MALARIA IN THE GAZELLE PENINSULA, PAPUA NEW GUINEA

Paul Raymond Crouch-Chivers

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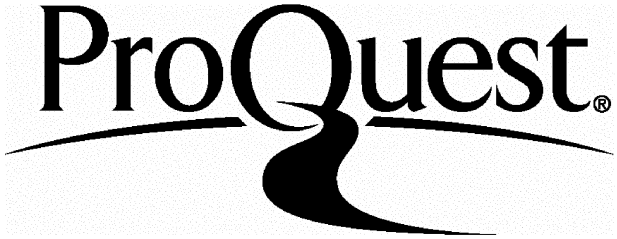
'...and I have no faith in anything
short of actual measurement...'

Charles Darwin 1855
(Life and Letters 11:51)



ABSTRACT

The Gazelle Peninsula is a densely populated area of major economic importance in the Islands Region of Papua New Guinea.

Malaria is endemic in the Gazelle Peninsula and changing patterns of transmission reflect those observed elsewhere in Papua New Guinea. Methods of malaria control have followed global strategies with a change in the recent fifteen years towards control at the individual and village level.

This study examines the epidemiology of malaria in the Gazelle Peninsula. It examines the history of malaria in Papua New Guinea, past attempts to control the disease and malaria morbidity patterns in the Peninsula. Malaria parasite prevalence was estimated by regular blood examination of children. The incidence of malaria was estimated from blood slide surveys of patients attending health facilities. Some behavioural characteristics of a major vector, Anopheles farauti, were studied.

Ten years after the original epidemiological study a review of malaria on the Duke of York Islands was conducted with special attention to permethrin impregnated bed nets and their effect on malaria transmission.

Malaria remained hypo-mesoendemic in most areas of the Gazelle Peninsula with Plasmodium falciparum infection

rates being twice those of Plasmodium vivax. Higher than average rates of infection were noted in Sinivit, Bitapaka and Duke of York Island census divisions. In villages below 200 metres (above sea level) parasite rates were approximately double those for villages above this altitude. Children under one year of age had infection rates considerably lower than those for older children in both high and low altitude villages.

People of all ages were affected by clinical malaria and there was a correlation between blood slide positivity in clinics and admissions to hospital.

Malaria transmission was briefly decreased by use of permethrin impregnated bed nets on the Duke of York Islands. However, a trial failed to demonstrate the long term usefulness of this method of malaria control.

Anopheles farauti maintained vigorous man-biting throughout the night. The vector was sensitive to DDT at doses used in household spraying.

Potential malaria control measures are discussed in the light of the findings of the study and in the spirit of primary health care.

CONTENTS

PART 1 MALARIA TRANSMISSION

FORWARD

The changing patterns of malaria transmission in the Gazelle Peninsula follow patterns similar to those observed elsewhere in coastal and lowland inland areas in Papua New Guinea. For the most part these patterns reflect the changing policies of the national Department of Health and later, the activities of provincial health authorities. In addition, rapid economic development in Papua New Guinea has stimulated migration of populations so that non-immune people have been subjected to hyperendemic malaria situations and people from stable malaria zones have introduced the parasites to previously unstable and non-malaria areas.

Throughout the last 100 years and more specifically since the early 1960s attempts to control the disease have had variable success. The situation in the mid-1980s was one of continuing transmission in most areas of the country below 1500 metres (above sea level) with high morbidity and mortality in children; in Highland areas with unstable, epidemic malaria the burden of the disease was carried by people of all age groups. In the Gazelle Peninsula malaria continued to be a major cause of admission to hospitals and health centres and an important cause of absence from work and school.

Following the cessation of household spraying with DDT in the early 1980s there was no organised programme of antimalarial activities in the country. Instead a loose

collection of ideas and possible strategies was suggested by the national Department of Health. For the most part, however, provincial health authorities had little knowledge on which method or combination of methods would be appropriate for their province and guidance from Port Moresby appeared, at best, erratic.

The problems facing health authorities, politicians, community leaders and the public in 1984 were:

1. What is the burden of malaria in the community?

2. What methodology will best identify areas within the Gazelle Peninsula that are worst affected by malaria?

3. What methodology will establish if malaria has seasonal variations in the Gazelle Peninsula?

4. What are the most cost effective and acceptable methods of malaria control?

5. How can the initiatives of overseas scientists be realistically sustained within existing health sector and community resources?

The study approached these problems using the following methods:

1. The burden of malaria in the community was measured by examining patterns of malaria morbidity and mortality during a prospective examination of hospital records.

2. Geographic and seasonal variations in malaria transmission were studied by:

(a) examining patterns of antimalarial drug consumption at health centres throughout the Peninsula.

(b) establishing a network of indicator villages and periodically sampling blood from children under ten years of age to determine area and age specific prevalence rates for the various malaria parasites.

(c) examining blood slides from patients with fever attending outpatient clinics in Rabaul to determine incidence rates and seasonal variations in transmission.

These studies identified areas of higher malaria transmission in the Gazelle Peninsula.

3. The value of permethrin impregnated bed nets in controlling malaria was studied in one location.

4. An examination of the biting behaviour of a major vector, An farauti, provided valuable information on potential control measures.

5. Sustainability was encouraged by ensuring that all study techniques were designed, implemented and analyzed using local health workers and the community.

In the search for workable solutions to the malaria problem in the Gazelle Peninsula this study examines the epidemiology and impact of the disease and past attempts to control it. Few detailed studies have been conducted in the Peninsula but we shall discuss those studies conducted elsewhere in Papua New Guinea which are relevant to the situation in the Peninsula.

Follow-up studies planned for the mid 1990s were compromised by the massive volcanic eruptions in Rabaul which destroyed the town and large areas of the surrounding Peninsula. Not least in this devastation was the loss of the malaria office and many epidemiological records from 1988.

The changing nature of provincial politics and health priorities created frequent resource constraints and the methods employed during the study were, in places, less than completely reliable. Frequent changes in levels of financial support for local health services necessitated modifications to methodology at short notice but at all times benefits were envisaged from the involvement of local staff. The results have been analyzed in a manner that furnishes practical information on control measures for malaria.

This work was analyzed and prepared on a Toshiba T1200 computer using MS Works, MS Word and Harvard Graphics programmes.

ACKNOWLEDGMENTS

This study was performed whilst the author was epidemiologist with the Department of Health in Papua New Guinea from 1985-1987. It describes the epidemiology of malaria in the Gazelle Peninsula, where the author was based. Much of the work described is on-going and is now being performed by the provincial health authorities.

This work would not have been possible were it not for the support of a multitude of people. At the Department of Health in Port Moresby Dr Q Reilly, former Secretary for Health, provided the medium for these studies. In Rabaul continual assistance was received from Mr E Renyard (Scientific Officer), Mr L Yalla (Technical Officer), Dr M Bolton (Assistant Secretary for Health, East New Britain Province) and field assistants Ravien and Martin. A host of malaria staff assisted with the collection and examination of blood slides and mosquitoes. At the Papua New Guinea Institute of Medical Research in Goroka and Madang considerable support and encouragement was given by Dr M P Alpers (Director). Drs P Heywood and P Garner and Professor I Riley also encouraged the establishment of the study. Continuous encouragement was received from colleagues Drs L Duncan and K N Edwards and from my London supervisor Professor D J Bradley (LSHTM).

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Finally my children, Simeon and Chou'upta, persevered with me throughout the duration of the study and must receive credit for their unending patience.

INTRODUCTION

Papua New Guinea (PNG) is an independent country in the southwest Pacific. It lies between latitudes 1 and 12 degrees South and longitudes 141 and 160 degrees East. It is east of the Indonesian province of Irian Jaya and north of Australia. The country consists of the eastern half of the island of New Guinea and islands to the northeast and east, the largest of which is New Britain (fig 1.1). The Gazelle Peninsula lies at the northern end of New Britain Island (fig 1.2).

The mainland of PNG is characterized by lowland swamps and plains and a central mountain range. Within these mountains is a complex system of ranges, upland valleys and volcanoes. North of this range lies the Sepik-Ramu-Markham trough and an area of plains and lowland swamps drained by the Sepik and Ramu rivers which flow north into the Bismarck Sea. The southern plains and lowlands extend from the south coast to the foothills of the central ranges. In the west these areas are drained by the Strickland and Fly rivers which flow into the Gulf of Papua. The central and eastern parts of these southern lowlands consist of marshy, coastal plains at the mouths of the many rivers, including the Purari drainage system, merging upstream into relatively well drained alluvial plains.

THE GAZELLE PENINSULA

The southern Bismarck island arc includes the island of New Britain. It is a typical island arc with a deep oceanic

trench to the south and a belt of volcanoes along its concave, northern coast. Most of the volcanoes are active or potentially so.

The island is divided politically into the West New Britain and East New Britain provinces with administrative centres at Kimbe and Rabaul respectively.

In the Gazelle Peninsula the town of Rabaul is located within the crater of two volcanoes. It is surrounded by the active secondary volcanoes Tavuvur, Palangiangia, Rabalanakaia, Kalamanagunan and Hatwara. The extinct cones of Tovanumbatir, Kabiu and Turangunan also dominate the town. The southern part of the peninsula is mountainous, heavily forested and sparsely populated compared to the northern part which is described below. The entire area experiences frequent tectonic and volcanic earthquakes. In September 1994 the almost simultaneous eruptions of Tavuvur, and Kalamanagunan volcanoes destroyed much of the township of Rabaul and surrounding countryside in Kombiu, Balanataman, Reimber, Central and Raluana census divisions.

In the northern part of the peninsula the soil is mainly volcanic ash and pumice and is very absorbent. The area is extensively cultivated with vegetable gardens, cocoa and coconuts. Climatic conditions in the peninsula are hot and wet. Rainfall averages 2500mm-4000mm per year with marked wet and dry seasons. During the drier months May through November rainfall averages 100mm per month. The daily

temperature ranges from 23 deg C to 32 deg C and humidity is 60% to 75% in Rabaul (McAlpine et al 1975).

The studies described here were performed in villages in the northern part of the Gazelle Peninsula, Watom Island to the north and the adjacent Duke of York Islands, which are situated between New Britain and New Ireland. The area is bounded in the south by the Kerevat, Nengmutka (Wawoi) and Warangoi rivers. In this area of 1400 square kilometres live approximately 101,000 people, which is 42% of the population of New Britain island. The area is densely populated: 65 people per square kilometre in the east, more than 110 people per square kilometre in the north and more than 600 people per square kilometre in the Rabaul urban and periurban areas. Main urban centres are Rabaul (population 16,000 in 1985), Kokopo (population 1,000) and Kerevat (population 1,000). The urban population comprises 19% of the study population.

There are 700 languages in PNG and linguistic and cultural patterns show a remarkable lack of uniformity. In the Gazelle Peninsula the Tolai people are the main cultural group. The main local language is Kuanua amongst the Tolais with Neomelanesian (Pidgin) and English the main languages of commerce and education.

There is an extensive road system in the area. Houses are traditionally built from woven bamboo, pandanus and coconut palms and are raised from the ground on wooden piles. A grass thatch forms the roof. Many traditional houses have

been replaced by permanent constructions with cement floors, fibro-cement walls and corrugated iron roofs. Some have insect screening and rain water tanks. Many villages have mains electricity but few have mains water supply.

A BRIEF HISTORY OF PAPUA NEW GUINEA

This account of the history of PNG is offered as a framework alongside which the early studies on malaria may be interpreted (Fig 1.3).

The earliest recorded descriptions of the island of New Guinea (Os Papuos) were made in the 16th and 17th centuries by Spanish and Portuguese navigators who were seeking new sources of spices, in addition to those already discovered in the Molluccas (Collingridge 1982). It was not until September 1875 that the first settlement of any permanency was established in what is now PNG.

The Methodist missionary George Brown and a group of missionary teachers from Fiji, Samoa and Tonga established their first station at Port Hunter (Molot) in the Duke of York islands and soon after at Raluana on the mainland of the Gazelle Peninsula. Commercial enterprises followed in 1876 at Makada (E Hernsheim & Co) and in 1877 at Mioko (T Farrel and E Forsythe - Goddefroy & Co, later Deutsche Handels-und Plantagen Gesellschaft) in the Duke of York islands.

In 1880 the notorious Marquis de Rays attempted to establish the colony of New France at Port Breton on the

southernmost tip of New Ireland. Malaria killed many of the original 150 colonists and disabled the remainder (Floch 1987). The colony was abandoned in 1882.

On 3rd and 4th of November 1884 the German flag was raised at Matupit island, near to where Rabaul now stands, and at Mioko. This action declared a German protectorate of the Bismarck Archipelago, the smaller islands and the New Guinea mainland. The protectorate was called Kaiser Wilhelmsland. Two days later J E Erskin proclaimed British sovereignty in that part of New Guinea between 141 and 155 degrees east longitude (Papua). In 1884 the west New Guinea mainland was annexed by The Netherlands.

From 1885-1889 the Neuguinea Kompagne administered German New Guinea. In 1889 the Imperial German Government took over administration and established their headquarters at Herbertshohe (Kokopo). This centre of government was transferred to Simpsonhafen (Rabaul) in 1910.

In 1901 in British New Guinea the Papua Act transferred the administration of British New Guinea to the Commonwealth of Australia and renamed it Papua. Australia took full control in 1906.

The entire country was under Australian military occupation from 1914-1921 during and immediately after the first world war. The Mandated Territory of New Guinea was then administered by Australia under League of Nations mandate from 1921 until the commencement of the second world war.

In 1942 the Australian New Guinea Administrative Unit (ANGAU) replaced the civil administration for the duration of the second world war.

The Japanese occupied the Gazelle Peninsula and part of the northern mainland from 1942-1945.

In 1946 civil administration returned to Papua and New Guinea; in the same year the United Nations approved a Trusteeship Agreement for New Guinea. In 1949 the Papua and New Guinea Act formalised the arrangement and established a legislative council for the Territory. The Territory of Papua and New Guinea was administered by the Australian government through the Administration in Port Moresby.

The country became self governing in 1973 and independent on 16th September 1975.

MALARIA IN PRE-INDEPENDENT PAPUA NEW GUINEA

For the purposes of clarity the name Papua New Guinea (PNG) will be used throughout. Most places are indicated on Fig 1.3.

In 1871-1872 and for six months in 1876 the Russian diarist and scientist Nicolai Miklоucho-Maclay lived at Garagasi Point, Astrolabe Bay near to where Madang is now located. His diaries describe his scientific observations and his sufferings from malaria (Miklоucho-Maclay 1975).

On 10th October 1871, three weeks after landing at Garagasi he notes;

'my first attack of fever laid me low today'.

On 13th October;

'I had another attack of fever. All are ill. It is very bad and when the rainy season begins it will probably be still worse'.

In 1878 Eduard Hernsheim noted at Makada in the Duke of York Islands that;

'the climate has proved to be very unhealthy and not a single white man escaped attacks of fever'.

In 1879 Hernsheim moved his commercial enterprise to Matupit which was at that time free from the unhealthy climate of Makada. At the same time other trading posts in Mioko in the Duke of York Islands moved to the mainland. Hernsheim noted that mosquitoes did not occur on Matupit but were present everywhere else along the coast (Sack & Clark 1983).

The German physician Schellong was based at Finschhafen on the mainland from 1886-1888 and described the malaria situation at this station (Ewers 1973). In 1886 there were 32 Europeans, 25 Malays and ten Chinese at Finschhafen. Half of the Europeans and 80% of the other groups suffered from malaria in one month. Schellong noticed that during construction of the town malaria was three times more common among those colonists who lived ashore compared to those who slept aboard a ship anchored in the harbor.

During Schellong's 26 months at Finschhafen there were 1402 cases of malaria amongst the colonists. In June 1887 every European suffered from the disease and in July 70% of the Europeans and 86% of the Melanesians suffered from it. Many Europeans were anaemic, had a 'nervous appearance' and had greatly enlarged spleens. Schellong notes;

'I knew six Europeans who only faintly resembled the people they were when they arrived some months before'.

Clinical malaria was diagnosed only half as often amongst Melanesians as in Europeans and Schellong attributed this to the Melanesian practice of burning fires at night and to not washing, so that the skin was covered with a permanent smoke and dirt crust.

The first information of malaria in the Gazelle Peninsula comes from Schellong who described that 27 out of 70 labourers from the area had enlarged spleens on arrival at Finschhafen.

Quinine was the only drug available for the treatment of malaria. It was also taken daily to prevent malaria. Because of the bitter taste of the only available liquid form of quinine Malays and Melanesians were reluctant to take it, even when sick. There were seven cases of blackwater fever at Finschhafen during Schellong's period there; most cases were fatal.

An outbreak of malaria in 1891 killed eleven Europeans, including the doctor. Survivors fled west to Stephansort

(Bodagim) and Hatzfeldhafen on the north coast and Finschhafen was abandoned. It is likely that these colonists introduced malaria into this previously malaria-free area.

Friedrich-Wilhelmshafen (Madang) was established in 1891-1892 and Dr Otto Dempwolff was the physician there from 1895-1898. During these three years there were 75 Europeans at Friedrich-Wilhelmshafen of whom four died from malaria and 20 were sent home to Germany because they were so sick. In two years Dempwolff noted 225 episodes of malaria amongst 57 Europeans and 768 episodes amongst 500 non-European workers. One European died and 55 non-Europeans died during this period, twelve of malaria. 18% of all illness amongst Europeans was malaria, including eighteen cases of blackwater fever.

On Robert Koch's recommendation Dempwolff returned to New Guinea from 1901-1903 and worked in various parts of the colony, including the Gazelle Peninsula. In the Gazelle Peninsula Dempwolff noted that the picture of malaria was quite different to that on the mainland. Malaria infection rates were lower and malaria affected adults and children; both groups had high spleen rates. There were malaria free areas adjacent to highly endemic areas and Dempwolff likened the situation to a chessboard; anophelines were found only in the endemic areas. Matupit was free from anophelines. At Herbertshohe (Kokopo) Europeans suffered severely from malaria and Dempwolff suggested that movements of infected people were spreading the disease to

previously malaria-free areas. Malaria incidence increased three-fold during the wet season and Dempwolff suggested that the native population had low immunity to the disease because it was seasonal.

Dempwolff also noted that many of the northern islands (Ninigo group, Wuoulu, Maty and Aua) were malaria free until the disease was introduced during early European contact.

The first literature in English on malaria in New Guinea came from Robert Koch. In 1900 Koch published a series of papers in the Deutsche Medicinische Wochenshrift, translated in the British Medical Journal the same year (Koch 1900 a, b, c, d).

Koch investigated malaria in Java and mainland German New Guinea. Like Schellong and Dempwolff his studies demonstrated several epidemiological features of malaria that have subsequently been shown to be a consequence of vector ecology and behaviour and human ability to acquire immunity to the disease. Koch noted that parasite rates were higher in children and he suggested that immunity was acquired by repeated infection. Malaria was rare in the Java highlands where there were no mosquitoes. Koch also noted that early attempts to control malaria were enhanced by its exclusivity to man. Thus he was able to decrease illness by 50% in the colonial army by prophylactic quinine.

At Stephansort on the north coast of the mainland Koch noted that malaria was mainly a feature of native children and immigrants (Chinese, Malays and Europeans). Amongst 273 Chinese labourers brought to Stephansort from Hong Kong in 1898, 125 died within one year, mostly of malaria. Because of this loss of life and illness due to malaria in immigrants Koch suggested that indigenous labor be bought only from areas known to be endemic with malaria.

Very few places in German New Guinea were considered absolutely free from malaria because people could carry the parasite in their blood for many years without being clinically ill. From his studies on migrant labourers from Neu Pomerania (New Britain) and Neu Mecklenburg (New Ireland) Koch suggested that these areas must be free from malaria. This observation is in contrast to that of Schellong who earlier noted that labourers from the Gazelle Peninsula had high spleen rates. These differences may be explained by the apparent patchy nature of endemicity in the area noted by Dempwolff.

Koch used quinine as the sole therapeutic measure. Proper treatment with quinine prevented relapses from tropical (tertian) malaria and weekly quinine prevented clinical malaria. Indeed he suggested that regular use of quinine may be a means of 'annihilating' malaria from German New Guinea;

'We are in a position, by means of the procedures which I have described, to make every malarious region, according to circumstance, wholly or nearly free from

malaria. Given a number of doctors, a sufficient supply of quinine and an intelligent and obedient population it will not be difficult to carry the struggle against malaria to a successful issue' (Koch 1900 c).

Koch suggested that persuasion and small presents might induce the population to consume the bitter quinine.

Koch notes that he intends travelling to Herbertshohe on the Gazelle Peninsula to continue his studies but there are no records of this visit.

Further reports of malaria in PNG describe the disease as it affected Australian soldiers, explorers and colonists as they entered the country during the First World War and afterwards. During the First World War Australian forces were affected with malaria (Breinl & Priestley 1916). A number of men had recurrences of malaria despite comparatively large doses of quinine. It appeared that Plasmodium vivax parasites from New Guinea were more resistant to quinine than those from other localities. These early authors may have been unaware of the limited action of quinine on the exo-erythrocytic forms of P vivax which cause relapses and of its lack of action against the P falciparum gametocyte.

Heydon performed surveys in Rabaul in the early 1920s (Heydon 1923). At this time the population of the town was '350 white, 1000 Asiatics, chiefly Chinese, and 1500 natives'. Anopheles punctulatus (Donitz, var moluccensis,

Swellengrebel) was thought to be the main vector in the area at the time. It was found breeding in swampy pools and ditches close to the shore where subsoil was close to the surface. Uncovered wells throughout the town also served as breeding sites. Periodic oiling and filling in of swampy areas and disused wells was advocated to control the vector.

Heydon confirmed the findings of the earlier German workers and noted that the variability in infection rates between villages was greater than seasonal changes in any one village. It was also demonstrated that the parasite rate rises to an early maximum and falls sooner than does the spleen rate amongst the native population.

After the First World War soldiers and civilians living in New Guinea were advised to take prophylactic quinine (Strong 1923). Strong recommended quinine bisulphate 0.3 grammes (5 grains) three times daily on Saturday and Sunday. He also stressed that it was important to avoid 'cold, over fatigue, constipation and excesses of all kinds'.

Irregularity of quinine intake and its role in blackwater fever was well known since the turn of the century. It is, perhaps, surprising that this complication of P falciparum malaria was not more common when quinine was as widely used as it was (Cavlov 1925).

THE EPIDEMIOLOGY OF MALARIA IN PAPUA NEW GUINEA

The story of the study of malaria in PNG follows the paths of the early explorers and colonists (Black 1974, Van Dijk & Parkinson 1974). As the country was explored and government stations established in already populated coastal and highland regions so the malaria situation was studied by government scientists and researchers. The colonisation process not only enabled malaria to be studied but it also changed the epidemiological pattern of the disease in various ways.

Traditional societies in PNG, particularly those in the highlands, were usually restricted to small areas. Non existent roads, steep mountains, deep valleys and intertribal warfare ensured that the spread of infectious disease was limited by minimal population movement (Black 1956 a). The most distant travel in pre-colonial times may have been to adjacent islands or valleys for gardening purposes and only few groups were nomadic (McMahon 1974 a). Temporary dwellings at lower altitudes exposed people to a potential malaria risk different to that at their home (Houghton 1980) but spread at higher altitudes was limited by the small, isolated nature of the populations and the reduced survival of the vector.

The establishment of areas of urbanisation encouraged indigenous migration to colonial towns as people sought employment and education, or were just curious. Major roads linked the highlands to the coast and increasing trade ensured regular movement of people, parasites and

vectors. Whilst ethnic groups retained strong attachments to their land, from the 1930s road, sea and air travel made visits to and from areas of differing malaria endemicity possible (Gunther JT 1955, Sharp 1979). Europeans and indigenes from highly malarious areas imported malaria parasites into unstable areas. Vector breeding potential was increased by road building, especially for An punctulatus. Agricultural and engineering developments created breeding sites for vectors and encouraged population movement (Sharp 1982, Houghton D 1974).

Massive environmental and population disturbances occurred in the New Guinea islands and along the north coast of the mainland during the Second World War: inland migration occurred and bomb craters were ideal for An punctulatus breeding (Black 1956 a).

An early and continuing situation which has enabled economic development in both highlands (tea, coffee) and lowland and coastal (copra, cocoa, rubber) areas has been population movements as part of organised labor schemes (Radford et al 1976). Similar schemes have been responsible for malaria epidemics elsewhere in the world (Ramsdale & Hass 1978).

In PNG people were recruited from areas of low malarial endemicity to work in plantations in mesoendemic and hyperendemic coastal and lowland areas. The resultant morbidity and mortality amongst this non-immune population encouraged the protection of labourers by legislation

(Territory of Papua and New Guinea 1953). The Native Labour Ordinance 1950-1952 was aimed mainly at highland labourers working in coastal plantations. It ensured that all plantation managers provided basic health care for their employees, including regular malaria prophylaxis. However, enforcement of this legislation in recent years has not been vigorous.

More recent major economic projects (Panguna copper mine in Bougainville [now closed], Ok Tedi gold and copper mine in the Star Mountains, Western Province) have made considerable efforts to reduce the effects of malaria in workers and hence the economic viability of these projects.

PNG may broadly be divided, in malaria terms, into the unstable Highlands, in which epidemics are seasonal features and the endemic coastal and lowland areas.

The Highlands comprise the valleys and mountains within the broad, central cordillera of the mainland. These areas are generally greater than 1500 metres above sea level but with valleys and fringe areas at lower altitudes. These highland areas of the mainland and similar areas in New Britain have marked dry seasons with cold, sometimes freezing, nights. The most detailed studies of malaria epidemiology in these areas were conducted in the 1950s, by which time early colonisation had already resulted in a significant flow of man, parasite and vector between zones of differing endemicity.

The Waghi Valley is a wide, fertile valley in the Highlands which has been a centre for agricultural development. The main town in this area, Mount Hagen, was a focus for exploration and settlement of more distant areas and is now a major commercial centre. The town of Minj is located at the eastern end of the valley and it was from this station that early malaria studies in the Highlands were carried out.

The main vectors in the Highlands are An punctulatus farauti Laveran and An punctulatus Donitz 1901. An punctulatus is found up to 1900 metres above sea level (Peters et al 1958), the upper level of malaria transmission being 1800-2000 metres. Other anophelines are found at these altitudes but are not incriminated in malaria transmission.

Malaria in the Highlands is unstable in areas above 1500 metres. Epidemics occur following the wet season when the water table rises in the valley floor and An punctulatus breeding occurs in shallow, temporary pools with clay in suspension (Sharp 1979). These seasonal epidemics may involve 50% - 70% of the population with 1% - 2% deaths (Peters & Christian 1960 a). It is most probable that there was formerly a much larger population in the Highlands and that depopulation was at least partly due to malaria. The slide positivity rate during an epidemic may reach 78%, being mainly P falciparum trophozoites and gametocytes. All ages of this non-immune population are affected during these epidemics. P vivax is more common

during non-epidemic times when malaria is, at best, hypoendemic-mesoendemic (McMahon 1974 b, Spencer TET & Spencer M 1955, Sharp 1979, 1982). During the dry season mosquito breeding declines and parasite rates fall to less than 5% with gametocytes less than 1%. Also during the dry season night temperatures fall considerably; people spend the evening inside smoke-filled huts. Vectorial capacity and man-mosquito contact are reduced to such a level that transmission no longer occurs (Peters 1965).

The picture of malaria in the lower lying and coastal areas is quite different. Climatic and environmental conditions are ideal for permanent breeding of An punctulatus inland and An farauti on the coast (Peters & Standfast 1957). Some An koliensis Owen and An karwari James have also been noted in areas bordering Irian Jaya and An koliensis in the Gazelle Peninsula towards the Bainings mountains in the south.

In these hot, humid regions people spend most time outside, particularly in the evenings. Many sleep outside and unprotected at night (Houghton 1980).

In Maprik in the Sepik region of the mainland there is intense transmission (Peters 1960 a, b, Peters & Standfast 1957). Malaria is holoendemic as shown by an adult spleen rate of 26% - 47% and infant and toddler spleen rates of 100%. In the 1950s the adult parasite rate was 83%, being mainly P falciparum with a high percentage of gametocytes.

An punctulatus is long lived, highly endophilic and endophagous in Maprik. The inoculation rate for this vector is 0.015 and Peters predicted that an 80% daily mortality would be necessary to interrupt transmission. He suggested that this would be difficult to achieve with six monthly spraying of residual insecticide and this has proven to be so (Peters 1960 b).

The Maprik area has been the only documented consistently holoendemic area in the country but other lowland areas have intermittently holoendemic zones particularly where large, previously non-immune populations have migrated. In the Madang area wide variations in the pattern of malaria have been noted, although a generally hyperendemic situation exists (Tulloch et al 1982). Early surveys in Manus, Sepik and around Lae and the north coast of Papua show a generally hyperendemic situation with seasonal changes following variations in rainfall (Hairston et al 1947, Mackerras & Aberdeen 1946). In the southern part of the mainland malaria is hyperendemic in Western Province (Peters 1957 a, Cattani et al 1983), mesoendemic in Kairuku (Zigas & Morea 1974) and hypoendemic to holoendemic in the D'Entrecasteaux Islands (Black 1954 a, Spencer TET 1962).

The three main vectors of malaria in PNG, An farauti, An punctulatus and An koliensis are found in different densities, at different altitudes and during different seasons. Most entomological surveys have been carried out by Peters, Christian and the Spencers. They made major contributions to our knowledge on malaria in PNG in the

1950s and 1960s. From 1958 to 1964 Peters published a series of detailed papers on the morphology of rarer Culicidae in PNG (Peters 1959 a, b, 1963 a-d, 1964) and with other authors has described the entomological situation in the Highlands and Sepik (Maprik) areas.

We have already noted the importance of An punctulatus and An farauti in the Highlands. An punctulatus prefers breeding in small, temporary collections of water, often with suspended clay material, such as are found alongside road constructions where inadequate drainage provides a situation for prolific breeding. An punctulatus also prefers areas of domestic construction and farming where similar ecological niches exist. An punctulatus has a marked seasonal pattern of breeding, densities increasing during the wet season.

At Minj in addition to An punctulatus Donitz and An farauti Laveran, An punctulatus 'intermediate' forms, (possibly An koliensis Owen), An annulipes Walker, An bancrofti Gilles and An papuensis Dobrotworsky (= An stigmaticus Walker) were found. Of these anophelines An punctulatus, An farauti, An koliensis and An bancrofti transmit malaria at lower altitudes. An annulipes has not been found to be infected in PNG although it is in Australia (Mackerras 1947). An farauti is the most abundant vector biting man in Minj (Peters & Christian 1960 b). An punctulatus is also found throughout the Highlands although it was earlier absent from the Goroka valley (Peters et al 1958).

Because of the lower temperatures in the Highlands aquatic stages and adults are larger. Females imbibe larger blood meals and the chance of becoming infected with gametocytes is increased. This is important in transmission when gametocyte densities are low.

An farauti has a distinct preference for human blood but will also feed on pigs and dogs. Despite the high concentration of smoke in highland houses An farauti is endophagic and endophilic.

An punctulatus lives longer at lower temperatures and it is likely that An farauti also does. 50% of An farauti survived sixteen days in the laboratory in one report (Peters & Christian 1960 b). The sporozoite rate of An farauti at Minj was 0.54% although rates up to 2.2% were recorded during the wet season. In specimens over sixteen days of age the sporozoite rate increased to 6.3%.

The peak man-biting density of An farauti is 80 times its dry season level and of all An farauti entering houses 70% feed on man and rest on the walls after feeding. At 20.6 deg C the gonotrophic cycle of An farauti is four days and the extrinsic cycle of P falciparum is 21 days, of P vivax sixteen days and of P malariae 28 days.

The marked seasonality of An farauti and An punctulatus in the Highlands makes control by residual insecticide spraying much more feasible than in areas where breeding

occurs throughout the year. DDT spraying shortly after the commencement of the wet season would be optimal for control.

In Maprik the main vector was An punctulatus which maintains a high density throughout the year (Peters & Standfast 1960). An farauti and An koliensis were also noticed in this area but at lower densities. There is no marked dry season in this area and humidity is constantly 70% - 90%. The daily survival for An punctulatus was 0.87 which indicated a low daily mortality. The sporozoite rate for An punctulatus varied from 1.0% to 6.1% with a mean of 3.3%. For An farauti the sporozoite rate was 2.4% and for An koliensis 2.9%.

In Maprik An punctulatus spends at least part of the night indoors, a small proportion spending at least 24 hours indoors. It has a biting peak at midnight whilst An farauti shows a preference for the early part of the night. An koliensis bites at all times. In contrast An farauti in Wewak bites readily outdoors shortly after dusk and some distance from habitation and in Madang An farauti and An koliensis have peak biting in the early hours of the morning.

In all study areas (the Highlands, the Sepik, Madang and the D'Entrecasteaux Islands) it was established that biting by anophelines occurred both inside and outside of village houses and that large numbers rested inside houses at night, leaving during the later part of the night and at

dawn (Peters & Christian 1960 b, Spencer TET 1962, Spencer M 1965).

In the Madang area malaria transmission increases during the August to January period in the southern region and September to February in the northern region, commensurate with increases in rainfall (Afifi et al 1980). An farauti and An punctulatus and to a lesser degree An koliensis are the vectors in this area. An farauti has similarly been noted as the main vector in the D'Entrecasteaux Islands (Spencer M 1965) although An punctulatus is also found there.

In the Gazelle Peninsula and Duke of York Islands An farauti, An punctulatus and An koliensis are found although An koliensis is limited to the inland, forest fringe areas of the Baining mountains. An farauti breeds along the coastal fringe and An punctulatus in temporary collections of water inland (Spencer TET et al 1974).

More recently the An punctulatus group of mosquitoes has been demonstrated by cellulose acetate allozyme electrophoresis to comprise six species and An farauti No 1 is found throughout the coastal areas of PNG and the Solomon Islands and this appears to be the predominant vector in the Rabaul area (Foley et al 1993, Foley et al 1994). In addition genomic DNA probes have been prepared for An punctulatus, An koliensis and An farauti No 4, An farauti No 5 and An farauti No 6 (Beebe et al 1994). This method enables species identification using squash or dot

blot preparations of parts of the mosquito. We anticipate these techniques will facilitate description of epidemiological features of the various species of malaria vector in PNG.

