

Health impact assessments of malaria and Ross River virus infection in the Southern Highlands Province of Papua New Guinea

J. HUI^{1,2}, T. DYKE³, H. DAGORO¹ AND R. C. SANDERS⁴

Papua New Guinea Institute of Medical Research, Madang, Tari and Goroka,
Papua New Guinea

SUMMARY

Malaria at an elevation of 1050 metres is common and highly endemic in the Tagari Valley in the Southern Highlands of Papua New Guinea. Health impact assessments showed that the risks of malaria and epidemic polyarthritis at a gasfield development project in this area were high. Baseline malariometric surveys were conducted in four villages in June and August 1990 and two follow-up surveys (May and December 1991) were made in the village of Nogolitogo near the gasfield pioneer base camp. A total of 941 blood smears were examined. Average malaria prevalence rates decreased with altitude from 56% (at 1050 m) to 9% (at 1700 m) for children 1-9 years of age and from 45% (at 1050 m) to 8% (at 1550 m) for those aged 10 years or more. The spleen rate for children less than 10 years old did not vary significantly with altitude, but average enlarged spleen for all ages decreased with altitude. Mean packed cell volume increased with altitude. *Plasmodium falciparum* was the most common malaria parasite found and *Anopheles punctulatus* the predominant vector. Ross River arbovirus (RRV) antibody prevalence was 59%. These results indicate frequent or constant transmission of malaria and pathogenic arboviruses. Entomological and epidemiological data suggested that the vulnerability of the valley community, the receptivity of the environment and the health hazards from malaria and RRV were high. Nonimmune Papua New Guineans and expatriate employees face high health hazards; therefore effective preventive measures are required to mitigate epidemics and avoid the likely heightened transmission of malaria and arboviruses caused by the development project.

Introduction

Mineral exploration and development in Papua New Guinea (PNG) has been taking place at an accelerating rate in the 1980s and through the 1990s. At present there are at least five large-scale mining consortiums operating in PNG: at Porgera (Western Highlands Province), Ok Tedi (Western Province), Misima (Milne Bay Province), Lihir (New Ireland Province) and Kutubu (Southern

Highlands Province). Such projects provide ideal situations for the outbreak of malaria and other vector-borne diseases which may have serious effects on the health of mining workers. Apart from skilled employees, many temporary residents and unscheduled migrants will be included among the newcomers to the area who are not immune to the local parasite strains. To some extent, this group may also introduce novel strains of malaria to which the local population is particularly susceptible.

1 Papua New Guinea Institute of Medical Research, PO Box 378, Madang, Madang Province 511, Papua New Guinea

2 Present address: Department of Public Health and Tropical Medicine, James Cook University, Townsville, Queensland 4811, Australia

3 Papua New Guinea Institute of Medical Research, PO Box 35, Tari, SHP 255, Papua New Guinea
Present address: 26 Rumdewan, Kingskettle, Fife KY15 7QR, Scotland, United Kingdom

4 Papua New Guinea Institute of Medical Research, PO Box 60, Goroka, EHP 441, Papua New Guinea
Present address: World Health Organization, Regional Office for the Western Pacific, PO Box 2932, 1099 Manila, Philippines

Infectious newcomers add to the reservoir of infection and increase its reproduction rate, affecting both the local population and the workforce. If living conditions for the labour workforce are less than adequate and mining activities are not monitored, new breeding places for mosquitoes may be created. Under these conditions serious epidemics can occur and lead to heightened transmission of stable malaria in isolated indigenous highland populations (1,2).

The aim of the Hides gasfield project is to provide electricity for mineral-based industries, which should improve socioeconomic conditions, but its impact on health is uncertain. In view of the possibility that the environmental determinants of health may be overlooked and because of the changing epidemiology of malaria in the highlands of New Guinea (3,4), we undertook a health impact assessment prior to gasfield development. This is a necessary prerequisite for understanding the environmental and social changes that will take place during the construction and operational phases. The transformation of the eco-epidemiology of local vector-borne diseases provides us with a

unique opportunity for performing a situation analysis, including the impact of increased malaria transmission on the local inhabitants.

Materials and Methods

Study site

Access to the Tagari Valley is by a 25 km unsealed road from Tari, the main township in the district. The valley, in the semiremote western corner of Southern Highlands Province, had a population of 358, made up of the inhabitants of Nogolitogo and Kuru, at elevations of 1050 m and 1150 m respectively (Figure 1). These villages are served by two aid posts which are under the administrative supervision of Komo Health Centre. Nogolitogo was the site of the pioneer base camp for the Hides Gasfield Project. Located on the eastern side of the valley are two major villages: Habuno (elevation 1550 m) and Idawi (1700 m).

