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INTRADOMICILLARY BEHAVIOR OF *ANOPHELES ALBIMANUS* ON THE COASTAL PLAIN OF SOUTHERN MEXICO: IMPLICATIONS FOR MALARIA CONTROL

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ABSTRACT. The postfeeding indoor resting behavior of *Anopheles albimanus* in experimental houses in southern México was investigated by using a mark–recapture procedure. The majority of mosquitoes rested inside houses after taking a blood meal indoors. There was a higher landing frequency on interior surfaces other than walls and roofs; however, mosquitoes rested for longer periods on these 2 surfaces. Successive landings on walls after short flights showed that mosquitoes gradually increased their mean landing height from 1.0 to 1.4 m. Similarly, mosquitoes resting at the base of inner roofs had a successive landing height range of about 0.5 m. Based on these observations and the potential for reduction of nearly 50% in the quantity of insecticide used and the time needed to apply it, village-scale studies involving the selective spraying of a 1-m-wide swath of insecticide on walls and on roofs are recommended in this area.

INTRODUCTION

The bionomics and behavior of disease vectors must be evaluated individually to determine their role in the transmission of disease-causing pathogens. Man–vector contact, a fundamental element of the transmission cycle, provides the basis for research in vector ecology. Indoor resting behavior, an essential component of man–vector contact, can be viewed as 2 separate components, pre-and postfeeding behavior. The first relates to host selection and feeding, and may include contact with surfaces as the mosquito moves indoors but before host contact is made. The second component determines the vector's orientation from feeding to resting, allowing a second opportunity for contact with indoor surfaces. It is within this framework, of pre- and postfeeding, that evaluation of behavior patterns of malaria vectors can determine appropriate methods for indoor application of residual insecticides for greater efficacy.

Vector longevity is another determining factor of vector capacity, and is measured by the numbers of mosquitoes that survive long enough to complete the sporogonic cycle of *Plasmodium* sp. parasites, allowing transmission to persist (Macdonald 1957). Reduction of vector longevity may best be achieved by an effective indoor resting mosquito control program. Through successive contact with the insecticide the daily survivorship of the vector population is reduced. Considering this, the objectives of this study were to determine how control measures can more effectively be used to reduce target vector populations by evaluating the indoor postfeeding resting behavior of *Anopheles albimanus* Wiedemann, the principal vector of malarial parasites on the Pacific coast of Chiapas, México.

MATERIALS AND METHODS

Study area: Beginning in 1985, several interrelated studies were carried out in a small village of 320 houses, Ranchería El Gancho (population 1,350), located on the Pacific coast of Chiapas, México, about 2.5 km west of the Guatemala border. Anopheline mosquitoes in the coastal plain are highly prevalent, in part due to the abundance of immature mosquito habitats (irrigation canals, flooded pastures, lagoons, etc.) associated with adult resting sites (low brush, trees, burrows, etc.). Malaria is endemo-epidemic (typically unstable) and *An. albimanus* is considered to be the primary vector in the area (Ramsey et al. 1986, Rodríguez and Loyola 1989). Houses are predominantly constructed of palm-thatch roofs with discontinuous walls made of palm poles and bamboo. This type of construction presents a reduced barrier to mosquito entry and facilitates indoor man–vector contact. Houses had not been sprayed with insecticide (DDT) since the national malaria campaign suspended treatments in 1982.

The area has a mean annual temperature of 27°C (range 18–42°C), relative humidity of 79% (range 61–95%) and an average annual rainfall of 2,152 mm. Malaria is prevalent year round but peaks occur during the wet season (May to mid-November) corresponding to greatest abundance of *An. albimanus*.

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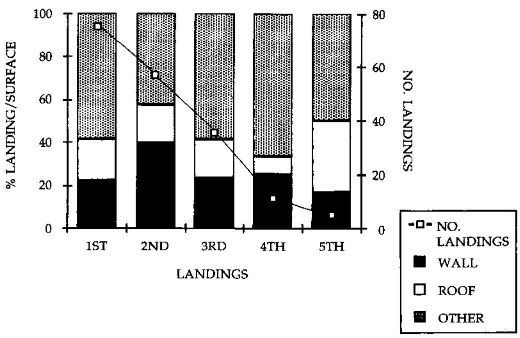

Fig. 1. Landing frequency and percentage of engorged *An. albimanus* on indoor surfaces.

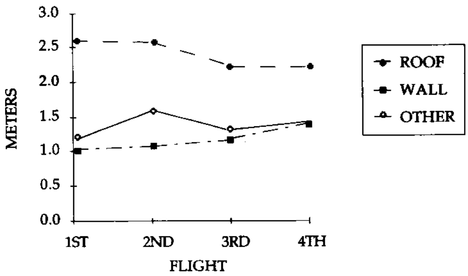

Fig. 3. Mean resting height of *An. albimanus* on indoor surfaces.

Mark–recapture (indoor resting behavior): Between June 1985 and January 1986, 2 technicians conducted weekly mark–recapture studies at peak biting hours between 1900 and 2300 h (Bown et al. 1986b) ("normal" indoor household activities were maintained during the hours of the study). The first technician served as human bait, sitting inside a house near the open front door. When a female *An. albimanus* landed and engorged, the second technician colored the mosquito with fluorescent powder and followed its movements with an ultraviolet lamp for 1 h. The number of landings, type of resting surfaces (wall, roof and/or other [furniture, floor, etc.]), resting time and height were recorded for each marked mosquito. Mosquitoes were continually observed for 1 h or until they left the house, whichever came first.

