Tropical Medicine and International Health

VOLUME 9 NO 10 PP 1081–1090 OCTOBER 2004

Malaria epidemiology in a rural area of the Mekong Delta: a prospective community-based study

A. Erhart[1], N. D. Thang[2], T. H. Bien[3], N. M. Tung[3], N. Q. Hung[4], L. X. Hung[2], T. Q. Tuy[2], N. Speybroeck[1], L. D. Cong[2], M. Coosemans[1] and U. D'Alessandro[1]

1 *Institute of Tropical Medicine Prince Leopold, Antwerp, Belgium*
2 *National Institute for Malariaology, Parasitology and Entomology (NIMPE), Hanoi, Vietnam*
3 *Provincial Malaria Station (PMS), Bac Lieu, Vietnam*
4 *Institute for Malariology, Parasitology and Entomology (IMPE), Ho Chi Minh City, Vietnam*

Summary Over the past 10 years, the Mekong Delta region in Vietnam has experienced fast socio-economic development with subsequent changes in malaria vectors ecology. We conducted a 2-year prospective community-based study in a coastal rural area in the southern Mekong Delta to re-assess the malaria epidemiological situation and the dynamics of transmission. The incidence rate of clinical malaria, established on 558 individuals followed for 23 months by active case detection and biannual cross-sectional surveys, was 2.6/100 person-years. Over the 2-year study period, the parasite rate and malaria seroprevalence (*Plasmodium falciparum* and *P. vivax*) decreased significantly from 2.4% to almost 0%. Passive case detection (PCD) of clinical cases and serological follow-up of newborns carried out in a larger population confirmed the low and decreasing trend of malaria transmission. The majority of fever cases were seen in the private sector and most were unnecessarily treated with antimalarials. Training and involvement of the private sector in detection of malaria cases would greatly improve the quality of health care and health information system.

keywords malaria, *Plasmodium falciparum*, *P. vivax*, transmission, private health care providers, over-treatment, Mekong Delta

Introduction

Malaria used to be highly endemic in the Mekong Delta region of Vietnam. In 1992, when the National Malaria Control Program started its activities, more than 360 000 malaria patients and 516 malaria deaths were reported in this area. After 5 years of intensive control activities, malaria morbidity was reduced by 65% and mortality by 95% (Vu Thi Phan 1998). Concomitantly, the Mekong Delta area experienced a rapid socio-economic growth with numerous research and development projects in agriculture, fishery and water resource management (Australian Government, D. o. t. E. a. H. W. s. o. s. d. 2002; JIRCAS Japan 1997; McNamee 2003; Ministry of Agriculture and Rural Development 2001).

In 1995, a community-based study carried out in An Trach commune estimated the malaria incidence risk at 3/1000 habitants/year. Probably this was an underestimation of the true incidence as at least half of the patients in this area attend private facilities that, until the year 2001, functioned independently without notification of cases or quality control of the treatments provided.

Considering the rapid socio-economic and ecological changes this region is experiencing, a re-evaluation of the malaria epidemiology and its transmission dynamics was needed. Malaria morbidity data were collected retrospectively from the health information system (HIS) and prospectively by setting up active detection of clinical cases and biannual cross-sectional surveys in a well-defined community, and passive case detection (PCD) combined to serological follow-up of newborns in a larger population.

Material and methods

Study population

The study was carried out from September 1999 to August 2001 in An Trach commune, Bac Lieu province, situated along the southern coast of the Mekong Delta region (Figure 1). The rainy season is from May to November, and the dry season from December to April. The total annual rainfalls were 3255, 2620.7 and 1191 mm, respectively in 1999, 2000 and the first 6 months of 2001, with peaks in May–June and in October (400–600 mm/month). The

