Host-Feeding Pattern of *Culex quinquefasciatus* Say and *Mansonia annulifera* (Theobald) (Diptera: Culicidae), the Major Vectors of Filariasis in a Rural Area of South India

P. PHILIP SAMUEL,1 N. ARUNACHALAM,1 J. HIRIYAN,1 V. THENMOZHI,1 A. GAJANANA,2 AND K. SATYANARAYANA1


**ABSTRACT** *Culex quinquefasciatus* and *Mansonia annulifera* are abundant in the rural areas of Kuttanadu, Kerala, India. Bloodmeal identification for individuals of these species collected in this region was determined by the agar-gel precipitin test. A total of 2,328 blood smears from *Cx. quinquefasciatus* (1,148) and *Ma. annulifera* (1,180) was tested. Results showed that *Cu. quinquefasciatus* and *Ma. annulifera* were highly anthropophilic and that human feeding accounted for 74 and 66% of the total bloodmeals tested. Feeding on cattle accounted for only 1.5 and 2.1% of *Cx. quinquefasciatus* and *Ma. annulifera* bloodmeals, respectively. This study showed the high anthropophilic feeding rates of *Cx. quinquefasciatus* and *Ma. annulifera* collected from an endemic belt of Malayan filariasis, where epidemiological studies revealed the coexistence of Bancroftian and Malayan filariasis.

**KEY WORDS** mosquito feeding pattern, *Mansonioides, Culex*

LYMPHATIC FILARIASIS (LF) is a debilitating disease that often draws social stigma to afflicted people and is a major cause of acute and chronic morbidity of humans in tropical and subtropical areas of Asia, Africa, the Western Pacific, and some parts of the Americas. Current estimates suggest that LF is responsible for the third highest global burden of disease behind malaria and tuberculosis (Nutman 2001). LF is considered a major obstacle to economic development in endemic countries and has been identified as the second leading cause of permanent and long-term disability (WHO 1994). Of the estimated 128 million cases of LF currently reported in at least 76 endemic countries, 91% are caused by *Wuchereria bancrofti*, while *Brugia malayi* and *B. timori* infections account for the other 9% (Michael and Bundy 1997). Over one-third of the World’s population is at risk of LF infection (WHO 1992). In India, Malayan filariasis is endemic in parts of Kerala, Andhra Pradesh, Tamil Nadu, Orissa, West Bengal, Assam, and Madhya Pradesh (Raina et al. 1995).

Mosquitoes of the *Culex pipiens* complex, especially *Culex quinquefasciatus* Say, are urban vectors of the nocturnally periodic *W. bancrofti* in Asia, Africa, the Western Pacific, and South America (White 1989). The main vectors of *Brugia malayi* are six species of *Mansonia* (White 1989). In India, *Mansonia annulifera* was the major vector of *B. malayi* (Sabesan et al. 2000). The feeding pattern of *Culex quinquefasciatus* was studied in urban areas, where it was found to feed on different hosts (Wattal and Kalra 1963, Arunachalam 1987). The host-feeding pattern of *Culex quinquefasciatus* collected from Rangoon, Bobo-Dioulasso, Jakarta, and Tanzania indicated a preference for humans (DeMeillon and Sebastian 1967, Subra 1973, Self et al. 1978, White 1971). Anthropophily predominated in Rangoon, Burma, and also in Pakistan (Reisen and Boreham 1976). The anthropophilic index of *Culex quinquefasciatus* in different states of India varied from 21.2% in Madras (now renamed Chennai) to a maximum of 64.7% in Kerala (Sathyaprakash et al. 1962). However, very few published studies on the feeding patterns of filariasis vectors in rural areas are available. The intensity of disease transmission in an area depends on the degree of human-vector contact. We therefore studied the feeding pattern of the vectors of Bancroftian and Malayan filariasis in a rural area of south India.

