MALARIA IN TREE CROP PLANTATIONS IN SOUTH-EASTERN AND WESTERN PROVINCES OF THAILAND

Pratap Singhasivanon[1], Krongthong Thimasarn[2], Surapon Yimsamran[1], Kenneth Linthicum[3], Kaew Nualchawee[4], Darasri Dawreang[5], Suthep Kongrod[1], Nilarat Premmanisakul[1], Wanchai Maneeboonyang[1] and Nelia Salazar[6]

[1]Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand; [2]Malaria Division, Ministry of Public Health, Bangkok, Thailand; [3]US Army Medical Component, AFRIMS, Bangkok, Thailand; [4]STAR Program, Asian Institute of Technology, Bangkok, Thailand; [5]Thailand Remote Sensing Center, National Research Council of Thailand; [6]SEAMEO TROPMED NETWORK, Bangkok, Thailand

Abstract. During the past three decades almost half of the existing natural tropical forests in Thailand were destroyed and replaced by cash crops, rubber, coffee, fruit orchards (durian, rambutan, mangosteen) and other commercial plantations. In order to determine the proportion of malaria cases contracted from such commercial plantations, an epidemiological study was conducted between June 1996 to May 1997 in two districts, one in Pong Nam Ron, located in a south-eastern province near the Cambodian border and another in Sai Yok, in a western province along the Myanmar border. Data were collected by passive case detection from patients attending the existing malaria clinics and active case detection by monthly malariometric survey in selected villages. All malaria cases were thoroughly investigated and classified according to exposure to different ecotypes prior to onset of malaria symptoms in the preceding two weeks. Malaria cases acquired from commercial plantations accounted for 35.2% and 11.2% in Pong Nam Ron and in Sai Yok districts respectively. In such plantations, most of the malaria cases were contracted from fruit orchards and to a lesser extent from rubber and teak plantations. From this study it is evident that commercial plantations provide a significant site of malaria transmission in addition to the forest and foothills areas in Southeast Asia where efficient vectors such as *An. dirus* and *An. minimus* are prevalent and have adapted to such changed ecosystems.

INTRODUCTION

Over the past three decades, major changes in land use predominantly for agricultural development have occurred in Thailand resulting in extensive deforestation. Thailand's once abundant forests have been systematically reduced through illegal logging, land encroachment, slash and burn practices and shifting agriculture. The country's forest area has been reduced from 273,628 km^2 (53% of the total area) in 1961 to 143,417 km^2 (28% of the total area) in 1989, a 47.6% decrease during the 28-year period (Ministry of Agriculture and Corporative, 1989, 1992).

Most of the cleared areas have been replaced by paddy land, upland crops, rubber plantations, fruit orchards and other tree crops. Such crops as rubber, coffee, teak and fruit orchards are major economic resources. For example, the area devoted to coffee plantations was more than doubled between 1974 and 1987 and in the early 1980s the Royal Thai Government actively promoted the planting of rubber and fruit trees (durian, rambutan, mangosteen and mangoes) in order to increase export volume.

Serious entomological and epidemiological problems may arise when forests are cleared and cultivated for commercial plantations (Chang *et al*, 1997). Currently there is ample evidence to indicate that *An. dirus* are able to adapt themselves in commercial plantations such as rubber, coffee, and fruit orchards (Rosenberg *et al*, 1990; Gingrich *et al*, 1990). The populations working and living in these plantations is therefore at high risk of malaria infection. The purpose of the present study was to determine the proportion of malaria cases contracted from commercial tree plantations compared to other ecological areas.

MATERIAL AND METHODS

Study sites

Pong Nam Ron and Sai Yok districts in Chanthaburi and Kanchanaburi provinces respectively, were selected as the study sites. Pong Nam Ron is a small district situated near the Thai-Cambodian

Correspondence: Dr Pratap Singhasivanon, Department of Tropical Hygiene, Faculty of Tropical Medicine, Mahidol University, 420/6 Rajvithi Road, Ratchathewee, Bangkok 10400, Thailand.
E-mail: tmpsh@mahidol.ac.th

border (12°54′N, 102°17′E) surrounded by the long mountainous Soi Dao chain on the western side and by plains with occasional plateaus on the eastern side. It is about 246 km southeast of Bangkok and has a population of 21,615, while Sai Yok district lies along the Thai-Myanmar border (14°08′N, 99°09′E), is approximately 185 km west of Bangkok, and has a population of 31,586.