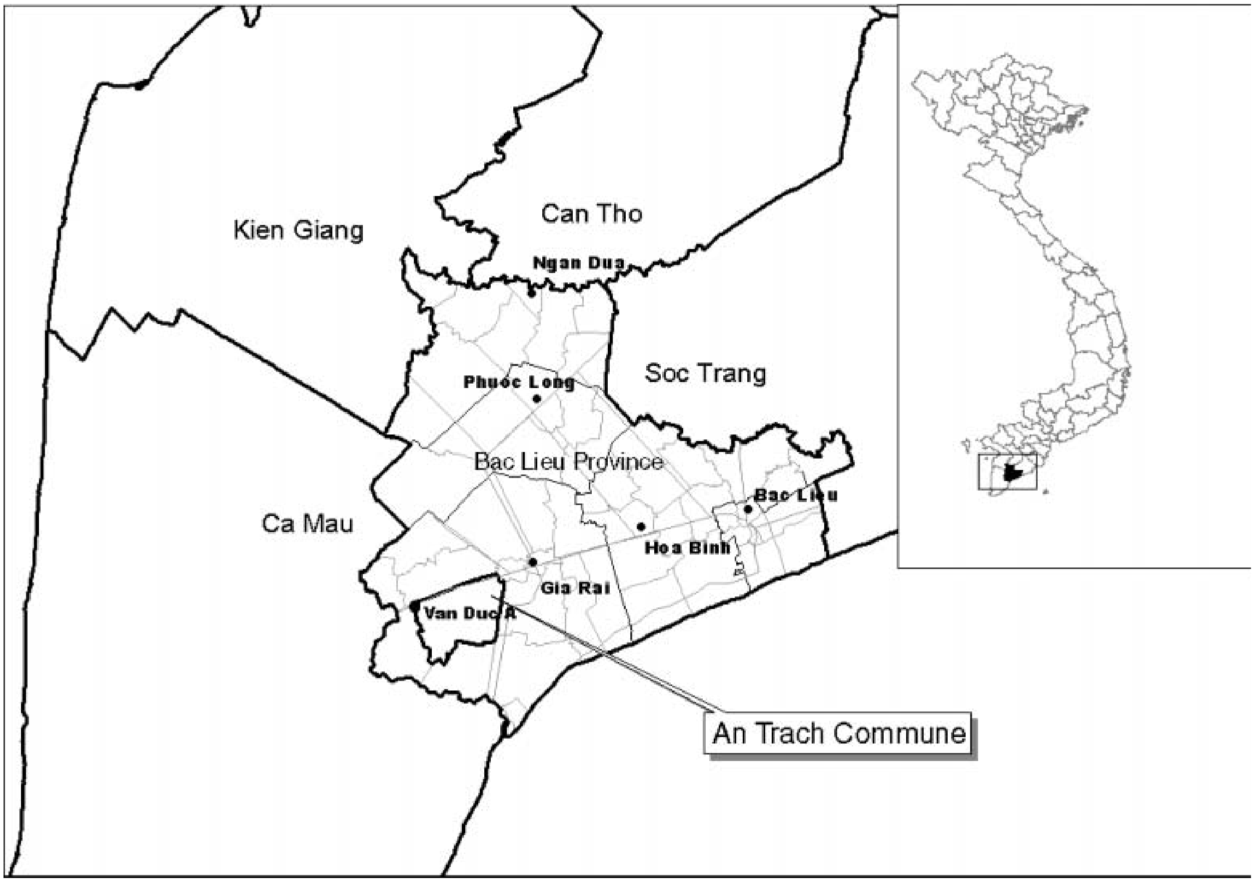

Figure 1 Map of the study area in Vietnam.

annual average temperature is 27.2 °C and the relative humidity 83.4%, exceeding 80% for at least 8 months/year. Malaria transmission is perennial with two peaks in April–May and October–November. *Anopheles sundaicus* is the main vector in this area, where numerous stagnant brackish water pools and canals constitute ideal breeding sites. This vector is present all year round with higher densities during the dry season when water salinity is highest. *Anopheles subpictus* is a secondary vector whose density peaks from September to November.

An Trach is a large commune (60 km^2) with about 25 000 inhabitants. The PCD of malaria cases was carried out in a section situated on the West Bank of the canal running through the settlement. There are four villages in the study area [Van Duc A (VDA), Van Duc B, Hoang Minh and Lung La] with about 6000 inhabitants in total and one of them, VDA, was selected for active case detection (ACD) because it is a typical village of this area, with good accessibility and with a Community Health Centre. Moreover, VDA, having the highest vector density, was chosen for the entomological study so that data on malaria transmission were already available. VDA has 1222 habitants, all belonging to the Kinh ethnic group. Living standards are higher than in the three other villages as VDA is near the national road and has various commercial activities besides agriculture. The area is flat, covered by an extensive network of pools and canals of standing brackish water used for shrimp rearing, the main and most profitable activity. Many Nippa trees (breeding sites for *A. sundaicus*) grow along the canal shores, and rice fields cover the main land. The southern half of the village, where mosquito collections were carried out, is divided into two banks by a small stream running north to south. All 105 households situated on both sides of the stream were selected for the ACD of malaria cases. This section of the village was representative of different types of house construction (wooden or palm leaves) and different socio-economic groups. Informed consent was obtained from the communal People's Committee, village leaders and from all permanent residents. Ethical approval was obtained from the Vietnamese Ministry of Health and from the National Institute for Malariology, Parasitology and Entomology (NIMPE), Hanoi.

Data collection

Information on the total number of consultations, the annual incidence of suspected malaria cases, the number of confirmed malaria cases, the total number of malaria treatments given and the slide positive rate (proportion of positive slides among those collected during cross-sectional surveys and consultations) was collected from the HIS annual reports (commune, district and provincial level) for the period 1994–98. Health staff was interviewed for information on health-seeking behaviour, accessibility and affordability of health care and malaria control activities.

At the beginning of the study a census of the 105 households selected for ACD was performed; information on occupation, bed net availability and previous vector control measures was also collected. Bed net availability (number of individuals sleeping in the house divided by the number of bed nets in use) was arbitrarily categorized into two groups – not adequate: no bed net or more than three persons/net; adequate = 1–3 persons/net. Since 1992, no vector control activity had been carried out in VDA village and bed nets were considered as non-treated with insecticides. ACD on all inhabitants of the 105 selected households started in September 1999 after completion of the census and the first cross-sectional survey and consisted in weekly home visits by two trained hamlet health workers (HHW). Malaria symptoms, consultations and treatments occurring between visits and the axillary temperature (BT) were systematically collected and reported on pre-coded standardized questionnaires. In case of fever (BT ≥ 37.5 °C) or history of fever within the past 48 h, a blood slide (thick and thin films) was collected. Slides were not read immediately after staining because of logistic constraints; they were sent every month to NIMPE, Hanoi, for microscopic examination. In the meantime, malaria cases were presumptively treated with a full course of artesunate tablets. Reasons for any prolonged absence (>1 week) were reported by the HHWs, who kept an updated census with population movements. People with a cumulative follow-up period of <12 weeks and malaria infections detected during the first week of follow-up were excluded from the analysis as the latter were considered as acquired before the start of the study. In addition to ACD, a cross-sectional survey was carried out in September 1999 and was followed by four others at a biannual rhythm, corresponding to the end of the long (August) and the short (January) rainy season (Table 3). Clinical examination assessed spleen size and BT and a blood sample for parasitaemia (thick and thin films), packed cell volume (PCV; microcapillary tubes) and malaria antibodies (filter papers) was collected as well as information on health-seeking behaviour, symptoms and/or treatments. Suspected malaria cases were treated presumptively.

