POPULATION DYNAMICS OF ANOPHELINES IN A MALATHION TREATED VILLAGE IN THE INTERMEDIATE ZONE OF SRI LANKA
by
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Abstract. — As part of research programme on malaria transmission in Sri Lanka, a study was made of man-biting anophelines at Nikawewera, a village on the border of the intermediate and dry rainfall zones. Weekly mosquito collections by night human bait (NHB) were performed inside and outside four fixed stations from October 1992 till March 1993. Houses in the village were treated with malathion by the Anti-Malaria Campaign in October and at the end of January 1993. An. culicifacies and An. tesselatus were the most abundant species. An. culicifacies was probably the only species responsible for malaria transmission. An. culicifacies densities varied between stations and reflected differences in availability of breeding places. An. culicifacies aggressivity is closely related to the rainfall pattern, increasing after the first monsoon rains in November and reaching a peak in late December — early January. Vectorial capacity, however, decreased during the first weeks of the rainy season. The maximum vectorial capacity was found in January. The night biting cycle of An. culicifacies showed a peak between 20.00 and 23.00 h. Since the introduction of electricity in the village, people go to bed later. This might reduce the impact of impregnated bednets on malaria transmission. The results show that malathion spraying as performed now is not very effective. The timing of the spray rounds should be improved. In order to limit malaria transmission, we suggest to advance the malathion spraying campaign of January with one month.

KEYWORDS : Malaria transmission; Vector control; Anopheles culicifacies; Malathion; Sri Lanka.

I. Introduction

Malaria in Sri Lanka is unstable and highly seasonal. The incidence of P. falciparum and P. vivax is closely related to the distribution pattern of the principal vector An. culicifacies. Its favoured breeding place is often produced by light rains. An. culicifacies, therefore, is rare in places of extreme rainfall (4). Malaria is endemic in the dry and intermediate zones where rainfall does not exceed 2,500 mm/year. Peak transmission is associated with the North-East monsoon from November to January. Occasionally epidemics occur in the wet zone (> 2,500 mm/year) during long periods of dry weather.

Mosquito control in Sri Lanka is mainly attempted by regular spraying of the houses in endemic areas with the residual organophosphor insecticide malathion. In spite of intensive control efforts, malaria is on the increase. In depth studies on vector behaviour, biting habits and longevity as well as breeding sites are essential for improving spraying strategies and for developing other vector control methods. The data reported here are part of an
extensive epidemiological survey at Nikawehera, a typical farming village on
the border of the Sri Lankan dry and intermediate zones (fig. 1). Data on
parasitology and serology in the human population will be reported else-
where. This paper reports on the occurrence, biting behaviour and longevity
of man biting anophelines during and after the NE monsoon season.

II. Materials and methods

II.1. Study area

The amount of rainfall in the Nikawehera area varies considerably from
one year to another, but the rainfall pattern remains the same. During the dry
season (April-June) tobacco and chilies are the main crops. In the rainy sea-
son (November-February), wetland rice is cultivated. The irrigation water is
derived via canals from a reservoir and from a stream bordering the village.

II.2. Selection of sampling sites

To identify the exact place of transmission and to compare mosquito
abundance in different parts of the village, four fixed stations were selected.
House no. 1 was located on the border of the village at 30 meters from the
river. House no. 2 was in the centre of the village, surrounded by other
houses and small pig sheds. House no. 3 was built along the main road, bor-
dering paddy fields. House no. 4 was located in a dense jungle area. All
houses had brick walls and tiled roofs.

Houses were sprayed with malathion by the Anti-Malaria Campaign
(AMC) at the end of October 1992 and at the end of January 1993. AMC
guidelines recommend spraying on a three monthly basis (four rounds/year).

II.3. Mosquito collections on human bait and dissections

The sampling stations were visited once a week from October 1992 till
March 1993. Human biting collections were made inside and outside the
houses. Four pairs of collectors worked in six-hour shifts between 18.00 h
and 6.00 h the following morning. To prevent a bias of data due to personal
differences in skill and mosquito attraction, catchers were rotated weekly be-
tween the houses. All biting mosquitoes were kept in plastic cups and collec-
ted every hour. Female anophelines were identified and kept at 4°C and dis-
sected the following day. The man biting rate (MBR in number/man/night)
was computed separately for the collections made indoors and outdoors and
for the total per house. Head and thorax of each individual Anopheles mos-
quiro were preserved at −20°C and tested for P. falciparum and P. vivax
sporozoites using an ELISA test. The ELISA kit was supplied by Dr. R. Wirtz
of the Walter Reed Army Institute of Research, USA. The P. falciparum and
P. vivax ELISAs were based on Mabs 2A10, 247-498 and NSV3, respec-
tively. The procedures for the test were the same as those described by
Wirtz et al. (12). All positive samples were reexamined to confirm the results.
Figure 1.
Map of Sri Lanka, showing zones of the country based on rainfall patterns, the major cities and the study area, Nikawehera.
III. Results