The inhabitants are local highland people of the Huli ethnic group, approximately 90% of whom belong to eight major family clans. Traditional houses are made of plank wood and

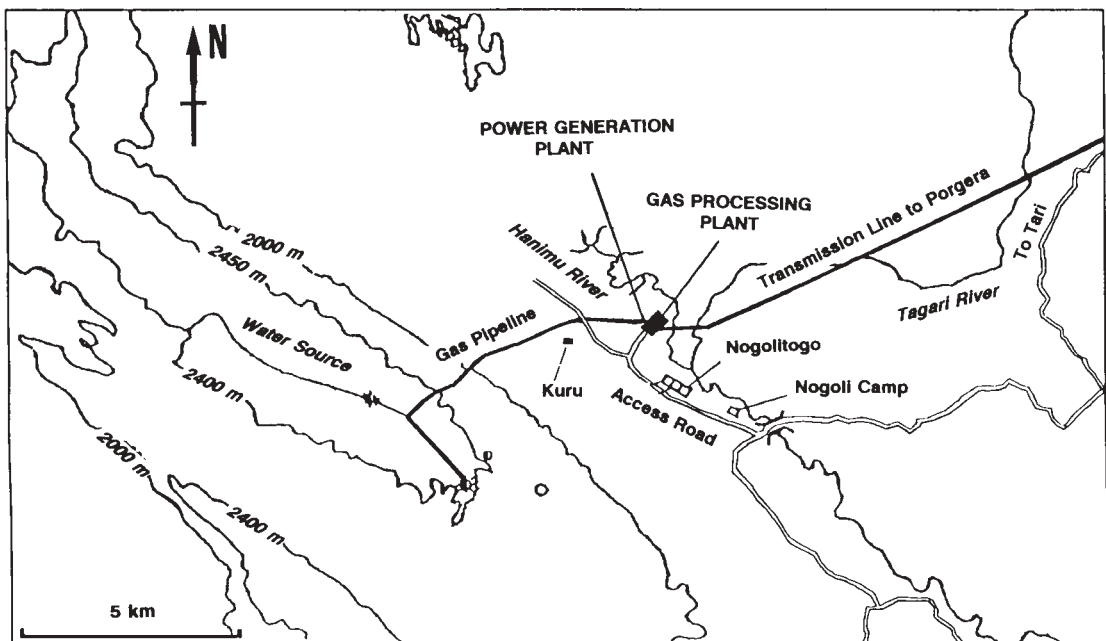


Figure 1. Map showing the villages and BP gasfield installations in the Tagari Valley, Southern Highlands Province, Papua New Guinea, where transmission of epidemic malaria was first reported in mid-1991.

bush grasses on or near ground level based on a circular floor design. The main area of the house is used for cooking, social gatherings and sleeping. There is no electricity or plumbing.

The wet months are from January to May (average rainfall 247.2 mm per month), and the period from June to September (average rainfall 176.8 mm per month) is only slightly drier. Mean annual rainfall for Tari over the period 1952-1970 was 2610 mm and mean monthly temperatures ranged from 15.3° to 26.6°C at Nogolitogo. At the drilling well sites (elevation 3000 m), mean monthly temperatures ranged from 6.9° to 16.2°C.

Malariometric surveys

Malariometric surveys, consisting of the examination of Giemsa-stained thick and thin blood smears and measurement of spleen size and packed cell volume, were conducted in June and August 1990 in 4 villages (Idawi, Habuno, Nogolitogo and Kuru) and again in May and December 1991 in Nogolitogo and Kuru. A total of 941 blood smears were examined. During community surveys, additional information collected included demographic characteristics, bednet usage the previous night, history of antimalarial drug consumption and burning of wood inside houses. A minimum of 200 microscopic fields were examined at a magnification of 1000 using oil immersion optics before a slide was declared negative for malaria parasites. Spleen size was recorded according to the classification of Hackett (5). A small blood sample was taken for quantifying packed cell volume using a capillary tube and haemocytometer reader.

Arbovirus antibody survey

In May 1991, venous blood samples were collected from residents in Nogolitogo for virological assays. The blood was allowed to clot and the serum was separated and stored frozen before transportation to the Papua New Guinea Institute of Medical Research (IMR) virology laboratory in Goroka. Serum samples were assayed for the presence of Ross River virus (RRV)-specific IgG using a sensitive and specific ELISA (enzyme-linked immunosorbent assay). All sera were tested at a final

dilution of 1:400. The assay system was standardized using known positive and negative control sera and results were reported as positive or negative for RRV IgG.