Pong Nam Ron district has the total area of 493,644 rai (197,458 acres), of which about 54% is used for agriculture while only 16% of 1,609,983 rai (643,993 acres) in Sai Yok is used for agriculture.

In Pong Nam Ron the majority of the labor force are working in tropical fruit orchards and to some extent in rubber plantations. Nowadays, the major durian, mangosteen and rambutan producing areas are concentrated in the eastern region, especially in Chanthaburi and the adjacent provinces.

In Sai Yok, the tree crop plantations of importance are mangoes, jackfruits and custard apples. Some of the forest-cleared areas are being replaced with teak replantation program.

Data collection

Two methods were used to collect the data from both study sites.

Passive case detection (PCD): There are two malaria clinics in each district providing free diagnosis and radical treatment of malaria covering populations in 5 subdistricts in Pong Nam Ron and 6 subdistricts in Sai Yok. Approximately 68-75% of all malaria cases received treatment from malaria clinics in the above-mentioned districts (estimation from a preliminary survey).

All the parasitologically confirmed malaria cases seeking treatment at malaria clinics at 2 Malaria Sectors in Pong Nam Ron and 2 Malaria Sectors in Sai-Yok were thoroughly investigated. A modified Epidemiological Form 3 was used to record detailed information of each malaria case in order to determine when and where the malaria transmission occurred. Other information such as job activities, types of vegetation cover surrounding the individual's shelter and sleeping place during the previous two weeks was also recorded to differentiate the types of exposure to various ecological areas. The classification of malaria cases acquired from different transmission sites was undertaken by the regular clinic staff after appropriate training, and checked for completeness by the research team.

The vegetation cover of different ecotypes was classified as forest, forest fringe, forest-cleared area (within and around the village) and commercial tree crop plantation (fruit orchard, rubber and teak).

Passive case detection (PCD) was performed prospectively from June 1996 to May 1997 in Pong Nam Ron and from June to September 1996 in Sai Yok. The PCD activity in Sai Yok was shorter because of the massive immigration of Mon, a minority ethnic group from Myanmar, in October 1996.

Active case detection (ACD): In order to determine the prevalence of malaria, a monthly malariometric survey was carried out between July to September 1996 in selected villages. In Pong Nam Ron, two hamlets in Village 1, and three hamlets in Village 7, in the center of fruit orchards with a total of 450 inhabitants and in Sai Yok, Village 8 (Wang Kra Chae) with 650 subjects were selected. Thick and thin blood smears were collected on the same slides from all the residents during the first week of every month. All positive cases were also similarly investigated by use of modified Epidemiology Form 3. Positive malaria cases were treated with appropriate antimalarials drugs according to the recommendation of the Malaria Division, Ministry of Public Health.

RESULTS

Passive case detection

Seven hundred and eighty malaria cases were investigated, of which 458 cases were from Pong Nam Ron (June 96-May 97) and 322 cases were from Sai Yok (June-September 96). Three hundred and eighty imported cases from Cambodia and Myanmar were excluded from the analysis. Almost all the malaria patients were of Thai nationality and mainly came from the endemic area in the study subdistricts. Of the total cases, 516 (66%) were males and 264 (34%) were females. Sixty-four percent of malaria patients were 20 years of age and above and 11.2% were children under 10 years of age. Fifty-nine percent of them were diagnosed as having *P. falciparum* malaria by thick blood smear.

The proportion of malaria cases contracted from different ecological areas is shown in Table 1. A greater percentage of individuals contracted malaria from commercial plantations in Pong Nam Ron (35.2%) compared to Sai Yok (11.8%). This difference is statistically significant ($p < 0.05$). Moreover, the forest-acquired malaria is responsible for

Table 1
Proportion of malaria cases contracted from different ecotypes through passive case detection in Pong Nam Ron and in Sai Yok districts.

