1969	1970	1971	1972
No. of babies	191	232	263	337
Mean Birth Weights in g (±S.D.)	2577±626.9	2671±516.9	2830±473.9	2829±460.7
No. (%) <2500g	79(41)	72(31)	56(21)	65(19)

in 1971 for all mothers and from 41% in 1969 to 21% in 1971 for babies of primigravidae. Further analysis of the birth weights and prematurity rates for all births in Malaita in 1972 showed a slight fall in the birth weights and an increase in prematurity rates. This was thought to be due to the probable resumption of transmission which has occurred on parts of the island during 1972. We examined all possibilities for influence other than antimalaria spraying on all these changes in birth weights. We concluded that the only possible reason was the removal of the burden of continuous malaria infections from the pregnant women as a result of DDT residual spraying.

Haemoglobin levels

Many people stated that their general health improved once spraying started. More precise evidence in support of this was found from examination of haemoglobin levels, especially in pregnant women. This is one of the more profound measures of the state of health of the community since anaemic women are more likely to have stillbirths, obstetric problems and low birth weight babies.

A review of the laboratory records in Kiluufi hospital, Malaita for the years 1964-66 showed many haemoglobins in the range 2.9-5.8 g/dl (both sexes, all ages). An analysis of 100 consecutive haemoglobins in May 1965 (i.e. 5 years before the start of spraying) showed 97% with a level below the normal value of 14.6 g/dl. The mean value was 8.7 g/dl (range 4.4 - 14.6). A later analysis in May 1975 (i.e. 5 years after the start of spraying) found only 25% of 100 consecutive records to be under 14.6 g/dl. The mean haemoglobin value was now 16.2 g/dl (range 11.0 - 21.9). Less dramatic changes were seen in a review of the ante-natal clinic records at Kira Kira hospital, Makira for 1971 and 1972. For 1971 (pre spraying) the mean haemoglobin was 14.9 g/dl (range 11.8 - 17.7) whilst in 1972 (post spraying) the mean haemoglobin was 15.8 g/dl (range 10.8 - 21.9). The generally high levels, even before spraying, are probably explained by the close proximity of these women to good gardens and good ante-natal care facilities.

Further convincing evidence came from the follow up of women proceeding to a subsequent pregnancy post spraying at Atoifi Adventist Hospital in East Malaita. The mean haemoglobin in 29 of these women, measured at first visit during the pre spraying years 1966-70, was 6.8 g/dl. The figure for 16 of the same women tested in the post spraying years 1971-74 was 11.1 g/dl (Larwood, personal communication). In the opinion of Larwood and his colleagues the malaria spraying made a major difference to the health of the expectant mothers. It was unusual pre spraying for a mother not to have had at least one attack of malaria during pregnancy and almost all had enlarged spleens. Following spraying malaria attacks were rare in pregnant women.

The Solomon Islands findings in changes in haemoglobin levels following DDT spraying were at least of a similar order to, and often greater than, the reported changes of 1-2 g/dl from Papua New Guinea (Schofield, Parkinson and Kelly 1964, Crane and Kelly 1972).

7.6 Effects on Population Dynamics

The effect of the interruption of transmission of malaria on population growth was clearly shown in the 1970 population census (Groenwegen et al, ibid). The annual growth rate in the population from the previous census of 1959 was 2.7% (Table 80). The provisional

TABLE 80

Population of the Solomon Islands, 1931-1976.

	1931	1959	1970	1976
Total	94,066	124,076	160,998	196,708
Annual increase over previous census	*	1.1%	2.7%	3.7%
Percentage under 15	NA	44.3%	44.6%	NA
Estimate of immigrants	NA	500	2,500	3,000
Totals excluding immigrants	*	123,576	158,498	193,708
Increase over previous census (after excluding immigrants)	*	29,510	34,922	35,210
Natural annual increase (%) over previous census	*	*	2.6%	3.7%

NA - Not available

Sources: Groenewegen et al (1973), Saint-Yves (1975[b]), Dudley & MacFadden (1976).

figures for the 1976 census show an even bigger increase of 3.7% from the 1970 census (Dudley and MacFadden 1976). By comparison the annual growth from 1931 to 1959 was only 1.1%. Before that population changes are largely speculative but it is possible there may have been serious depopulation in the 19th century.

A study of population changes was made for the sub-districts of south Guadalcanal (the 'weather coast') by Chapman and Pirie (1974) covering the period 1931-72. This analysis showed a greater rate of increase in the overall population after World War II compared with before World War II. It also showed an even greater rate of increase from 1963 onwards. In the opinion of Saint-Yves (1975[b]) this could only be accounted for by the onset of DDT spraying in 1962-63. Casual analysis of this group of some 8000 people is, however, very suspect due to sampling errors and a very high migratory turn-over.

Problems of inter and intra island migrations have also confused the analysis of growth trends in other islands. However Saint-Yves (ibid) has shown that, after adjustment for internal migration, the Western district showed the greatest growth rate between 1959 and 1970 of 5.3% per annum. This was the district most fully covered by antimalaria operations between 1963 and 1970. In the then unsprayed Malaita district the annual growth rate was only 1.0%.

A detailed age breakdown of the 1976 census is not yet available but the population pyramids in the 1959 and 1970 surveys were both characteristic of moderately high birth and death rates. They showed a very broad base with nearly $\frac{1}{3}$ of the population under 10, 45% under 15 (Table 80) and well over 50% under 20. The over 65 group accounted for little more than 5% of the whole population. This is in marked contrast to many of the developed countries which have only 20-25% of their population under 15 and as much as 10-15% over 65.

Whilst it appears that the removal of malaria may have contributed significantly to population growth in the Solomon Islands, it is clear that a major spurt occurred in the late 1950s and early 1960s even before eradication operations got under way. This may have been due to the gradual improvement in rural health services but is more likely to have been due to the yaws eradication campaign. This island wide effort, conducted between 1956 and 1959 (Chapter 4.2), may well have so improved health and morale that a major growth spurt followed. The social changes that were going on all the time were all much more gradual and therefore unlikely to have suddenly accelerated population growth.

7.7. Effects on the Environment

Any major attempt to alter the life style of a living organism will invariably result in disturbances to other constituents of the environment. Whilst DDT was specifically aimed at reducing the longevity of anopheline mosquitoes it also directly affected many other insects and indirectly affected many other animals. One of the most immediate effects was the loss of domestic cats. This was because they licked off toxic doses of DDT from their fur or because they ate affected insects or geckoes and then accumulated lethal doses. The loss was widespread. It was only alleviated by keeping the cat in a bamboo cage on the periphery of the village for several days and feeding it with coconut milk and domestic scraps.

With all the cats dying there was an inevitable increase in the rat population. Rats certainly destroyed bedding and consumed food supplies. They also ruined some young coconuts. In spite of all this there was little chance of rats spreading plague or leptospirosis in the Solomons since these diseases are not endemic.

Another effect, mentioned in Chapter 7.4, was the appearance of large numbers of bed bugs (Cimex lectularius) and cockroaches. The bed bugs of the Solomons were shown to be susceptible to DDT but it appears that they frequently failed to come into contact with a sufficiently lethal dosage. In addition it is thought that some predators of bed bugs or their eggs were killed by the DDT thus removing the necessary competition which maintained the ecological balance.

Little is known about the short and long term effects of DDT spraying on the fauna, and especially on bird life, in the Solomons. Claims were made that DDT spraying was responsible for the deaths of chickens and young pigs. In North Malaita a small caged crocodile in a stream was reported to have died when spraymen emptied their spray cans upstream. Reports were also periodically received about river fish dying as a result of indiscriminate disposal of DDT. It has been claimed by some authorities that men may be seriously affected by DDT but there is little evidence to date to support such claims. Some spraymen in the Solomons used DDT almost daily for more than ten years without any obvious ill effect. No tests were done on DDT levels in human fat in the islands. However, limited studies in Papua New Guinea (Siyali, Wilkinson and Parkinson 1974) certainly showed that there was an increase in DDT fat levels in the general population in areas where DDT had been used extensively.

Reports of damage by DDT to the leaf of houses in Papua New Guinea led to similar claims being made in the Solomon Islands. None of these could be substantiated. The sum total of unfavourable reactions to the use of antimalarial measures was minute compared with the manifold and widespread benefits.

7.8 Effects on Economic Development

In recent years demands have often been made that disease prevention programmes should be shown to produce savings over the expenditure that would have been made, had the money not been spent on intervention. This ignores the humanitarian aspects and has often been difficult to prove. Nevertheless, Russell (1955) suggested that 'no country is so poor as to afford not to control malaria' and Pampana (1969), in claiming malaria to be the world's most expensive disease, quoted numerous examples of countries where economic benefits followed on from the control of malaria. In the case of the Solomon Islands M.E.P. a calculation was made (Table 81) that the programme would 'pay for itself' within 16 years. The various assumptions that were made have been included in the footnotes to the table.

Notwithstanding the potential savings made in health service expenditure further analysis showed that a number of other benefits occurred probably as a result of the activities of the M.E.P. Several

TABLE 81

Estimated Savings resulting from the Malaria Eradication Programme

Year	A Investment in MEP ($A000)	B Costs of Malaria[1] ($A000)	C Projected Costs if no Eradication[2] ($A000)	Savings ($A000) C-(A+B)
-3	0	140	-	
-2	0	150	-	
-1	0	160	-	
1	100	160	170	- 90
2	200	100	180	-120
3	300	50	190	-160
4	400	20	200	-220
5	500	10	210	-300
6	500	0	220	-280
7	500	0	230	-270
8	400	0	240	-160
9	300	0	250	- 50 -1560
10	200	0	260	60
11	100	0	270	+170
12	50	0	280	+230
13	25	0	290	+265
14	25	0	300	+275
15	25	0	310	+285
16	25	0	320	+295 +1580

Notes: 1. It is assumed that once eradication operations start the costs will rapidly fall.

2. These increase with inflation, population growth and with improved services as more people come for attention.

The costs of malaria to the community are calculated as follows:

Costs of Malaria in any one year

(a)	Number of Cases per annum	- treated in Outpatients	15,000
		- treated in Inpatients	1,500
(b)	Cost of treating cases		$A 150,000
(c)	Total work force (1970)		10,511
(d)	Average wage (1970) - $A10 per week		
(e)	Projected total cases in work force		1,051
(f)	Loss of earnings due to malaria		10,510
		Total of b and c	$A160,510
		(rounded to	$A160,000)

TABLE 81 - continued

Notes on (a) - (f)

(a) Averaged out for hospitals only over the period 1960-70, i.e. prior to any serious eradication measures. This takes no account of the numerous other cases treated in clinics making up a total of probably 100,000 cases a year.

(b) These costs include 'overheads' (Buildings, transport, equipment, drugs, wages). Outpatients and Inpatients malaria cases average at least 20% of totals. If another 5% is added for malaria related diseases the costs of malaria may be calculated to be 25% of total medical expenditure. In 1960-70 average expenditure was $A600,000 per annum.

(c) Solomon Islander males, 1970.

(d) Figure from Annual Report of Labour Division 1970 - rounded to whole numbers.

(e) and (f) Assuming 10% of workforce is affected once each year and is laid off for one week during this period (Pampana 1969) - probably a conservative estimate.

If a perusal is made of Chapter 6.3 page 109 it will be seen that the actual cost of the M.E.P. in 1970 and 1975 was greater than the rough figures quoted in Column 'A'. If an additional $A 100,000 is added to the investment during the first nine years, then it would take another 3 years, with savings running at $ 300,000 per annum, for the investment to break even.

examples will now be given of economic progress which followed shortly after the initiation of DDT spraying operations. It should be noted in passing that the original Pilot Project (in Guadalcanal/Savo and the Western Solomons) was aimed specifically at those areas with the greatest immediate economic potential.

The most remarkable change was the marked increase in domestic exports from 1965 onwards (Figure 58). This was two years after the start of the Pilot Project and followed a long period of non-growth. The increase was due to expansion in the timber and fishing industries. It was not due to changes in copra production except in 1974 when copra prices doubled. Even though copra production remained basically static (Figure 58) the quality of copra showed a steady improvement from 1964 onwards (Figure 59). This was most noticeable in the copra produced by Solomon Islanders which was only 20% 1st grade in 1964 but nearly 60% 1st grade by 1972. Big increases were also seen in the acreage of coconut new plantings and in cattle pastures, notably on Malaita. Many of these followed on shortly after the commencement of DDT spraying. Another important growth area was in tourism. The number of arrivals and departures (Figure 60) began to show a big increase in the mid 1960's. This was paralleled by a spurt in the tourist industry which started in the early 1970's just at the time when the island wide eradication programme was getting under way. Finally in the field of economic development a number of island co-operative societies began to show a marked increase in turn-over only when their respective islands came under DDT spray cover (Figure 61). The least spectacular progress was that seen in Guadalcanal where malaria was less under control than elsewhere.

Fig. 58. DOMESTIC EXPORTS AND COPRA PRODUCTION 1956-74

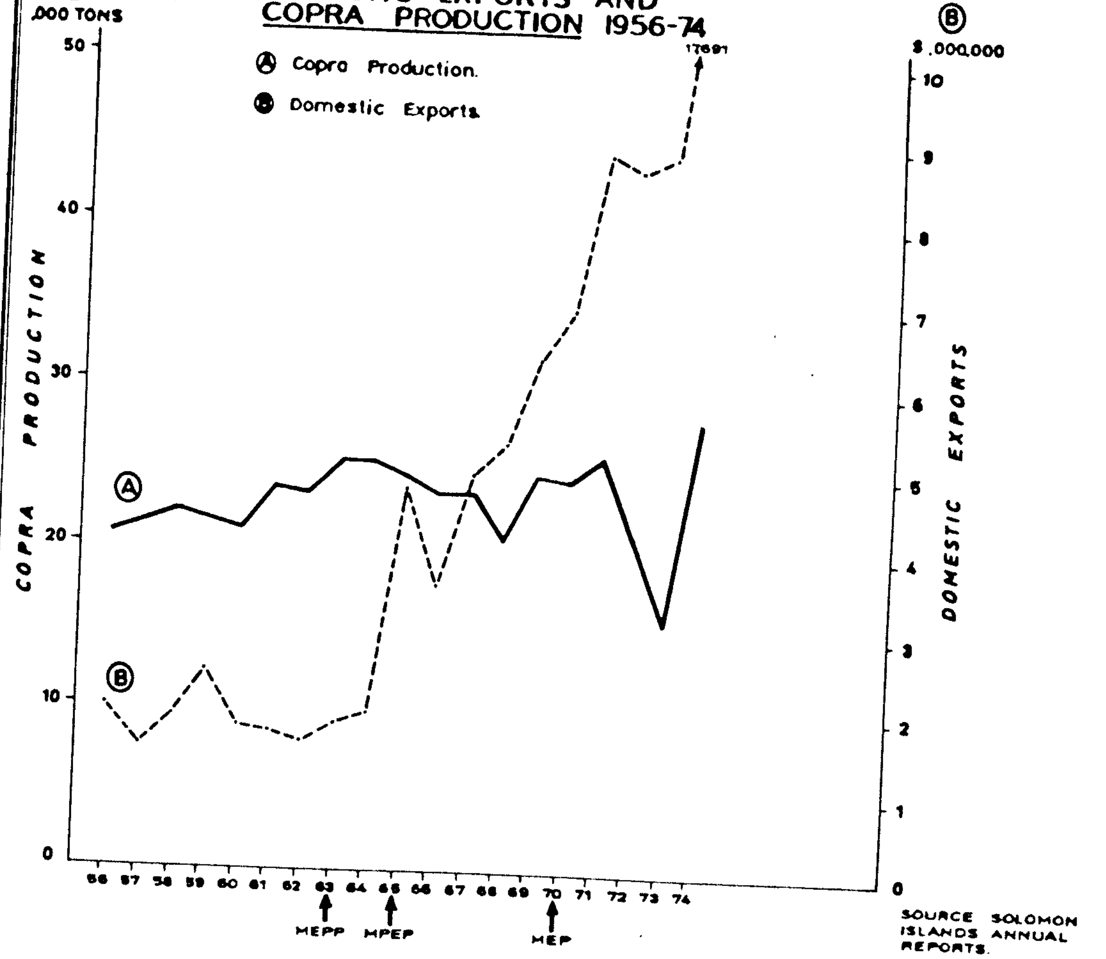


Fig. 59 COPRA PRODUCTION PERCENTAGE PRODUCED AS Ist. GRADE

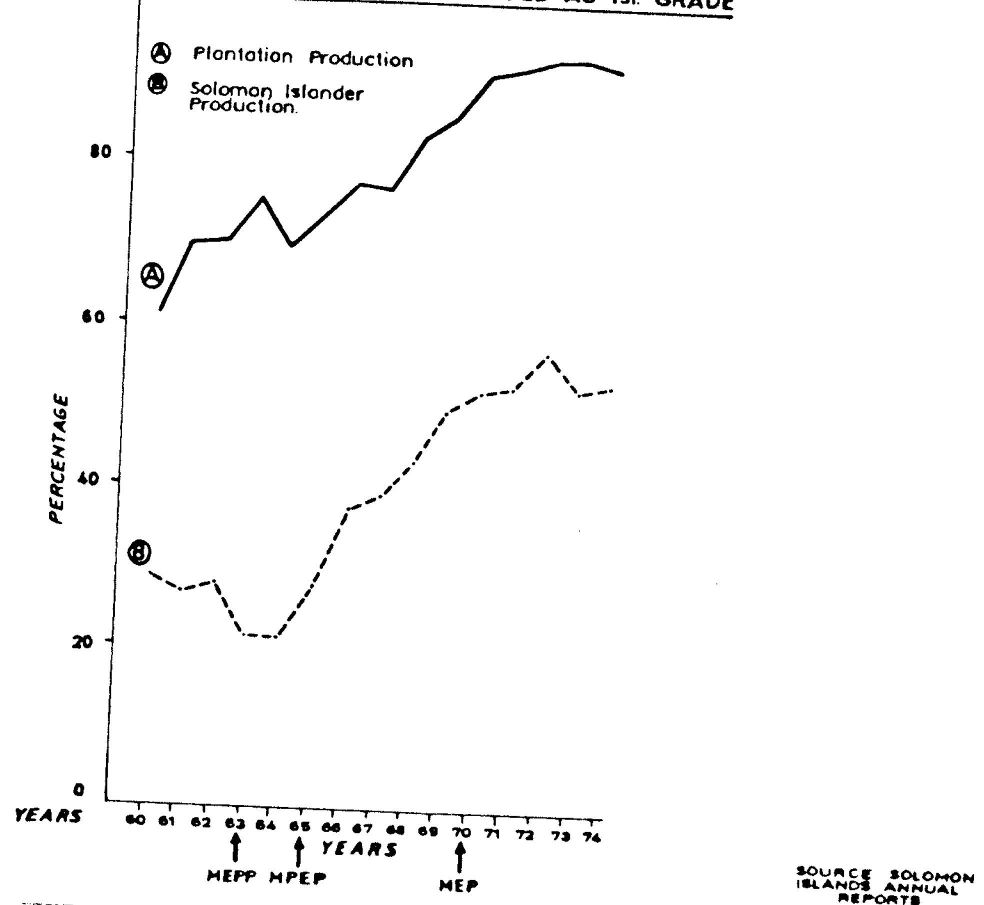
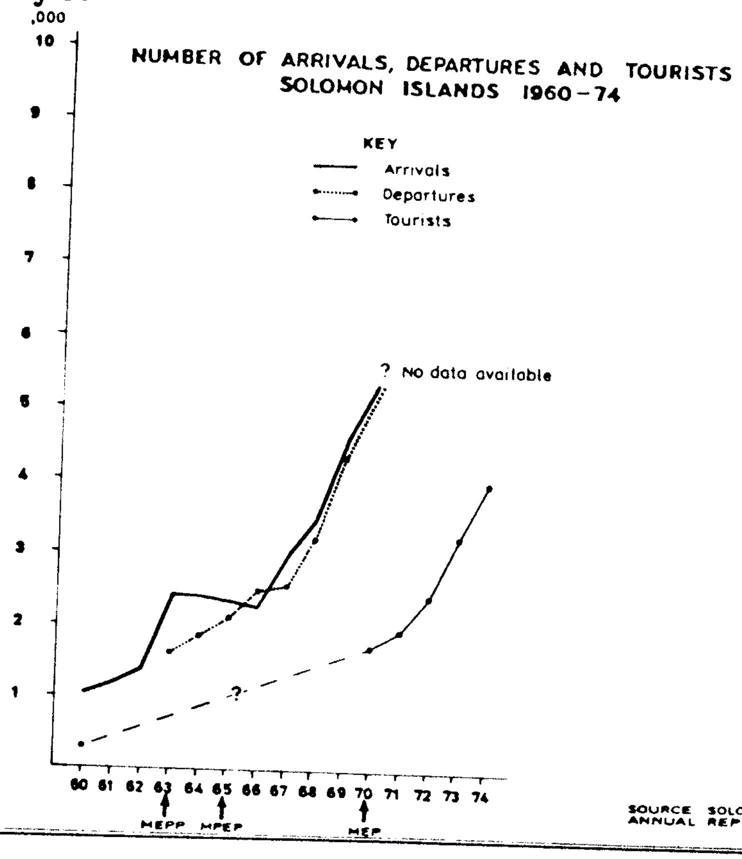


Fig. 60.

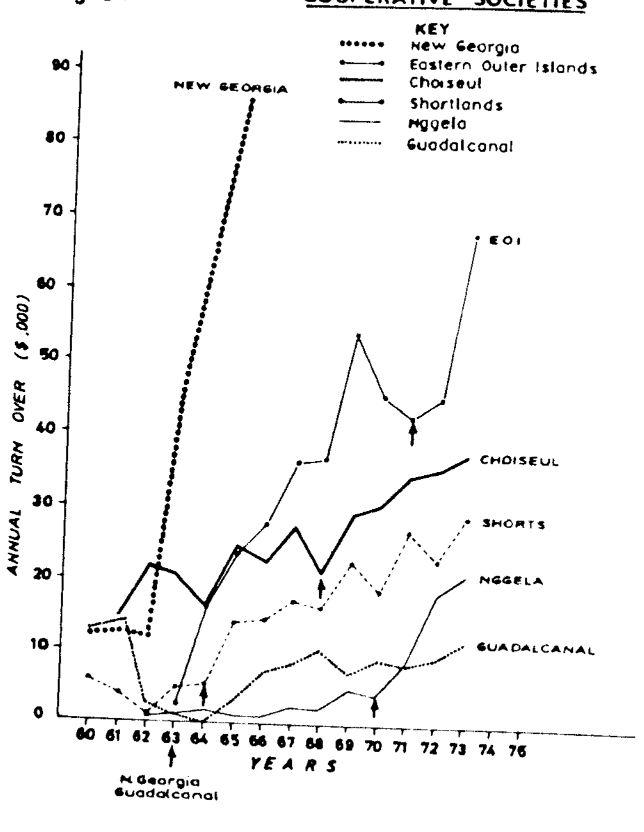


SOURCE SOLOMON ISLANDS ANNUAL REPORTS.

MEP 8.1

Fig. 61.

ANNUAL TURN OVER OF VARIOUS COOPERATIVE SOCIETIES



SOURCE COOPERATIVE DEPT.
MINISTRY OF AGRICULTURE AND
RURAL ECONOMY

NOTE In Figures 58 – 60 the arrows ↑ indicate start of :-

MEPP – Malaria Eradication Pilot Project

MPEP – Malaria Pre Eradication Programme

MEP – Malaria Eradication Programme

In Figure 61 the small arrow ↑ under the Island line indicates the start of Anti-malaria spraying in that Island.

It is reasonable to conclude that most of these economic indicators showed a turn for the better only when the people felt healthier after the burden of malaria had been removed. This was corroborated by a number of plantation managers who noticed that their labour was more energetic. They also claimed that the labour spent far less time off work once their families were no longer constantly sick with fever. School teachers also reported much improved attendance and better attention in class once spraying had started. This was yet another benefit in that, in time, better educated school leavers would be expected to contribute more usefully to the economy.

Finally in the field of economic development it is probable that the Guadalcanal Plains could not have shown the commercial expansion that it has done had malaria continued to be rampant. Even though malaria is not fully under control in this area, it is very doubtful whether people would have worked there at all had the formerly highly malarious state been maintained.

CHAPTER 8

DISCUSSION

8.1 The overall malaria problem

The results that have been presented have clearly established malaria to be the major health problem in the Solomon Islands. Prior to the eradication operations the disease was responsible for widespread morbidity and mortality amongst the people. None of the earlier efforts against the disease made more than a very minor impact for a short period of time. It is quite probable that the ravages of malaria seriously held up economic progress in many areas.

In spite of the country being relatively poorly developed in almost every sense the Malaria Eradication Programme has made a major impact on the disease. The health of the people has been much improved and economic development has proceeded at a rapid pace. The methods used for the eradication of malaria have clearly been effective in most areas in spite of several setbacks. An increasing refusal rate in a few small areas has meant that transmission has continued there and threatened the overall success of the whole programme.

In the next year or two decisions will have to be made on whether to continue the all out onslaught or to ease up on the expenditure and go for a control programme. Some of the people have now nearly forgotten about the serious effects of the disease on their quality of life. If they are willing to accept the intrusions of the malaria teams for a few more years then an all out effort may succeed. The end result will depend on the strength of commitment by government, the quality of work of the malaria teams and the co-operation by the people. The government will require a return in economic terms for the substantial investment made so far in the prevention of disease and the promotion of health. The people will wish to see their children remaining free from infection and themselves fit and healthy for everyday life. The results to date are a reasonable indication that these needs have been met. There appears to be every justification in consolidating and continuing the effort and in going all out to achieve the final goal.

8.2 The extent of the malaria problem in the Solomon Islands

A criticism of most Malaria Eradication Programmes is that they have gone ahead without really knowing what they were in for. This is to some extent relevant to the Solomon Islands programme where very little base line data was available in the early stages. The local knowledge and the findings of a small number of surveys did, however, indicate that malaria was a very big problem in the islands. This alone was justification to go ahead with some antimalaria effort. It did not help, however, when the time came to assess in detail the effects of the antimalaria operations. As time went on, efforts were made to obtain the rudiments of entomological and parasitological data from each island. In spite of the many gaps the sum total of information outlined in Chapters 2, 4 and 7 was sufficient to say that a state of mesoendemicity obtained on most of the islands. A few areas were hyperendemic or even holoendemic. At the other end of the scale some localities had no malaria at all or, at most, very low grade transmission.

No doubt more knowledge of the pre spraying behaviour of the vectors and especially of A.farauti, would have been valuable. It is doubtful, however, whether any additional knowledge would have resulted in a change of strategy. Nor would it even have resulted in the abandonment of the whole operation. The long term peaks in the incidence of malaria over periods of 3-4 years (Figure 1, Chapter 2) may have been of assistance in deciding on the optimum time for launching the anti-malaria operations. The trends may also have given a forecast of the serious epidemic of 1973 on Guadalcanal. Without more details, particularly of the immune state of the people and of longitudinal changes in vector behaviour, it is not possible to reach any firm conclusion on this speculation.

The disruption of annual records from 1970 onwards (Table 1 & Figure 1, Chapter 2) was a big disappointment. It was at precisely this time that the impact of the antimalaria operations would have been seen. Whilst a drop in admissions and in malaria admissions was seen from 1962 onwards it would have been very valuable to show the dramatic drop in overall admissions due to malaria once the full M.E.P. began to take effect from 1970 onwards. A large drop was actually seen in 1970 and 1971 but these records were unfortunately incomplete.

It was suggested in Chapter 2 that malaria was present in the Solomon Islands long before the modern phase of exploration. This is almost certainly true of the main islands but may not be so of the outer groups. Local evidence suggests that it was the travels of the missionaries and possibly of the traders that took the disease to the Polynesian islands. Increasing movement all round the islands undoubtedly allowed replenishment of the parasite reservoir whenever this was showing signs of diminishing.

The highly organised post World War II Marching Rule movement (Allan 1951) probably operated to disseminate rather than contain malaria. By living close together in stockaded villages and by maintaining excellent communications the people rapidly spread polio around Malaita during the 1951 epidemic (Cross 1975). By bringing people out from their remote and safe mountain villages it is probable that malaria was also increased in this way. Later when councils became established both government and missions inadvertently encouraged people to move to the malarious coastal villages for ease of contact. The pagans of East Kwaio on Malaita probably saved themselves much unnecessary suffering by remaining aloof in their hill hamlets.

The even greater mobility of the people following political and economic emancipation has further compounded the problem of containing malaria. Since completely free movement is allowed it is easy for a recently cleared island to become infected again. Screening of every new arrival at the point of entry is virtually impossible due to the wide variety of routes and irregularity of journeys. And yet, if a total embargo were to be put on all travel for 3-6 months, it is possible that all the remaining foci of malaria could be eliminated.

8.3 The philosophy of eradication

The initial enthusiasm for the eradication of malaria (WHO 1955) has now been tempered by the serious setbacks of the last few years. It is now realised that malaria eradication with available methods is quite unrealistic in many areas. In spite of the setbacks, at the end of 1974 some 1572 million (81.3%) out of 1935 million people in formerly malarious countries were largely free from the ravages of the disease (WHO 1975[a]). The ever present threat of malaria in the remaining 363 million people still makes it the leading cause of morbidity and mortality in the tropics. This fully justifies the continuing effort to try and control or eradicate the disease.

In the early 1960's it was reasonable to give serious consideration to the merits of eradication in the Solomon Islands. It could have been argued that it was not justified to go ahead with such an ambitious programme with such meagre resources and such a poorly developed rural health service. Even allowing for generous aid and abundant WHO expert advice some may have asked whether it was wise to go ahead with such a formidable task. The generally favourable response of the vectors and the parasites to the attack measures suggest that the attack was justified. The splendid co-operation of the people further enhanced this decision. By the mid 1970's the programme had gone on so far that a debate on the philosophy may have appeared irrelevant. Nevertheless, a point was being reached where diminishing returns were operating and where some serious review would be necessary. Few would disagree that where there are good prospects for the adequate control or eradication of a disease,then every effort should be made to achieve those aims. Only where severe technical problems, political complacency, population resistance or prohibitive costs arise should these aims be modified. Even then careful consideration should be given to the profound effects of the disease on the economy of the country and on the quality of life of the people. If then, it is clearly impracticable to continue the eradication exercise, it should be modified or discontinued.