CLINICAL MALARIA IN PNG

It is not the aim of this study to document clinical features of malaria which are well described elsewhere. Clinical symptoms and signs of malaria in PNG are similar to those described in other malarious countries (Gracey & Biddulph 1968). There are, however, some interesting and unusual features of PNG malaria which are noteworthy.

In stable areas malaria is mainly a feature of children and non-immune immigrants. In children fever, hepatosplenomegaly, anaemia and/or convulsions are the main presenting features. Other symptoms include diarrhoea and vomiting, cough, jaundice and disturbances of consciousness (Eastman 1974). The best clinical predictors for a positive blood slide in children are splenomegaly and fever in the absence of cough, chest indrawing and diarrhoea and temperatures above 38 deg C are a good predictor of P falciparum infection. In adults vomiting often predicts P falciparum infection (Genton et al 1994).

Most deaths from malaria are due to cerebral malaria. Deaths usually occur soon after admission amongst children who have been ill for more than two days at home (Suebu 1976). Cerebral malaria occurs more commonly amongst older children in PNG but does not appear to be more common

amongst children from the Highlands who, it might be assumed, are less immune (Stace et al 1982). In highland hospitals patients of all ages are admitted with equal frequency, especially during epidemics and with similar morbidity and mortality patterns (Peters & Christian 1960 a).

A low case fatality rate, 5.4%, was achieved in Madang using intramuscular quinine in cases of cerebral malaria (Stace et al 1982). Other centres record case fatality rates for cerebral malaria ranging from 29% (Mount Hagen) to 85% (Lae).

More insidious effects of malaria are due to anaemia. Haemolysis due to malaria and blood loss due to hookworm infestation are the main causes of iron deficiency anaemia in PNG (Williams & Naraqui 1979). Although it is difficult to quantify the contributions of these infections to anaemia malaria contributes significantly to anaemia observed in coastal and low lying inland areas of the country. Malaria induced anaemia almost certainly compromises the immune response to infectious agents resulting in high mortality from pneumonia and diarrhoea. Severe anaemia with or without symptoms of malaria is not unusual and haemoglobin levels of less than 7.0 G% are common (Neave 1976).

Almost all splenomegaly in PNG is due to malaria; there is no schistosomiasis, leishmaniasis or sickle cell disease which cause splenomegaly in other developing countries.

The relationship between splenomegaly and anaemia has been studied, in particular the role of the grossly enlarged spleen of tropical splenomegaly syndrome (Vines 1967, Crane & Pryor 1971, Parry et al 1974, Crane et al 1985). The spleen enlarges in response to recurrent malaria infection; at the same time it removes parasites and erythrocytes from the circulation.

In the Upper Watut Valley the highest parasite rates were observed amongst those adults without splenomegaly and P vivax was the most common parasite found in this stable, mesoendemic area. The spleen rate decreased at altitudes greater than 5000 feet (1500 metres) as malaria transmission decreased. Peak parasitaemias were seen in children aged three years.

Tropical splenomegaly syndrome was seen mainly in adults and regular antimalarials administered to these people resulted in a reduction of spleen size and increases in haemoglobin levels (Parry et al 1974). Immune complexes containing IgM, other immunoglobulins, complement and malarial antibody were present in tropical splenomegaly syndrome (Crane 1977) and improvement with antimalarials was almost certainly due to freedom from circulating malaria parasites, as shown by decreases in serum IgM levels.

Malaria control activities in the islands region were similarly responsible for increases in haemoglobin levels (Vines 1967).

It is, perhaps, surprising that the grossly enlarged spleen in tropical splenomegaly syndrome does not rupture more frequently. Most reports of ruptured spleen in PNG, whether spontaneous or traumatic, occur when the spleen is impalpable (Symes & Smyth 1959, D Hamilton personal communication).

In many areas of the south west Pacific hepatomegaly has been noted as well as splenomegaly in the chronically malaria infected individual. There is a positive correlation between liver and spleen size in older children and adults in this area (Black 1955 c, Black 1956 a). However, poor diet may also contribute to liver enlargement.

Papuan children with an adequate diet and malaria had smaller livers than those with a poor diet and malaria. The liver was smaller in children with an adequate diet whether the spleen was enlarged or not (Oomen 1957). In the PNG highlands the influence of protein malnutrition on liver enlargement is considerable, particularly amongst children (Peters 1957 b). Nutritional status is therefore important when assessing hepatosplenomegaly in malaria.

In endemic areas recurrent malaria is associated with chronic malnutrition, as evidenced by stunting of growth in children under two years of age, in both highland (Sharp & Harvey 1980) and lowland (Vrbova et al 1982) populations. This stunting may result from retarded intrauterine growth

and low birth weight, as demonstrated in Africa (McGregor IA et al 1983), or from a direct effect on the growth of young children. This later relationship is suggested by an association between splenomegaly and stunting noted in highland children. The long-term effects of recurrent malaria on childhood growth depends also on childhood feeding practices so that adequate nutrition may limit stunting (Heywood & Harvey 1986). Although malaria infection is less common is severely malnourished children, recurrent malaria and chronic malnutrition are factors predisposing to high mortality in this age group.

The relationship between malaria and malnutrition has been described in Africa (McGregor etal 1956) and the complexity of the relationship is reflected in the many factors impacting on the epidemiology of the individual conditions.

The relationship between malarial nephrosis and P malariae infection has been well established (James 1939). 80% of these children are under seven years of age and present with oedema, ascites, albuminuria, splenomegaly and anaemia. 53% have P malariae in their blood. The condition responds well to antimalarials. Of those who die of renal failure secondary amyloidosis may be a complicating feature. Secondary amyloidosis has been described amongst the Anga people of the Watut Valley (McAdam 1978) who appear to be genetically susceptible to amyloidosis when subjected to a sufficient stimulus. Malaria is probably the prime stimulus for elevation of serum amyloid A protein. This same population is

susceptible to tropical splenomegaly syndrome (Crane & Pryor 1971).

INHERITED FACTORS AND MALARIA

Hereditary ovalocytosis is an uncommon condition in PNG (McMillan 1968) and Eastern New Guinea (McMillan & Kelly 1967). The condition has dominant inheritance in most areas (Castelino et al 1981) although a distinctive type of the condition with an autosomal recessive inheritance has been reported in high prevalence amongst some tropical lowland dwellers (Amato & Booth 1977). Interest in this condition centres around, amongst other factors, its relationship to infection with P falciparum. There is evidence that ovalocytes are resistant to infection with P falciparum and this has been demonstrated during in vitro culture of parasites (Kidson et al 1981).

Early field studies failed to demonstrate any relationship between ovalocytosis and malaria in children (Babona & Amato 1976) but later work suggested otherwise (Castelino et al 1981, Serjeantson et al 1977, Kidson et al 1981). Parasite rates for both P falciparum and P vivax were lower in 2-4 year old children with ovalocytosis in one study (Cattani et al 1987). The situation in the Ok Tedi region of Western Province is less clear, there being no obvious protective effect of ovalocytosis on P falciparum infection although there may be some protective effect against P vivax and P malariae infections (Schuurkamp et al 1989).

The nature of resistance of ovalocytes to infection with P falciparum is not fully understood but ovalocytes appear to be more thermostable and less deformable than normocytes, a potentially important factor in the ability of merozoites to penetrate the erythrocyte membrane. The more recently described Band 3 protein variants may be the important cell membrane components which prevent entry of the malaria parasites to the erythrocyte (Jones et al 1990).

Hereditary ovalocytosis does appear to be restricted to areas of endemic malaria in PNG and may, therefore, be selectively more frequent by the resistance it confers to infection with P falciparum (and P vivax).

As with hereditary ovalocytosis there is a similar relationship between glucose-6-phosphate dehydrogenase (G6PD) deficiency and malaria (Yenchitsomanus et al 1986, Schuurkamp 1992). There is evidence that G6PD deficient cells do not support the growth of P falciparum (Roth et al 1983) and this factor may therefore be at a selective advantage in malaria areas. In ENBP the prevalence of G6PD deficiency in males in 0-19%.

The sickle cell gene and Duffy negative blood group, which are important protective influences against P falciparum and P vivax malaria in Africa, are not found in PNG (Ree 1979). However, in PNG there is strong correlation between alpha thalassaemia and malaria prevalence. On the north coast of the mainland, where malaria is hyper-holoendemic

the frequency of alpha thalassaemia is 68% compared to the Highlands (unstable malaria) where the frequency of the gene deletion in 2-5% (Flint et al 1986). In other areas of intermediate transmission the frequency of alpha thalassaemia is 24% and in ENBP 11.5%. The prevalence of beta thalassaemia is not so dramatically correlated with malaria infection, probably because of the more serious consequences of the disease. The prevalence of beta thalassaemia in ENBP is 4.3% and up to 8% in other coastal areas (Booth & Garo 1978, Hornabrook et al 1972). The condition is rare in the Highlands (Vaterlaws et al 1981).

The Gerbich blood group antigen is also correlated with the prevalence of P falciparum and P vivax infections (Serjeantson 1989). Lower infection rates are found in Gerbich negative people (8%) compared to Gerbich positive people (19%). It is also noteworthy that 10% of people in the malarious coastal zones are Gerbich positive compared to the Highlands where people are uniformly Gerbich negative (Booth et al 1972). Gerbich negative people may therefore have some selective advantage in malarious areas (Booth & Simmons 1972).

The relationship between malaria prevalence and inherited features of red blood cells is therefore complex and certainly difficult to quantify against environmental factors which affect malaria transmission.

MALARIA ERADICATION AND CONTROL PROGRAMMES

Spencer has recently summarised the chronology of malaria control activities in PNG, including the period 1957-1990 when most nationwide activities were accomplished (Spencer M 1992).

The concept of malaria eradication, later control, in PNG was born out of early encouraging results of tests which studied the effect of residual insecticide spraying on anopheles mortality. In test areas in the Sepik (Peters & Standfast 1958) and the D'Entrecasteaux Islands (Spencer M 1965) the indications were that a properly organised and executed spraying programme would interrupt transmission. The high level of achievement necessary in the holoendemic Maprik area was noted early (Peters 1960 b). Reservations about reaching and sustaining these levels were an early warning that this approach in isolation was unlikely to result in a sustained effect on transmission and this has proven to be so. Also the scientists and planners in colonial PNG were not to predict the changes in government and central administration which were to affect the ability of the malaria service to implement any control programme. They were also not to predict the impact of economic and ecological changes that have swept through the country and influenced many disease control programmes.

In post war PNG malaria was a considerable constraint to economic development. In 1954 it was estimated that 25% of all deaths were due to malaria. It was predicted that life expectancy would double if malaria were eradicated. In

unstable areas seasonal epidemics paralysed the population and many died. These highland areas were particularly sought after for agricultural development and control of malaria therefore became fundamental for development.

Although Black pointed out at an early stage that residual spraying with dieldrin or DDT was the only effective method to interrupt transmission (Black 1955 d), larval control and mass drug treatment would also play their part (Black 1956 b). A national commitment to the importance of malaria control was needed and this has, to a large degree, always been the case. Guidelines for the planning and execution of eradication programmes were prepared (World Health Organisation 1957). Similar methods were followed in PNG and other South Pacific countries (Black 1956 b).

Shortly after the cessation of the Second World War area spraying in the island region was carried out, including Rabaul town (Mackerras et al 1950). In southern East New Britain (Palmalmal District) area spraying with DDT in oil destroyed not only An punctulatus adults but also the aquatic predators of mosquito larvae and the vectors quickly reestablished the breeding sites within two months of cessation of treatment. This was not a recommended strategy for areas where the vector mosquitoes were not abundant.

In this post war period bednets impregnated with DDT in kerosene were widely used by expatriates and

dimethylphthalate or citronella oil gave additional personal protection (Harper et al 1947).

The effectiveness of house spraying with DDT was demonstrated after the second world war by military groups in Papua (Bang et al 1947). DDT in kerosene was applied to the walls of houses at concentrations of 100 mg per square foot every four months. The populations of An punctulatus and An subpictus decreased by 95% and the parasite rate in a sprayed village was lower that in a control village. In children less that 2 years of age the parasite rate was 68% in the sprayed village compared to 91% in the control village; the differences were less marked in the older age groups. The spleen rates were unchanged over the short duration of the study.

At the time that DDT spraying was being tested in PNG similar work was being conducted in Irian Jaya (then Netherlands New Guinea). Van Thiel and Metselaar demonstrated that anophelines alighted on a near surface after sucking blood and that they were therefore susceptible to any residual insecticide on these surfaces. After spraying with DDT over 80% of An punctulatus were killed in a house after feeding and all but 6% died within the next 24 hours (Van Thiel & Metselaar 1955). Dieldrin was completely effective in destroying anophelines.

Pilot projects also demonstrated the usefulness of spraying in reducing malaria morbidity in the same area. It did not completely prevent transmission but the parasite rate

decreased from 46% to 32% in hyperendemic areas and from 18% to 8% in mesoendemic areas. The sporozoite rate decreased from 1.2% to 0.2% (Metselaar 1956).

These results suggested that DDT residual spraying may be a useful method to reduce transmission and although by itself may not be responsible for eradicating malaria in highly endemic areas (Black 1955 a, Peters 1960 b, Slooff 1964)) it may be successful in the unstable Highlands (Peters & Christian 1960 b).

Seven years after these pilot studies eradication was almost achieved in Irian Jaya. This was accomplished by regular house spraying and mass administration of chloroquine and pyrimethamine. Complete eradication was not possible because of the mobile nature of the population. Migration caused subsequent resurgence of P falciparum in the population whose immunity had been lost (Metselaar 1961).

The usefulness of DDT (and dieldrin) was confirmed in the PNG studies. In Maprik six monthly spraying with DDT resulted in a dramatic drop in the population density of the main vector An punctulatus, also An farauti and An koliensis and the infant parasite rate dropped from a pre-spray level of 72.6% to 7.9% after three years. Hospital cases of malaria were reduced by 50% and the proportion of P vivax, P malariae and mixed infections decreased considerably (Peters & Standfast 1958).

In the D'Entrecasteaux Islands results were similar to those obtained in Maprik (Spencer M 1965); there was a marked drop in the population of An farauti, the main vector. Administrative difficulties resulted in a four month delay of one spray round and there was an increase in transmission which illustrated the necessity of a rigorous operation schedule.

An punctulatus was more susceptible to DDT than An farauti or An koliensis. However, all species were sensitive within the ranges of concentrations used for field control. The step from these experimental situations to a programme in a territory where some areas had not even had contact with the outside world and in which many parts were not under any form of administrative control was huge. Fortunately a rudimentary rural health care system was developing in PNG in the 1950s and this provided a mechanism for support to eradication efforts; attempts to eradicate malaria without this extended health service were not encouraged (Colbourne 1962 a, b).

The importance of a continuing financial and political commitment to malaria eradication, once it had been started, was emphasised by Black (Black 1955 a). Early doubts about the feasibility of such a national programme were raised by Gunther who repeatedly spoke of the dangers of 'slovenly half measures' and the risk of insect resistance (Gunther CEM 1955, 1956). He also warned against support from the programme being withdrawn when efforts were having maximum benefit. There was a real

danger of decreasing immunity in the population without guaranteed continuation of control. A 'guaranteed continuance of funds, without interference by remote control, is needed to ensure complete success for any scheme of control'. The concept of continuing to fund a programme for a disease problem which had become rare was going to require intense education of politicians.

For the most part the Australian government continued to fund the malaria programme and the problems subsequently encountered were not due to shortage of funds.

Eradication of malaria was therefore seen as humanly and economically necessary and technically feasible. The principle of malaria eradication by DDT house spraying backed up by larval control and mass drug administration were similarly applied in other south Pacific countries (Avery 1974, Saint-Yves 1968, Black 1955 a, 1956 b, 1968, Colbourne 1962 a, b) and other areas (Peters 1960 c).

The malaria eradication programme in PNG relied on DDT applied at regular (six-monthly) intervals at a concentration of 2 grammes per square meter in the lowlands while the same dosage was applied once a year, shortly after the start of the wet season, in the Highlands. An organisation comprising senior technical and scientific staff, administrators, a parasitologist, an entomologist and operations supervisors was established in Port Moresby. In the districts supervisors, squad leaders and spraymen were responsible for the actual house spraying (Peters 1959

c). The programme was organised along WHO guidelines (1957) into preparatory, attack, surveillance and maintenance stages (Radford 1968, Radford & van Leeuwen 1969, Black 1969, Pampana 1969). The estimated cost over fourteen years was to be 2.3 million pounds or an annual per capita expenditure of 2s 11d (Peters 1959 c). However, actual costs were much higher.

Operations commenced in 1957. In 1960 towns and pilot projects were covered and spraying commenced in the islands. By 1965 32% of the rural population and 38% of the population in highly malarious areas were covered. In 1970 53% of the population was covered. In the sprayed areas the parasite rates were reduced to about one quarter of their original levels. In Maprik following three years of spraying parasite rates had fallen from >80% to 7.9% but complete interruption of transmission was never achieved (Peters 1962). In East New Britain the parasite rate had fallen from a pre-operational level of 18.1% in 1961 to 6.3% in 1973. The parasite rate increased thereafter.

In 1960 malaria comprised 14.5% of all hospital admissions; this figure was reduced to 5.7% in 1973 even though total admissions had increased because of the increase in medical facilities. The case fatality rate remained unchanged at 1.02%, however (Parkinson & Tavil 1973, Parkinson 1974).

In 1962 Peters warned against technique failures, population migration, exophagy of An farauti and

An koliensis and community resistance which would compromise the programme. Despite this warning, the results of the programme were disappointing (Peters 1962). In many areas parasite rates did not fall sufficiently to enable surveillance to be commenced. A programme review in 1966 noted a weak administration and low standards of spraying operations (Gabaldon 1966) and in 1970 'The reasons for the poor achievements are chiefly sub-standard operations in the field and ineffective supervision' (Colbourne & Stevenson 1970). No geographical reconnaissance was done until 1970. Many buildings were unsprayed. Supervision was not effective, forms were completed without reference to accuracy, individual responsibility was lacking and the idea of checking was sometimes shunned. At the central administration there was no entomologist and staff shortages at this level plagued the programme.

In 1970 approximately A$ 1.7 million was being spent annually on the programme but there was a general lack of commitment, an attitude created by years of faulty spraying and discouraging parasite rates.

There was considerable community resistance to DDT spraying. It was unsightly, it disrupted households and caused rapid deterioration of thatch roofs (McMahon 1972). In PNG and Malaysia roof damage was shown to be due to the chalcid fly predator (Anthrocephalus species) of the larval stage of the pyralid moth Herculia nigrivita. The predator was destroyed by DDT. The moth larva fed on the palm and

sago leaf roofs and increased after DDT spraying. Addition of malathion destroyed both fly and larva (Bourke 1973, Thevasagayam et al 1978). Increases were also reported in bedbugs, Cimex hemipterus, which were resistant to DDT. These were controlled by the addition of malathion (0.2g/sq m) to the DDT.

Reviews of the malaria programme in 1969 and 1970 (World Health Organisation 1969, Colbourne & Stevenson 1970) advised intensification of spraying in areas that could be covered effectively at the expense of other areas which were inaccessible or where refusal was high. Malaria eradication was considered too ambitious with the present quality of operations and general lack of support. The central organisation was to be strengthened as well as increasing numbers of inspectors and supervisors in the regions. Based on these reviews total coverage of the population would be achieved only in 1975 with passive and active surveillance in some areas of low prevalence (Parkinson 1973 b, Parkinson & Tavil 1973). Cessation of spraying was anticipated in some of the island provinces in 1979.

These recommendations were in accordance with a global rethinking of malaria control strategies (Bruce-Chwatt 1980). Eradication was clearly impossible in all but a few areas and other goals would be necessary.

The policy of the PNG Department of Public Health at that time was as follows:

'Using the best possible means available for the particular situation, to control malaria to the extent that it is no longer a major public health problem and to maintain this standard of control until basic health services have developed to a stage where eradication of malaria can be contemplated..... every effort should be made to switch by stages to a programme of eradication'. (Parkinson & Tavil 1973, Parkinson 1974).

By 'best possible means' was meant;

(a) the use of residual insecticide spraying of all structures in which people congregate, work or rest and which are not otherwise protected from invasion by female anopheles mosquitoes,

(b) the use of antimalarial drugs in

(1) the mass treatment of focal outbreaks of the disease,

(2) mass treatment of captive population groups,

(3) small, nomadic communities where, due to the nature of the habitat, residual spraying is ineffective,

(4) the presumptive treatment and radical treatment of cases of malaria as they occur.

(c) the destruction of breeding sites and larval control by drainage and larviciding with oils and non-residual insecticides (Department of Health, Papua New Guinea 1973).

'Control' meant to reduce the parasite rate to less than 2% in children under five years of age. Using this criteria

control was never achieved so the question of progressing to eradication never arose. Many were quick to point out problems with this reoriented strategy but few had workable solutions to the problem (Zigas & Rodrigue 1972, McMahon 1972, Parkinson 1973 a)

The first thirteen years of the malaria eradication programme in PNG therefore came to an end and the reoriented strategy commenced in 1970. It was to continue until 1979 when attempts to integrate malaria control into general health services and primary health care activities were made. Malaria control policies since the 1974-1978 National Health Plan have continued to emphasise community involvement, reduction of vector breeding sites, personal protection and ready access to early treatment. In addition plans to improve the quantity and quality of diagnostic services were formulated (Department of Health, Papua New Guinea 1973, 1985, 1991).

From 1971 to 1980 the number of staff throughout the country employed in the Malaria Control Programme increased from 832 to 1430 but up to 20% of positions remained unfilled; many of these were key technical staff. Of the full time staff approximately half were public servants and half casual labourers. Expatriate staff comprised 10% of public servants in 1971, mainly in senior professional and technical categories; this figure decreased to 5% in 1973 and 2% in 1975. An indigenous director of the programme was appointed in 1973. In 1983 the Malaria Section at the Department of Health was incorporated into the Disease

Control Division and actual malaria control activities became provincial responsibilities. In 1990 the Malaria Section was moved from the Disease Control Division to the Environmental Health Division, although remaining within the same Primary Health Services Branch of the Department of Health.

The annual expenditure of the Malaria Service increased from A$ 1.6 million in 1971 to K 4.0 million in 1982 (A$ 1.00 = K 1.00, originally). Expenditure on malaria control comprised 10.3% of total health expenditure in 1980.

In East New Britain expenditures on malaria remained between A$ 106,000.00 and K 133,000.00 between 1972 and 1980, increasing to K 248,000.00 in 1983, thence K 227,000.00 in 1984. In 1984 per capita expenditure on malaria in this province was K 1.60; this was 8% of the provincial health budget for this year.

PRIMARY HEALTH CARE AND MALARIA CONTROL

The world health community endorsed the goal of 'health for all by the year 2000' in 1979. This milestone in global health policy was to ensure the provision of 'health care based on practical, scientifically sound and socially acceptable methods and technology, made universally available to the community through their full participation and at a cost that the community and country can afford.....in the spirit of self reliance and self determination' (World Health Organisation 1981).

The primary health care concept was not new to PNG. For many years the Aid Post Orderly had provided village level curative health care to rural populations. Many developing countries did not have this basic level health service. If malaria control by this approach was to be successful then it should work in PNG. What was needed was an extension of the responsibility for health care to the people.

The differing patterns of malaria epidemiology from village to village suggested that 'no subset of measures will have universal application' and 'control measures should be tailored to the local situation' (Charlwood 1984). For malaria control this approach demanded a complete reorganisation of concepts and strategies. The people were to take charge of their own health, including malaria, and the government health services would facilitate their efforts through education, instruction and technical support. What had been an entirely government administered programme was to be reoriented so that the stimulus, impetus and manpower would come from the community (Reilly 1986, Moir & Garner 1986).

The response to the primary health care approach was mixed. It was difficult to disband the already monumental malaria service with its one thousand employees. It was more difficult to encourage provincial health and village authorities to pick up the responsibility for malaria control. We shall examine what progress has been made towards this in the Gazelle Peninsula.

Involvement of villagers in malaria control was not a new concept in PNG. In 1954, before spraying with residual insecticides commenced, rural people in the Trobriand Islands (D'Entrecasteaux Islands) had demonstrated that, at least in the short term, they were able to supervise their own mosquito control programmes (Black 1954 a, 1955 b). At the same time it was demonstrated that totaquine (extracted from cinchona trees grown in the Highlands) was not effective as a traditional suppressive of malaria but it did demonstrate that the people in these islands could take a regular prophylactic if necessary (Gunther JT 1974). Black expressed reservations about the feasibility of prophylaxis over a long period (Black 1956 c).

Very early in the war against malaria it was realised that a programme of 'bonification' of villages would do more to control malaria than house spraying and drugs;

'Integral bonification implied a three-fold policy of hydraulic, agricultural and hygienic intervention with the primary aim of reducing breeding sites for malaria' (Gunther JT 1974). Christian had already demonstrated that drainage of large areas would reduce breeding sites (Christian 1969) and naturalistic methods would support this approach. Gambusia affinis fish had already proven useful (Harper et al 1947). Gunther repeatedly encouraged an emphasis on bonification through health education rather than in applying all efforts into residual spraying and drug reinforcement. Health education was essential to the success of any control programme for without a desire for

such control from the people any intervention would have a short lived effect (Carlaw & Saave 1963).

A prerequisite to integrating malaria control into village level primary health care activities was their integration into general health services (Saave 1964, Black 1974, Farid 1974). Only in 1984 when malaria control became an entirely provincial responsibility was the national malaria service trimmed to a core of technical advisers.

The World Health Organisation formalised the primary health approach to malaria control by stressing the importance of a national commitment and by demonstrating that community participation was indispensable (World Health Organisation 1978). Malaria control was an integral part of any economic development programme and if government programmes had failed in their attempts to achieve this then clearly another approach should be tried. The basic premise was that immediate decreases in mortality could be expected from village-based treatment for malaria and that source reduction, larvicides and oiling would achieve more in the long run, be less expensive and would be on-going methods administered at a village level.

As transmission of malaria in an evolving community was changing, so the concept of the epidemiology of malaria being a function of both biological and psychosocial factors was born (McMahon 1974 b). Human behaviour was possibly a more important influence on attempts at malaria control than any parasitological or entomological variable.

An almost certain factor in the failure of the mass campaigns in malaria eradication was the fact that the integrity of such campaigns was determined by factors of an administrative, social and political nature rather than by technical aspects (Gonzales 1965). For treatment and prophylaxis alone the costs may be outside the health budget of many countries (Bruce-Chwatt 1979, Pampana 1969).

Village based treatment and source reduction remain the cornerstones of the primary health care approach to malaria control in PNG, with residual insecticide spraying as an additional control measure in supportive villages.

MALARIA PROPHYLAXIS

Chemoprophylaxis for malaria was shown to be undesirable for indigenes in highly endemic areas. Paludrine was shown to decrease immunity to malaria and was advised against because of the difficulty in maintaining supplies, thereby leaving the population unprotected and at reduced immunity (Gunther CEM 1946). Attempts to administer prophylaxis through chloroquinised salt were also unsuccessful in West New Guinea; the risk of chloroquine resistance was increased although this method, combined with spraying, was thought may interrupt transmission (Meuwissen 1963, 1964). Regular chemoprophylaxis did improve the well being of those taking the drugs but the risk of severe malaria infection when supplies broke down in general abrogated this approach.

In areas where immunity was low anyway, such as the Highlands of PNG, prophylaxis, regularly administered, improved haemoglobin levels and childhood growth (Giblin 1954, Spencer TET 1956). Such programmes appeared feasible, at least in the short term. In Netherlands New Guinea 93% of a local highland population attended for weekly chloroquine. The parasite rate decreased to almost zero although continual reintroduction of parasites prevented eradication (Van Dijk 1958).

A longitudinal study of the feasibility of administering prophylaxis regularly to children in Madang showed that village-based voluntary dispensers were quite capable of administering regular amodiaquine to 1506 children in 40 villages (Stace 1977, 1978, Stace & Pariwa 1981). Coverage was over 70% over a 12 month period. The slide positivity rate decreased from 29% to 3.7% over this period. Amongst children taking prophylaxis the spleen rates were approximately one third those in control villages. Similar results were obtained in Africa (Omer 1978). The Madang study was discontinued when parasite rates increased in subsequent years despite continued good compliance. Chloroquine-resistant P falciparum was confirmed in Madang and elsewhere in 1980 (Gibson 1980) but there was no conclusive evidence that the prophylactic low levels of antimalarial in the community encouraged its emergence.

For people from unstable areas and long-term visitors to PNG reliance on personal protection from biting and weekly chloroquine was recommended (Biddulph 1987). For visitors

to areas of high malaria transmission or areas with chloroquine resistant P falciparum a combination of chloroquine and Maloprim (or Fansidar) was recommended (Currie et al 1989).

For practical purposes the mass administration of weekly antimalarials to the population, even through village-based dispensers, was unlikely to succeed. In contrast, readily available single-dose treatments from village dispensers may reduce morbidity from malaria yet be unlikely to interfere with drug sensitivity patterns.

MALARIA DRUG RESISTANCE

The potential problem of drug resistance in malaria control has constantly compromised their widespread use for long periods. Irregularity of dosage and constant low levels of antimalarials in the community encourages the spread of resistant strains of P falciparum.

Drug resistance in malaria therapy is not new to PNG. During the Second World War resistance to atebrin in the Wewak area was documented (Steward 1977). In 1961 a soldier on irregular proguanil prophylaxis developed P falciparum malaria. The strain was inoculated into three Europeans on regular proguanil prophylaxis and all developed P falciparum malaria. Further subinoculation into two Europeans also on proguanil prophylaxis similarly resulted in P falciparum infection. Proguanil resistance has been reported during irregular prophylaxis in visitors to Papua New Guinea (Wainer & Rowley 1961). A combination

of proguanil and chloroquine was not effective as a prophylaxis against malaria in PNG (Henderson et al 1986).

Of major public health concern has been the spread of resistance of P falciparum to chloroquine. This was initially reported in the region in Irian Jaya in 1974 (Clyde et al 1976) and shortly afterwards in PNG in Western Province (Grimmond et al 1976, Yung & Bennett 1976 a), Wewak (Yung & Bennet 1976 b) and in Maprik and Popondetta (Han & Grimmond 1976). It is likely that P falciparum resistance to chloroquine arose spontaneously although the frequency of travel of mining expatriates between South-East Asia and PNG may have introduced resistant species into the community.

Resistance was confirmed using WHO protocols (Grimmond 1979, World Health Organisation 1973). Resistance was at R1 level and patients recovered with sulphadoxine-pyrimethamine. The onset of chloroquine resistance in PNG was commensurate with similar developments in South-East Asia and Indonesia (Smrkovski et al 1985).

Much interest was generated at this time in Australia because of the dangers to visitors contracting chloroquine resistant malaria in PNG and introducing it into Australia. There was a call for general availability of Fansidar and Maloprim for prophylaxis (Hennessy et al 1977, Howells 1977).

Extensive testing of chloroquine resistance in the Madang area was carried out in 1979-1980 at the PNG Institute of Medical Research. Twenty three out of 26 children showed *in vitro* chloroquine resistance but the same patients were cleared of infection within seven days after treatment with chloroquine. However, seven showed recurrence of parasitaemia within the following 28 days (Vrbova & Gibson 1980). There appeared to be poor correlation between *in vitro* and *in vivo* testing, due to immune factors in the host which were not present during testing in the laboratory. Subsequent *in vivo* studies in Madang children demonstrated R1 resistance in four out of sixteen children, R2 resistance in five out of sixteen and R3 resistance in a further one child. Four of the sixteen children were sensitive to chloroquine (Darlow & Vrbova 1981). Similar studies in Rabaul at this time demonstrated R1 resistance in eight out of thirteen children, R2 resistance in three and R3 resistance in two (Tulloch 1980).

R1 resistance was widespread in PNG by the mid 1980s (Dulay *et al* 1987). While the majority of patients continued to respond to chloroquine treatment there was no need to alter the standard managements for malaria (Department of Health, Papua New Guinea 1980, 1988) but health workers were alerted to the problem of resistance and instructed on treatment with quinine and Fansidar (Darlow & Vrbova 1981). Standard managements continued to prescribe amodiaquine and chloroquine for uncomplicated malaria. For cerebral malaria treatment was to be with quinine and Fansidar. Primaquine was added as a single dose to destroy

gametocytes; this was a public health measure to prevent the spread of resistant strains of P falciparum.

In 1987 Peters warned that P falciparum resistant to chloroquine was more likely to develop resistance to other drugs (Peters 1987). At the time P falciparum resistance to chloroquine was demonstrated in the Upper Fly region of Western Province tolerance to quinine was also noted (Grimmond et al 1977). Subsequent studies in this area have not confirmed P falciparum resistance to quinine or Fansidar (Schuurkamp 1992). Some cross resistance of P falciparum has indeed been demonstrated between chloroquine and amodiaquine in the same region and amodiaquine has subsequently shown to be ineffective in children symptomatic with P falciparum in endemic areas (Sapak et al 1991). There is also evidence of P vivax resistance to chloroquine and tolerance to pyrimethamine (Schuurkamp 1992).

Of considerable concern have been reports of P falciparum resistance to Fansidar in South East Asia (Doberstyn et al 1979, Schmidt et al 1977), Irian Jaya (Rummens et al 1979) and Madang (Darlow et al 1980). Clearly careful monitoring of antimalarial drugs is needed to prevent this problem becoming widespread (UNDP/World Bank/WHO 1981, Smrkovski et al 1985).

DEMOGRAPHY AND VITAL STATISTICS OF THE GAZELLE PENINSULA

The population of the Gazelle Peninsula is composed of indigenous Tolai people and a smaller group of Bainings people. Immigrants from other areas of PNG, Asia, Australia and other countries form a small proportion of the population and most of these are located in and around Rabaul town and the many plantations in the Peninsula. Population movements following the 1994 volcanic eruptions are described below.

In 1985 the population of the Gazelle Peninsula was estimated by extrapolation from the 1980 national census:

Gazelle Peninsula population 1985:

Urban and periurban settlements	15,409	(16%)
Rural villages	68,322	(72%)
Plantations, missions, schools	11,429	(12%)
TOTAL	95,160	

The population of other areas of the province is much lower but has a similar distribution.

