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Altitude and the risk of bites from mosquitoes infected with malaria and filariasis among the Mianmin people of Papua New Guinea

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Abstract

The Mianmin are a mobile population occupying a remote lower montane area at 100–1200 m altitude in the north-western interior of Papua New Guinea (PNG). Major medical problems include malaria and bancroftian filariasis. An entomological survey conducted along an altitudinal transect from 170 to 1000 m identified *Anopheles koliensis* as the predominant malaria vector below 650 m, with *A. punctulatus* dominating at the higher elevations. Proportions of mosquitoes with malaria circumsporozoite antigens diminished with increasing altitude, as did the proportion of mosquitoes infected with stage 3 larvae of *Wuchereria bancrofti.* These patterns are consistent with increases in the length of the extrinsic incubation period associated with the lower temperatures found at higher altitudes. Inoculation rates varied less regularly with altitude, owing to local variation in biting rates, but were sufficient even at the higher elevations to maintain a high parasite prevalence in the human population. Results support recent suggestions that the 'population-sink' model of the PNG highland fringes needs additionally to consider local variation due to non-altitude-related ecological factors.

Keywords: malaria, filariasis, *Plasmodium falciparum, Plasmodium vivax, Wuchereria bancrofti, Anopheles koliensis, Anopheles punctulatus,* transmission, altitude, Papua New Guinea, Mianmin

Introduction

The risk of acquiring arthropod-borne diseases often changes with changes in population densities and locations. The seasonal migration of Vlachas shepherds in Greece between summer mountain homes and winter in the seasonally malarious plains enabled them successfully to avoid malarial attacks (BARBER *et al.*, 1936). Population displacement as a result of catastrophes such as wars is often associated with increases in vector-borne diseases (RUSSELL *et al.*, 1963). RILEY (1983) has argued that malaria is the primary determinant of population distribution within Papua New Guinea (PNG), while CRANE (1986) has shown an association between hyper-reactive malarious splenomegaly and shifts in habitation from non-endemic areas to malaria endemic areas of that country.

Anthropologists and demographers have also been concerned with the dynamics of population processes in PNG. A proposed 'population-sink' model (BAAL, 1961; STANHOPE, 1970; JENKINS, 1987; HYNDMAN & MORREN, 1990) may help to explain the observation that the highlands valleys are densely populated whilst the surrounding highland fringe areas are much more sparsely inhabited. The model envisages population growth in the horticulturally intensive highland valleys which are relatively free of arthropod-borne disease, and population expansion thence into the lower-lying fringes, where the people encounter arthropod-borne disease on an unprecedented scale, and are unable to thrive. Malaria and filariasis, in particular, would be expected to be more prevalent at lower altitudes where the warmer temperatures favour both mosquito survival and faster parasite development through the extrinsic incubation period.

This model has attracted the attention of scholars working with the 20 or so Mountain Ok cultures occupying the central ranges of the New Guinea cordillera and its northern and southern fringes, between the Strickland Gorge in the east and Mount Mandala, in Irian Jaya, in the west (SWADLING, 1983; CRAIG & HYNDMAN, 1990). The Mianmin, whom we discuss here, are the most northerly representatives of this group of cultures (MORREN, 1986). Historical evidence suggests that the ancestral Mianmin homelands are in the mid-altitude northern fringes, and that over the last 100–150 years they have been expanding into lower altitudes (GARDNER, 1981). They now inhabit several ecological zones ranging in altitude from 100 m to 1200 m (all of which are perennially wet and effectively aseasonal) in one of the least accessible and least economically developed parts of PNG. The Mianmin provide an opportunity to examine aspects of the relationship hypothesized by the population-sink model.

Methods

Study sites

The specific sites surveyed were near the PNG border with Irian Jaya, in the densely forested and steeply dissected terrain that forms the catchment system of the upper Sepik and August rivers and their tributaries, in southern Sandaun Province. In March–May 1986, surveys were conducted at Yapsiei, a government station 180 m above sea level, 2 nearby Mianmin settlements of Boitrantema and Betabenafip, and the more remote villages of Beitafip, Banefip and Yominbip at altitudes of 240 m, 650 m, and 1000 m, respectively.

Entomological surveys

Mosquito landing catches were performed as described previously (BURKOT *et al.*, 1987). They were conducted both indoors and outdoors, but usually under shelter because of regular heavy rainfall, and usually in villages or hamlets within an hour's walk from a village. Landing catches were generally performed from 18:00 to 06:00 (with a change of personnel at midnight). Landing catches were conducted from 22:00 to 06:00 in Beitafip, where catches before 22:00 yielded negligible numbers of mosquitoes. Results are reported as per 'collector-nights', which were generally composites of collections by 2 different individuals with a proportional adjustment for an incomplete night's collection. Captured mosquitoes were anaesthetized and identified as either anopheline or culicine. Anophelines were either stored dry with silica gel, for subsequent examination by enzyme-linked immunosorbent assay (ELISA) for circumsporozoite (CS) antigens, or in ethanol, for later dissection for filarial infection. Culicines were stored in ethanol.