Passive case detection took place in the four villages of the commune where, in addition to the communal health centre (CHC) situated in VDA, one private practitioner per village collected blood slides and other relevant information from all fever patients. Suspected malaria cases were treated presumptively with artesunate tablets.

A 1-year serological follow-up of all newborns was also carried out in the four villages. After obtaining the mother's consent, a blood sample for malaria antibodies was collected on filter paper from all newborns as soon as possible after delivery. Each had four additional blood samples taken every 3 months and when possible, a last one at 18 months of age.

Laboratory methods

Blood slides were stained with a 3% Giemsa solution for 45 min. The number of asexual forms per 200 white blood cells (WBC) was counted and parasite densities were computed assuming a mean WBC count of 8000/µl. A slide was defined as negative if no asexual forms were found after counting 1000 WBC. Slide reading was blinded and quality controlled at the Institute of Tropical Medicine (ITM), Antwerp (Belgium) (all positives and 10% negative slides).

At first reading a 99% agreement was found: discrepant slides were re-read together by both technicians until agreement was reached. Microcapillary tubes were centrifuged and PCV was determined with a manual Hawksley micro-haematocrite reading method according to WHO standards (WHO 1980).

Blood samples on filter paper (Whatman No. 3) for Indirect Fluorescent Antibody Test (IFAT) measuring total antibody titres were stored at −20 °C (Demedts & Wery 1985). *Plasmodium falciparum* and *P. vivax* antigens were prepared from *in vitro* cultures and directly from infected blood respectively. Both infections were from two patients from South Vietnam. For the infants' serological follow-up, IgM and IgG titres against *P. falciparum* were measured. Negative controls were obtained by pooling the sera of five malaria-free individuals; positive controls for each species were obtained from five patients having had several *P. falciparum* and *P. vivax* clinical episodes. The serum dilutions ranged from 1/40 to 1/640. Slide reading was blinded and double reading for all samples reached agreement for more than 98% at first reading: discrepant samples were re-read and results confirmed by a third technician at ITM. Case definitions were:

- Suspected malaria: patient with typical malaria symptoms without microscopy results.
- Clinical malaria: fever (BT ≥ 37.5 °C) and/or history of fever in the past 48 h with a blood slide positive for Plasmodium asexual forms.
- Positive IFAT: titres ≥1/80 for either current or recent *P. falciparum* or *P. vivax* infections.
- New infections estimated by IFAT (five surveys): in two consecutive surveys IFAT from negative to positive or, if previously positive, twofold increase or titres remaining at ≥1/320.

Statistical analysis

Data were analysed with STATA 7.0 software (StataCorp, College Station, TX, 2001). Clinical malaria (*P. falciparum* and *P. vivax*) incidence rates by ACD were calculated for each group at risk in the cohort study. Person-years at risk were calculated by considering each individual visit in which the subject was present and not under antimalarial treatment as 1 person-week. No recrudescence was observed and, given the small number of malaria cases, both *P. falciparum* and *P. vivax* infections were considered together for the risk factor analysis of clinical malaria. Geometric mean values were used to calculate the mean parasite density and mean IFAT titres across surveys. As repeated measurements were carried out on each individual in ACD, clustering was addressed by applying Generalized Estimating Equations (GEE) as described previously (Zeger & Liang 1986). A binomial family and its default link and exchangeable working correlation structure were used. The time variable (t) was the week number and individuals were taken as the cluster units. Univariate odds ratios (OR) were calculated for the risk of new clinical episodes. Within household clustering effect was investigated. The estimation of the malaria incidence, according to the evolution of malaria antibodies titres, was carried out by computing all new infections determined by IFAT (see *Case Definition*) against the total person-years at risk found in ACD. For PCD, univariate- and multivariate-adjusted ORs for the risk of malaria among fever cases were calculated using a logistic regression model. The seroconversion rate for malaria antibodies in infants was estimated by computing the total number of infants that turned positive for *P. falciparum* IgM over the total number of children-months at risk.

Results

Retrospective data on malaria morbidity in An Trach

Malaria data for An Trach (Table 1) are not available fore the period before 1994, the year the CHC was built. Between 1994 and 1998 malaria cases were treated presumptively as microscopy was not available; the annual consultation rate (0.4–0.5 consultation/person/year) and the incidence of suspected malaria cases (1–2/100 person/year) was extremely low. In 1995, a campaign for the active detection of malaria cases considered all fever patients as malaria cases, although only 9–10% were parasitaemic. The malaria incidence risk was estimated at 0.33/100 persons/year.

