

RISK FACTORS FOR MALARIA INFECTION AMONG RUBBER TAPPERS LIVING IN A MALARIA CONTROL PROGRAM AREA IN SOUTHERN THAILAND

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Abstract. Rubber tappers work begins at midnight during the feeding time of *Anopheles maculatus* and *An. minimus*, two common malaria vectors in southern Thailand. We studied the association between rubber tapper behavior and malaria infections as reported to the Notified Disease Surveillance System during 2010 in Prachuab Khiri Khan Province, Thailand. In that province insecticide treated bednets are distributed free to the population and insecticide residual spraying is performed annually. A random sample of 394 rubber tapper households was interviewed from October 2010 to May 2011. Twenty-six households (6.6%) had at least one family member who contracted malaria during 2010. Poisson regression was used to identify potential characteristics associated with malaria. Multilevel Poisson regression was used to test for simultaneous effects of tapper behavior and household risk for malaria infection. The estimated incidence rate ratio (IRR) for contracting malaria among those owning a farming hut was 2.9 (95% CI 1.1-7.3, $p < 0.05$) after controlling for other variables. Even in areas where control programs are in place, malaria infection among rubber tappers is common. Given the Thai Government's plan to expand the rubber plantation areas to other regions of the country without specific prevention for this at-risk population, the malaria burden in Thailand may increase.

Keywords: rubber plantation, malaria, risk, insecticide-treated net (ITN), long-lasting insecticidal net (LLIN), farming hut, Thailand

INTRODUCTION

Southern Thailand has a monsoon climate suitable for rubber plantations (*Hevea brasiliensis*), allowing Thailand to become the world's leading natural rubber produce since 2006 (OAE, 2009). Due to growing demand for rubber, the Thai

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Government has promoted rubber cultivation and expanded rubber plantation areas from southern to the other parts of Thailand (ICEM, 2003; OAE, 2009).

Rubber tappers begin work as early as midnight. This time corresponds to the feeding time of *Anopheles maculatus* and *An. minimus*, two common malaria vectors in southern Thailand (Rattanaarithkul *et al*, 1996; Yasuoka and Levins, 2007).

The Ministry of Public Health of Thailand has been conducting both vertical and horizontal operations to control malaria. The malaria affected provinces in Thailand are classified into four categories based on malaria endemicity: A1, a perennial transmission areas with more than 6 months of cases reported each year; A2, a periodic transmission areas where cases are reported in fewer than 6 months per year; B1, high risk areas where no cases have been reported during the previous three years but vectors are present; B2, a low risk area where neither cases nor vectors have been found (WHO, 2008). In the horizontal control program insecticide-treated bed nets (ITNs) are distributed to the population for free and indoor residual spraying (IRS) has been conducted yearly since 2005 in B1 and B2 areas. The vertical control program is conducted by the Department of Disease Control and partially funded by the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM). This program has been conducting IRS and providing ITN and long lasting insecticide treated bed nets (LLINs) to at risk populations in A1 and A2 areas since 2008 (WHO, 2008).



Fig 1–Study site.

Previous studies have shown at-risk populations, such as agriculturists and farmers, are still affected by malaria even though they sleep under ITN/LLIN (Erhart *et al*, 2005; Nonaka *et al*, 2010). Therefore, we conducted this study to identify risk factors for malaria infection among rubber tappers living in a malaria control program area.

MATERIALS AND METHODS

The study area was located in Ban Chairaj Subdistrict, 22 km from Bang Saphan Noi District Office in Prachuab Kiri Khan (Fig 1). Ban Chairaj borders Myanmar and Chumphon and has six hamlets: Ban Chairaj, Ban Kok Ai Poek, Ban Bang Charoen, Ban Thong In, Ban Nong Hin and Ban Mak Phoo. According to the Chairaj Subdistrict Administration Organization, Ban Chairaj has a registered

population of 6,371 comprising 1,844 households. Agriculturist is the main occupation, with 80% of the working population employed on pineapple, oil palm and rubber plantations. The rainy season in Ban Chairaj is from June to October with the temperature ranging from 27°C to 41°C.