Laboratory examination

All *Anopheles* mosquitoes dried in silica gel were counted, identified to species on morphological criteria (BELKIN, 1962) and subsequently examined by ELISA for *Plasmodium falciparum* and *P. vivax* CS antigens using the monoclonal antibodies 2A10 and NSV3, respectively (BURKOT *et al.*, 1987). Ethanol-preserved

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anophelines or culicines (a maximum of 20 per night) were stained, dissected and examined for *Wuchereria bancrofti* larvae (NELSON, 1959).

Results

Mosquito collections were made at each of 6 base locations for a total of 67·7 collector-nights. Anopheline mosquitoes were more abundantly collected in landing catches at virtually all altitudes below 1000 m than were culicine mosquitoes (Table 1). A wide range in anopheline abundance was found among the collection sites. At elevations below 1000 m, median numbers of anophelines captured per collector-night ranged from 3 at Betabenafip (200 m) to 70 at Boitrantema (170 m). Culicine numbers collected in landing catches per collector-night ranged from 0·5 at Beitafip (240 m) to 6·5 at Banefip (650 m). No anopheline was collected at Yominbip at an altitude of 1000 m during 7 collector-nights.

More than 93% of anopheline mosquitoes collected at or below 240 m were *A. koliensis*. In contrast, all anophelines captured at 650 m were *A. punctulatus*, accounting for 91% of the *A. punctulatus* collected (Table 2).

Both *A. koliensis* and *A. punctulatus* contained CS antigens: *A. koliensis* had CS antigen positivity rates of 0·57% and 0·76% for *P. falciparum* and *P. vivax*, respectively, whereas *A. punctulatus* was positive for *P. falciparum* CS antigen only (0·68%). The overall CS antigen positivity rate for all malaria species in all anophelines decreased with increasing altitude: at Boitrantema, at an altitude of 170 m, 2·28% of anophelines collected contained CS antigen, whereas at the highest collection site at which anophelines were collected (Banefip at 650 m), 0·54% of anophelines contained CS antigen. Discounting Betabenafip and Yominbip, at which 5 and no anophelines, respectively, were collected, combined *P. falciparum* and *P. vivax* malaria inoculation rates varied from 29 to 434 per year (Table 3).

The proportion of filarial-infected mosquitoes harbouring stage 3 filarial worms followed a similar trend: 33% (1 of 3) of infected mosquitoes collected below 200m had stage 3 larvae, whereas 14% (1 of 7) did so at 240m (Table 4). None of the 8 filaria-infected mosquitoes collected at 650 m contained stage 3 larvae. Inoculation rates for bancroftian filariasis could be estimated only for Beitafip and Boitrantema, with 59 and 1368 bites per year by mosquitoes infected with stage 3 larvae (Table 4).

Table 1. Collection rates of anopheline and culicine mosquitoes in the Mianmin area, Papua New Guinea

Location	Altitude (metres)	Collector-nights	No. collected per collector-night[a] Anophelines	Culicines
Boitrantema	170	4·6	70 (50–92)	5 (3–8·3)
Yapsiei	180	15·8	9 (0–20)	2·6 (0–17·5)
Betabenafip	200	4·3	3 (2–7)	4 (0–7)
Beitafip	240	24	12·5 (4–53)	0·5 (0–5)
Banefip	650	12	68 (21–156)	6·5 (2–14)
Yominbip	1000	7	0 (–)	0 (0–4)
Total		67·7	12·6 (0–156)	2 (0–17·5)

[a]Median (range in parentheses).

Table 2. Numbers and identification of mosquitoes collected in the Mianmin area, Papua New Guinea

Location	Altitude (metres)	*Anopheles* *A farauti*	*A. koliensis*	*A. punctulatus*	*A* sp.[a]	Total	Culicines[a]
Boitrantema	170	0	171	4	162	337	23
Yapsiei	180	0	124	14	11	149	59
Betabenafip	200	0	5	0	11	16	16
Beitafip	240	3	229	17	137	386	27
Banefip	650	0	0	553	234	787	107
Yominbip	1000	0	0	0	0	0	7
Total		3	529	588	555	1675	239

[a]Alcohol-preserved specimens: species identification was not attempted.