**Materials and Methods**

**Study Area**

Six villages, namely Kavalam, Molagan Thurthy, Neelamperoor, Nehru Trophy Ward, Pulimeenu, and Velisyanadu, which are located around the Vembanad Lake in Kuttanadu region of Kerala state of India, were selected as index villages for this study. Kuttanadu is a warm, humid region with fairly uniform temperature ranging from 21 to 35°C throughout the
year. Humidity in general is high all through the year. Most of the people (65,770) living in these villages are agricultural laborers who live in huts. Cattle (6,751), goats (2,658), pigs (22), dogs (1,739), fowl (71,391), and ducks (14,491) are the common domestic animals in Kuttanadu (data from 1998 Alappuzha District Livestock Census). Pigs are reared in the backyards of a few houses. The annual average rainfall is ~300 cm, of which 83% is received during the southwest monsoon months of July–September. Four seasons are observed in this region. These are postmonsoon season, January–March; summer season, April–June; southwest monsoon season, July–September; and northeast monsoon season, October–December.

Mosquito Collection

Resting blood-fed mosquitoes were collected from outdoor vegetation and bushes with drop nets from 07 to 08 h (De Zulueta 1950). Indoor mosquito collections were made using the World Health Organization (WHO) hand catch method from 08 to 09 h (WHO 1975). Mosquitoes were identified with the keys of Mattingly (1971) and Sirivanakarn (1976). This study was carried out at monthly intervals from June 1998 to December 2001.

Bloodmeal Identification

Fully blood-fed female mosquitoes were placed on ice and transported to the laboratory. Stomach contents were smeared on Whatman No. 1 filter paper strips, dried, and stored at 4°C. The filter papers were later transported to the main laboratory in Madurai for processing. The agar-gel precipitin test of Collins et al. (1986), with minor modifications as described in Reuben et al. (1992), was used to identify bloodmeals. Antisera to six hosts, cattle, pig, duck, goat, fowl, and human, were obtained from the Serologist, Government of India, Kolkata, India.

Feeding index is defined as the proportion of feeds on one host compared with the proportion of feeds on a second host divided by the expected comparative proportion of feeds on these two hosts based on factors affecting feeding. These factors include abundance and size of hosts. The feeding index is expressed mathematically as

$$FI = \frac{Ne}{Ne'} \left( \frac{Ef}{Ef'} \right)$$

where $FI$ = feeding index; $Ne$ = number of observed feeds on host I; $Ne'$ = number of observed feeds on host II; $Ef$ = expected proportion of feeds on host I; and $Ef'$ = expected proportion of feeds on host II.

Thus, an index of 1.0 indicates equal feeding on the two hosts, while figures less than 1 and greater than 1 indicate a decrease or increase in feeding on the first host relative to the second. The main advantage of the feeding index is that it does not require a full animal census. This method is particularly suited for the analysis blood-feeding behavior in areas in which there are a limited number of hosts (Kay et al. 1979a).

Statistical significance of different blood-feeding patterns was evaluated with a $\chi^2$ test that was carried out using Epi Info version 6.04b-January 1997 (Database and Statistics Program for Public Health, Centers for Disease Control and Prevention (CDC), USA, World Health Organization, Geneva, Switzerland).

Results

A total of 1,148 Cx. quinquefasciatus and 1,180 Ma. annulifera bloodmeals was tested. Overall, 75% (1,751) of the bloodmeals tested were identified. Ma. annulifera fed on humans about half the time (66%), while only 2% fed on cattle. Double feeding was low in Ma. annulifera, and the double feedings that were recorded were from cattle and humans (0.7%) and from cattle and goats (0.3%). Pig feeding accounted for 0.3% of the Ma. annulifera bloodmeals. In the blood-fed mosquitoes collected outdoors ($n = 64$), the feeding pattern was 20% on cattle, 3% on humans, and 5% on pigs. Except for mosquitoes collected indoors ($n = 1,116$), the percentage of feeding was 1% on cattle and 69% on humans (Fig. 1). Pig feeding was
The seasonal feeding trends of *Culex quinquefasciatus* also showed high feeding rates on humans (60–81%) throughout the year and a low feeding rate on other hosts. Feeding index calculations for *Culex quinquefasciatus* were greater than 1, indicating increased blood feeding on humans (Table 1).

