EARLY DETECTION OF MALARIA IN AN ENDEMIC AREA: MODEL DEVELOPMENT

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Abstract. A malaria epidemic warning system was established in Thailand in 1984 using graphs displaying the median or mean incidence of malaria over the previous five years compiled from malaria surveillance data throughout the country. This reporting mechanism is not timely enough to detect the occurrence of a malaria epidemic which usually occurs at the district level over a short period of time. An alternative method for early detection of a malaria epidemic employing the *Poisson* model has been proposed. The development of this early malaria epidemic detection model involved 3 steps: model specification, model validation and model testing. The model was based on data collected at the Vector Borne Disease Control Unit (VBDU) Level. The results of model testing reveal the model can detect increasing numbers of cases earlier, one to two weeks prior to reaching their highest peak of transmission. The system was tested using data from Kanchanaburi Province during 2000 to 2001. Results from model testing show the model may be used for monitoring the weekly malaria situation at the district level. The *Poisson* model was able to detect malaria early in a highly endemic province with a satisfactory level of prediction. As the application is essential for the malaria officers in monitoring of malaria epidemics, this early detection system was introduced into malaria epidemiological work. The model may be helpful in the decision making process, planning and budget allocation for the Malaria Control Program. The software for early malaria detection is currently implemented in several endemic areas throughout Thailand.

INTRODUCTION

The current surveillance system in Thailand is carried out by Vector Borne Disease Control Officers. Both active and passive case detection data are reported routinely, (Malaria Division, 2003). Some of the epidemiological data were not used to detect and analyze malaria epidemics. Although, the Malaria Control Program in Thailand has generally maintained a good surveillance system and conducted the appropriate control measures, especially in remote areas, malaria epidemics are not detected quickly enough. There is a delay in reporting from the district level to the national level. There is also a lack of expertise at the lower levels, and control measures are implemented slowly with minimal coordination and expertise. If the surveillance system, data analysis, reporting and notification were improved, then control measures could be taken immediately (Najera *et al*, 1998).

The epidemic warning system was based on normal distribution using the monthly mean number of cases and the mean plus or minus two standard deviations (mean ± 2SD). The

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monthly cases were plotted if the number was more than the mean + 2SD (Cullen *et al*, 1984). This method is not timely for detecting malaria epidemics which usually occur within a short period of time. Therefore, *Poisson* distribution was considered as an alternative method for developing an early detection model. *Poisson* distribution is the probable distribution of the number of times an event occurs which happens rarely. Malaria epidemics are common events which happen only intermittently (Onori and Grab, 1980). Malaria data fit the assumptions of the *Poisson* distribution well enough to generate an early detection system for malaria epidemics, and provide a better fit for monitoring the malaria situation within a limited time period.

The objective of this study was to develop an early detection system to monitor for malaria epidemics so that epidemics can be detected early enough and control efforts can then reduce morbidity, mortality and transmission. In developing this early detection model, there were three steps used in model development, namely model specification, validation and testing.

METHODS

Data sources for model development

Data for model development was collected from Kanchanaburi Province, Thailand, endemic for malaria. The weekly malaria cases reported were obtained for the fiscal years 2000 and 2001 using a data extraction form that was modified from a malaria epidemiological report form, Bureau of Vector Borne Diseases, Department of Disease Control, Ministry of Public Health.

Kanchanaburi Province is located near the Thai-Myanmar border. Since differences in geographical distribution led to differences in malaria transmission patterns, the data collected focused on control areas with perennial (A1) and periodic (A2) malaria transmission. The A1 and A2 areas were denoted by following the area stratification of the Thai Malaria Control Program. The *Poisson* distribution of the weekly mean number of cases was calculated for the nine Vector Borne Disease Control Units (VBDU) in Kanchanaburi Province during 2000-2001 (two years) as a point estimation. Since the malaria data represented a number of events over a period of time, it fitted the assumptions of the *Poisson* distribution, which is considered a method for developing an early detection model.