Ecotypes	Pong Nam Ron		Sai Yok		Total	
	Cases	%	Cases	%	Cases	%
Forested area	126	27.5	191	59.3	317	40.6
Forest fringe	51	11.1	42	13.1	93	12.0
Forest-cleared area	120	26.2	51	15.8	171	21.9
Tree crop plantation	161	35.2	38	11.8	199	25.5
Total	458	100.0	322	100.0	780	100.0

Table 2
Age-specific malaria cases in different ecotypes in Pong Nam Ron and Sai Yok districts.

	Pong Nam Ron							
Ecotype	0 - 9 (n=40)	10 - 19 (n=111)	20 - 29 (n=88)	30 -39 (n=103)	40 - 49 (n=61)	50- 59 (n=32)	60 + (n=23)	Total (n=458)
Forest cleared	30.0%	34.2%	18.2%	27.2%	21.3%	31.3%	13.0%	26.2%
Tree crop plantation	42.5%	36.0%	35.2%	34.0%	32.8%	40.6%	21.7%	35.2%
Forest area	7.5%	17.1%	39.8%	33.0%	32.8%	18.8%	39.1%	27.5%
Forest fringe	20.0%	12.6%	6.8%	5.8%	13.1%	9.4%	26.1%	11.1%
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Sai Yok							
Ecotype	0 - 9 (n=47)	10 - 19 (n=85)	20 - 29 (n=56)	30 - 39 (n=58)	40 - 49 (n=37)	50 - 59 (n=25)	60 + (n=14)	Total (n=322
Forest cleared	14.9%	23.5%	16.1%	13.8%	5.4%	8.0%	21.4%	15.8%
Tree crop plantation	34.0%	10.6%	3.6%	6.9%	8.1%	4.0%	21.4%	11.8%
Forest area	25.5%	48.2%	73.2%	72.4%	75.7%	80.0%	50.0%	59.3%
Forest fringe	25.5%	17.6%	7.1%	6.9%	10.8%	8.0%	7.1%	13.0%
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

almost 60% of transmission in Sai Yok and only 27.5% in Pong Nam Ron ($p < 0.05$). The occurrence of malaria in the forest fringe zone is essentially distributed similarly in both districts. A majority of subjects working in fruit tree plantations contracted malaria while working in orchards in Pong Nam Ron (95.7%) and Sai Yok (89.5%). Fewer individuals contracted malaria from the rubber plantation and teak reforestation area (Fig 1). The highest proportions of malaria were among children under 10 years of age and were acquired from tree crop plantations in Pong Nam Ron (42.5%) as well as in Sai Yok (34.0%) compared to other ecotypes. In Sai Yok forest malaria cases were predominantly seen in the age group 10 years and above whereas in Pong Nam Ron, except in the 10-19 age category, malaria was observed in all other groups (Table 2). In the tree crop plantations children under 15 years of age experienced malaria two fold greater than in the forested area. Higher malaria occurrence was observed in males compared to females in both the forested areas (74.1%) and in commercial plantations (61.3%).

Plasmodium falciparum was the dominant parasite species in all ecotypes in Pong Nam Ron, whereas in Sai Yok there was an equal prevalence of *P. falciparum* and *P. vivax* malaria in most ecological

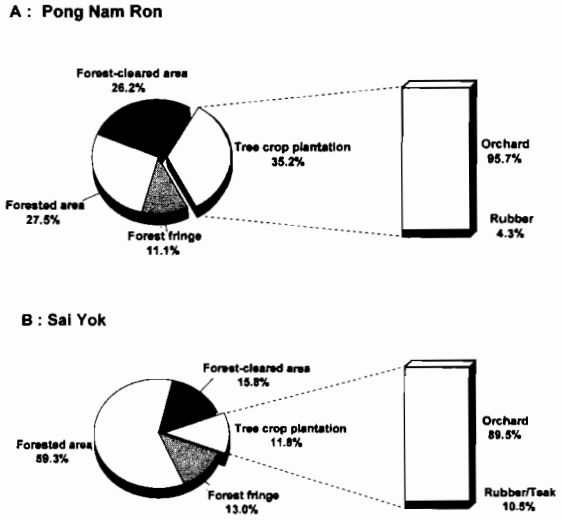

Fig 1-Malaria in different tree crop plantations in Pong Nam Ron and Sai Yok districts.