The population density is approximately 120 people per square kilometre. In 1985 this varied from over 600 in the Rabaul urban and periurban areas to sparsely populated areas in the western, southwestern and southern parts of the Peninsula.

In 1985 the growth rate of the Gazelle Peninsula was 7.5% whilst that for the whole province was 2.7%; the PNG growth rate was 2.2%. At this time the high growth rate in the

Peninsula reflected inmigration from other areas of PNG to plantations and periurban settlements. The excess of inmigration over outmigration contributed 3.5% to the growth rate. The rate of natural increase was 4.0% which was much higher than the rate of natural increase for other areas of the province and the country; the rate of natural increase for PNG was 2.23%.

The age structure of the population indicates the broad based pyramid typical of less developed countries; both provincial and national pyramids are similar in shape, with 16% of the population being under five years of age. 3.3% and 3.4% are under one year of age in East New Britain province and PNG respectively. The excess of males in the province, particularly those in the 15-19 year age group, is the result of inmigration (fig 1.4).

Vital statistics are extracted from the National Health Plan 1986-1990:

	ENBP	**PNG**
Life expectancy at birth	males 53.2yr females 52.8yr	males 48.7yr females 50.7yr
Crude birth rate (all sectors)	33.4/1000	34.2/1000
(CBR Gazelle Peninsula - both sexes 41/1000)		
Crude death rate (all sectors)	10.8/1000	13.2/1000
General fertility rate (all sectors)	172/1000	153/1000
Total fertility rate (females 15-49 years)		5.4
Infant mortality rate (per 1000 live births)	males 57 females 56 both sexes 57	males 78 females 66 both sexes 72
Childhood mortality rate	males 29	males 43

(per 1000 live births)	females 33 both sexes 32	females 41 both sexes 42
Adult literacy rate		45%
Daily per capita calorie intake		2247
Daily per capita protein intake (grams)		45

ECONOMIC STATUS OF THE GAZELLE PENINSULA

The small area of the Gazelle Peninsula is well served by an extensive road system, public transport service and many villages have electricity; some have reticulated water supplies. The area is also well served by primary and secondary schools, aid posts and health centres. Most of these services are run by the provincial and national governments. However, church organisations, notably the Catholic and United churches, provide significant health and educational services.

The main cash crops in the area are copra and cocoa; other major sources of income include employment in government and private enterprises in Rabaul and on plantations, fishing, local vegetable marketing and transportation. The international and domestic port at Rabaul is a focus for commerce and the reason why Rabaul and the Gazelle Peninsula have developed faster than other areas in Papua New Guinea in recent years. The port is the main exit and entry point for all exports and imports; very few goods travel by air.

Economic indices for the Gazelle Peninsula are not readily available. However, since 79% of the population of the East New Britain Province live in the Peninsula provincial

data provides a reasonable estimate of the economic status of people living in the Peninsula.

ENBP has the highest per capita income of any non-mining province in PNG. Excluding the capital and the mining provinces of North Solomons and Western, the per capita income in ENBP is 31% higher than that in New Ireland Province, the next most wealthy province and 29% higher than the national average. The domestic income per person in 1983 in ENBP was K770.00 (1 kina = 1 US dollar = 0.5 pounds sterling); 49% of this income was from the 'market component' (copra and cocoa mainly) and 44% from wages (National Statistical Office 1983).

The high economic status enjoyed by the people of ENBP should be considered when evaluating the effectiveness of previous attempts to control malaria and of any likely successful interventions for the future.

HEALTH SERVICES IN THE GAZELLE PENINSULA

For many years in PNG an extensive health care delivery system has ensured that basic health services were available to a large proportion of the population. Health priorities have ensured that most people living in rural villages have access to curative health services from a network of village-based aid posts and preventive care from a system of mobile Maternal and Child Health (MCH) clinics.

The aid post system in PNG was developed in the 1950s during the time of the Australian administration. Aid Post

Orderlies (APO) now receive a one-year training in basic curative health care and public hygiene. The system works well as a curative service but has minimal impact on disease prevention through health education and public hygiene programmes. APOs refer medical problems to the nearest health centre, which is staffed by a health extension officer (HEO), nurses and nurse aides.

A much wider range of curative and preventive health services is available at health centres. HEOs receive a three-year training in clinical medicine, public health and preventive medicine. MCH nurses operate from health centres and conduct vaccinations (BCG, triple antigen, oral polio vaccine, pigbel, measles, tetanus toxoid), nutritional assessment (weight for age only) and antenatal care in villages. They also offer a curative health service in areas where there is no aid post.

The next level of clinical care is the hospital in the provincial centre. In ENBP Nonga Hospital functions as both a provincial hospital and the referral hospital for the islands region. It is well equipped for secondary and tertiary health care via its various specialist medical services.

Information on the health status of the population is only reliably available from health centres and hospitals. Only hospital data are accurate for pathologically confirmed diagnoses in inpatients; most inpatients at health centres are diagnosed and treated on clinical criteria only, which

for most purposes is quite adequate. Standard medical and surgical management regimes for children and adults ensure an appropriate level of clinical care at all levels of the health service (Department of Health, Papua New Guinea 1980, 1988).

The Gazelle Peninsula is well equipped with accessible health facilities and staff (fig 1.5). A regional medical store in Rabaul ensures a continuous supply of essential drugs and vaccines.

Health Facility (hc health centre)	**Administering Agency**	**Population covered 1985**
Nonga Hospital) Rabaul Town Clinic)	Government	43,660
Vunapaka hc	Government	10,900
Butuwin hc	Government	6,960
Tapipipi hc	Government	5,150
Kerevat hc	Government	6,360
Warongoi hc	Government	2,730
Molot hc	Government	5,610
Vatnabara hc	United Church	2,210
Gaulim hc	United Church	5,160
Vunapope Hospital	Catholic Church	18,780
Napapar hc	Catholic Church	5,160
Paparatava hc	Catholic Church	7,570
		120,250

(Note: Kerevat, Gaulim and Warangoi health centres cover additional populations in the adjacent Bainings mountains).

The data presented below are for ENBP unless otherwise stated:

	ENBP	PNG
Population more than 2 hours from a health facility	6% (Gazelle Peninsula only)	9.2%
'000 per outpatient facility	2.7 (")	1.2
'000 per inpatient facility	10.5(")	6.9
population per hospital or health centre bed	157	243
'000 per HEO or doctor	5.9	5.1
'000 per nurse	7.4	4.4
'000 per APO	2.3	1.7
Supervised births (at hc or hospital)	109%	40%
MCH Services (1984): Vaccination coverage in infants		
Coverage with 3rd dose triple antigen	54%	34%
Coverage with 3rd dose oral polio vaccine	52%	32%
Coverage with BCG	75%	66%
Coverage with measles vaccine	51%	26%

PNG national data (and to a certain degree ENBP data) obscures wide variations in distribution of services in different provinces and between urban and rural areas. In the Gazelle Peninsula the areas least served by static health facilities are those to the east (Bitapaka census division) and the west (Livuan and western part of Central census divisions). All areas in the Peninsula are, however, well covered by monthly MCH clinics.

PATTERNS OF MORBIDITY AND MORTALITY

(Nonga Hospital and East New Britain Division of Health records).

1. Four leading causes of death (hospitals and health centres, 1983):

ENBP		**PNG**	
Pneumonia	15.2%	Pneumonia	22.7%
Perinatal	11.3%	Perinatal	9.0%
Pulmonary/ cardiovascular	7.3%	Malaria	7.6%
Malaria	6.7%	Diarrhoeal disease	7.4%

2. Five leading causes of admission to hospitals and health centres in PNG (1984):

Obstetric conditions	19.7%
Pneumonia	14.1%
Malaria	11.3% (1985 10.5%, 1986 8.5%)
Accidents, violence	8.9%
Diarrhoeal disease	6.7%

3. Case fatality rates for leading causes of death in PNG (1984):

Perinatal	11.0%
Pneumonia	3.4%
Malaria	1.6% (1985 3.0%, 1986 1.6%)

4. Average number of beds occupied per day by patients with common conditions at hospitals and health centres in ENBP (1983):

Obstetric conditions	72.2
Malaria	41.6

Pneumonia	31.7
Diarrhoeal disease	10.4

5. Average number of days inpatient stay by patients with common conditions in ENBP (1983):

Pneumonia	7.9
Obstetric conditions	6.2
Diarrhoeal disease	4.8
Malaria	4.5

6. Malaria morbidity and mortality, Nonga Hospital, Rabaul:

Admissions

	1985	1986
Adult (>15yr) cases of malaria	498	399
Childhood (<15yr) cases of malaria	372	456
Totals	870	855
Total admissions during the year	8,256	10,003
Malaria cases as % of total admissions	10.5%	8.5%

Deaths

	1985	1986
Adult (>15yr) deaths due to malaria	15 (CFR 3.0%)	9 (CFR 2.3%)
Childhood (<15yr) deaths due to malaria	11 (CFR 3.0%)	5 (CFR 1.1%)
Total deaths due to malaria	26	14
Total deaths	232	214
Malaria deaths as % of all deaths	11.2%	6.5%

	Malaria deaths/total deaths	% deaths due to malaria
1980	13/182	7.1

1981	13/188	6.9
1982	16/170	9.4
1983	10/110	9.1
1984	9/150	6.0
1985	26/232	11.2
1986	14/214	6.5

Malaria is, therefore, a major cause of ill-health and death in the Gazelle Peninsula.

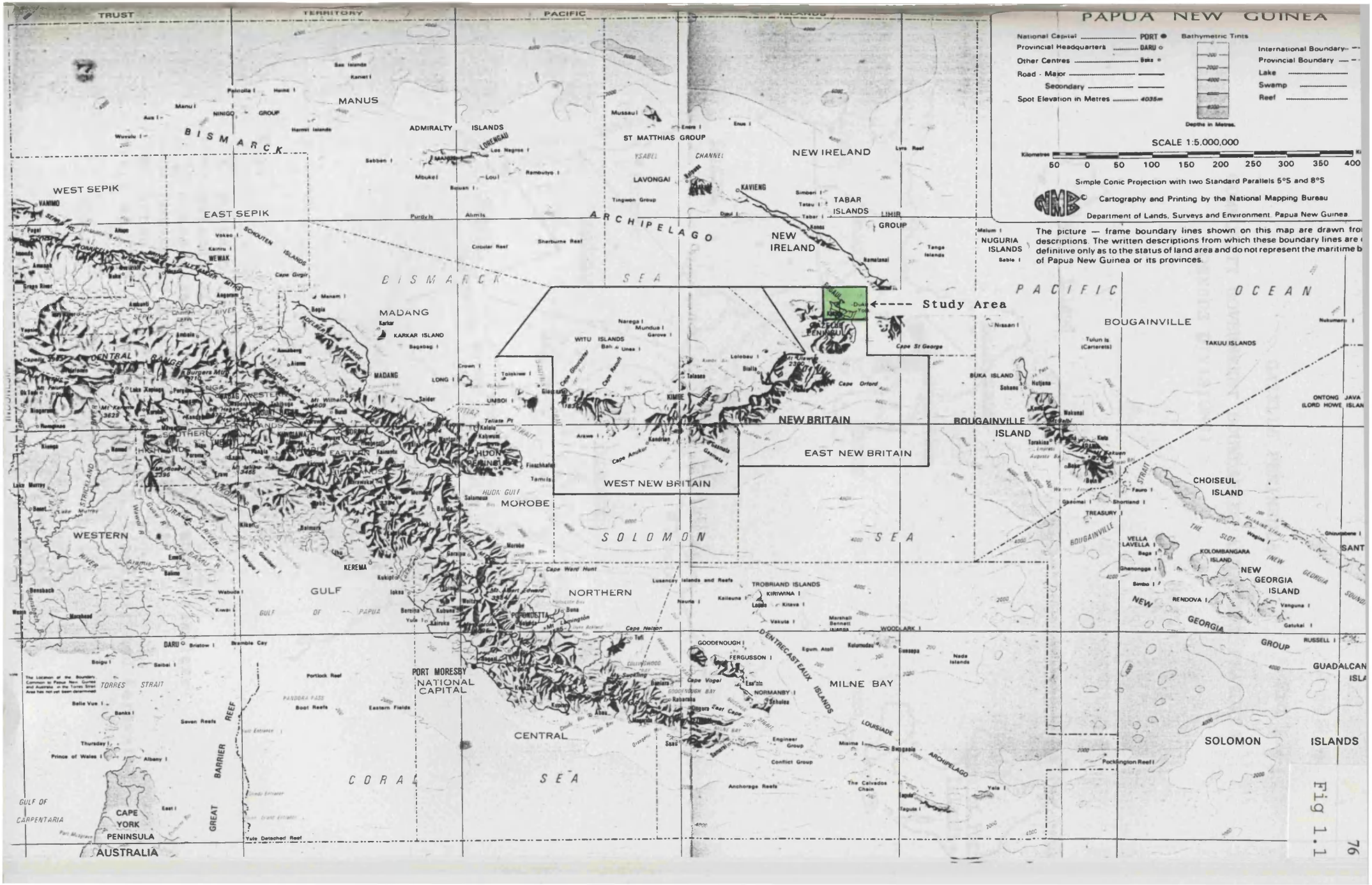
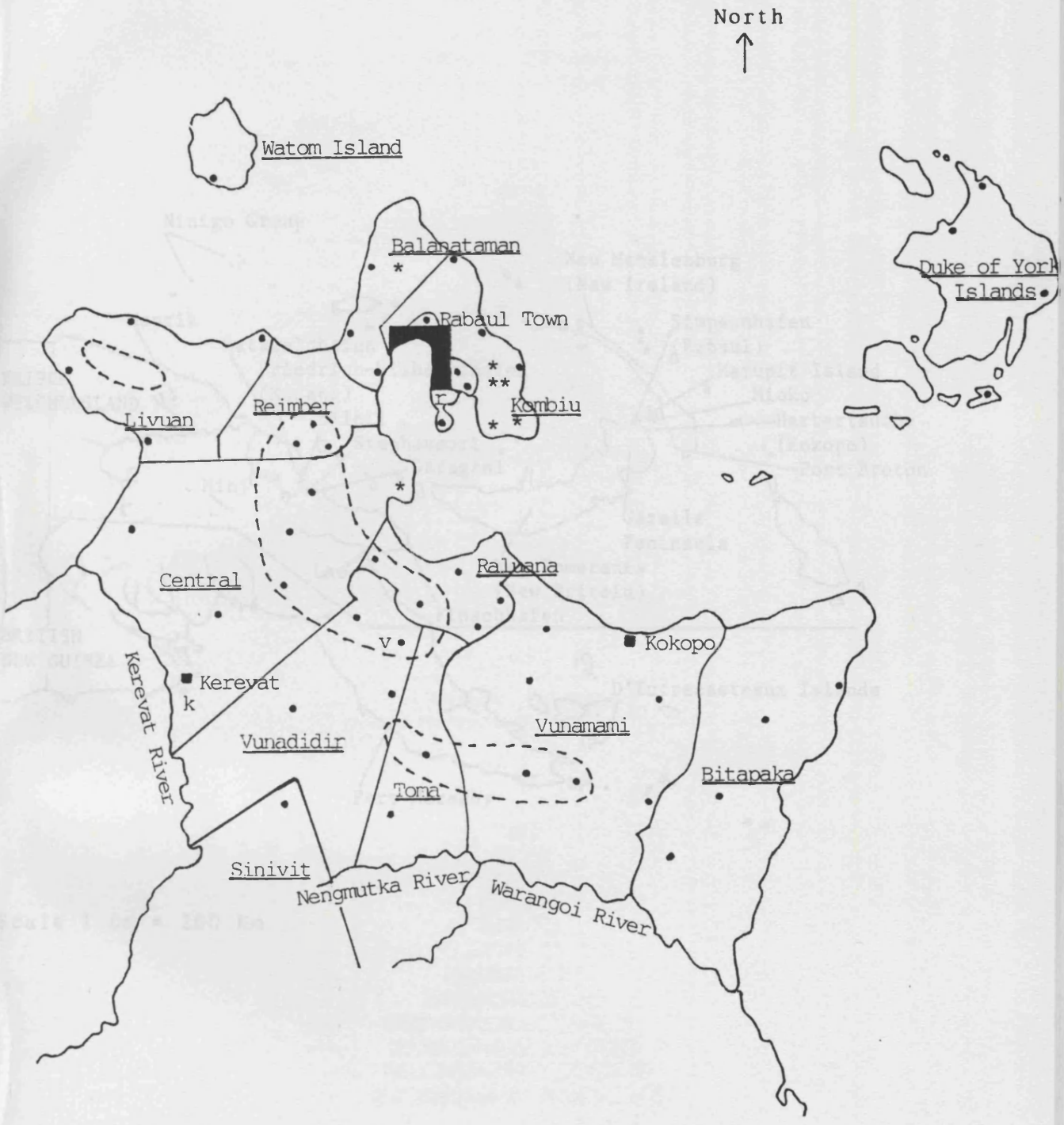

PAPUA NEW GUINEA
National Capital ..... PORT MORESBY
Provincial Headquarters ..... DARU
Other Centres ..... Buka
Road - Major
Secondary
Spot Elevation in Metres 4035m
Bathymetric Tints
Depths in Metres
International Boundary
Provincial Boundary
Lake
Swamp
Reef
SCALE 1:5,000,000
Kilometres 50 0 50 100 150 200 250 300 350 400
Simple Conic Projection with two Standard Parallels 5°S and 8°S
Cartography and Printing by the National Mapping Bureau
Department of Lands, Surveys and Environment, Papua New Guinea
The picture — frame boundary lines shown on this map are drawn fro
descriptions. The written descriptions from which these boundary lines are
definitive only as to the status of land area and do not represent the maritime b
of Papua New Guinea or its provinces.
Study Area
TRUST TERRITORY PACIFIC ISLANDS
MANUS
ADMIRALTY ISLANDS
ST MATTHIAS GROUP
NEW IRELAND
LAVONGAI
KAVIENG
TABAR ISLANDS
LIHIR GROUP
NUGURIA ISLANDS
BISMARCK ARCHIPELAGO
WEST SEPIK
EAST SEPIK
WEWAK
MADANG
KARKAR ISLAND
BISMARCK SEA
PACIFIC OCEAN
BOUGAINVILLE
TAKUU ISLANDS
BUKA ISLAND
ONTONG JAVA (LORD HOWE ISLAN
WITU ISLANDS
KIMBE
NEW BRITAIN
EAST NEW BRITAIN
WEST NEW BRITAIN
BOUGAINVILLE ISLAND
CHOISEUL ISLAND
TREASURY
VELLA LAVELLA
KOLOMBANGARA ISLAND
NEW GEORGIA ISLAND
NEW GEORGIA GROUP
RENDOVA
RUSSELL
GUADALCAN
ISLA
MOROBE
HUON PENINSULA
SOLOMON SEA
WESTERN
GULF
KEREMA
NORTHERN
TROBRIAND ISLANDS
KIRIWINA
WOODLARK
GOODENOUGH
FERGUSSON
NORMANBY
MILNE BAY
D'ENTRECASTEAUX ISLANDS
LOUISIADE ARCHIPELAGO
SOLOMON ISLANDS
DARU
TORRES STRAIT
PORT MORESBY
NATIONAL CAPITAL
CENTRAL
CORAL SEA
GULF OF CARPENTARIA
CAPE YORK PENINSULA
AUSTRALIA
GREAT BARRIER REEF

Fig 1.1

Fig 1.2

GAZELLE PENINSULA

COMMUNITY GOVERNMENT BOUNDARIES AND OTHER FEATURES (CENSUS DIVISIONS)



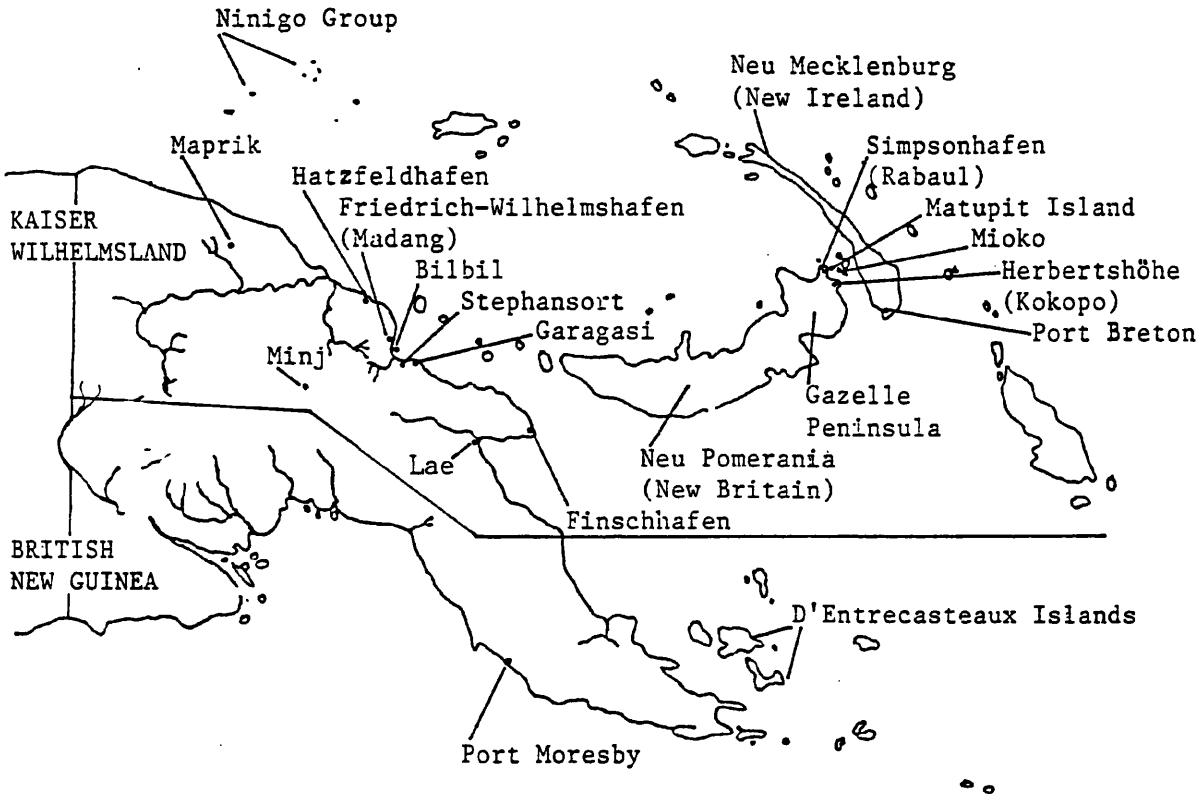
Key:

* volcano
• malaria indicator village
areas greater than 200 meters above sea level
—— community government boundaries
■ urban centres
r,v,k weather stations at Rabaul, Vunadidir and Kerevat

Scale 1 cm = 4 Km

'PAPUA NEW GUINEA' IN 1900 Fig 1.3

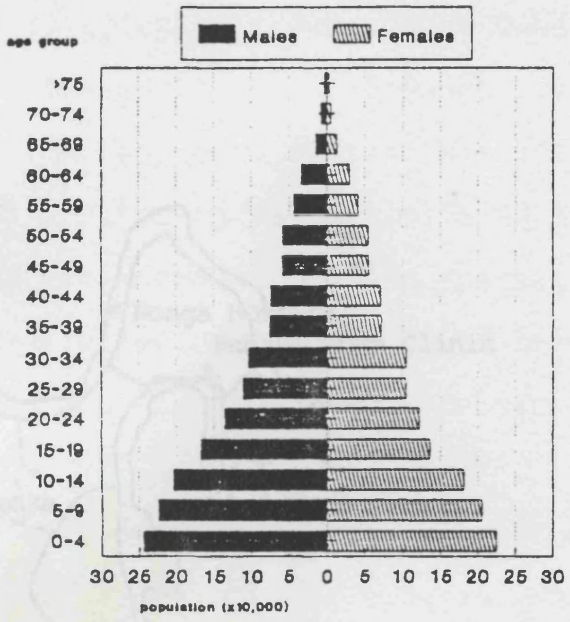
(including places mentioned in text
but established after 1900)



Scale 1 cm = 200 Km

Fig 1.4

1980 POPULATION
PAPUA NEW GUINEA



1980 POPULATION
EAST NEW BRITAIN PROVINCE

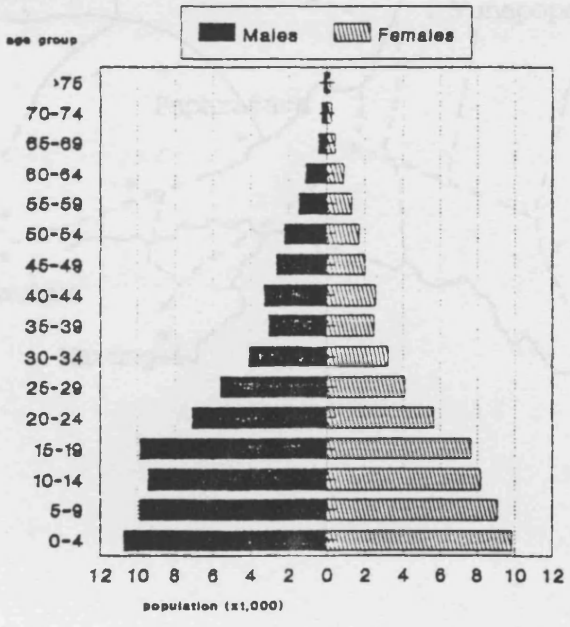
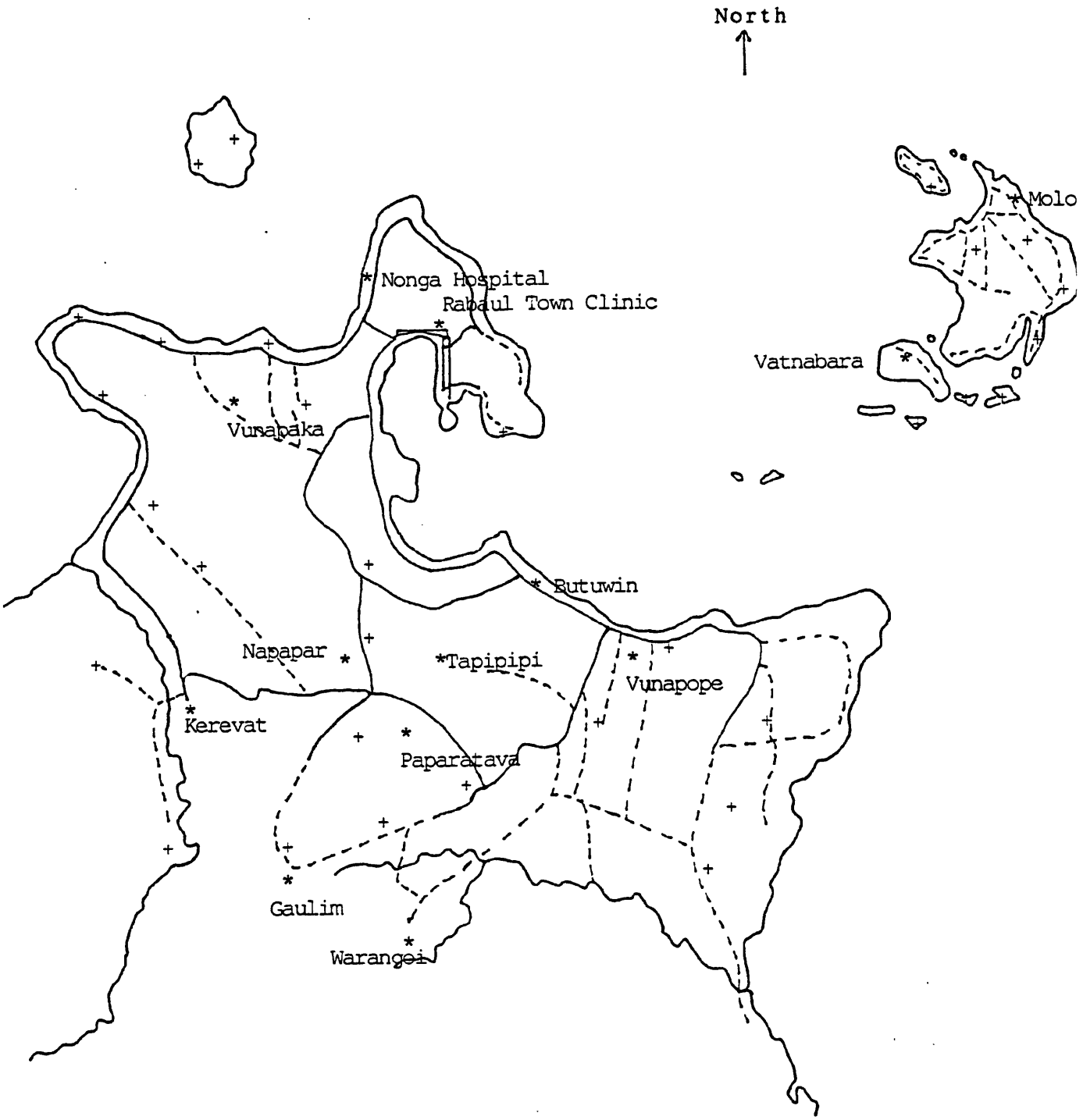


Fig 1.5

GAZELLE PENINSULA

HEALTH FACILITIES



Key:

sealed road
unsealed road
* health centre
\+ aid post

Scale 1 cm = 4 Km

PART 1

MALARIA TRANSMISSION

INTRODUCTION

Household spraying with DDT in the Gazelle Peninsula officially ceased in 1984, although coverage had been declining for ten years before this (fig 2.2). A programme of malaria monitoring was established in mid 1985 for all the island provinces in PNG and special attention was given to the Gazelle Peninsula because of its economic importance to the area and high population density.

It was an original aim of this study that any form of malaria monitoring would provide information to provincial health authorities that was ongoing, would identify areas of high transmission and would indicate the success, or otherwise, of local control measures. The project therefore utilised provincial health resources whenever possible with minimal financial or personnel support from the National Department of Health.

Malaria incidence was monitored by detection of malaria amongst people attending outpatient facilities in Rabaul (passive case detection, pcd). Malaria prevalence was monitored by three-monthly surveys of children 0-9 years of age in selected indicator villages. Morbidity of malaria was measured by monthly monitoring of children and adults discharged from Nonga Hospital.

Reliable retrospective parasitological (and entomological) data were difficult to locate but some information was

available from previous annual reports from the Malaria Service at the Department of Health and from provincial reports located in Rabaul. Hospital inpatient data was surprisingly easy to locate due to an efficient medical records section at Nonga Hospital.

MEASUREMENT OF MALARIA TRANSMISSION

Transmission, as applied to malaria, may best be described as a measure of the ability of the malaria parasite to circulate within the community ie. between man and mosquito. In areas where vector breeding is low and survival short then the vector density in relation to man is low and transmission may not occur. Conversely a high density of infected mosquitoes in relation to man will permit a vigorous exchange of parasites. In this study age-specific and species-specific parasite rates have been used as an indication of transmission, particular attention being given to P falciparum rates as indicators of new infections.

METHODS

MALARIA MORBIDITY AND MORTALITY:

A simple monthly tally of admissions and deaths due to malaria was established at Nonga Hospital. Clerks in the medical records section maintained a separate register for all cases of malaria admitted to both adult and childrens wards. These registers were completed within four weeks of the patient leaving the hospital. Many patients had malaria as an occasional finding and a positive blood slide was almost always recorded as a case of malaria on the

discharge diagnosis in addition to any other disease. This over recording of clinical malaria was a constant feature and reflected difficulty with prioritizing diagnoses by medical staff. However, for the purposes of examining trends in malaria morbidity this problem may be disregarded.

Nonga Hospital receives patients from the northern and western parts of the Gazelle Peninsula. Seriously ill patients are likely to by-pass rural aid posts and health centres and come straight to Nonga Hospital. The hospital also receives patients referred from the Rabaul Town Clinic which serves the town and adjacent settlements and villages. It is not possible to calculate the exact catchment area and population of the hospital for the purposes of establishing morbidity and mortality rates.

A retrospective study of 50 deaths recorded as malaria or cerebral malaria included notes from early 1983 to mid 1986. Records for the most recent 48 deaths were located and examined for age, sex, place of birth, place of residence, final diagnoses, number of days sick, blood slide result and cerebro-spinal fluid result.

Very few deaths from any cause were confirmed by post mortem examination. The diagnosis of cerebral malaria was made when the following features were present: blood slide positive for P falciparum, convulsions and/or changes in level of consciousness or altered mental state.

DISPENSING OF ANTIMALARIAL DRUGS

Malaria transmission may be reflected in the dispensing of antimalarial drugs at health institutions; areas of high transmission may be suggested by high rates of antimalarial drug consumption. A review of antimalarial drug consumption in 1985 was carried out by examining records at the Area Medical Store in Rabaul. This store dispenses drugs to all government and church hospitals and health centres in the province; health centres issue these drugs to aid posts in their area.

Rates of consumption were calculated for each health centre/hospital in the Gazelle Peninsula using 1985 projected census data.

MALARIA PREVALENCE:

A major component of this study was to establish a system of indicator villages in the Gazelle Peninsula to monitor malaria endemicity and to highlight regions of more intense transmission. This system was to be of permanent service to the provincial health authorities to assist them with the planning of antimalarial activities. The location and frequency of sampling of these indicator villages was therefore determined with local health resources in mind.

Indicator village sampling had been performed for many years as part of an evaluation of the effectiveness of DDT household spraying. We thus had some information from 1970 onwards. However, it was not clear what epidemiological parameters had been used in the selection of indicator

villages and it was decided early to reselect villages by sound epidemiological sampling, to ensure appropriate representation for all areas in the Peninsula.

It was envisaged that three-monthly sampling from children under ten years of age would provide a useful profile of malaria transmission. This age group was previously sampled in the evaluation of DDT spraying and seemed appropriate in this mesoendemic area. Children in this age group could be relied upon to either attend regular MCH clinics (for vaccination and nutritional assessment) or to be at primary school; thus compliance was ensured. Older children and adults would be less likely to reflect changes in transmission due to higher levels of immunity and certainly be less likely to be available for blood sampling.

Community announcements via local radio, through MCH clinics and by local discussion informed the public of the nature of the study and of its importance to malaria control in the area. Only four parents objected to the study and their children were excluded from the sample.