### Discussion

The Kuttanadu study region of Kerala state forms an interface of marine, estuarine, and fluvial systems representing a highly complex ecosystem in India. Most of the region is below mean sea level and is waterlogged throughout most of the year. Ponds, channels, and canals act as perennial mosquito breeding habitats that support the growth and proliferation of different types of Mansonioides mosquitoes, the vectors of Malayan filariasis. Kerala is an endemic belt of Malayan filariasis, where epidemiological studies have reported the coexistence of Bancroftian and Malayan filariasis (Raina et al. 1995).

In our study, *Culex quinquefasciatus* was the most abundant species taken in indoor resting collections comprising 54.4% of the total collection. *Ma. annulifera* comprised 22.8% of the indoor collections. Similarly, *Culex quinquefasciatus* made up 50.04% and *Ma. annulifera* 27.73% of the total all night indoor landing collections, indicating the preference of these species for humans (Arunachalam et al. 2001). Our blood-feeding studies of the major filariasis vectors, *Ma. annulifera* and *Culex quinquefasciatus*, indicated a tendency toward high anthropophilism. Host-feeding studies of *Mansonia* vectors of Malayan filariasis in Orissa showed that the anthropophilic index was 65.5% for *Ma. annulifera* (Hazra et al. 2002). The relative abundance, coupled with high human vector contact and a higher transmission potential, makes *Ma. annulifera* the most important vector of Malayan filariasis in Shertallai region of Kerala state (Sabesan et al. 1991).

### Table 1. Feeding indices of *Ma. annulifera* and *Cx. quinquefasciatus*

<table>
<thead>
<tr>
<th>Mosquito species</th>
<th>Feeding index</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ma. annulifera</em></td>
<td>3.4</td>
</tr>
<tr>
<td><em>Cx. quinquefasciatus</em></td>
<td>5.1</td>
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Ma. annulifera showed a high preference for humans throughout the year (56–76%), and no significant difference in the seasonal feeding pattern was noted. In Orissa, the human forage ratio of Ma. annulifera was 0.8 compared with 0.7 for Ma. uniformis, 0.59 for Ma. indiana, and 0.35 for Ma. dives (Hazra et al. 2002). The human/cattle feeding index for Ma. annulifera in our study was greater than 1, indicating a preference for humans. A seasonal variation in the feeding pattern of Cx. quinquefasciatus was observed in rural areas of New Delhi. A low human feeding rate (14.2%) was observed in winter, whereas human feeding was high (81%) in summer (Kaul and Wattal 1968). In Mysore City, the anthropophilic index was 96.5% during premonsoon and 91.9% during monsoon months, with some preference for bovine and birds (Gowda and Vijayan 1992). In the current study, human was the only preferred host, and the trend existed throughout the year, with low preference on the other hosts. Multiple bloodmeals occurred at a very low rate (<0.7%) because suitable hosts were available in the habitats sampled and the feeding success was high.

The number of filariasis cases in India, like many other mosquito-borne diseases, is not only persistent, but also constantly increasing. Bancroftian filariasis is generally considered an urban disease, which is currently spreading to rural areas (Rahman and Sharma 1990). Cx. quinquefasciatus is the major vector of Bancroftian filariasis in urban and semiurban areas, and Ma. annulifera is the major vector of Malayan filariasis in rural areas. Rapid urbanization without adequate civic amenities, particularly proper drainage, leads to a buildup of high populations of these mosquito vectors. The results of our study conducted in this rural area revealed that Ma. annulifera and Cx. quinquefasciatus are abundant. Both species are anthropophilic, despite the number of different hosts available to them in rural habitats. The higher percentage of human bloodmeals from indoor collections indicates the high degree of human-vector contact that is the main criteria for active transmission of any pathogen to human populations. Hence, the high anthropophilic nature of these filariasis vectors may be one of the reasons for the rapid spread of Bancroftian filariasis and Malayan filariasis in rural areas. The problem of LF in rural areas has not received attention in spite of the fact that over two-thirds of 428 million people at risk of infection in India live in rural areas. In the absence of any control measures in rural areas, the number of cases continues to increase. To solve this problem, adequate vector control programs need to be made available in rural areas.

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