In VDA, the consultation rate was even lower than in the commune as a whole (0.2–0.3 consultation/person/year) and during the period 1994–98 the incidence of suspected malaria cases decreased considerably: from 1.6 to 0.5/100 person/year. Blood slides were taken only in 1995: only one of seven collected was positive for *P. vivax*. According to health centre data the bed net coverage in 1998 was about 75%.

ACD and malariometric surveys in VDA

A total of 558 individuals representing 910.7 person-years at risk (median follow-up time per individual: 92 weeks)

Table 1 Retrospective data on malaria situation in An Trach commune and Van Duc A (VDA) village: 1994–98

	An Trach commune					VDA village				
Year	Total population	Total consultation	Consultation rate/person/year	Suspect malaria cases	Positive slides	Total population	Total consultation	Consultation rate/person/year	Suspect malaria cases	Malaria treatments
1994	21 908	10 637	0.49	356	–	1645	516	0.31	27	51
1995	22 528	11 243	0.50	864	75	1698	423	0.25	20	43
1996	23 081	9875	0.43	152	15	1731	469	0.27	12	24
1997	23 648	12 058	0.51	402	–	1771	601	0.34	16	25
1998	24 229	11 206	0.46	243	–	1819	571	0.31	9	15

were investigated (Table 2). The study population was young (median age: 22 years), stable (90% of permanent residents) and ethnically homogenous (all but one were Kinh). Most of the active population (309 of 338) were farmers (rice cultivation and shrimp rearing). Bed net coverage was high, there were bed nets in 96% of the houses. Emigration (6% of the population) was evenly distributed and during follow-up no malaria case was detected among the emigrants. Forty-five (8.1%) individuals were lost to follow-up, mainly for emigration or travelling.

During 23 months of follow-up, a total of 17 (12 *P. falciparum*, five *P. vivax*) clinical malaria cases were identified, representing an overall incidence rate of 1.9/100 person-years at risk. No clustering of cases was observed. The univariate risk factor analysis showed that women were less at risk than men (OR = 0.41) at 10% significance level ($P = 0.09$). The odds for malaria were significantly higher (OR = 6.66; $P = 0.01$) during the short rainy season (September–December) than in the dry season (January–April). There was a trend for higher incidence rates in young adults, farmers and people sleeping in houses where bed nets were not available but this was not statistically significant. In the group of children aged 0–9 years only one infection (a 7-years old boy) was detected.

Table 2 Baseline characteristics of the study population

Total number of individuals	558
Total (person-years)	910.7
Median follow-up time, weeks (range)	92 (16–94)
Median date of entry, week (range)	1 (1–66)
Median date of exit, week (range)	101 (47–101)
Sex, M/F (ratio)	272/286 (0.95)
Median age (at entry), years (range)	22 (0–89)
Age categories (year), *n* (%)	
<1	15 (2.7%)
1–9	86 (15.4)
10–19	131 (23.5)
20–39	197 (35.3)
40–59	84 (15.0)
≥60	45 (8.1)
Ethnic group, *n* (%)	
Kinh	557
Chinese	1
Bednet availability, *n* (%)	
No	17 (3.1%)
Yes	537 (96.2)
Missing data	4 (0.7)
Professional categories, *n* (%)	
No (children, students)	176 (31.5%)
Farmers	309 (55.4)
Others (business, officer, health, teachers, etc.)	29 (5.2)
Retired, disabled	44 (7.9)
Status, *n* (%)	
Residents (four deaths, 11 newborns)	507 (90.9)
Emigrants	33 (5.9)
Immigrants	16 (2.9)
Several movements (immigrate, emigrate, etc.)	2 (0.3)

Between the first and the fifth survey, the coverage went down from almost 80 to 66%, however, the characteristics of the participants were very similar across the five surveys (data not shown). Neither severe anaemia nor enlarged spleen was observed. Malaria seroprevalence as well as parasite rate decreased gradually across the five surveys from 2.4 to 0.6% and 0% respectively (chi-square test for trend, $P < 0.05$) (Table 3). The same significant trend was observed for the gametocyte carriage, which was initially very low (Table 3). Geometric mean values (five surveys together) for parasite density and IFAT titres were low, 104.1/μl (95% CI: 53.7–201.8) and 126.2 (93.0–171.2) respectively, usually with lower figures for *P. vivax*. From the second survey onwards, no symptomatic infections or parasitaemia was detected in the 2–9 years old group. The incidence rate of malaria infections estimated by IFAT was slightly lower than the incidence of clinical malaria measured by ACD: 1.1/100 person-years. However, only three of the 10 new infections detected by serology had also been detected by ACD. By summing all the non-overlapping cases detected by both methods, the incidence rate of infections was 2.6/100 person-years. Among the malaria cases detected only by ACD, half of them did not participate in the following survey and could not be detected by serology. The other half was found to be seronegative probably because of the low antibody titres (Table 3). Most of the seven seropositive individuals detected by survey only were present and healthy during the weekly home-visits.