Probably the most realistic philosophy on malaria control or eradication in the Solomon Islands is one of cautious optimism. The success that has been achieved on many of the islands should encourage an effort aimed towards the final 'knock out'. If this cannot be achieved within the next few years then the country should not be disappointed with good control. One of the resolutions of the 28th World Health Assembly (WHO 1975[c]) was that countries should make renewed efforts to control malaria within their ability to do so. This endorsed the recommendations of earlier assemblies and of the WHO Expert Committee on Malaria (WHO 1974[b]). That these efforts should also include the possibility of a return to simple methods like good control and local self help was emphasised by Jeffery (1976) and by the Brazzaville Conference (WHO 1974[a]).

Perhaps after a few more years of holding operations we may see a further technical breakthrough in the eradication of malaria. Now that the WHO is on the brink of a spectacular success with the eradication of smallpox, it may be expected to turn again with renewed vigour to the eradication of malaria. Encouraging signs were seen in 1974 with the setting up of a special programme of Research and Training in Tropical Diseases (WHO 1975[a]). This included malaria amongst the six major tropical diseases to be tackled. Perhaps a renewed vigour will bring a malaria vaccine nearer to reality or find more effective drugs, insecticides or other techniques to combat vector and parasite.

8.4 Organisation and Management of the Programme

A unique feature of the M.E.P. was the involvement of District Commissioners in the organisation of the early stages of spraying operations. This was effective in the early 1970's but during the rapid constitutional changes of the mid 1970's it became less realistic. Responsibility was then put more and more directly in the hands of the Malaria Field Operations Officers. An idea mooted on several occasions was the devolution of responsibility for spraying and surveillance to the local councils. This was consistent with government policy to give councils a bigger say in handling their own local affairs but was fraught with the difficulty of being able to maintain high standards. Inexperienced councils going through a stage of rapid transition already had a large number of problems to deal with so it was considered better to keep the organisation in the hands of experienced malaria staff.

Whilst it was generally accepted that more and more health work would be devolved to local councils in the long term, the immediate organisation still required attention. An interesting but impracticable solution was to put the whole job out to tender, or perhaps to put each island to tender, possibly by local councils. Another suggestion was to bring in trained army units to deal the final knock out to the residual foci. Commonwealth army units with tropical experience would be well equipped for such a task. Some type of National Service, with young people being deployed to carry out short term clearance and drainage operations, was another possibility.

A further administrative problem was the difficulty in obtaining experienced and mature supervisors. The concept of direct and autocratic supervision is contrary to the culture of Solomon Islanders who require decisions to be made by free discussion and consensus. In an M.E.P. quick and decisive action is often needed. Many of the younger men with a reasonable secondary education lacked the wisdom of years and their subordinates would not always respect and obey them. The basically high standards of supervision that were achieved is a credit to the motivation of the men involved and to their various training officers.

8.5 Operations

Geographical reconnaissance

The need to obtain total, complete, sufficient and regular coverage in spraying operations has been highlighted on many occasions (e.g. Pampana 1969, W.H.O. 1967[b]). The way to do this is to have a very accurate knowledge of the location and number of all structures requiring spraying. This can only be achieved by careful surveys and detailed recording of data. In effect this means making spot maps of all villages with accurate numbering of all houses. House cards require to be placed in each house so that operations may be fully recorded.

In the Solomon Islands the average sized village has only 50 people. Many of the villages are much smaller being nothing more than small hamlets. They are often very difficult to spot on maps and difficult to locate on the ground. They are widely scattered and often several hours walk apart even if sometimes within visible distance.

During the Pilot Project and the Pre Eradication Programme village spot maps were laboriously made and updated each spraying cycle. Even with the limited area covered it was apparent that many villages in Guadalcanal were not correctly recorded. Nevertheless all houses in all villages had house cards. Gradually the updating fell behind. As new areas came under spray coverage it was realised that it was impossible to keep up with the making of spot maps for all villages. A compromise was made with only those villages with more than 10 houses having spot maps. Later during the full Eradication Programme even this was dropped and then only villages with special problems had their houses plotted in detail.

In the course of time the key map that evolved was the 1:50,000 zone map. This was found to be the most important operational map. On it every single village and hamlet was plotted along with other important topographical features (Chapter 6.4). Each village had the total structures and total population marked in. Even with this simple map great difficulties were experienced in regularly updating and maintaining high standards of accuracy and cartography.

It has often been suggested that without good village spot maps, you cannot be sure that every house has been sprayed. Nor can you be sure of locating cases. The guarantee of spray coverage is probably better obtained by a good system of field supervision than by perfect paperwork. Location of cases in the Solomon Islands is done far better by word of mouth. People in villages know all of their neighbours. Problems only arise when names are incorrectly recorded or false or alternative names given. In any case over many years we have never been able to get case detection agents to consistently record house numbers. Passive Case Detection agents cannot record them anyway when they take blood slides in clinics. Most people do not know the house number which has been imposed on to them by the health agent.

A further criticism of failure to carry out spotting of all houses on village maps is the absence of an independent cross check on spraying operations. This we accept. Our only answer was to challenge visitors to find anywhere,any unsprayed house that we did not already know about. The existing system of reporting is sufficiently accurate to ensure that nearly all the information on missed structures is soon forthcoming. Of course this means that,strictly speaking,we cannot have an accurate record of spray coverage. This is true, but again field cross checking of returns does confirm the findings of the paper returns. We were therefore able to say with some confidence that the refusal rate in 1975 was over 10% in Malaita and under 3% in Makira.

Spraying operations

DDT has now been used for the residual spraying of dwelling houses in the Solomon Islands for more than 13 years. During that time there has never been any sign of resistance by the Anopheles punctulatus group to this insecticide. Since DDT remains the cheapest and most effective insecticide there has never been any serious consideration of alternatives. In most areas of the Solomons anopheline densities have been markedly reduced,and the transmission of malaria interrupted,by the standard application of DDT at 2 gm/m^2 once every six months. Where transmission has continued the reason has often been because of inadequate operations. On some occasions there was an interval of more than six months in the spraying. On others the spraying was on time but the coverage of dwellings was incomplete due to refusals.

This was seen most noticeably in Malaita (Chapter 7.3) where a steadily increasing rate of refusals led to a major breakdown in the operation. The slight improvement in spray coverage in the second round of 1975 was followed by a big reduction in malaria cases. This was mainly because of a concentration of effort on those villages where transmission was known to be continuing.

In Vaghena, North Choiseul and on Nggela island transmission continued for some time in spite of a carefully supervised spraying operation which achieved nearly 100% coverage at six-monthly intervals. On these islands the interval between spray rounds was reduced to 4 months as part of a combined intensive operation which included mass drug administration. The reduction to 4 months was based on the tenuous evidence from Nggela and Makira that densities of A.farauti rapidly increased at a period four months after the last spray cycle. (Sloof 1969, van Seventer 1972, Taylor 1974). As soon as malaria was cleared from these areas the cycle was reverted to the usual six monthly one.

In north Guadalcanal the spray cycle was also reduced to an interval of 4 months. This was after a period of about 18 months of 'interval spraying' which was also aimed at obtaining a better spray coverage. This special programme, which was carried out mid way between the two regular cycles, covered only the lower two metres of the walls of the dwellings. The justification was based on findings by Sloof (1969) and M.E.P. staff that the normal resting position of A.farauti in unsprayed houses was below 6 feet (2 metres) 81.4% of the time. The logic of this exercise may be disputed on the grounds that the habits of A.farauti change when they are exposed to DDT spraying and that they do not then rest at all on sprayed walls. Therefore leaving the upper parts unsprayed or less sprayed may actually encourage anophelines to rest indoors and so continue transmission. In the end the interval spraying was discontinued for practical reasons since it was felt that spray teams were not taking the job seriously even under very close supervision. Now, even after the introduction of the four monthly interval in spray cycles, transmission still continues in north Guadalcanal. There were occasional refusals, but generally the coverage was well over 95%. The continuing transmission was undoubtedly due to the very high density of anophelines and the high mobility of the people. This is discussed in more detail later in this chapter.

It is in many ways surprising that regular spray rounds have been maintained year after year on most of the islands. The upheaval of moving furniture is perhaps not so great, but the loss of cats and the increase in rats and bed bugs is a considerable nuisance. Fortunately the profound improvement in health has not gone unnoticed by the people. The danger has been where complacency has prevailed after several rounds and the people have forgotten about the ravages of malaria. Regrettably the only way in which public co-operation may be obtained at this stage is by the onset of a devastating epidemic. A reason frequently given for failure to maintain spraying schedules was a breakdown in transport. This was occasionally aggravated by labour unrest especially towards pay day. Bad weather also caused serious delays. In a country with such treacherous reefs, precipitous mountains and raging torrents it is quite remarkable that the teams were able to keep on time most of the time. Ships and road vehicles took an enormous battering and standards of maintenance and repair were not always entirely reliable. Furthermore, in a country so far from main trade routes long delays in supplies and spares frequently occurred. Great credit must be given to the transport and maintenance staff for keeping the malaria teams on the move most of the time.

. Parasitological evaluation

The ultimate evaluation of the effect of the Malaria Eradication Programme is whether or not there is any malaria in the community. The examination of blood slides has been widely used as a means of evaluation in the Solomon Islands. The difficulty in assessment by serial surveys in the 2-9 age group was the small numbers of people on many of the islands and the possibility of contamination from recent migrants. Another difficulty was the long time often required to obtain a small number of blood slides from remote hill villages if genuine random sampling was to be practised. The tendency to collect slides from accessible coastal villages probably resulted in a higher parasite rate on occasions. On the other hand these same villages were more likely to be the ones in which a good spraying operation had been carried out. There was therefore always a possibility of missing out foci of malaria elsewhere.

Whilst the regression pattern for P. falciparum malaria invariably followed the standard pattern of Macdonald and Göckel (1964) this was never so for P. vivax. In spite of this it is clear that the transmission of P. vivax was interrupted in many areas. Over the years a characteristic pattern emerged (see Chapter 7.3). It is now proposed that any regressions which fall within these limits in the south-west Pacific should be accepted as evidence of interruption of *P. vivax* transmission. It was not possible to formulate any pattern for *P. malariae* except to say that this parasite usually disappeared from survey returns within two years of starting spraying. The one possible finding of *P. ovale* in an early survey was not confirmed at the W.H.O. Reference Laboratory in Manila (van Dijk, personal communication). This parasite has been found, however, on rare occasions in Papua New Guinea (McMillan 1968[a]).

Although there has been some dissent in recent years about the value of Macdonald's models (Nâjera 1974) they have been of value in evaluation in the Solomon Islands. Their use should therefore be continued in the malarious countries of the south-west Pacific for the evaluation of the early attack.

Evaluation by routine malaria surveillance has also been very effective in the Solomon Islands. It has been shown (Chapter 7.2) that Passive Case Detection (PCD) is invariably more efficient than Active Case Detection (ACD) in picking up malaria cases. There is therefore every justification in building up a comprehensive network of PCD agencies. Experience has shown that these should concentrate mainly on the fully qualified, well trained and strongly motivated nursing staff in the Rural Health Clinics. People of more limited training like Village Health Aids (Dressers) sometimes do well but usually need constant encouragement. School teachers, headmen and other community leaders tend to rapidly fall off after an initial burst of enthusiasm. With these the return is usually not worth the effort unless the agent is in some remote area without any health agency.

An Annual Blood Examination Rate (ABER) of 10% of the population is the accepted minimum coverage of the population for effective surveillance (Black 1968). In almost all of the islands of the Solomons this has been easily exceeded every year. But even here there may be anomalies since analysis of the surveillance returns has shown that remote villages are often left out of the ACD visits. Most villages are visited once a fortnight but often only 25% of the village will be contacted since it is usual for the majority to be absent in the daytime. Surveillance during the late afternoon and early evening would make far more sense. However, the long distances and the need to travel by daylight would mean that very few villages could be covered at this time. Case detection is tedious work and the agents have usually earned a well deserved rest by the end of the day. Certain age and sex groups may easily be missed. Young men in particular are seldom in the village by day. Even if they are they often treat the collection of blood slides frivolously. With an ABER which is often well over 50%,and mass blood surveys being carried out around most cases,it is likely that few malaria cases are now going undetected in the Solomon Islands. There will still be a few who do not show a parasitaemia at the time of collection or whose parasite load is so low that they escape detection. For these the more sophisticated techniques of fluorescent microscopy or immune antibody testing may be used in the future. When this stage is reached there will be a good case for offering a substantial financial reward to the person who first detects any new outbreak. This method was used with particular success in the final stages of the eradication of smallpox from several countries. (Kaplan 1975).

A problem common to case detection and to effective treatment is the physical difficulty of communications in the Solomon Islands. Since ACD Agents usually go out for a week at a time,and air or shipping services may operate only weekly or fortnightly,there are often big delays in getting slides into the laboratory. These delays may also affect the viability of the slide since no effort is made to stain it in the field. Peripheral laboratories are not the answer since both men and equipment rapidly deteriorate in these without supervision. There may also be further delays in getting results back to the field so that a person with circulating gametocytes may go on infecting mosquitoes for some considerable time. These delays have been much improved by using wireless telegraphy and the Solomon Islands Broadcasting Services to alert malaria agents about new cases. Delays in getting slides to the laboratory have sometimes been improved by the use of courier services. In other areas there is just no way, short of prohibitively expensive speedboat or helicopter collection, of speeding up the process. In the smallpox eradication campaign in Ethiopia the use of a helicopter vastly improved the surveillance coverage of remote mountain villages (Kaplan ibid). These versatile machines have been used for mineral exploration in the Solomon Islands. If still available in the late 1970's they may prove to be of use in speeding up the final mopping up operation in remote areas.

Whilst the evaluation of the early attack phase has been relatively easy the consideration of when to revert from Attack to Consolidation has caused some difficulty. The accepted criterion for a change in phase is that the Annual Parasite Incidence (API) for a given region must have reached 0.1‰ (Black 1968, W.H.O. 1964). This assumes that the surveillance coverage has been adequate during that period. In the Solomon Islands, with such small numbers of people and such frequent contamination, the figure of 0.1‰ was considered unrealistic. The Independent Assessment Team of 1973 (Tewari and Colbourne 1973) suggested an arbitary figure of 2.0‰ which was readily accepted and applied. This was twenty times more generous than the 'official figure' and therefore that much riskier. In practice however this proved to be a reasonable compromise. The important thing really was to ensure that speedy action was taken once there was any suspicion that transmission had been resumed.

The ease with which malaria can return to even a remote island was shown in early 1974 with a small outbreak on Sikaiana (Chapter 7.3). This followed the return of an infected priest to an island where delays in spraying operations had undoubtedly allowed the vector to re-establish itself.

Following on from the serial parasite surveys, the method of parasitological assessment used in the Solomon Islands was the analysis of surveillance returns. This was done monthly and yearly by zones and islands by calculating the Slide Positivity Rate (SPR) per centum and the Annual Parasite Incidence (API) per thousand. Since the SPR was calculated only from Active and Passive Case Detection returns there sometimes may have been some dilution resulting from over enthusiastic collections. Once the SPR reached low levels the API was introduced. Since this measured the total malaria case incidence from all sources it was a more accurate measure of the true incidence of malaria in the community. A difficulty in making comparisons was found in translating the pre spraying prevalence survey results into malaria incidence. The only two incidence surveys that were carried out were applicable only to their respective localities. When comparisons were made between the changes in SPR and in API the actual fall in malaria did not appear to be as dramatic as was shown by the serial surveys. The serial survey measured the major fall whilst the surveillance returns measured the more insidious one.

Chemotherapy

Antimalarial drugs have been one of the strongest weapons in the attack on malaria for many years. When correctly used for treatment of clinical cases their effect is often dramatic. When used as part of the two pronged attack against parasite and vector in an eradication programme their contribution is fundamental. The ability of the malaria parasite to develop resistance to a number of different drugs has, however, caused a number of problems throughout the world (Peters 1970). The day is still eagerly awaited for the discovery of a safe, single dose, long acting, wide spectrum, anti-malarial drug. The most promising new drug mefloquine has not yet reached that stage where it can be widely used in practical programmes. In any case,too rapid widespread abuse of this drug will probably lead to the rapid development of resistance (Peters 1975). Meanwhile we continue the struggle with the very effective but still limited drugs available. The Solomon Islands is perhaps fortunate in that its parasites are readily susceptible to clinical cure with chloroquine. They are unfortunate in that they have at least one strain of vivax malaria, the Chesson strain, which requires larger and more prolonged doses of primaquine than any other strain in the world.

Drugs for presumptive treatment

During the Pilot Project and the Pre Eradication Programme the only drug used in presumptive treatment was a single dose of chloroquine 600 mg. for adults. It was known that this treatment would sterilize many P. falciparum infections but it was equally well known that it would not sterilize the gametocytes of this parasite. Therefore, during the later stages of the full Eradication Programme primaquine was also added to the presumptive treatment for the purpose of killing these gametocytes. Pyrimethamine was also used for the same purpose for a brief period during the earlier years until its efficacy came under suspicion.

Once the Consolidation phase was started in the Western Solomons, primaquine was withdrawn from the presumptive treatment. This was mainly because of the increasing concern over the toxic effects of the drug. We were well aware of the arguments of Black (1968) that the time of apparent eradication is just the time when a gametocytocidal drug is needed. This is in order to ensure quick sterilisation if any parasites should still be around. Consideration was even given to removing chloroquine also from the presumptive treatment. No treatment at all was soon rejected however, since it was accepted that the medical attendant must be seen to be giving some therapy in order to retain credibility in the eyes of the patient.

Radical treatment

A problem of great importance in the eradication of malaria in the Solomon Islands has been that of obtaining adequate radical treatment for *P. vivax* cases. From the time that the fast relapsing characteristics of the south-west Pacific (later called Chesson) strain of *P. vivax* were first realised (Metcalf and Ungar 1944) until the present day there has been no treatment which provides an absolute guarantee of radical cure. The therapeutic need for high doses of primaquine administered over a relatively long period has always had to be balanced against the toxic effects. Concern that high doses might precipitate a haemolytic crisis has restrained increases being made in the dosage. This has been of particular importance in glucose-6-phosphate dehydrogenase deficient subjects.

Soon after World War II it became apparent that the newly introduced 5 day x 15 mg.primaquine treatment for *P. vivax*, as used successfully in India (W.H.O. 1961), was quite inadequate for the south-west Pacific strains of *P. vivax* malaria. When the treatment was extended to fourteen days preliminary studies in U.S.servicemen still resulted in a high relapse rate (Edgcomb *et al*.1950). An increase in dosage to 30 mg. daily for 14 days resulted, however, in no relapses in five cases followed up for 350 days. More extensive studies in the U.S.A. (Arnold *et al*.1954, Courtney *et al*.1960) continued to find a high relapse rate with the 14 day x 15 mg. regime. Even the intermittent regime of 45 mg. weekly for 8 weeks, proposed by Arnold *et al*.(ibid), introduced in an attempt to mitigate the toxic effect of high dosages of primaquine, resulted in a 10% relapse rate (Alving *et al*.1960).

Meanwhile in Australia, Black (1958) found that in presumed latent *P. vivax* malaria in government officers returning from Papua New Guinea a treatment with 22.5 mg x 14 days primaquine resulted in an 8% incidence of subsequent malaria. This compared with a rate of 55% in a comparable untreated group. No relapses occurred in eleven people from the Solomon Islands and the New Hebrides with presumed latent malaria. They were given 15 mg.primaquine per day for 14 days. No toxic symptoms were noted in the 15 mg. per day group but some of those on 22.5 mg. per day experienced nausea, vomiting and abdominal discomfort. No reduction in haemoglobin was observed with a daily dosage of 15 mg.

As soon as the Malaria Eradication Pilot Project got under way in the Solomon Islands the 15 mg. x 8 weeks regime of radical treatment for P. vivax was chosen knowing that even this might result in some relapses (Macgregor 1966). Field studies in Savo Island soon proved this to be so with a relapse rate of 63% within three months of completion of treatment. The recommendation of the Third Inter-territorial Malaria Conference for the south-west Pacific in 1963, when faced with this dilemma, was to arbitrarily increase the length of time of administration by 50%. At last, following further trials on Savo and Ranongga Islands (in which 149 P. vivax cases were followed up for at least five months) not a single relapse occurred. The 45 mg. x 12 weeks primaquine regime therefore became the standard radical treatment for P. vivax malaria in the Solomon Islands (Alves 1965, Macgregor ibid).

After using the twelve week regime for ten years practical considerations led to the utilisation (in 1973) of the 5 day x 15 mg. primaquine treatment in certain areas with large numbers of P. vivax infections. This allowed comparison to be made by W.H.O. staff members Paik (1974) and Saint-Yves (1975[a])of the efficacy of this treatment compared with the 12 week one. In a review of 161 cases of P. vivax treated by the 5 day x 15 mg. regime in 1972, Paik found a relapse rate of 14.9%. There was a relapse rate of 9.8% for the 51 cases treated by the 12 week by 45 mg. regime. In the review by Saint-Yves, covering nine different areas in the Solomon Islands during 1973, the 1024 5 day cases had 12.2% of subsequent attacks whilst the 435 12 week cases had a subsequent attack rate of 5.3%. In both of these reviews the follow up was for six months or longer. The possibility of reinfection could not be completely ruled out but it was concluded that the 12 weeks x 45 mg. regime is normally quite satisfactory under field conditions in the Solomon Islands. It is certainly superior to the 5 day treatment.

Since even these results were not fully satisfactory it was decided in 1974 to treat all cases of P. vivax malaria by one of two regimes. These were either primaquine 45 mg. x 12 weeks (total 540 mg.) or primaquine 30 mg. x 14 days (total 420 mg.). Cases undergoing the 14 day treatment were treated in a hospital or clinic under close supervision whenever possible. The purpose of this was to ensure adequate treatment and to keep a close watch on side effects. In all of the 14 day treatments completed there were reports of side effects (nausea, vomiting, headache) in only a very small number. No relapses were seen in any cases which genuinely completed the full 30 mg. x 14 days treatment. A small prospective study of 27 P. vivax cases from north Guadalcanal, which was started by Saint-Yves (personal communication) in April 1975, resulted in several relapses when the single dose of primaquine 45 mg. was used. None of the cases subjected to the 15 mg. x 14 days or the 22.5 mg. x 14 days primaquine treatment showed any sign of relapses after one year of follow up. This limited trial led Saint-Yves to conclude that a closely supervised basic 15 mg. x 14 days treatment would probably be sufficient to cure most of the Solomon Island P. vivax strains. He considered this to be further evidence endorsing the findings of Black (see page 317) that the P. vivax strains become easier to treat in the easternmost parts of Melanesia.

The preliminary reports on the trials being carried out in Bougainville on primaquine 15 mg. x 14 days and primaquine 45 mg. x 8 weeks confirm that there is still a high rate of relapse with these treatments (Tavil, personal communication). In view of the past experiences with relapses the treatment of choice for the radical treatment of P. vivax malaria in the eradication programme in the Solomon Islands should remain primaquine 30 mg. x 14 days. This is probably also the most suitable treatment for P. vivax in Papua New Guinea. It may be possible for the New Hebrides P. vivax to be treated with lesser dosages according to informal reports from those islands (Greenhough, personal communication). It may also be possible to reduce the dosage in the Solomon Islands if further evidence is produced to show that the 15 mg. x 14 days treatment is adequate for a radical cure.

The use of depot antimalarials

During the early 1970's we gave serious consideration to using the depot antimalarial cycloguanil pamoate, possibly in combination with oral chloroquine or amodiaquine. This drug had been shown by Coatney et al. (1963, 1964) to exert at least six months protection against the Chesson strain of P. vivax in the U.S.A. in non-immune volunteers not exposed to reinfection. Cycloguanil was also found to protect for at least 12 months against infections by *P.falciparum* if challenged by the bite of an infected mosquito (Contacos *et al*.1964).

The use of depot antimalarials was found to be of less value in Australia and Papua New Guinea. In patrol officers recently returned from Papua New Guinea to Australia (Black *et al*.1966[a,b]) found that the intramuscular injection of 'Camolar' (cycloguanil pamoate), alone or in combination with DADDS,* delayed the onset of *P.vivax* malaria for only three months.

In 1965, in the Rabaul area of New Britain in Papua New Guinea, Rieckmann (1966) treated proven *P.falciparum* and *P.vivax* cases with intramuscular 'Camolar' plus oral amodiaquine. The parasitaemia disappeared within 72 hours. In an area where malaria transmission was clearly continuing *P.falciparum* infections reappeared within 150 days and *P.vivax* within 90 days. In a subsequent study in the same area Rieckmann (1967) found that 'Camolar' alone prevented the reappearance of *P.vivax* for 60 to 90 days. The use of DADDS alone prevented *P.vivax* for only 30 days, whilst the two drugs in combination prevented *P.falciparum* for 90 days and *P.vivax* for 60 to 90 days. This second study gave some evidence suggesting a reduced susceptibility of both parasites to the proguanil group of drugs.

The ability of 'Camolar' to prevent the appearance of malaria parasites in the blood stream for a period of at least two months in field conditions may have been of value in the Solomon Islands in areas where transmission was continuing. We thought, however, that side

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* diacetyldiaminodiphenyl sulphone.

effects were a greater risk in continuous field conditions. If the public became unco-operative due to painful injections or abscess formation then a high refusal rate would inevitably follow. In addition it was considered bad practice to drive the infections out of the blood for a short period only to have them reappear. There was also a distinct possibility of resistance developing. We considered it more important to improve the other factors aimed at interrupting transmission and to ensure adequate radical treatment of all proven cases.

Other methods of drug administration

The use of medicated salt was never given very serious consideration in the Solomon Islands. The vast majority of people cannot be reached by this method since they do not buy salt for cooking or food additive purposes. One of the most efficient methods of distribution might have been through religious gatherings or custom feasts. Not surprisingly these methods were not considered too seriously since the very bitterness of the drugs would soon have resulted in widespread population resistance.

Resistance to antimalarial drugs

There is no evidence to date (January 1977) of resistance by any of the malaria parasites present in the Solomon Islands to any of the antimalarial drugs regularly in use in the islands.

The nearest geographical area where there is any resistance by *P. falciparum* to chloroquine is in West Irian (Ebisawa and Fukuyma 1975, Clyde *et al*.1976). It is predicted that this may spread into Papua New Guinea within a few years. The Solomon Islands are then next in line. In addition, skilled technical staff is recruited from Sabah and the Philippines to the Solomons for the timber industry. In each of these areas resistance is present at least at the RI level (W.H.O. 1973[a]).

None of the reports of P. falciparum resistance to chloroquine from neighbouring Papua New Guinea have been authenticated. The only reported investigation into resistance was that carried out in Milne Bay in April 1971. In this study Saint-Yves (1971) found no recrudescence of P. falciparum parasitaemia over a period of 28 days following treatment of 22 slide positive cases. This was with a three day course equivalent to 1500 mg. (25 mg/kg body weight) chloroquine for adults. Further chloroquine resistance trials were carried out during 1975-76 in Papua New Guinea (Tavil, personal communication). None of these trials found any evidence of resistance by P. falciparum to chloroquine.

The only investigation in the Solomon Islands into resistance by P. falciparum to antimalarials was that by Clyde et al. (1974) using the Solomons (Nes) strain isolated in Guadalcanal in July 1973. This strain, studied in adult volunteers in Maryland, proved sensitive to standard doses of chloroquine used curatively (1500 mg. base for 3 days) and prophylactically (300 mg. base weekly). Proguanil 100 mg. salt daily also suppressed the strain whilst pyrimethamine 25 mg. weekly was ineffective for this purpose. For curative use 50 mg. daily of pyrimethamine failed to clear the parasitaemia resulting in a classification of resistance by P. falciparum to this drug at the RIII level. This drug was also ineffective as a sporontocide. Radical cure was also obtained with 10.7 g. or 13.2 g. of quinine sulphate administered for eight days. With dosages and length of treatment less than this resistance at RI or RII levels was obtained. The findings of Clyde and his colleagues add to the earlier studies of Meuwissen (1961) who found that P. falciparum was resistant to both pyrimethamine and proguanil in West Irian. Although Clyde found no resistance to proguanil, the findings by Rieckmann (ibid) in New Britain of reduced susceptibility by both P. falciparum and P. vivax to the related cycloquanil are an indication that the proguanil group of drugs should be treated with suspicion in the south-west Pacific.

No tests of resistance by P. vivax and P. malariae to antimalarials have been carried out in the Solomon Islands. This is of no relevance at this stage since the problem is one of adequate dosage rather than one of actual resistance.

In vitro drug sensitivity tests

It has been recommended that regular in vitro testing be carried out on the sensitivity of prevalent malaria parasites to the drugs commonly in use in the country (W.H.O. 1973[a]). This has not been done in the Solomons but it was seriously considered during 1974. It was decided, however, that the exercise was of sufficiently low priority to be excluded. The possibilities for testing P. falciparum became progressively less during 1974-75 due to the disappearance of the high density parasitaemias required for such testing.

Toxicity

The toxic effects of chloroquinine and primaquinine have been well publicised by Peters (1970) and by the World Health Organisation (1973[a]). Nearer to the Solomon Islands Rhodes (1974) has reviewed the toxicity of antimalarials used in Papua New Guinea.

With the frequent use of chloroquine and primaquine (allowing for as much as 420 mg. primaquine in 14 days) the per capita exposure to antimalarials must be as high in the Solomon Islands as anywhere in the world. Prior to eradication operations intramuscular chloroquine was widely used. No deaths were officially documented but sudden death following chloroquine injection certainly occurred. Once the severe malaria cases were removed from the community, health staff were instructed to use intramuscular chloroquine only for very serious cases. In spite of this one death was recorded in the Eastern Solomons in 1974. This was in a seven year old girl who had difficulty in taking oral chloroquine as part of her radical cure for a P. vivax infection.

Chloroquine has not been used for suicide as in neighbouring New Hebrides and Papua New Guinea (Wilkey 1973[b]). Complaints are frequently heard about nausea, headache and visual disturbances following chloroquine administration but these invariably turn out to be due to ingestion on an empty stomach. The need to continue daily activities after the malaria agent has visited may also result in more side effects than usual. So far no ocular stigmata have been noted in Solomon Islanders during annual visits by the Australian opthalmic surgery team (Galbraith, personal communication). In Papua New Guinea, however, Rhodes (ibid) has claimed that long term prophylactic doses of 300 mg. chloroquine weekly may cause ocular damage. No other abnormalities have been reported following the widespread use of chloroquine including its frequent use in pregnant women.