It was originally envisaged that one village would be sampled each day, the cycle being repeated in the same order each quarter. There are approximately 60 working days per quarter, 50 when holidays are excluded. The 1981 census book for the Gazelle Peninsula was used for sampling. The census book lists villages and their total populations. Individuals are not listed and there is no

indication of the ethnic origin of people or their duration of residence in the Peninsula.

The following groups were excluded from the calculation of total population and sampling interval; they were either mobile populations or thought not to be major foci for malaria transmission: missions, high schools and urban areas with insect-screened houses. Peri-urban settlements and plantations were included.

Total population = 74,187

Sampling interval= 74,187/50 = 1,484

This interval was used to systematically locate indicator villages from the census book. Forty nine villages were identified in this manner and all available children under ten years of age sampled (table 1, fig 1.2).

This method of sampling is biased for larger population villages. It was important, therefore, to demonstrate that transmission (or parasite rate) was not a reflection of village size.

Using records from 1982-1984, there was no correlation between village size and parasite rate for six surveys of 'old' indicator villages ($r = -0.08$).

It was desirable, therefore, to use a sampling method that biases towards larger villages since more blood slides would be obtained, making the efforts of sampling more worthwhile and the parasite rates obtained more robust and

reliable indicators of transmission. However, all villages identified by the sampling interval were included. A comparison of village population distributions in the Gazelle Peninsula and in the indicator villages selected demonstrates this selection for larger villages (fig 2.1).

For the first and second surveys in 1985 the duration over which blood slides were taken was 40 days, spanning two months. For the first and second cycles of 1986 this period was reduced to 20 days; this was necessary due to relocation of provincial health staff and a reduction in funding for transportation. This reduced survey period still reflected the transmission of malaria parasites in the community and although it represented a deviation from the original protocol it was decided that these survey data would be valuable, although possibly less sensitive than surveys over longer periods.

Thick and thin blood films were prepared on the same slide for each child sampled. Slides were fixed, stained with Giemsa and examined by microscopists in the Regional Malaria Laboratory in Rabaul. Five percent of all positive and negative blood slides and all mixed and P malariae infections were checked by a supervisor and the author. The quality of blood slides was variable. Early attempts to measure parasite counts proved impractical and this was clearly not an on-going possibility for provincial malaria staff.

MALARIA INCIDENCE:

Passive case detection (pcd) provided information on malaria incidence and for logistic and quality control reasons this was limited to the health facilities in the Rabaul urban area.

Every person attending at a health facility in PNG with a fever should have a blood slide taken for malaria parasite examination. In the Gazelle Peninsula blood slides were taken at Nonga Hospital outpatient department and at the childrens (under five years of age) and adult outpatient sections of Rabaul Town Clinic. Other health centres and private clinics in Rabaul yielded very small numbers of blood slides and were excluded from this study for the purposes of establishing patterns of malaria incidence.

For this study only those slides collected at the children's and adults outpatient clinics in Rabaul were analyzed; at Nonga Hospital blood slides were irregularly collected and of very poor quality.

The denominator population for this type of passive case detection (pcd) is difficult to calculate but, within broad limits, may assumed to be approximately 50,000, this being the population of the four most northern census divisions in the Gazelle Peninsula, the Rabaul urban community and adjacent parts of Central and Toma census division.

Blood slides from pcd were collected, fixed, stained, examined and checked as above for indicator village slides.

Retrospective blood slide reports were available for the period 1980-1984 and prospective data collected for 1985-1987.

CLIMATIC INFORMATION:

Rainfall was measured at Rabaul airport (1980-1987), Kerevat Agriculture Station (1980-1987) and rainfall and temperature were recorded at Vunadidir College (1985-1987) (fig 1.2).

In addition historical data on rainfall and temperature were gathered from weather stations at Rabaul, Kerevat, Warangoi and Kokopo.

PART 1 RESULTS

DDT HOUSEHOLD SPRAYING ACTIVITIES: (fig 2.2)
There was a dramatic decline in spraying in the mid 1970s, with further gradual declines until cessation of routine spraying in 1984. The pre-spray parasite rate was 18.1% (1969). The annual parasite rate decreased to <10% by early 1970s and thereafter increased gradually to 14% in 1983 and to 30% in 1984.

During the period 1985-1987 parasite rates continued at 10-20% level in low altitude villages and 5-15% in high altitude villages (fig 2.7).

There was a gradual increase in the proportion of P falciparum infections from 50% in the 1970s to 80% by 1984.

Neither the parasite rate nor the proportion of P falciparum infections dramatically changed when spraying coverage dropped from 70% of dwellings in 1974-1975 to 30% in 1977-1978.

CLIMATE: (figs 2.3, 2.4, 2.5)
Historical patterns of rainfall throughout the Gazelle Peninsula demonstrate a distinctive dry season during the months May-October (fig 2.3). This dry season is more pronounced in Rabaul than in the more southern areas of Kokopo and Kerevat. Marked wet and drier seasons were noted during the period 1980-1987 at Rabaul airport and

Kerevat Agriculture Station although at Kerevat the pattern was not so clear and the dry season less pronounced (fig 2.4). There was marked seasonality in rainfall at Vunadidir College at 440 metres above sea level (fig 2.5).

The temperature varied little throughout the year, being 24-32 deg C at Rabaul and 22-28 deg C at Vunadidir (fig 2.5).

MALARIA ADMISSIONS AND DEATHS: (fig 2.6)
Monthly malaria admissions to Nonga Hospital varied from a low of 18 cases (May 1987) to 115 cases (Jan 1986). Approximately 50% of admissions were children (<10 years of age) and 50% were adults. Annual admission figures show half the number of admissions during 1987.

Year	Adult admissions	Child admissions	TOTAL
1985	372	498	870
1986	399	456	855
1987	269	131	400
TOTAL	1040	1085	2125

Notes and death certificates of patients dying of malaria were incomplete and often contained confusing information.

There were 48 deaths from malaria reported during the three year period 1985-1987. Of these 25 were adults and 23 were children. One fifth of these deaths (10/48) occurred in 1987, commensurate with fewer admissions during this period.

Most deaths were complicated by other health problems and it was not always possible to determine the precise cause of death.

Cerebral malaria accounted for fourteen of the 48 deaths (30%) of which nine were male and five female, seven adults and seven children. Ten of these people who died from cerebral malaria were long term residents of the Gazelle Peninsula and four were visitors from non-endemic areas (mainly the Highlands of the mainland). Three of these four visitors were adults. Blood slides positive for P falciparum were found in ten of the fourteen patients who died from cerebral malaria. The mean duration of illness of people dying from cerebral malaria was 3.6 days.

DISPENSING OF ANTIMALARIAL DRUGS: (table 2)

Table 2 demonstrates the rate of consumption (per head of population) of the various antimalarial preparations routinely used in the treatment of fever and malaria. Treatments are standardised in the various treatment handbooks (Department of Health, Papua New Guinea 1980, 1988).

For routine cases of fever amodiaquine (children) and chloroquine (adults) are prescribed. For amodiaquine in children the average consumption was sixteen tablets/year (range seven at Gaulim health centre to 46 at Kerevat). At

Rabaul health facilities the rate was fourteen tablets/year. For chloroquine the average consumption was twelve tablets/year (range six at Gaulim to eighteen at Warangoi), the rate at Rabaul health facilities being twelve tablets/year.

Consumption rates of primaquine were high at Kerevat and Warangoi (six and five tablets/year) and low at Gaulim, Vatnabara and Molot (one, nil and two tablets/year) with the Rabaul rate being two tablets/year over the same period.

Consumption rates of quinine tablets and injectable forms of quinine and chloroquine (for severe malaria) showed little variation between health facility.

MALARIA PREVALENCE:

INDICATOR VILLAGES

Figure 1.2 and Table 1 illustrates the location and altitudes of the 49 indicator villages. In these villages lived an estimated 19,500 people which, in 1985, comprised 26.3% of the total population of the Gazelle Peninsula. The populations were distributed between high and low altitude villages as follows:

	No villages	1985 population	Children <10 yr (30%)
High alt (>200 masl)	15 (31%)	6019 (31%)	1806
Low alt (<200 masl)	34 (69%)	13482 (69%)	4045
TOTALS	49	19501	5851

A review of the map demonstrated that villages were well distributed throughout the Gazelle Peninsula and included coastal and inland villages, plantations and four periurban settlements.

SURVEYS

Six malaria prevalence surveys were conducted over the two-year period July 1985-July 1987.

Survey 1	Jul - Aug 1985	(mid dry season)
Survey 2	Sep - Oct 1985	(early wet season)
Survey 3	Jan - Feb 1986	(mid wet season)
Survey 4	May - Jun 1986	(early dry season)
Survey 5	Aug - Sep 1986	(late dry season)
Survey 6	May - Jul 1987	(early dry season)

Parasite and age specific parasite rates followed the same general pattern in low and high altitude zones (tables 3, 4 & 5, fig 2.7). The pattern was not apparent in some individual villages.

Rates of infection declined during the dry season and early wet season (July-Oct 1985, Surveys 1 and 2), increasing during the wet season (Jan-Feb 1986, Survey 3) declining during the following dry season (May-Sept 1986, Surveys 4 and 5) and increasing again during the following early dry season (May-July 1987, Survey 6). Peaks in transmission during Survey 3 (wet season) were noted in Balanataman, Reimber, Toma, Sinivit, Bitapaka and Watom Island census divisions.

In low altitude villages parasite rates during Survey 3 (wet season) were, indeed, significantly higher than those observed in other surveys:

Low altitude villages:

Survey 3, pr = 20.8%

Other Surveys, pr = 15.6%

$X^2 = 31.1$, $p = << 0.001$

Although a peak in parasite rate is observed in high altitude villages in Survey 3 this is not significantly different to that in other surveys:

High altitude villages:

Survey 3, pr = 8.6%

Other surveys, pr = 8.9%

$X^2 = 0.09$, $p = > 0.01$

Parasite rates in low altitude zones were, in general, double those in high altitude zones (figs 2.7, 2.8, 2.9). This was more marked in the age groups 1-4 and 5-9 years than in infants. There was little difference in the total parasite rate for children 1-4 years and 5-9 years within an altitude zone.

Low altitude villages, all surveys pr = 16.4%

High altitude villages, all surveys pr = 8.9%

$X^2 = 144.4$, $p = << 0.001$

At low altitudes parasite rates for children 1-9 years of age were double those for infants. This pattern was also observed at high altitudes except for Surveys 4 and 5 (May - Sep 1986, dry season) where the infant parasite rate was

very similar to that in older children. Never the less, even at high altitudes the infant parasite rate was significantly lower than that in older ages groups.

Low altitude villages:

Infant pr = 7.0%

1-9 yr pr = 17.6%

X^2 = 96.3, p = << 0.001

High altitude villages:

Infant pr = 4.3%

1-9 yr pr = 9.6%

X^2 = 17.8, p = << 0.001

Rates of infection with P falciparum were approximately double those of P vivax at low altitudes, both parasites demonstrating similar patterns of infection during the various seasons (fig 2.8). At high altitudes the differences between rates of infection with P falciparum in infants and older children was not so marked as that at low altitudes and there was almost no difference in age-specific rates of infection with P vivax at high altitude (rates generally <5%) (fig 2.9). Mixed infections were rare.

Low altitude villages:

P falciparum, all surveys pr = 10.7%

P vivax, all surveys pr = 5.5%

X^2 = 217.6, p = << 0.001

High altitude villages:

P falciparum, all surveys pr = 6.3%

P vivax, all surveys pr = 2.6%

$X^2 = 66.8, \quad p = << 0.001$

High rates of malaria transmission were noted in Sinivit (pr 12%-85%), Bitapaka (pr 21%-40%) and the Duke of York Islands (pr 28%-45%) (table 6, figs 2.10 - 2.14). Intermediate and erratic parasite rates (two or more rates >20%) were noted in Livuan, Toma, and Watom Island and parasite rates in general were <20% in other census divisions. However, caution is needed in interpreting differences in rates of transmission between census divisions, between surveys and between age groups within census divisions as numbers of blood slides collected was very variable and in some surveys indicator villages were missed entirely due to bad weather or village social events.

MALARIA INCIDENCE:

There is a general similarity in trends of positive blood slides, for P falciparum and P vivax, at both childrens (<5 years of age) and adult clinics in Rabaul during the period 1980-1987 (figs 2.15-2.18). P falciparum appeared to constitute 50-90% of all positive blood slides collected at clinics. Mixed infections were rare.

There is no clearly repeated pattern of positive blood slides throughout each year. For 1984 and 1985 there was a considerable increase in positive blood slides due mainly

to an increase in P falciparum infections, followed during 1986 and 1987 by a marked decrease of P falciparum infections. The total number of blood slides taken, the numbers positive and the slide positivity rate decreased over the period 1986-1987 compared to the previous two years.

There were clear peaks in both the numbers of positive blood slides (P falciparum) and slide positivity rates in April-May 1984 and January 1985 in both clinics. A peak in Jun-July 1985 in the adult clinic was followed by a similar peak in the childrens clinic in Jul-August 1985. During 1986 there are clear peaks in January and a lesser peak in April in both clinics, a pattern that is hardly observed in 1987.

For the three years of the study there was a correlation between the number of admissions of adults and children to Nonga hospital and the number of positive blood slides collected at the Rabaul clinics (fig 2.19).

Table 1

MALARIA INDICATOR VILLAGES

GAZELLE PENINSULA

Community Government, Village	metres above sea level	Est total pop 1985 (1981 pop + 7.5% AGR)	Est <10 yr pop 1985 (30% total)
Duke of York Islands			
Molot	10	281	85
Nabual	10	299	85
Kabilomo	5	594	180
Mioko	5	220	65
Watom Island			
Vunabuk	10	454	135
Balanataman			
Karavia	20	297	90
Nonga	40	508	150
Malaguna 2	10	482	145
Kombiu			
Matalau	20	741	220
Baai	40	462	140
Matupit 2	5	622	185
Korere	10	585	175
Rabaul Urban			
Malay Town Settl't	10	976	295
Admin Comp Settl't	10	363	110
Rapindik Settl't	10	123	35
Reimber			
Vunaulaiting	240	451	135
Raburbur	240	276	85
Vunalaka	300	310	95
Livuan			
Kabakada	20	323	95
Ratongor	10	602	180
Lungalunga	10	364	110
Kabaira	5	74	20

Community Government, Village	metres above sea level	Est total pop 1985 (1981 pop + 7.5% AGR)	Est <10 yr pop 1985 (30% total)
Central			
Napapar 5	160	384	115
Napapar 1	310	485	145
Tinganagalip	380	648	195
Navunaram	400	610	185
Vunakambi	10	82	25
Raluana			
Nguvalian	70	328	100
Bitabaur	160	299	90
Ralalar	270	268	80
Tinganalom	170	592	180
Talakua	350	250	75
Vunadidir			
Ratavul	400	283	85
Vunadidir	440	413	125
Rapitok 3	150	447	135
Rabagi 2	200	448	135
Toma			
Tagitagi 2	220	384	115
Viviran	100	560	170
Sinivit			
Ivere	140	181	55
Vunamami			
Vunamami	60	715	215
Vunabalbal	140	418	125
Malakuna 1	220	452	135
Ramale	80	300	90
Ulaulatava	240	290	90
Tobera	180	117	35
Bitapaka			
Ralubang	200	451	135
Korai	140	186	60
Malakuna 2	70	360	110
Reiven	40	163	50

ANTIMALARIA DRUGS DISPENSED FROM AREA MEDICAL STORE, RABAUL TO HEALTH CENTRES AND HOSPITALS, GAZELLE PENINSULA
JAN - DEC 1985

HC/HOSP	POP APPROX	primaquine tabs 7.5mg	primaq tabs/pop	amodiaquine tabs 100mg	amodiaq tabs/<5yr child	chloroquine tabs 150mg	chloroq tabs/pop	quinine tabs 300mg	quinine tabs/pop	* chloroquin injection 200mg/2ml	chloroq amps/pop	** quinine injection 600mg/10ml	quinine amps/pop
Rabaul town clinicplus Nonga Hosp	44800	87000	1.9	93000	13.8	540000	12.1	7400	0.2	11220	0.3	3328	0.1
Butuwin	7200	23000	3.2	14000	13.0	84000	11.7	500	0.1	1020	0.1	175	0.0
Tapipipi	4300	8000	1.9	14000	21.7	73000	17.0	0	0.0	840	0.2	1825	0.4
Vunapaka	11200	2000	0.2	23000	13.7	82000	7.3	0	0.0	410	0.0	1200	0.1
Kerevat	6500	39000	6.0	45000	46.2	81400	12.5	800	0.1	690	0.1	1813	0.3
Warangoi	2800	15000	5.4	15000	35.7	51000	18.2	0	0.0	720	0.3	450	0.2
Vunapope	19300	48000	2.5	45000	15.5	332000	17.2	5000	0.3	1640	0.1	1575	0.1
Napapar	5300	9200	1.7	11000	13.8	41000	7.7	100	0.0	300	0.1	128	0.0
Paparatava	7800	26200	3.4	9000	7.7	85000	10.9	900	0.1	980	0.1	875	0.1
Gaulim	5300	5500	1.0	4000	6.7	29000	5.5	0	0.0	1010	0.2	625	0.1
Vatnabara	2300	0	0.0	10000	29.9	16000	7.0	0	0.0	280	0.1	700	0.3
Molot	5700	10000	1.8	11000	12.9	38000	6.7	0	0.0	440	0.1	450	0.1
TOTAL GAZELLE PENINSULA	122500	272900	2.2	294000	16.0	1452400	11.9	14700	0.1	19550	0.2	13144	0.1

* chloroquine 200mg/2ml includes amps 80mg/2ml (corrected)
** quinine 600mg/2ml includes amps 120mg/2ml (corrected)

Table 2

Fig 2.1

GAZELLE PENINSULA VILLAGE AND MALARIA INDICATOR VILLAGE POPULATIONS

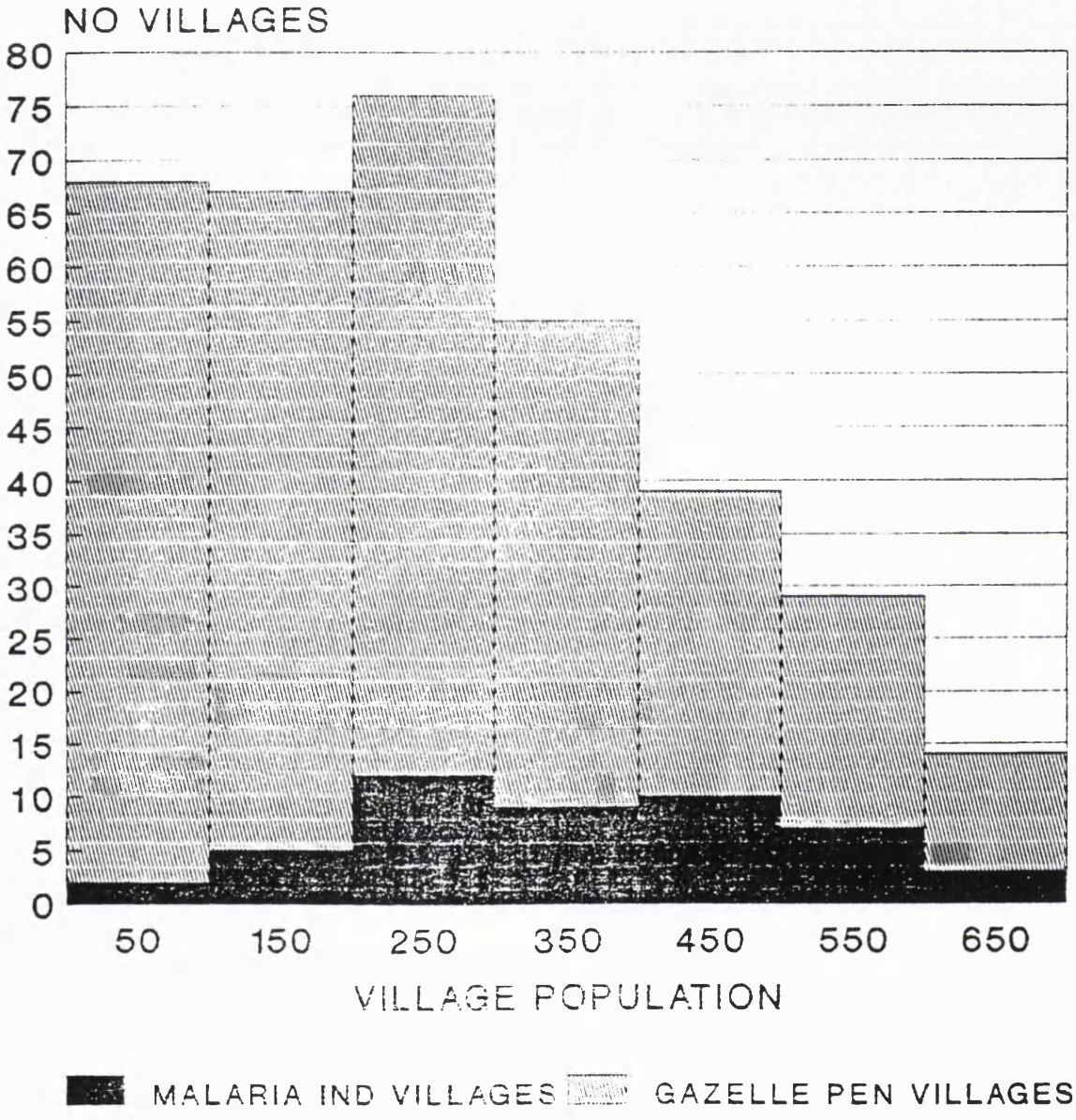
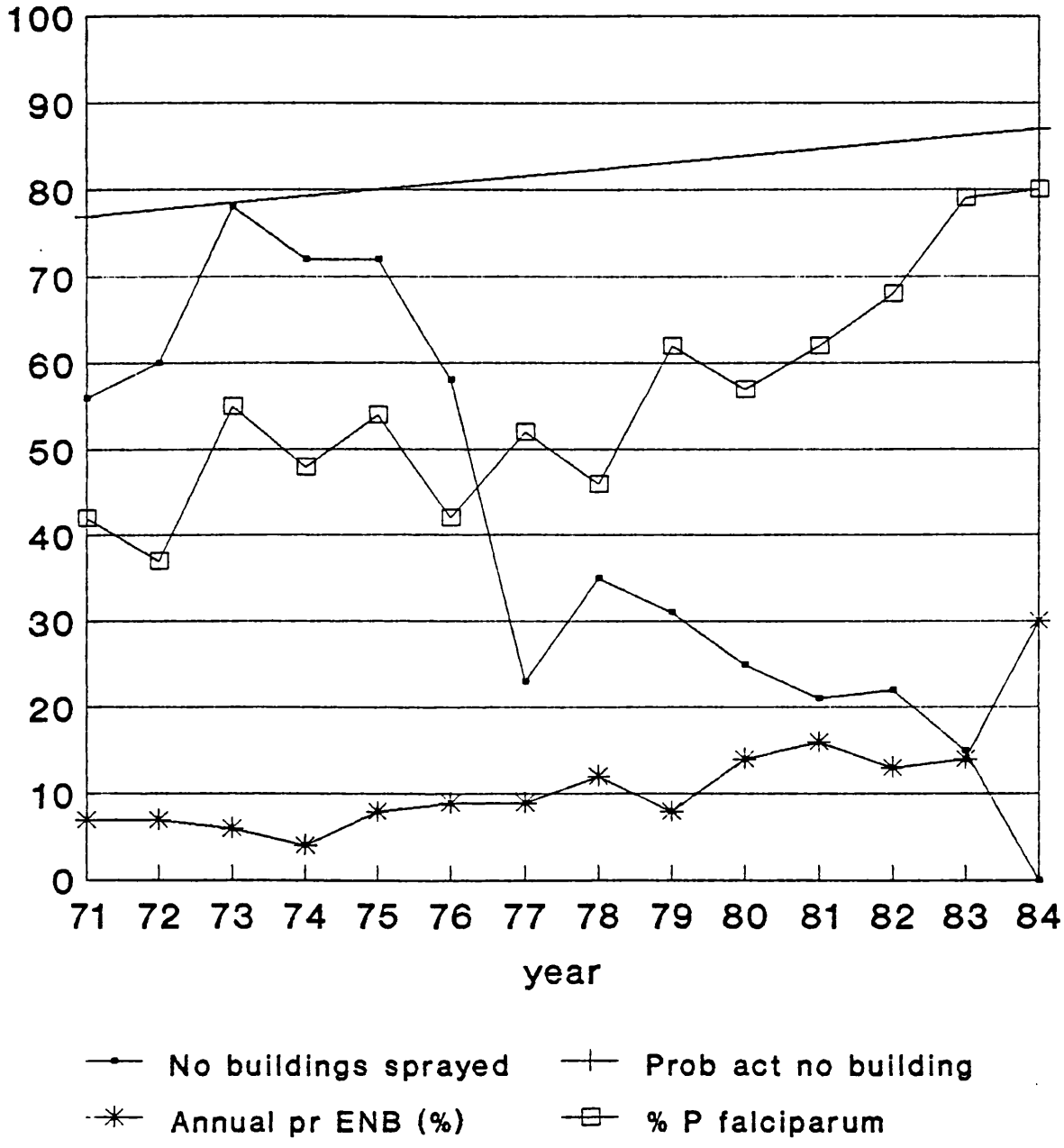


Fig 2.2

DDT HOUSEHOLD SPRAYING AND PARASITE RATE, EAST NEW BRITAIN



buildings x 1000

Fig 2.3

MEAN MONTHLY RAINFALL
GAZELLE PENINSULA

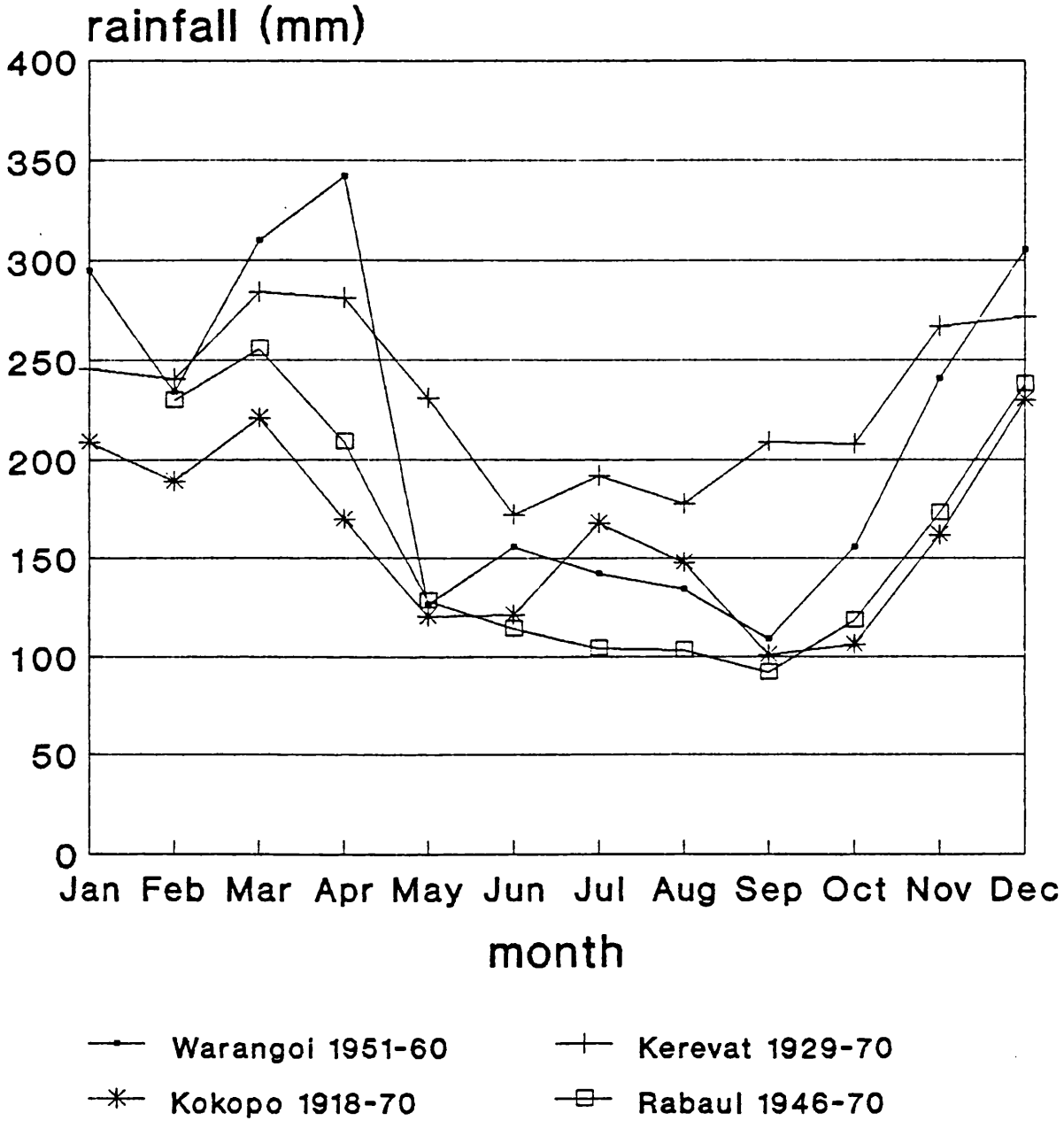
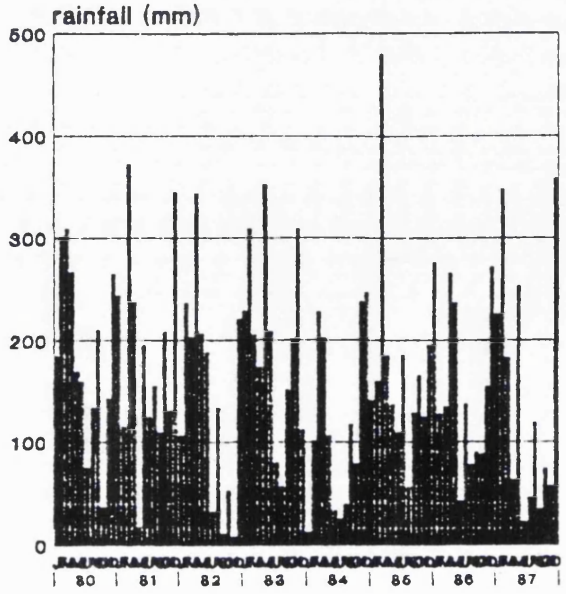


Fig 2.4

MONTHLY RAINFALL
RABAUL



MONTHLY RAINFALL
KEREVAT

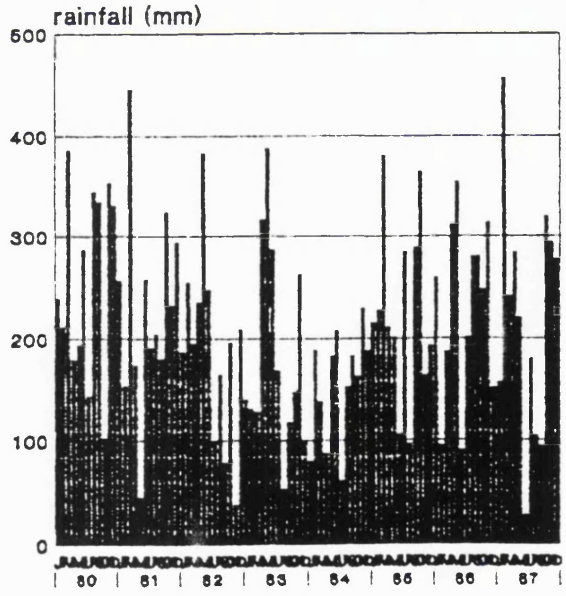
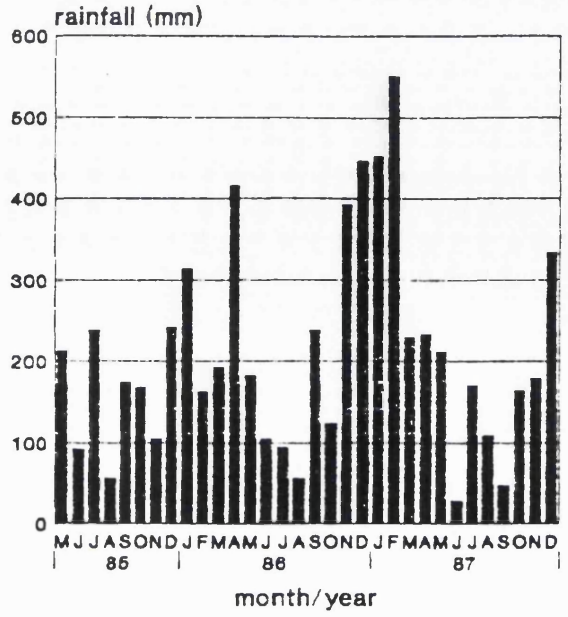


Fig 2.5

MONTHLY RAINFALL
VUNADIDIR



TEMPERATURES
VUNADIDIR

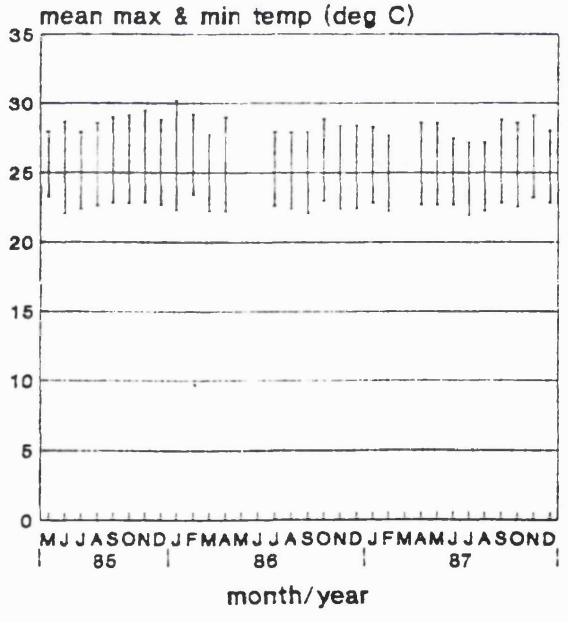
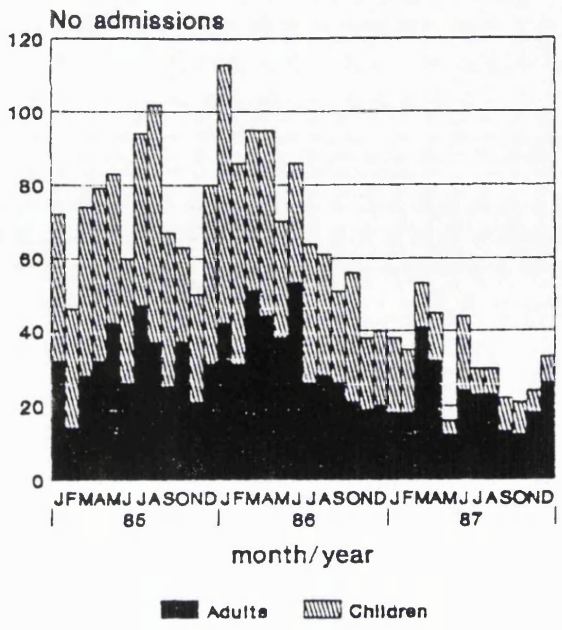