Malaria transmission in An Trach commune (PCD)

A total of 1105 fever cases were detected by PCD for a population estimated at 6082 inhabitants in 1999. About two-thirds (752 of 1105) came from the two more distant villages, i.e. Hoang Minh and Lung La, and almost 60% (640 of 1105) consulted one of the four private health clinics. Among these fever cases, there were significantly more men than women (sex ratio = 1.9) (chi-square test, $P < 0.05$). The distribution of the other parameters (age, profession and ethnic group) was similar to that of the study population in VDA (Table 2). About 124 cases of clinical malaria were detected [70 *P. falciparum* (56.4%), 54 *P. vivax* (43.5%)]; 60% of these in private health facilities. The incidence risk of malaria was 1.1/100 persons/year, ranging from 1.1 to

Table 3 Malariometric indices across five cross-sectional surveys in Van Duc A

Parameters	Survey 1 (September 1999, $n = 420$)	Survey 2 (January 2000, $n = 401$)	Survey 3 (August 2000, $n = 382$)	Survey 4 (March 2001, $n = 377$)	Survey 5 (August 2001, $n = 348$)
Survey coverage, %	79.4	76.5	72.6	71.8	66.3
Mean packed cell volume (PCV), (SD)	40.5 (4.4)	41.0 (4.1)	40.8 (3.9)	42.6 (4.4)	41.2 (3.9)
Overall parasite rate, % (*n*)	2.4 (10)	0.8 (3)	1.6 (6)	0.5 (2)	0
Plasmodium falciparum, n	3	0	3	2	
Plasmodium vivax, n	7	3	3	0	
In 2–9 years old, % (*n*)	5 (3)	1.7 (1)	0	0	0
Gametocyte rate, % (*n*)	1.7 (7)	0	0.8 (3)	0.5 (2)	0
Symptomatic malaria, % (*n*)	1 (4)	0.2 (1)	0	0	0
Current fever or fever in the past 48 h, % (*n*)	23.1 (97)	12.7 (51)	1.6 (6)	8.8 (33)	3.7 (13)
Seroprevalence, % (*n*)	2.4 (10)	1.5 (6)	2.1 (8)	0.5 (2)	0.6 (2)
Plasmodium falciparum	10	6	5	2	2
Plasmodium vivax	0	0	3	0	0

1.6/100 persons/year according to the village. The risk of malaria among fever cases was significantly lower during the second year than the first (OR = 0.50, $P = 0.001$) and during the rainy season (OR = 0.53, $P = 0.002$) (Table 4). The odds of malaria were higher in individuals aged 10 years or more (OR = 2.52, $P = 0.02$) but did not vary according to hamlet, gender or profession.

Serological follow-up

No malaria infection was detected among the 73 newborns followed up for at least 12 months, although one baby had maternal antibodies at birth (*P. falciparum* IgG); the one-sided 97.5% CI around this nil seroconversion rate ranged from 0 to 0.05 infections/person-years.

Health-seeking behaviour and malaria diagnosis

By ACD, the fever incidence rate was 22.0/100 person-years (315 of 910.7) while by PCD the fever incidence risk was 9.5/100 persons/year (1105 of 6082). About a third of fever cases reported having consulted a health facility, mostly a private one (60% in ACD, 68% in surveys), and a large proportion of patients had been treated for malaria: 76% (19 of 25) of fever cases reported in ACD and 48% (21 of 44) in surveys. Over the whole community, on average 62% (688 of 1105) of the fever cases were treated as malaria, although the proportion varied between villages and increased significantly (chi-square test for trend, $P < 0.001$) from the CHC (47%) to the furthest village (92%). The proportion of malaria positive slides among these suspected cases were 13%, ranging from 10 to 16%, the lowest proportions being found in the two furthest villages.

Discussion

The combination of ACD, PCD and serological follow-up of newborns shows that malaria transmission has been decreasing over a short period of time and is disappearing from this area. At village level, the incidence rates of clinical cases (ACD) and of malaria infections (surveys) were extremely low, 2.6 infections/100 person-years being the highest figure found. Moreover, the five consecutive surveys showed a significant decreasing trend for both parasite and gametocyte rates, and the malaria seroprevalence, confirming the decreasing transmission over the 23 months of follow-up. Such a decreasing trend could not be observed by ACD, as the number of clinical cases was too low. At commune level, the findings were similar: the incidence risk of clinical malaria measured by PCD was very low and the serological follow-up of newborns confirmed such a low level of transmission. These data are consistent with the entomological results obtained by the 2-year quarterly mosquito collections (April 1998–November 2000) performed in VDA (Trung *et al.* 2004). Despite very high biting rates of the main vector *A. sundaicus* (up to 190 bites/man/night), none of the 11 000 mosquitoes collected had sporozoites. This contrasts with previous data showing that, in the period 1960–75, the sporozoite rates of *A. sundaicus* and *A. subpictus* ranged between 0.2 and 2.4%. Similarly, sporozoites were found in the early 1990s in both species collected in a similar coastal area near Ho Chi Minh City (HCMC) (Am *et al.* 1993). The densities of both species were similar and about 10-fold lower than those of *A. sundaicus* in 2000. The very low parity rate of *A. sundaicus* supports the idea that the survival rate of this potential vector is too low to ensure effective malaria transmission

Table 4 Risk factors for clinical malaria among fever cases in An Trach commune ($n = 124$ cases)