Model specification

The model specification was based on the theory of *Poisson* distribution. The weekly mean number of cases was calculated with a 95% confidence interval (interval estimation) following the assumptions of the *Poisson* distribution using STATA software. The area between the weekly mean and the upper limit of the *Poisson* distribution was considered as the detection area of the model. The upper limit was considered as the critical point for the early detection model. The *Poisson* distribution equation is shown below.

$$P\,(N=k) = \frac{e^{-\lambda}\lambda^{k}}{k!}$$

Where:

k is the occurrence (k being a natural number, including zero, and k = 0, 1, 2, ...),

e is the base of the natural logarithm (e = 2.71828...),

$k!$ is the factorial of k,

λ is a positive real number, equal to the expected number of occurrences that occur during the given interval.

A line graph of the weekly means and the lower and upper limits with 95% confidence intervals for the *Poisson* distribution is shown in Figs 1 and 2. The weekly *Poisson* distribution patterns in Kanchanaburi had different patterns in areas A1 and A2. The distribution in area A1 was greater than in A2. The study

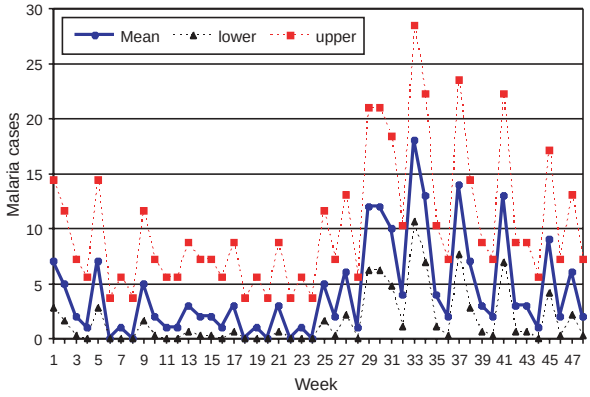

Fig 1–The *Poisson* distribution of the mean number of weekly malaria cases in area A1, VBDU1, Kanchanaburi Province, FY 2000-2001.

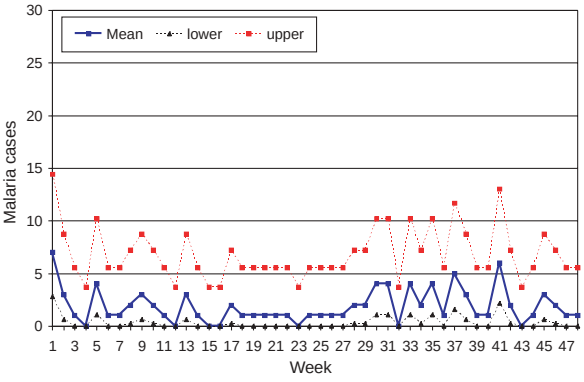

Fig 2–The *Poisson* distribution of the mean number of weekly malaria cases in area A2, VBDU1, Kanchanaburi Province, FY2000-2001.

period was divided into 48 weeks per year. The weekly mean numbers of malaria cases in area A1 tended to be higher from the 25th week to the 40th week (or from April to July). This finding corresponds to graphs showing the average monthly annual parasite incidence along the Thai border (Konchom *et al*, 2003).

Model validation

Model validation was performed using the time series technique. The time series of the monthly malaria cases during 1991-2001 in Kanchanaburi was analyzed to investigate the distribution of malaria cases during the past 11 years. A line graph of the monthly malaria cases in Kanchanaburi Province is shown in Fig 3. The number of malaria cases was highest in 1999 and lowest in 1997. The malaria cases during these two years were plotted using the *Poisson* distribution model for validation. It was expected that the number of cases in the year with the highest malaria number of cases would be higher than the upper limits of cut-off level of the *Poisson* distribution model. In contrast, the number of cases in the year with the lowest malaria cases would be lower or equal to mean of the *Poisson* distribution model.

Model testing

Application of the early detection system was tested at the VBDU level. The four VBDUs in Kanchanaburi Province with the highest and lowest malaria incidences were selected for system testing. The weekly malaria cases in 2002 were recorded for the control area in the four selected VBDUs using the data extraction form. Application testing took place by inputting the weekly malaria data collected into the program. The data were compared to the line graphs of the *Poisson* distribution model and plotted automatically. A significant increase was determined whenever the data in those particular weeks rose above the upper limit of the model.

The four VBDUs in Kanchanaburi which were selected for system development and testing are located in highly endemic areas (VBDU 4 Sai Yok and VBDU 9 Sangkhla Buri) and low malaria transmission areas (VBDU 1 Dan Makham Tia and VBDU 2 Bo Phloi). The number of weekly cases in 2002 was collected for each of the four VBDUs and plotted on the *Poisson* distribution model.