Fig 2.6

'MALARIA' ADMISSIONS 1985-1987
NONGA HOSPITAL, RABAUL



'MALARIA' DEATHS 1985-1987
NONGA HOSPITAL, RABAUL

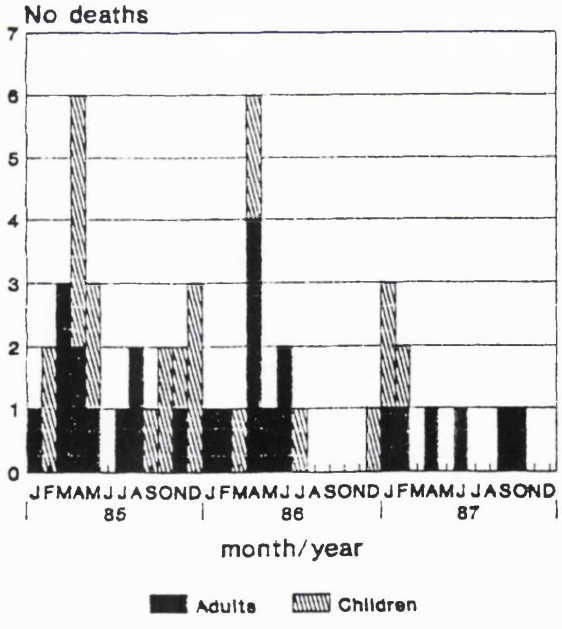


Table 3

LOW ALTITUDE VILLAGES, GAZELLE PENINSULA - PARASITE RATES

Age Group	No blood slides	P falciparum +	P falciparum pr%	P vivax +	P vivax pr%	P malariae +	P malariae pr%	All parasites +	All parasites pr%
SURVEY 1									
1-11 mo	249	11	4.4	6	2.4	0	0.0	17	6.8
1-4 yr	1241	139	11.2	88	7.1	1	0.1	228	18.4
5-9 yr	1300	147	11.3	92	7.1	2	0.2	241	18.5
0-9 yr	2790	297	10.6	186	6.7	3	0.1	486	17.4
SURVEY 2									
1-11 mo	140	4	2.9	2	1.4	0	0.0	6	4.3
1-4 yr	623	38	6.1	23	3.7	0	0.0	61	9.8
5-9 yr	991	83	8.4	44	4.4	1	0.1	128	12.9
0-9 yr	1754	125	7.1	69	3.9	1	0.1	195	11.1
SURVEY 3									
1-11 mo	265	20	7.5	6	2.3	0	0.0	26	9.8
1-4 yr	929	143	15.4	84	9.0	0	0.0	227	24.4
5-9 yr	667	96	14.4	37	5.5	2 *	0.3	135	20.2
0-9 yr	1861	259	13.9	127	6.8	2	0.1	388	20.8
SURVEY 4									
1-11 mo	263	13	4.9	3	1.1	0	0.0	16	6.1
1-4 yr	935	101	10.8	47	5.0	0	0.0	148	15.8
5-9 yr	557	67	12.0	26	4.7	4 *	0.7	97	17.4
0-9 yr	1755	181	10.3	76	4.3	4	0.2	261	14.9
SURVEY 5									
1-11 mo	226	3	1.3	4	1.8	0	0.0	7	3.1
1-4 yr	773	79	10.2	59	7.6	0	0.0	138	17.9
5-9 yr	1090	85	7.8	69	6.3	5 *	0.5	159	14.6
0-9 yr	2089	167	8.0	132	6.3	5	0.2	304	14.6
SURVEY 6									
1-11 mo	192	20	10.4	2	1.0	0	0.0	22	11.5
1-4 yr	772	106	13.7	28	3.6	2	0.3	136	17.6
5-9 yr	619	109	17.6	30	4.8	1	0.2	140	22.6
0-9 yr	1583	235	14.8	60	3.8	3	0.2	298	18.8
ALL SURVEYS									
1-11 mo	1335	71	5.3	23	1.7	0	0.0	94	7.0
1-4 yr	5273	606	11.5	329	6.2	3	0.1	938	17.8
5-9 yr	5224	587	11.2	298	5.7	15	0.3	900	17.2
0-9 yr	11832	1264	10.7	650	5.5	18	0.2	1932	16.3

* 9/115 *P malariae* slides from Kabilomo, Duke of York Is.

Table 4

HIGH ALTITUDE VILLAGES, GAZELLE PENINSULA - PARASITE RATES

Age Group	No blood slides	P falciparum +	P falciparum pr%	P vivax +	P vivax pr%	P malariae +	P malariae pr%	All parasites +	All parasites pr%
SURVEY 1									
1-11 mo	77	7	9.1	0	0.0	0	0.0	7	9.1
1-4 yr	331	29	8.8	16	4.8	0	0.0	45	13.6
5-9 yr	343	37	10.8	19	5.5	0	0.0	56	16.3
0-9 yr	751	73	9.7	35	4.7	0	0.0	108	14.4
SURVEY 2									
1-11 mo	58	1	1.7	0	0.0	0	0.0	1	1.7
1-4 yr	233	11	4.7	4	1.7	0	0.0	15	6.4
5-9 yr	427	17	4.0	10	2.3	0	0.0	27	6.3
0-9 yr	718	29	4.0	14	1.9	0	0.0	43	6.0
SURVEY 3									
1-11 mo	149	4	2.7	0	0.0	0	0.0	4	2.7
1-4 yr	421	31	7.4	10	2.4	0	0.0	41	9.7
5-9 yr	195	18	9.2	3	1.5	0	0.0	21	10.8
0-9 yr	765	53	6.9	13	1.7	0	0.0	66	8.6
SURVEY 4									
1-11 mo	139	3	2.2	1	0.7	0	0.0	4	2.9
1-4 yr	433	20	4.6	8	1.8	0	0.0	28	6.5
5-9 yr	174	6	3.4	1	0.6	0	0.0	7	4.0
0-9 yr	746	29	3.9	10	1.3	0	0.0	39	5.2
SURVEY 5									
1-11 mo	67	3	4.5	2	3.0	0	0.0	5	7.5
1-4 yr	230	11	4.8	13	5.7	0	0.0	24	10.4
5-9 yr	349	17	4.9	7	2.0	0	0.0	24	6.9
0-9 yr	646	31	4.8	22	3.4	0	0.0	53	8.2
SURVEY 6									
1-11 mo	97	4	4.1	0	0.0	0	0.0	4	4.1
1-4 yr	388	31	8.0	15	3.9	0	0.0	46	11.9
5-9 yr	189	19	10.1	4	2.1	0	0.0	23	12.2
0-9 yr	674	54	8.0	19	2.8	0	0.0	73	10.8
ALL SURVEYS									
1-11 mo	587	22	3.7	3	0.5	0	0.0	25	4.3
1-4 yr	2036	133	6.5	66	3.2	0	0.0	199	9.8
5-9 yr	1677	114	6.8	44	2.6	0	0.0	158	9.4
0-9 yr	4300	269	6.3	113	2.6	0	0.0	382	8.9

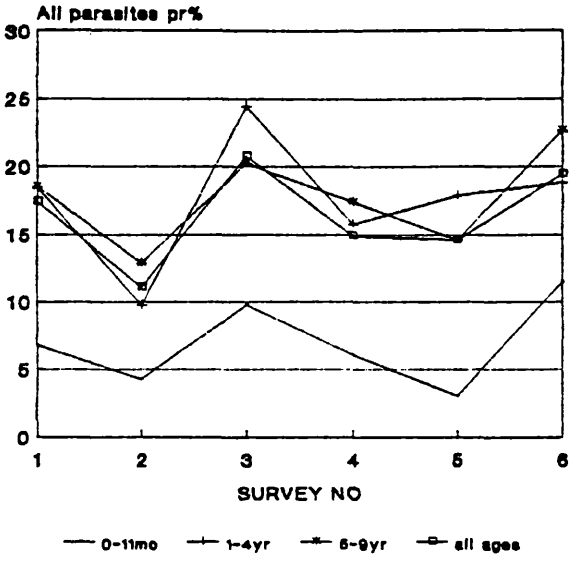
Table 5

ALL VILLAGES, GAZELLE PENINSULA - PARASITE RATES

Age Group	No blood slides	P falciparum +	P falciparum pr%	P vivax +	P vivax pr%	P malariae +	P malariae pr%	All parasites +	All parasites pr%
SURVEY 1									
1-11 mo	326	18	5.5	6	1.8	0	0.0	24	7.4
1-4 yr	1572	168	10.7	104	6.6	1	0.1	273	17.4
5-9 yr	1643	184	11.2	111	6.8	2	0.1	297	18.1
0-9 yr	3541	370	10.4	221	6.2	3	0.1	594	16.8
SURVEY 2									
1-11 mo	198	5	2.5	2	1.0	0	0.0	7	3.5
1-4 yr	856	49	5.7	27	3.2	0	0.0	76	8.9
5-9 yr	1418	100	7.1	54	3.8	1	0.1	155	10.9
0-9 yr	2472	154	6.2	83	3.4	1	0.0	238	9.6
SURVEY 3									
1-11 mo	414	24	5.8	6	1.4	0	0.0	30	7.2
1-4 yr	1350	174	12.9	94	7.0	0	0.0	268	19.9
5-9 yr	862	114	13.2	40	4.6	2	0.2	156	18.1
0-9 yr	2626	312	11.9	140	5.3	2	0.1	454	17.3
SURVEY 4									
1-11 mo	402	16	4.0	4	1.0	0	0.0	20	5.0
1-4 yr	1368	121	8.8	55	4.0	0	0.0	176	12.9
5-9 yr	731	73	10.0	27	3.7	4	0.5	104	14.2
0-9 yr	2501	210	8.4	86	3.4	4	0.2	300	12.0
SURVEY 5									
1-11 mo	293	6	2.0	6	2.0	0	0.0	12	4.1
1-4 yr	1003	90	9.0	72	7.2	0	0.0	162	16.2
5-9 yr	1439	102	7.1	76	5.3	5	0.3	183	12.7
0-9 yr	2735	198	7.2	154	5.6	5	0.2	357	13.1
SURVEY 6									
1-11 mo	289	24	8.3	2	0.7	0	0.0	26	9.0
1-4 yr	1160	137	11.8	43	3.7	2	0.2	182	15.7
5-9 yr	808	128	15.8	34	4.2	1	0.1	163	20.2
0-9 yr	2257	289	12.8	79	3.5	3	0.1	371	16.4
ALL SURVEYS									
1-11 mo	1922	93	4.8	26	1.4	0	0.0	119	6.2
1-4 yr	7309	739	10.1	395	5.4	3	0.0	1137	15.6
5-9 yr	6901	701	10.2	342	5.0	15	0.2	1058	15.3
0-9 yr	16132	1533	9.5	763	4.7	18	0.1	2314	14.3

Fig 2.7

TOTAL PARASITE RATES
GAZELLE PENINSULA
LOW ALTITUTDE



TOTAL PARASITE RATES
GAZELLE PENINSULA
HIGH ALTITUTDE

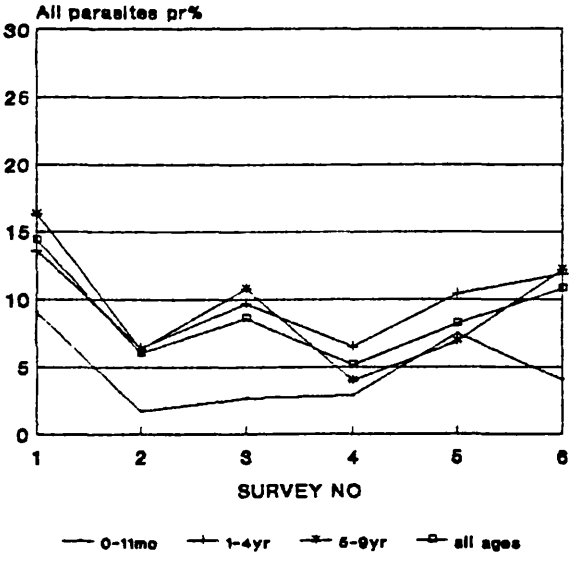
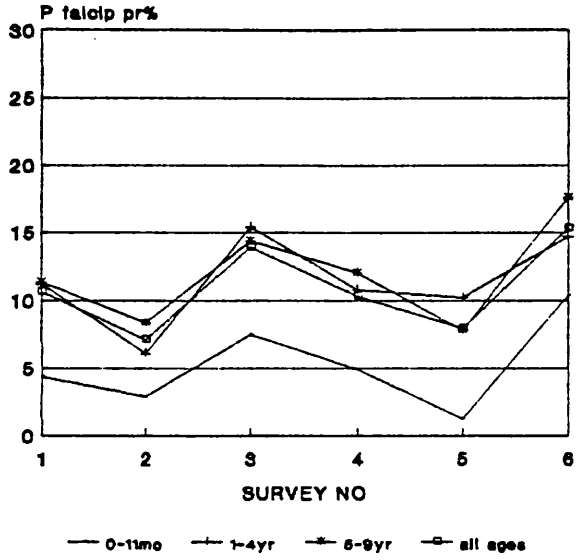


Fig 2.8

P FALCIPARUM PARASITE RATE
GAZELLE PENINSULA
LOW ALTITUDE



P VIVAX PARASITE RATES
GAZELLE PENINSULA
LOW ALTITUDE

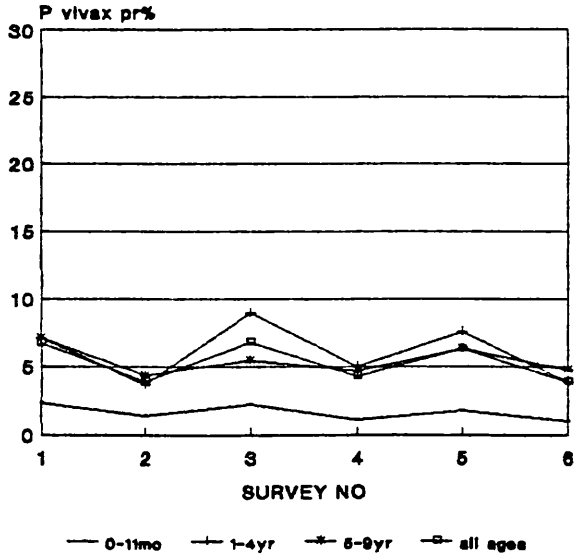
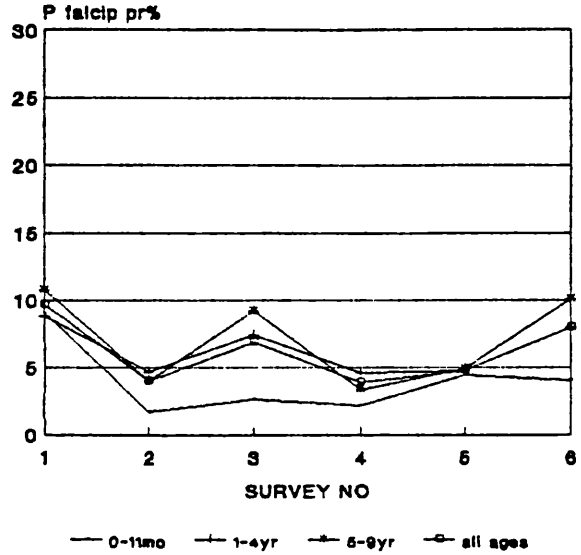


Fig 2.9

P FALCIPARUM PARASITE RATE
GAZELLE PENINSULA
HIGH ALTITUDE



P VIVAX PARASITE RATES
GAZELLE PENINSULA
HIGH ALTITUDE

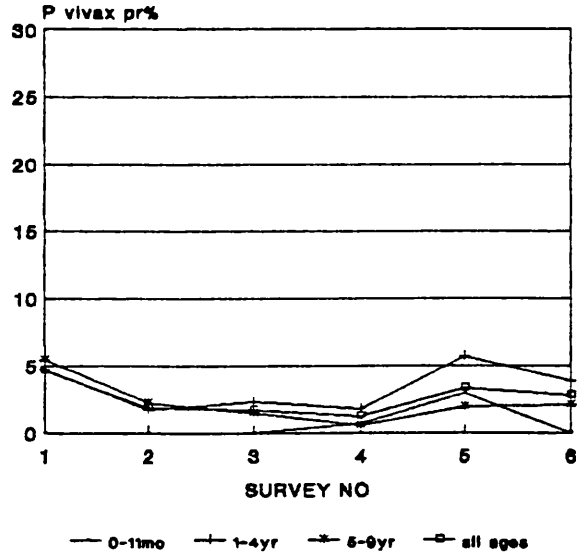


Table 6

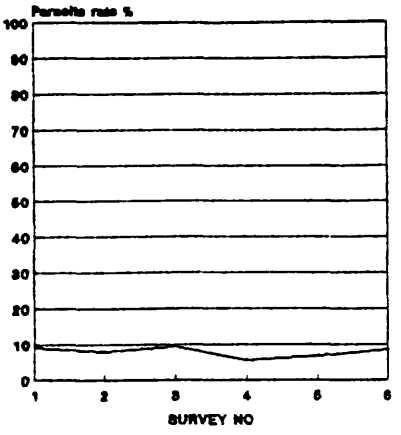
CENSUS DIVISONS, GAZELLE PENINSULA
0-9 YR PARASITE RATES

SURVEY NO

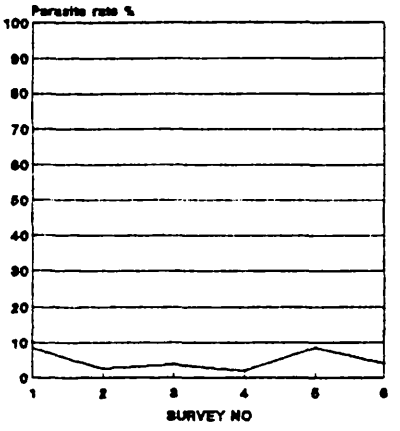
	1		2		3		4		5		6	
CD	n	pr%	n	pr%	n	pr	n	pr%	n	pr%	n	pr%
Kom	334	9.3	540	8.1	213	9.4	367	5.7	404	6.9	288	8.7
Rab	258	8.5	73	2.7	54	3.7	103	1.9	107	8.4	97	4.1
Bal	238	11.3	184	6.5	166	15.1	192	9.9	226	7.1	115	20.9
Rei	143	8.4	182	2.7	108	11.1	191	4.2	181	8.3	209	11.5
Liv	437	21.5	321	19.3	310	17.7	304	18.4	346	15.6	180	26.7
Cen	167	10.2	390	10.0	298	11.1	202	7.9	306	7.8	52	1.9
Ral	363	13.2	382	6.5	267	6.4	201	2.0	313	6.1	341	6.7
Vun	363	8.8	88	12.5	297	12.8	210	7.6	202	4.5	162	9.9
Tom	181	23.2	170	14.7	127	27.6	57	3.5	77	20.8	68	13.2
Sin	25	12.0	0	-	43	62.8	28	32.1	12	41.7	13	84.6
Vun	206	11.2	138	4.3	244	5.7	190	6.0	179	23.5	185	16.8
Bit	246	27.2	70	21.4	209	33.5	151	24.5	95	25.3	139	39.6
DOY	400	37.8	0	-	223	36.8	245	35.1	173	44.5	358	27.9
Wat	66	13.6	48	16.7	67	35.8	60	23.3	114	16.7	0	-

Fig 2.10

PARASITE RATES, 0-9 YEARS
KOMBIU CD



PARASITE RATES, 0-9 YEARS
RABAUL URBAN CD



PARASITE RATES, 0-9 YEARS
BALANATAMAN CD

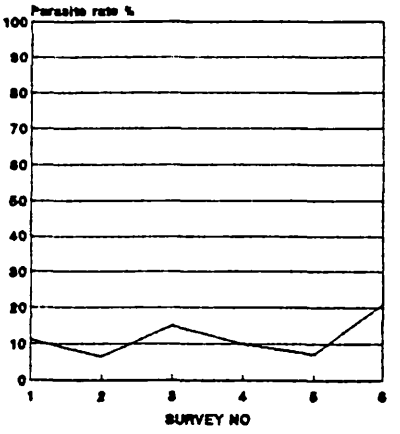
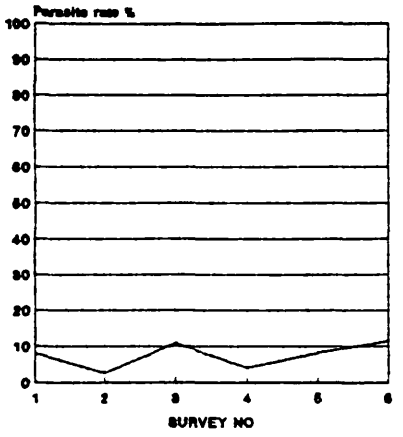
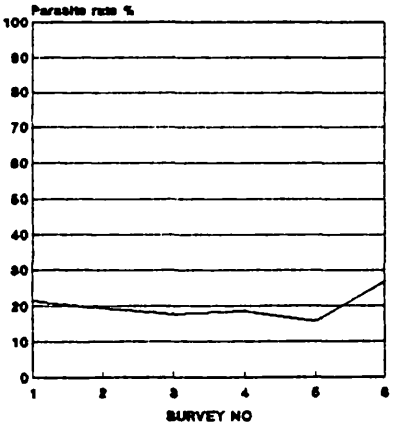


Fig 2.11

PARASITE RATES, 0-9 YEARS
REIMBER CD



PARASITE RATES, 0-9 YEARS
LIVUAN CD



PARASITE RATES, 0-9 YEARS
CENTRAL CD

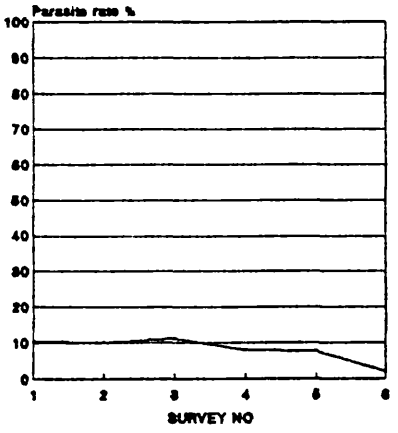
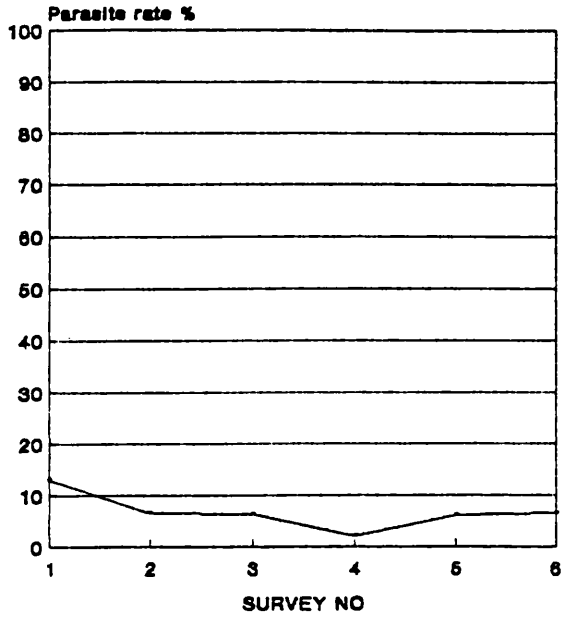
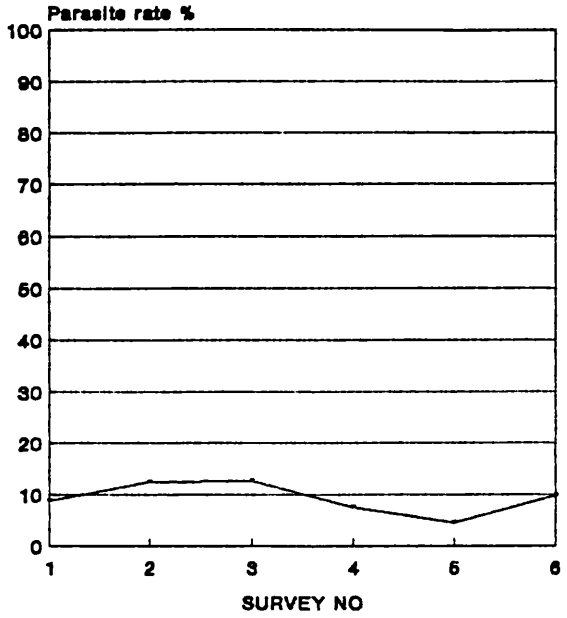


Fig 2.12

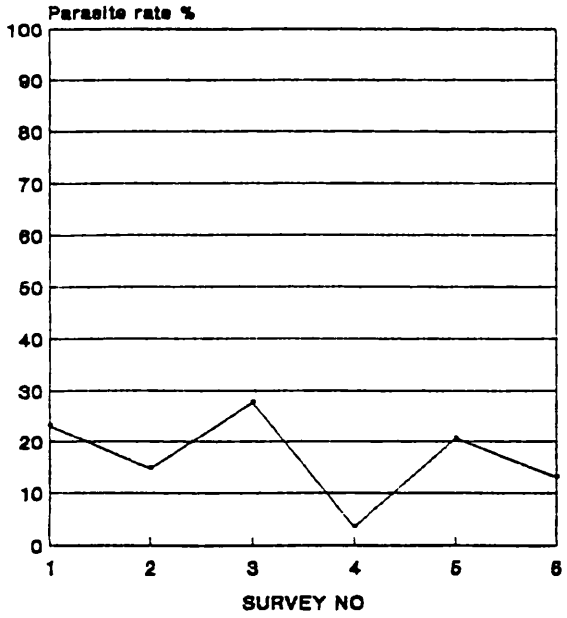
PARASITE RATES, 0-9 YEARS RALUANA CD



PARASITE RATES, 0-9 YEARS VUNADIDIR CD



PARASITE RATES, 0-9 YEARS TOMA CD



PARASITE RATES, 0-9 YEARS SINIVIT CD

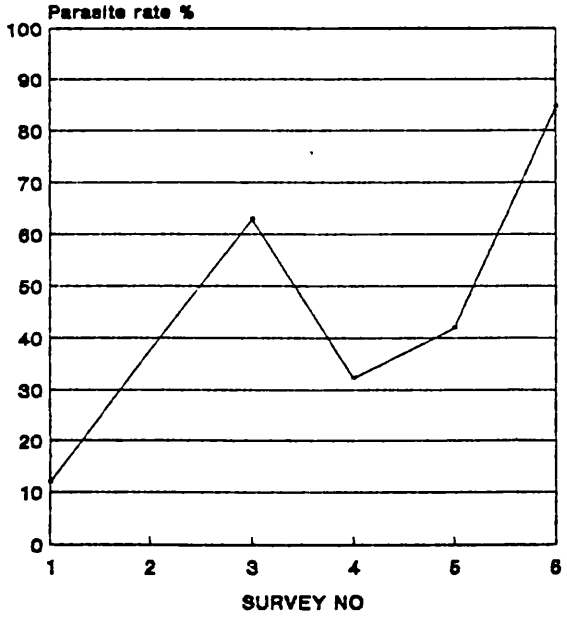
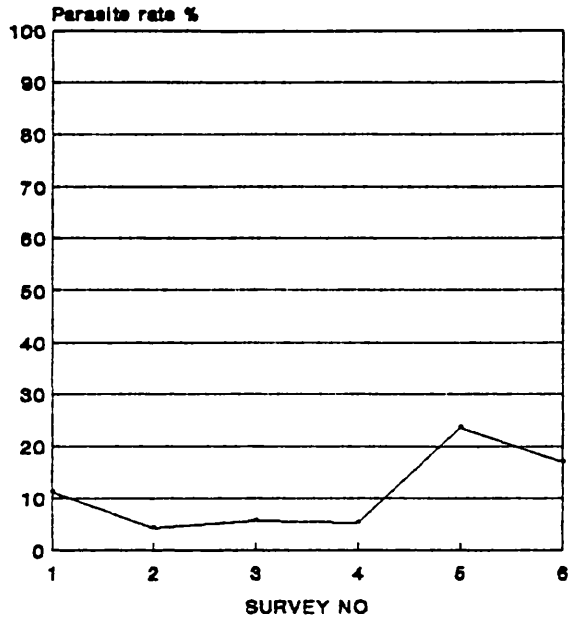


Fig 2.13

PARASITE RATES, 0-9 YEARS
VUNAMAMI CD



PARASITE RATES, 0-9 YEARS
BITAPAKA CD

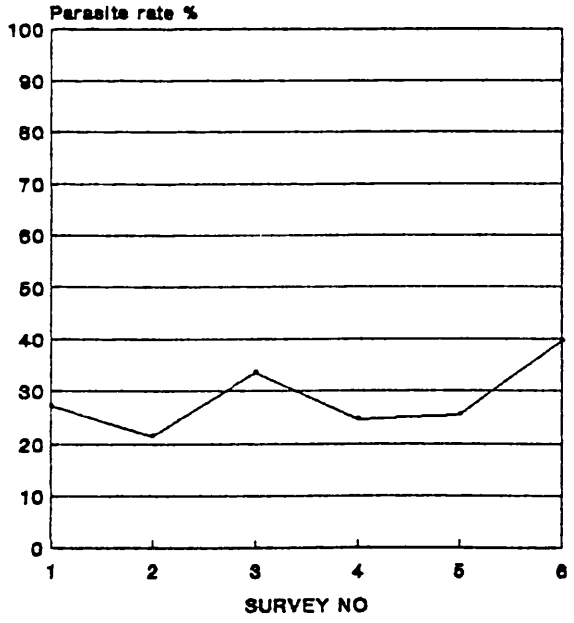
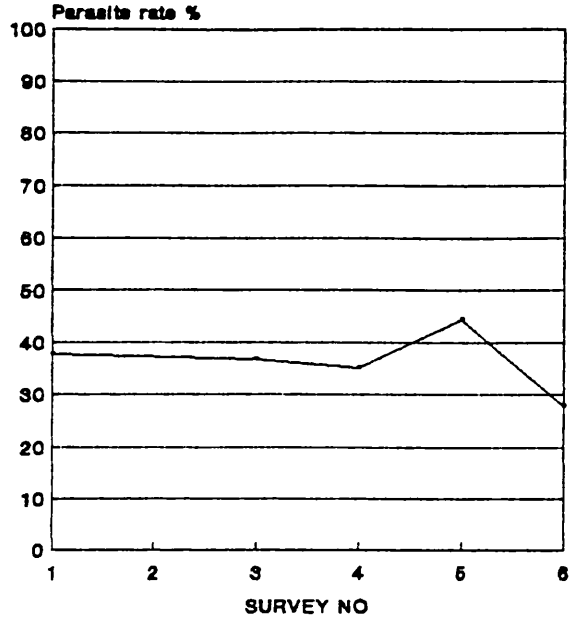


Fig 2.14

PARASITE RATES, 0-9 YEARS
DUKE OF YORK ISLANDS CD



PARASITE RATES, 0-9 YEARS
WATOM ISLAND CD

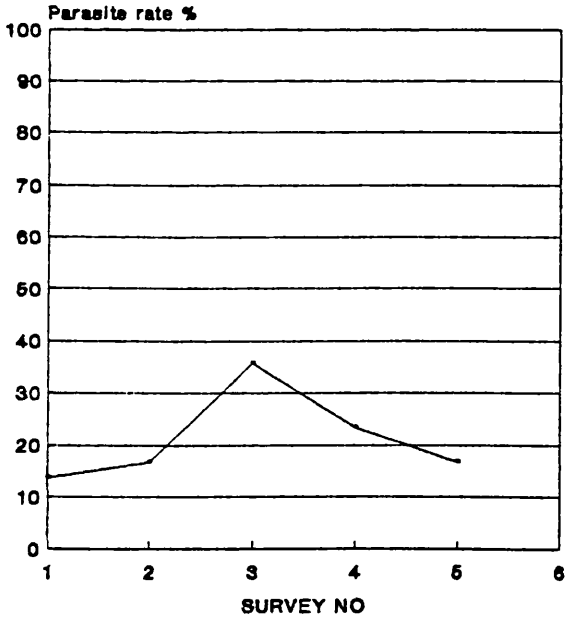
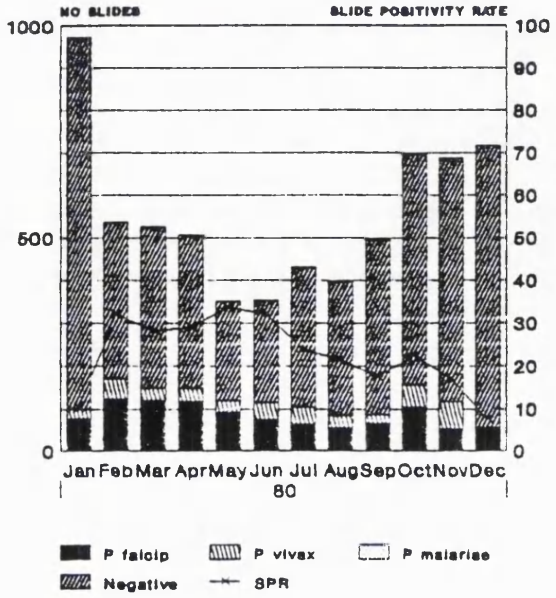
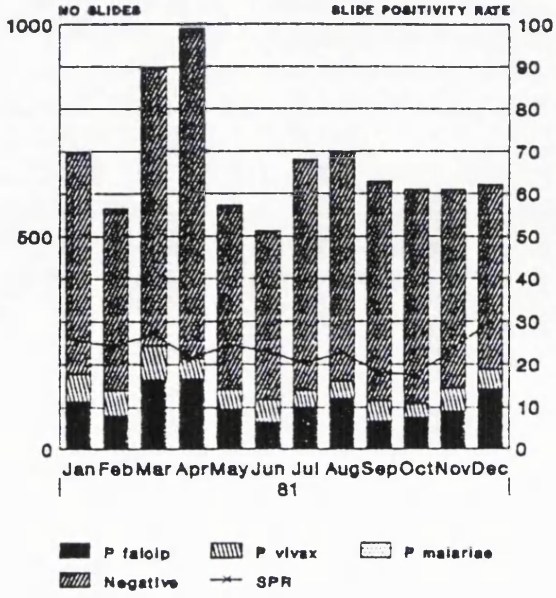