Entomological studies

During surveys in June 1990, flooded ground pools, ruts and potential breeding places were examined and mosquito immatures from these habitats collected and identified. All-night human bait and light trap collections were conducted for 5 or 6 consecutive nights in the months of June and August 1990 at Nogolitogo followed by collections in May and December 1991 at Nogolitogo and Kuru. In August 1990 mosquito catches in houses producing smoke and no smoke were compared to those from an outdoor site. Collectors shifted their stations after midnight, and all collections were categorized by hour and site. Anophelines were identified to species and individually examined for circumsporozoite antigen using species-specific monoclonal antibodies in a solid-phase enzyme-linked immunosorbent assay for *Plasmodium falciparum* (2A10), *P. vivax* (NSV3), *P. vivax* (VK247) and *P. malariae* (CDC) (6-9). 1 positive and 8 negative controls were run on each plate. Assays were limited to the mosquito head-thorax and the absorbances were read at 405 nm on a Multiskan ELISA reader. Samples were considered positive by ELISA if absorbance values (at 30 min) exceeded the mean plus 3 standard deviations of the 8 negative control mosquitoes.

Results

The baseline malaria point prevalences in the Tagari Valley, with respect to two different age groups among four villages at different elevations, are shown in Table 1. Overall malaria prevalence was highest at Nogolitogo (1050 m) and declined with increasing altitude. The expected increased susceptibility among the 1-9 year old children is shown in Table 2.

Plasmodium falciparum was the most common malaria parasite found in the valley and accounted for 65% of all infections, irrespective of altitude (Figure 2). *Plasmodium vivax* was identified in 21% of the positive smears. Mixed infections, including some with *P. malariae*, accounted for the remaining 14%.

TABLE 1

MALARIA PARASITAEMIA PREVALENCES BY AGE IN FOUR VILLAGES OF VARYING ELEVATION
IN THE TAGARI VALLEY, JUNE AND AUGUST 1990

Village	Elevation (metres)	1-9 years					10 years+				
		No	Pf	Pv	Mixed	Total	No	Pf	Pv	Mixed	Total
Idawi	1700	34	5.9	2.9	0	8.8	67	0	0	0	0
Habuno	1550	55	20.5	7.7	5.5 ^a	33.6	102	7.8	0	0	7.8
Kuru	1150	34	5.9	2.9	14.7 ^a	23.5	93	10.7	3.2	1.1 ^c	15.1
Nogolitogo	1050	40	28.7	20.0	7.5 ^b	56.2	74	34.4	6.5	4.1 ^a	45.0
Total		163	15.9	8.6	6.7	31.3	336	12.8	2.4	1.2	16.4

^a Pf+Pv

^b Pf+Pv (1 case) and Pf+Pm (2 cases)

^c Pf+Pm

Pf = *P. falciparum*; Pv = *P. vivax*; Pm = *P. malariae*

TABLE 2

SPLENOMEGALY AND AVERAGE ENLARGED SPLEEN RATES OF THE TAGARI POPULATION BY AGE IN
JUNE AND AUGUST 1990

Village	Elevation (metres)	1-9 years		10 years+		All ages	
		SR %	AES	SR %	AES	SR %	AES
Idawi	1700	44.1 (34)	2.2	4.5 (67)	2.0	17.8 (101)	2.1
Habuno	1550	45.5 (55)	1.9	25.5 (102)	2.5	33.6 (152)	2.2
Kuru	1150	44.1 (34)	2.2	36.6 (93)	2.4	38.6 (127)	2.3
Nogolitogo	1050	47.8 (23)	3.0	48.6 (74)	3.1	48.5 (97)	3.1

Figures in parentheses are number of persons examined

SR = spleen rate; AES = average enlarged spleen (Hackett's scale)

When analyzed with respect to age group, more than 50% of the infections in the under 10 year old group were identified as *P. falciparum*. Malaria parasite rates were not significantly different between the age groups 1-9 years and 10 years and over in Kuru and Nogolitogo ($p > 0.1$); only in Habuno was the parasitaemia prevalence significantly higher in children in the younger age group. Mixed infections were more common in the 1-9 year old group. Of the 15 mixed infections (Table 1), there were 12 *P. falciparum* with *P. vivax*, and 3 *P. falciparum* with *P. malariae*.

Follow-up surveys in May and December

1991 revealed increased malaria prevalence rates among the two groups compared to the predevelopment phase (data not shown). Significant increases were seen in Kuru ($p < 0.01$) but not in Nogolitogo ($p > 0.1$) 11 and 18 months after the baseline survey.