RESULTS

Time series analysis of the mean number of weekly cases was performed for 2002, revealing no occurrence of a malaria epidemic in any of the four VBDUs. The results show

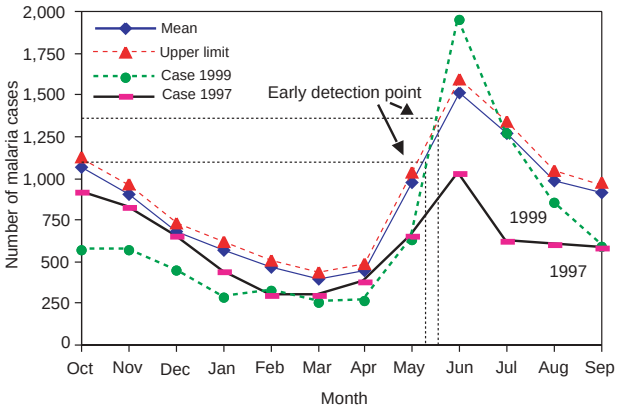

Fig 3–*Poisson* distribution of the mean number of monthly malaria cases in Kanchanaburi Province.

the same malaria patterns as the time series trend. The early detection system gave satisfactory results for detecting cases correctly.

In Fig 1 and Fig 2 the area between the weekly mean and the upper limit of the *Poisson* distribution is considered the detection area of the model. The upper limit of the *Poisson* distribution is considered the critical point for early detection. The line graphs for the weekly means detected an abnormal number of cases if the number rose above the upper limits for that week. This indicates the malaria situation may be close to a malaria epidemic for the following week.

The results in Fig 3 show the highest peak for monthly malaria cases occurred in May to July 1999, which was higher than the upper limits of the *Poisson* distribution. These findings indicate the malaria cases started to increase in the second week of May, were higher at the end of May and rose to their peak in June. The model detected the epidemic before its peak in June, detecting the epidemic one to two weeks before the peak.

The number of malaria cases in the year with the lowest frequency (1997) was lower than the lower cut-off level of the *Poisson* distribution model.

DISCUSSION

Figs 1, 2 and 3, reveal the *Poisson* distribution model may be used as an early detection model. The model can detect an increasing number of cases one to two weeks before they reach their highest peak, as seen in Fig 1. The line graphs of weekly mean *Poisson* distribution were interpreted by considering whether the cases in that week fell within the detection area or not. If one week the existing cases are above or equal to the borderline upper limit, this may predict that the malaria situation may worsen in the next week. This early detection model was corresponding to the explanation of a monitoring system concept described by Delacollette in 2001, (Delacollette, 2001). This study confirms that the early detection of malaria epidemics may be based on epidemiological data collected. The early detection model is an essential component in the monitoring system.

The weekly means of malaria cases in area A1 of Kanchanaburi Province were high from the 25th week to the 40th week (or from April to July) as shown in Figs 1 and 2. This system was useful for monitoring of malaria trends at the VBDU level. System testing showed the application gave satisfactory results for the monitoring of malaria at the district level. The results of this application may help local officers analyze the weekly malaria situation. The early detection system could increase the capacity of district malaria officers for decision making, prevention and malaria control. This model may be useful at the VBDU level of the Thai Malaria Control Program and may be implemented in all VBDUs throughout the country, especially in highly endemic provinces.

Since a computer is an essential instrument for running the early detection model, the Bureau of Vector Borne Disease should survey the computers at each VBDU. The Department of Disease Control should develop

a plan to provide computers to the VBDU where they are none. The 30 border provinces should be considered as first priority for computer due to budget limitations. A training course on basic statistics and computers needs to be developed in addition to training regarding the early detection system.

The reporting system needed to be improved in order to have feedback from the VBDU level to headquarters when malaria epidemics occur. The reporting forms need to be revised for weekly data collection and to allow essential data to be entered into the early detection system.

In conclusion, *Poisson* distribution is an effective alternative method for the development of an early detection system. This early detection model gave satisfactory early detection results. The model fulfilled the assumption of the *Poisson* distribution. The model detected the increasing numbers of cases one to two weeks before reaching their highest peak of transmission. The weekly mean *Poisson* distribution results were interpreted as to whether the numbers of cases for that week were above or below the cut-off levels.

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