	Clinical malaria risk, % (*n*/*N*)	OR (95% CI) Unadjusted	OR (95% CI) Adjusted*
Total	11.2 (124/1105)		
Year 1 (27/09/1999–30/09/2000)	14.4 (80/557)	1	1
Year 2 (01/10/2000–28/08/2000)	8.0 (44/548)	0.52 (0.35–0.77)†	0.50 (0.33–0.74), $P = 0.001$
Season			
Dry (January–April)	14.8 (45/304)	1	1
Rainy (May–August)	10.3 (47/456)	0.66 (0.43–1.02), 0.59 (0.36–0.95)†	0.53 (0.35–0.79), $P = 0.002$
Rainy (September–December)	9.3 (32/345)		–
Hamlets (one missing)			
Van Duc A	10.2 (15/147)	1	
Van Duc B	12.4 (24/194)	1.24 (0.63–2.46)	
Hoang Minh	9.7 (43/444)	0.94 (0.51–1.75)	
Lung La	13.3 (41/308)	1.35 (0.72–2.53)	
Sex			
Male	11.1 (81/727)	1	–
Female	11.4 (43/378)	1.02 (0.69–1.52)	
Age groups (year)			
0–9	5.0 (7/140)	1	1
10–19	12.6 (35/277)	2.75 (1.19–6.36)†	
20–39	12.4 (52/421)	2.68 (1.19–6.04)†	2.52 (1.14–5.57),
≥40	11/2 (30/267)	2.41 (1.03–5.63)†	$P = 0.02$
Profession			
Pre-profession	9.0 (26/289)	1	–
Farmers	12.2 (88/723)	1.40 (0.88–2.23)	
Others	10.8 (10/93)	1.94 (0.82–4.59)	

* The adjusted model is a logistic regression. †$P < 0.05$.

(Coosemans *et al.* 1992). The incidence of clinical malaria observed in VDA could be explained by a sporozoite index of 1/300 000 or lower (Trung *et al.* 2004), an extremely low figure that could not be detected by the number of mosquitoes analysed. Not only was the mean parity rate low (47%), but it decreased by 40% between November 1999 and November 2000, indicating a shortened lifespan of *A. sundaicus*. Interestingly, while the density of *A. sundaicus* increased more than 50-fold between April 1998 and April 2000, *A. subpictus*, whose density was threefold higher than that of *A. sundaicus* in April 1998, disappeared completely after April 1999. The opposite density dynamics of these two vectors can be related to socio-economic development and subsequent changes in vectors ecology. Continuous extension of brackish water surfaces for shrimp farming is done to the detriment of fresh water surfaces for rice cultivation, favouring the development of *A. sundaicus* while *A. subpictus*, less tolerant to salinity, disappears. Therefore, the decreasing malaria endemicity observed in VDA can be related to the reduction of *A. sundaicus* vectorial capacity and to the disappearance *A. subpictus*, a potentially important secondary vector. In addition to these ecological changes, the wide use of artemisin derivatives, not only in VDA but also introduced in the national guidelines since 1995, could have contributed to the observed decrease in malaria transmission by reducing gametocyte carriage (White 1999).

The malaria epidemiology in this area of the Mekong Delta is extremely different from that of another sentinel site in central Vietnam (Suoi Kiet commune, Binh Thuan province) where the same methods were used (Erhart *et al.* 2004). In Suoi Kiet, the incidence of malaria clinical attacks and infections was more than 10-fold higher than in VDA, while the density of the main vector was about 100-folds lower. In both areas, malaria incidence was strongly associated with socio-economic factors, although in opposite directions. In Suoi Kiet, forest work, the most profitable activity, increased the risk for malaria, while in VDA the development of shrimp rearing with its subsequent ecological changes decreased it. The results from these two sentinel sites summarize the current malaria epidemiological situation in Vietnam. Malaria has been efficiently controlled and even eliminated from many provinces in north and southern Vietnam but it remains endemic in Central Vietnam where the complex epidemiology of forest malaria remains a challenge for control. This rapidly changing situation is strongly related to the fast economic development the country is experiencing.

The malaria incidence risk estimated by PCD over the whole commune was three times higher than the one measured in 1995 and probably this can be explained by the important role played by the private practitioners. Indeed, the consultation rate in the CHC, during the period 1994–98 was extremely low with an average of <1 consultation/person every 2 years. As reported by the local health staff, many patients attend private rather than public health facilities. This is confirmed by the prospective data: at commune level, the majority of fever patients consulted private clinics where most of the malaria cases were diagnosed. Therefore, only about one-third of all malaria cases are actually recorded by the HIS. The private health sector is well developed in Vietnam, especially in the southern part of the country (Gertler & Litvack 1998). Private pharmacies and doctors are the two most common health care options for TB patients in HCMC and about 50% across all socio-economic strata initially opt for a private provider (Lonnroth *et al.* 2001a,b). Similarly in our study area, most patients prefer to pay private practitioners for their malaria treatment, although this is available free-of-charge in public health facilities. In low- and middle-income countries case management in the private sector might be poor (Uplekar & Rangan 1993; Uplekar *et al.* 1996; Singla *et al.* 1998) and obviously there is little or no notification of cases (WHO 1982; Aljunid 1995). Nevertheless, disease notification is a major component of communicable diseases surveillance programmes and provides key information for the planning and evaluation of different control programmes. The involvement of private practitioners in monitoring of case management and disease notification, although difficult to achieve, would be highly beneficial for the quality of care itself as well as for that of the HIS. Following the findings of this study, the provincial malaria station in Bac Lieu initiated a collaboration with the private practitioners for the detection and treatment of malaria cases. Private doctors were asked to take blood samples from all suspected malaria cases and to notify all the confirmed cases. In exchange, they could benefit from diagnostic facilities, training and new guidelines provided by the public health system. If successful this local initiative could be extended to other provinces and to other control programmes such as dengue or TB.