With the known propensity of negroid races to carry a genetic deficiency of the haemopoetic enzyme glucose - 6 - phosphate - dehydrogenase (G6PD) early concern was expressed over the high dosages of primaquine being used. This lead to the use of the 8 week and later the 12 week regime of radical treatment following the proof of the mitigation of the haemolytic effects of primaquine by this method (Arnold et al.1954, Alving et al.1960). The lack of toxicity was confirmed by Vivona et al.(1961) when they showed that even after 22 consecutive weekly doses of 45 mg. primaquine no toxic effect followed. Following this the use of primaquine became more widespread. During the 1970's a survey was made of the G6PD trait in the Solomon Islands. The island incidence in males varied from 6 to 10% (Hunter Williams, personal communication) with the expression being strongest in the Eastern Solomons. This compared with Papua New Guinea where the overall incidence in males was reported as 5.8% (Young, Smith & Woodfield 1974) ranging from 0% in the Highlands to 9% in Bougainville and 35% in New Ireland.

Apart from occasional complaints of nausea and headache no serious side effects were reported from the use of primaquine until early 1973. Then a 9 year old boy died in New Georgia from a haemolytic crisis which followed shortly after a single dose primaquine treatment. Subsequently four non-fatal cases of haemolytic anaemia were reported following exposure to primaquine. With an increase of dosages in the 14 day treatment to 30 mg. daily extra vigilance was kept up by all malaria staff for side effects. Even with these high doses the majority of treatments were taken without adverse effects.

Mass drug administration

Antimalarial drugs were widely used for mass treatment during the eradication programme. On several occasions this was the major factor which tipped the balance in the interruption of continuing low grade transmission. Notable failures were in north Guadalcanal and Malaita. These were because of the high intensity of transmission rather than operational factors. There was always the danger that mass drug administration would be used to cover up a poor basic operation. Where the field operation is known to be near perfect and there are no technical problems then there is a case for mass drug administration. Any such exercise requires a thoroughly detailed organisation and maximum co-operation from the people. These standards were achieved in several exercises in the Solomon Islands. The ideal method would be the use of a single dose, long acting drug which was easy to administer and which lasted several months. Chlorproguanil, after showing early promise, did not fulfil this ideal. Since no new universally applicable antimalarial has become available since the introduction of pyrimethamine in 1952 use has had to be made of chloroquine and primaquine in the Solomon Islands. Proguanil has seldom been used. Pyrimethamine was discontinued in 1968 even before resistance was confirmed to this drug in the islands (Clyde et al, ibid). The other drugs used against malaria (e.g. sulphonamides, DADDS and tetracycline) have never been considered necessary because chloroquine and primaquine have proved to be so satisfactory.

Where frequently relapsing P. vivax malaria was a problem the mass drug administration was in effect a mass radical treatment of the whole population. In the Gilbertese communities in Vaghena a weekly treatment with primaquine for twelve weeks finally resulted in a clearance of malaria from the community. This was after the failure of two exposures to the 5 day treatment. On north Guadalcanal, where the intensity of transmission was high, the twelve week treatment failed to achieve a clearance. This population was even more itinerant than the Gilbertese. The chances of reinfection were very high in many villages. In both communities a combined approach using even further supplementary measures was considered necessary. In the Gilbertese communities this consisted of larviciding the known anopheline breeding sites in swamp taro beds. In north Guadalcanal it consisted of stream clearance, filling of swamps and ultra low volume spraying (see below).

Where P. falciparum transmission was the main problem (as in north Choiseul and Nggela) a single treatment with chloroquine and primaquine monthly for four to 6 months was effective. This was also tried in parts of Malaita where, at a later stage, the 3 day radical treatment was also utilised. In theory the 3 day treatment should achieve a knock out if properly administered. In practice in Malaita this was not so probably because of the high refusal rate and continuing opportunities for transmission. A further 3 day treatment some 10 to 14 days later, to pick up the new infections already developing in mosquitoes may have achieved the knock out. The main problem here was the one of mobilisation and supply of staff. The compromise monthly treatment, easier to organise and easier on the people, did achieve clearance in Nggela and Choiseul. It also cleared many areas of Malaita towards the end of 1975.

There are a number of objections to the use of mass drug administration. There is the possibility of the parasite developing resistance due to repeated exposure of suboptimal doses (Arnold et al. 1961). In order to avoid this Arnold advised the use of a good blood schizonticide (e.g. chloroquine) with the primaquine. There is no evidence yet that the use of primaquine and chloroquine has lead to the development of resistance by the Solomon Islands parasites to these drugs. Furthermore their short term intensive use is justified in the hope of a 'knock out'. This will then avoid the need for their prolonged use in the future. Then there is the danger of serious side effects. These may be detrimental to one or two individuals. They may result in massive non co-operation by the public. The occasional serious side effect must be weighed against the overall benefit that is being obtained by the community from these drugs. The balance is,however, a delicate one especially when the high dosages of 30 mg. primaquine are being administered daily for fourteen days. Good public co-operation is essential. A continuous and careful watch is required at all times to ensure that there are not too many adverse reactions. An explanation must be given to individuals and community leaders so that the importance of drug taking is fully understood. We have been remarkably fortunate in the Solomon Islands in having a people who very much appreciate the value of antimalaria therapy. This is probably because they well appreciate the ravages of the disease and do not want to see it return. They also know about the dramatic effects of the Yaws Eradication campaign in the late 1950's. One minor disadvantage of this is that many people think that the magic needle is the universal panacea. Intramuscular chloroquine is still very much in demand. With the virtual disappearance of cerebral malaria its use is to be condemned except in very special circumstances.

A further objection to the use of mass drug administration is that this leads to complacency in other operations. The spraymen and case detection agents may not bother about a first class job because they know everyone is going to be treated with drugs anyway. The attention of the supervisory staff may be diverted exclusively to the drug administration to the detriment of other operations. The staff in the Solomon Islands have been well aware of these dangers. The mass drug administration has usually been carried out by special teams under senior staff supervision. Whilst this allows the other teams to continue their work without interruption it may lead to each team working in total isolation which is equally undesirable. It is here where senior staff leadership and co-ordination is paramount.

The use of mass drug administration has been given some emphasis because of its prime importance in the eradication of malaria in the Solomon Islands. With a small population of only 196,708 (1976 census) it may be said that everyone could surely be administered a radical cure for their malaria. It might even be possible to do this all at the same time to achieve the final knock out. Indeed this was considered in conjunction with the 1976 census when everyone was contacted by some agent of government. Why not use the same agents to administer twelve weekly doses of antimalarials ? It is an attractive idea, but administratively virtually impossible. Many of the villages are very isolated. The population is constantly on the move,often walking many miles in a day through dense jungle. What has happened is that this type of exercise has been carried out on a limited scale by malaria staff in the exercises already mentioned. The costs are high but justifiable when weighed against the continuing costs of a holding operation rather than a complete removal of the disease.

Prophylaxis

The type of prophylaxis used by non-immune visitors to the Solomon Islands is of no great relevance to the eradication programme. Regular administration of antimalarials to special risk groups like pregnant women, plantation labour and the under fives was discontinued in all areas once transmission was interrupted. The controversy between the use of chloroquine or proguanil is really only of importance to the expatriate. Even with this group the interest is decreasing in parallel with the risks of exposure. It has been argued that regular daily drug taking is easier and more reliable than weekly. Also that a drug which is being kept in reserve for first line treatment should not be used for prophylaxis. On these criteria daily proguanil would be the drug of choice for prophylaxis. The objection to this in the south-west Pacific is the evidence that P. falciparum is resistant or partially resistant to the proguanil group in West Irian (Meuwissen ibid) and in Papua New Guinea (Rieckmann ibid). There was also the much earlier evidence of acquired resistance developing in P. vivax to suboptimal doses of proguanil administered to prison volunteers in the U.S.A. (Arnold et al.ibid). The use of weekly pyrimethamine is also contraindicated due to the finding of resistance by P. falciparum to this drug in West Irian (Meuwissen ibid) and more recently in the Solomon Islands (Clyde et al.ibid). The experience of at least two medical officers on the island of Makira in the Eastern Solomons confirms that pyrimethamine is of no use in prophylaxis (Mackay and McDonnel, personal communications). Mepacrine (Atebrin) has long been out of favour following reports of resistance by P. falciparum in the East Sepik District of New Guinea (Fairley 1946). The strains were thought by Peters (1970, 1974) to have been brought in by the Japanese troops from south-east Asia and to have subsequently died out. Quinine has also been long considered unsuitable for prophylaxis (but still lifesaving for radical treatment). It has recently been shown to have only limited value for prophylaxis in the Solomons due to resistance at the RI and RII levels (Clyde et al.ibid). On the available evidence and experience there is only one drug for malaria prophylaxis in the Solomon Islands. That is chloroquine at an adult dosage of 300 mg. weekly. This drug is only a suppressive so that there are still chances of the reappearance of P. vivax once it has been stopped.

The risks of a newly returned expatriate developing a fatal P. falciparum infection are of considerable interest to the clinician. Whilst most of the malaria imported into Britain is from Africa and Asia (Bruce-Chwatt, Southgate & Draper 1974, British Medical Journal 1976) occasional cases of P. vivax are brought in from the Solomon Islands and Papua New Guinea (Manson-Bahr, personal communication). Several cases of malaria, including occasional P. falciparum, are imported into Australia every year from Papua New Guinea (Black 1974). The importance to the clinician is to make the correct diagnosis and to carry out the correct treatment (Maegraith 1973, 1974, Bruce-Chwatt et al.ibid, British Medical Journal 1975).

Newer Drugs

None of the drugs used in more recent years for resistant malaria have been tried in the Solomon Islands. There has never been any indication to use these drugs since there has been no sign of resistance by any of the parasites to the readily available chloroquine and primaquine. The use of additional drugs was considered to be an unnecessarily expensive and unjustified complication to an already difficult programme.

Should any drug suddenly become available which had the ability to rapidly cure the Solomons strains of malaria, we would see an overnight improvement in the state of malaria. The small population of the Solomons, although scattered, is very amenable to drug therapy. By injection there would be a near guarantee of 100% coverage due to the enormous reputation that all injections enjoy. Even by the oral route a very high degree of acceptance would be likely. Simultaneous administration would not be easy, but by utilising the skills of census enumerators this could probably be achieved without too much difficulty. Should any such a drug become available in the near future then the Solomon Islands would be a good place in which to carry out a trial. An area with continuing high grade transmission, like lowland Papua New Guinea, would be an even better test.

Behaviour of the vector

In the mountain areas above 500 metres the drop in temperature to 4°C or more below the coastal figures may well be sufficient to discourage survival of adult anophelines. Even where they do survive they may not survive long enough for malaria parasites to develop right through to the sporozoite stage. In these tenuous circumstances two or three rounds of DDT spraying are probably quite sufficient to tip the balance against vector and parasite.

The major climatological factors influencing vector behaviour are the diurnal changes in humidity and the intensity and frequency of rainfall (Chapter 3.2). Following cyclones there is often a period of low rainfall and low humidity. Longitudinal surveys in Guadalcanal and Makira clearly showed a marked fall in vector densities following cyclones resulting in a lowering of the potential for the transmission of malaria. The danger follows when the vector experiences a population explosion and man, recovering from the shock, starts to rebuild his houses.

The normal prevailing winds are of no consequence in vector ecology except that the daily land breeze may blow anophelines inland and the night land breeze may possibly blow the mosquitoes into coastal villages from their inland breeding sites. There is no evidence in the Solomon Islands for the wide dispersal across country that has been described in parts of North Africa. Nor is there any evidence for canoe, ship or aircraft dispersal but this must remain a distinct possibility (Peters 1965).

Each of the three malaria carrying mosquitoes in the Solomon Islands is an efficient vector. The two subsidiary ones A.koliensis and A.punctulatus are only of minor interest since they rapidly disappeared once DDT spraying started. No alternative vectors were found but the primary vector A.farauti proved to be a very hardy adversary. Where densities were low prior to spraying A.farauti either disappeared or fell to such low levels that transmission was clearly interrupted. Where densities were high no amount of conventional spraying, however well carried out, resulted in complete disappearance. The change from predominantly indoor,all night biting to predominantly outdoor early evening biting allowed for easy man vector contact during the peak of man's outdoor activities close to the village. Whether there was a change of habit due to DDT repellency or there was the emergence of a hardier strain of A.farauti, as suggested by Taylor (1975), is largely irrelevant to the attack on the vector. The problem in north Guadalcanal is that vectors are still biting people carrying gametocytes. They are then living long enough to develop sporozoites and infect more people. The close supervision of spraying and the reduction of the spraying interval to 4 months still failed to achieve the interruption of transmission although this was very nearly done in the dry season of 1972 (Figure 47). Even the use of mass drug administration with over 80% population coverage still failed to interrupt transmission. It became clear during 1973-74 that no further progress would be made unless an attack was made on the other stages of the vector's life cycle or on the vector outdoors (see next section).

The original surveys of vector distribution were very limited except for the quite detailed surveys on Malaita and Makira (Taylor 1974). We do not know the original distribution or density of anophelines in New Georgia and the Shortlands nor on most of Guadalcanal. Post spraying surveys were also very limited in many areas. Even when spraying was withdrawn in New Georgia distribution surveys were only carried out in a few indicator areas. This means that assessment of receptivity to malaria has been largely empirical but it may be reasonably presumed that many locations have a high receptivity.

The major survey method was by night catches in the early evening since this was the time the vector was most active. Whole night catches were carried out from time to time to ensure that no changes had taken place in the biting pattern of the vector. Catches were conducted by indoor man biting and outdoor man biting methods exclusively since it was extremely rare to find A.farauti resting on a sprayed wall. Day catches and searches in probable outdoor resting places were also unproductive. More sophisticated techniques were not used because it was considered that these could not contribute anything more useful to a problem already well known. Since only one sporozoite was ever found in post spraying anopheline dissections, studies on vectorial capacity were soon abandoned. These studies were not encouraged by the high parous rates that were usually found since it was quite clear vectors were living long enough to continue to transmit malaria.

A problem of greater practical importance was the reappearance of malaria in some hill villages in Guadalcanal following cessation of spraying. Entomological surveys revealed low densities of A.punctulatus in scattered localities and it was suspected that this was responsible for the outbreak. No vector was found in the high bush villages above 500 metres yet several people from these villages were infected. Migrations are so frequent to the coastal villages that it was often difficult to find out exactly where any infection was acquired. The presence of a presumably 'extinct' vector led to an early re-introduction of spraying in the Guadalcanal bush. The problem was more difficult on Malaita where transmission was resumed in coastal areas during 1974-75. Several inland riverine villages also had malaria but in these it was not too difficult to find A.farauti. We remained reluctant to reintroduce spraying to the hill villages because many of these had been the most resistant to spraying in the past. They were also difficult and expensive to spray. A small number of surveys failed to find any stage of anopheline in these villages. Such is the limitation of the surveys when carried out tediously for many days or even weeks, that the vector may still escape detection. It is also likely that anophelines may fly up into hill villages from their riverine sites.

Supplementary measures against the vector

It was in only a very few areas that supplementary measures were used against the anopheline. The methods used were ultra low volume insecticide against the adult and larvicides, stream clearance and swamp filling against the aquatic stages. Many other methods were considered from time to time. All were rejected as being impracticable or prohibitively expensive. There is no doubt that the very intensive measures of the type used by the U.S. Forces in World War II (Harper, Lisansky & Sasse 1947, Oman and Christenson 1947) did result in marked reductions in anopheline densities. It is only at a time of major world or national crises, however, that governments are prepared to spend the enormous sums of money required for such activities as aerial spraying and major drainage and clearance schemes. In normal times malaria control and eradication programmes must make the best use of the modest finances provided. Even so there may be the occasional justification when an all out blitz over a short period will save the government much recurrent expenditure in the future. North Guadalcanal may be one such case.

The female anopheline adult spends more of its time outdoors than indoors following the commencement of DDT spraying. It is therefore reasonable to look for ways in which to attack the adult outdoors. It is known that the female of the *A. punctulatus* group flies straight to the breeding site in the early morning after taking a blood meal (Black 1955[b], Spencer 1971). After laying eggs the female rests under vegetation near the ground, only to return to bite man or another animal in a day or two for a further blood meal. Massive clearance of bush around breeding sites would make resting opportunities difficult, but the method robs the village of much needed shade and subsistence crops. One solution would be to attack the adult on the wing or whilst resting. Since most female anophelines are en route for a blood meal in the early evening an attack around dusk would seem to be the most appropriate. As an alternative an attack in the early morning around the breeding sites would catch the females during egg laying. The successful use of ultra low volume insecticide against *Aedes aegypti* for the control of dengue epidemics in south-east Asia (Pant, Nelson & Mathis 1973) led us to consider its use for anopheline control. After delays in obtaining insecticides and machinery, trials were carried out in north Guadalcanal in September and October 1975. The u.l.v. particles of malathion were sprayed from a Land Rover based Legco pump. The insecticide was directed around the periphery of the village and the drift was expected to penetrate at least 200 metres into the bush. It was originally hoped to apply the u.l.v. spray in early August during the time of lowest vector densities and lowest intensity of transmission. On evaluation up to the end of 1975 there was no conclusive evidence that u.l.v. spraying was resulting in reduced vector densities. This was not entirely surprising when the method was applied at a time when seasonal densities were already rising. The use of u.l.v. spray was by no means written off and further trials are continuing to find the optimum timing and placing of applications. We were encouraged by reports from Haiti (Eliason, Volvick & Karam 1975) that u.l.v. malathion had been used there to successfully control Anopheles albimanus and so reduce P. falciparum malaria during the epidemic season. These good results were obtained after intensive application of aerial spraying making due allowances for infiltration of mosquitoes from adjacent untreated areas. The inability to obtain this type of coverage may well be one of the reasons for failures so far in the Solomon Islands.

Several other methods of attack on the adult were considered after Bryan (1973) had dismissed the possibilities of field use of sterile males or of hybrid zoophilic females in the south-west Pacific. The use of knock down pyrethrum sprays was considered to be of little value in preventing man vector contact in villages. In properly screened houses this would be of value but few individual householders would use it sufficiently regularly for it to be of use. Aerial spraying was dismissed on the grounds of high cost. As a final resort however, in very limited foci it may still have a place. The use of mosquito nets in villages was also unlikely to prevent contact since not even the children were ready for bed in the early evening at the time of maximum anopheline biting activity. Personal mosquito repellents were not practicable for the most vulnerable group namely the children. Mosquito coils (joss sticks) had similar limitations. All of these methods were expensive and very unlikely to be kept up for long by the average villager.

Even with these failures further methods were tried including the use of an attractant trap as described by Wright (1968). In this mosquitoes are attracted to a small supply of heat, humidity and carbon dioxide emanating from a candle and water container in a stove pipe. Wright found the method effective for attracting culicines but we found it to be completely useless for attracting anophelines. Another potentially promising idea was therefore abandoned. Finally the possible use of predators of the adults was discussed. This was dismissed due to there being no known animal available with such specific propensities.

A little more promise was shown over alternative measures against the aquatic forms and especially the larvae. The value of these measures is that three of the four stages in the life cycle of the anopheles are in water. The disadvantage in the Solomon Islands is the enormous expanse of water offering ideal breeding opportunities. Elimination of some swampy areas was a possibility never to be considered seriously due to the enormity of the task. Clearance of vegetation from streams was dismissed by van Seventer (1972) as being of no value. It was considered earlier by Laird (1955) that this could even create greater breeding opportunities by removing the shade cover and allowing anopheline larvae easy access to the sunlight they enjoy. However, in a limited trial carried out in Tamboko in 1975 using voluntary labour from the village, clearance resulted in a virtual disappearance of the larvae. The method was considered promising enough to continue in selected foci during 1976. It was also considered that self-help could not be relied on for any long term project. Local labour would therefore have to be paid pro rata for work done.

Having created the minimum number of opportunities for breeding a further attack was made on the aquatic stages with Abate larvicide. This was shown conclusively in a field trial at Gilutae, West Tadhimboko to almost completely eliminate larvae for a period of up to 7 days after application. Again the method was expensive so that it could only be applied for a limited period in serious foci.

Finally for the small number of larvae remaining it was expected that some of the u.l.v. malathion being used to kill adults would drift on to the breeding sites. In view of the disappointing results with u.l.v. malathion as an imagicide some consideration was also given to concentrating the attack on the adults mainly around the breeding sites rather than around the villages. No evidence is yet available that this method has any special advantages.

In the intermittently estuarine areas immediately behind the beaches it was thought at one time that regular drainage or tidal flow schemes might have been of value. Tidal flow was quickly dismissed due to the expensive damming required. In a very limited trial carried out at Gilutae (Figure 5) no evidence could be obtained that regular breaching of the sand bar made any difference to the larval densities. It appeared that, even with drainage, anophelines still found opportunities to deposit their eggs.

The final possibility of an attack on the aquatic stage was the use of predators and pathogens. The larva eating fish Gambusia affinis was introduced into Ontong Java during the abortive eradication exercises of 1954 and 1960 (Hollins 1957, BSIP 1961). There is no evidence in the records that the Gambusiae specifically made any contribution to the reduction of malaria. Had their presence been long lasting there would not have been the set backs that were seen in that operation. During World War II Gambusiae were also introduced into parts of Guadalcanal Plains (Harper et al.1947). Again the additional methods were so extensive that the individual contribution of Gambusiae could not be evaluated. The only claim for any success with this method in the south-west Pacific was that of Holland (1933) in New Ireland. At Kavieng the control of anophelines was ineffective until Gambusiae were introduced. In villages where the fish was put into breeding sites the spleen rate fell from 24.6% to 4.2% in two years. Following this success Gambusiae were distributed to other centres. It was considered by the Chief Medical Officer to be the most successful antimalaria measure used in the Territory of Papua New Guinea (Ford 1950). In later years this view was not maintained. The prevailing view of entomologists and fisheries experts in Papua New Guinea is that Gambusiae have not had any noticeable effect on vector densities (Venters, personal communication).

In spite of the limitations in Papua New Guinea we were keen to try Gambusiae again in the Solomons. Searches in the numerous pools around the Guadalcanal Plains eventually located some specimens. Some of these were transferred on three separate occasions to a small stream where baseline entomological surveys had already been carried out. No change was seen in adult larval densities following the introduction of the fish. Unfortunately, they were not seen again which somewhat invalidated the experiment. Further experiments were proposed since the method was still considered to have possibilities.

Another fish reported to have been introduced into Guadalcanal is the larva eating Notobranchus guentheri. This fish thrives in areas with a marked dry season. The season in Guadalcanal is probably neither dry enough nor long enough to allow the fish to thrive at the expense of others. It does not appear to have had any effect on the densities of anopheline larvae in the Solomons.

The use of microbes as a means of controlling insect vectors of disease has been suggested from time to time. The fungus *Coelomomyces* has been found on mosquito larvae in many parts of the world but has seldom proved to be of any detriment to its host. Genga & Maffi (1973) reported the fungus on species of *Aedes* in the Solomons. A potentially more promising pathogen is currently under investigation in the School of Public Health and Tropical Medicine in Sydney (Sweeney *et al*.1973). The organism is very similar to *Metarrhizium anisopliae*, a pathogenic fungus of terestrial insects. In laboratory studies larvae of mosquitoes and other insects have been found to be susceptible to infection and death. Field tests are now required to prove the true value of the pathogen. A pathogen specifically favouring anopheline aquatic stages would be ideal but there are possibilities that this more general pathogen may be available in a few years. Research with viruses may also find suitable pathogens to the adult or aquatic stages in the near future (W.H.O. 1973[b]).

Effects of migrations

The importance of migrants disseminating malaria has been well documented. From studies in Africa, Prothero (1965) concluded that internationally co-ordinated eradication projects would be needed where boundary control was impossible. Several examples have been given in Chapter 7.3 of migrants disseminating malaria in the Solomon

Islands. A particular problem exists with migrations across the border between Bougainville and the Shortland Islands. It has not yet been possible to reach a parallel stage of progress in these two localities but a good deal of liaison has been made between the Solomons and Papua New Guinea. Efforts are being made by Bougainville to reach a similar state of progress so that no contamination will result (Tavil, personal communication).

A further problem of migrations is where people remain static in a highly anopheline favourable environment. The most obvious example is in north Guadalcanal. In this area of high development potential the population is steadily expanding. This is due to natural increase and to migrations from all over the Solomons to look for work. Intensive efforts have still failed to completely interrupt the transmission of malaria in this area. In these circumstances the final answer would be to move the people away from the problem but this would defeat the objective of this being a development area. Continuing co-operation with the health authorities by the companies and their staff will go a long way towards solving the malaria problem. Failure to eradicate malaria from this key area will provide a permanent reservoir for dissemination of the disease throughout the islands. If malaria is not cleared from the Guadalcanal Plains it is very likely that their full development potential will not be achieved.

Use of self help

In spite of all the efforts of the authorities man frequently encourages anopheline breeding and biting. By siting his villages close to anopheline breeding sites and spending the early part of the evening out of doors man is indeed his own worst enemy. Perhaps more attention should be paid to the suggestion by Gillett (1975) that there is unlikely to be any further reduction in mosquito borne disease until we find ways of changing the behaviour of man. Efforts were made towards the end of 1975 to encourage the people of Tamboko village to the east of Honiara to voluntarily clear the streams of vegetation. Initial results were encouraging and it was proposed to expand the effort around those villages on north Guadalcanal where malaria transmission was still continuing. Although there is no television in the country the Solomon Islands Broadcasting Service (SIBS) is well received in many villages. Brief health features were broadcast from time to time during all stages of the M.E.P. A family radio programme along the lines of the B.B.C. 'Archers' was also being considered in 1976. It was proposed to feed into this programme certain ideas on self help. This would then be a further development of the recommendations made by W.H.O. (1974[b]) to take cultural attitudes, beliefs and behavioural attitudes more into account when preparing health education and self-help exercises.

Newer methods of control and eradication

The existing methods of ground control, insecticide spraying and drug treatment have now nearly reached their limits of effectiveness. No new insecticides or drugs are on the immediate horizon and the proposed biological and pathological methods of vector control do not yet appear to be practicable. Since man continues to create a favourable environment to malaria transmission some other method must be sought to halt the ravages of the disease.

The use of vaccines has been shown in recent years to be remarkably effective in the control and near elimination of several diseases. Since the malaria parasite stimulates an immune response following an infection it is reasonable to assume that a field vaccine will be produced in the foreseeable future. Progress in this field has been both exciting and disappointing. After the practicability of utilising protective malarial antibodies was demonstrated in humans in the early 1960's (Cohen, McGregor & Carrington 1961) progress has been relatively slow. The numerous immunological strains and the ability of malaria parasites to change their antigens in order to evade the immune defenses of their hosts (Brown & Brown 1965) have not made the task an easy one. Vaccines have now been prepared which will give protection against homologous strains of malaria parasites in monkeys for several months(Sadun, Wellde & Hickman 1969). There is no sign yet of a vaccine for man which will induce life time immunity against all strains of malaria parasites. Nevertheless man has been induced experimentally to develop effective antibodies against P. falciparum and P. vivax malaria (Clyde et al. 1973, 1975) so that effective vaccines for field use may possibly be available within the next decade (W.H.O. 1975[b])

The field use of an effective vaccine would transform the malaria problem almost overnight in many countries. If a few residues of malaria are to remain in the Solomon Islands then this should surely be one of the first countries in which to use the vaccine. The relatively small population could soon be immunised and transmission effectively interrupted. The continuing immunisation of the newborn would then maintain the herd immunity until the malaria parasite was completely removed from the country. The immunological approach must surely be the ultimate answer in malaria eradication since all existing methods are so crude and expensive and sadly,often so ineffective.

8.6 Effects of the Malaria Eradication Programme

Effects on other diseases

Amongst a large number of fringe benefits resulting from the work of the M.E.P. the easiest to measure directly is the effect on other diseases. Several other diseses, notably filariasis, have been improved by the work of the M.E.P.

It has been suggested by Webber (1975) that A.farauti does not transmit Wuchereria bancroftii as efficiently as it does malaria parasites. Filariasis requires intense local transmission over a considerable length of time to the same population to become well established. The reduction of vector densities need not be so great to achieve interruption of filariasis transmission. Below a point which is less critical than that for malaria, filariasis may be expected to die out naturally. Webber has also suggested that the most satisfactory model for showing a decline in filariasis is to measure densities and not simply parasite rates. Such declines have been amply demonstrated in north-west Choiseul where it may reasonably be claimed that filariasis is well on the way to being eradicated (Chapter 7.4). It is probable that Wuchereria bancroftii can survive in the people of the Solomon Islands for at least 8 years and probably up to 12 years. The need for prolonged pressure on the vector is, however, emphasised by the earlier findings of van Dijk (1964) in West Irian and McMillan (1968[b]) in New Guinea. They found that $6\frac{1}{2}$ to 7 years of DDT spraying still failed to reduce the filaria rate in highly malarious areas. Where spraying is about to be discontinued after 10-12 years it may still be necessary to use drug therapy to clear the residues of filariasis. This would require the closest supervision if the difficulties experienced in Fiji in treating the last small reservoir of infection (Desowitz and Southgate 1973) are to be avoided. Should eradication of filariasis be achieved long term surveillance of human and mosquito populations would also need to be kept up for many years in the way advocated by Bryan and Southgate (1976) for Samoa.

Besides specifically combating malaria and filariasis there has been an overall improvement in health due to increases in mean haemoglobin levels, better maternal health, improved birth weights and a reduction in the prematurity and still birth rates. The production of a better quality baby may well have a more profound effect on the long term well being of the community than any other single health measure (Macgregor and Avery 1974). When legitimate claims can even be made for a decrease in respiratory disease and tuberculosis as a result of antimalaria work then the health value of the exercise really does appear to be beyond any dispute.

Effects on population growth

The marked increases in population growth between 1959-70 and 1970-76 have been outlined in Chapter 7.6. It is very likely that the first growth spurt followed on from the successful yaws eradication campaign. Later expansion occurred as a result of improved living standards and a spreading out of the rural health services. Whilst the Malaria Eradication Programme certainly resulted in more infants surviving it is difficult to know how much of the population explosion can be ascribed directly to the effects of the M.E.P. At current rates the population may be expected to double within the next 20 years. This rapid increase is not necessarily detrimental to the community. Some economists argue that in countries with a labour intensive economy a steady population growth is necessary to provide the labour force needed for production. The Solomon Islands is one of the rare developing countries in the world with a surfeit of cultivatable land. The majority of the people still live on a subsistence basis by shifting agriculture. Much land is wasted or under utilised. It is possible that the Solomon Islands could support half or even one million people. The danger lies in the too rapid growth in both individual family units and in the whole society. This would put an intolerable strain on all the government services. A too restricted expansion would inhibit economic growth. A compromise is clearly required. It is fortunate that the government, after some years of reluctance, is now giving full backing to a Family Health Programme sponsored by the British government. This aims to provide a reasonable Family Planning Service to those who desire it but without pressing it on those who do not. The agencies involved have shown a keen interest. There are now good prospects that the too rapid population growth of 3.5% per annum may be reduced in the near future to a more reasonable 2%.