Spleen rates in the 1-9 year age group did not vary significantly with elevation but the average enlarged spleen (AES) over all ages decreased with elevation (Table 2). Spleen rates were significantly higher in the 1-9 year old group than in those 10 years and older in Idawi ($\chi^2 = 21.6$, $p < 0.001$) and Habuno ($\chi^2 = 6.0$, $p < 0.05$). Spleen rates were not significantly

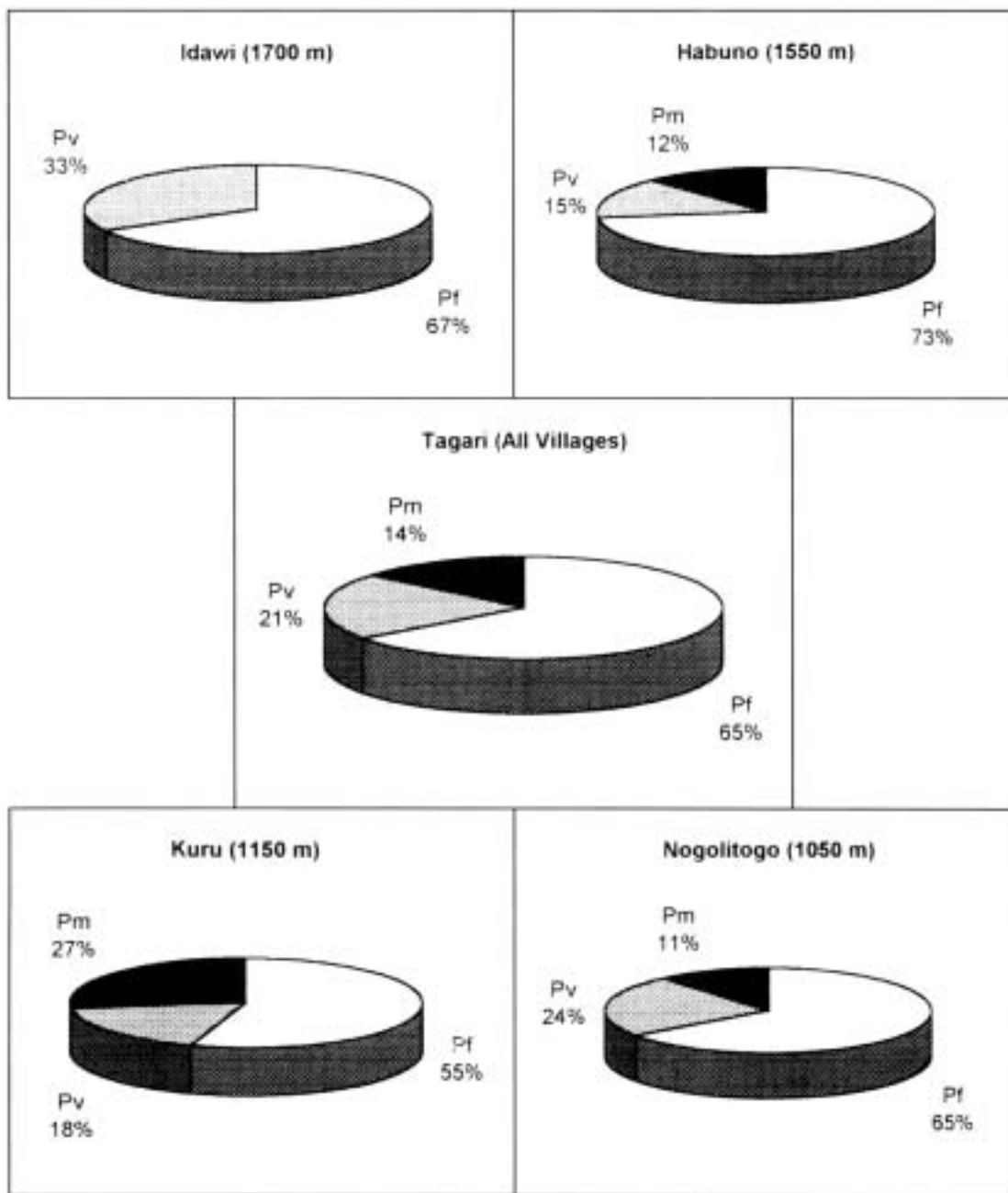


Figure 2. Period prevalence of three parasite species of human malaria in four villages in the Tagari Valley. Pf = *Plasmodium falciparum*, Pv = *P. vivax*, Pm = *P. malariae*.

affected by gasfield development in Kuru 11 months ($p=0.46$, Fisher's exact test) and 18 months ($\chi^2=0.34$, $p=0.53$) after the baseline survey (data not shown). Similar nonsignificant results were observed in Nogolitogo 11 months ($p=0.59$, Fisher's exact test) and 18 months ($\chi^2=2.16$, $p=0.14$) after the baseline survey.