RESULTS

Mark–recapture (indoor resting behavior): A total of 88 marked mosquitoes were studied. Of these, 17% (15/88) had no apparent contact with indoor surfaces at all. Of those that contacted indoor surfaces after biting, landing was more frequent on nonsprayable surfaces (59%) (43/73 landings/first flight) (i.e., furniture, floors, etc.), as compared to sprayable surfaces such as walls (22%) (16 landings/first flight) or roofs (19%) (14 landings/first flight). Overall landing frequency on walls was higher than on roofs. The highest landing frequency on sprayable surfaces was 2 (57%, from 22 landings on walls and 10 on roofs, out of 56) (Fig. 1). Only 11 mosquitoes landed more than 5 times (not shown on Fig. 1).

Mosquitoes rested for longer intervals on walls and roofs during the sampling period (June–January) than on other surfaces (Fig. 2). The cumulative mean resting time on walls was 25.4 ± 7.1 (SD) min followed by shorter periods on roofs (15.5 ± 7.1 min) and on nonsprayable surfaces (8.4 ± 7.0 min). Between June and January an increasing trend, in favor of longer resting periods, was found on walls but not on other surfaces.

The change in preferred mean landing heights according to surface by month varied little (Fig. 2). Mean landing heights varied from 0.7 to 1.3 m on the walls and from 2.1 to 2.5 m on inner roofs. Overall, wall landings after each flight showed that mosquitoes gradually increased their mean landing height from 1.0 m on the first landing to 1.4 m on the fourth landing (Fig. 3). Conversely, the mean landing height on roofs began at 2.6 m on the first landing and decreased to 2.2 m on the fourth. The mean resting height for all surfaces was approximately 1.4 m. Variation in landing heights between flights by surface type was similar.

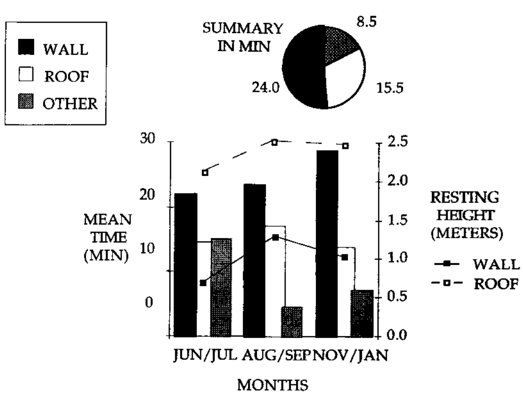

Fig. 2. Mean monthly resting time and height of *An. albimanus* on indoor surfaces.

DISCUSSION

Anopheles albimanus has been found to have a peak feeding activity between 1800 and 2300 h (Elliott 1968, Bown et al. 1987) and is known to be generally exophagic. It readily feeds upon man but prefers domestic animals (Breeland 1972, Loyola et al. 1993). Loyola et al (1993) also found that after taking a blood meal, *An. albimanus* frequently rests inside and outside houses; however, the majority of indoor-resting mosquitoes first feed outdoors on animal blood.

Our observations of indoor behavior demonstrated that after feeding on man, nearly 80% of those mosquitoes that had contact with indoor surfaces landed more than once, but the highest frequency was only 2 landings. Mosquitoes landed more frequently on interior surfaces other than walls and roofs; however, they rested for longer periods on walls and roofs.

In a mark–release study carried out in Indonesia, *Anopheles aconitus* Dönitz rested at a height of less than 1 m (Damar et al. 1980). Following this observation, Bang et al. (1981) effectively reduced indoor landing rates and resting time (by producing higher mortality) of the same vector by spraying a single horizontal swath along the lower portion of indoor walls. In our study, preferred landing heights of *An. albimanus* were greater than 1 m on walls and at the base of the inner roof, therefore making it necessary to spray higher wall and roof surfaces to effectively control adults.

The present policy of malaria control programs in México and Central America is to spray all interior walls, eaves, half of inner roof surfaces and the under surfaces of furniture. However, findings presented here suggest that a high potential of control, in areas where *An. albimanus* is the sole or most prevalent vector, can be achieved even if interior walls are not fully sprayed. It was calculated that if a 1-m swath was sprayed on walls beginning at 0.75 m from the floor as well as a similar swath sprayed on roofs beginning at 3.0 m from the floor and extending down, the volume of insecticide and the number of man-hours could be reduced by nearly 50%. It can be argued that although many insecticides have some degree of repellent effect, especially immediately after spraying (Bown et al. 1986, Loyola et al. 1991), mosquitoes may avoid contact with sprayed areas. However, experiments have determined that when houses were sprayed with insecticide, it was possible to achieve high indoor mortality (an indicator of insecticide contact), because natural resting behavior allowed sufficient contact time with treated surfaces (Arredondo-Jiménez et al. 1993). In a partial spray evaluation (a technique that targets preferred vector resting sites) recently carried out on a village scale in southern México, it was determined that when only wall and roof surfaces were sprayed with an insecticide (bendiocarb) applied at 1-m swaths, mosquito mortality rates were the same as those houses sprayed using the traditional method (Arredondo-Jiménez et al. 1992).

In summary, these results show that after taking a blood meal, *An. albimanus* typically rests indoors. By determining their resting patterns it should be possible to apply indoor control measures to those areas where they are most commonly found and reduce excessive use of insecticide. A more rational use of insecticide products for mosquito control would still have as its objective attenuation of vector–man contact, but more importantly, reduction in vector life expectancy and its probability of becoming infective.

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