A sample size of 380 households was required for statistical significance in this study with a 95% confidence interval. The study was conducted from October 2010 to May 2011. Family members from 394 random households were invited to participate in the study by trained health volunteers. This study was approved by the Institutional Review Board of the Faculty of Public Health, Mahidol University. The household head was invited to be the key informant in each sampled household. If the head of the household was absent, the spouse or a dependent aged at least 18 years was invited to participate. Informed consent was obtained from all subjects prior to participation in the study. We collected information from subjects through face-to-face interviews using pre-tested questionnaires. The data were entered into EpiData Entry software, Version 3.1 (270108).

The questionnaire asked about sociodemographic characteristics, rubber tapper occupational variables, use of vector control methods, personal mosquito bite protection behavior, household location and environmental characteristics. The sociodemographic variables included sex, age, family monthly income, education level and the number of children under age five years living with the family. The number of family workers who were rubber tappers was used to represent family size instead of the number of family members because this variable was identified only the family members

assumed to be exposed to mosquito bites during rubber tapping. We asked about the time of rubber tapping among family members who identified themselves as rubber tappers.

Occupational variables asked about included of type of rubber tapper, tapping system and type of residence. Rubber tappers was classified into three categories: owner only (low risk), owner and tapper (moderate risk) and paid tapper (high risk). The paid tapper was considered as high risk because their wages depend on the amount of latex they tap each night. Regular tapping time was divided into two categories: 7:00 PM-4:00 AM (high risk) and other times (low risk). The tapping system refers to the method the tapper uses to obtain the latex. The majority of the systems consisted of two consecutive tapping days with a break on the third day (2d/3) or three consecutive tapping days with a break on the fourth day (3d/4). This variable demonstrates the exposure frequency. Residence types were divided into the primary house being a farm hut on a rubber plantation (high risk), the primary house being on a rubber plantation (moderate risk) and the primary house not being on a rubber plantation (low risk). The primary house referred to the place where the informant was living with his/her family members.

Use of a vector control method included a history of having IRS during 2010 and using ITN or LLIN. Use of ITN or LLIN during the previous week was considered use of a net. We also asked about the number of persons sharing the net. Subjects were classified into those not sleeping under a net (high risk), sleeping under an untreated bed net (moderate risk), sleeping under an ITN or LLIN part of the time and under an untreated net part of the time (low-moderate risk) and

sleeping only under an ITN or LLIN (low risk). The other vector control method investigated was how often (never/rarely, sometimes, always) they used a mosquito repellent coil at night. Personal mosquito bite protection behaviors asked about were use of repellent and wearing a long sleeve shirt during tapping.

Household locations were plotted using a Global Positioning System (eTrex Legend, Garmin International, Olathe, KS). Waypoints recorded were latitude, longitude and altitude, recorded to an accuracy of 10 meters. Environmental variables asked about were the presence of a pond larger than 500 m² within 500 m of the home and distance from the home to the nearest paved road. Google Earth mapping version 6 (Google, Mountain View, CA) was used for mapping. Health volunteers determined the home's building materials (brick and cement, wood or a combination).

Each subject was asked about a history of a household member contracting malaria during 2010 and those peoples' names were checked against the Notified Disease Surveillance database for the type of malaria during that same year. The names of noninfected members were also checked against the database to reduce false negatives.

The data were analyzed with descriptive statistics, bivariate and multivariate Poisson regression, and multilevel Poisson regression. Descriptive statistics were used to describe characteristics of malaria infected individuals and the 394 households classified by presence of malaria infection in the household during 2010. Quantitative variables were presented as medians and ranges for nonnormally distributed variables.

Households were divided into three

groups: no malaria infection in the household during the study period or the presence of one or more episodes of malaria in the family. The chi-square test was used to investigate for trends of malaria infection by household characteristics.

The observed variance (0.12) of the malaria episode was approximately equal to its mean (0.08) and the proportion of the zero-count for the dependent variable was 93.4% (368/394), similar to the probability of its zero-count event (exponent of the negative value of its mean; 0.92), Poisson regression was used to identify household characteristics associated with malaria episodes. Variables found to be potentially associated with malaria episodes on bivariate Poisson regression, defined as those with a *p*-value <0.10, were included in the multivariate Poisson regression. A variable with a *p*-value <0.05 on multivariate Poisson regression was considered statistically significant (potential household risk).

Multilevel Poisson regression was performed by taking the potential household risks from the multivariate Poisson regression and the individual variables to assess for the effects of factors associated with malaria infection. The individual-level variables included in the multilevel model were sex, age, marital status, education and personal protection behavior, (use of repellent and wearing a long sleeved shirt when tapping). These variables were the malaria preventive measures provided for the people by health authorities and were accessible measures. At the household level, the effect of the residence type was tested for variation of its intercept with the multilevel model to interpret whether the effect varied by its characteristics or not.