Besides the problem of under-reporting malaria cases, many fever cases continue to be treated with antimalarial drugs even if the blood film does not show any parasitaemia. More than 50% of the fever cases reported either by ACD or surveys, or those detected by PCD, were treated as malaria but parasitaemia could be found in only a few of them. This is not a new problem: in 1995–96 only 10% of the suspected malaria cases were microscopically confirmed. Reports from Northern Vietnam, where malaria has been eliminated from many provinces, show that fever cases continue to be massively treated as malaria (Erhart *et al.* 1999; National Institute of Malariology, P. a. E. 2002, 2003). Symptoms and signs of malaria overlap with several other common infectious diseases and the presumptive diagnosis can result in a high degree of over-treatment (Olivar *et al.* 1991). Several attempts to identify key clinical signs have showed some potential with various degrees of sensitivity and specificity (Gomez *et al.* 1994; Redd *et al.* 1996; Luxemburger *et al.* 1998; Bojang *et al.* 2000). However, the validity of these algorithms depends on many factors such as endemicity, perception of the disease in the population, relative incidence of other febrile illnesses, self-treatment, drug resistance, and they have to be adapted to different sociocultural and epidemiological settings. In low endemic areas, the performance of these algorithms is usually very poor (Chandramohan *et al.* 2001). In our study site a large proportion of patients was unnecessarily treated on a presumptive basis with antimalarial drugs and such proportion was higher in the two peripheral villages situated far from the CHC. The relative importance of other febrile diseases is shown in Table 4 where the incidence of fever cases increases by 33% between the dry and first half of rainy season while the incidence of malaria did not change. This is probably due to viral diseases, which are more prevalent during the wet season and whose symptoms are very similar to malaria. In this situation, the use of rapid diagnostic tests, by private practitioners, at least to exclude *P. falciparum* malaria, could improve the accuracy of the diagnosis and consequently decrease the use of relatively expensive drugs such as the artemisinin derivatives. Moreover, health care providers (public and private) should be trained in the differential diagnosis of fever in order to provide adequate treatment for the other febrile illnesses, which are currently largely mistreated. This strategy could improve the patient's satisfaction and confidence in the health care quality. Moreover, it would enhance greatly not only the strategy of 'early diagnosis and effective treatment' of malaria but also of other febrile illnesses such as TB and dengue. In conclusion, early (and accurate) diagnosis and effective treatment (with artemisinin-based combinations) remains the gold standard strategy for malaria control in this low transmission area.

Acknowledgements

We thank all the study participants in Van Duc A and the two Hamlet Health Workers for their effective contribution to the present study. We are especially grateful to the staff of the Provincial Malaria Station of Bac Lieu Province, of IMPE in Ho Chi Minh City and NIMPE, Hanoi for their full and constant support to this study. The project was funded by the Belgian Cooperation in the framework of the Institutional Collaboration between ITM, Antwerp and NIMPE, Hanoi.

References

Aljunid S (1995) The role of private medical practitioners and their interactions with public health services in Asian countries. *Health Policy and Planning* **10**, 333–349.

Am NT, Riec LQ, Huyen VT & Lan NB (1993) Etudes entomo-épidémiologiques du paludisme dans la zone côtière de Ho Chi Minh-Ville, 1990–1992. *Cahiers Santé* **3**, 323–330.

Australian Government, D. o. t. E. a. H. W. s. o. s. d. (2002) *Case Study: Mekong Delta Mixed Shrimp Culture – Mangrove Forestry*. Accessed on 22-10-2003. http://www.deh.gov.au/commitments/wssd/publications/mekong.html

Bojang KA, Obaro S, Morison LA & Greenwood BM (2000) A prospective evaluation of a clinical algorithm for the diagnosis of malaria in Gambian children. *Tropical Medicine and International Health* **5**, 231–236.

Chandramohan D, Carneiro I, Kavishwar A, Brugha R, Desai V & Greenwood BM (2001) A clinical algorithm for the diagnosis of malaria: results of an evaluation in an area of low endemicity. *Tropical Medicine and International Health* **6**, 505–510.

Coosemans M, Wéry M, Mouchet M & Carnevale P (1992) Transmission factors in malaria epidemiology and control in Africa. *Memorias do Instituto Oswaldo Cruz, Rio de Janeiro* **87** (Suppl. 3), 385–391.

Demedts P & Wery M (1985) Indirect immunofluorescence using differentiating antigens in detection of imported malaria. *Annales de La Societe Belge de Medecine Tropicale* **65** (Suppl 2), 89–96.

Erhart A, Thieu NQ, Kieu DV *et al.* (1999) *Retrospective Study on Malaria Epidemiological Situation in Khoi Village, Phu Cuong Commune, Hoa-Binh province: 1992–1998*. Report.

Erhart A, Thang ND, Toi LV *et al.* (2004) Forest malaria in Vietnam: a challenge for control. *American Journal of Tropical Medicine and Hygiene* **70**, 110–118.

Gertler P & Litvack J (1998) Access to health care during transition: the role of the private sector in Vietnam. In: *Household Welfare and Vietnam's Transition*, (eds D Dollar, P Glewwe & J Litvack). World Bank, Washington, DC, pp. 61–98.