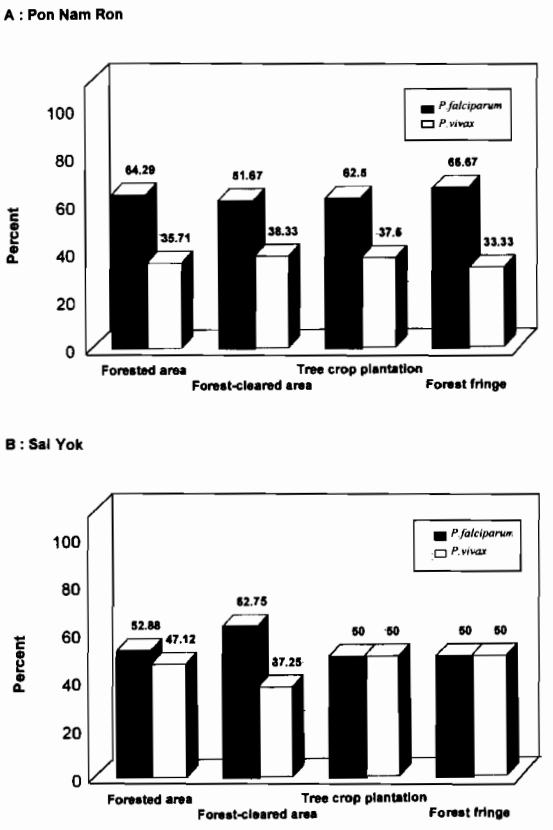

Fig 2-Proportion of malaria parasite species in different ecological areas in Pong Nam Ron and Sai Yok districts.

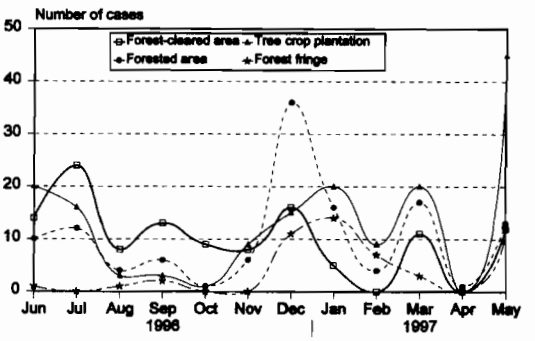

Fig 3-Monthly variation of malaria cases contracted in various ecotypes in Pong Nam Ron districts (June 96-May 97).

areas except in the forest-cleared zone (Fig 2). Monthly variation of malaria cases in different ecotypes in Pong Nam Ron is shown in Fig 3. There were two district peaks of malaria cases in fruit tree plantations observed during May to July (rainy season) and November to March (dry season) while in the forested area majority of cases occurred during November to January.

Active case detection

Average malaria prevalence rates from a 3-month survey (July-September, 1996) in Pong Nam Ron and Sai Yok among the selected groups of the population were 0.55% and 2.1% respectively. The maximum cumulative prevalence rate was observed among the 5 to 14 year age group *ie* 1.2% in Pong Nam Ron and 2.4% in Sai Yok.

DISCUSSION

Numerous studies have demonstrated that *An. dirus* cytospecies has the ability to adapt to changing environmental conditions from its natural forest habitats, for example, in gem pits (Kitthawee *et al*, 1993), abandoned charcoal pits under mature rubber, wheel ruts under rambutan trees (Rosenberg *et al*, 1990), water in wells in fruit orchards (Tun-Lin *et al*,1986) etc. In southern Thailand, this changed ecology favored the breeding of *An. minimus* and high densities were encountered in coffee plantation (Suvannadabba, 1991). In Malaysia, high density of *An. maculatus* is also observed in durian orchards during the durian season (June to September), thereby increasing the risk of malaria for individuals sleeping in the orchards (Ponnampalam, 1975). The results of our study clearly indicated

that the commercial fruit crop plantations provide a major site of malaria transmission in addition to the forested foothills where efficient vectors such as *An. dirus* are prevalent. In Pong Nam Ron more than one-third of the malaria cases were contracted from these plantations while in Sai Yok there was an upward trend of transmission of malaria cases associated with this area.