III.1. Anopheline fauna

In total, 1,030 Anophelines were collected. Ten species were identified: An. culicifacies (44.66 %), An. tesselatus (30.39 %), An. subpictus (8.64 %), An. barbirostris (7.86 %), An. vagus (6.41 %), An. varuna (0.39 %), An. pallidus (0.49 %), An. aconitus (0.49 %), An. maculatus (0.39 %) and An. annularis (0.29 %) (1). Only the first two species were found in appreciable numbers. An. subpictus has been incriminated as a vector of human malaria in the Northeastern Province of Sri Lanka (2). However, with a human blood index of 0.0025 (11) this species cannot be considered as a good vector and might only play a role in malaria transmission when it is abundant.

III.2. Man biting rate (MBR)

An. culicifacies

The mosquito density of the principal vector An. culicifacies closely follows the rainfall pattern: the average MBR gradually increased from 1.9 bites in October to 5.5 bites per man per night in January and decreased to 1.8 and 1.3 in February and March, respectively (fig. 2). Significant variation of densities were observed between different locations in the village (fig. 3). In house no. 1, close to the river, the MBR varied from 3 bites/m/night (BMN)

![Figure 2](image-url)

Man biting rates of An. culicifacies. Average of four nights per month on a weekly basis.
Figure 3.
in October to 22.8 and 26.3 in December and January, respectively. In the centre of the village (house no. 2), a maximum 6.5 bites BMN night was reached in November, while in the station close to the paddy fields (house no. 3) a peak of 10 BMN was found in December and January. In house no. 4, adjacent to the jungle, *An. culicifacies* were only observed in very small numbers.

The MBR was slightly larger outdoors than indoors throughout the period of the survey. Surprisingly the MBR did not decrease more drastically indoor than outdoor after malathion spraying (fig. 2).

The biting rate of *An. culicifacies* in the village was determined for each successive hour of the night. It was found that it bites throughout the night, with a peak biting rate between 20.00 h and 23.00 h (fig. 4). 50.5 % of all parous females bite before 23.00 h (table 1).

<p>| TABLE 1 |
| Parity distribution of <em>An. culicifacies</em> before and after people go to sleep |
|----------|-----------|-----------|------------|-----------|</p>
<table>
<thead>
<tr>
<th>Hour</th>
<th>Nullip.</th>
<th>Parous</th>
<th>Semi-gr. Gravid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-23 h</td>
<td>7.6 %</td>
<td>30.6 %</td>
<td>20.0 %</td>
<td>58.2 %</td>
</tr>
<tr>
<td>23-06 h</td>
<td>5.9 %</td>
<td>30.0 %</td>
<td>5.9 %</td>
<td>41.8 %</td>
</tr>
<tr>
<td>Total</td>
<td>13.5 %</td>
<td>60.6 %</td>
<td>25.9 %</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>
An. tessellatus

MBR increased sharply in December reaching 8.2 bites per man per night. 74% of An. tessellatus at this stage were nulliparous. In January the MBR dropped to 0.3.

A significant variation was observed between the different houses, the highest man biting rates being observed in the centre of the village and close to the jungle (fig. 3).

III.3. Age composition and longevity

Age composition was estimated over the whole season. The proportion nulliparous, parous and gravid females were computed per month (fig. 5).

The proportion of parous females was high throughout the monsoon season and malathion spraying could not prevent a steady increase of the parity index, that reached a maximum in January. The proportion of females feeding in the semi-gravid stage dropped in November after the rains had started.

III.4. Sporozoite index

In the first ELISA test, eight An. culicifacies out of 455 were found positive for P. falciparum Ma 2A10-R1 and two for P. vivax Ma 247-498 CS variant. No mosquito was found positive for the P. vivax Ma NSV 3 variant. However, none of the positive results could be confirmed in the control tests so they should be considered as false positive results.

![Figure 5. Age distribution of An. culicifacies.](image-url)
III.5. Epidemiological analysis

The analysis of the extrinsic cycle in *An. culicifacies* was made starting from basic formulas (5, 6).