Gomez M, Espino FE, Abaquin J, Realon C & Salazar N (1994) Symptomatic identification of malaria in the home and in the primary health care clinic. *Bulletin of the World Health Organization* **72**, 383–390.

JIRCAS Japan (1997) *Collaborative Research on Methods to Improve Farming Systems in the Mekong Delta Region*. Accessed on 22-10-2003. http://ss.jircas.affrc.go.jp/engpage/annualreport/1997/overview/rschsites2.htm

Lonnroth K, Thuong LM, Linh PD & Diwan VK (2001a) Utilization of private and public health-care providers for tuberculosis symptoms in Ho Chi Minh City, Vietnam. *Health Policy and Planning* **16**, 47–54.

Lonnroth K, Tran TU, Thuong LM, Quy HT & Diwan VK (2001b) Can I afford treatment? Perceived consequences of health care provider choices among people with tuberculosis in Ho Chi Minh City, Vietnam. *Social Science and Medicine* **52**, 935–948.

Luxemburger C, Nosten F, Kyle DE, Kiricharoen L, Chongsuphajaisiddhi T & White NJ (1998) Clinical features cannot predict a diagnosis of malaria or differentiate the infecting species in children living in an area of low transmission. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **92**, 45–49.

McNamee P (2003) *Measures for Sustainable Development in the Inland Wetland Area in the Mekong Delta*. Accessed on 22-10-2003. http://www.unescap.org/drpad/vc/conference/bg_vn_1_msd.htm

Ministry of Agriculture and Rural Development (2001) *Water Resources Management for Agricultural Development and the Role of the Institute of Water Resources*. Accessed on 22-10-2003. http://www.agroviet.gov.vn/en/stories/TinTiengAnh/WaterResourcesManagement.asp

National Institute of Malariology, P. a. E. (2002) *Annual Report from National Malaria Control Program in Vietnam 2001*. Hanoi-Vietnam.

National Institute of Malariology, P. a. E. (2003) *Annual Report from National Malaria Control Program in Vietnam 2002*. Hanoi-Vietnam.

Olivar M, Develoux M, Abari AC & Loutan L (1991) Presumptive diagnosis of malaria results in a significant risk of mistreatment of children in urban Sahel. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **85**, 729–730.

Redd SC, Kazembe PN, Luby SP *et al.* (1996) Clinical algorithm for treatment of *Plasmodium falciparum* malaria in children. *Lancet* **347**, 223–227.

Singla N, Sharma PP, Singla R & Jain RC (1998) Survey on knowledge and attitudes and practice for tuberculosis among general practitioners in Delhi, India. *International Journal of Tuberculosis and Lung Diseases* **2**, 384–389.

Trung HD, Van Bortel W, Sochanta T *et al.* (2004) Malaria transmission and major malaria vectors in different geographical areas of Southeast Asia. *Tropical Medicine and International Health* **9**, 230–237

Uplekar MW & Rangan S (1993) Private doctors and tuberculosis control in India. *Tubercle and Lung Diseases* **74**, 332–337.

Uplekar MW, Juvekar SK, Tarande SD *et al.* (1996) Tuberculosis management in private practice and its implication. *Indian Journal of Tuberculosis* **43**, 19–22.

Vu Thi Phan (1998) *Epidemiological Characteristics of Malaria in Vietnam 1992–1997*. http://www.ec-malaria.org/mcsi/lib.nsf/issue1. No. 1.

White NJ (1999) Antimalarial drug resistance and combination chemotherapy. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences* **354**, 739–749.

WHO (1980) Erythrocyte volume fraction. In: *Manual of Basic Techniques for a Health Laboratory, 1980*. 1st edn. WHO, Geneva, pp. 379–385.

WHO (1982) Expanded programme on immunisation: poliomyelitis prevalence surveys. *Weekly Epidemiological Record* **57**, 361–368.

Zeger SL & Liang KY (1986) Longitudinal data analysis for discrete and continuous outcomes. *Biometrics* **42**, 121–130.

Authors

Annette Erhart (corresponding author), **Nico Speybroeck**, **Marc Coosemans** and **Umberto D'Alessandro**, Prince Leopold Institute of Tropical Medicine, Nationalestraat 155, 2000 Antwerp, Belgium. Tel.: +32-3-247-63-08; Fax: +32-3-247-63-59; E-mail: aerhart@itg.be; nspeybroeck@itg.be; mcoos@itg.be; udalessandro@itg.be

Ngo D. Thang, **Le X. Hung**, **Tran Q. Tuy** and **Le D. Cong**, National Institute of Malariology, Parasitology and Entomology, BC 10 200, Tu Liem District, Hanoi, Vietnam. Tel.: +84-4-854-30-34; Fax: +84-4-854-30-15; E-mail: thangnimpevn@fpt.vn; lxhung@netnam.vn; nimpe@netnam.org.vn

Nguyen Q. Hung, Institute of Malariology, Parasitology and Entomology, 699 Trang Hung Dao street, District 5, Ho Chi Minh City, Vietnam. Tel.: +84-8-835-31-17; Fax: +84-8-839-07-34; E-mail: vmcpimpehcm@saigonnet.vn

Tran Hung Bien and **Nguyen Minh Tung**, Provincial Malaria Station, 46 Hoang Dieu Street, Bac Lieu Town, Bac Lieu Province, Vietnam. Tel.: +84-0781-824-711