The number of malaria cases acquired in plantations in Pong Nam Ron is about three times greater than in Sai Yok: the reasons could be attributed to the larger agricultural area under plantation as well as the larger workforce. Between 1986 and 1995 the proportion of land area covered by forest in Chanthaburi Province on the Cambodian border fell from 37% to 23.5% and the area used for rubber plantations and fruit orchards (durian, rambutan, mangosteen) increased from 18.5% to 25.2% during the same period (Gomes, 1998). The difference observed between the two districts is unlikely to be due to the longer period of data collection by PCD in Pong Nam Ron since the proportion of malaria cases acquired from plantations during the first three months (June-September, 1996) was more or less similar (31%) compared to the twelve-month period (35.2%).

Since it is not possible to obtain information regarding the exposure status among non-malaria cases in the entire sub-district, we could not determine the actual malaria incidence associated with various ecotypes. These results must be interpreted cautiously since they are based only on the analysis of the numerator of malaria cases. Nevertheless, the results of this study is compatible with previous studies carried out in Thailand (Butraporn *et al*, 1986; Fungladda and Sornmani, 1986; Somboon *et al*, 1998) and elsewhere (Rosenberg and Maheswari, 1982; Myint and Ye, 1991; Tun-lin *et al*, 1995), that the forest and forest fringe zones are the major sites of malaria transmission where the major mosquito vectors are *An. dirus* and *An. minimus*. In this study about 53% of the total malaria cases were acquired from the forest and forest fringe areas.

The unexpected low monthly prevalence rates of malaria through active case detection in both districts were due to the fact that only positive malaria cases found during the first week of every month were taken into account. Many individuals in the selected hamlets who were ill after the first week were included in the PCD as they came to seek the treatment at malaria clinics.

It is important to recognize the possibility of misclassification bias that may occur in this study. The determination of an individual's exposure status to different ecotypes may be subjected to error since classification of malaria cases into various categories of ecological areas is based on the detailed history obtained from patients within the past 2 weeks. Classification of malaria cases into distinct groups according area of exposure is a straightforward matter if an individual stays in the same place for at least 2 weeks prior to the onset of malaria symptoms. The accurate categorization of cases could be difficult when an individual had had history of staying in different places within the specified time period. Furthermore, interviewing techniques and phrasing of questions, the age and educational background of the respondents, the time interval between the exposure in different ecological areas and the interview, the degree of the detail sought, and the willingness on the part of patient to provide the actual information may affect the validity of the responses.

If the probability of misclassification of a malaria case into a particular ecotype is equally distributed among other categories, then the estimate would represent the actual value. However, if the probability of misclassification is more or less prone to one particular category than the others, then overestimation or underestimation of a point estimate in a certain category would occur. In our study we have attempted to minimize the error in classification of exposure according to ecotypes by standardizing the questions in the modified case investigation form as well as making the criteria for classification as specific as possible based on predetermined criteria. Therefore, we think that such biases may be unlikely to occur in our study.

Since the tropical fruit orchards, rubber, and other tree crop plantations provide suitable microenvironmental conditions coupled with high adaptability of anopheline vectors to breed in such places, the transmission dynamics of malaria in these ecosystems should play an extremely important role. The danger from *An. dirus* is not only that it is very resistant to control within its habitat, but it is an extroaordinarily efficient disease vector with long life span and high preference to feed on human blood, so that only a small population is necessary to maintain extremely high levels of malaria endemicity.

Reforestation programs which replace natural forests will inevitably have unpredictable effects on vector ecology (Walsh *et al*, 1996) and the intensity of disease transmission by insect vectors may be influenced by developments in agriculture and forestry. The periodic exposure to the bite of mosquito

vectors among semi-immune residents as well as the nonimmune laborers working and living in these tree crop plantations may lead to altered pattern of malaria endemicity with occasional rise of malaria cases to epidemic level. The implication of this is the necessity for additional control strategies that might be required to combat malaria in these changed ecosystems.