Effects on the Economy

It was shown in Chapter 7.8 that a number of improvements in economic development occurred simultaneously with the control and eradication of malaria. There have been increases in Solomon

Islander copra production and in tourism, in new coconut plantings and in cattle herds. Local co-operative societies have shown a marked upsurge in their trading turnover. Many of these changes have followed on from activity by the Administration and Agriculture Departments. But perhaps it is a little more than coincidental that many of these have occurred immediately following the start of spraying on an island. The general upsurge in domestic exports did not start until 1965 which was two years after the start of the Malaria Eradication Pilot Project. Could a healthier work force have had anything to do with these changes ? In the absence of quantitative data on work attendance this is difficult to prove but, if the testimony of the employers is anything to go by, then there can be little doubt about it. Maybe, rather than prove our own case, perhaps we should ask what other environmental changes occurred at the identical times to so improve the economy. It would be difficult to find any convincing influence other than malaria eradication.

Regardless of the benefits to the overall economy which could be argued to justify the programme purely on economic grounds, it has also been shown in Chapter 7.8 that the programme will 'pay for itself' within 16 years. This is not a bad investment when the end product is a healthy nation with a healthy work force and a much improved quality of life. By the end of 1975 the government had already invested over $A 4 million into the eradication of malaria. There is a reasonable chance that the further investment of $A 2 million will see the job to fruition within the next few years. It therefore seems eminently reasonable for government and the aid agencies to give every possible support over the next few critical years (Baker 1973).

Effects on the quality of life

The lifting of the overwhelming burden of malaria can only be fully appreciated by those who have had a direct personal contact with the ravages of the disease. The father, who is now able to work regularly must surely be impressed with the changes. All the more so when he sees that his wife is not worn out by childbirth and that he does not lose every alternate child before they are five years old. Then, when he sees his children enjoying good health and able to attend school regularly, he cannot fail to be impressed. Surely this is an enormous improvement on the quality of life for all his family. There may well be disadvantages with spreading urbanization and civilisation but surely these are still less than those attending chronic debility and disease.

One major danger of the rapidly expanding population is the creation in time of a partly educated teenage group. Unless useful employment or occupation is found for them serious and detrimental social changes may well follow.

Effects on the ecology

The most profound effect of the M.E.P. on the ecology was the death of most of the cats in the villages due to DDT spraying (see Chapter 7.7). The resultant increase in rats certainly caused much hardship. Advice and facilities were offered at very modest charges but few of the villages took them up. They expected the M.E.P. to solve a problem which was, after all, only exacerbated by the DDT spraying and not caused by it. Short of a very intensive campaign there was little more that could be done although the rat problem was certainly one of the major reasons for refusals to spraying in some areas. The increase in bedbugs and cockroaches was also a problem. On occasions malathion was added to the DDT preparation and the mixture sprayed thoroughly into and under bedding.

We do not know how much DDT there is in the environment or in animals and man in the Solomon Islands. Nor do we know how much of this can be directly blamed on the M.E.P. and how much on its extensive use in agriculture in the past. There is little evidence that any of the marine, bird or insect life has been seriously affected at this stage. We do know however that occasional deaths of river fish were due to the careless washing down of DDT in rivers after spraying.

There is no strong environmental lobby in the Solomon Islands and the government currently has no intention of banning DDT. Most of the agricultural use has now been discontinued but a strong case remains for its continued use in malaria eradication. The potential environmental hazards have to be weighed up against the enormous benefits to man. On present evidence the case is strongly in favour of man but it behoves M.E.P. staff to take great care in the use of this potentially dangerous insecticide.

8.7 Factors militating against success

All major disease control and eradication programmes require full government backing and a high degree of public co-operation. This is true of a Malaria Eradication Programme more than any other because the balance between the parasite and man getting the upper hand is such a delicate one. A few houses unsprayed or one case allowed to go untreated will soon allow transmission to start up again.

A big non-immune population is almost as susceptible as a new arrival to the ravages of a malaria epidemic.

Whilst technical problems (e.g. resistance by the vector to insecticides or by the malaria parasite to drugs) may be a cause of failure, it is often operational factors which are the real reason (Avery 1974). Technically there is no great problem in the Solomon Islands. Even on the difficult islands of Guadalcanal and Malaita the transmission of malaria can be interrupted given an efficient operation and full public co-operation.

Prospects will be much improved if there is political and economic stability and administrative competence. Again these can be achieved given wise leadership and sound planning. We need to be sure, not only of adequate financing of the M.E.P. and the whole health programme, but also of full political and administrative support. This is far more than simply agreeing that the 'M.E.P. is doing a good job'. The politician must be seen to actively support the programme in the Legislative Assembly, in the council chambers and in his constituency. Unfortunately, on occasions, community leaders are the first to actively oppose community health work. Often this is a failure of communication by the health worker but sometimes there is more to it than that. The community leader may gain face or status locally by being seen to get away with opposing or resisting the far off central government. Or there may well be other issues. It is the duty of the health worker to do the best he can to find out the reasons and to get all community leaders working closely with him. He can do this by being seen to do a good job himself. He can also do it by taking a genuine interest in, and concern for, the grievances of the objectors.

Other factors preventing success are administrative failures. The whole government machine must be seen to actively support the programme as a matter of first priority. This means so many things. Appointment of good quality staff to fill key administrative and clerical positions. Removal of bureaucratic obstructions. Speedy procurement and delivery of supplies. Prompt and adequate remuneration for the job over and above the regular government salaries and wages. Regular and efficient maintenance of transport equipment. Recognition of the hardship of the job. Good promotion prospects for those who do a good job. Again liaison between the government agencies must be of a high standard at all levels. In many ways it is the intermediate liaison between ship's bos'n and field supervisor, between mechanical foreman and squad leader, that is so important. A M.E.P. which has full control of all its equipment and supplies is probably the best arrangement for then only they can take the blame. In the Solomon Islands, such autonomy is quite impracticable and good will must prevail.

And what of leadership ? Last, but of course, not least. Given dynamic and inspired leadership the man in the field will go through many privations and hardships to keep the job going. Without it he will soon falter. In a field programme such as Malaria Eradication even the most senior staff must be seen to be in the field actively encouraging the men. It is not a matter of spying and looking for fault. It is far more a matter of inspiration and encouragement (Lancet 1975).

There is also no place for nepotism and security of tenure in a Malaria Eradication Programme. It is no place for political intrigue and complacency. It requires military brilliance rather than bureaucratic conservatism. Yet it also requires steady perseverence with proven methods to see the job through. In a small country like the Solomon Islands, going through such rapid political, social and economic changes, it is almost inevitable that young and inexperienced people will hold senior jobs for many years. Job security may be good for their personal well being but the North American system of accountability could well be better for the good of the job - and for the good of the people.

Another vital factor in the success or failure of all health programmes is the co-operation of the public. This is particularly so in mass drug administration (Paik & Avery 1974) and in spraying operations. Co-operation has been so good in most Solomon Islands villages in the past that we are apt to take this for granted. Recent refusals to spraying in Guadalcanal and Malaita confirm several earlier reports that these islands would be difficult (Chapter 2.1). Once the main dramatic impact has been seen people are not always prepared to go through with the continuous spraying and drug taking. The bed bugs and the rats become more important than the malaria. Action is therefore required to deal with public grievances and also to win people over again to acceptance of spraying and drug taking. A delicate public relations exercise may be required. Much depends on the behaviour and demeanour of the malaria field staff. New or different techniques may be required to obtain full public co-operation.

Regrettably perhaps, to some considerable extent success does depend on personalities. Under the ideal system this would not be so. But,to be realistic, success will depend on the willingness and determination of a small handful of politicians and health staff and on the acceptance by the public that the inconvenience is worthwhile.

8.8 The consequences of failure

If we were to say that thousands of people would die if malaria were to become highly endemic again we might be accused of sensationalism. Yet that is not an entirely remote possibility. If everything was left to slide then that is exactly what could happen. Of course it probably would not happen because, long before then, emergency measures would have been put into action to stem the tide. But sadly, that would probably already be too late. We would be right back to the old days again when more than 20% of all cases seen in hospitals were due to malaria. The medical staff would no longer have time to work on other health problems. They would be spending all of their time on malaria again.

Failing complete disaster, with a massive epidemic like the one in Ceylon in 1967-68, there could be a more gradual or insidious slide. The country need not even be as malarious as before, but there would still be much chronic sickness. Children would die and mothers and babies would become debilitated. The increase in malaria would increase recurrent costs in the expenditure on health services and school absenteeism would rise. Economic development would probably be seriously affected. People would probably become so demoralised by the failure that it would be many years before further attempts could be made to eradicate malaria. Still births and abortions would increase and babies would be smaller and weaker. Other diseases like filariasis and respiratory disease would be on the increase again.

Having gone so far, failure is really quite unacceptable. An expenditure of more than $A 4 million will have been wasted. Not entirely wasted perhaps because people will have enjoyed malaria free good health for a few years. But certainly wasted in terms of the results that could have been obtained. It therefore behoves those who do appreciate the consequences to constantly keep up the reminder to those who do not see them so clearly.

Once malaria has been eradicated the very highest standard of vigilance will have to be kept up by the Health Service and especially by the staff of the Rural Health Clinics. Since malaria still remains uncontrolled in most of Papua New Guinea and the New Hebrides a very close watch will have to be kept on all visitors from those countries. Cases of P. vivax or P. malariae malaria undetected in the past may relapse after many years of quiescence. The vector anophelines will return to their former levels in many areas so that receptivity will be very high on many islands. Vulnerability to reinfection will be particularly high in the Western Solomons where free migration is being encouraged to and from Bougainville. This area will require the closest surveillance by health staff. The slightest sign of an outbreak will require the most vigorous and speedy measures to put it down (Khalid & van Dijk 1975).

8.9 The development of the Health Services

Even if malaria is eradicated from the Solomon Islands during the late 1970's the maintenance of this eradication will depend finally on the strength of the basic health services. These services were concentrated on the main centres for many years. With a policy of building up the Rural Health Clinics starting in the early 1960's, the targets were not reached until 1974. The staffing with registered nurses still lags some way behind the building programme. There is therefore a very big danger that the health care coverage of the community will not be comprehensive enough to give the necessary strength to malaria surveillance.

Trends in recent years have repeatedly laid emphasis on the need in developing countries for the provision of simple, widely distributed health centres and aid posts rather than for high quality hospitals (e.g. King 1966, Bryant 1969, Morley 1973). This need and the recognition of the importance of a primary health care worker (auxiliary) who is neither a doctor nor a nurse has received further strong endorsement by the World Health Organisation (Newell 1975).

These needs, already recognised in the Solomon Islands from the time of the Pilot Project, were reinforced in the National Development Plan (Solomon Islands 1975). This included in the Health Sector an aim to control and then eradicate the main disease threats within the country. Amongst the principal methods to be employed were included:-

i) The involvement of communities in the health programme by devolving health services to local councils.

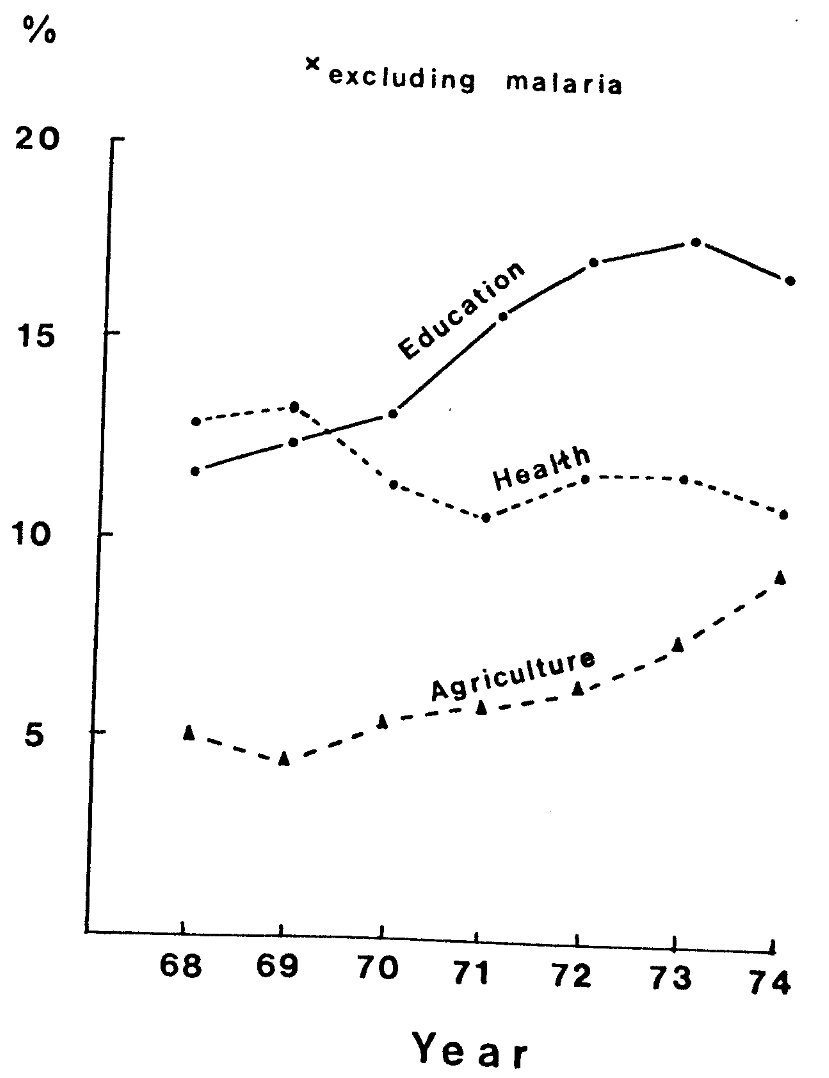
ii) a concentration of effort and expenditure on the delivery of health services to people, rather than on the development of centralised institutions.

iii) the basing of the health service on a network of health centres each supervising a group of clinics with each clinic being able to supervise the work of several aid posts.

Although it appears at the moment that the Solomon Islands is slowly building up a satisfactory health service there are dangers that this progress may not continue. The draft National Health Plan, a development in more detail of the National Plan, was prepared during 1975. In this plan special emphasis was placed on completing the build up and staffing of the Rural Health Clinics. Emphasis was also given to the need to build up the Village Health Aid Posts and to the training of Village Health Aids. This programme cannot be fully implemented until it is endorsed by the central government. Even if these plans are allowed to go ahead there are dangers that insufficient staff will be available to carry out training programmes.

There is also the question of political direction and leadership. There is good evidence that government is putting less emphasis on health and more on education and agriculture (Figure 62). The recurrent expenditure on health (excluding Malaria Eradication) may have increased slightly in actual money between 1968 and 1974. In real spending value however, when inflation is allowed for, this represents a decrease. The per capita expenditure at $US 5.2 per annum (1971) is generous compared with many developing countries but minute when compared with the developed World (Table 82). The percentage of the national budget spent on health is also generous especially when it is realised that the M.E.P. is funded as a capital project. Nevertheless this generosity should not be allowed to fall behind because of more vociferous claims from other sectors. The expenditure on Health has actually shown a decline compared with that on Education and Agriculture (Figure 62). This is not to argue that there should be any great changes in allocations nor that there should

Fig. 62. Percentage of recurrent expenditure spent on Agriculture, Education and Health[x]. Solomon Islands. 1968-74.



Sources. S.I. Annual & Medical Reports.

TABLE 82

Government annual expenditure on health services, selected countries

Country (year)	Per capita (recurrent) expenditure $ US	Health Expenditure as % of total Government (recurrent) expenditure
Solomon Islands (1971)	5.2	10.6
Fiji (1971)	7.0	7.4
Papua New Guinea (1971)	6.8	7.3
Australia (1971)	40.7	6.9
United Kingdom (1971)	99.7	9.4
U.S.A. (1972)	149.0	6.9
Indonesia (1971)	0.1	1.2
Zaire (1971)	0.45	1.8
Nigeria (1971)	0.3	1.3

Notes:

1. Precise comparisons are not possible as the differentration between recurrent and capital expenditure is not always stated.
2. Per capita expenditure corrected to $US at mid year rates for year stated, or as quoted in $US in original source.

Sources:

World Health Statistics Report Vol. 28 No. 1 Geneva, W.H.O. (1975).

W.H.O. Technical Report Series No. 537 Annex 2. Geneva. W.H.O. (1974).

be any massive increase in expenditure. It should be recognised however, that expenditure on health is every bit as important as expenditure on education and development of resources as an investment in economic development. (Myrdahl 1968, Bryant 1969) Health should not be considered in isolation from other elements in the development process. If specific direction is not given to health programmes then the health, and in turn the economy, of the country is likely to suffer.

An unpredictable factor is political stability. If this is present steady progress will probably be made. The remarkable improvements in the health of the people of China, Cuba and Tanzania (Newell 1975) are a convincing testimony to the value of a consistent regime for this type of work. Equally important is the need to get the priorities right for the development of the health services. Even in the developed world serious questions are now being asked about the undue emphasis on hospital and clinical medicine (Lalonde 1974, Illich 1975, DHSS 1976). The danger is perhaps even greater in the developing world where the results of treatment of the preventable diseases are often most dramatic. The constituents and the politicians are far more likely to ask for hospitals not only for prestige but also because the results of their work are easier to measure. So the responsibility for a balanced approach remains entirely with the health workers who are the only people with sufficient experience and knowledge to inform the decision makers. The battle is a constant one and it may be a good deal more difficult to convince ones own medical colleagues than it will be to convince politicians.

Much more training is required at all levels. At the senior level the requirement is for planning, organisation, management and budgeting skills. At the junior level the need is for the basic technical skill to do the specific job. If this training is neglected the consequences will again be a poor development of health services and an unhealthy, economically unproductive population.

8.10 Options for the future

In the final analysis there are three possibilities for the future in the control or eradication of malaria in the Solomon Islands. These are:-

(i) To write off the whole operation.

(ii) To continue an all out onslaught with the objective of eradication as soon as possible and preferably well before 1980. Once eradication is achieved to follow a strict programme of maintenance to ensure that malaria does not return.

(iii) To maintain eradication in those islands where it has been achieved. To continue a holding or control operation in the other islands.

The first option is clearly unacceptable politically, socially and even economically since so much effort has already been put in and the results have been good so far.

A decision between the second and third options is much more difficult. The second requires a high standard of operation, good backing up by the Rural Health Services and a guaranteed firm commitment by government with full political and administrative support. The expenditure will continue to be high for a small number of years and then slowly decrease to low levels. Once complete, malaria will no longer be a problem for the community. However, the chances of the reintroduction of malaria will be very high.

The third option means that malaria will always remain in the Solomon Islands until some other technical breakthrough is made. Nevertheless, the problem should not be of major proportions.

Continuous DDT spraying and drug treatment would be required in certain areas in order to control the disease. There would always be a risk of a serious epidemic breaking out. A modest level of recurrent expenditure would be required every year. It would be difficult to budget exactly how much money was required and epidemics would require costly emergency measures. It is possible that the economy of the country would be affected if malaria became endemic again.

At the end of 1976 then, with the excellent progress made so far, the only immediate option is to continue the full all out onslaught. If high standards are kept up and the necessary support is provided there are very good prospects for the eradication of malaria from the Solomon Islands. If during 1977-78 it becomes apparent that administrative, political and public support is lacking then the only realistic answer will be a continuous control programme. This would have to continue indefinitely until such time as the climate of opinion changed or until a new technical breakthrough was made. Such a programme would be in full accord with the recommendation of the Brazzaville Conference (W.H.O. 1974[a]) that malaria continue to be given the highest priority in the health plans of countries where the disease remains endemic.

SUMMARY and CONCLUSIONS

Malaria is the main disease scourge of the Solomon Islands. Throughout the historical record malaria has had a major influence on the lives of the people. It has been responsible for a high infant mortality and much of the continuous sickness and debility. It has also held back social and economic development. In spite of being almost at the end of its range of distribution, malaria is as severe in the Solomon Islands as anywhere else in the world. The proximity of villages to coastal swamps and riverine areas has made the continuous transmission of the disease particularly easy. The high mobility of the people both between and within the islands has allowed further easy spread.

In 1962 the (then British) Solomon Islands government and the World Health Organisation jointly launched a Malaria Eradication Pilot Project. This developed in 1965 into a Malaria Pre Eradication Programme and in 1970 into a full Malaria Eradication Programme. This was inevitably an expensive exercise due to the difficult communications and relative lack of social development. Some of the technical problems were also formidable but not insuperable.

At the start of operations the country was thoroughly mapped with even the smallest village being located on the 1:50 000 scale maps. Surveys were carried out to determine the status of malaria on each island. Most of the villages were regularly sprayed once every six months and a high degree of public co-operation was obtained in most areas. Soon after spraying started further surveys were carried out to measure the fall in malaria and the changes in the habits of the vector anophelines. A system of surveillance was also set up to seek out the last residues of malaria. Blood slides were collected by Active or Passive Case Detection from all fever cases and from any other people suspected of carrying malaria. The Active Case Detection was carried out by mobile malaria agents visiting every household in every village once every two weeks. Passive Case Detection was carried out by static health agents or volunteers working from their clinics or bases. Whenever a blood slide was taken a presumptive treatment of Chloroquine and Primaquine was administered. When a blood specimen was found to have malaria parasites in it the patient was located as quickly as possible. He was then given a radical cure for his particular species of malaria. As soon as a case was detected remedial measures were carried out in order to try and prevent the spread of infection. The patient was also followed up to ensure that he remained fully cured.

In nearly all of the islands it was found that the anopheline vectors rapidly disappeared once spraying started. If they did not disappear completely, as with A.farauti, their numbers fell to low levels. There was also a change in the biting habit of A.farauti from all night indoor and outdoor biting to predominantly outdoor biting in the early hours of the evening. This was often coincidental with the maximum outdoor social activity of man. The parasite rates measured in most of the serial surveys rapidly fell to low levels. With P.falciparum the regression patterns nearly always followed the theoretical models of Macdonald indicating that transmission of this parasite had been interrupted by the methods being used. With P.vivax the regression patterns failed to follow Macdonald's models. They did, however, follow the patterns previously described by Macgregor in the Pilot Project.

A provisional new model for the regression pattern of *P. vivax* in the South West Pacific has therefore been proposed.

In certain special cases the typical models of regression were not followed. The most notable example was on the island of Nggela where original surveys had shown holoendemic malaria. On this island a combined approach was required with a prolonged mass drug administration before malaria was cleared from the community. On the island of Malaita there were several areas where transmission was resumed after being originally interrupted. This was due to an increasing refusal rate which reached over 10% in some places during 1974-75. In several other islands small pockets of resumed transmission broke out from time to time. Most of these were cleared up after the use of intensive remedial measures.

Two special problems proved more difficult to solve. The intinerant Gilbertese were eventually cleared of their malaria after a 12 week radical treatment of the whole population. The highly malarious north Guadalcanal, after becoming nearly clear of the disease in 1972, was still not clear by the end of 1975. This area of high population mobility and rapid development is in an environment highly favourable to anopheline mosquitoes. In an effort to knock out the final residues of malaria a number of additional measures were taken during 1974-75. These included reduced intervals between spray rounds, mass drug administration and larviciding of breeding sites. An even further effort was made during the low transmission season in 1975 using ultra-low-volume spraying in the early evening in an effort to reduce anopheline densities. Many areas were cleared but some foci still remained at the end of the year.

Meanwhile the operation reached an advanced stage in most of the Western Solomons during 1974-75. An Annual Parasite Incidence of less than 2‰ was achieved in many of the islands. This resulted in the withdrawal of spraying and an entry into the consolidation phase of eradication. Progress was sufficiently well advanced in several other islands in the Central and Eastern Solomons to give good prospects for these to enter into consolidation during 1976-77. Given a final solution to the north Guadalcanal problem there were good prospects that all of the islands would be entirely free from malaria by the end of 1979.

It may be reasonably claimed that the full eradication programme made considerable inroads into the removal of malaria from the Solomon Islands during the years 1970-75. The overall health of the people improved remarkably. The removal of the burden of malaria was probably one of the prime factors in stimulating the dramatic changes in economic growth. Meanwhile, the rapid increase in population during the 1960s and 1970s was a matter for some concern. At present rates a doubling of the population in less than 20 years might be expected to cause serious social and economic problems in the future.

If the eradication of malaria is to be maintained it is essential for a number of conditions to be fulfilled. The final removal of that last residue of malaria requires the total commitment of government. It requires full support from politicians, government staff, health staff and the people. If a really intensive effort is not made the consequences are likely to be tragic and disastrous. Malaria may well return with a vengeance and spread like wildfire throughout the country causing much debility. In order to provide the necessary support to complete the job there needs to be a further strengthening of the network of rural health clinics. These must be properly built, fully staffed and regularly supported, supplied and maintained.

Given these modest requirements the Solomon Islands may expect to achieve the eradication of malaria from all of the islands by 1980. The sterling efforts of the health teams will not have been in vain and the people will be able to look forward to a healthy and happy life in their verdant south sea islands.

GLOSSARY

Active Case Detection (ACD). The collection of blood slides from fever cases for the detection of malaria. This is carried out by trained mobile agents who visit every village once a fortnight.

Anopheles farauti	(A.f.)	The three vectors of malaria in the Solomon Islands. All belong to the *Anopheles punctulatus* group.
koliensis	(A.k.)	
punctulatus	(A.p.)	

Annual Blood Examination Rate (ABER). The percentage of a given population examined in any year for malaria by the collection of blood slides from Active or Passive Case Detection.

Annual Parasite Incidence (API). The number of malaria cases, expressed per thousand (‰) population, detected in any one year in a given locality.

Beu. The traditional men's 'custom place' or 'tambu house' where all the ancestral relics and skulls are kept. Certain parts are forbidden to all except custom priests. The whole beu is strictly forbidden to women.

Bisi. The traditional hut at the edge of the village in which women must spend their periods of menstruation and childbirth. Strictly forbidden for men to enter.

Bride Price. The traditional fee paid by a man and his family for the purchase of a wife. The payment may be made either in conventional money ($A) or in shell money ('tafuliae').

Classification of Endemicity of Malaria.

Degree of Endemicity	Spleen (or Parasite) rate in 2-9 age group
Hypoendemic	Under 10%
Mesoendemic	10 - 50%
Hyperdendemic	50 - 75%
Holoendemic	Over 75%

Modified from the Kampala Classification (W.H.O. 1951) and from Metselaar and van Thiel (1959).

Malaria Eradication Pilot Project (M.E.P.P.) A short term project carried out in a limited but typical area of a country to investigate the feasibility of carrying out a full Eradication Programme.

Malaria Eradication Programme (M.E.P.) is a special campaign aimed at the ending of malaria transmission and the elimination of the reservoir of malaria infection. This campaign is limited in time, but carried out to such a degree of perfection that, when it comes to an end, there is no resumption of transmission.

Malaria Pre-Eradication Programme (M.P.E.P.) A programme aimed at the build up of the necessary staff, equipment and expertise prior to carrying out a full Malaria Eradication Programme. This will usually continue the work of the Pilot Project in a limited area but will also carry out more extensive surveys elsewhere. It will also aim to build up the infrastructure of Rural Health services to such a standard that they are capable of materially assisting the M.E.P. to achieve its aims.

Malaria Region A geographical area usually covering an administrative sub-district. There are usually 3-7 zones in each Region covering a total of 5-15000 people. Each of the 19 Regions in the M.E.P. is under the control of a Field Supervisor.

Malaria Zone A geographical area usually covering one or two council wards of 2500-5000 people. Some zones for remote islands are much smaller. The Solomon Islands M.E.P. includes a total of 116 zones.

Marching Rule A nativistic anti-government movement which gained its major support in Malaita between 1945 and 1949. 'Marching' is an anglicised corruption of the 'Are 'Are word 'Masina' meaning brotherhood.

Plasmodium falciparum	(P.f. or f.)	The three species of malaria found in the Solomon Islands
Plasmodium malariae	(P.m. or m.)	
Plasmodium vivax	(P.v. or v.)	

Note: Mixed infections containing two or more species are quoted as f.m., f.v., v.m. or f.v.m.

Slide Positivity Rate (SPR) The percentage of any group of blood slides, collected by Active and/or Passive Case Detection, found to contain malaria parasites.

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Note: All positions refer to Solomon Islands, unless otherwise stated.

ACKNOWLEDGEMENTS

It was only because of the skilled and dedicated devotion to duty by the staff of the Solomon Islands Ministry of Health that it was possible to carry out the work on which this thesis is based. Further, without the excellent co-operation of the people, none of this would have been possible. I therefore gratefully acknowledge the major contribution that was made to the work by the Solomon Islands people and by the health staff and other workers throughout the islands.

In the preparation of this thesis I am most grateful for the detailed help given to me by Mr. Jathaniel Lalaonafaka (Microscopy), Mr. Bartholomew Riolo (Epidemiology), Mr. Aloysius Foligeli (Entomology) and Mr. Samuel Hong (Geographical Reconnaissance). These and other staff of the Solomon Islands Malaria Eradication Programme were of valuable assistance in the collection, compilation and presentation of data.

In addition I am also grateful for assistance, advice and criticism from senior staff members Mr. Boaz Seijama, Principal Malaria Eradication officer and Dr. David Turner, Senior Field Operations Officer. I also wish to thank former staff members Mr. J. Davidson and Dr. B. Taylor and the past and present members of the World Health Organisation team in the Solomon Islands, Dr. M. Maffi, Dr. Y.H. Paik, Dr. H.H. Ch'en, Dr. I.F.M. Saint-Yves, Dr.R. Sloof, Mr. F.D.Gibson, Mr. O.K. Habash and Mr. L.W. Lawrance for their valuable assistance and advice over the years. I am particularly grateful to

Dr. J. D. Macgregor (formerly Director of Medical Services in the Solomon Islands) for his close interest over many years. It was his encouragement which finally prompted me to put this work on the record as a follow up of his earlier thesis.

For technical advice on certain aspects of this thesis I am grateful to Professors R.H. Black (Sydney), M.J.Colbourne (Hong Kong) and W.Peters (Liverpool) and to Dr. W.J.O.M. van Dijk, WHO Senior Malaria Adviser, Western Pacific Region (Manila). I am also very grateful for valuable criticism and advice from Professor J.Knowelden (Sheffield) and Mr. A.B.Cross, FRCSI. (Birmingham, formerly Surgeon Specialist, Solomon Islands). My sincere thanks also go to Mrs. Susan Cooper of the Statistics Department of the West Midlands Regional Health Authority for statistical advice and to Miss H.M. Barker, Medical & Scientific Co-ordination Dept. and Mr. T.J. Burgess, Educational Services Dept. of Schering Chemicals Ltd., Burgess Hill, Sussex for generous assistance in the reproduction of the figures. To the several people involved in the difficult task of typing, setting up and printing, my sincere thanks are but a token of my gratitude for their efforts.

