THE RELATIONSHIP BETWEEN THE ABUNDANCE OF *MANSONIA* MOSQUITOES INHABITING A PEAT SWAMP FOREST AND REMOTELY SENSED DATA

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Abstract. The present study aimed to demonstrate the relationship of some environmental factors, vegetation greenness index (NDVI) and land surface temperature (LST), with the seasonal variations of *Mansonia bonneae* and *Ma. uniformis* in Khosit Subdistrict, Narathiwat Province. It was found that the *Mansonia* population lagged one month behind but correlated positively to NDVI, LST and rainfall. A rise in the number of mosquitoes was directly related to a rise in vegetation, temperature and rainfall.

INTRODUCTION

Different mosquito species, both larval and adult stages, vary in their habitat requirements (WHO, 1982). The characteristics of water bodies, including vegetation, play a role in determining which mosquito species inhabits an area (WHO, 1989). Larvae of *Anopheles minimus* and *An. maculatus* sl. prefer clear water, inhabiting the edges of clean, gently running streams, and emergent vegetation without organic material. Others such as *An. sundaicus* inhabits coastal areas with high salinity (Service, 1993), *Mansosia annulata* and *Ma. bonneae* require extensive vegetation cover and inhabit swamp forests and relatively permanent water bodies with organic material (Wharton, 1962). The main factor limiting the numbers of mosquitoes in any area is the availability of their breeding places which is directly affected by environmental factors. Various environmental factors, particularly rainfall and temperature, control the population dynamics of mosquitoes inhabiting natural breeding places. For example, rainfall, which not only creates more breeding habitats, but also increases evapotranspiration and vegetation coverage, cools the environment and directly affects reproduction and survival of *Mansonia* species (Wharton, 1962). Changes in biological, physical, and chemical parameters in the environment that affect the habitat of insect vectors are not easily characterized over large areas. Current techniques for locating larval habitats and monitoring mosquito populations are labor-intensive, time-consuming, and impractical over large areas. At both regional and local scales, the spatial and temporal patterns of vector populations are strongly influenced by elevation, temperature, precipitation and humidity (Dutta and Dutt, 1978). The vegetation of an area reflects the integration of all these factors, and this integration can be sensed remotely. Because remote sensing data acquired in the visible and infrared regions of the electromagnetic spectrum are sensitive to slight differences in vegetation and water, they provide a potential tool for surveying large areas to identify vector habitats and direct control measures.

The possibility of using remote sensing to identify habitats of vectors has been described elsewhere for many other diseases (Bergquist, 2001; Hay *et al*, 1996; Zhou *et al*, 2001). These studies focused on the use of remote sensing to identify and to map potential vector habitats based on vegetation, water, and soil. Attempts

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have been made to go beyond habitat mapping and make predictions of when and where vector reproduction and disease transmission risk will be greatest for developing operational surveillance and control programs. The studies by Cross *et al* (1984), Linthicum *et al* (1987), and Pope *et al* (1992) attempted to use remote sensing to predict the temporal as well as spatial patterns of habitat development, vector populations, and disease transmission risk. Recent studies also have investigated the application of remote sensing and spatial analysis techniques to identify and to map landscape elements that collectively define vector and human population dynamics related to disease transmission risk (Wood *et al*, 1992; Beck *et al*, 1997; Dister *et al*, 1997; Sithiprasasna *et al,* 2003). Previous work by Gleiser *et al* (1997) suggested that it might be possible to estimate mosquito abundance in advance using data of NDVI, rainfall and temperature. To determine relationships between environmental factors and mosquito fluctuations, seasonal variations in *Mansonia* mosquitoes were compared with vegetation greenness index (NDVI) and land surface temperature (LST) in Khosit Subdistrict, Narathiwat Province.

MATERIALS AND METHODS

Data

The monthly abundance of *Ma. bonneae* and *Ma. uniformis* in a swamp forest fringe area in Khosit Subdistrict during 1998-1999, was collected from the annual reports of the Division of Filariasis Control. Rainfall data were obtained from a regular record of the “Sirindhorn Research and Nature Study Center”. NOAA satellite image (10-day composite) for Narathiwat Province (1998) was obtained.

Software

The softwares used for this research were: “Environment for Visualising Images (ENVI version 3.2)” provided by InfoResearch, ArcView GIS version 3.1., and Excel spreadsheet.