The mean packed cell volume (PCV) for the 1-9 year olds and all age groups increased with altitude (Table 3). The highest mean PCV was found amongst ridge dwellers at Idawi; Nogolitogo had the lowest mean PCV and therefore the most anaemic population. The mean PCVs in 1-9 year olds and over all age

TABLE 3

DISTRIBUTION OF MEAN PACKED CELL VOLUME (PCV) BY AGE IN FOUR VILLAGES OF VARYING ELEVATION IN THE TAGARI VALLEY, JUNE AND AUGUST 1990

Village	Elevation (metres)	1-9 years			All age groups		
		n	Mean PCV	95% CI	n	Mean PVC	95% CI
Idawi	1700	14	38.6	34.9-42.3	31	40.0	37.1-42.3
Habuno	1550	21	34.3	32.6-36.0	56	35.9	35.1-36.9
Kuru	1150	15	38.2	34.6-41.8	43	37.9	35.4-40.3
Nogolitogo	1050	13	31.7	29.0-34.3	93	33.9	32.6-35.2

n = sample size
95% CI = 95% confidence interval

groups in Nogolitogo were significantly lower than those in Idawi ($p < 0.05$).

Self-reported use of antimalarial drugs during the previous 10 days indicated a higher

consumption at Kuru (35%) and Nogolitogo (26%) (Figure 3). In Idawi and Habuno drug utilization was lower. At Nogolitogo, where the aid post orderly (APO) had no policy to administer prophylactic chloroquine, the

Village (altitude, metres)

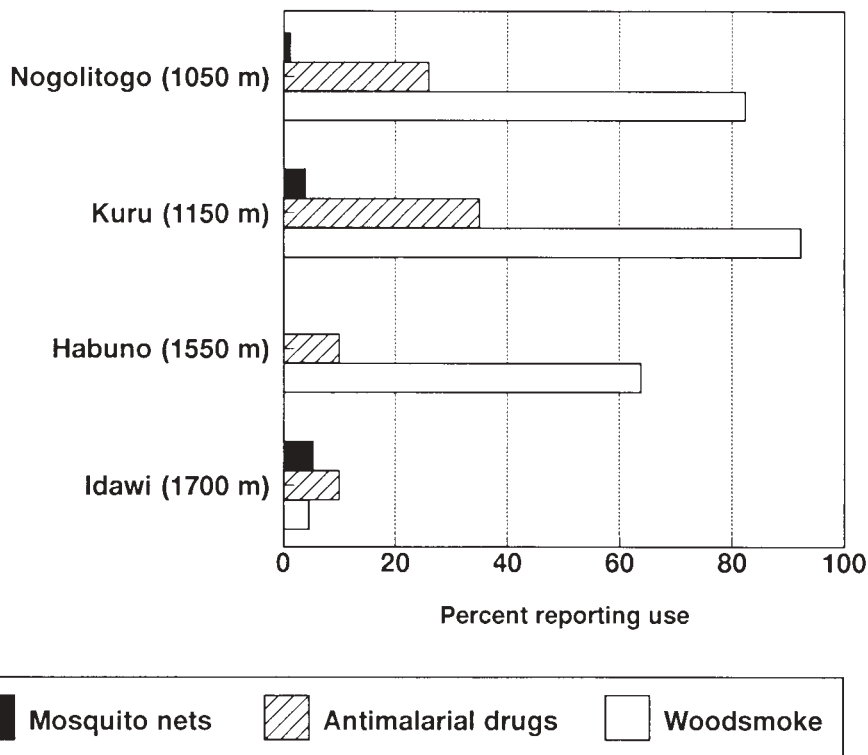


Figure 3. Self-reported use of antimalarial drugs, mosquito nets and woodsmoke by village.

Age group (years)