Finally, I wish to thank His Excellency the Governor of the Solomon Islands and the Permanent Secretaries, Ministry of Education and Cultural Affairs and Ministry of Health and Welfare for permission to publish.

I sincerely trust that the copies of this thesis that will be presented to the Solomon Islands government will be of interest and value to the people of those happy islands.

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Malaria Eradication
in the

S.I.

W.H.O

Solomon Islands

This booklet has been prepared by the staff of the Malaria Eradication Programme to explain our work to all those who may be interested in it.

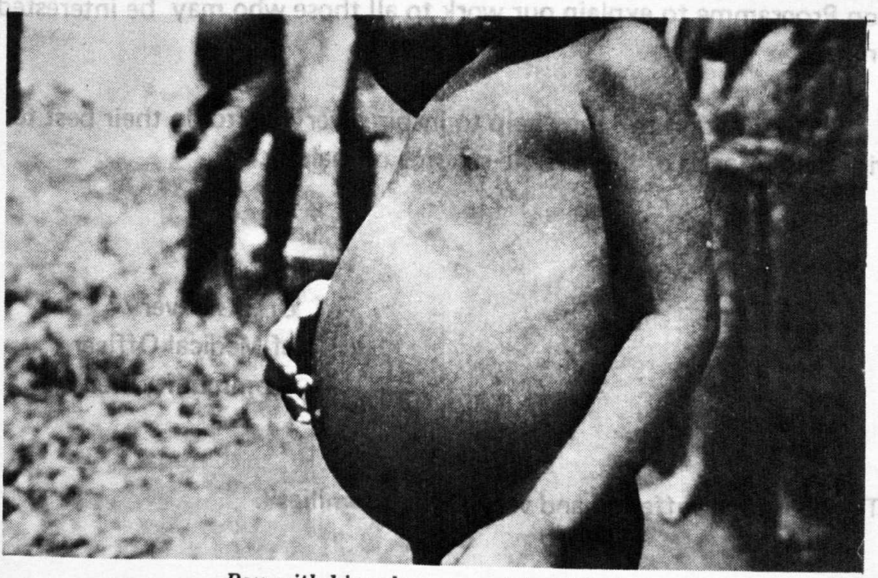
We trust that this may help to inspire everyone to do their best to rid these islands of the terrible scourge of malaria.

Dr J.G. Avery
Chief Medical Officer
(Community Health)

To "Our long suffering and very patient families".

INTRODUCTION

Malaria is the major community health problem in the Solomon Islands. In the past almost everyone caught malaria but the people most affected were the young children. The worst parts of the Solomons were Nggela, North Guadalcanal and Makira. In a few islands, like Bellona, Anuta and Tikopia, and in some artificial islands and the high bush, there was no malaria.



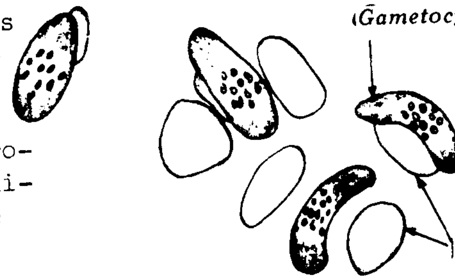
Boy with big spleen caused by Malaria

For some years now it has been possible to control and even eradicate malaria. This is done by using DDT spray against the Anopheles mosquito which carries malaria parasites and by treating positive cases with chloroquine and primaquine medicine.

In the Solomons few serious attempts were made to control malaria, apart from the efforts of the U.S. forces in 1942-45, until the early 1960s. Then the Government, with the help of WHO, launched a Malaria Eradication Pilot Project (MEPP) in 1962. By 1970 this had further expanded into a full Malaria Eradication Programme (MEP) which now covers the whole of the Solomons.

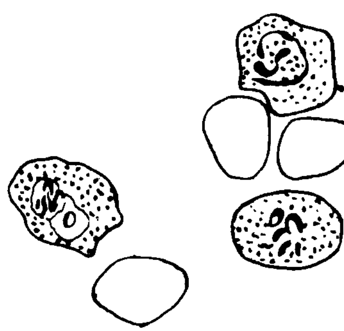
TRANSMISSION OF MALARIA

Malaria is usually transmitted, or passed on, from one person to another by the bite of an infected female *anopheles* mosquito. That mosquito must have bitten, about 10 days previously, a person carrying malaria gametocytes in his blood. The 10 days is the period required for these gametocytes to develop into sporozoites in the salivary gland of the mosquito.



Plasmodium falciparum gametocytes in red blood cell. (magnified)

Sporozoites, after being injected by the mosquito into the blood of man, quickly enter the liver to start the Primary Liver Phase. Here these parasites undergo a series of divisions and changes to emerge into the blood plasma some 10-30 days later (depending on the species) as merozoites. This is the time of the first fever. The merozoites rapidly enter red blood cells and emerge again 48-72 hours later (again depending on the species) only to re-enter further red blood cells. This explains the fever every 2nd or 3rd day. Eventually the blood phase dies out, but meanwhile gametocytes may have been formed. These are the only form which is capable of multiplying inside the mosquit to continue the life cycle.



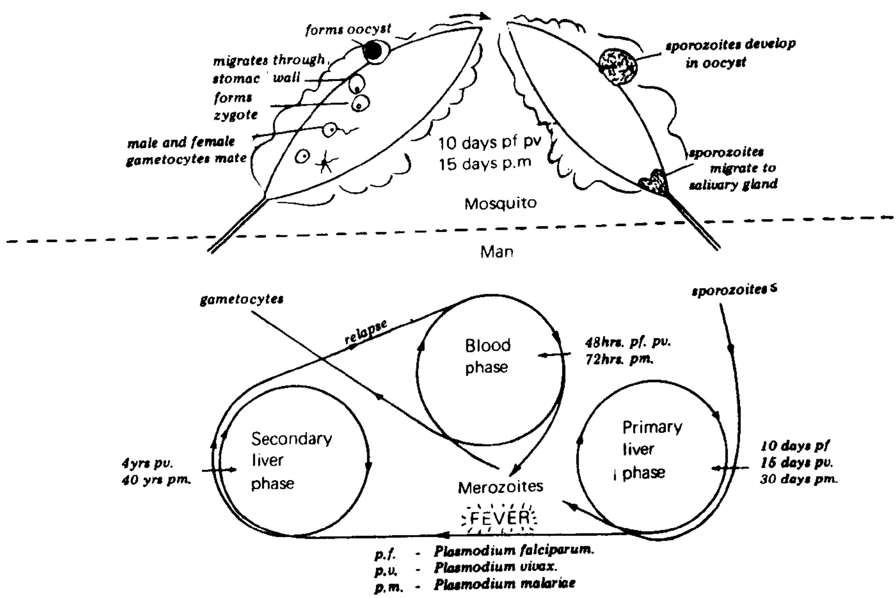
Plasmodium Vivax Parasite in red blood cell. (magnified)

The parasite of *Plasmodium vivax* and *Plasmodium malariae* is also capable of completing a Secondary Liver Phase. Parasites may remain quiescent for a long time only to break out weeks, months or years later as a Relapse and start up the whole life cycle all over again.

LIFE CYCLE OF MALARIA PARASITE IN MAN AND MOSQUITO

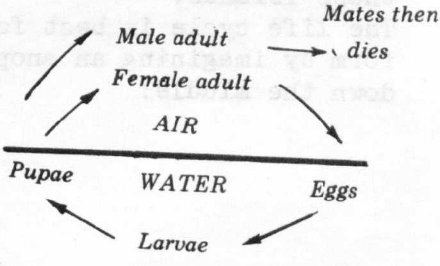
There are four human malaria parasites namely, *Plasmodium* (P. for short) *falciparum*, *P.vivax* *P.malariae* and *P.ovale*. The first two are common in the Solomons. *P.falciparum* is responsible for the serious and often killing form of malaria. *P.malariae* is rare whilst *P.ovale* is unknown in these islands.

The life cycle is best followed in diagramatic form by imagining an anopheles mosquito being split down the middle:



ERADICATION-SPRAYING OPERATION

The female anopheles, in order to mature her eggs and complete the life cycle must take a blood meal. The anopheles mosquitoes in the Solomons prefer to take their blood meals mostly from humans. After their belly has been filled with blood they are usually too heavy to fly away. They must rest in a dark place on the walls of a house or under the furniture.



Life cycle of Anopheles

If we now spray all the inside surfaces, under furniture and under the floors and eaves of houses with DDT the mosquito may take in a fatal dose of the poison the next time she rests on the wall. Even if she does not rest on the wall the smell of the DDT is usually enough to drive her outside where she will soon be killed by other insects or birds. Even if the anopheles has bitten an infected person as long as the mosquito dies before she has had time to develop sporozoites in her salivary gland (ie. within 10 days) then she cannot transmit malaria. Once the cycle of transmission is broken then we soon find the number of malaria cases begining to fall quite quickly. In order to achieve this spraying has to be of a very high standard and be carried out at least once every 6 months.

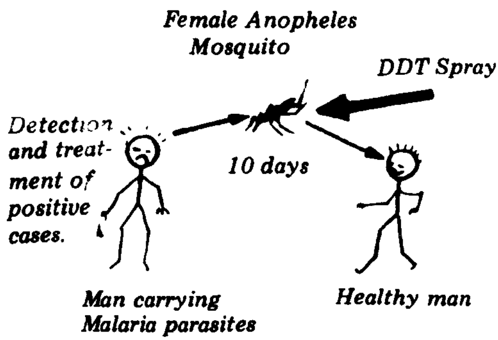
All inside surfaces and furniture are sprayed every 6 months.

ERADICATION - SURVEILLANCE

In addition to attacking the anopheles mosquito, we also try to reduce the chances of transmission by looking for malaria cases (Case Detection) and treating all the positives with anti-malarial drugs (Case Treatment).

The whole activity of looking for and treating malaria cases is called Surveillance. This also includes any case follow up and remedial measures we may need to take if transmission is still continuing.

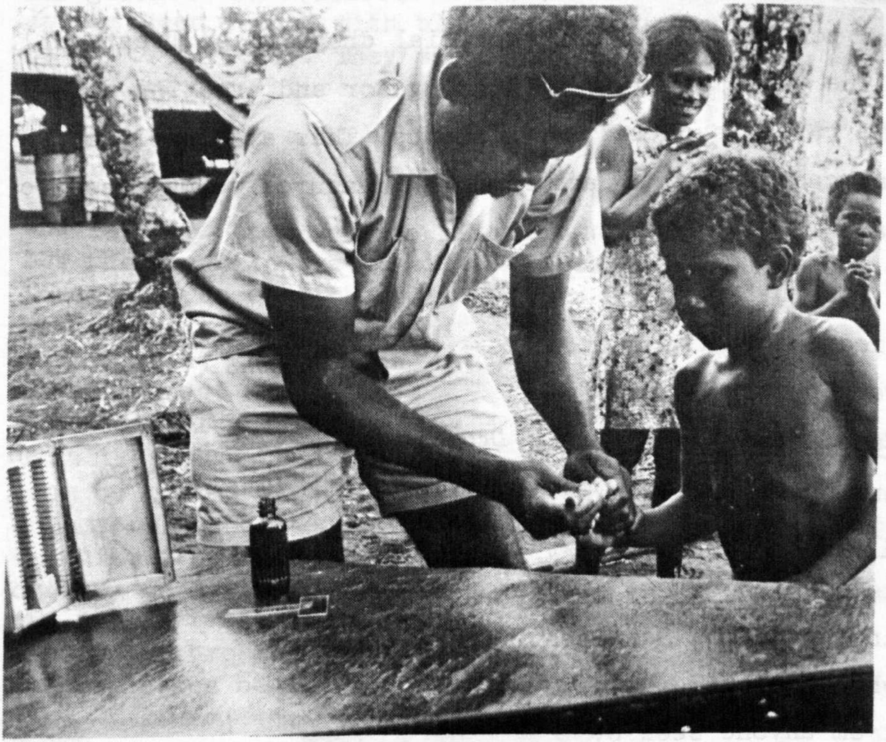
Case Detection is carried out in two main ways namely by Passive Case Detection (P.C.D.) and by Active Case Detection (A.C.D.). P.C.D. is carried out by staff in the Health Services, who take blood slides from anyone seen by them to be sick with fever. It is also sometimes carried out by volunteers like teachers.



The two main methods of Eradication

A.C.D. is carried out by touring malaria technicians who visit every house in every village once every fortnight. They take blood slides from anyone presently or recently sick with fever.

A.C.D. is aimed to find all the fever cases who cannot go to the hospitals and clinics, usually because they live too far away. Whenever a blood slide has been taken by PCD or ACD a single dose of Presumptive Treatment with Chloroquine and Primaquine is always given.

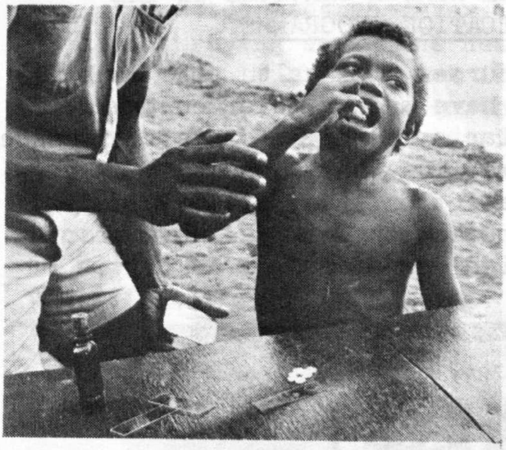


Active case detection

The blood slides are quickly despatched to the laboratory. Positives are given a full course of Radical Treatment with Chloroquine and Primaquine.

A long treatment is necessary (3 days for *P.falciparum*; weekly for 12 weeks for *P.vivax* and *P.malariae*) because some of the parasites would otherwise remain hidden for a long time in the liver.

If the treatments are faithfully taken all of the malaria parasites in the body will be killed and there will then be no more chance of getting another attack or of passing the malaria on to another person.



By taking the medicine given to him, the boy is helping to make a malaria free future for everyone.

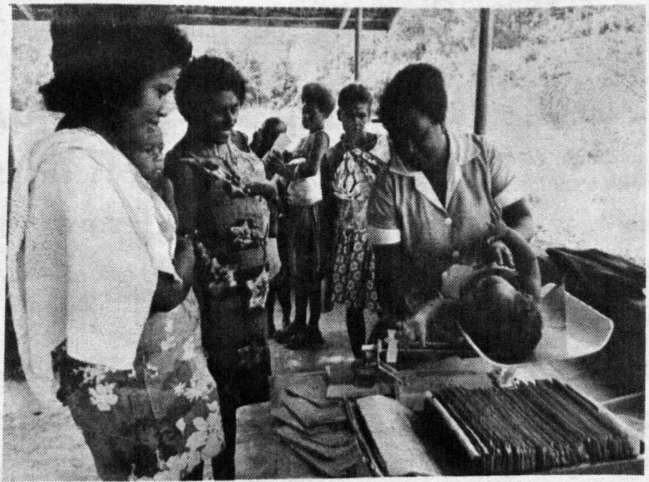
If there has been a positive malaria case in the village a special malaria team will usually spend several days there to carry out Remedial Measures. The purpose of this is to seal off the malaria outbreak and stop it spreading out any further. It is therefore important for everyone to act quickly once a malaria case has been found in a village.

There are several things to be done. One is to carry out a very careful Follow up spray of all houses in the village and its neighbours. Another is to take blood slides from all the house contacts of the cases and from any new fever cases. Sometimes this means taking blood slides from the whole village.

Finally a most important activity is to give chloroquine to all the people in the village (Mass Drug Administration). This is to prevent them getting an attack of malaria and passing it on to other people. Later on malaria staff will make regular checks on the village. It may be necessary to repeat the Remedial Measures several times before the outbreak is stopped completely.

THE PART PLAYED BY THE HEALTH SERVICES IN THE MALARIA ERADICATION PROGRAMME

The doctors, sisters, nurses and health aids working in hospitals and clinics have made a major contribution to the eradication of malaria in the Solomons ever since the start of the Programme. They have done this by carrying out Passive Case Detection. (See P.7). On many occasions the staff of the Health Services have also carried out the full radical treatment of positive malaria cases.



Nursing staff in Rural Health Clinic

Nurses, especially those working in the Rural Health clinics, have also helped the Malaria Eradication Programme by explaining the work to the people and by sorting out problems and queries. It has often been their presence which has persuaded people of the importance of house spraying or of taking medicines. Another important group of health workers making a major contribution to the success of the M.E.P. has been the Health Inspectors. By encouraging people to build good quality houses, to keep rivers and streams clean, to fill in swamps and keep the villages clean and tidy they have made it easier for spraymen to carry out their work. They have also tried to make it a little more difficult for anopheles mosquitoes to breed wherever they please.

When spraying stops the Health Services will play an even more important part in the Malaria Eradication Programme. Eventually, when the case detection agents also stop their village visiting (A.C.D.), the only defence against the re-entry of malaria into the islands will be the Health Services. It is vitally important that the network of hospitals and clinics be kept supported and fully staffed to ensure that the defences remain of a high standard.

PROSPECTS FOR THE FUTURE

If DDT spraying and malaria surveillance are kept up to a very high standard there is little doubt that malaria will eventually be eradicated from the Solomons. There are even good prospects that this may happen within the next few years.

The job is a difficult and expensive one. It certainly cannot be done by the Malaria Eradication Programme alone. It cannot even be done by the Ministry of Health and Welfare alone.

Happy malaria free family

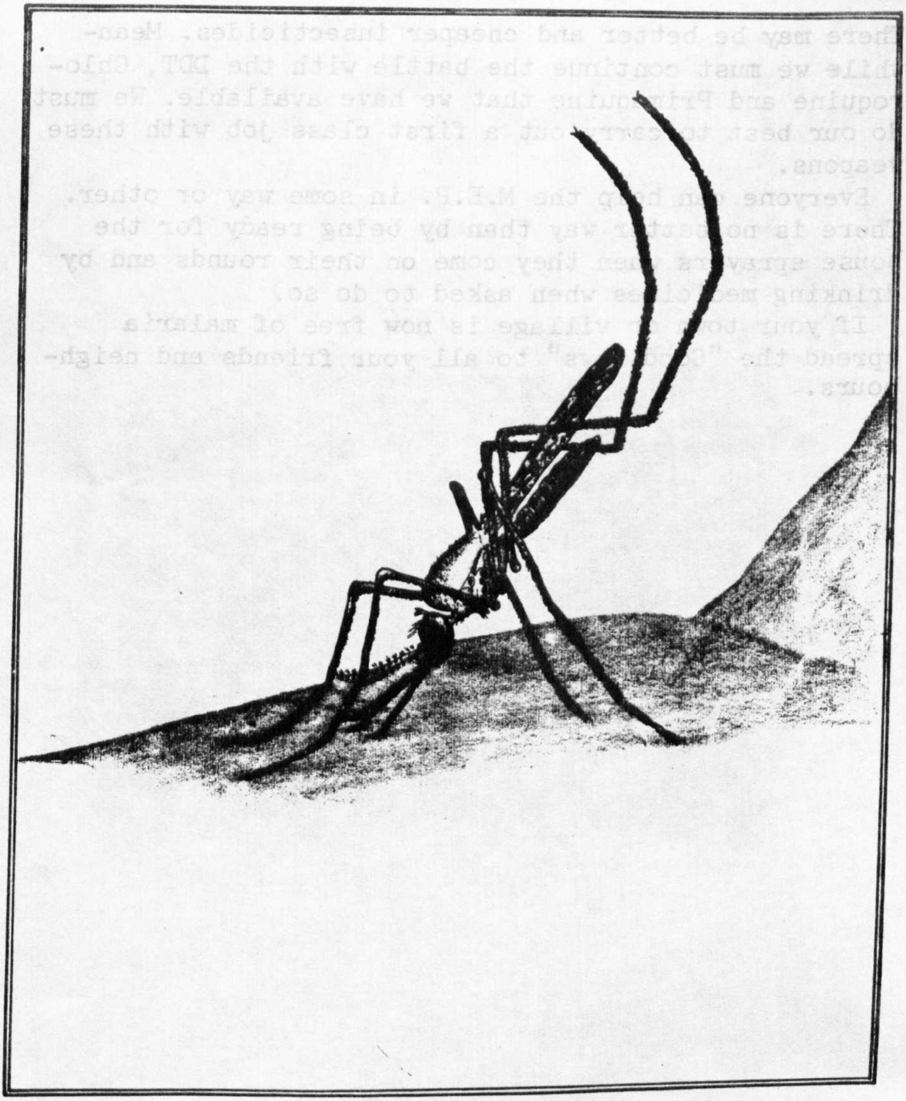
There are many people who have already helped and who, we are sure, will continue to do so. These include the Administration, Government Ministries, Councils, church leaders and community leaders. A most important person is the villager himself, without whose cooperation, eradication of malaria would not be possible. If all of these people continue to work together for the common goal of eradicating malaria from the Solomons then we may be sure that success wil be achieved.

In the long distant future a vaccine against malaria may become available. It may be possible that new, more effective and more long lasting drugs will be discovered.

There may be better and cheaper insecticides. Meanwhile we must continue the battle with the DDT, Chloroquine and Primaquine that we have available. We must do our best to carry out a first class job with these weapons.

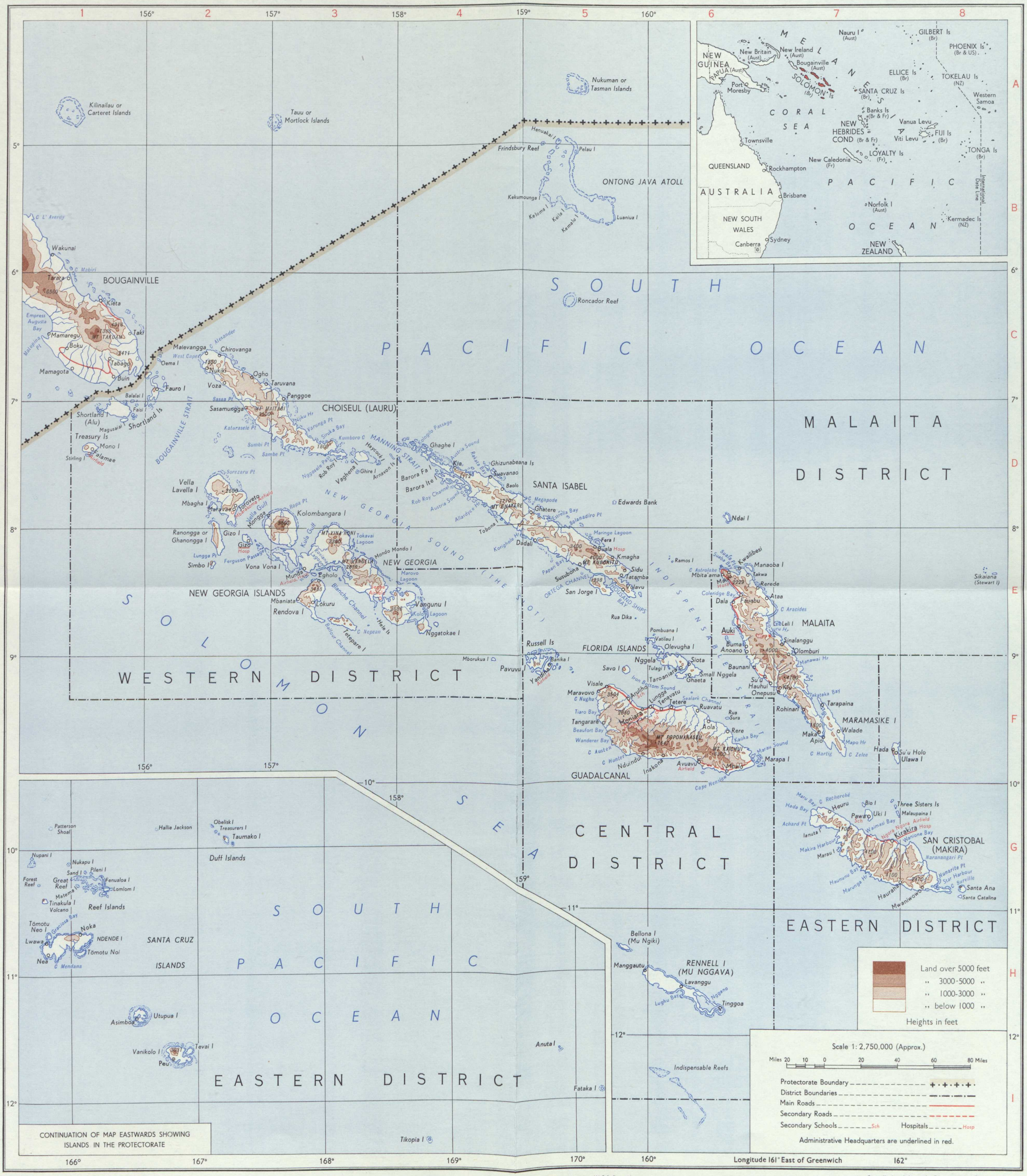
Everyone can help the M.E.P. in some way or other. There is no better way than by being ready for the house sprayers when they come on their rounds and by drinking medicines when asked to do so.

If your town or village is now free of malaria spread the "Good News" to all your friends and neighbours.



The cause of all the trouble - a female Anopheles mosquito biting man.
(magnified)

[redacted] SOLOMON ISLANDS



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Finisim Malaria bulong iu

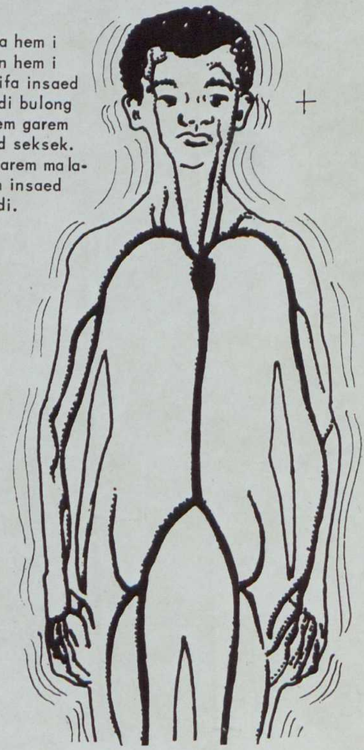
Hem i stil plande malaria kes long vilij bulong iu. Plande pipol olketa luk gud bat olketa garem malaria germ stap insaed long bodi bulong olketa.

Fo spreim olketa wol long haos hem i gud bat hem i no save kilim germ bulong malaria bikos meresin ia DDT olketa usim fo sprei hem i kilim nomoa moskito fo karem malaria bat no save kilim germ insaed long bodi bulong man.

Fo finisim go malaria germ, efri pipol nao mas takem "Drug", meresin fo drinkim. Efri pipol mas drinkim meresin ia wan taem long efri wik fo samfala manis.

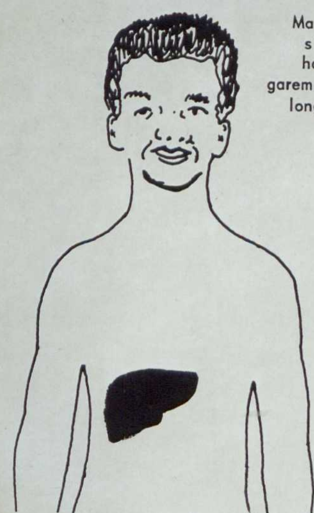
Spreim haos hem i namba wan for kilim olketa moskito long wol long haos.

Bat olketa germ wea kosim malaria save stap insaed long bodi bulong iu. Taem olketa stap insaed long blad bulong iu hem mekem iu fil sik an iu garem fifa an koul.

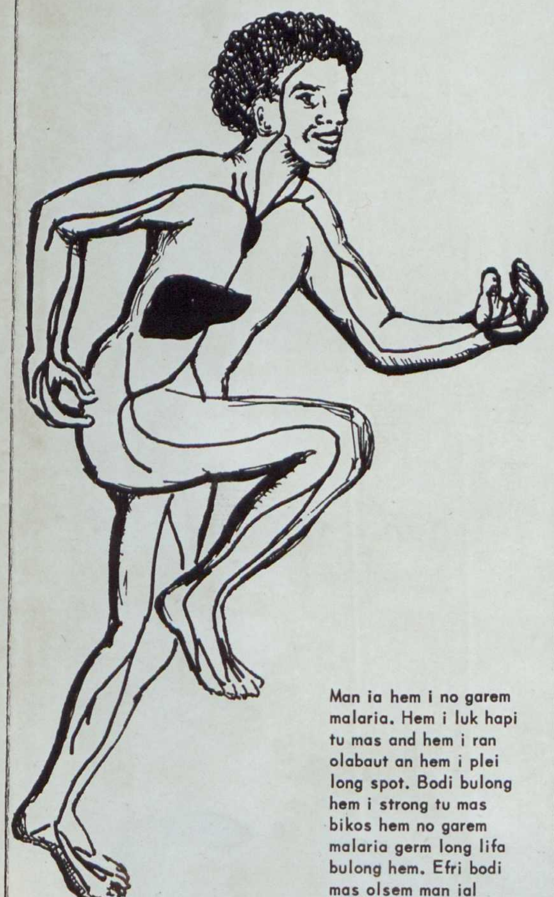


Piksa ia hem i som man hem i garem fifa insaed long bodi bulong hem. Hem garem koul and seksek. Hem i garem ma la-ria germ insaed long bodi.

Samtaem iu no fil sik sapos iu garem malaria germ insaed long bodi bat iu save spredem malaria go long samfala pipol moa. Fo kilim olketa malaria germ ia efri wan mas drinkim meresin fo malaria.



Man ia hem i no sik. Hem i luk hapi bat hem i garem germ insaed long lifa bulong hem.



Man ia hem i no garem malaria. Hem i luk hapi tu mas and hem i ran olabaut an hem i plei long spot. Bodi bulong hem i strong tu mas bikos hem no garem malaria germ long lifa bulong hem. Efri bodi mas olsem man ial

Plande pipol long hia garem malaria an samfala moa maet garem malaria germ insaed long bodi bulong olketa.

Hem nao mifala, pipol waka long malaria mas givim meresin ia fo kilim malaria germ insaed long bodi.