The chi-square test was carried

Table 1
 Characteristics of malaria infected individuals living in rubber-tapper households in Chairaj Subdistrict, Bang Saphan Noi District, Prachuab Khiri Khan Province, Thailand.

Level of analysis	No.	%
Individual (<i>n</i> =33)		
Age		
18-40 years	17	51.5
> 40 years	16	48.5
Sex		
Male	18	54.6
Female	15	45.4
Type of infection		
<i>P. falciparum</i>	23	69.7
<i>P. vivax</i>	9	27.3
Unidentified	1	3.0
Household (<i>n</i> =26)		
Type of rubber tapper		
Rubber owner and tapper	15	57.7
Paid tapper	9	34.6
Rubber owner but not tapper	2	7.7
Tapping time		
7:00 PM-4:00 AM	24	92.3
Other times	2	7.7
Household (<i>n</i> =26)		
Residence		
House not on plantation	12	46.1
House on plantation	2	7.8
House and farming hut	12	46.1

out using Epi Info version 3.3.2 (CDC, Bethesda, MD), the Poisson regression and multilevel Poisson regression were performed using the *xtmixed* command in STATA 9.0 (STATA Corp, College Station, TX).

RESULTS

Of 394 households participating in this study, 26 (6.6%) had at least one family member who experienced malaria

infection, as reported in the Notified Disease Surveillance system during 2010. Of those 26 households who experienced malaria, 12 (46.1%) had one member who contracted malaria and 14 (53.9%) had more than one individual with malaria. A total of 33 individuals experienced malaria, of whom 23 (69.7%) had *P. falciparum*, 9 (27.3%) had *P. vivax* and one had an unknown type of malaria. Of the 33 individuals with malaria, 18 (54.6%) were male (Table 1). Of the 26 households with a member who had malaria, 57.7% owned rubber plantations and tapped their own rubber and 92% routinely tapped during the feeding time of *An. maculatus* and *An. minimus* 7:00 PM-4:00 AM. The proportion of families whose house was not on a plantation (46%) and those who owned both a primary house and a farming huts were the same (Table 1).

Of the 394 households surveyed 190 (48.2%) were located in an A2 area, 5 (1.3%) were located in an A1 area and the rest were located in B1 or B2 areas. The distribution of malaria cases by area (A1, A2, B1, B2) was approximately the same. Of the 394 households, the median number of family members was 4 (range: 1 to 8), the median income per month was about 15,000 Baht (30 Baht = 1 USD) and the range was 2,000 Baht to 100,000 Baht (Table 2).

Almost half (196/384, 49.7%) of the rubber tappers also owned rubber plantation and worked as tappers. The majority of households (305/394, 77.4%) tapped rubber during 7:00 PM-4:00 AM. Eighty-four point eight percent (334/394) tapped 2 or 3 days, they had a 1 day break (Table 2).

Forty-seven point two percent of respondents (186/394) reported they had received ITN/LLIN from health services (data not shown), and 93.1% (367/394) said

Table 2
Association between various characteristics and malaria among study subjects
(N=394).

Characteristics	Percent (N=394)	Malaria episodes per household (percent)			p-value
		0 (n=368)	1 (n=12)	>1 (n=14)	
Family monthly income (Baht)					
≤ 15,000	52.4	52.3	75.0	35.7	0.62
> 15,000	47.6	47.7	25.0	64.3	
No. of children aged < 5 years					
None	75.6	76.3	75.0	57.1	0.13
≥ 1	24.4	23.7	25.0	42.9	
Type of rubber tapper					
Rubber owner and tapper	49.7	49.5	50.0	57.1	0.60
Paid laborer	28.9	28.5	41.7	28.6	0.69
Rubber owner but not tapper	21.3	22.0	8.3	14.3	0.07
Tapping time					
7:00 PM - 4:00 AM	77.4	76.9	83.3	85.7	0.27
Other time	22.6	23.1	16.7	14.3	
Tapping system					
2d/3 or 3d/4	84.8	85.3	66.7	85.7	0.51
Other	15.2	14.7	33.3	14.3	
Residence					
House not on plantation	64.2	65.5	33.3	57.1	0.14
House on plantation	17.8	17.9	8.3	21.4	0.97
House and farming hut	18.0	16.6	58.3	21.4	0.06
Had IRS during 2010					
Yes	40.1	39.4	50.0	50.0	0.31
No	59.9	60.6	50.0	50.0	
More than 2 persons sharing net					
Yes	41.7	41.2	33.3	61.5	0.28
No	58.3	58.8	66.7	38.5	
Use of mosquito net					
No	6.8	7.1	0.0	7.1	0.71
Slept under untreated net	62.4	62.5	58.3	64.3	0.99
Slept under untreated net and ITN, LLIN	13.4	13.6	25.0	0.0	0.38
Slept only under ITN, LLIN	17.4	16.8	16.7	28.6	0.31
House wall material					
Cement/brick	74.2	73.8	83.3	76.9	0.59
Wood/combination with wood	25.8	26.2	16.7	23.1	
Pond within 500 m					
Yes	68.0	68.5	58.3	64.3	0.55
No	32.0	31.5	41.7	35.7	
Distance from paved road					
> 10 m	52.5	51.9	50.0	69.2	0.28
≤ 10 m	47.5	48.1	50.0	30.8	