Satellite images for Narathiwat were available only for the year 1998. Therefore, this study was based on the mosquito data collected in Khosit Subdistrict during 1998-1999. The satellite image processing methods for determination of NDVI and LST were taken from Nitatpattana (2001). Monthly image files (*.img) of Khosit Subdistrict were selected and collected by ArcView GIS. All image files were then opened by ENVI to obtain minimum, maximum and mean values for the digital number for CH1 and CH2 for NDVI determination, and CH 3, 4 and 5 for LST recorded in text file format (*.txt). Finally, the minimum, maximum and mean values from each channel were input into an Excel spreadsheet file for calculation of NDVI and LST. The NDVI and LST data were then displayed with monthly variations in *Mansonia* biting rate over the study period.

The numbers of *Mansonia* mosquitoes caught by human landing catches were transformed to log (N+1) which normalized the collection data and allowed more realistic means to be calculated and the application of parametric statistical tests (Service, 1993). The measurement of environmental factors, such as rainfall and temperature, were likely to be normally distributed (Elliott, 1977) and NDVI was related to rainfall and temperature. Therefore, multiple linear regression analysis between the logarithmic transformed mean monthly numbers of *Mansonia* mosquitoes caught and each environmental factor (rainfall, NDVI and LST) were used for analysis. The average time of *Mansonia* development from ovipositing until adult emergence in this region is approximately 25 days (Chiang *et al*, 1985). Hence, the correlation between mosquito biting rates and environmental variables during the concurrent and previous month were investigated.

RESULTS

Fig 1 demonstrates the seasonal abundance of *Mansonia* mosquitoes presented as log (N+1) and annual rainfall. Both *Ma. bonneae* and *Ma. uniformis* revealed bimodal patterns in biting densities with peaks in October and January following low and high rainfall, respectively. The remotely sensed data, NDVI and LST, were derived for Khosit Subdistrict and compared with the monthly biting density of *Mansonia* mosquitoes. The correspondence between the remotely sensed NDVI, LST variables and *Mansonia* abundance presented as log (N+1) is illustrated in Fig

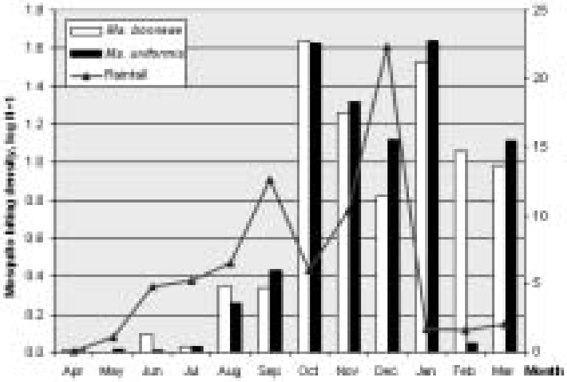
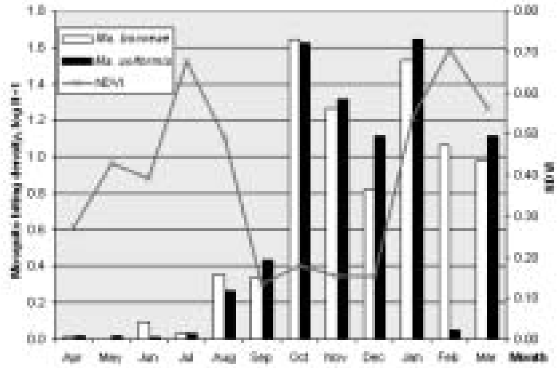


Fig 1–Seasonal variation of *Mansonia* biting density, log (N+1) and rainfall in Khosit Subdistrict (1998).

a



b

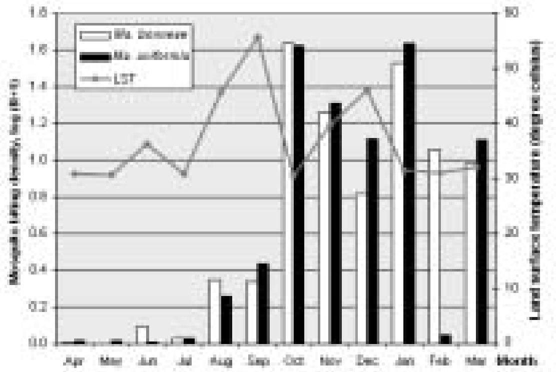


Fig 2–Seasonal variation of *Mansonia* biting density, Log (N+1) and remotely sensed data, NDVI (a) and LST (b) in Khosit Subdistrict (1998).

Table 1
Correlation coefficients of determination relating monthly environmental variables and logarithmic transformed numbers for *Ma. bonneae* and *Ma. uniformis*caught in Khosit Subdistrict (p≤0.01, *df*3).