Samfala pipol waka long malaria babae kam long vilij bulong iu fala wan taem long efri wik fo_____manis. Babae olketa givim meresin ia long efri wan long vilij bulong iu. Plis iu mas kam long hia efri wik for tekem meresin ia.

Plis helpem mifala fo finisim go malaria from vilij bulong iu an olso from aelan bulong iumi.

MALARIA TIM BABAE VISITIM
IU EFRI____________________
LONG____________________

Plis iu mas kam long taem ia.

Malaria Transmission and Fetal Growth

J. D. MACGREGOR, J. G. AVERY

British Medical Journal, 1974, 3, 433-436

Summary

In view of the known relation between infection of the maternal circulation of the placenta with Plasmodium falciparum and impaired fetal growth a study was made of the effect on birth weights of a malaria eradication campaign in the British Solomon Islands. Mean birth weights rose substantially within months of starting antimalarial operations. The increases between 1969 and 1971 averaged 252 g in babies of primigravidae and 165 g in all babies. The proportion of babies with birth weights of less than 2,500 g fell by 8% overall and by 20% among babies of primigravidae. The adverse effect of malaria transmission on fetal growth was apparently reversible if transmission of infection in the community was interrupted up to as late as the third trimester of pregnancy. The beneficial effects of malaria eradication operations on infant survival, child development, and social attitudes in developing countries are discussed.

Introduction

Child mortality in the British Solomon Islands in the past, in the absence of any form of malaria control, was high. Wrightson (1951) reported that 50 of the 111 children born in the island of Savo during the period 1948 to 1950 died at birth or in very early childhood and that the average number of living children per family was only 2·15 despite a fertility rate of the order of 175 per 1,000 women of child-bearing age yearly. Malaria must have contributed substantially to this mortality because before the start of antimalarial operations in 1962 the prevalence of malarial infection in the Savo Island population as a whole was 39·1%—*Plasmodium falciparum* infections constituting 47% of the total—and of the infants no fewer than 3% had simultaneous triple infections with *P. falciparum*, *P. vivax*, and *P. malariae* (Macgregor, 1966).

A pilot project in 1962-4 had shown that it was technically feasible to eradicate malaria from the British Solomon Islands. It seemed to us therefore that a most important field for study in relation to eradication operations would be their effect on infant and child survival and, as an aspect of that, on birth weights. This was not only because of the known predilection of *P. falciparum* for placental tissue (Clark, 1915; Blacklock and Gordon, 1925; Garnham, 1938) but also because of the associated low birth weight, first recognized by Bruce-Chwatt (1952), and the general prevalence of low birth weights among babies in malarious countries (Lawson and Stewart, 1967). An intensive malaria eradication campaign extended in 1970 to the island of Malaita enabled us to observe whether a reduction in malaria transmission led to an increase in birth weights, and this paper reports our findings.

Methods

BIRTH WEIGHTS

In 1965 there was no centrally organized system of birth-notification in the British Solomon Islands and records of birth weights were very incomplete. A procedure was therefore established whereby all births under medical or nursing care were notified to the central health authority. Baby scales, mostly provided by Unicef, were issued and staff were trained to use them and to complete the birth notification forms. Much help was freely given by Professor W. Brass in redesigning the project and in improving the notification procedures with a view to computer analysis.

Not until 1968, however, was the standard of notifications—from some 80 hospitals and clinics throughout the country—deemed good enough for computer analysis of birth weights. This showed a highly significant difference, averaging 147 g, between the birth weights of babies born on the island of Malaita, where malaria was both endemic and uncontrolled, and those born on islands which had been subjected to antimalarial spraying for several years. The difference was most notable in babies born to primigravidae. In 1969 the presentation of data was slightly modified to show also the number and proportion

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of babies with birth weights under 2,500 g. While in other respects very similar to the findings in 1968, the 1969 data showed that there was a significant excess ($P < 0{\cdot}001$) of low birth weights among babies born on Malaita Island. Moreover, no fewer than two out of every five babies born to primigravidae weighed less than 2,500 g compared with one out of every five in malaria-controlled areas.

Since there are many ethnic differences among the Melanesian inhabitants of the Solomon Islands archipelago that could conceivably have affected the findings, it was clearly essential to continue the investigation and to observe the effect on birth weights of interrupting malaria transmission on Malaita Island. Fortunately, the first round of insecticidal measures was not scheduled to begin there until the second half of 1970. With a population of 50,659 Malaita Island is the most densely populated of the major islands within the British Solomon Islands Protectorate (total population, 1970 census, 160,998). Moreover, the people of Malaita, despite 14 distinct linguistic groups, are ethnically homogeneous.

PARASITOLOGY

The prespraying malariometric survey of Malaita, though not strictly on a random basis, covered enough villages in coastal, lagoon, and hill areas for the island reliably to be classified as mesoendemic. Overall, the survey showed in the 2-9 year age group a *P. falciparum* species rate of 7·3% and a parasite formula of *P. falciparum* 23·3%, *P. vivax* 71·3%, *P. malariae* 5·4%. Though *P. vivax* predominated *P. falciparum* made a substantial contribution to the parasite load.

Spleen rates were not routinely measured but the rates in the 2-9 year age group in a sample of several coastal village populations were in the range of 60-80%. Had these surveys been carried out more extensively the island as a whole would probably have been classifiable as hyperendemic. In general we can say that high spleen and parasite rates were common in villages at low altitude and on the coast while lower rates prevailed in villages at higher altitude and also in those on artificial islands in the offshore lagoons.

The parasite rates in pregnant women were not recorded in the survey, but it may reasonably be assumed that many if not already malarious must have been exposed to infection during the course of their pregnancies. The fact that placental infections can occur from the fourth month of gestation onwards (Garnham, 1938) is noteworthy.

ENTOMOLOGY

The principal vector of malaria in Malaita Island, as in the Solomons generally, was found to be *Anopheles farauti*, subsidiary vectors being *A. punctulatus* and *A. koliensis*. Before residual insecticidal spraying these vectors were found in abundance at many sites, but after spraying *A. punctulatus* and *A. koliensis* disappeared completely and *A. farauti* became scarce.

ANTIMALARIAL OPERATIONS

The principal antimalarial measure employed in Malaita, as elsewhere in the Solomon Islands group, was residual spraying of DDT at a rate of 2·0 g/m^2 to the interior sprayable surfaces of all dwellings, public buildings, and farm huts in order to kill or disable as many as possible of the adult female anopheline mosquitoes responsible for transmitting malaria. Using 75% technical grade DDT water-dispersible powder residual spraying began on Malaita Island during July 1970 and made satisfactory progress. The first cycle was completed in December 1970. The second spraying cycle began during January 1971 and the third, again on schedule, in July 1971. The overall coverage obtained was an estimated 97% of all sprayable structures.

During 1972 substantial disruption of spraying schedules resulted from delayed delivery of DDT supplies from overseas, and though not greatly reflected in the parasitological picture up to September some evidence of renewed though low-grade transmission of malaria did accumulate in the latter part of 1972.

Results

MALARIOMETRIC

Malariometric parasite surveys of the 2-9 year age group carried out every six months after the start of spraying in villages selected randomly throughout the island clearly showed a steady and rapid initial fall in the *P. falciparum* parasite rate together with an initial rise and subsequent slower fall in the *P. vivax* rate (table I). The fall in the *P. falciparum* rate satisfied the first standard for the interruption of malaria transmission as defined by the World Health Organization Expert Committee on Malaria (World Health Organization, 1966). While not quite coming within the expected slope for zero reproduction (fig. 1) it nevertheless met the minimum acceptable rate of fall, corresponding to a reproduction rate of 0·2 (Macdonald and Göckel, 1964).

The initial rise in the *P. vivax* rate was probably associated with the apparent suppressive effect of *P. falciparum* infections on *P. vivax* parasitaemia, as described by Shute and Maryon (1954), while the subsequent very slow fall in the *P. vivax* rate was typical of happenings in the Solomon Islands. This was probably a characteristic of the fast-relapsing Chesson strain of *P. vivax*, which can persist in the body for up to four years or more (Hill and Amatuzio, 1949). Though Macdonald and Göckel (1964) postulated that the declination rate representing zero reproduction of *P. falciparum* was generally valid whichever parasite might predominate Macgregor (1966) showed that the Solomon Islands strain of *P. vivax* does not conform to expectations in this respect.

Again, out of 1,452 children in the age group 0-23 months examined during the period March to September 1971 only 10 were found to have *P. falciparum* infections. Unfortunately it is not recorded whether the older infants in this group

TABLE I—*Results of Surveys of Parasite Rates in 2-9 Year Age Group Before and After Start of Cyclical Spraying Operations*

Date of Survey	No. of Months after First C.S.O.*	No. Examined	Total Parasites†		*P. falciparum*			*P. vivax*		
			No. Positive	Rate (%)	No. Positive	Rate (%)	% of Prespray Rate	No. Positive	Rate (%)	% of Prespray Rate
Before spraying: 1969-70		2,174	646	29·7	159	7·3	100	485	22·3	100
After spraying: April 1971	6	970	325	33·5	40	4·1	56·4	272	28·0	125·6
September 1971 ..	12	920	242	26·3	12	1·30	17·8	212	23·0	103·1
April 1972	18	1,178	217	18·4	10	0·85	11·6	183	15·5	69·5
September 1972 ..	24	1,278	163	12·8	5	0·39	5·3	153	12·0	53·8

*C.S.O. = Cyclical spraying operations.
†"Total Parasites" includes *P. malariae* infections, which are not shown separately.

could have contracted the infection before spraying operations began. Nevertheless, since four of these 10 infections were discovered only during the last quarter of 1971 transmission of the disease must almost certainly have continued in some areas until then, albeit at a very low level.

As in many other malaria eradication programmes (World Health Organization, 1971) the third W.H.O. standard concerning the ratio of heavy to light infections regrettably could not be applied as evidence of the interruption of malaria transmission owing to a shortage of the special laboratory skills needed for this assessment. On the whole, however, we considered that our findings indicated that there was a very substantial if not entirely complete interruption of malaria transmission in Malaita Island during the latter part of 1970, 1971, and the first two-thirds of 1972.

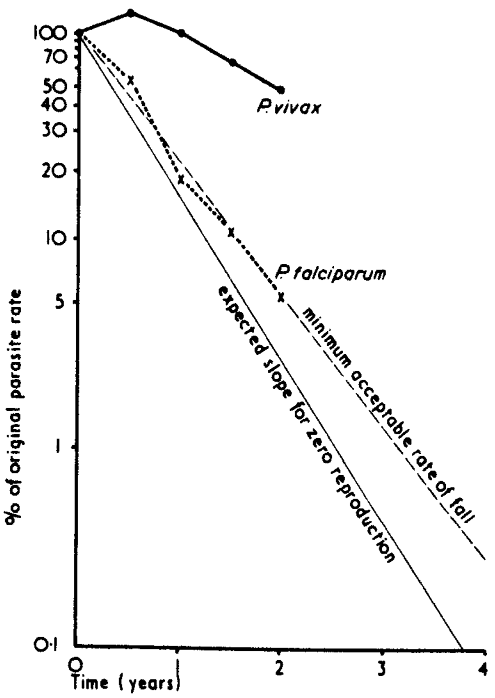

FIG. 1—Fall in Malaria parasite rates in 2-9 age group in Malaita Island during period mid-1970 to September 1972.

BIRTH WEIGHTS AND PREMATURITY RATES

The returns under the voluntary birth notification scheme steadily increased from year to year. In 1971 an estimated 69% of all births were notified, with Malaita Island ahead of this average by an additional 4%.

Birth weights in Malaita increased dramatically between 1969 and 1971, the increases averaging 252 g in babies of primigravidae and 165 g in all babies (tables II and III). The number of low birth weights (< 2,500 g) fell to levels virtually identical with those in the malaria-controlled area. These findings prompted a re-examination of the 1970 data to see how closely they could be linked to the initial application of insecticide.

TABLE II—*Birth Weights of Babies of Primigravidae born in Malaita Island 1969-72*

	1969	1970	1971	1972
No. of babies	191	232	263	337
Mean birth weight in g (±S.D.)	2,577 ± 626·9	2,671 ± 516·9	2,830 ± 473·9	2,829 ± 460·7
No. (%) <2,500 g	79 (41)	72 (31)	56 (21)	65 (19)

TABLE III—*Birth Weights of all Babies born in Malaita Island 1969-72*

	1969	1970	1971	1972
No. of babies	970	1,073	1,162	1,469
Mean birth weight in g (±S.D.)	2,869 ± 530·2	2,909 ± 530·4	3,034 ± 488·4	2,994 ± 500·9
No. (%) <2,500 g	199 (21)	212 (20)	137 (12)	209 (14)

The low birth weight rate for the third quarter of 1970 proved to be 16% (50 out of 308) and for the last quarter 14% (34 out of 246), while the average weight of the 246 babies born in the last quarter of the year was 104 g heavier than the 1969 mean birth weight for all babies. Caution is of course necessary in interpreting these figures, because of the fairly small numbers. Nevertheless, the latter figure represents some 63% of the overall gain in Malaita birth weights from 1969 to 1971 and can be correlated with the percentage spraying coverage of the Malaita population attained at mid-October 1970. The lag period between the interruption of malaria transmission and release of fetal growth potential may therefore be not much more than about a month.

The decline in the Malaita Island low birth weight rates year by year over the period is also compared graphically in fig. 2 with the corresponding rates in the malaria-controlled areas other than Malaita. We think the slight deterioration in 1972 reflected the disruption of the supply of insecticide and the consequent less-than-adequate interruption of malaria transmission.

We considered whether these findings might have been affected by a large increase in specific medication. We think this may be discounted. The consumption of antimalarial drugs in Malaita hospitals and clinics did not increase during the period—in fact, it decreased from 1971 onwards. The issue of such drugs prophylactically to pregnant women was not encouraged as an act of policy and no retail drug outlets or private medical practitioners existed on Malaita Island at the material time.

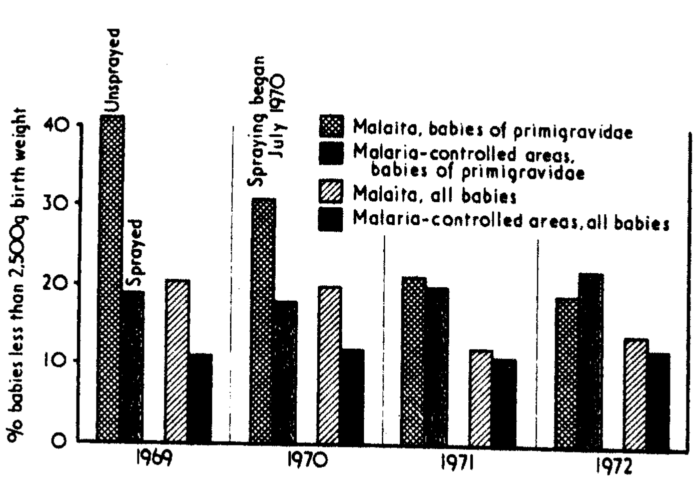

FIG. 2—Incidence of low birth weight among babies in British Solomon Islands related to malaria eradication operations.

Discussion

Jelliffe (1967) deplored the fact that despite some 15 studies since Clark's (1915) the possible relation of placental malaria to the enormous problem of infant wastage in many developing countries had been little recognized. The position has not materially changed. Authoritative documents barely mention malaria as a threat to normal fetal development. Though the global eradication campaign launched by the Eighth and Ninth World Health Assemblies has achieved the most astonishing success, with over 1,000m people living in areas freed from endemic malaria (World Health Organization, 1971), malaria transmission is still unchecked in many countries, most notably in tropical Asia and Africa. It therefore seems timely to reconsider the part which malaria may play in affecting fetal development, to say nothing of perinatal morbidity or infant and child mortality.

Garnham (1938), describing the reticuloendothelial reaction in the placenta in different forms of malaria, pointed out that in certain phases of malaria the intervillous spaces contained an almost solid mass of reticuloendothelial cells, and he found it difficult to understand how the fetus was nourished. He thought that many of the abortions in malaria probably resulted from fetal death through physical interference with the placental circulation rather than to the direct effect of malaria toxins. Blacklock and Gordon (1925) also postulated that malarial infection of the mother predisposed to accidents during pregnancy or at birth, and Clark (1915) reported no fewer than 44 accidents (abortions, stillbirths, premature labours) in 400 maternity cases. In seven of the 44 the placenta was infected with *P. falciparum* whereas the placenta was so infected in only 12 of the 356 normal deliveries. Subsequent workers (Bruce-Chwatt, 1952; Archibald, 1956; Cannon, 1958; Spitz, 1959; McLaren and Ward, 1962; Jelliffe, 1967) concentrated their attention particularly on the difference between live birth weights associated with infected placentae and those associated with uninfected placentae. All except McLaren and Ward found significantly smaller mean birth weights in babies when the placenta was infected compared with birth weights when the placenta was uninfected. In McLaren and Ward's cases the difference was only marginally significant.

Unfortunately there is no correlation between the presence of malaria parasites in the peripheral blood and placental infection. Hence it is impossible to identify women in an endemic area who have had a *P. falciparum* placental infection. Even if it were it would hardly be possible to categorize such women as infected or uninfected for placental infections are known to occur virtually at any time after the embryonic placenta has become a functioning organ. Some of the women investigated in the studies quoted are also likely to have recovered naturally from a placental infection just before being categorized as uninfected. There must, therefore, have been at least some overlap between the categories "infected" and "uninfected" in the hyperendemic situations prevailing, and if so the fact that significant birth weight differences were recorded suggests that fetal recovery from the effects of placental infections must have been relatively swift. Moreover, the wide variation in the mean birth weight differences reported by the above authors and the lack of apparent correlation with overall placental malaria positivity rates may be a function of the degree to which the "uninfected" samples were in fact "infected" before the diagnostic examination at term.

We hope that the present study, by comparing birth weights in an endemic area before and after interrupting malaria transmission, provides a clearer picture of the quantitative effects of placental malaria. It shows a remarkably stable birth weight pattern in both the malaria-controlled areas and in the endemic area (Malaita Island) after malaria transmission was interrupted. It also shows a rapid rise in all birth weights, and especially in babies of primigravidae, after the initial application of insecticide in Malaita Island, together with an extraordinary decline in the proportion of low birth weight babies—again most noticeable in those of primigravidae. The special susceptibility of primigravidae to malarial infection has been commented on by Bruce-Chwatt (1952). More recently McGregor *et al.* (1970) have also discussed pregnancy in relation to malaria immunology.

Bearing in mind the special place the first baby—and in many cultures particularly the first-born son—has taken throughout the ages in folklore, religious testimony, and the law of inheritance no other measure is likely to have such profound implications for social attitudes in the family health field than one which seems selectively to enhance the chances of survival of the first-born child. This aspect apart, however, the interruption of malaria transmission, particularly the transmission of *P. falciparum*, must have materially contributed to the chances both of survival and of healthy development of some 8% of the live-born Malaita children who formerly were in the low birth weight category. Moreover, the implications do not relate only to the quantitative aspects of survival, since there is now ample evidence (Fitzhardinge and Steven, 1972) that children whose fetal growth was impaired tend to be intellectually below average and to have learning difficulties. Thus, quite apart from the devastating infant mortality of up to 500 per 1,000 which malaria can cause in unprotected rural communities, countries labouring under the burden of this disease clearly may be at a substantial disadvantage educationally.

We thank the many nurses in the British Solomon Islands whose unstinted co-operation in completing many thousands of elaborate birth-notification forms made this study possible, and the staff of the Malaria Eradication Programme for their highly effective field operations. We also thank the Overseas Development Administration, Foreign and Commonwealth Office, London, for financial support towards the cost of data processing; the Chief Secretary, Western Pacific High Commission, Honiara, for permission to publish; Dr. F. B. Eyres, Honiara, for his comments on the 1970 data; and, by no means least, Professor W. Brass, Department of Medical Demography, London School of Hygiene and Tropical Medicine, both for his encouragement and for his scrutiny of the statistical aspects of this paper.

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Printed in Great Britain by Bourne Offset (Iver) Ltd., Iver, Bucks.

[*Extract from Papua New Guinea Medical Journal*, Vol. 17, No. 1, December, 1973—March, 1974.]

A Review of the Malaria Eradication Programme in the British Solomon Islands 1970-1972

J. G. AVERY

This review is of the first 3 years of the Malaria Eradication Programme in the Solomon Islands. It discusses particularly the operational methodology, progress made and special problems encountered. Certain failures in the programme are outlined, the lessons from which may possibly be of benefit to countries undertaking similar exercises.

INTRODUCTION

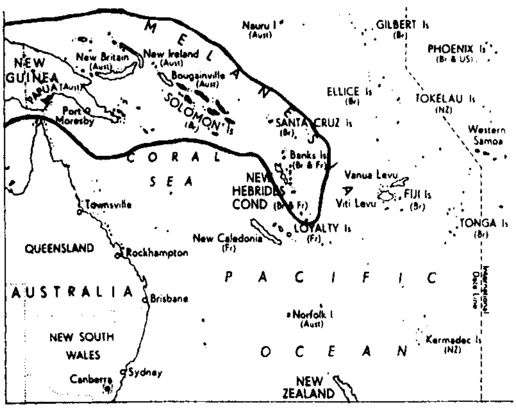
MALARIA is the major community health problem in the Solomon Islands. In addition to causing much morbidity and mortality it has probably seriously inhibited economic growth.

The first long term efforts to control the disease were not made until 1961. In that year a joint BSIP Government/WHO Malaria Eradication Pilot Project (MEPP) was launched. This evolved into a Malaria Pre-eradication Programme (PEP) in 1965 and into a full Malaria Eradication Programme (MEP) starting in 1970.

This paper reviews progress in the first three years of the MEP, discussing reasons for failures in some areas and measures undertaken to remedy these.

GEOGRAPHICAL BACKGROUND

The British Solomon Islands are a British Protectorate situated to the east of Papua New Guinea. Most of the islands are rugged and mountainous (maximum altitude 2,300 metres) often with treacherous off-shore reefs. There are several volcanic islands, some still active, and a few coral atolls. There is one extensive area of plains, the Guadalcanal Plain to the east of the capital Honiara. Earthquakes are frequent on some islands.



Map 1.—The malarious area of the South West Pacific

The islands lie in the equatorial oceanic and tropical oceanic climatic zones. Temperatures average around 27 degree Celsius (80 degrees Fahrenheit) with little diurnal variation except in the vicinity of high mountains. There are two distinct wind patterns. The N.W. monsoon blows from November until April whilst the S.E. trade wind blows from May to October. There are occasional cyclones in the N.W. season. Rainfall is seasonally uniform in most of the islands with averages of between 200 to 500 cm per annum. Seasonal high rainfall is experienced in the high rainfall area of the weather coasts of Makira and Guadalcanal in the S.E. season. Seasonal low is experienced during the same season in the rain shadow area on the north coast of Guadalcanal. Humidity is high.

Of the total population of 160,998 (census of 1970) 93.1 per cent are Melanesian. The remainder are Polynesian—3.9 per cent living on the outer islands; Micronesian (Gilbertese)—

Plate I.—Solomon Island village

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1.4 per cent living in scattered new settlements mainly in Western District; European, Chinese and other races 1.6 per cent—living mainly in the towns. The annual growth rate is estimated to be 3 per cent. The capital, Honiara with a population of 11,191 (census of 1970) is the only real urban settlement.

THE PAST MALARIA SITUATION

For many years most of the evidence for the existence of malaria in the Solomons was based on clinical diagnosis. Malaria was said to be rampant on most islands (Macgregor 1966). Prior to the commencement of eradication operations extensive prevalence surveys were carried out.

These showed that most islands experienced mesoendemicity, i.e., with spleen rates of 11 to 50 per cent in the 2 to 9 age group. In some of the outer islands and in N. Guadalcanal, N. San Cristobal and Nggella hyperendemicity (2 to 9 age spleen rate—51 to 75 per cent) was found. Other outer islands, notably, Bellona, Tikopia, Anuta, Santa Ana and Santa Catalina experienced only hypoendemicity (2 to 9 age spleen rate 0 to 10 per cent) and the vector was not found. Rennell and most of the Reef Islands also experienced hypoendemicity and the vector was found there only in very low densities.

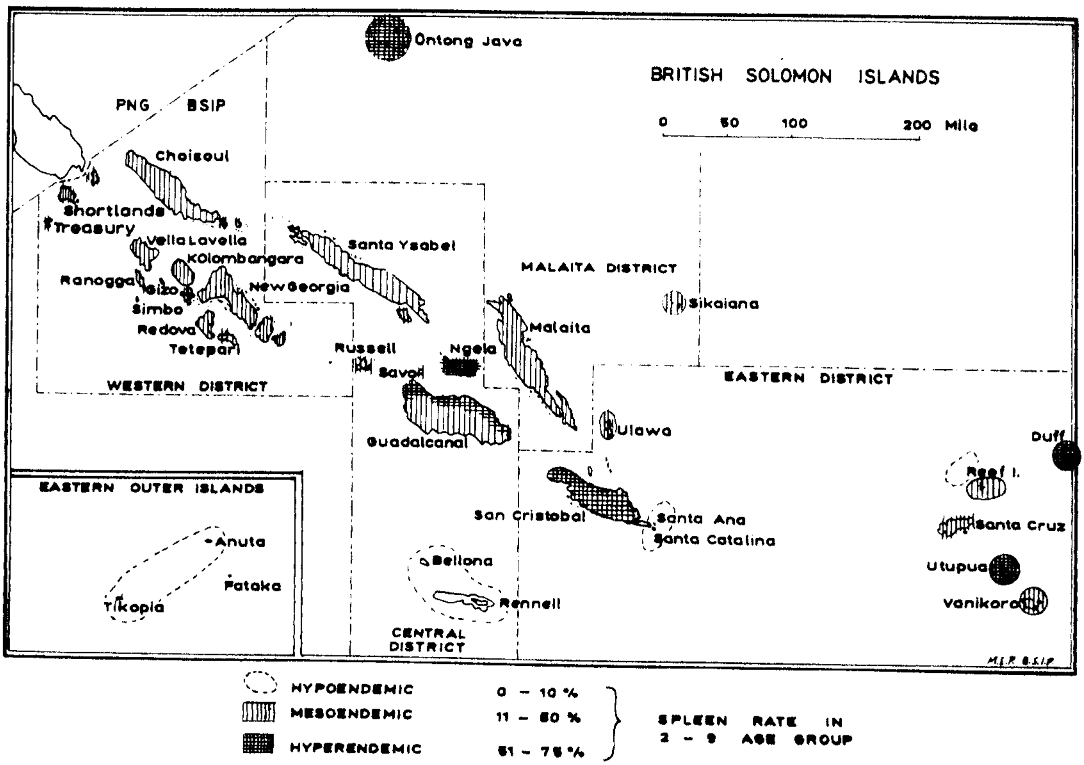
The pre-spraying incidence surveys and, more recently, surveillance data have revealed seasonal increases in malaria at the start and end of the N.W. monsoon season.

HISTORY OF MALARIA CONTROL AND ERADICATION

There were no serious anti-malaria activities in the Solomons until the control brought about by the U.S. forces in the combat areas, mainly Guadalcanal, during 1942-1945. Control then lapsed until late 1961 when the BSIP Government/WHO Malaria Eradication Pilot Project (MEPP) started in Guadalcanal, Savo and parts of New Georgia. The MEPP evolved into a Malaria Pre-eradication Programme (PEP) in 1965 and extended its activities with the inclusion of Shortlands and the rest of New Georgia. Shortlands had already been sprayed since 1959 by the Papua New Guinea Administration. In 1968 Choiseul was also included.

In 1970 there was further expansion into a full malaria eradication programme, the plan of operations at present covering the period

MAP 2. ENDEMICITY OF MALARIA PRIOR TO D.D.T. SPRAYING OPERATIONS



1970-1975. From late 1969 the remaining islands were gradually brought into the operations and by mid 1972 the whole of the malarious area was under DDT spray cover. Meanwhile surveillance operations were maturing in the Central and Western Districts and commencing in a rudimentary way elsewhere.

PRESENT AND PROJECTED OPERATIONS

The whole of the malarious area is now under DDT spray cover. The only islands not sprayed are the ones with no proven vector. All islands are subjected to some form of surveillance.

The state of antimalaria operations at 1st January, 1973 may be seen in *Map* 3.

During 1973 Malaita will be brought under full surveillance. Plans will also be drawn up for similar operations in the Eastern District.

The Western District, Ysabel, Russells, Ontong Java and Sikaiana will be reviewed with a view to entry into consolidation (i.e., cessation of DDT spraying operations) in 1974. It is intended to keep Shortland Islands under full DDT spraying operations until a similar stage has been reached in neighbouring Bougainville. There is no target date yet for consolidation in remaining Central, Malaita, and Eastern Districts.

PARASITOLOGY AND ENTOMOLOGY

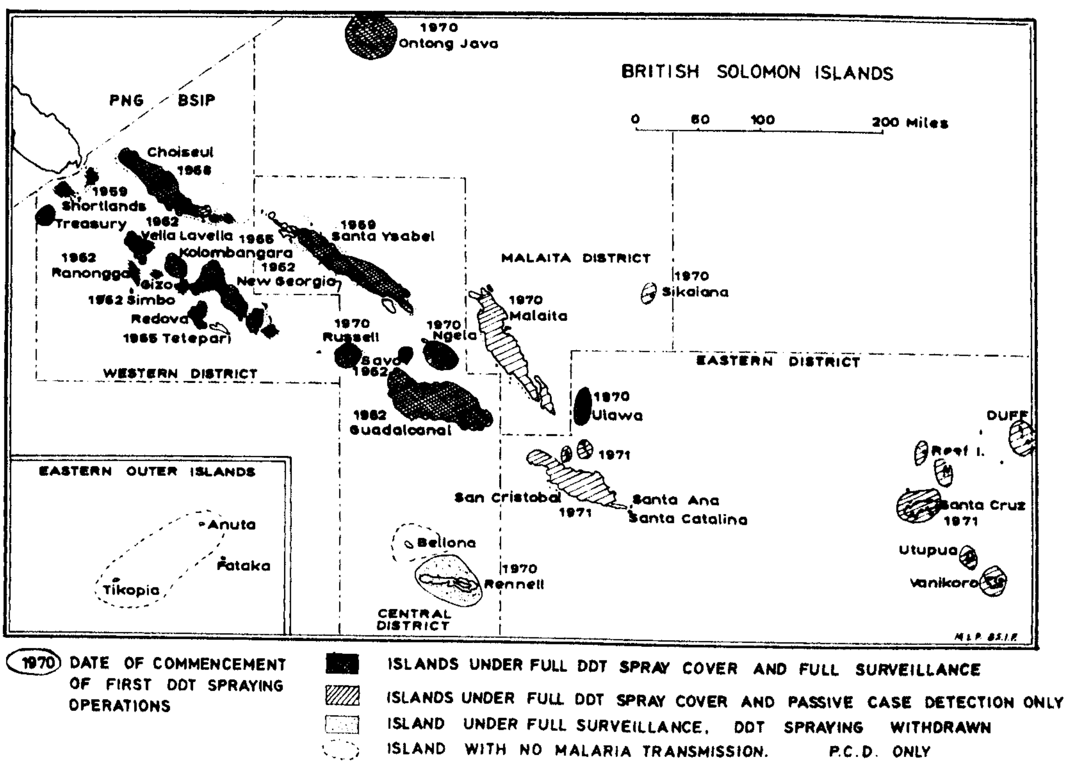
Parasitology

There are three species of human malaria in the Solomons: *P. vivax* is the commonest species; *P. falciparum* is also common and is responsible for many of the acute, serious and sometimes fatal infections; *P. malariae* is relatively uncommon.