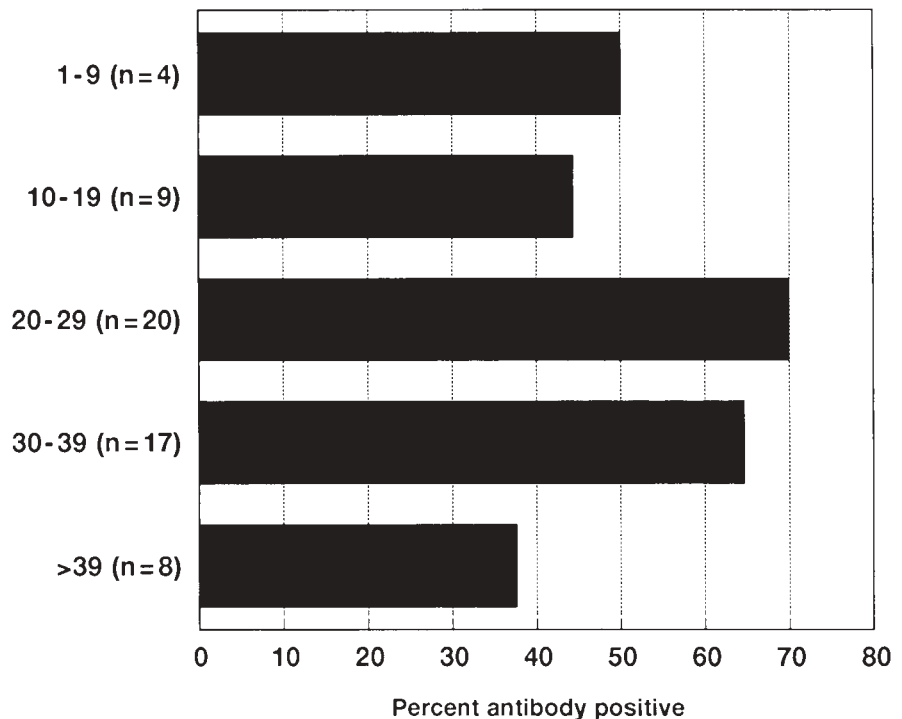


Figure 4. Proportion of sera ELISA-positive for Ross River virus (RRV) IgG antibody by age group in Nogolitogo (1050 m).

reported rate probably reflected its greater use for therapeutic purposes.

Inhabitants at Kuru reported the greatest use of woodsmoke at night: 92%, compared to 5% at Idawi (Figure 3). Overall, there was a low self-reported use of mosquito nets compared to antimalarial drugs and woodsmoke (Figure 3). However, in a random sample survey conducted in December 1991, bednet utilization rates increased to 25% and 32% in Nogolitogo and Kuru respectively. In August 1991, the company responsible for the gas extraction (BP Exploration) supported the bednet program only. The Provincial Department of Health implemented a vector control program consisting of residual house spraying using 2 g DDT/m² and distribution of 341 permethrin-impregnated bednets (0.5 g active ingredient/m²) to the inhabitants of Kuru and Nogolitogo. Fogging using Resigen insecticide was also applied twice per month around the base camp area. It was reported that the two communities gave good cooperation by assisting household census and

bednet dipping activities (T. Grein, personal communication).

The proportion of the sample population positive for RRV IgG antibodies detectable by ELISA increased with age: 34 (59%) of the 58 serum samples assayed were found to be positive (Figure 4).

Random larval surveys of ground pools, ditches, depressions and pig ruts usually revealed a >10:1 distribution in favour of *Anopheles punctulatus* over *An. farauti*. Morphological examinations of adult mosquitoes captured during human-landing collections revealed that 2950 (99.6%) of 2963 were *An. punctulatus*; the remaining 0.4% were *An. farauti*.

Average human landing rates in Nogolitogo and Kuru were 10.3 and 1.7 bites per person-night respectively. Of 515 anophelines (501 *An. punctulatus* and 14 *An. farauti*) examined by ELISA, 9 *An. punctulatus* tested positive

TABLE 4

NUMBERS OF *ANOPHELES PUNCTULATUS* AND CULICINES CAPTURED IN HOUSES WITH AND WITHOUT SMOKE AND AT AN OUTDOOR SITE OVER FIVE CONSECUTIVE NIGHTS IN NOGOLITOGO

Night	Numbers of mosquitoes collected					
	House without smoke		House with smoke		Outdoor	
	<i>An. punctulatus</i>	Culicines	<i>An. punctulatus</i>	Culicines	<i>An. punctulatus</i>	Culicines
1	43	nd	120	nd	76	nd
2	149	20	87	12	75	10
3	256	16	170	17	357	17
4	145	26	89	20	125	32
5	234	43	117	7	279	39
Total	827	105	583	56	912	98

nd = not done

(1.8%) for circumsporozoite antigens. 7 infective specimens had been collected in Nogolitogo and 2 in Kuru by light traps and biting collections. 5 mosquitoes (1.0%) reacted with the monoclonal antibody to *P. falciparum*, 1 (0.2%) each reacted with the monoclonal antibody to *P. vivax* (VK210) and *P. vivax* variant VK247, 1 tested positive for both *P. falciparum* and *P. vivax* VK210, and 1 tested positive for both *P. falciparum* and *P. malariae*. Combining human bait rates with sporozoite rates resulted in an overall entomological inoculation rate (EIR) of 0.163 and 0.046 infective bites/person/night in Nogolitogo and Kuru respectively.