ACKNOWLEDGEMENTS

The authors would like to thank the UNDP/ World Bank/WHO Special Program for Research and Training in Tropical Diseases for providing the financial support for this study. Thanks are also expressed to all the staff of Malaria Sectors in Pong Nam Ron and Sai Yok districts who have helped in data collection. Their wholehearted support and enthusiasm for this activity are gratefully acknowledged.

REFERENCES

Butraporn P, Sornmani S, Hungsapruek T. Social, behavioural, housing factors and their interactive effects associated with malaria occurrence in east Thailand. *Southeast Asian J Trop Med Public Health* 1986; 17: 386-92.

Chang MS, Hii J, Buttner P, Mansoor F. Changes in abundance and behaviour of vector mosquitoes induced by land use during the development of an oil palm plantation in Sarawak. *Trans R Soc Trop Med Hyg* 1997; 91: 382-6.

Fungladda W, Sornmani S. Health behavior, treatment-seeking patterns, and cost of treatment for patients visiting malaria clinics in western Thailand. *Southeast Asian J Trop Med Public Health* 1986; 17: 379-85.

Gingrich JB, Weatherhead A, Sattabongkot J, Pilakasiri C, Wirtz AR. Hyperendemic malaria in a Thai village: Dependence of year-round transmission on focal and seasonally circumscribed mosquito (Diptera: Culicidae) habitats. *J Med Entomol* 1990; 27: 1016-26.

Gomes M. More crops, more disease? *World Health Forum* 1998; 19: 274-80.

Kitthawee S, Edman JD, Upatham ES. Mosquito larvae and associated macroorganisms occurring in gem pits in southern Tha Mai District, Chantaburi Province, Thailand. *Southeast Asian J Trop Med Public Health* 1993; 24: 143-51.

Minisry of Agriculture and Coopearatives. Agricultural Statistics of Thailand Crop Year 1988/89. Bangkok; 1989.

Ministry of Agriculture and Cooperatives. Agriculture in Thailand. Bangkok; 1992.

Myint L, Ye H. Study of the malaria situation in forested foothill and nearby plain areas of Myanmar. *Southeast Asian J Trop Med Public Health* 1991; 22: 509-14.

Ponnampalam JT. The durian season in Peninsular Malaysia as a factor in the epidemiology of malaria. [Letter] *Trans R Soc Trop Med Hyg* 1975; 69: 285.

Rosenberg R, Andre RG, Somchit L. Highly efficient dry season transmission of malaria in Thailand. *Trans R Soc Trop Med Hyg* 1990; 84: 22-8.

Rosenberg R, Maheswary NP. Forést malaria in Bangladesh. I. Parasitology. *Am J Trop Med Hyg* 1982; 31: 175-82.

Singh N, Singh OP, Sharma VP. Dynamics of malaria transmission in forested and deforested regions of Mandla District, central India (Madhya Pradesh). *J Am Mosq Control Assoc* 1996; 12: 225-34.

Somboon P, Aramrattana A, Lines J, Webber R. Entomological and epidemiological investigations of malaria transmission in relation to population movements in forest areas of north-west Thailand. *Southeast Asian J Trop Med Public Health* 1998; 29: 3-9.

Suvannadabba S. Deforestation for agriculture and its impact on malaria in southern Thailand. In: Sharma VP , Kondrashin AV, eds. Forest malaria in Southeast Asia. Proceedings of an informal meeting WHO/ MRC. New Delhi: 1991: 221-6.

Tun-Lin W, Moe-Moe, Htay-Aung, Myo-Paing. Larval density estimation of well-breeding anophelines by mark-release-recapture technique in Burma. *Mosq Borne Dis Bull* 1986; 3: 1-4.

Tun-Lin W, Myat-Myat-Thu, Sein-Maung-Than, Muang-Muang-Mya. Hyperendemic malaria in a forested, hilly Myanmar village. *J Am Mosq Control Assoc* 1995; 11: 401-47.

Walsh JF, Molyneux DH, Birley MH. Deforestation: effects on vector-borne disease. *Parasitology* 1993; 106 (suppl): S55-75.