There are probably several strains of *P. vivax* since the parasite is more persistent in some islands than in others. It is very likely that the Chesson strain of *P. vivax* described by Alving (1960) is present since vivax malaria relapsing on several occasions over a long period of time is a not infrequent finding. Hill and Amatuzio (1949) recognized that the south-west Pacific vivax strain relapsed over a period of up to 5 years after the original infection and not the 1 to 2 years thought earier.

In Malaita District Hospital during 1969 prior to the start of spraying operations 2,206 slides were collected from fever cases of all

MAP 3. STATE OF ANTIMALARIA OPERATIONS - 1st. JANUARY 1973



ages presenting to out patients. Six hundred and forty-eight (29.4 per cent) of these were positive for malaria and, of these, 437 (67.4 per cent) were due to *P. falciparum*. Thus whilst prevalence surveys showed a predominance of *P. vivax*, incidence surveys showed *P. falciparum* to the fore.

Entomology

The main vector of malaria in the Solomons is *Anopheles farauti* and the two subsidiary vectors are *A. punctulatus* and *A. koliensis*. Surveys carried out on most islands confirm the widespread distribution of *A. farauti*. The subsidiary vectors are more restricted. *A. farauti* may be found in high densities on many islands particularly on North Guadalcanal and Nggela where slow running streams abound.

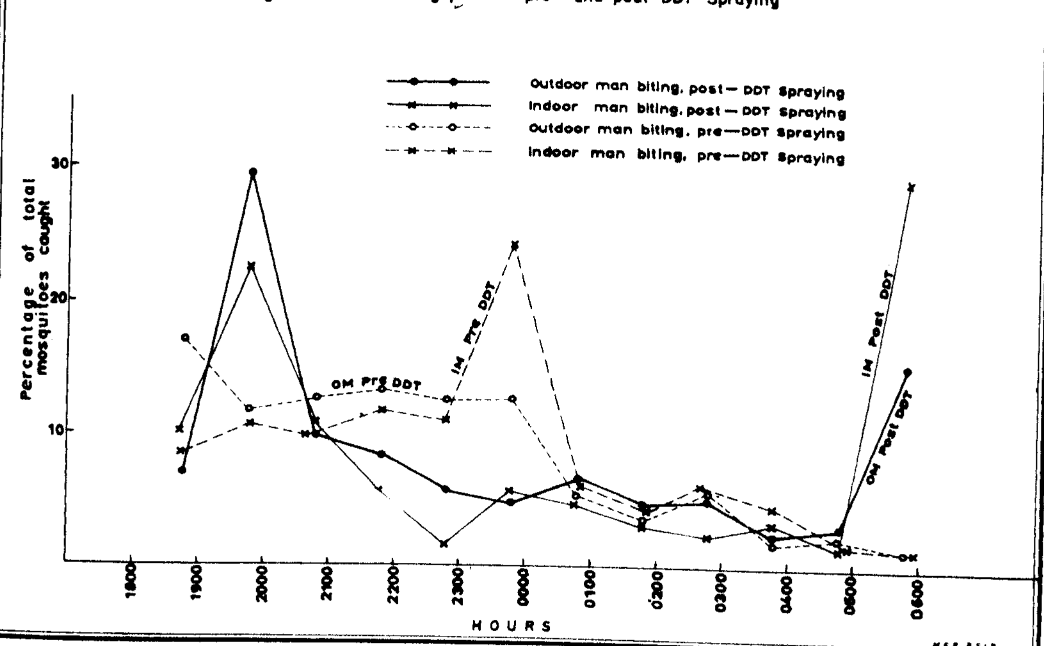
After the commencement of DDT spraying the vectors almost completely disappeared on Ysabel and Malaita. On North Guadalcanal and San Cristobal, however, they remained in high densities. In these areas more detailed longitudinal studies were carried out prior to and following spraying operations. These findings, reported by Taylor (1972) and van Seventer (1972) confirmed the earier findings of Slooff (1969) that there was a distinct change in biting times after spraying. Prior to spraying, indoor and outdoor biting rapidly reached a peak after sunset and remained relatively high during the second quarter of the night, from 9 to 12 p.m. After spraying the peak biting period was still rapidly reached, but equally quickly fell by 9.30 to reach low levels for the rest of the night except for another peak just before sunrise (*Figure* 1A).

The peak biting period post-spraying also coincides with the peak of outdoor social activities in many villages thus creating good opportunities for transmission.

Prior to DDT spraying vectors could be found by indoor man biting, outdoor man biting and indoor resting methods. After DDT spraying indoor man biting fell more than outdoor man biting and it became almost impossible to find any vector indoor resting. This suggests that the *A. punctulatus* complex seldom comes into direct contact with the DDT. The mosquito appears far more likely to stay out of doors and therefore be more susceptible to the mercy of the elements and predators.

In all tests on biting preference *A. farauti* has been found to be strongly anthropophilic (Human Blood Index over 0.8). DDT susceptibility tests using standard WHO test kits have been carried out from time to time, the last being on Nggela and North Guadalcanal in early 1972 (van Seventer 1972). There have been no signs to date that *A. farauti* is resistant to DDT, the February, 1972 test giving a LC50

Fig 1A. Farauti biting pattern, pre and post DDT Spraying



with 1.3 per cent DDT and a LC100 with 4.0 per cent DDT. No detailed studies on life expectancy have been carried out, but over 80 per cent of all *A. farauti* caught on North Guadalcanal are parous. A high survival rate of mosquitoes caught outdoors, e.g., over 90 per cent of fed anophelines more than 24 hours, was obtained.

Spraying Operations

From the start the only insecticide used against the vector has been DDT applied at the rate of 2 gm technical DDT per square metre to the inside surfaces, eaves and underfloors of all dwelling houses and other buildings in which people may spend any part of the night. Every effort is made to obtain total, complete, sufficient and regular coverage. Cyclical spraying is carried out by full-time teams once every 6 months. In some of the problem areas this interval has been reduced to 4 months. The percentage of missed or refused structures is, on average, 5 per cent per cycle.

In addition small follow-up spray teams visit most villages to spray missed, refused, repaired or new structures. Initially they do this at 6-week intervals but once surveillance is fully established the follow-up spraying is usually carried out in conjunction with the surveillance teams.

Delays in supplies and minor population resistance during 1972 resulted in some failures, especially in Malaita District. Population resistance has been building up due to bed bug irritation but the addition of 0.5 per cent malathion to the DDT mixture has relieved this in most areas.

In a few heathen hamlets of Malaita there have been more widespread refusals, mainly in areas with few vectors. These refusals have usually been overcome by discussions between the District Administration and heathen leaders.

Prior to the first spraying operations accurate maps were made, a scale of 1:50,000 locating all villages and hamlets and indicating the total structures therein. During subsequent spray rounds these maps are thoroughly revised. Detailed village spot maps and census are not made except in special circumstances. As the programme progresses it is proposed to devote considerably more attention to mapping and census to ensure total coverage. This should be of considerable value for other community health exercises in the future.

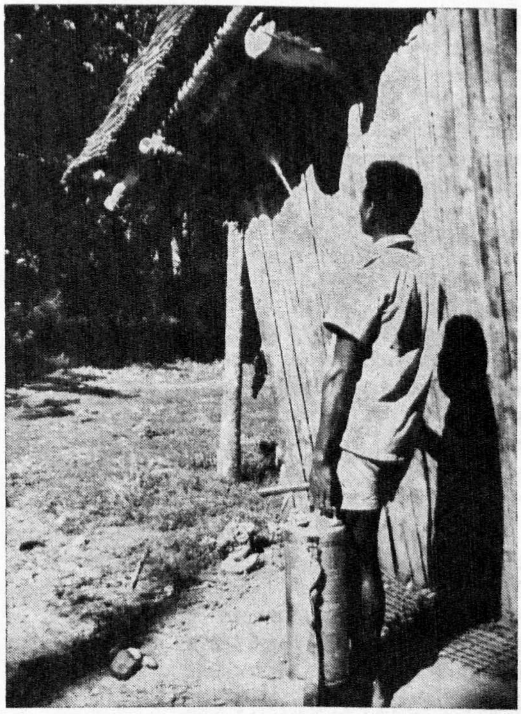


Plate II.—Spraying a dwelling house with DDT

SURVEILLANCE

Malaria surveillance in the Solomons follows standard lines. It consists of Active Case Detection (ACD); Passive Case Detection (PCD); radical treatment of cases; case investigation and follow-up and remedial measures.

ACD is carried out by mobile malaria staff, the agents visiting every house in every village once a fortnight. PCD is carried out by static staff of the basic health services and also by voluntary agents, especially teachers. Blood slides are taken for detection of malaria parasites from all people with a current or recent history of fever. Fever is assessed either clinically or as any temperature over 37.8 degrees Celsius (100 degrees Fahrenheit). When ACD and PCD are efficiently carried out, working in conjunction, there is a good chance that most malaria cases will be picked up.

Presumptive treatment with chloroquine 600 mg and primaquine 45 mgm adult dose—*pro rata* for children—is given to all fever cases from whom blood slides are taken. Slides are dispatched to Central Hospital or one of the district laboratories. The results of all positive slides are dispatched to the various regional

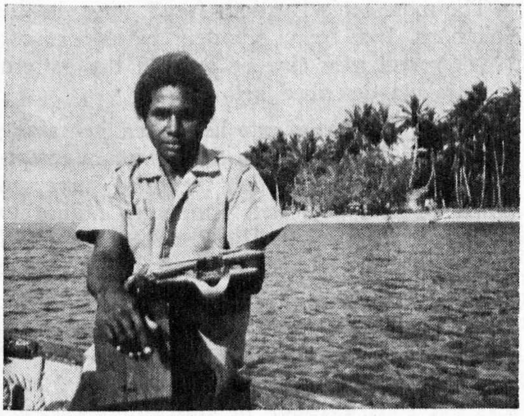


Plate III.—ACD agent landing at village

centres with case treatment cards and case investigation forms. The case, once located, is then administered the full radical treatment by the malaria ACD agent or by a special drug administrator.

A simple case investigation is also carried out as well as appropriate remedial measures as required. On completion of radical treatment cases are followed up with a monthly blood slide, *P. falciparum* cases for 6 months, and *P. vivax* cases for 12 months.

The drug treatment for proven malaria cases is long and tedious. A 5-day regime is used for *P. falciparum* malaria. This is, for adults—

First day—

start Chloroquine 600 mg
sunset Chloroquine 300 mg
Primaquine 15 mg

Second and third days—

sunset Chloroquine 300 mg
Primaquine 15 mg

Fourth and fifth days—

sunset Primaquine 15 mg

A 12-week regime is used for *P. vivax* malaria. This is, for adults—

First day—

start Chloroquine 600 mg
sunset Chloroquine 300 mg

Second day—

sunset Chloroquine 300 mg

Third day and then weekly for 11 *weeks* (i.e., total of 12 weeks)—

sunset Chloroquine 300 mg
Primaquine 45 mg

Pro-rata doses are used for children.

The regime for *P. falciparum* has been used, with minor modification, since the Pilot Project. The regime for *P. vivax* was originally an 8-week one as advocated by Alving (1960). Although the characters of the Solomons strain(s) of *P. vivax* are not well established, the South-West Pacific (Chesson) strain is known to be difficult to cure radically with the 8-aminoquinolines. A strain of *P. vivax* from Papua New Guinea showed a relatively poor response to primaquine given at 15 mg base for 14 days (WHO 1961). Clinical experience in Honiara also confirmed a poor response to the 14 day regime (Macgregor 1966). The difficulty of obtaining radical cure of *P. vivax* with the primaquine 8-week regime was reported by Alves (1964) and Macgregor (1966). The 12-week regime with 45 mg primaquine weekly was introduced in 1963 and has been used ever since. Slightly increased dosages were also used for the younger age groups. The only exception to this has been the use of the 5-day regime for *P. vivax* as well as for *P. falciparum* in areas of high endemicity to bring down the case load.

Relapses have occurred even with the 12-week treatment. Many of these have occurred in the younger age groups and it is suspected that they are due to inadequate dosage or incomplete treatment. A field investigation of the relapse rate by monthly follow-up of 51 *P. vivax* cases completing the 12-week regime in North Guadalcanal showed 9.3 per cent of parasitological relapses and 3.9 per cent of clinical relapses (symptoms plus parasitaemia). These relapses occurred between 2 to 6 months after completion of medication. An investigation of 161 *P. vivax* cases completing the 5-day regime in North Guadalcanal showed 14.2 per cent of parasitological relapses and 6.2 per cent of clinical relapses. These relapses occurred earlier than those after the 12-week regime. They ranged from 1 to 6 months but were mostly around 2 to 3 months and rarely beyond that. Similar findings were found with the relapses after the 5-day treatments in the Gilbertese Island of Wagina.

There is no evidence of drug resistant malaria of any type in the Solomons. Also there have been no proven haemolytic crises due to primaquine sensitivity in association with Glucose-6-Phosphate Dehydrogenase deficiency.

ASSESSMENT AND PROGRESS

Two main parasitological methods are used for the assessment of progress. They are—

(*a*) Serial malariometric surveys, usually every 6 months, for the first 2 years following commencement of DDT spraying operations. These blood surveys are usually confined to the 2 to 9 age group carried out in randomly selected villages.

(*b*) Routine blood slide collections from fever cases by ACD and PCD agents.

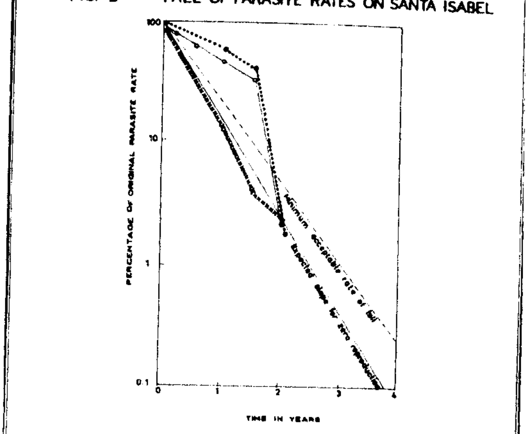
Results of Progress-Serial Surveys

Serial blood surveys in the 2 to 9 age group have been carried out in most of the islands brought under spray cover during 1970-1972. These include Ysabel, Russells, Nggela, Malaita, Ulawa, San Cristobal and Eastern Outer Islands.

The assessment of progress on all islands is made using the rate of fall of parasite rates described by Macdonald and Gockel (1964), and endorsed by the WHO Expert Committee on Malaria Tenth Report (WHO 1964).

In Santa Ysabel (population 8,600) and Russell Islands (population 2,800) there has been a steady regression in *P. falciparum*, the slope falling within the expected slope for zero reproduction (*Figures* 2 and 3). The fall in *P. vivax* malaria, whilst being initially slow, has at the period two years after the first spray round, also fallen near to, or within, the minimum acceptable rate of fall.

FIG. 2 FALL OF PARASITE RATES ON SANTA ISABEL



The more typical pattern for *P. vivax* in the Solomons has been reported by Macgregor (1966) and may also be seen in the pattern for Malaita described below.

The *P. falciparum* rate has fallen just along the line or slightly within the minimum acceptable rate of fall although the third survey in Small Malaita indicated temporary failure to interrupt transmission. The *P. vivax* rate of fall has been very slow and two years after the start

FIG. 3 FALL OF PARASITE RATES ON RUSSELL ISLANDS

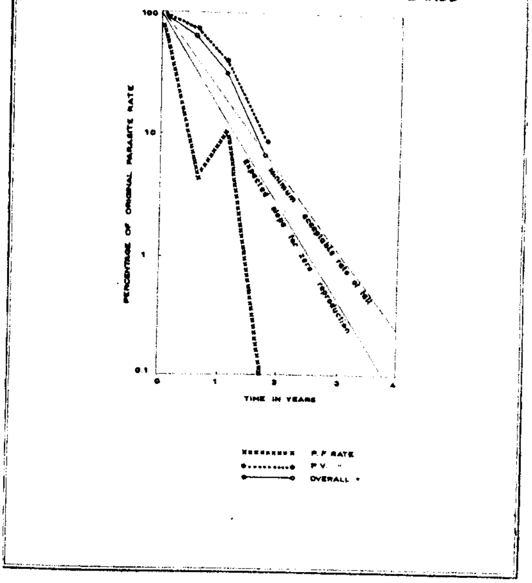
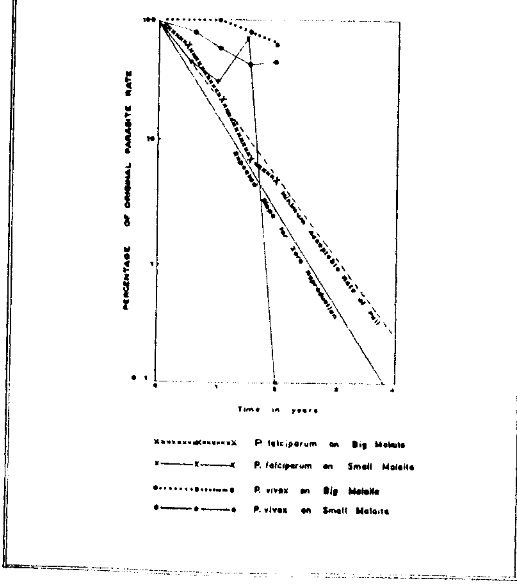


FIG. 4 FALL OF PARASITE RATES ON MALAITA



of spraying had still fallen to only 45 per cent (in Small Malaita) and 69 per cent (in Big Malaita) of the original *P. vivax* parasite rate. Similar patterns in the fall in parasite rates have been noted in Ulawa, San Cristobal and the Eastern Outer Islands.

Results of Progress—Routine Surveillance

The results of all blood slides collected by ACD and PCD during 1970-1972 are shown in *Table* 1.

These figures show that in each district except Central, as the surveillance effort has intensified, so the number of slides collected has increased, reaching in Western 65.9 per cent, Malaita 35.8 per cent and Eastern 27.3 per cent of the population respectively in 1972. The total positives and the percentage slides positive for each district has fallen for each of the three years. Malaita and Eastern show the dramatic drop in percentage slides positive that is to be expected in the first two years following commencement of spraying operations. Central and Western have shown an easing of the rate of fall but Western is showing good signs of a breakthrough to very low levels. In Central and Malaita Districts total *P. falciparum* showed an insignificant drop. These figures are a reflection of focal outbreaks of *P. falciparum* malaria in these districts.

The crude figures do not show the relative contributions made by ACD and PCD towards case detection. These may be seen for 1972 by referring to *Table* 2.

In all districts except Malaita PCD has yielded a greater percentage of slides positive. In Malaita and Eastern the ACD aspect of surveillance is still only rudimentary. In Western District more than twice as many slides were collected by ACD than by PCD, yet the percentage yield from PCD was almost twice as high as that from ACD. This emphasises the importance of PCD in surveillance.

The figures do not reveal the variations at Regional or Zonal level. The areas poorly covered are usually the remote islands or those with very poorly developed communications.

The distribution of malaria at Regional and Zonal level also shows considerable variation. In Central District in 1972, 1,102 of the 1,656 cases were from North Guadalcanal, including Honiara. Three hundred and twenty-one cases were from Nggela. The remaining 232 cases were scattered around Guadalcanal, Ysabel and Russells with only one case from Rennell and Bellona. Whilst North Guadalcanal and Nggela have yet to show real signs of a breakthrough the remainder of the district has progressed well. Honiara has shown a marked improvement from 1,791 cases in 1970 to 566 cases in 1971 and 232 cases in 1972.

In the Western District in 1972, 216 (57 per cent) of the 378 cases were from the Gilbertese community. The Melanesian community in North West Choiseul had the next highest number with 101 (27 per cent) cases. This included 33 of the 36 *P. falciparum* cases. Small focal outbreaks occurred elsewhere following importation of cases or relapses. Most outbreaks were contained within 2 to 3 months although N.W. Choiseul was not fully resolved by the end of 1972.

The distribution of cases in Malaita District was widely scattered during 1972. Failures in DDT supplies and other operational difficulties in mid-year resulted in some resurgence of

Table 1.—Blood slides examined from ACD and PCD; total *P. falciparum*; percentage slides positive 1970-72

District	Year	Number of slides examined from ACD and PCD	Total positives. (All species)	Total P.falciparum	Percentage slides Positive
Central (Popn *55,288)	1970	33,961	4,523	1,758	14.0
	1971	28,891	1,923	527	6.4
	1972	32,437	1,656	543	5.1
Western (Popn *33,787)	1970	12,726	520	46	4.2
	1971	16,655	422	38	2.5
	1972	22,275	378	36	1.7
Malaita (Popn *51,838)	1970	3,663	1,451	449	39.6
	1971	7,014	1,070	63	15.3
	1972	18,543	1,016	87	5.5
Eastern (Popn *21,276)	1970	Insufficient data			
	1971	2,503	928	417	36.7
	1972	5,510	918	159	16.6

* Population figures are from 1972 counts by malaria staff. They are probably less that the true figures.

Table 2.—Blood slides examined from ACD and PCD; number of positive from ACD and PCD; percentage positive slides from ACD and PCD; all Districts 1972

District	Nnmber of slides examined from ACD and PCD		Number of slides positive from ACD and PCD		Percentage of slides positive from ACD and PCD	
	ACD	PCD	ACD	PCD	ACD	PCD
Central	17,457	14,980	761	895	4.4	6.0
Western	15,453	6,822	217	161	1.4	2.4
Malaita	2,331	16,212	128	888	5.5	5.4
Eastern	759	4,751	67	851	8.8	17.9

malaria including an increase in *P. falciparum* cases. These outbreaks were resolving by the end of the year and, with steadily maturing surveillance, the district can be expected to progress to low levels during 1973.

In the Eastern District there was all round good progress. Towards the end of 1972 there was a small increase in malaria in some parts of the District notably on the north coast of San Cristobal and in Ndendi Island (Santa Cruz). These were attributed to the effects of cyclones. Throughout the Eastern District, except in the remote Outer Islands, surveillance has been maturing well so that during 1973 a clear picture of the trouble spots should emerge.

PROBLEM AREAS IN THE SOLOMONS

At present three areas, namely North Guadalcanal, Nggela and the Gilbertese settlements in the Western District present serious obstacles to progress. In the former two areas, problems are thought to have arisen from the behaviour of the anopheline vector which is associated with the habits of people, and in the latter area the problem is mainly related to special living conditions of the Gilbertese. More details of the nature of problem areas, the causative factors responsible for persistence of transmission in these areas, and selection of satisfactory supplementary measures are dealt with separately in this special issue.

(*a*) *North Guadalcanal*—

The problem area covers the most populous coastal plains of Guadalcanal extending some 100 km east of the capital, Honiara. Approximately 8,000 people of the plains are more closely in contact with civilization, highly mobile and potentially less co-operative. They frequently spend the early part of their evenings out of doors at the time corresponding with the peak biting times of vector anophelines. The north coast of Guadalcanal has long been known as one of the most malarious areas of the Solomons. During World War II malaria was only controlled in the U.S. troops in this area after extensive engineering works and regular oiling, but this fell into disuse soon after. This area subsequently came under spray cover in 1962. Before Malaita and Nggela were protected with DDT spraying, many of the *P. falciparum* cases were thought to have originated from these unprotected islands. The start of spraying in Malaita and Nggela in 1970 resulted in a decrease in the number of imported cases so revealing the true picture of the problems in this area. For nearly 2 years from the beginning of 1971 to late 1972, when there were delays in DDT delivery, the insecticide coverage on North Guadalcanal was of a high standard. Operational factors were not considered to be the reason for persistence of transmission. There have been no signs of resistence of the vector to DDT and of the parasite to chloroquine. The reason for continuing transmission in this area is, then, due to high vector density with a marked outdoor biting tendency, the peak of which coincides with man's maximum outdoor evening activities.

(*b*) *Nggela*—

This group of islands is 50 km (30 miles) to the north of Guadalcanal. The population in the 1970 census was 5,350. The islands have extensive breeding sites especially on the north coast. DDT cyclical spraying started in April, 1970 and has continued regularly at 6-monthly intervals. Four serial post-spraying parasite surveys have been conducted. The surveys up to the third showed failure to interrupt transmission. Between July and October, 1972 a mass drug administration using single dose chloroquine/pyrimethamine monthly was carried out in north Nggela. The results of this were reflected in a big drop in parasite rates in the fourth survey. This could not be taken as proof, however, that transmission had been interrupted. The continuation of transmission in spite of good spraying is seen to be due to the combination of initially high endemicity (parasite rate in the 2 to 9 age group was 70.8 per cent) and high outdoor vector densities.

(*c*) *Gilbertese settlements in Western District*

The Gilbertese migrated to the Solomons during 1956-1958 due to population pressures on their own non-malarious islands. They now number 2,300 (1970 census), 1,800 of whom are in the Western District. They were first settled on uninhabitated, swampy Wagina, an island to the east of Choiseul. There they received regular doses of prophylactic drugs, but it appears that this soon fell into disuse. Soon *P. falciparum and P. vivax* malaria became established and some deaths were reported. Around 1959 some Gilbertese moved to Titiana and other villages near Gizo and to new villages in the Shortland Islands. Wagina was first covered with DDT in 1968 but low grade transmission of *P. vivax* malaria has continued there and in other Gilbertese communities in the Western District, mainly because of the special living conditions of this group. These were villages on low lying ground with the staple swamp taro beds nearby; sub-standard housing with roll-down walls and easy contact vector anophelines by people spending much of the night in unwalled community halls (Maneaba) etc.

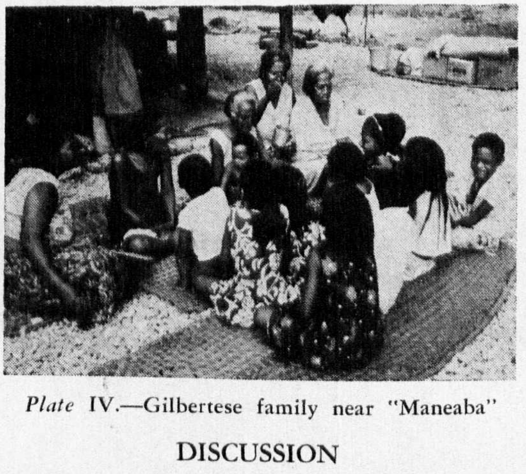


Plate IV.—Gilbertese family near "Maneaba"

DISCUSSION

The classical malaria eradication methodology is used in the Solomon Islands. DDT residual spraying of houses is aimed at the vector anophelines whilst radical treatment of proven cases is aimed at the parasite in man. In most of these tropical islands with mesoendemic malaria the method has been very successful. Where failures have occurred they have been operational and not due to insecticide resistance.

The stages leading up to the full MEP were somewhat prolonged (1962-1970). In retrospect it is considered that for a small country it is better to run a small Pilot Project in a small, uncontaminated area or island to prove feasibility and then to go full into an all-out eradication campaign. If the social, political and economic factors are unfavourable then the attack should be withheld until the conditions are more favourable. This does not preclude, however, a modest control programme in the interim. This should indeed be encouraged in order to build up the necessary experience.

Many factors may disrupt spraying and surveillance schedules. These include adverse weather and failures in supplies, equipment and transport. Constant watch must always be kept to see that minimum disruption occurs. Spraying and surveillance of a high standard is obligatory and this requires well-trained, mature, high calibre supervisory staff to keep up the standards. A particular difficulty in the islands is the long delays in communications. This results in, for example, a long interval between blood slides being taken and radical treatment being given if proved positive. This delay, sometimes as long as 60 days, results in a considerable rise in transmission potential. Indiscriminate usage of insecticide or drugs may result in wastage, overexpenditure and delays in further supplies. It is also important to ensure correct dosages of insecticide and drugs for the same reason.

Where transmission has continued in spite of well executed spraying operations it may be necessary to carry out supplementary measures. Due to the formidable environmental problems, the difficulty in attacking the vectors and the impossibility of immobilising the people the most satisfactory supplementary measure in the Solomons is that of Mass Drug Administration. This is expensive, costing $A0.86 per round per capita for one round of the 12-week regime. The cost of house spraying is $A0.35 per capita per cycle. Proper geographical reconnaissance, family census and the use of a family register to keep records of each administration are essential to ensure full coverage, supervision and assessment.

Whilst there are many problems in running a Malaria Eradication Programme in a highly malarious tropical island environment there are also distinct possibilities of success given correct methodology and dedicated application.

ACKNOWLEDGEMENTS

I wish to thank His Excellency the High Commissioner of the Western Pacific for permission to publish. My thanks are also due to the many staff members of the British Solomon Islands Malaria Eradication Programme whose long and faithful devotion to duty has enabled much of the work reported here to be carried out. I also greatfully acknowledge the support of the World Health Organization.

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[*Extract from Papua New Guinea Medical Journal,* Vol. 17, No. 1, December, 1973—March, 1974.]

Problem Areas in the Malaria Eradication Programme in the British Solomon Islands

Y. H. PAIK AND J. G. AVERY

Three problem areas exist for malaria eradication in the British Solomons: namely North Guadalcanal, Nggela and the Gilbertese Settlements in Western Solomons. The Malaria Eradication Programme in the Solomons appears to be otherwise satisfactory as judged by the 1973 *WHO Independent Assessment Team. The causes of these problems are defined and possible effective supplementary measures are considered for the Solomons. Mass chemotherapy appears to be a successful procedure in conjunction with other supporting measures.*

INTRODUCTION

"Problem areas" or "areas with technical problems" (World Health Organization, Expert Committee on Malaria (WHO ECM) 1968) can be defined as: "Those where the planned single or combined attack measures correctly applied have failed to interrupt transmission".