Fig 2.15

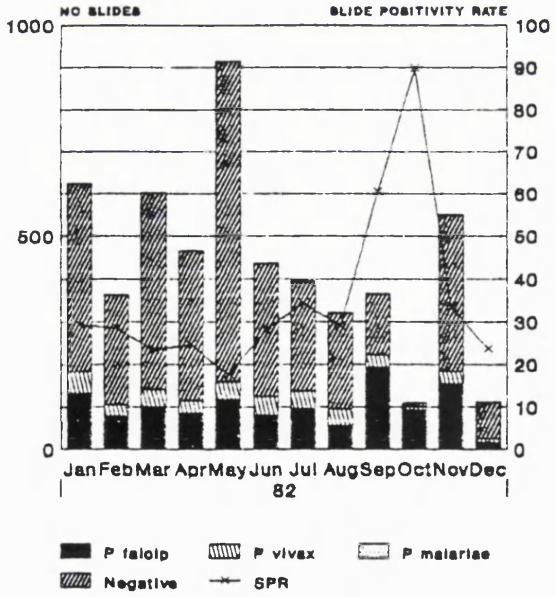
MALARIA INCIDENCE 1980
CHILDRENS OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1981
CHILDRENS OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1982
CHILDRENS OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1983
CHILDRENS OUTPATIENT CLINIC RABAUL

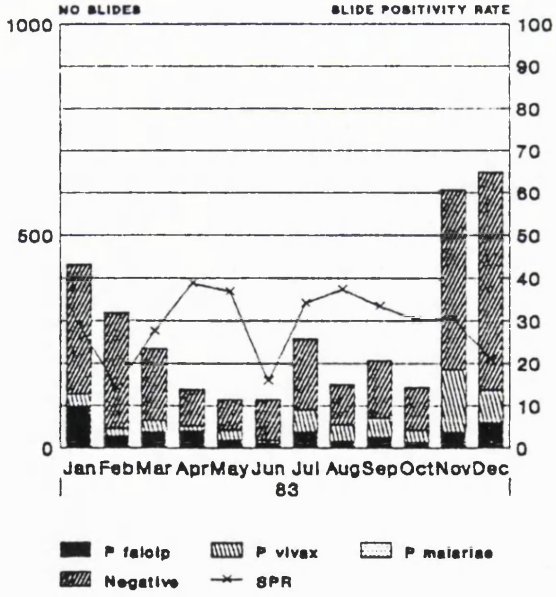
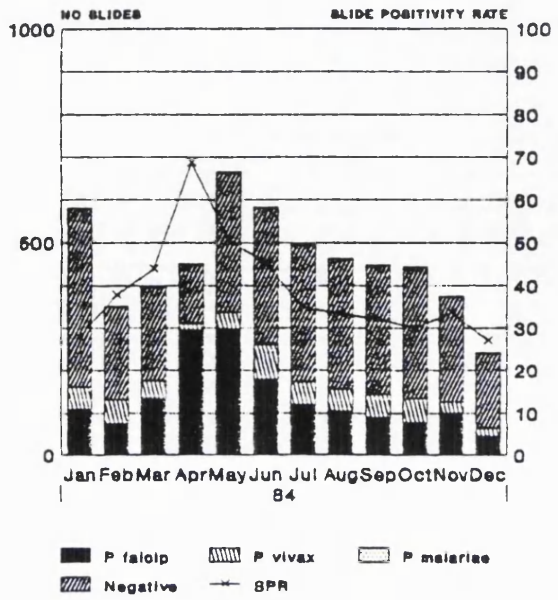
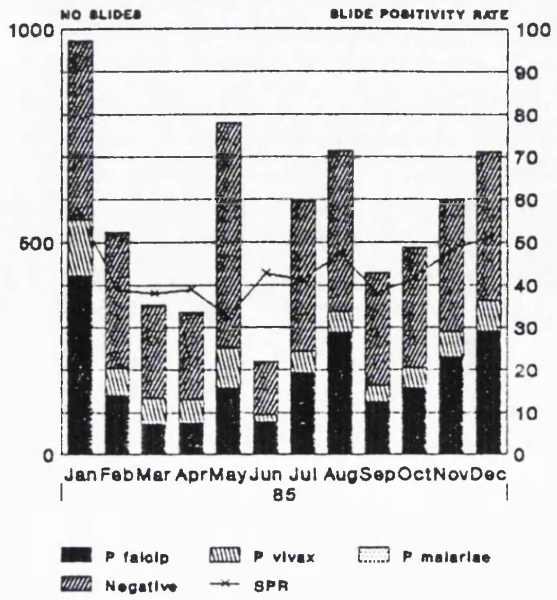


Fig 2.16

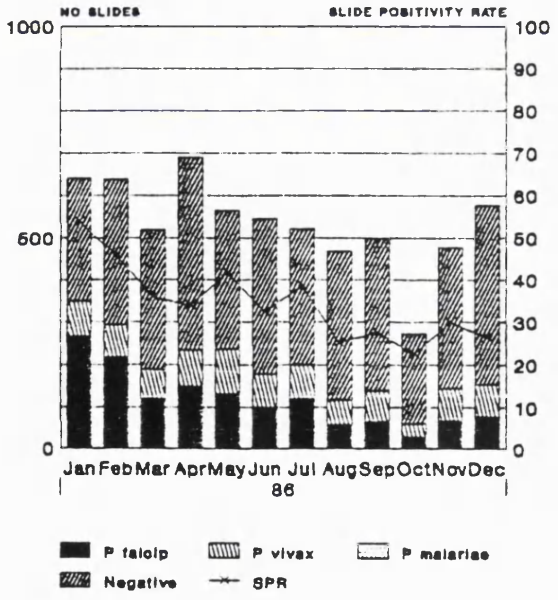
MALARIA INCIDENCE 1984
CHILDRENS OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1985
CHILDRENS OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1986
CHILDRENS OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1987
CHILDRENS OUTPATIENT CLINIC RABAUL

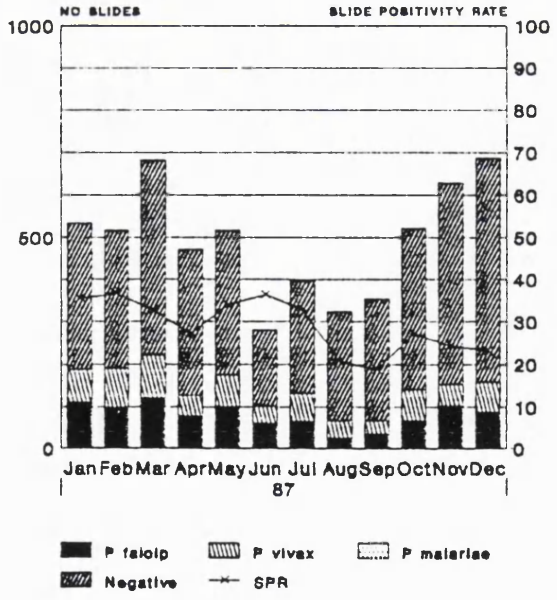
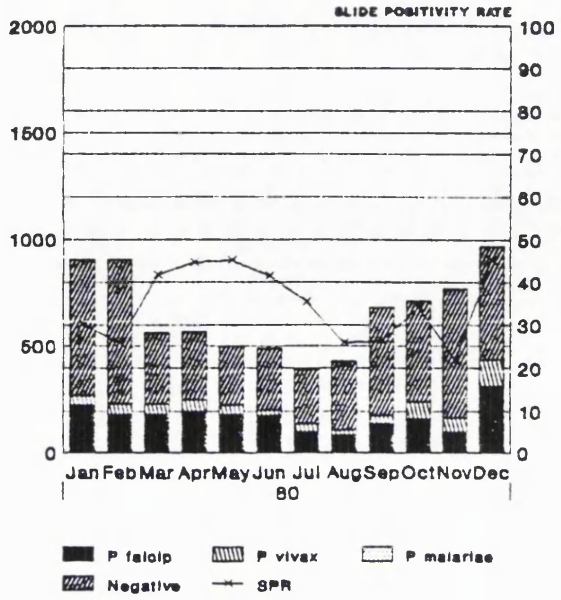


Fig 2.17

MALARIA INCIDENCE 1980
ADULT OUTPATIENT CLINIC RABAUL



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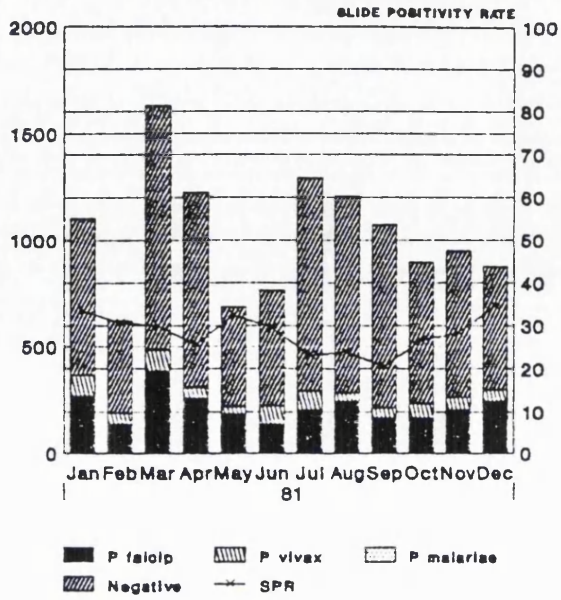
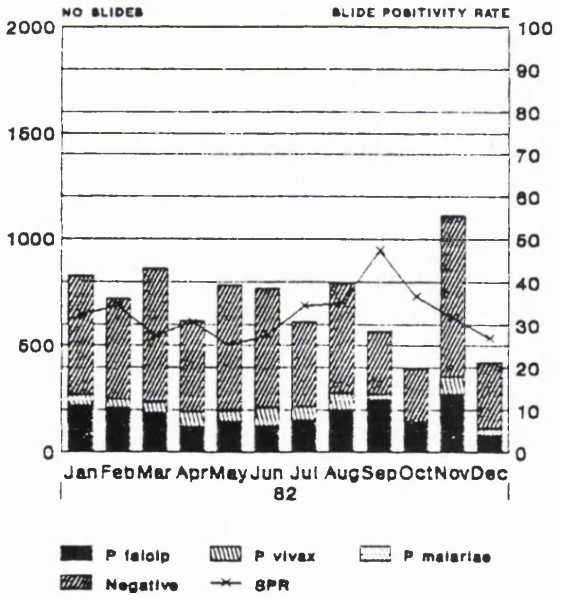
ADULT OUTPATIENT CLINIC RABAUL



MALARIA INCIDENCE 1982
ADULT OUTPATIENT CLINIC RABAUL



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ADULT OUTPATIENT CLINIC RABAUL

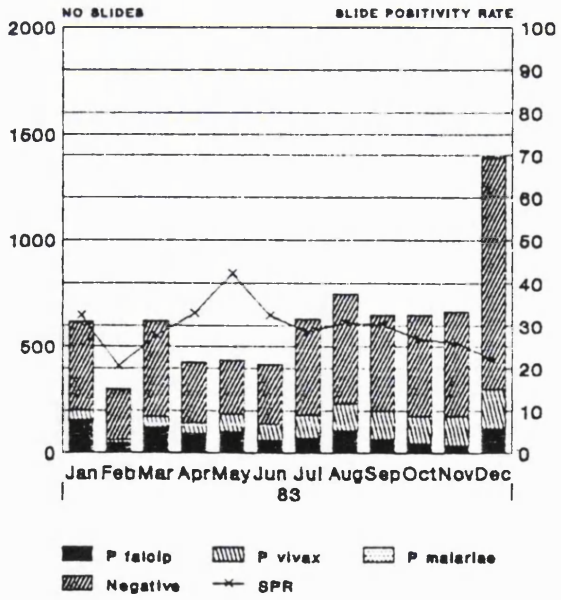
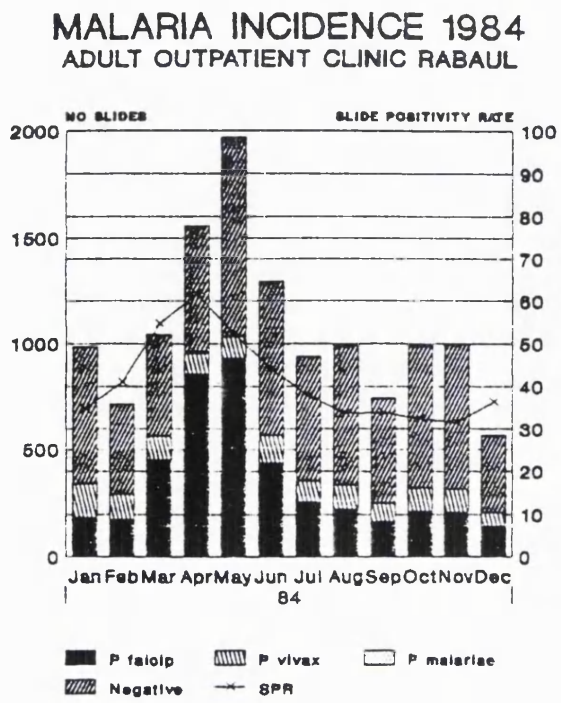
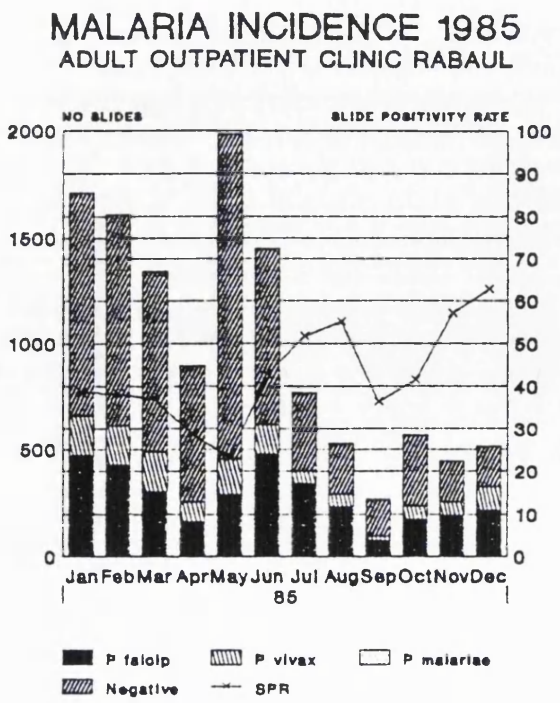
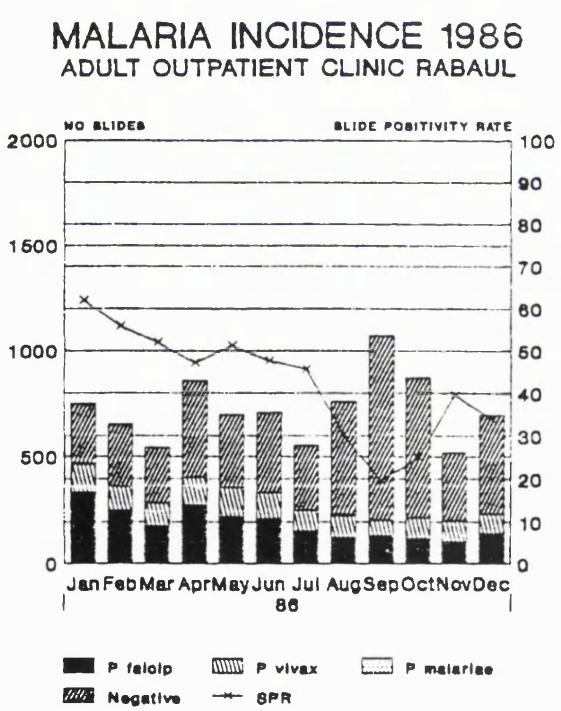


Fig 2.18


MALARIA INCIDENCE 1984
ADULT OUTPATIENT CLINIC RABAUL
NO SLIDES
SLIDE POSITIVITY RATE
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
84
P falcip
P vivax
P malariae
Negative
SPR


MALARIA INCIDENCE 1985
ADULT OUTPATIENT CLINIC RABAUL
NO SLIDES
SLIDE POSITIVITY RATE
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
85
P falcip
P vivax
P malariae
Negative
SPR


MALARIA INCIDENCE 1986
ADULT OUTPATIENT CLINIC RABAUL
NO SLIDES
SLIDE POSITIVITY RATE
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
86
P falcip
P vivax
P malariae
Negative
SPR

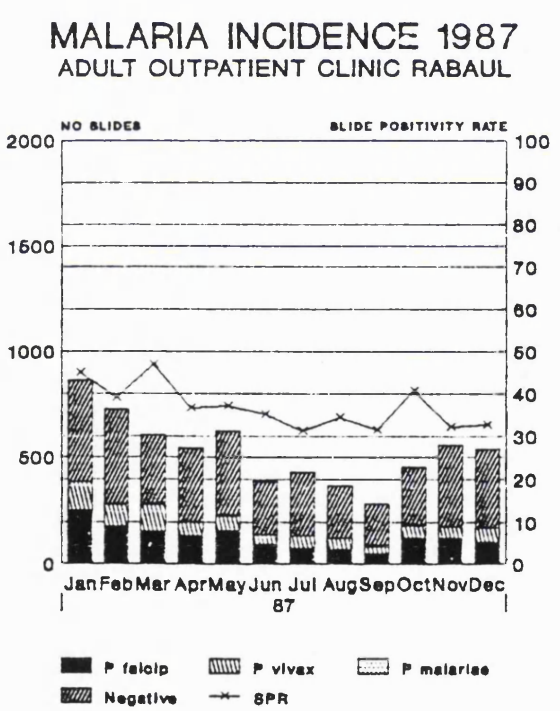
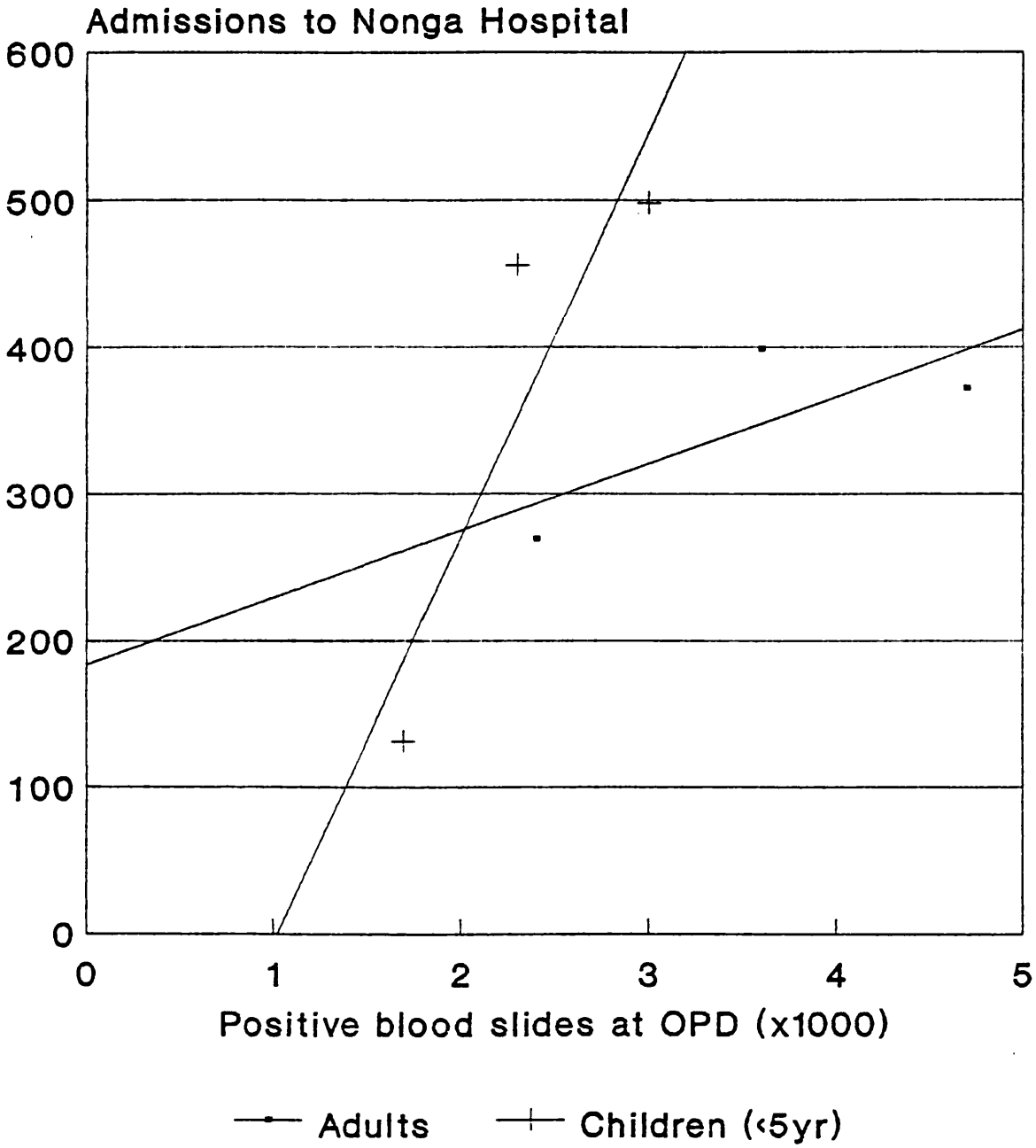

MALARIA INCIDENCE 1987
ADULT OUTPATIENT CLINIC RABAUL
NO SLIDES
SLIDE POSITIVITY RATE
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
87
P falcip
P vivax
P malariae
Negative
SPR

Fig 2.19

MALARIA ADMISSIONS AND INCIDENCE RABAUL 1985-1987



PART 2

BEHAVIOUR OF ANOPHELES FARAUTI

INTRODUCTION

Parasitological studies were supplemented with a limited study of the biting behaviour of An farauti. This vector was the only species found in the study area. During the survey period the vector was found in large numbers in coastal areas and studies were limited to these areas. The study aimed to examine the man biting behaviour of An farauti at different times of the night, both inside and outside of village houses.

Many variables impact on a study of this nature, not least being availability of man and animal hosts (Charlwood et al 1985), structure and elevation of houses, weather patterns, amount of light and the use of insect repellents. For the most part villages were similar in structure and are described above. Few village houses were screened against insects and most were at ground level. Most households kept dogs and chickens and some had pigs. All animals slept outside at night in contrast to the Highlands of PNG where animals sleep inside houses at night. In fine weather people sat outside in the evening, either on the ground or on platforms raised one to two metres above the ground. They moved inside to sleep at 9 - 11 pm. Most households had kerosene lamps which were extinguished on retiring. Very few adults used bed nets but they were sometimes used for small children. During hot nights some people actually slept outside.

METHODS

The period December 1985 - February 1986 was chosen for the study. It was anticipated that this period would be after the start of the wet season and that conditions for mosquito breeding would be optimal. Several villages were surveyed and three costal villages selected because of the larger numbers of vectors caught each night. Rapolo, Takubar and Kabakaul are coastal villages of a similar size and structure and are accessible from Rabaul by road (fig 3.1). All villages had dogs but only Rapolo had pigs in any great number. Pigs were kept in pens away from houses at night. Villages were studied monthly for three months; the same team of mosquito collectors rotated around these three villages spending three nights in one village each week. Villages were mapped and all houses located before mosquito collections commenced.

The mosquito collecting team comprised a supervisor and six collectors, three inside houses and three outside. Collections were made for 40 minutes in each hour from 6pm to 6am; biting was very rare before 6pm. All mosquitoes biting exposed limbs were caught. Aspirators were used to transfer biting mosquitoes to holding containers for identification and dissection for parous state; estimation of exact parity was not attempted.

Each hour a census of the village was conducted, noting people inside and outside houses. Weather conditions were noted although measurements of rainfall, wind speed and temperature were not made.

Parasitological surveys of children under nine years of age were conducted in these Villages three times in 1985 and twice in 1986, over the period of the entomology surveys.

Kabakaul village had not been sprayed with DDT since 1982. Rapolo was sprayed in April 1985 and Takubar was sprayed in April and August 1985 and March 1986. Spraying was performed by trained spraymen under supervision of a malaria 'eradication' officer using DDT water dispensable powder at a concentration of 5%, which yielded a surface concentration of 2 G/sq m.

The sensitivity of An farauti to DDT was determined in October 1985 in Rapolo village using a WHO susceptibility test kit.

RESULTS

From a knowledge of the number of mosquitoes biting one man in 40 minutes and a census of the village at that time it is possible to estimate the number of biting mosquitoes in the village during that period. This can be estimated for both indoor and outdoor situations and for each hour of the night. Similarly the numbers of mosquitoes biting indoors and outdoors can be estimated as a percentage of the total biting population. Mean mosquito biting populations can be calculated for each month and for the three-month period for each village.

Figures 3.2 to 3.4 illustrate biting rates for each month and for the three-month period for each village.

The man-biting rate (ma) is calculated as follows:

$$ma = \frac{\text{total biting mosquito pop. in one night in village}}{\text{total human pop. in one night in village}}$$

This reflects the number of biting mosquitoes for every one person in the village during one night.

There were wide variations in the estimated total numbers of biting mosquitoes in a village each night:

VILLAGE	Mean number of biting mosquitoes in village in one night			
	Dec	Jan	Feb	Mean
Rapolo	5,333	3,074	6,536	4,982
Takubar	3,839	10,133	9,832	7,872
Kabakaul	3,784	1,790	1,771	2,448

There was also considerable variation in the proportions of anophelines biting indoors and outdoors in Rapolo and Kabakaul and this does not appear to be entirely explained by changes in weather.

The man-biting rate varied but was highest in Takubar, which was sprayed with DDT four months before the survey (ma = 75.0 in Takubar, 26.9 in Rapolo and 22.9 in Kabakaul). From a small sample of 100 mosquitoes most of these anophelines were parous (75%) indicating that they

had not been destroyed by DDT following previous blood meals.

In Rapolo and Kabakaul biting occurred mostly during the period 6pm - midnight with greater proportions biting inside during rainy nights. Almost all mosquitoes fed before 12 midnight in Rapolo and Kabakaul on fine evenings. Mosquitoes commenced biting outside then moved indoors after 9pm - 11pm. In Takubar the biting pattern varied but in general biting was more spread throughout the night, so that 25% fed between 12 midnight and 6am.

The pattern of biting appeared to be influenced almost entirely by the lateness of the hour, weather patterns and the movement of people. During fine weather 30 - 50% of mosquitoes fed outdoors in Rapolo and Kabakaul before 9pm and these mosquitoes would presumably rest outside also. During wet weather man and mosquito moved indoors earlier.

Table 7 and figure 3.5 illustrate the changing malaria transmission pattern in these three villages. Parasite rates do not reliably decrease following DDT spraying in Takubar: increases in transmission were noted following two of the three spray rounds. The single spray round in Rapolo did result in a decrease in transmission; this was not noted in Kabakaul which was unsprayed at the same time.

Age-specific indices of transmission are difficult to interpret because of the small numbers of children in each group. However, the parasite rate (all species) in

children under nine years of age in Takubar was 53% after three spray rounds compared to 30% in Rapolo and 41 % in Kabakaul.

SENSITIVITY OF AN FARAUTI TO DDT

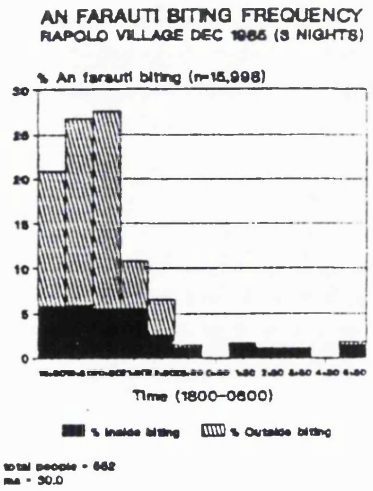
Figure 3.6 illustrates the susceptibility of An farauti to various concentrations of DDT measured in Rapolo two months prior to these studies. The LC50 from this regression line is 0.77% DDT (LC84 1.37%, LC16 0.425%) which indicates that An farauti is sensitive to DDT at the concentrations used during routine house spraying. A previous test in 1966 indicated a LC50 of 0.48% (Sweeney AW 1966) and this suggests that tolerance to DDT is occurring. The goodness to fit of the regression line (x^2 = 1.35) indicates that the mosquito population was homogeneous.