Table 2 (Continued).

Characteristics	Percent (N=394)	Malaria episodes per household (percent)			
		0 (n=368)	1 (n=12)	>1 (n=14)	p-value
Altitude					
> 150 m	17.7	16.5	30.0	38.5	<0.05
≤ 150 m	82.3	83.5	70.0	61.5	
Used electric fan at night					
Sometimes/Never	49.2	47.8	75.0	64.3	
Always	50.8	52.2	25.0	35.7	0.07
Used coils at night					
Sometimes/Never	75.9	74.7	91.7	92.9	
Always	24.1	25.3	8.3	7.1	0.05
Keep the light on at night					
Sometimes/Never	54.6	53.8	83.3	50.0	
Always	45.4	46.2	16.7	50.0	0.59

they regularly slept under a net regardless of the type. Forty-one point seven percent (153/394) said more than two persons shared a net regardless of the net type. Twenty-four point one percent (95/394) reported always using a coil at night; the proportion of using decreased with increasing numbers of malaria episodes (Table 2).

No significant associations were seen between type of rubber tapper, regular tapping time, tapping system and residence type and the presence of malaria. No significant associations were seen between use of IRS during 2010, use of mosquito nets, 2 or more persons sharing a mosquito net, use of an electric fan at night, use of a mosquito coil at night and keeping the light on at night and the presence of malaria. Having the altitude of the house located higher than 150 meters was associated with malaria. Of the houses with an altitude above 150 meters the percentages of families with no cases of malaria, one

case of malaria and more than one case of malaria were 16.5%, 30.0% and 38.5%, respectively. Family monthly income and number of children under 5 years of age, were not associated with malaria (Table 2).

Household characteristics were included in the bivariate analysis using Poisson regression to identify factors associated with malaria episodes. The total tapping time per household was used to represent family size and was included in the bivariate Poisson regression analysis. Family income, type of tapper, tapping system, tapping time, history of IRS in 2010, use of mosquito nets, having more than 2 persons sharing a net regardless of the net type, house wall material, the presence of a pond within 500 meters of the house, distance from a paved road, always keeping the light on at night and house location (A1/A2 area) were not associated with malaria infection in the household. Multivariate Poisson regression analysis showed owning a farming hut on a rubber

Table 3
Bivariate and multivariate Poisson regression analysis of factors associated with malaria infection among subjects.

Variables	IRR	<i>p</i> -value	Adjusted IRR (95% CI)	<i>p</i> -value
Family monthly income (Baht)				
≤ 15,000	1.3	0.42		
> 15,000	1			
Tapping time during 7:00 PM-4:00 AM	1.1	0.01	1.0 (1.0-1.1)	0.06
Tapping at other times	1			
Type of rubber tapper				
Plantation owner but not tapper	0.4	0.13		
Paid laborer	1.1	0.71		
Plantation owner and tapper	1			
Tapping system				
2d/3 or 3d/4	0.7	0.34		
Other	1			
Residence				
House and farming hut	3.1	<0.01	2.3 (1.02-5.1)	<0.05
House on plantation	1.2	0.72	0.9 (0.3-2.8)	0.87
House not on plantation	1			
Had IRS during 2010				
Yes	0.6	0.18		
No	1			
More than 2 persons sharing any type of net				
Yes	1.5	0.27		
No	1			
Use of mosquito nets				
No	1.1	0.85		
Sleeping under untreated net	0.8	0.77		
Sleeping under untreated net and ITN, LLIN	1.4	0.68		
Sleeping under ITN/LLIN	1			
House wall material				
Cement/brick	0.7	0.41		
Wood/ combination with wood	1			
Pond within 500 m				
Yes	0.8	0.59		
No	1			
Distance from paved road				
> 10 m	1.4	0.41		
≤ 10 m	1			
Altitude				
> 150 m	2.3	<0.05	2.0 (0.9-4.4)	0.09
≤ 150 m	1			
Use electric fan at night				
Sometimes/Never	1			
Always	0.4	<0.05	0.5 (0.2-1.1)	0.08