Problem areas depend mainly on two factors: the human host and the insect vector. The relative importance of these factors often varies between countries, and even between districts in the same country. Problem areas thus require intensive studies within field projects.

In 1970, a Malaria Eradication Programme (MEP) commenced, although at this time two districts, Central and Western, had already been subjected to 8 years' spraying coverage. The spraying was extended to the remaining two districts, Malaita and Eastern, and by mid 1972, total spray coverage for the whole Protectorate except for a few vector-free Polynesian outer islands was attained.

Serial blood surveys of the population on the various islands which came newly under attack were carried out at 6-monthly intervals. The results to date show that a fall in falciparum parasite rate has met the expectations laid down in the 10th WHO ECM Report, on most islands, except for Nggela. On Guadalcanal and in the Western District, with a long lasting spraying, the progress was steady except for the north coastal areas of Guadalcanal and a few Gilbertese settlements in the Western District (see *Figure* 1).

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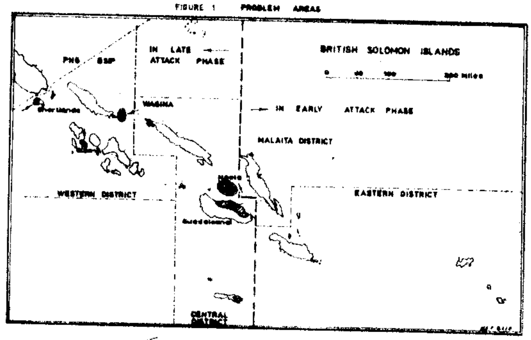
FIGURE 1 PROBLEM AREAS



AREA WITH CONTINUING TRANSMISSION (PROBLEM AREAS)

(*a*) *North Gaudalcanal*

This area with a mainly Melanesian population of about 8,000, lies in the alluvial plain east of Honiara, the capital town. The numerous swamps and tributary creeks in this plain are heavily overgrown by jungle. The swamps have little water during the dry season, but in the rainy season (December-April), they form extensive breeding areas.

During the Guadalcanal Campaign of the Pacific War, the American forces experienced a tremendous malaria hazard in this area (morbidity due to malaria—1,558 per 1,000 annum was recorded for the initial period of the campaign, Macgregor 1966). After the war, Black (1952) carried out a malaria survey in the BSIP and reported holo or hyperendemicity in two villages in this area.

The overall parasite rate obtained in Guadalcanal for the pre-spraying period (spraying commenced in 1962) was 30.0 per cent with *P. falciparum* dominating (Macgregor 1966). The parasite rate dropped to 11.6 per cent in the first post-spraying survey and 4.1 per cent in the second. There was thus a great reduction in endemicity after the commencement of house spraying. The third survey showed that the positive cases, particularly *P. falciparum*, were concentrated along the north and north-eastern coasts of the island. In view of considerable traffic between these coastal areas and unprotected Malaita (population more than 50,000), it was then reported that a large proportion of *P. falciparum* cases was "imported" (Chen 1964). After spray cover to adjacent areas was commenced, a fairer picture of the problems existing was obtained. Over 80 per cent of the malaria cases detected were investigated as to the origin of infection and only a few of these were "imported" and most cases were clearly "indigenous".

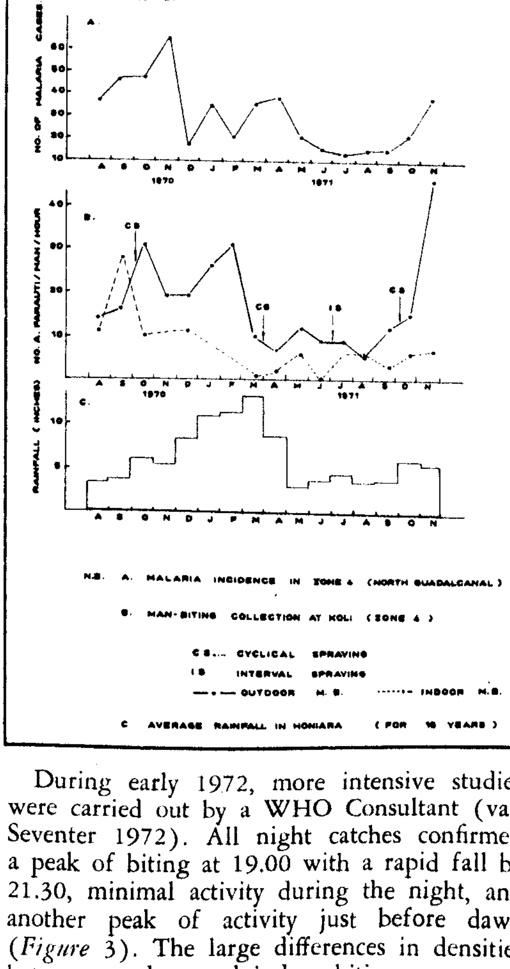
Since May, 1971, "overhaul operations" were commenced to improve the malaria situation in North Guadalcanal. These operations included: (i) high quality attack operations; (ii) a scheme of "interval spraying" of all surfaces below 2 metres every 3 months, in addition to the usual cyclical spraying; and (iii) intensive surveillance measures. Despite a high degree of intensity of the field operations, no marked improvements were seen in this area.

For nearly two years from the beginning of 1971 to late 1972, the insecticide coverage in North Guadalcanal was nearly total, complete, regular and sufficient. Refusals to house spraying were rare and there were few hidden garden huts. There are no nomadic groups though the people are highly mobile. Thus, operational factors were not considered to be the reason for the persistence of transmission.

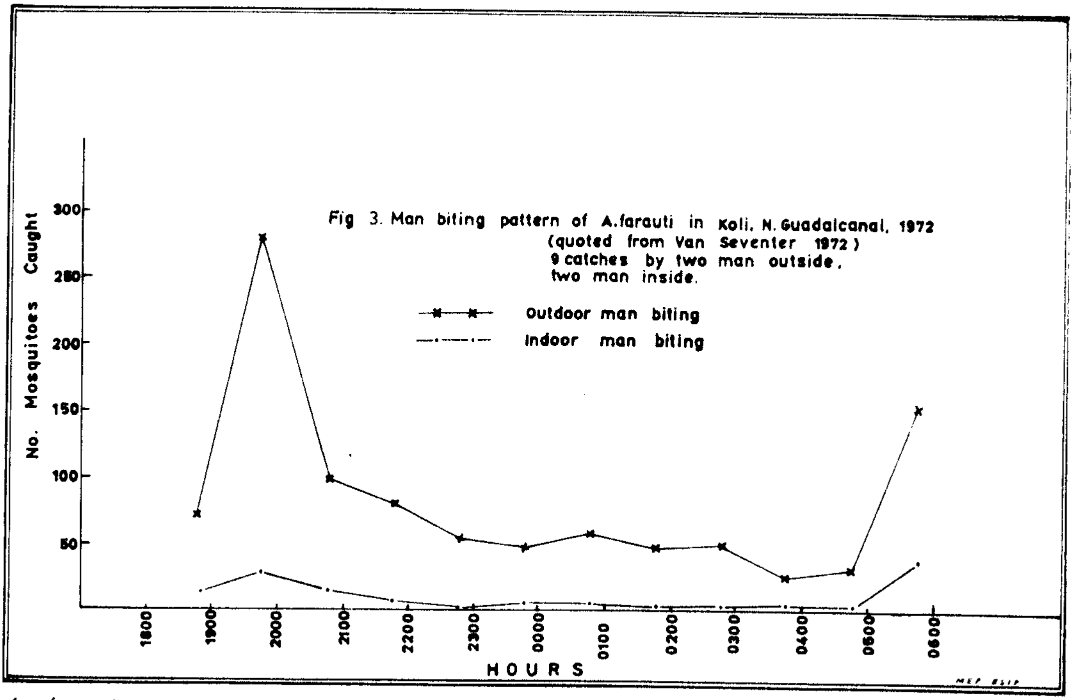
Recurrent *P. falciparum* cases after standard chloroquine/primaquine treatment were rarely noted. The parasite formula which was checked each quarter has constantly been keeping a ratio of 20-30 per cent P.f: 70-80 P.v., but no single case of reversion in the formula was ever seen. The latest tests undertaken by a WHO Consultant (entomologist) in two places in North Guadalcanal showed no resistance of *A. farauti*, the principal vector, to DDT.

The behaviour of *A. farauti* has been studied more on Guadalcanal than elsewhere in the Solomons. A consolidated record of biting densities of *A. farauti* from 1965 to 1968 showed the increased tendency of this vector to bite out of doors (outdoor man-biting mosquito numbers/man hour . . . 7.9; indoor man-biting mosquito numbers/man-hour . . . 1.7) and its peak nocturnal activity to occur in the early evening—7.00 p.m. (Slooff 1969). One of Slooff's interesting observations was that the overall mortality of house-visiting *A. farauti* did not increase very much on the occasion of re-spraying (under experimental conditions). Similar findings in this area were also obtained by us during 1970 and 1971 from one of the notorious malaria foci, Koli village, where no correlations between the density of *A. farauti*, especially outdoor biting, and the occasions of cyclical spraying and interval spraying were demonstrated (*Figure* 2).

FIG. 2



During early 1972, more intensive studies were carried out by a WHO Consultant (van Seventer 1972). All night catches confirmed a peak of biting at 19.00 with a rapid fall by 21.30, minimal activity during the night, and another peak of activity just before dawn (*Figure* 3). The large differences in densities between outdoor and indoor biting were attributable to refractory behaviour of *A. farauti* towards DDT. However, whether this refractoriness is due to DDT irritability or to deterrent effect of this insecticide needs more careful study. It was suspected that many vectors were not getting a lethal dose of DDT. Man vector contact was made very easy by the people spending the early part of the evening out of doors at exactly the time of peak biting activity. Other entomological findings needing to be mentioned are: (i) high parous rate of



A. farauti—over 80 per cent; (ii) human blood index—0.8; and (iii) bio-assay test yielded 100 per cent kill.

The causative factors responsible for this continuing transmission thus appeared to rest on three factors, (a) refractoriness of *A. farauti* towards DDT, (b) the habit of subjects to stay outside late and (c) a marked outdoor biting tendency of the vector coinciding with man's maximum outdoor evening activity.

(*b*) *Nggela Group*

Nggela is a group of islands which are close to Guadalcanal. They have an area of 150 square miles with a dominantly Melanesian population (1970 census). The prespraying malariometric survey showed hyperendemicity (spleen rate—71.2 per cent in children of 2-9 years, Maffi 1971). These islands have extensive breeding sources which are particularly abundant in the north coastal areas. Many villages on the north coast are usually at a close distance to low lying swampy areas and blocked streams. The area has received 7 cycles of spraying to date almost regularly at 6-monthly intervals. Four serial post-spraying blood surveys, covering at least 50 per cent of the children aged 2-9 years each time, carried out by a WHO Laboratory Specialist gave the results shown in *Table* 1 (quoted from Gibson 1973).

***Table* 1.—Summary data of malariometric surveys on Nggela (quoted from Gibson 1973)**

Survey	Months after 1st spray round	Overall parasite rate	P. fal. parasite rate.
Pre-spray (Maffi) Aug. '69		70.8	12.5
1st post-spray (Gibson), April. '71	12	23.8	9.0
2nd post-spray (Gibson). Oct. '71	18	30.1	5.1
3rd post-spray (Gibson), May '72	25	27.8	12.1
4th post-spray* (Gibson), Dec. '72	32	9.4	0.7

*This survey was done after a MDA in the north coastal area, July-October, 1972. The results of this survey are, therefore, not relevant to assessment of imagocidal attack.

Between July and October, 1972, a mass drug administration using single dose chloroquine/pyrimethamine monthly was carried out in north Nggela. The results of this are reflected in the fall in parasite rates in the fourth survey. This cannot be taken as proof, however, that transmission was interrupted. Surveillance data collected by Passive Case Detection and additionally by Active Case Detection from August, 1972 (*Figure* 4) showed numerous *P. falciparum* cases and clear confirmation that transmission had not been interrupted. During and after the mass drug administration the number of *P. falciparum* cases fell dramatically and the *P. vivax* cases also fell. However by February, 1973 transmission returned to the original level.

DDT spraying on Nggela has been very good with total, complete, sufficient and regular coverage. Night catches carried out in March, 1972 confirmed earlier findings that the extent of *A. farauti* outdoor man biting was intense. A bio-assay test carried out in March, 1972, at a house sprayed 4 months previously, resulted in a complete kill after 1 hour exposure (van Seventer 1972).

We could judge that the intensive outdoor transmission, like that found in North Guadalcanal, is the responsible causative factor. However, the dominance of falciparum malaria despite a long lasting and efficient spraying needs more careful study.

(*c*) *Gilbertese settlements in Western District*

There are some 2,300 Gilbertese in the Solomons. Within the Western District, the Gilbertese are scattered in a few areas, namely Wagina Island (1,000), Shortland Island (200) and in a few villages on Gizo Island and its neighbouring two small islands (700). As these people were originally non-immune, frequent epidemics exclusively of *P. vivax* were reported in the past. Gilbertese settlements are now the major foci of malaria in Western District. Of 378 cases of malaria in the district in 1972, 216 (57 per cent) were Gilbertese.

The reasons for continuing transmission are: (i) the sites of most Gilbertese villages are on low lying swampy ground (this is connected to the cultivation of taro (*Colocasia* spp.) as their staple food); (ii) spraying is unsuccessful because of sub-standard housing, and its effect doubtful because of the design of Gilbertese houses with roll down walls (*Figure* 5); and (iii) contact with vector anophelines is made easy by large numbers of people spending most or all the night in unwalled community halls "maniaba" (*Figure* 5).

The causative factors for the persisting transmission in the Gilbertese settlements are thus mainly related to their special living conditions.

FIG 4. MALARIA INCIDENCE IN NGGELA, 1971 – 1973

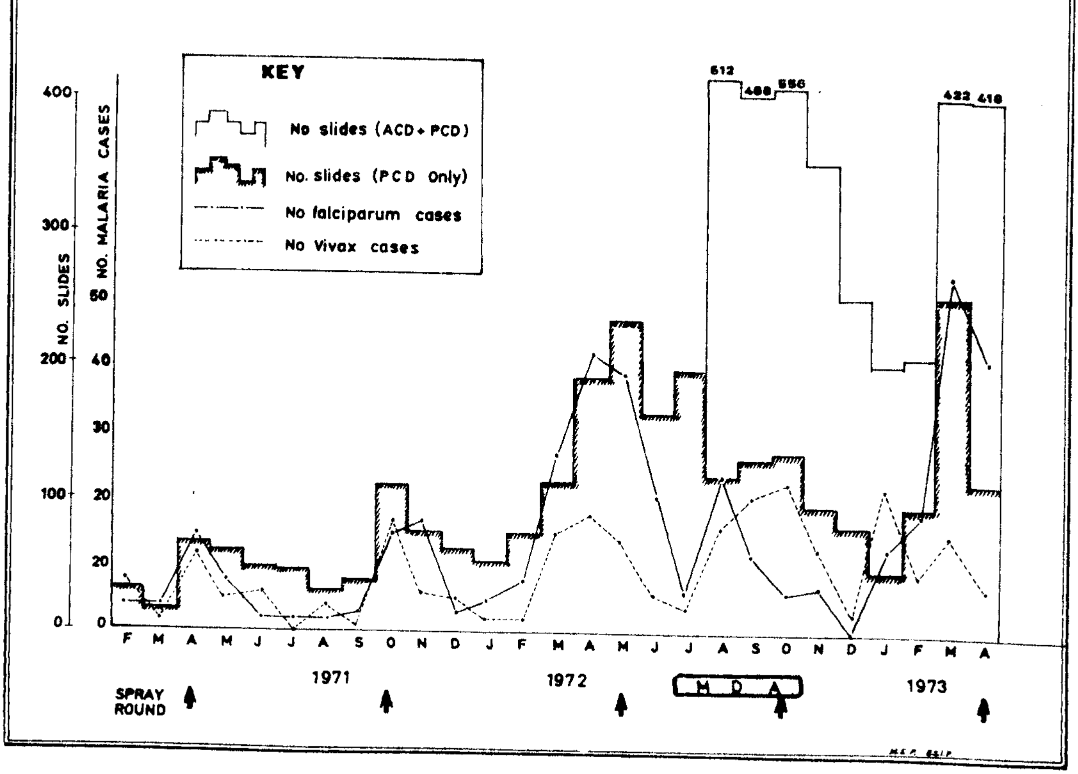
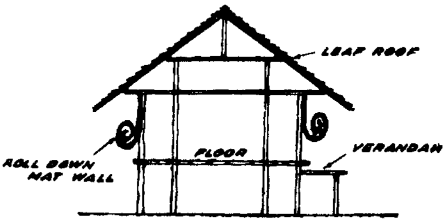
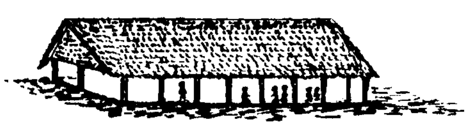


FIG 5.



CROSS— SECTION OF A TYPICAL GILBERTESE HOUSING



A COMMUNITY HALL. "MANIABA" IN A GILBERTESE VILLAGE

SELECTION OF SUPPLEMENTARY MEASURES

In several reports, the WHO ECM has emphasized the importance of concentrated attack, usually by the application of a single technique—insecticide spraying—though not to the complete exclusion of other methods (WHO ECM 1968). A combination of insecticidal and chemotherapeutic measures is often necessary to achieve the goal of eradication. As the use of a combination of two systems of attack makes for increased workload and costs, often leads to inefficiency in both, and also complicates the operations of the programme, it is most essential that the factors responsible for ineffective or inadequate imagicidal attack be clearly established and remedied before undertaking any combined measures.

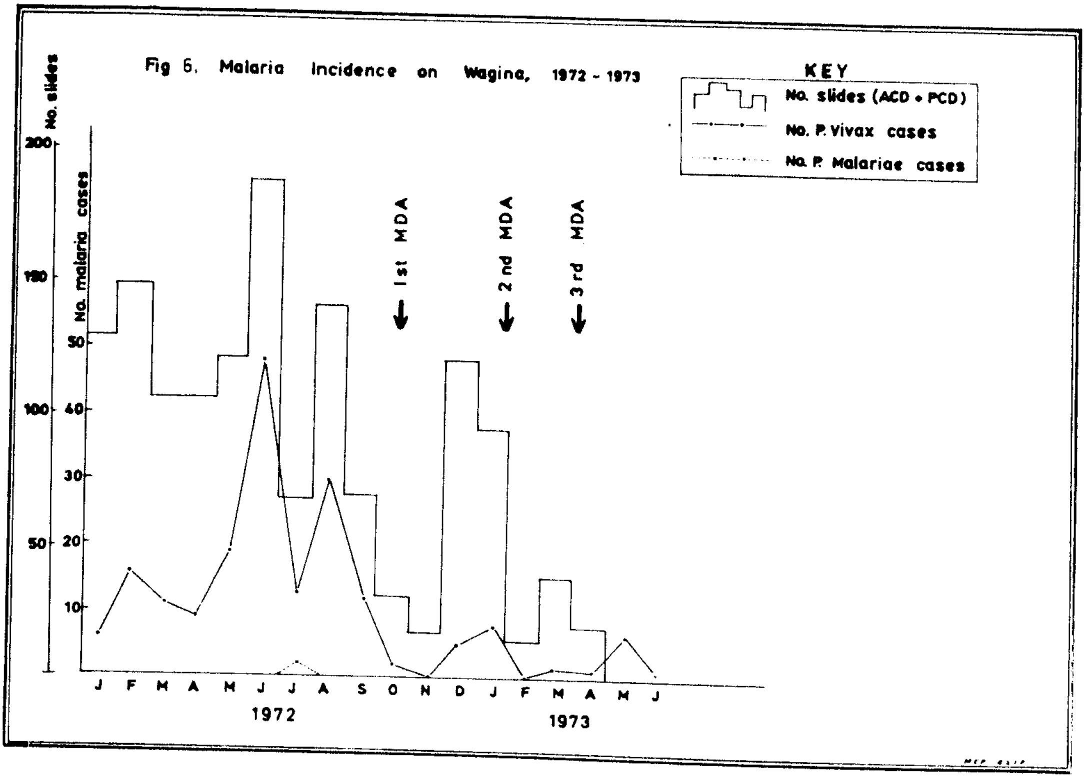
The main purpose of supplementary measures is to enhance the effect of residual spraying to rapidly decrease the reservoir of infection to the level at which it can be handled by surveillance techniques. Some of the measures considered are: (a) Chemotherapeutic measures; (b) Anti-larval measures—chemical, mechanical and biological; and (c) Alternative spraying such as space spraying. As a remedial action, but not as a supplementary one, change of insecticide can also be considered. The use of medicated salt (Pinotti's method) is not conceivable (its effectiveness is not in question) because many rural people in the Solomons use sea water for cooking and rarely purchase table salt. The use of environmental control and water management may require intensification and additional support. Such engineering operations should be undertaken by the local administration although at present the financial position of both the local and the central government precludes their implementation. Many references are found in the literature to the use of larvicidal oil and chemicals under normal and special conditions. However, in view of the extent and nature of the numerous breeding places in north Guadalcanal, larviciding operations seem not easy to tackle. There are still no readily available biological control measures. In view of the relatively small population compared with the large and difficult land area, mass drug administration (MDA) is the method of choice. Space spraying by means of ground ultralow volume (ULV) application of insecticides is also feasible, but change of insecticide is not envisaged. However, both activities—larviciding and/or ULV technique—might have to be considered should the DDT spraying on a 4-monthly basis supplemented by MDA prove unsuccessful in the problem areas.

EXPERIENCE WITH MASS DRUG ADMINISTRATION

(*a*) *Wagina and Shortland*

The whole population of these islands (all Gilbertese) was administered 3 rounds of the 5-day regime (totalling 1.5 gm of chloroquine and 75 mg primaquine for adults). A complete census was taken and a record of each administration was kept in a family register. The first two rounds were closely supervised and the population coverage was high (over 90 per cent).

Summarising the results of MDAs on Wagina (*Figure* 6), and Shortland, it has been found that *P. vivax* cases have continued to occur on Wagina in spite of an exercise with satisfactory coverage, but not significantly in Shortland. However, 19 cases on Wagina in the first 6 months of 1973 compares very favourably with the 108 cases in the corresponding period of 1972. There is still no guarantee that transmission has been interrupted, but there has been a virtual halting of the usual seasonal epidemic. These results have been obtained at considerable cost and effort and further exercises will be required to interrupt transmission permanently. The Gilbertese community is very prone to relapsing *P. vivax* malaria. A period of 50 to 60 days is the commonest time for relapses to occur after



incomplete radical treatment, i.e. the 5-day regime. On Wagina the 5-day regime is easier to administer under strict supervision than the 12-week scheme, because of the island's difficult communications with the District centre. In any case there is no guarantee that the longer regime would effect a radical cure in all cases. Because the Gilbertese are so itinerant it will be necessary to include the whole ethnic group in two areas, Gizo and Wagina, in any further MDAs.

(b) Nggela

An epidemic of *P. falciparum* malaria started in Nggela in March, 1972 in spite of regular DDT house spraying of a reasonable standard (*Figure* 4). Cyclone "Ida" at the end of May, 1972, threatened further deterioration resulting in a decision to apply monthly MDA with a single combined dose of chloroquine 600 mg/pyrimethamine 50 mg (for adults) to the population in the north coastal areas from July, 1972 for four months. As this MDA was carried out as an emergency measure to contain the epidemic, no census was taken and the organization was imperfect. However, it may be assumed with reasonable confidence that some 90 per cent of the available population in the north coastal area received prophylaxis. The post-MDA blood survey done in December, 1972 showed a dramatic fall in falciparum parasite rate from 12.5 per cent in pre-MDA to 0.7 per cent post-MDA (Gibson 1973). Unfortunately this quiescence lasted for only 2 months and there was a rise in *P. falciparum* cases in January, 1973. The reason for this quick resurgence was probably due to insufficient coverage of the total area, the MDA covering only the north coastal area containing 2/5 of the total population in Nggela.

The exercise gave confidence that a monthly MDA with a single combined dose was very effective in reducing the incidence of malaria dominated by *P. falciparum*. A better organized MDA will be repeated in the future if house spraying to be done on a 4-monthly basis fails to improve the malaria situation of Nggela.

DISCUSSION

(a) Mass drug administration

The most difficult problem has been the administration of the correct dosage to the younger age group. A high relapse rate had been found among this group even after the standard 12-week treatment. A second or third relapse is not uncommon. Some of these may not be genuine failure of radical cure but "drug failure" due to improper administration or absorption, or incorrect dosage for age. These cases may often be the cause of maintaining transmission in some localities in Western District. Since it is not easy for children to swallow bitter tablets, chloroquine phosphate (injectable form) was mixed with lemon cordial to obtain a mixture containing 20 mg base chloroquine per 1 cc of mixture. To avoid clumsiness in the field in crushing primaquine tablets into the mixture a preparation of chloroquine/primaquine/lemon mixture was also used. A 10 cc plastic syringe fitted with a rubber catheter 5 cms (2 inches) in length was used to instil the mixture into the mouth. Once the "squirting technique" was mastered it became much easier to administer the correct dose.

In view of some refusals and an indifferent attitude by people in the MDA in North Guadalcanal, it is considered that this exercise should not be prolonged. It should be applied for a short period during the low transmission season to give maximum impact on the parasite. A careful explanation should be given to as many people as possible and close contact kept with the community leaders.

Three useful methods have emerged from trials in the Solomons. These are: (i) in areas with a still high endemicity due to *P. vivax* and *P. falciparum* (i.e. North Guadalcanal) a weekly treatment with chloroquine/primaquine during the low transmission season; (ii) in areas with *P. vivax* liable to epidemic flare up (i.e. the Gilbertese settlements) intermittent rounds, at 2-monthly intervals, with the 5-day chloroquine/primaquine regime prior to expected peak transmission season; and (iii) in areas with predominantly *P. falciparum* liable to epidemic flare up (i.e. Nggela) monthly, or even fortnightly, single dose chloroquine/primaquine prior to and during the transmission season.

There should be no slackening of surveillance during MDAs and care is needed to see that other malaria staff do not take this as an excuse for a well earned rest. The surveillance is needed not only for assessment, but also to pick up and treat any relapsing cases.

(*b*) *Spraying*

Although DDT house spraying fails to interrupt the transmission, is was the DDT that brought the hyper or mesoendemicity on Nggela and Guadalcanal down to the present lower endemicity. A rapid and disastrous deterioration of the epidemiological situation was demonstrated following the inability of spray squads to cope with many rebuilt huts after cyclone "Ida" hit the eastern sector of Guadalcanal. This provided evidence of high transmission potentials in the areas where the pre-spraying endemicity had been extremely high. To enhance protection with DDT it was decided to shorten the intervals of cyclical spraying from a 6-monthly basis to a 4-monthly basis in North Guadalcanal and Nggela.

Change of insecticide is not envisaged at this stage. Because of their exophilic character, large numbers of *A. farauti* still may not come into houses sprayed with new insecticide in those areas where the blood meals are readily available outdoors.

Space spraying by means of ground ultralow volume (ULV) application would be worth trying to reduce outdoor densities of *A. farauti* if this is to be done around villages at dusk. However, its practicability is limited to easily accessible villages on Guadalcanal.

ACKNOWLEDGEMENTS

The authors wish to thank His Excellency the High Commissioner of the Western Pacific for permission to publish. Our thanks are also due to the staff members of the malaria project in the Solomons and the U.S. Peace Corps volunteers for their assistance in the field mass drug administration trials, and to Professor D. F. Clyde of the University of Maryland for his helpful advice and criticism.

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Methods of Malaria Control and Eradication

A. P. RAY

A brief history of the development of the modern methods of malaria control and eradication is followed by discussion of the relative merits of the main measures used in rural and urban areas. The importance of the careful selection by malariologists of feasible methods of control for the particular situation is stressed as is the necessity for meeting the prerequisites before deciding upon a malaria eradication programme. Intradomiciliary spraying of residual insecticides, in particular DDT, is still the method of choice in rural areas, while difficulties have been experienced using this method in urban areas. However in urban areas, engineering works are permanent features in reducing mosquito-genic conditions and although initially more costly would in the long run more than pay for themselves. Account of such methods should be taken in developing town plans.

The inability to control malaria by the use of drugs and larvicides alone is described, but their value as a supplementary measure where other methods may produce an insufficient degree of malaria control is stressed.

A BRIEF BACKGROUND

AN association between malaria and marshy areas has been established from as far back as 400 B.C. References in the early literature, link malaria not only with marshes but also with insects and mosquitoes breeding in such places. Greek and Italian writings point out that drainage of marshes resulted in reduction of mosquitoes and malaria. However, it was not until the late nineteenth century (1880) that Lavern discovered malaria parasites. Subsequently, Ross in 1898 was able to show that anopheles mosquitoes are the vectors of human malaria. Curiously enough the weapon (DDT) which was established by Mueller in 1943, to be highly effective in interrupting malaria transmission was synthesised by Zeidler in 1874 well before the discovery of the malaria parasite. At about this time Koch began advocating the regular use of quinine for prevention of malaria (Ross 1910). These developments led to an organized control of malaria in some of the important construction works such as the Panama and Suez canal zones. The measures included personal protective measures against the biting of mosquitoes, drainage schemes, antilarval activities with the help of oil and chemicals and daily administration of quinine which was also used for the treatment of overt cases of malaria.

Following the outstanding success of these projects and the experience gained for the prevention of mosquito breeding and the destruction of the mosquitoes at the aquatic stages, many antimalarial projects were taken up throughout the world. However, the main weapon DDT, now used against the adult stages of the vector was not well known until the early nineteen forties.

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Limitations of these measures

A closer scrutiny of many earlier projects indicated that the control activities were restricted to large construction areas, agricultural industries like tea and rubber,. mining and similar other economic potential regions, as well as some important urban areas. Financial considerations usually ruled the situation. Where the costs of the antimalarial projects were contingent expenses to work, the administration was prepared to accept the plan, such as during the construction of the Panama Canal, where the expenses towards malaria control measures reached 5½ per cent of capital outlay (Home 1926). It is also well known that industrial organizations with a heavy sickness rate amongst the labour forces, were prompt to support antimalarial projects. For other considerations some urban areas also received a great deal of attention.

Paradoxically, the rural population who bore the main brunt of malaria were left to their own resources because of the enormous financial implications for the control of malaria through the then existing methods.

It was not until the end of the last war that newer tools and better technical knowledge was available for large scale activities in rural areas.