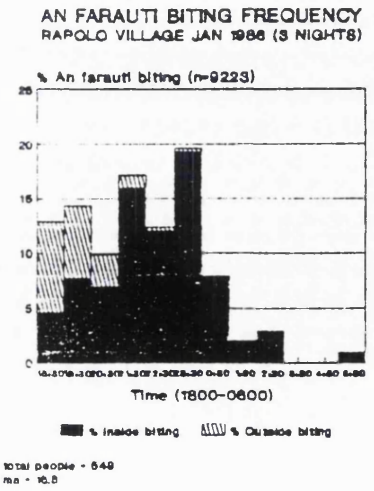
MOSQUITO COLLECTION VILLAGES Fig 3.1

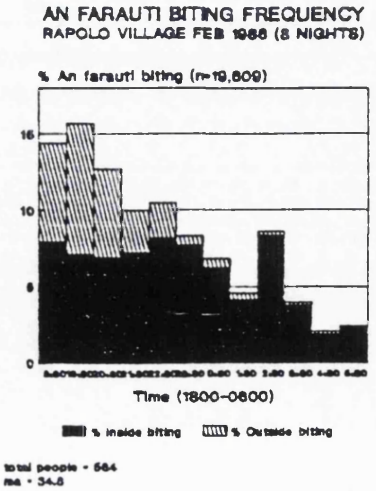
GAZELLE PENINSULA

Scale 1 cm = 4 Km

Fig 3.2


AN FARAUTI BITING FREQUENCY
RAPOLO VILLAGE DEC 1985 (3 NIGHTS)
% An farauti biting (n=15,998)
Time (1800-0600)
% Inside biting
% Outside biting
total people = 562
ma = 30.0


AN FARAUTI BITING FREQUENCY
RAPOLO VILLAGE JAN 1986 (3 NIGHTS)
% An farauti biting (n=9223)
Time (1800-0600)
% Inside biting
% Outside biting
total people = 548
ma = 16.8


AN FARAUTI BITING FREQUENCY
RAPOLO VILLAGE FEB 1986 (3 NIGHTS)
% An farauti biting (n=19,809)
Time (1800-0600)
% Inside biting
% Outside biting
total people = 564
ma = 34.8

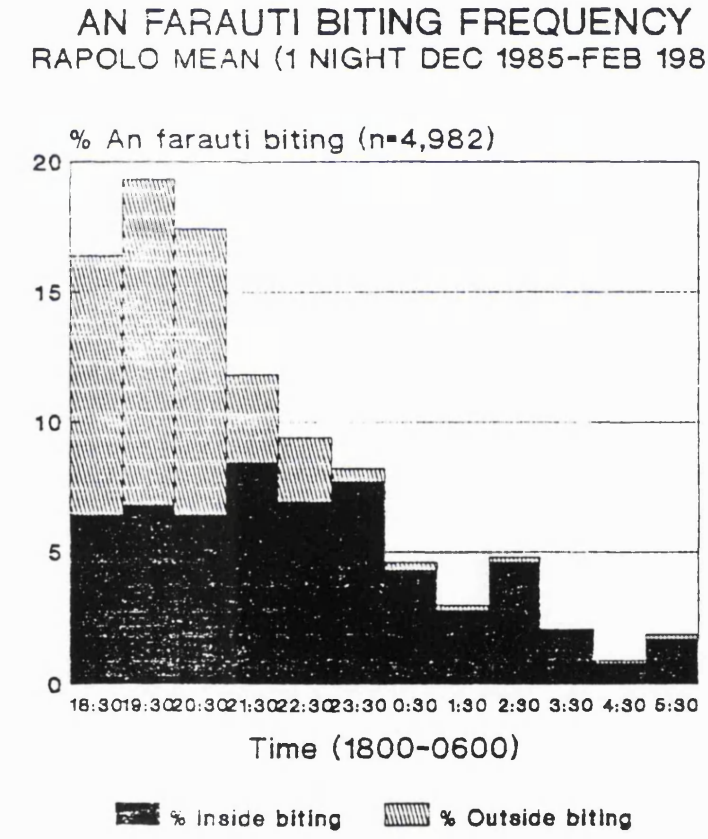
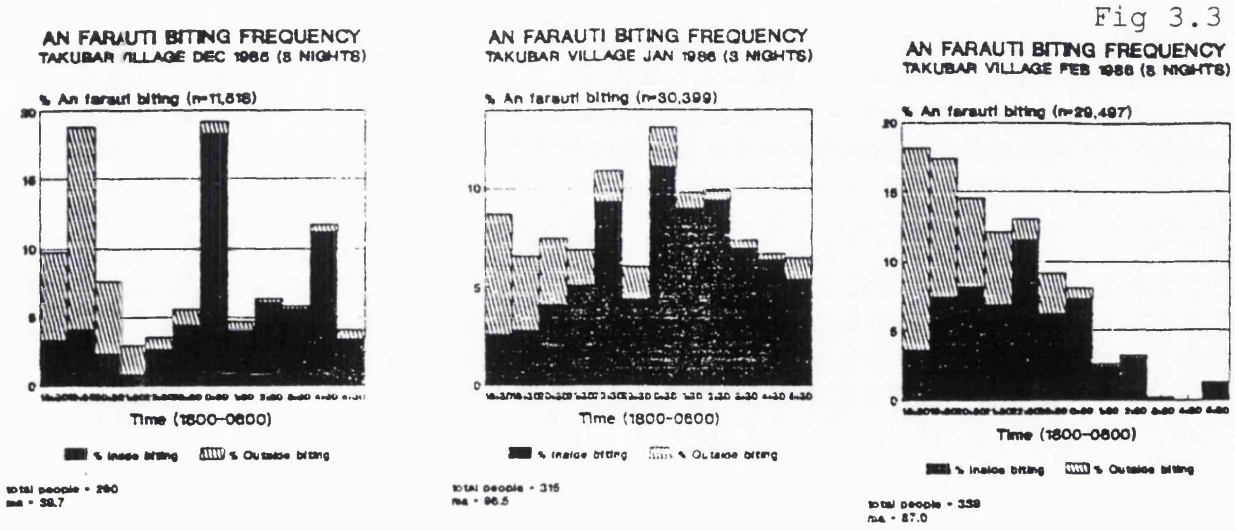
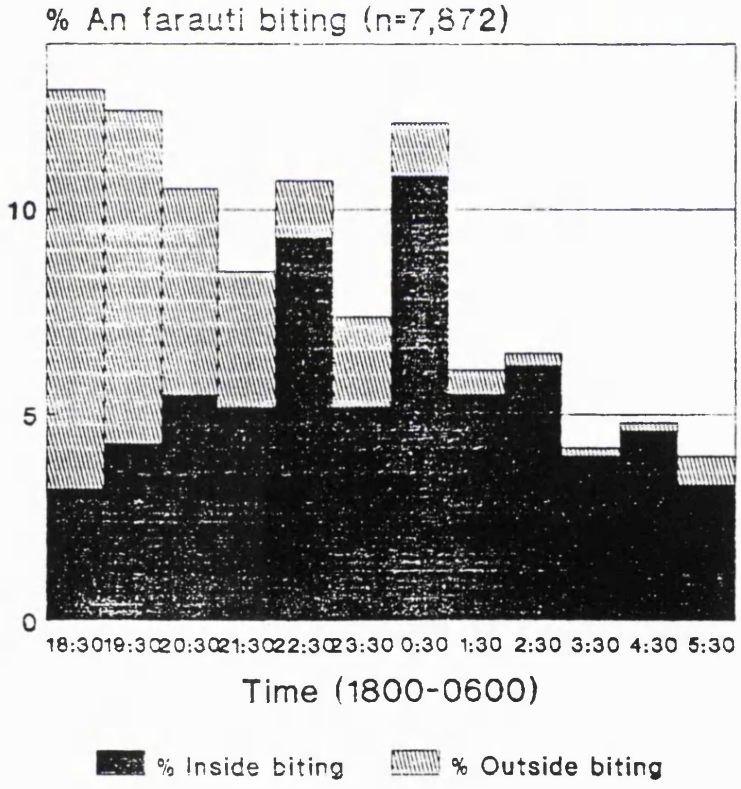

AN FARAUTI BITING FREQUENCY
RAPOLO MEAN (1 NIGHT DEC 1985-FEB 1986)
% An farauti biting (n=4,982)
20
15
10
5
0
18:30 19:30 20:30 21:30 22:30 23:30 0:30 1:30 2:30 3:30 4:30 5:30
Time (1800-0600)
% Inside biting
% Outside biting
total people 1 night = 185
ma = 26.9

Fig 3.3

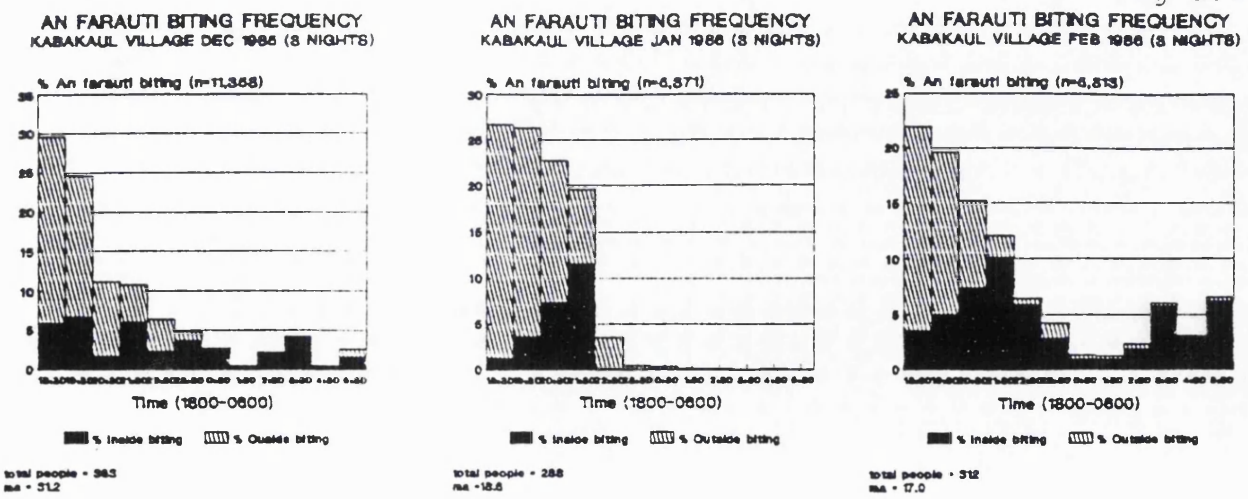


AN FARAUTI BITING FREQUENCY
TAKUBAR MEAN (1 NIGHT DEC 1985-FEB 1986

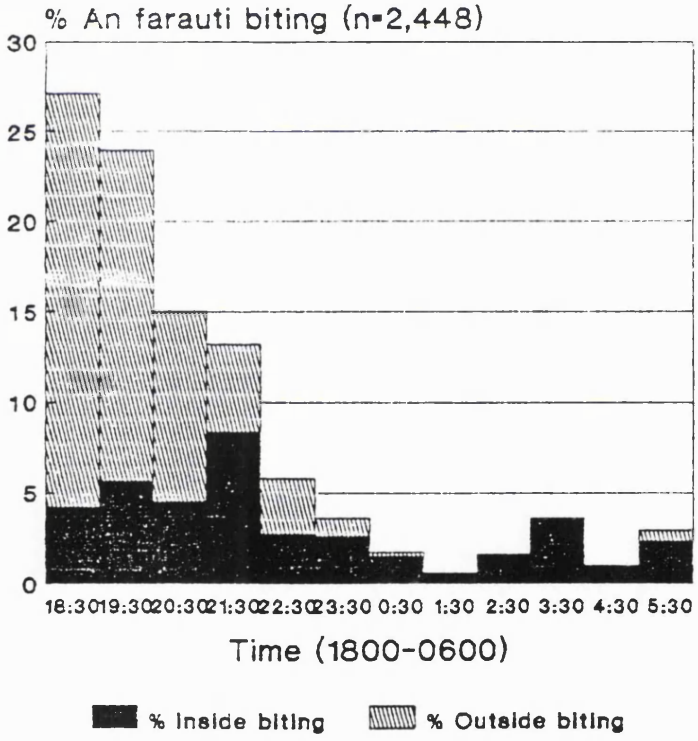


total people 1 night = 105
ma = 75.0

Fig 3.4



AN FARAUTI BITING FREQUENCY
KABAKAUL MEAN (1 NIGHT DEC'85-FEB'86)



total people 1 night = 107
ma = 22.9

MOSQUITO COLLECTION VILLAGES, GAZELLE PENINSULA
0-9 YR PARASITE RATES

Table 7

RAPOLO

Date	No blood slides	total pr %
3/85	127	53.5
6/85	92	16.3
9/85	59	33.9
3/86	54	25.9
5/86	56	41.1
8/86	40	30.0
5/87	47	19.1

TAKUBAR

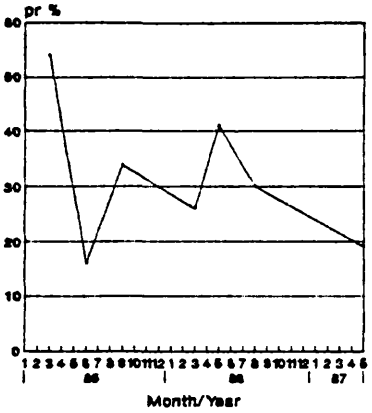
Date	No blood slides	total pr %
2/85	45	53.3
6/85	22	54.5
12/85	24	41.7
3/86	18	44.4
5/86	19	52.6
5/87	15	33.3

KABAKAUL

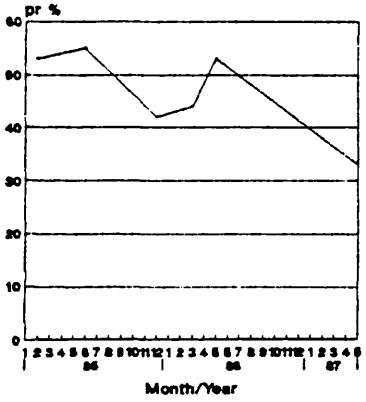
Date	No blood slides	total pr %
3/85	55	50.9
6/85	41	65.9
8/85	44	47.7
3/86	36	36.1
5/86	23	30.4
8/86	37	27.0

Fig 3.5

RAPOLO VILLAGE
TOTAL PARASITE RATE



TAKUBAR VILLAGE
TOTAL PARASITE RATE



KABAKAUL VILLAGE
TOTAL PARASITE RATE

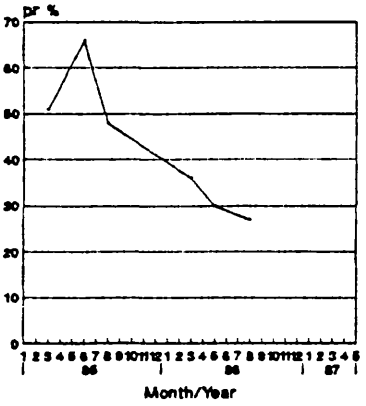
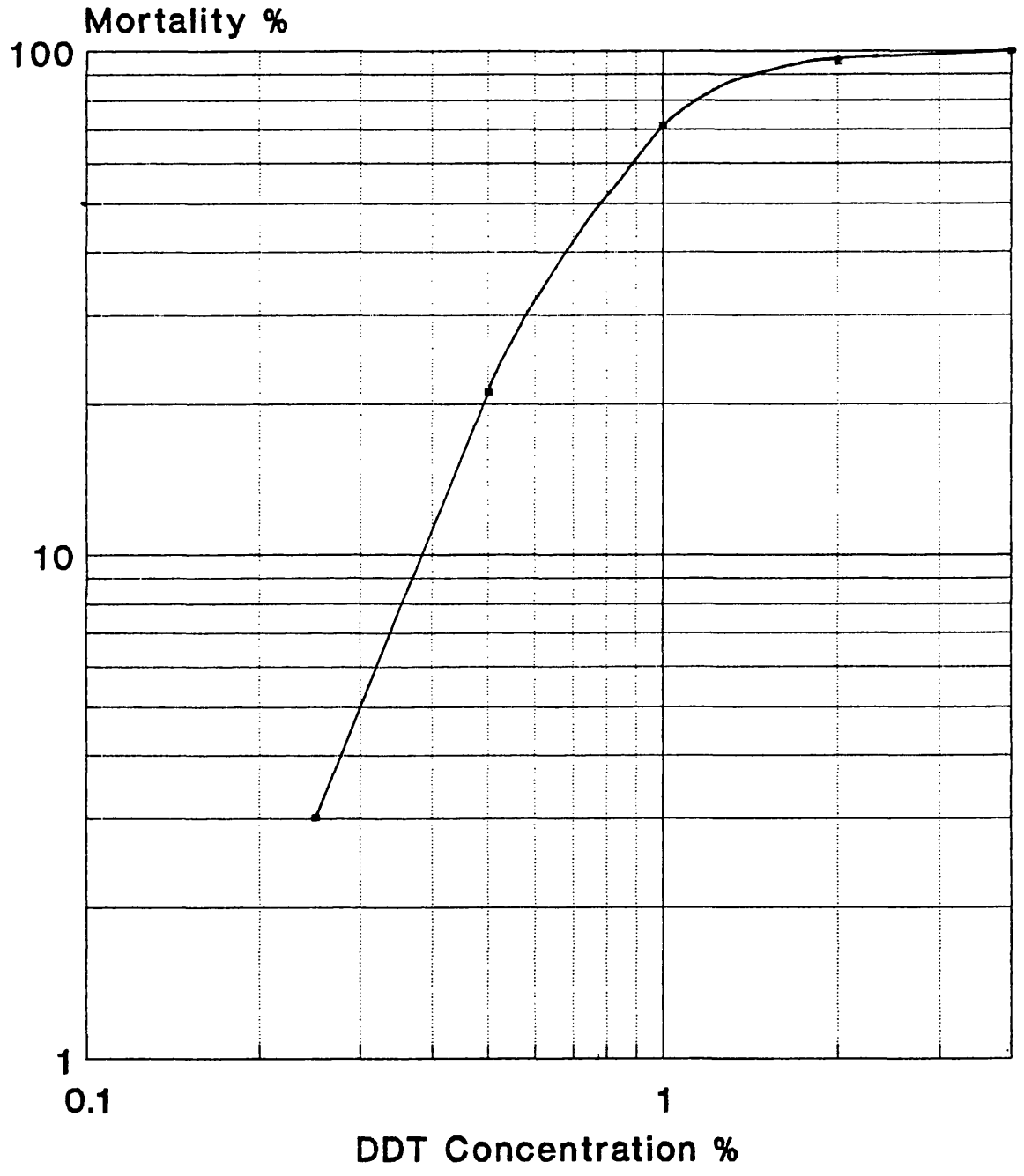


Fig 3.6

SENSITIVITY OF AN FARAUTI TO DDT RAPOLO VILLAGE OCT 1985



LC50=0.77%

PART 3

REVIEW OF MALARIA TRANSMISSION ON DUKE OF YORK ISLANDS

INTRODUCTION

The Gazelle Peninsula was revisited in October 1996. This visit enabled discussions with staff on the value of the malaria prevalence and incidence monitoring systems established some ten years previously. This visit also enabled examination of the permethrin impregnated bed net trial which was planned for in 1986 in the Duke of York Island but not performed until 1988. The trial continued for two years.

As noted above, on 19 September 1994 Tavuvur and Kalamanagunan volcanoes erupted almost simultaneously. Destruction of Rabaul town and surrounding villages and settlements by earthquakes and ash fall was immense. Some 90,000 people were evacuated from Rabaul and Kombiu, Balanataman, Reimber, Central and Raluana census divisions just prior to the eruptions. Three people died during the eruptions, of which two deaths were from traffic accidents during evacuation.

Displaced people were originally cared for in centres at schools, plantations and townships throughout the Peninsula. Most non - Tolai people, who had no traditional land in the Gazelle Peninsula, were moved to their own provinces on adjacent islands and the mainland. Many Tolais have now returned to their original villages but up

to 30,000 have relocated permanently in one of four resettlement areas in the southern part of the Peninsula.

At present only the northern part of Rabaul town is inhabited; the entire commercial centre, 90% of housing and all periurban settlements having been totally destroyed. There are plans to establish essential services to the northern part of Rabaul town which services the wharf and associated industries.

Nonga Hospital still functions as the provincial hospital having relocated temporarily to Kokopo during the eruptions. The hospital is now relatively isolated, most people now living in the central, eastern and southern parts of the Peninsula and not in the previously more densely populated northern part.

Provincial health services and the Regional Epidemiology Unit (now Regional Support Unit) have been established at Butuwin, approximately three kilometres west of Kokopo. Other government services are scattered throughout the Peninsula as buildings and space permit.

One month following the volcanic eruptions staff re-entered the ruins of the malaria and provincial health offices to retrieve equipment and records. Working in dangerous conditions some epidemiological records were retrieved but many malaria records were lost in a mire of volcanic ash and mud.

Since 1994 health services in East New Britain have been in a state of reorganisation and major infrastructural and management plans will take many years to implement.

Major political and economic changes have occurred in PNG during the past eight years. The civil unrest in Bougainville is now in its tenth year, the National Government has changed three times, the PNG currency, the Kina, has devalued approximately 40% and social insecurity and crime remain major problems in most towns. It is not surprising to learn that these changes have impacted on health care delivery in urban and rural areas.

In 1990 staffing levels in the national malaria section of the Division of Disease Control were severely reduced and responsibilities for malaria control were handed to Environmental Health Services. This resulted in disruption to malaria reporting at all levels. Information on malaria from provinces is no longer gathered and data from East New Britain province are at best haphazard and of such quality that an assessment of the value of control methods is very difficult.

METHODS

During the October 1996 visit to the Gazelle Peninsula staff at the provincial health office, the malaria office and the Regional Epidemiology Unit were interviewed. Available records were examined with particular reference to the following:

1. Malaria prevalence data for the Duke of York Islands for the period 1988 onwards.

2. A report on the Permethrin Impregnated Bed Net Trial (1988 - 1989). This report included methodological information and parasite rate data for the two year period of the trial. Further information on the trial was obtained from staff.

In addition a brief survey of ten stores in Kokopo was conducted to assess the availability and costs of family sized bed nets. Stores were randomly selected in the main street of the town and the managers interviewed. The following questions were asked:

1. Do you stock family sized bed nets?
2. If yes, how much do they cost?
3. If yes, when did you start stocking them?
4. Do you stock permethrin?

RESULTS

MALARIA PREVALENCE DATA ON DUKE OF YORK ISLANDS:

Incomplete data were available for the period 1988 - 1993. Table 8 details these data for the four indicator villages on the Islands and this data has been added to that obtained for the period 1985 - 1987, which formed part of the original study. These combined parasite rates appear in Figure 4.1. Apart from low parasite rates observed in 1989 during the bed net trial there does not appear to have been any decline in malaria transmission from 1985 to 1993.

PERMETHRIN IMPREGNATED BED NET TRIAL ON DUKE OF YORK ISLANDS 1988 - 1990:

It was established during the original study that in 1985 - 1987 the Duke of York Islands had consistently high parasite rates for children under ten years of age. This location was therefore chosen for a trial of permethrin impregnated bed nets. Notwithstanding the relative inaccessibility of the Islands a concerted effort was made to impregnate bed nets every six months and to monitor malaria prevalence by blood slide surveys.

It is, perhaps, disappointing that this trial did not incorporate the original four indicator villages for which malaria data were available for the previous three years. Instead seven new villages were selected on Makada island (Nagaila, Narakoi, Palipal, Raputput) and the main island (Kumlokor, Inlimut, Kababiai). There were no control villages.

Pre trial blood surveys were performed at four of the seven trial villages: it is not clear why the other three villages were not sampled at this stage. The entire population of these villages was surveyed; sampling was not limited to under ten year old children as in previous indicator village surveys. During this pre trial survey parasite rates ranged from 21% to 56% (Tables 9, four villages, under one year old children and Table 10, four villages, all age groups). The mean parasite rate for all

ages in these four villages was 27%, with P falciparum comprising 82% of all parasites.

At the time that the four pre trial villages were surveyed a mass blood survey of some thirteen additional villages throughout the Islands was performed and this indicated a mean parasite rate of 19% (range 5% to 44%) with P falciparum comprising 76 % of all parasites.

Bed nets were sold to residents in the seven trial villages for K 2.00 each and initially 230 were sold. Additional nets were sold prior to each permethrin impregnation session. Nets were impregnated with permethrin solution to yield a final dose of 0.5 G cm^{-2} (range 0.4 G cm^{-2} to 0.67 G cm^{-2}). An additional charge of K 0.50 was made for each impregnation.

Nets were impregnated with permethrin on the following occasions and in the numbers indicated:

Date	No nets impregnated	Total nets	% of prev total impregnated
5/88	230	230	
12/88	149	281	65
7/89	174	424	62
11/89	263	n/a	n/a

By the fourth impregnation session demand for bed nets was enormous and they were being widely sold throughout the Duke of York Islands.

Blood slide surveys were performed prior to each impregnation session at the seven trial villages.

PARASITE RATES IN BED NET TRIAL VILLAGES:

Tables 9 and 10 describe the pretrial and subsequent parasite rates for the seven trial villages for infants and for all ages combined.

In six out of seven villages there was a decline in parasite rate from the pre trial survey in April 1988 (27%) (and / or the survey prior to the second impregnation in November 1988, 9%) to the survey prior to the third impregnation in April 1989 (2%), thereafter parasite rates rising to levels similar to those at the commencement of the trial (18%). Infant parasite rates and rates for all ages show similar trends although infant parasite rates returned to less than half their original level (pre trial 53%, fourth survey 20%).

The early decline in parasite rates noted in the trial villages was mirrored by low parasite rates recorded in the under ten year old population in late 1988 in the original four indicator villages, which were, presumably, not using impregnated bed nets. Although parasite rates were lower in trial villages in the late 1988 / early 1989 period the different age composition of the populations surveyed does not permit direct comparison or conclusions to be made.

BED NET AVAILABILITY IN STORES IN KOKOPO

Table 11 describes the result of the survey of stores in Kokopo township. Nine out of ten stores stocked family bed nets with prices ranging from K 15.00 to K 18.40. Three stores stocked bed nets prior to 1990 and four stores commenced selling nets in late 1994, after the volcanic eruptions and movement of thousands of people to the Kokopo area. No stores stocked permethrin.

Fig 4.1

PARASITE RATES, 0-9 YEARS DUKE OF YORK ISLANDS CD

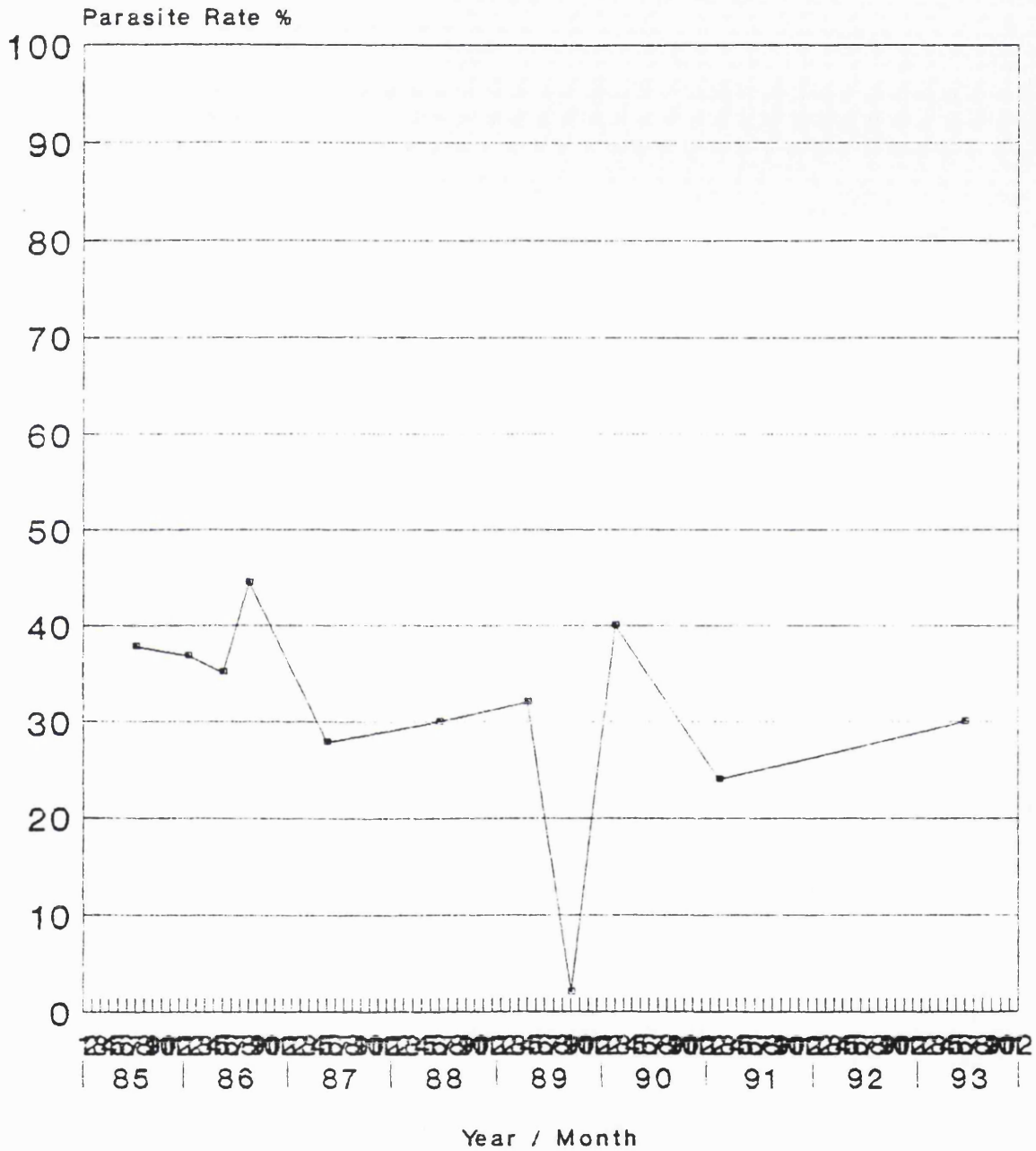


Table 8

PARASITE RATES IN DUKE OF YORK ISLANDS 1988 - 1993

Mo/Yr	<1yr pos/ total	<1yr PR%	1-9yr pos/ total	1-9yr PR%	0-9yr pos/ total	0-9yr PR%	P falcip/ total parasite	P falcip %
6/88					78/258	30		
4/89	8/20	40	50/162	31	58/182	32	31/58	53
9/89	1/16	6	1/86	1	2/102	2	2/2	100
2/90	4/22	18	72/166	43	76/188	40	31/72	47
2/91	13/80	16	96/328	29	99/409	24	36/109	33
1992	no surveys							
6/93					67/240	30	54/67	81

Table 9

PARASITE RATES - PERMETHRIN IMPREGNATED BED NET TRIAL

VILLAGES (< 1 YR AGE GROUP)

Vill	Pre Trial pos/total 4/88	Pre Trial PR %	11/88 pos/ total	11/88 PR %	4/89 pos/ total	4/89 PR %	11/89 pos/ total	11/89 PR %
NAR	0/9	0	5/27	19	1/11	9	2/7	29
RAP	7/10	70	2/8	25	0/23	0	6/12	50
KUM	12/22	55	1/7	14	1/3	33	8/32	25
KAB	15/23	65	0/1	0	1/15	7	5/26	19
PAL			9/38	24	2/28	7	0/11	0
INL			10/38	26	0/12	0	4/28	14
NAG			0/30	0	0/23	0	6/36	17
TOTAL	**34/64**	**53**	**27/149**	**18**	**5/115**	**4**	**31/152**	**20**

All surveys P falciparum > 70%

Table 10

PARASITE RATES - PERMETHRIN IMPREGNATED BED NET TRIAL

VILLAGES (ALL AGES)

Vill	Pre Trial pos/total 4/88	Pre Trial PR %	11/88 pos/ total	11/88 PR %	4/89 pos/ total	4/89 PR %	11/89 pos/ total	11/89 PR %
NAR	6/23	26	0/7	0	1/23	4	2/14	14
RAP	18/78	23	5/85	6	4/55	7	9/25	36
KUM	23/112	21	18/140	13	0/67	0	13/61	21
KAB	20/36	56	7/106	7	2/78	3	13/57	23
PAL			5/33	15	2/76	3	0/37	0
INL			16/78	21	0/35	0	6/40	15
NAG			2/148	1	0/97	0	13/70	19
TOTAL	**67/249**	**27**	**53/597**	**9**	**9/431**	**2**	**56/304**	**18**

All surveys P falciparum > 70%

Table 11

BED NET AVAILABILITY SURVEY, KOKOPO

STORE	YEAR SALES COMMENCED	PRICE PNG KINA	PERMETHRIN AVAILABLE
SEE	<1900	15.50	NO
AND	1996	18.00	NO
BAR	1994 *	15.00	NO
MON	1990	18.40	NO
GIN	1994 *	18.40	NO
SUP	DO NOT SELL		NO
KOK	1994 *	16.00	NO
WON	1992	15.00	NO
JIM	1994 *	15.00	NO
NAK	<1990	17.00	NO

* Commenced sales within one month of volcanic eruptions in September 1994.

DISCUSSION

The story of malaria in PNG and the Gazelle Peninsula is not unique. Similar features of the disease have been described in other areas of the Pacific (Black 1954, 1956 a, Peters 1962, Macgregor 1966, World Health Organisation 1969). The detail with which early medical workers and researchers described the disease in PNG is, in part, a reflection of the importance of the country as a major colonial centre for early exploration and trade in the Pacific and as a key location for wartime activities and subsequent strategic defence.

Colonial involvement in the island of New Guinea enabled malaria studies by German, Dutch, British and Australian scientists and each contributed descriptive epidemiological and entomological data and information on control measures. This information has contributed to formulating global efforts to control malaria. Intense transmission of malaria still occurs in some lowland areas of the mainland and PNG continues to be a major focus for malaria research.

There can be little doubt that malaria has spread geographically since the first colonial settlers came to PNG. These settlers themselves probably introduced the disease into previously malaria-free areas either via parasites in their own blood or by importing labourers from infected areas. As geographical obstacles were breached and as ethnic animosities resolved so movement of people throughout the mainland, between lowlands and highland

valleys and between mainland, coast and islands ensured a vigorous traffic in malaria parasites and vectors. The proliferation of roads, especially in the Highlands, has enabled people to move freely between areas of differing endemicity and this they do in the pursuit of employment and commerce and as pressure from the densely populated Highlands forces people to seek a livelihood elsewhere.

Malaria remains prevalent throughout the year on the coast, lowlands and in the island provinces and is seasonal in the highland areas (>1500 masl) of the mainland and larger islands. In some highland areas there are, however, warm, humid valleys and vigorous transmission occurs throughout the year in these valleys in the same way that it does in lowland areas.

In lowland areas with variable but low endemicity, including most of the Gazelle Peninsula, seasonal changes in transmission are not always easy to detect. However, pronounced dry seasons may effectively remove vector breeding sites and parasite rates decline. In these areas seasonal epidemics occur with death and disease affecting those less immune, including migrants from the Highlands areas of the mainland.

In stable areas with persistent high rainfall, such as the Sepik region of the mainland and other areas with permanent vector breeding sites, transmission occurs year round and the population is burdened by recurrent fevers, anaemia, large spleens and high childhood mortality and morbidity.

The Gazelle Peninsula, because of its low altitude and pronounced dry seasons is an area of hypo-mesoendemicity with seasonal variations. These variations are more pronounced in areas in the north and slightly elevated inland areas.

Relatively few data were recorded by early colonists on malaria in the indigenous population: they described its effects on the European settlers and the effect of the disease on imported and indigenous labourers. In the 1940s and onwards a more community based approach established that malaria was a major cause of morbidity and mortality amongst indigenes and suggested that its control would improve the quality of life and life expectancy.

In the 1950s extensive entomological studies established the main vectors of malaria in both highland and lowland regions. In the Gazelle Peninsula An farauti and An punctulatus are the main vectors with small populations of An koliensis in the Bainings mountains. An farauti appears to be limited to the coastal fringes of the Peninsula.

Vector breeding sites are often difficult to locate. For a large part of the Gazelle Peninsula the soil is highly absorbent, a consequence of the volcanic nature of the area. Some areas are steeply sloped so that despite frequent rain little ground water is to be found. Clearly though sufficient ground water remains for anopheles breeding to occur.

The development of any strategies for malaria control should consider not only the epidemiology of the disease, the behaviour of the vector and the limitations of any control method but also the requirements and expectations of the people. The most potent control measures will not succeed without participation of the community.

The people of the Gazelle Peninsula are amongst the most highly educated and wealthy of all ethnic groups in PNG. There can be little doubt that the failure of early DDT spraying programmes was at least in part due to failure to involve villagers; it became something that 'the government' did every six months and something that involved considerable inconvenience to the population. Refusals met with hostilities from the malaria workers and the combination of locked houses, hostile and disinterested workers and poor technical performance resulted in the ultimate complete lack of viability of the programme as a government run operation. Interestingly, since cessation of the programme some villagers have demanded resumption of the spraying programme and this perceived need has been used as a starting point for a package of interventions which included spraying.

The high standard of health enjoyed by the people of the Gazelle Peninsula is a consequence of their wealth, fertile soil, high level of education and relatively low population density. The area is renowned in PNG for being one the most pleasant to work in and government health services

have relatively little trouble attracting staff. The Tolai people of the Peninsula are intensely devoted to their land and the extended family support system ensures that many Tolais return to the Peninsula, even after long periods of study and work in other parts of PNG.

Despite these relatively favourable conditions of living and health malaria still ranks as a major cause of ill health and death in the Gazelle Peninsula. Malaria is the fourth most common cause of death, after pneumonia, perinatal and pulmonary and cardiovascular causes. As diabetes, atheromatous vascular disease and cancer become more common amongst the Tolais we may expect malaria to become less important as a major cause of death.

Although malaria is recorded as the third most common cause of admission to health facilities in East New Britain Province (8%-10%) many of these final diagnoses are not confirmed by positive blood slides. A similar situation exists nationally. Many cases of fever have already received presumptive treatment with amodiaquine or chloroquine and failure of the fever to resolve is probably because of independent viral, not malaria, infections. However, these cases are almost always recorded as malaria. The morbidity reporting situation in health facilities other than hospitals must necessarily be less accurate due to a relative lack of clinical skills and diagnostic facilities.

When malaria is confirmed in a patient admitted with fever clearly many more are not admitted. The thousands of positive blood slides collected at outpatient departments throughout the area confirms the high prevalence of malaria in the community but low admission rate for the disease.

Hospital mortality data are notoriously unreliable. Rarely a heavy infection with P falciparum is accompanied by signs and symptoms of cerebral malaria and any resultant death may, with reasonable accuracy, be ascribed to malaria even in the absence of post mortem analysis. More commonly though a slightly anaemic patient with an enlarged spleen and a pyrexia of unknown origin dies and the cause of death is recorded as malaria because no other pathology can be found for the death certificate. There were no records of post mortem brain pathology.