At Nogolitogo, landing rates of *An. punctulatus* were not significantly different between a smoked house and an unsmoked house (mean reduction 30%, paired t test=1.47, df=4, p=0.22) and between an unsmoked house and an outdoor site (mean reduction 9%, paired t test=0.57, df=4, p=0.59) (Table 4). Culicine landing rates were not significantly different between a smoked house and an unsmoked house (mean reduction 47%, paired t test=1.50, df=3, p=0.23), between a smoked house and an outdoor site (mean reduction 43%, paired t test=1.35, df=3, p=0.27) and between an unsmoked house and an outdoor site (105 vs 98 bites). Nocturnal landing times peaked at midnight followed by a second peak at 0500 hours.

Discussion

Malaria was found to be endemic in

Nogolitogo and Kuru, the two villages at lower elevation in the Tagari Valley. Here, the study population exhibited traits of acquired immunity consistent with moderate-to-intense exposure and probably seasonal transmission. However, at the highest altitude (1700 m), Idawi with the lowest parasite rate and a relatively high spleen rate in children 1-9 years must be regarded as a marginal environment for transmission of malaria. Elsewhere in Papua New Guinea, a spleen rate of 6% associated with any parasitaemia was reported among a recently contacted Haruai group (n=132) living at 1400 to 1900 m altitude in the Western Schrader range (10). Although transmission is highly improbable at higher altitudes, the highland populations are very mobile since they hunt or farm within transmission zones at lower altitudes. In contrast, favourable conditions for heightened transmission of near-stable malaria typical of a mesoendemic malarial zone occur at Nogolitogo and Kuru. The endemicity in the study area is lower than in the coastal and lowland populations of Papua New Guinea, for example in the Madang and Wosera areas, where 72% of the children under 10 years have an enlarged spleen and 57% have parasitaemia (2,11).

We consider that baseline data on the use of health services and indicators of health, such as packed cell volume, presence of aminoquinolines in urine and reported use of mosquito nets for protection, provide useful information in the selection and evaluation of

appropriate interventions for a community experiencing a dramatic environmental transformation. The ready availability and consumption of antimalarials appears to be relatively common in the two villages at lower altitudes, which reflects the severity of malaria. The respective self-reported usage of 26% and 35% in Nogolitogo and Kuru (Figure 3) is more than double the 13% positive rate for aminoquinolines detected in urine samples among the coastal population in the Madang area (12).

The results of this study extend the known distribution of Ross River virus, which is the most common and widespread alphavirus causing epidemic polyarthritis among humans in Australia and PNG (13,14). It is associated with a nonfatal but highly debilitating polyarthritis which can result in significant reductions in individual and community productivity. The high antibody prevalence of RRV may reflect closer proximity to bush and rainforest or increased occupational exposure. Altitudinal differences were noted in the prevalence of RRV infection in five Papuan and Irian Jaya (West New Guinean) highland populations living at elevations of about 1300 m (15), with positive reactors to certain flaviviruses (dengue, Murray Valley encephalitis, Japanese encephalitis and yellow fever antigens) disappearing above about 1500 m, while positive reactors to other alphaviruses (Chikungunya and Semliki Forest antigens) predominated at considerably higher altitudes

(16). The absence of flavivirus activity in the highland plateau (16) does not necessarily rule out the introduction of Murray Valley encephalitis from the coastal lowlands, since inhabitants from these areas recorded seroprevalence positivity rates of 95% to 100%, and communities in the low hill country and deep mountain valleys showed intermediate rates.

The increasing prevalence of RRV antibodies with age across all age groups suggests persistent or cyclic virus transmission. With high rainfall throughout the year this could mean continuous breeding and activity of arbovirus vectors. High spleen rates and malaria infection rates indicate chronic febrile disease which would probably mask the occurrence of illness due specifically to arbovirus infection. This would obscure an epidemic excursion of such viruses into these people. Antibodies in young children indicate infection at an early age suggesting continuous circulation of arboviruses within the Tagari Valley. Collections of sera from nonhuman vertebrates and viral isolations from mosquitoes were not conducted in this study.

These baseline epidemiological and entomological data have direct implications for assessing the health risks of the project. These are summarized in a health impact forecast for malaria and Ross River arbovirus (Table 5). In its simple form, we considered three main components (17) which may contribute to the

TABLE 5

SUMMARY HEALTH FORECAST FOR MALARIA AND EPIDEMIC POLYARTHRITIS

	Project Title:	Hides Gasfield Development		
	Type:	Gasfield extraction		
	Location:	Tagari Valley		
	Date of forecast:	August 1990 - May 1991		
	Project Phase:	Baseline		
	Community Group:	Huli		
Disease	Vulnerability of community	Receptivity of environment	Vigilance of health services	Health hazard
Malaria	High	High	Supportive, no prevention and diagnosis	High
Epidemic polyarthritis	High antibody prevalence	High	No prevention and diagnosis	High

potential health hazard. Firstly, the vulnerability of the community, especially newcomers, was high due to high malaria prevalence among residents, particularly children and adult male inhabitants; the latter group would seek work opportunities at or around the base camp or the power plant site. Nogolitogo and Kuru are closely situated to these installations. Thus the migrant population was potentially susceptible to infection, there was little protective immunity against the disease and exposure was expected to occur on a large scale.