Table 3. Presence of *Plasmodium* circumsporozoite antigen and inoculation rates for anopheline mosquitoes collected in the Mianmin area, Papua New Guinea[a]

Location[b]	Altitude (metres)	Total no. tested	*P. falciparum* No. positive	Daily inoculation rate	*P. vivax* No. positive	Daily inoculation rate
Boitrantema	170	175	1 (0·57%)	0·28	3 (1·71%)	0·91
Yapsiei	180	138	2 (1·45%)	0·09	0 (–)	0
Beitafip	240	249	1 (0·40%)	0·04	1 (0·40%)	0·04
Banefip	650	553	3 (0·54%)	0·26	0 (–)	0
Total		1115	7 (0·63%)	0·06	4 (0·36%)	0·03

[a]Including only locations where more than 100 anophelines were examined.
[b]No mosquito containing circumsporozoite antigen was found at Betabenafip or Yominbip.

Discussion

As part of an anthropological study of the Mianmin, parasitological and entomological studies were carried out to assess the health status of this population and the varying risk of acquiring arthropod-borne parasites throughout the altitudinal range of the Mianmin. The results should be interpreted with the caution due to this being a cross-sectional survey, but the aseasonality of the Mianmin environment renders a cross-sectional survey more representative than would otherwise be the case.

Malaria and bancroftian filariasis are known to be transmitted in PNG by members of the *A. punctulatus* complex, with certain culicine mosquitoes transmitting bancroftian filariasis as well (BRYAN, 1968). Both diseases are major causes of human morbidity in the highly endemic lower regions. The vectors of malaria among the Mianmin are *A. koliensis* and *A. punctulatus*, as determined by morphological examination. *A. koliensis* was found only at or below 240 m, whereas *A. punctulatus* was predominantly collected above 240 m.

The population-sink model attempts to explain the distribution and movement of human populations in re-

Table 4. Daily and yearly biting rates of mosquitoes infected with third stage larvae of *Wuchereria bancrofti* collected in the Mianmin area, Papua New Guinea

Location[a]	Altitude (metres)	No. of infected mosquitoes/no. dissected: Total	Stage 3 larvae	Infective biting rates[b]: Daily	Yearly
Boitrantema	170	3/20	1/20	3·750	1368·8
Yapsiei	180	0/20	0/20	0	0
Betabenafip	200	0/15	0/15	0	0
Beitafip	240	7/80	1/80	0·163	59·3
Banefip	650	8/60	0/60	0	0
Total		18/195	3/195	0·225	82·0

[a]No mosquito from Yominbip was dissected.
[b]Calculated from the proportion infected with third stage *W. bancrofti* larvae and the summed median anopheline and culicine densities given in Table 1.

lation to altitude in PNG, exemplified by the Mianmin who have migrated into lower altitudinal zones. While the general relationship between altitude and malaria endemicity is well known (PETERS *et al.*, 1958; PARKINSON, 1974), small area variations in malaria endemicity (CATTANI *et al.*, 1986) may confound the general trend of diminishing transmission with increasing altitude.

Mosquitoes containing CS antigen were found throughout much of the altitudinal range surveyed, at 170–650 m, with positivity rates which declined with increasing altitude. Filaria-infected mosquitoes were collected from 170 m to 650 m, but mosquitoes infected with stage 3 larvae were found only up to an altitude of 240 m. These trends of decreasing prevalence rates for CS antigen and stage 3 larvae in mosquitoes with increasing altitude are probably functions of the decreasing temperature with increasing altitude, which would slow the developmental rate of both malarial and filarial parasites in their vectors. Thus there was consistency with one aspect of the population-sink model, in the form of a regular increase with decreasing altitude in the risk that a given mosquito bite will be infective. Inoculation rates, however, showed a less regular relationship with altitude, reflecting local mosquito abundance as well as infectivity.

It is unlikely that the altitude range within which the Mianmin villages surveyed fall is sufficiently large to affect substantially the parasite prevalence in the human population. While malaria transmission was not seen at Yominbip at 1000 m, a yearly malaria inoculation rate of 95 infected bites was recorded at an altitude of 650 m. In the absence of easily accessible health services, this would be more than sufficient to maintain a very high human malaria prevalence.

The risk of malaria transmission, the inoculation rate, is composed of both the proportion of infective mosquitoes and vector mosquito abundance. The probability that a mosquito will be infective was found to be inversely related to altitude, which is consistent with the population-sink model. The second component of the inoculation rate, mosquito abundance, was not related to altitude, except at the highest elevation where anophelines were not found. It appears that the abundance and biting rates of mosquitoes are substantially influenced by non-altitude-associated variations in local mosquito ecology (e.g., abundance of breeding sites, blood meal sources, etc.). In the broadest sense, therefore, the risk of vector-borne disease is inversely related to altitude. Within the altitudinal range surveyed here, however, systematic altitudinal variation in the risk of bites from mosquitoes infected with malaria and filariasis does not appear to provide a powerful explanation for the local distribution of human populations.

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