Table 3 (Continued).

Variables	IRR	<i>p</i> -value	Adjusted IRR (95% CI)	<i>p</i> -value
Used coil at night				
Sometimes/Never	1			
Always	0.2	<0.05	0.3 (0.1-1.4)	0.14
Keep the light on at night				
Sometimes/Never	1			
Always	0.6	0.17		
House located in A1/A2 area				
Yes	2.3	<0.05	2.1 (1.0-4.7)	0.06
No	1			

plantation was significantly associated with malaria infection after controlling for other factors (Table 3).

Multilevel Poisson regression analysis showed males had twice the chance of contracting malaria than females but this was not statistically significant. The risk of contracting malaria was not different between couples living together and other groups. Age and education level were also not associated with malaria risk. Neither use of repellent nor dressing in a long sleeve shirt while tapping were associated with malaria infection. Forty-three point two percent of respondents (336/778) reported they always used insect repellent and 40.0% (280/778) reported they always dressed in a long sleeve shirt when tapping (data not shown). The tappers that did not always practice protective measures were at higher risk of malaria infection than those that always practiced them. After controlling for other variables, no individual characteristics or personal protection measures was associated with malaria. Owning a farming hut was associated with malaria (IRR 2.9; 95% CI 1.1-7.3, $p < 0.05$) (Table 4). Of the 71 households who owned farming huts, 16 (22.5%) had slept under ITN/LLIN during

the previous 7 days and 3 out of those 16 (18.7%) reported using ITN/LLIN in their farming hut (data not shown). There was no variation between residence type and malaria (Table 4).

DISCUSSION

Malaria infection among rubber tappers was common in areas where control programs are in place. There were daily exposures to mosquito bites at multiple locations. Many studies have found sleeping in farming huts increases the risk of contracting malaria (Somboon *et al*, 1998; Seng *et al*, 1999; Erhart *et al*, 2005; Matthys *et al*, 2006). In many agricultural areas, farmers stay in farm huts during the harvest season but on rubber plantations, rubber tappers stay in farm huts continuously, exposing them to risk for mosquito bites, especially toward the end of the rainy season when Anopheline breeding places are numerous (Seng *et al*, 1999; Matthys *et al*, 2006).

Vector control measures (ITN/LLIN and IRS) have been proven to be effective in preventing malaria infection (Sharp *et al*, 2002; Lengeler, 2004; Tami *et al*, 2004; Kimani *et al*, 2006; Gamble *et al*, 2007;

Table 4
Association between various risk factors and malaria among study subjects.

Level	Characteristics	Adjusted IRR (95% CI)	p-value
Individual level	Sex		
	Male	1.8 (0.8-4.1)	0.14
	Female	1	
	Age		
	18-40 years	1	
	> 40 years	0.8 (0.3-2.1)	0.72
	Marital status		
	Living together	1.0 (0.3-2.6)	0.93
	Single/divorced/separated	1	
	Education		
	≤ Primary school	1	
	> Primary school	1.0 (0.4-2.6)	0.97
	Used repellent		
	Not always	1.9 (0.6-5.8)	0.24
Always	1		
Dressed in a long sleeve shirt when tapping			
Not always	2.9 (0.7-11.1)	0.12	
Always	1		
Household level	Residence ^a		
	House and farming hut	2.9 (1.1-7.3)	< 0.05
	House only	1	