Mosquito species	Correlation coefficient (r^2)	
	Lag 0 month	Lag 1 month
Ma. bonneae	0.13	0.44
Ma. uniformis	0.25	0.58

2. The NDVI peaked in July (0.7), followed by a sharp decline until September, with little fluctuation between September and December, then a sharp rise until February (0.7) with a range of 0.1 - 0.7 (Fig 2a). LST demonstrated two peaks in September (55.7ºC) and December (46.0ºC) with a range of 30.4º-55.7ºC (Fig 2b). The annual NDVI and LST variation showed a bimodal pattern, possibly related to the biting patterns of *Mansonia* mosquitoes with peaks in October and January.

Table 1 shows the correlations between environmental variables (rainfall, NDVI, LST) and monthly biting density of *Mansonia* mosquitoes in log transformation with two lag times, where 0 corresponds to concurrent and 1 to one month before. There was no significant correlation found between rainfall, NDVI, and LST and biting densities of *Ma. bonneae* (r^2 = 0.13; p≤0.01) and *Ma. uniformis* (r^2 = 0.25; p≤0.01) at lag 0. However, a correlation between rainfall, NDVI and LST and the log transformation of the mosquito densities became evident after a 1-month lag for *Ma. bonneae* (r^2 = 0.44; p≤0.01) and particular *Ma. uniformis* (r^2 = 0.58; p≤0.01) (Table1). The present study found that the mosquito data correlated with satellite data one month previously.

DISCUSSION

Mansonia mosquitoes, unlike other mosquitoes, use aquatic plants as important sources of breeding and living during immature stages. The relationships between host plants and larvae are strong and obvious (Laird, 1988). Hence, rainfall may not directly affect the breeding places of mosquitoes. Rainfall also increases the relative humidity and thus the longevity of adult mosquitoes. Within certain limits, longevity of a mosquito decreases with rising temperature and increases with increasing relative humidity (Molineaux, 1988). The relationships among changing temperatures, precipitation, and relative humidity, however, are complicated and the processes affecting atmospheric humidity suggest only a small change in relative humidity as the atmosphere gets warmer (Mitchell and Ingram, 1992). Tucker *et al* (1985) and Linthicum *et al* (1987) established that NDVI is a reliable indicator of rainfall. NDVI patterns do not relate to any permanent spatial variation in vegetation types, but instead to the local occurrence of rainfall (Townshend and Justice, 1986). High NDVI values negatively corresponded with high rainfall, but LST values positively corresponded with rainfall.

At our study site, dense vegetation peaked in three-month periods, from June-August and January-March. NDVI, LST, and rainfall had a relationship with the fluctuation of *Mansonia* populations in the peat swamp forest. The lag time after which mosquitoes reached their biting peaks was one month after NDVI, LST, and rainfall (Fig 2). The mosquito densities exhibited significant correlation with NDVI, LST, and rainfall with a lag time of 1 month. *Ma. uniformis* prefers to breed in open swamp areas, unshaded by trees, but *Ma. bonneae* prefers inhabiting swamp forests (Wharton, 1962). This indicates that the mosquito populations, particularly *Ma. uniformis,* depend on these environmental factors. Both *Mansonia* species lagged one month behind changes in NDVI, LST, and rainfall (Table 1), which means that a rise in the number of the mosquitoes was directly related to the rise in greenness of vegetation, temperature, and rainfall. In heavily vegetated surfaces, particularly in peat swamp forests, the surface (canopy) temperature is also controlled by available water at the root zone, soil moisture and more directly by evapo-transpiration (Carlson, 1986) which is related to the host plants of *Mansonia* mosquitoes. This finding is similar to various studies conducted earlier. Guimaraes *et al* (2000) also demonstrated that temperature, relative humidity and rainfall significantly influenced the population dynamics of various species of mosquitoes, including *Coquillettidia* spp, which has a biology similar to *Mansonia* mosquitoes. A study carried out in Africa by Thomson *et al* (1997) on monthly composite NDVI values was also positively correlated with the density of freshwater species *An. gambiae.*

The present study did not attempt to draw a definitive picture of the seasonal abundance of *Mansonia* mosquitoes in relation to these environmental variables. The direct causal link between these environmental factors and the mosquito density in the peat swamp forest is of research interest. Higher frequency measurements and more time series of field investigations and remotely sensed data would be needed to confirm their associations, to resolve the true response and study how the mosquitoes respond to environmental factors.

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