Secondly, the environmental receptivity to malaria transmission was high since there was likely to be an explosive increase in malaria infection. The gasfield project had created numerous vector breeding sites thus allowing more opportunities for human contact with vectors. Elevated human biting rates and inoculation rates of *An. punctulatus*, the most commonly reported vector in the Tagari Valley, were reported.

Thirdly, vigilance was very good, since the health services provided by the gasfield project included effective preventive measures (such as vector control and targeted chemoprophylaxis for employees) and chemotherapy provided by the company doctor and a health nurse. In an effort to minimize the negative impact of gasfield development on vector-borne disease transmission and hence to improve the quality of life for the residents of Tagari Valley, two major interventions were introduced. The gasfield company operated a health clinic with malaria diagnostic services and together with the health department introduced a vector control program during the operation phase.

Epidemiological and entomological investigations identified two events provoked by this forecast statement that probably exacerbated the malaria situation in Nogolitogo. As early as March 1991, three months after the commencement of earthmoving works and campsite construction activities, the company doctor reported that 76% of the Giemsa-stained thick blood films were positive for malaria; the slide positivity rates fluctuated between 68% and 73% during April and May 1991 (T. Grein, personal communication). When the self-reported case

detection results were combined with the elevated period prevalences in May 1991, the epidemiological data strongly suggested an epidemic during the first six months of the year. This outbreak was responsible for 94% of the *P. falciparum* infections detected by the clinic over a three-month period. Parasitologically confirmed cases were promptly treated with appropriate antimalarials.

The environmental transformation occurred in a highlands setting where extensive earth excavation provided the ephemeral freshwater breeding sites preferred by *An. punctulatus* mosquitoes. In many ways, the ecological setting was similar to the one described by Anthony et al. (1) in the highlands of Irian Jaya. For example, we also observed that large tracts of shallow ground pools and ditches were blocked since they were not often connected with main streams that traversed the valley. With rare exceptions, nearly all potential and actual larval habitats, such as the ubiquitous pig ruts and wallows and the innumerable small surface water pools in the clay-based topsoil, were open and fully exposed to the sunlight and supported sparse to moderate algal growth. As observed in the highlands of Irian Jaya (1), it is probable that newly disturbed soil was rapidly colonized leading to sharp rises in the recruitment rate and a build-up of the adult *An. punctulatus* population after the rainy season. These conditions were ideal for outdoor transmission, which was enhanced by the company providing outdoor recreational and entertainment facilities for employees and visitors.

Furthermore, changes in human ecology and behaviour have increased the incidence or severity of malaria and led to heightened transmission in one of the two villages. When the village men recruited by the company began to shift their social activities from the smoke-filled houses to areas in and around the base camp, they placed themselves at a much greater risk for malaria. Not only had they left an area in which the smoke acted as a mosquito repellent, but they had moved into semi-open areas and shelters with unscreened windows that were commonly surrounded by pools of emerging mosquitoes. Although the custom of burning wood in the highlands home did not protect catchers against the bites of *An*

punctulatus and culicines, studies in the East Sepik showed that smoke produced by burning specific plant materials is effective in repelling human-biting mosquitoes (18). In The Gambia, wood smoke did not protect children from malaria in areas of moderate transmission (19). The high entomological inoculation rate (EIR) and anopheline density in Nogolitogo is sufficient to sustain stable transmission. The indoor anopheline activity was generally present throughout the early evening till early morning, when the temperatures dropped as low as 15°C, and the villagers remained inside to keep warm. In the lowland and coastal areas of PNG, *An. punctulatus* has a habit of frequent human biting and high daily survival rates (20-22).

As Papua New Guinea is entering an economic boom era of mining development, the dramatic changes in human ecology and environment will add another dimension to the changing eco-epidemiology of malaria in the highland fringe areas. In this scenario, the epidemiology of vector-borne diseases is closely related to mining and rural development which contributes to improved road and air communications and coastal-to-highlands migration taking place much faster than ever before. Although control measures were instituted after the realization of the malaria epidemic, the likely causes of heightened transmission have been defined. The lessons learned from this experience and the Ok Tedi Mining project (23) must serve as a guide for future improvement in mitigating disease outbreaks and increased public sector participation. In remote areas, this usually involves a vertical control program which provides trained sprayers, equipment and insecticides. The health sector generally and other government agencies should become involved in a multisectoral approach, and the participation of private enterprise is essential when it is responsible for mining projects.

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