^aRandom effect of the intercept Var (SE) = 0.10 (0.47); $p = 0.73$

Khamlome *et al*, 2007; Noor *et al*, 2007; Tseng *et al*, 2008; Bukirwa *et al*, 2009; Zhou *et al*, 2010). Our findings show none of the vector control measures significantly reduced the risk of malaria infection in our study population. This indicates that malaria risk is still present. Tappers sleep under ITN/LLIN at home but not in the farming hut, called a “kratom”, meaning a temporary shelter constructed of wood or bamboo with a thatched roof. The number of those reporting sleeping under ITN/LLIN in the farming hut was low in this study, which differs from a previous study that assessed malaria risk factors in rice-farming cultivation in Lao PDR and Tanzania and found common use of ITN in farming huts and the main residence

(Hetzl *et al*, 2008; Nonaka *et al*, 2010). This differences from our study may be explained by differences in the study populations and cultivation practices. Rice farmers and their families usually move from their home to the rice paddy where they stay in a temporary shelter during harvest season. To prevent malaria infection among children, ITN are commonly used at night (Hetzl *et al*, 2008; Nonaka *et al*, 2010). Rubber tapping occurs ten months per year with a two-month break in January and February. They stay in the “kratom” at night while tapping then return to their house in the morning. This activity occurs 2 to 3 day, then with 1 day of rest. It may not be convenient for tappers to carry ITN/LLIN to the plantation

daily and some adults may think they are immune to malaria (WHO, 2012). ITN/LLIN coverage was 30% (121/394) in the main residence but only 4% (3/71) in the farming hut. In contrast to Thailand, a study from Tanzania showed high rates of mosquito net use in farming huts and low malaria incidence in the population (Hetzl *et al*, 2008). The use of ITN/LLIN in the farming hut is an important strategy to reduce risk of malaria among rubber tappers. The use of IRS in farming huts on plantations is rare. Regarding persons sharing nets, regardless of net type, our results are similar to those of Hetzel *et al* (2008) and Abe *et al* (2009) who found the number of persons sharing a net was not associated with malaria infection; unlike the findings of Nonaka *et al* (2010) who found net coverage associated with malaria.

This study should be interpreted with caution. First, malaria cases may have been underestimated. The case definition of malaria infection according to the Notified Disease Surveillance system has pros and cons. The system is part of the National Universal Insurance Scheme, so the data are obtained only from government healthcare providers, not the private sector. Second, the case definition of malaria in the Notified Disease Surveillance system is based on laboratory confirmation; classification of species of infection is subject to doubt. This study looked at malaria infection as a whole so species misclassification is not important. Third, the prevalence of malaria in this study was not seriously affected by relapsing *P. vivax* infections. Less than 30% of cases were *P. vivax*. *P. vivax* infections may have been overestimated only slightly.

The impact of ITN/LLIN on malaria reduction has been studied in many populations (Tami *et al*, 2004; Kimani *et al*, 2006;

Gamble *et al*, 2007; Khamlome *et al*, 2007; Noor *et al*, 2007). However, our findings suggest use of ITNs/LLINs did not have an impact on malaria infections. This may be explained by the rubber tappers perhaps acquiring malaria infection from mosquito bites acquired during overnight stays at farming huts on plantations (adjusted IRR 2.9; 95% CI 1.1-7.3), where reported use of ITN/LLIN was only 4%. Eighteen percent of rubber tappers studied (71/394) owned farming huts on their plantation; these people needed special attention from malaria control programs. Increased use of ITN/LLIN at farming huts should be promoted among tappers. The reported use of insect repellent was also low (43%) though this method suitable and available to rubber tapper. Repellent should be freely distributed to rubber tappers.

The number of rubber tappers is expected to increase under the Thai Government's plan to expand rubber plantations to other regions of the country and the Free Trade Agreement that reduces tariffs on rubber products. Without specific prevention programs this population will have increasing problems with malaria.

ACKNOWLEDGEMENTS

This study would not have been completed without the partial support of the China Medical Board (CMB) Fund (PHRU/CMB 03/2010). Special thanks go to Mr Samart Karuchit for his advice regarding the Global Positioning System device. We also extend our appreciation for the support from Mr Varut Chairathprapa and the staff of the Chairaj Health Promoting Hospital in Chairaj Subdistrict, Bang Saphan Noi District, Prachuab Khiri Khan Province, Thailand and to Mrs Vanida Ouyaharn, Mrs Saja Sangkaew,

Mrs Pilailak Romvichiean, Ms Sujitra Chansuwan, Mrs Yuwadee Chuachai, Ms Ravivan Thipboonthong and the health volunteers of Chairaj Subdistrict.

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