The probability of a sick person seeking hospital admission is higher in the Gazelle Peninsula than in other parts of the province or PNG. However, in some of the more remote parts of the Peninsula (Sinivit, Bitapaka, Duke of York Islands) where communication and travel are difficult it is likely that illness and death from malaria occurs in villages and this is not noted in the provincial health records. Also non-Tolai ethnic groups living in the Gazelle Peninsula are also less inclined to use the health services. These immigrant groups, especially those from the Highlands of the mainland, may have lower immunity to malaria than their Tolai neighbours and we expect malaria to be more common amongst them.

It is a common practice in PNG hospitals and health centres for terminally ill patients to go home to die. Unconscious or seriously ill patients are frequently removed from the facility by relatives, not always with the knowledge of health staff. These deaths are not recorded in the mortality statistics.

The use of hospital data for monitoring malaria may only be used as a most general guide. Providing prevailing social, economic and medical diagnostic conditions remain constant some general trends on the burden of malaria in the community may be inferred.

Many of the problems described for malaria monitoring apply also to other major causes of admission and death. For the purposes of establishing priorities for health interventions accurate statistics on malaria transmission are not necessary. Rather, a broad indication of the relative importance of the disease, amongst other major causes of morbidity and mortality, is required so that resources can be allocated appropriately.

We have noted that rates of hospital admission for malaria are reflected in rates of positive blood slides collected at outpatient departments, at least in the Rabaul urban setting. The system of collecting blood slides from all patients with fever attending outpatient facilities worked well in Rabaul; slides were examined speedily and accurately, although not usually on the day the slide is

taken. Blood slide results do not, however, influence patient management as standard management regimes for fever do not take into account the result except in those few cases of illness regarded as 'serious' or 'treatment failure', when the blood slide result will influence further patient management.

At other health facilities in the Gazelle Peninsula this system of passive case detection works less successfully. At Vunapope (Catholic) Hospital in Vunamami census division some diagnostic facilities are available but the number of blood slides collected is small and irregular. At government health centres laboratory equipment supply, staff supervision, transportation and reporting is irregular so that no useful information on the malaria situation can be obtained with any degree of reliability by this method.

The results from passive case detection described in this study must be interpreted with caution. Whilst quality control remained constant during the period of the study, the number of slides collected depended not only on the number of patients attending with fever, but also on the level of training of outpatient staff, availability of equipment, level of supervision and availability of laboratory staff. Absence of the microscopist or a shortage of blood slides, for even a short period, resulted in an automatic decline in the number of slides taken and positive blood slides without there being any real change in the numbers of patients presenting with fever. However,

these outpatient blood slides were examined independently of inpatient slides (and prevalence blood slides) and there are similar trends in numbers of positive blood slides in childrens and adult clinics and malaria admissions during the period 1985-1987. It is unlikely that constraints affected all laboratories to the same degree.

There is no clear explanation for the decline in positive blood slides and admissions for malaria (especially children) in 1986 and 1987, or indeed for the low number of positive slides in 1983 in both outpatient clinics. Indicator village surveys demonstrate a rise in parasite rate for the province after cessation of spraying in 1984 (from 14% to 30%). Before 1984 provincial parasite rates were influenced by other areas of high transmission (mainly coastal Pomio district). Since then the density of indicator villages and numbers of blood slides collected in the Gazelle Peninsula make the provincial data largely a reflection of the situation in the Peninsula. Continuation of parasite rates of 10%-20% in low altitude villages and 5%-15% in higher altitude villages in the Gazelle Peninsula for the three years 1985-1987 do not suggest any decline in community infection with malaria which would explain the decreases in positive blood slides in outpatient clinics and number of malaria admissions during this period.

There was a relative excess of negative blood slides in the period 1980-1983. This may reflect a low incidence of malaria, a high incidence of viral infections or may indicate a technical failure in the reading of blood

slides. There certainly was a greater awareness amongst health staff of the importance of taking blood slides from 1984 onwards following supervision from the provincial malaria authorities. In addition inservice training for malaria microscopists and quality control hopefully achieved a higher standard of accuracy in reading slides. The apparent 'epidemic' of P falciparum infection in April-May 1984 in both childrens and adult outpatient clinics is demonstrated by a rise in total number of falciparum infections and a rise in the slide positivity rate, due almost entirely to P falciparum. The slide positivity rate otherwise remained a poor indicator of transmission.

A primary health care programme in malaria control was initiated in 1985 in Livuan, Vunadidir, Toma, Central, Raluana and Duke of York Islands census divisions, although not all villages were represented. Community groups were organised by village leaders and education delivered, in Neomelanesian and Kuanua languages, on transmission of malaria and how the community can help control the disease. Emphasis was on reduction of breeding sites and the provision of early treatment. A total of 70 community antimalarial dispensers were trained for Livuan, Vunadidir, Toma and Central census divisions. These dispensers were taught basic symptoms and signs of malaria and a simplified dosage regime for chloroquine depending on the size/age of the patient. In addition houses in some villages in Vunadidir and Raluana were sprayed with DDT when there was total agreement amongst the villagers that this would result in complete coverage of that village. Two cycles

were achieved in Vunadidir and one in Raluana but only isolated, non-indicator villages were sprayed and it is unlikely that this intervention influenced the parasite rates observed for those census divisions or altitude zones.

These primary health interventions, especially village based treatment of fever, may have contributed to decreased rates of attendance at Nonga Hospital and Rabaul outpatient clinics.

It is possible that future improvements in equipment supply and laboratory staffing will enable blood slide examination at rural health centres. This certainly is the aim of both provincial and national health authorities. Extension of passive case detection to health facilities throughout the province is a relatively simple and cost effective method of monitoring malaria. Given a stable population, a constant supply of equipment, and trained laboratory and nursing staff, then passive case detection becomes a useful addition to inpatient morbidity data. This type of malaria monitoring does not, however, provide information on malaria transmission at a village level. Passive case detection enables the malaria situation at a census division or district level to be examined (biased towards urban and accessible areas) but this type of information may be what is required by provincial health authorities for planning for disease management, as opposed to control.

Indicator village surveys provide community-based, epidemiologically sound prevalence information on malaria. Appropriate sampling will enable the malaria situation to be examined and compared over a wide area and over a period of time. Heavily infected areas and seasonal variations in transmission can be identified and, where resources are limited, control measures identified. Prevalence studies are, however, expensive of time, personnel and transport and, as experienced during this limited study, they are the first activities to be deleted from provincial health activities when funds are short. This is understandable when health priorities target preventive and promotive activities in villages and rural health facilities.

Limited prevalence studies may indicate areas of high transmission but, as we have noted in this study, seasonal variations necessitate that these should span at least one year to accommodate all seasons. Even then temporary changes in climate may lead to uncharacteristic rates of transmission.

Within the Gazelle Peninsula there appears to be distinct differences in levels of transmission depending on the altitude of the village, even within the narrow range sea level up to 200 metres above sea level. Infections with P falciparum appeared to be up to 6% higher than those of P vivax at low altitude. At high altitude this difference was reduced to 3%. Infant parasite rates for P falciparum were considerably lower than those for age groups 1-4 years and 5-9 years at both high and low altitudes; this

difference in age-specific rates of infection was not so apparent for P vivax infections. However, small numbers of blood slides positive for P vivax at high altitude make comparison of infant parasite rates and rates in older children difficult.

There was no clear seasonality in rates of transmission in individual census divisions. Of the eleven census divisions included in this sample six showed marked peaks of transmission during survey 3 (mid wet season 1986). Variations in the numbers of blood slides collected for each age group and between census divisions and surveys makes more detailed analysis of age-specific and area-specific rates of infection unreliable.

Higher parasite rates were observed in Sinivit, Bitapaka and Duke of York Islands census divisions. In Sinivit there was only one indicator village (Ivere), in Bitapaka there were four indicator villages (Ralubang, Korai, Malakuna 2, Reiven). The indicator villages in Sinivit and Bitapaka are traditional Tolai villages and would not contain more than a few migrant families. These two census divisions are amongst those furthest from Rabaul and the indicator villages are at altitudes ranging from 40 to 200 masl. Rainfall in Kerevat (and presumably nearby Sinivit) was higher than in Rabaul and whilst there were no specific readings for the western part of the Peninsula this windward edge of the Peninsula was noted to be considerably 'wetter' than neighbouring Vunamami.

Many immigrants in the Gazelle Peninsula are from lowland areas of the mainland and adjacent islands and might be expected to have some immunity to malaria. However, as noted above, a proportion of the population in the southern census divisions are immigrants from non-malarious areas of the PNG Highlands working on plantations. Immigrant labourers usually spend two to three years contracted to particular plantations. Very few migrants take malaria prophylaxis. There is no accurate data on the numbers of immigrants in the various areas of the Gazelle Peninsula or their duration of residence so it is difficult to describe their contribution to overall malaria transmission. However, focal high parasite rates were noted in some plantations in Vunamami and Bitapaka areas during surveys which were not part of this study. The question of malaria prophylaxis for non immune migrant labourers could be examined as part of a study on migrant health needs.

It is interesting to note that consumption of amodiaquine and primaquine was highest at Kerevat health centre and amodiaquine and chloroquine highest at Warangoi health centre. These data are at best only suggestive of higher infection rates in the south. Paradoxically Gaulim health centre, also in the south, recorded low rates of consumption of antimalarials. However, this church run health centre was functioning largely as an aid post for the duration of the study and was closed for part of the time due to staffing problems and it is unlikely that the information on drug usage is reliable.

We have noted above that these southern regions of the Gazelle Peninsula have few roads and very limited access to reliable transportation. Access to health facilities is difficult for many people and the data on antimalarial drug consumption for these areas are likely to underestimate the degree of malaria transmission.

The four indicator villages in the Duke of York Islands with high parasite rates are all at sea level and on the coastal fringe of the Islands. Access to health services is also difficult for many in this island community.

In villages nearer Rabaul the proportion of houses with some form of insect screening increases. More remote villages were less likely to have screening and more likely to be constructed of traditional bush materials. In addition access to early treatment, during daily travel to Rabaul, may also contribute to lower parasite rates in these northern areas.

Areas at altitudes greater than 200 metres above sea level experienced similar rainfall to those at lower altitudes and temperatures only slightly lower than those on the coast. These areas, which form part of the rims of the original volcanic craters, are steeply sloped and composed of the same highly absorbent soil (volcanic ash and pumice) found at lower altitudes. However, the combination of slope and high soil absorbency probably results in fewer collections of ground water for anopheles breeding than that found at lower altitudes. This theory was not tested

in the present study. It is, maybe, surprising that between the narrow altitude ranges defined for this study consistent differences of 5%-15% in total parasite rate were noted for all age groups and for P falciparum and P vivax.

P malariae was rare in both incidence and prevalence blood slides. No cases of P ovale were observed; These are extremely rare in PNG (Jackson 1944, McMillan 1968).

Parasitological data is supported by a spleen survey of 1507 children in the low altitude indicator villages and 377 children in the high altitude indicator villages performed during the period December 1985 - January 1986. This survey, organised and supervised by the author as part of a separate nutrition survey, demonstrated a significantly higher spleen rate (23%) in children 0-9 years of age in low altitude villages compared to those living at high altitudes (2%) (X^2=84.89, $p<<0.001$). The age specific spleen rates of children 0-5 years of age in low altitude villages are illustrated in fig 5.1. These changes in spleen rate are a reflection of the increasing parasite rates observed in these children.

The results indicate that malaria transmission increases with distance from Rabaul and decreases with increase in altitude. The most likely reasons for this are increased anopheles breeding and biting at lower, wetter, altitudes and, possibly, decreased access to health services and antimalarial drugs.

Wide variations in childhood parasite rates (60.2%-37.7%) and parasite ratio (21.7%-12.6% P vivax) were noted in the Madang area and it is quite likely that similar village to village variations exist in the Gazelle Peninsula. Only a general indication of area-wide malaria transmission can be obtained by the current sampling methods (Cattani, Moir et al 1986, Cattani, Tulloch et al 1986).

A very limited study of the biting behaviour of An farauti was performed as part of this study. In the three coastal villages studied this vector appeared to follow people and bite them whether they were inside or outside of their houses. The patterns of biting varied within one village and between villages. In Rapolo in December almost all biting was outside and over by midnight whereas in February biting continued, mainly inside, throughout the night. In Takubar biting was more spread throughout the night with peak inside biting around midnight and the early hours of the morning but with considerable biting outside in the early parts of the evening. In Kabakaul most biting was outside during the early part of the evening and all biting largely over by midnight. More elaborate studies are needed to determine the influence of weather patterns on biting behaviour. Similar studies of An farauti in other locations of Papua New Guinea confirm the outside biting behaviour and note it to be strongly zoophilic also (Charlwood et al 1986). Earlier studies in PNG, West Irian and British Solomon Islands have suggested that An farauti has a human blood index of 81%, the remaining 19%

preferring dogs (Bruce-Chwatt et al 1966). We have not studied animal biting in this study but clearly this must be considered when designing control strategies.

In coastal villages of the Gazelle Peninsula people spend most of the evening outside. The air is cooler, meals are prepared and much time is spent chewing betel nut and talking late into the evening. Children may not retire early, as in other cultures, but stay up with their parents and older siblings. Most social activity occurs on the ground in the evening. Some villagers have constructed platforms at various levels above the ground in an attempt to keep cool and dry and, as reported in some villages, to reduce the problem of biting insects.

Clearly any control measures need to address this issue of outside biting by the vector.

Parasite rates were variable and high (15%-55%) in Rapolo, and very high in Takubar and Kabakaul (mostly >40%). These parasite rates are considerably higher than rates noted for indicator villages in the same census divisions. Even Kabakaul in Bitapaka census division had parasite rates up to 66% whereas those for indicator villages in the same area remained 20%-40%. These high parasite rates measured in Rapolo, near Rabaul, and at Takubar and Kabakaul in otherwise areas of lower transmission indicate the patchy nature of malaria infection, as recorded also by earlier malaria workers in the Peninsula.

A single DDT spray round in Rapolo resulted in a decline in parasite rate but it is difficult to comment on the significance of this. Beneficial effects of DDT household spraying were not confirmed in Rapolo in 1966 where the irritating effect of DDT caused An farauti to leave houses without feeding. Also fewer mosquitoes were attracted to sprayed houses (Sweeney 1966). In Takubar there was no appreciable decline in parasite rate following three DDT spray rounds, even though household coverage in excess of 80% was achieved each round.

Sensitivity testing suggested that An farauti in the Gazelle Peninsula was still sensitive to DDT in the concentrations used although compared to earlier studies some tolerance had occurred (Sweeney AW 1966). DDT continues to result in dramatic declines in infant parasite rates (55% to 2%), total parasite rates (65% to 18%) and spleen rates (79% to 47%) in previously unsprayed areas of the country (Schuurkamp et al 1987). However, in the Gazelle Peninsula with so much biting (and presumably resting) occurring outside and early in the night it is not difficult to appreciate that indoor spraying may have limited impact on vector populations.

In some coastal villages bednets are used. Small children are more likely to be protected in this way than are older children and adults. Adults maintain that bednets are suffocatingly warm to sleep under and prefer the occasional discomfort of biting insects. In 1987, as part of primary health interventions for malaria control, bednets

impregnated with permethrin were introduced to villages in the Duke of York Islands. This was part of a package of interventions which included reduction of breeding sites and training of village dispensers for the early treatment of fever. These activities were nominally to be supervised by the local health officer at Molot.

In Madang permethrin impregnated bed nets were very popular but not so much because they reduced biting from mosquitoes but because they controlled irritation from bed bugs and head lice (Charlwood & Dagoro 1989). These impregnated bednets reduced the malaria parasite rate in trials in PNG (Graves et al 1985), Africa (Jaenson et al 1994) and the Solomon Islands (Kere et al 1993). In the Solomon Islands the biting population of An farauti was reduced by 71% and the rate of P falciparum infection declined considerably; the effect on P vivax infection was less marked (Hii et al 1993).

The trial of permethrin impregnated bed nets on the Duke of York Islands was disappointing because of the failure to establish controls, failure to establish base line prevalence rates for three out of seven trial villages and for failure to establish some indication of actual bed net usage; in the Duke of York Islands bed nets were reported to be unpopular with adults because they stifled air flow but they were more popular for use with young children.

Changes in parasite rates observed during the bed net trial on the Duke of York Islands are difficult to interpret.

Periodic fluctuations in parasite rates, as demonstrated by previous indicator village surveys, are the consequence of natural phenomena related to vector breeding, feeding and survival, the dynamics of malaria parasites and the degree of immunity in the community. The declines in parasite rate noted during the second and third blood surveys, notable though they are, cannot entirely be attributed to the effect of the permethrin impregnated bed nets. The very low parasite rates observed at the third survey (infant parasite rate 2%, all ages parasite rate 4%) are certainly lower than any previously observed but the subsequent rise in parasite rates tends to argue for normal seasonal variations (more vigorously sought than previously), changing behaviour of the community with regard to their use of bed nets, technical problems with impregnation with permethrin or a temporary change in the biting behaviour of the vector. Although bioassay studies during the trial confirmed 100% mortality of the vector in the concentrations of permethrin used the design and duration of the study does not permit further speculation on the long term value of this tool.

Failure of the Duke of York Island impregnated bed net trial to demonstrate sustainable declines in malaria transmission should not persuade against the use of this technique for malaria control. It is likely that more scientifically rigorous testing will confirm other studies from PNG and elsewhere on the usefulness of this method of malaria control.

Further studies are contemplated in PNG on the use of curtains impregnated with permethrin to effect reductions in parasite rate. Impregnated curtains will enable people to sleep freely, without the suffocating effect of a bednet, yet some contact between mosquito and insecticide will be maintained.

Alphamethrin, as an alternative to permethrin, has recently been demonstrated to be cheaper and more effective in reducing biting of malaria vectors in China (Dapeng et al 1994) and this is clearly worthy of further investigation in PNG.

This study into malaria in Gazelle Peninsula has examined, albeit cursorily, the incidence and prevalence of malaria, the clinical disease burden and the behaviour of the vector, An farauti. The results demonstrate variable patterns of transmission depending on altitude and distance from Rabaul and characteristics of vector behaviour which suggest high man-biting densities.

It is unlikely, given the highly mobile nature of the people of the Peninsula and visitors to the area, that elimination of the parasite will ever be possible. Although the Peninsula is relatively isolated by land routes, regular plane and boat travel inevitably result in the importation of parasite and vector. Reduction of the burden of clinical malaria can, however, be attempted. Because of the economic and social factors discussed above if the control measures suggested below are to be

successful anywhere in PNG it is likely that they will succeed in the Gazelle Peninsula.

Suggested strategies for malaria control in the Gazelle Peninsula:

1. Access to treatment: An early, low cost and effective measure to reduce the burden of clinical malaria is to improve access to treatment. At present access to antimalarials is at hospital, health centres and aid posts, but many villages are far from these facilities. Most people in the Peninsula recognise the symptoms and signs of malaria and tend to sit and suffer, rather than travel long distances to seek treatment. For most immune older children and adults malaria is a mild illness but in younger children and in non immune 'immigrants' the disease may rapidly become an overwhelming parasitaemia, or result in chronic anaemia, splenomegaly and malnutrition. Early treatment of these susceptible groups is therefore important.

The limited experience with village dispensers of chloroquine in this study suggests that they were effective and well used. What has not been evaluated, however, is the long-term effect of this strategy on patterns of resistance of P falciparum to chloroquine. Whilst single dose chloroquine regimes had been shown to be 98% successful in West Africa (Breman et al 1987) it is possible that this regime will increase resistant strains of the parasite in the Gazelle Peninsula where the problem

has already been demonstrated. In West Africa and PNG the standard treatment regime for the treatment of malaria is now three days.

Regularity of drug supply to many areas of the country is an increasing problem and it is possible that this problem will eventually reduce the effectiveness of village dispensers, who remain 'outside' the official network of health workers. It is unlikely that full courses of chloroquine, properly administered, will increase the problem of drug resistance, but the ever increasing tendency is to stop taking the bitter drug when symptoms subside, usually on the second day of treatment and this clearly enhances the spread of resistant strains of P falciparum.

Standard management regimes for malaria for health workers prescribe the use of amodiaquine for infants and children under 18Kg, although chloroquine may be used if amodiaquine is not available. The potential dangers of having two antimalarials available to village dispensers has to be weighed against the difficulties of getting small children to take the bitter chloroquine. The potential for confusing drug and dosage is considerable. It is also worrying that the limited effect of amodiaquine on P falciparum infections has already been noted on the mainland north coast (Sapak et al 1991). In addition, observation of techniques for administering any oral drug to young children, even by health workers, demonstrates much of the drug being spat out, or dribbled down the chin

and it does not seem to matter what the drug is. It does not seem worthwhile increasing the number of antimalarials available to village dispensers when there is clear evidence of problems with the existing programme.

In the Gazelle Peninsula antimalarials are available in chemist shops and in supermarkets. Trade stores in villages do not, in general, stock these items. There is no reason, apart for commercial considerations, why chloroquine (and appropriate instructions for use) should not be available in these trade stores. In chemist shops bottles of chloroquine are correctly labelled (in English and Neomelanesian) for both treatment and prophylactic doses and the drugs are potent. Labelling for treatment doses can be easily translated into Kuanua, or any other local language. We have noted that a large proportion of the population in the Gazelle Peninsula is literate, including women, and availability of antimalarials in the household seems the next stage towards encouraging people to take responsibility for their own health, in much the same way that home fluids and sugar-salt solution are encouraged for diarrhoea.

In common with other urban centres in PNG attempted and successful suicides have occurred with chloroquine and some community groups have expressed concern over the ready availability of the drug. This seems an unreasonable argument against the promotion of chloroquine which will certainly save more lives than the occasional intentional overdose. The question of accidental overdosage with

chloroquine needs addressing by clear labelling and verbal explanation by the dispenser and may be incorporated into general health education themes.

Some groups of people in the Gazelle Peninsula are at high risk of developing severe malaria, including pregnant women and 'immigrant' labourers and for these groups we need to give special attention to prophylaxis. Regular drug treatment of any kind is notoriously difficult. The colonial system of the local plantation manager giving weekly chloroquine appears to have broken down, although most managers still treat episodes of fever adequately. Pregnant women receive weekly chloroquine (and iron and folic acid tablets) as a routine during antenatal checks. However, antenatal clinics are not regular outside of the main urban centres.

2. Social mobilisation and health education: Whatever strategy is used to control malaria, people need to be informed about the availability of services and motivated to use them. Fortunately the Tolai people of the Gazelle Peninsula are a highly socially motivated ethnic group and the region abounds with a strong tradition of social and cultural organisations. However, migrant groups are not so well organised and it is these groups that need targeting for education programmes.

Public communication in the Gazelle Peninsula is via radio (national and provincial radio stations in English, Neomelanesian and Kuanua), national newspaper (town areas

only), television and a host of less well defined channels. The highly organised network of social groups in the Peninsula includes womens groups, youth groups and every village has very strong church groups. The Catholic and United Churches are well established in the community and their potential role in health education is considerable.

Of all government extension services the maternal and child health service is the most aggressive in delivering services to villagers. Monthly clinics in villages are regular, well organised and deliver curative, preventive and promotive health services, including treatment of illness, nutritional surveillance, immunisation, antenatal care and health education. The promotive component of this work is not always exploited as much as it could be because of the pressure of more practical and 'measurable' services but observation of the Catholic health services demonstrated a well organised series of discussions and demonstrations on common health problems of the area, including practical malaria control. The government health services were weak on organised health education in villages although all workers realised they should be doing this.

A series of health education charts has been prepared by the national Department of Health, with assistance from the World Health Organisation, on malaria control and although their effectiveness has not been evaluated it appears that at least some community leaders are implementing the control strategies suggested.

Villagers can be encouraged to reduce potential vector breeding sites, at least in the vicinity of their houses. Swampy areas can be drained or filled-in, or if this is not possible then the larvae-feeding fish Gambusia affinis can be placed. These fish breed and survive well in the Gazelle Peninsula.

It is difficult to control, except by the most aggressive measures, breeding sites in plantations. Small collections of ground water are many, difficult to locate and fill quickly again after the next rain. Some clearing of vegetation may reduce these pools but this is an intensely laborious task in this tropical environment. Periodic spraying with a knock-down insecticide has been attempted in urban areas, mainly to reduce Aedes populations, but this is rarely practical or cost effective in rural and plantation areas.

There is a growing awareness of the usefulness of insect screening to houses and as permanent building materials replace bush materials we may expect the use of insect screening to increase. This will not, of course, protect those people who spend much of the evening outside their houses but may help to reduce biting of infants and small children.

Not withstanding the disappointing results of the permethrin bed net trial in the Duke of York Islands there is increasing global awareness of the value of mosquito

nets. Decreased transmission has been noted when only 80% of households use impregnated bed nets and nets, even without permethrin, have been shown to be particularly effective against anopheles, which depart a room if unable to find a blood meal. This does, however, increase the biting of unprotected individuals (Charlwood 1986). Permethrin impregnated nets have also been shown to be useful in controlling filariasis; An punctulatus is deterred from entering the house that contains permethrin nets (Charlwood & Dagoro 1987a).

It is clear from the Duke of York Island trial that bed nets were well received and that demand was, and continues to be, high. It is also clear that the Department of Health is unable to meet the requirements to supply bed nets and that the commercial sector, in the Gazelle Peninsula at least, is able to respond to the demands for bed nets. Stores demonstrated that they were able to respond rapidly to consumer demand for bed nets during the volcanic eruption and that continued demand has not resulted in any shortage in the area.

Verbal reports suggest that impregnated bed nets are gaining in popularity, especially for children. Strategies for regular impregnation have not been tested over a wide area and whilst there is no reason to believe that this could not be organised on a regular basis at the local health centre or aid post the low rates of impregnation of bed nets during the bed net trial indicates that

accompanying health education strategies, rather than financial constraints, are lacking.

There is no reason why the government should monopolise the use of permethrin. With continued rationalisation of resources within the Department of Health it is unlikely that it would be able to sustain a programme of six monthly bed net impregnation. Insecticides and herbicides are used throughout plantation areas of PNG and it is but a short step to teach retailers and users how to impregnate bed nets every six months. The well established network of community groups and commercial organisations lends itself to the dissemination of this kind of information and provincial health authorities could improve their association with these groups for the purpose of teaching and demonstrating these practical malaria control measures.

Mosquito coils are widely available in PNG and these have been shown to be effective in reducing the numbers of mosquitoes inside houses (Charlwood & Jolley 1984). The burden of this strategy falls on the people who must have money for the continued purchase of the coils. This continued expense may not be possible in those less affluent groups, in bush material, unscreened houses and those living furthest from retail outlets.

The outside biting behaviour of <u>An farauti</u> remains a problem and one which is not approached by any of the strategies discussed above. Personal protection against biting by covering the skin with clothing or using personal

repellents seems impractical, although this has been advocated for many years (Black 1977). The tropical environment, continuous sweating and the economics of these measures limit their use to expatriate and urban communities.

Soap containing DEET (diethyltoluamide) and permethrin has been shown to reduce insect biting for up to eight hours and this method may be more acceptable and affordable than other forms of repellent. DEET soap used early in the evening may reduce the problem of early night biting by An farauti both inside and outside houses (Charlwood & Dagoro 1987b).

In many PNG societies pigs and chickens are kept near to houses, although in the Gazelle Peninsula pigs are usually housed at a distance from sleeping areas. If humans are protected and animals are within biting distance of blood-seeking, predominantly zoophilic anophelines then man biting will be reduced. We do not have information on the feeding habits of An farauti No 1 but zooprophylaxis may be considered as part of an integrated programme of malaria control (Garret-Jones et al 1980).

It has been demonstrated that, instead of sitting on the ground, people sitting on platforms raised two metres or more above the ground are afforded some protection against biting by malaria vectors (Charlwood et al 1984). This is a strategy which would be practical and acceptable in this area. Indeed, many houses have raised platforms under

trees on which the family eat and rest during the day and evening.

3. Health staff training: Ongoing training and supervision of health staff is fundamental to the continued improvement of health services.

For malaria control, health staff in PNG are still suffering from the legacy of the National Malaria Control Programme, which effectively isolated field health workers (and the public) from responsibility for malaria control. Malaria control was something the government malaria workers did and communication between them and other health workers was minimal and not always constructive. Communication between malaria worker and the public was worse. When provinces incorporated malaria control into primary health care programmes there was much misunderstanding and ill feeling. Health workers were reluctant to take on the extra work load and malaria workers saw a threat to their livelihood and were protective of their knowledge, skills and information.

Some progress has been made as malaria workers retire and resources are released for primary health care. For many older health workers malaria control is a new responsibility; younger workers will have received education at their training institution. For all health workers an organised programme of instruction and follow up is essential for effective malaria control, as it is for other primary health care programmes.

Rural health staff (and the public) should receive regular, supportive supervision from provincial technical staff. They should receive adequate supplies of drugs, blood slides, staining materials and forms and most important feedback on the malaria situation in their area and adjacent health centre areas. Regular meetings to discuss a range of health care programmes will enable staff to compare successes and failures and to bring problems to the attention of malaria programme managers.

4. DDT household spraying: It is unlikely that ongoing DDT household spraying will be useful in the Gazelle Peninsula, except as an adjunct to other successful control measures in outbreak situations. In these situations spraying by locally recruited and trained people will be the strategy of choice. Complete spray coverage of some villages in Toma and Vunadidir census divisions was achieved as part of a comprehensive community-based malaria control programme in 1985 and similar high coverages utilising local labor have been noted elsewhere in PNG in the past (Kolter 1979).

Whilst the vector remains susceptible to DDT its outdoor biting behaviour and the general reluctance of people to have their houses sprayed regularly limit the usefulness of this strategy.

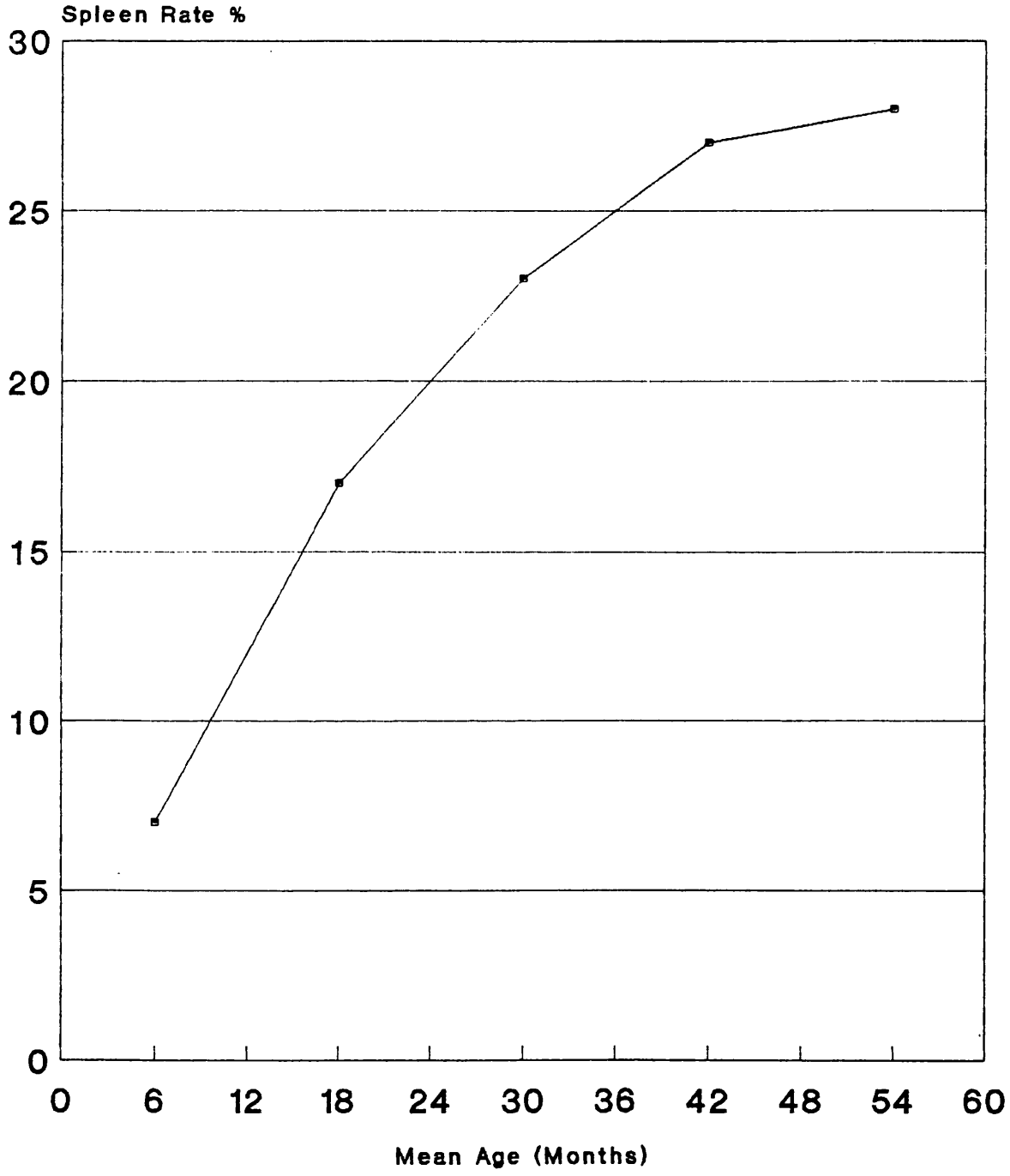
COMMENT

It is not appropriate for health authorities alone to decide which measure, or combination of measures, for malaria control should be used for any particular area in the Gazelle Peninsula. Primary health care approaches demand considerable input and participation from villagers and this is in line with current global policies on malaria control (World Health Organisation 1993). This approach encourages personal and community responsibility for health and ensures a higher degree of sustainability of effort. The role of health authorities is to provide advice, technical resources and initiative and avail themselves of community groups to introduce the topic of malaria control, work with the people to plan a control strategy and provide ongoing support to enable them to carry out their chosen methods.

Through the highly developed social, political and public service structures in East New Britain Province malaria control initiatives may be reinforced through education, health and social services as part of an integrated strategy of social development and to this end national and provincial health plans should reflect this commitment through budgetary and resource allocation.

Fig 5.1

SPLEEN RATE, CHILDREN 0-5 YEARS OF AGE LOW ALTITUDE VILLAGES, GAZELLE PENINSULA



Low alt = 0-200 metres above sea level

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