The daily aggressivity rate \( ma \) was calculated from monthly averages of the number of BMN indoors and outdoors. The man-biting frequency (a) is the product of the estimated daily frequency of 0.4 (7) and the human blood index of 0.389 (11). Therefore \( a = 0.16 \).

The life expectancy was in average 17.4 days for the whole period.

The mean vectorial capacity (v.c.) for the whole season was 4.7 for *P. falciparum* and 5.4 for *P. vivax*. The v.c. ranged from 0.29 and 0.52 in November to 22.6 and 24.95 in January.

The sporozoite index in the mosquito population can be derived from the gametocyte index in the human population. Mass surveys performed in the village in November and March revealed a gametocyte index of 0.0094 and 0.023 for *P. falciparum* and *P. vivax* respectively. The calculated sporozoite index was low throughout the transmission season, with an average of 0.010 for *P. falciparum* and 0.028 for *P. vivax*.

From the daily entomological inoculation rate (\( h_e = ma s \)), the number of infective bites per year can be estimated. A person in our study area risks to be bitten 0.93 times per year by mosquitoes infected with *P. falciparum* and 2.57 times with *P. vivax*. For our calculations we assumed that transmission only takes place from October to March and not during the other six months of the year.

IV. Discussion and conclusions

*An. tesselatus* has been recorded as a secondary vector of malaria in the Indo-Iranian Zone. Laboratory colonies of *An. tesselatus* are being used in Sri Lanka for studies on transmission blocking immunity. In the laboratory *An. tesselatus* has proven to be an efficient malaria vector (3). In our study area, however, the role of *An. tesselatus* in malaria transmission was very limited because of its low survival rate. *An. tesselatus* larvae are usually found in swamps or shaded pools in the wood (10). This explains why 90 % of *An. tesselatus* were found in and around the house close to the jungle area. Other classical breeding places for *Anopheles tesselatus* are rice fields, but the large quantities of pesticides used on the fields make it unlikely that larvae would survive.

The principal vector of malaria in the study area is *An. culicifacies*. As expected, highest vector densities were found close to the river. Pools in the banks of irrigation channels form ideal breeding sites. *An. culicifacies* are more attracted to cattle and other domestic animals than to man (HBI 0.389). In the centre of Nikawehera, pigs and cattle are kept close to the houses at night. This might divert mosquitoes from the human population and explains the low man-biting frequency in the centre of the village.

At the end of the dry season (September-October), the proportion of gravid females in the man biting population is largest. This suggests that during the dry months, the oviposition and probably the maturation of eggs are delayed and that more than one blood meal is taken per gonotrophic cycle.
Such feeding is, however, of little consequence epidemiologically because of the greatly reduced densities during that season.

*An. culicifacies* has a peak biting rate between eight and eleven o’clock in the night. In December 1992, electricity was introduced in Nikawehera. Since television made its entry in village life, people go to bed later. We have noted that half of parous females, the most likely vectors, feed before adults go to sleep. This should be considered when impregnated bed nets are promoted on large scale as an alternative or supplementary vector control measure. However, different sibling species of *An. culicifacies* may occur in different parts of the island and if they have different biting preferences and behaviour should be investigated.

Houses are sprayed with malathion by the Sri Lankan Anti-Malaria Campaign at three monthly intervals. However, the villagers do not wholeheartedly cooperate with the spraying teams of the AMC. One reason for this is the nuisance is mainly due to high densities of *Culex* spp. which are poorly affected by these treatments, while the densities of the target mosquito, *An. culicifacies*, are comparatively low even during the transmission period.

After the application of a residual insecticide, a reduction in vector density (e.g. in man-biting rate) and of the mean age (e.g. a reduction in the proportion of parous) can be expected. In Nikawehera, however, we saw an increase in vector densities two weeks after the spraying round of October. This can be explained because breeding places became more abundant after the first rains in November.

Moreover, life expectancy and vectorial capacity were only temporarily reduced resulting in January in the highest peak of vectorial capacity. A second spray round took place at the end of January. A marked decrease in vector density was observed in February as could be expected by the end of the rainy season when breeding places become more scarce. However, the proportion of parous females was not drastically reduced. This may be a cause of concern together with the unchanged ratio of mosquitoes biting indoor or outdoor after spraying. Whether this is due to insecticide resistance, inappropriate use of insecticides, use of outdated insecticides or lack of cooperation from the part of the population should be investigated. From our observations and interviews with villagers and spray teams, it is probably a combination of all these factors. It is obvious that the effect of the residual insecticide was not long enough to have the desired impact on malaria transmission. We suggest that the spray round of January should be advanced to the second half of December. If malathion is still efficient both mosquito density and longevity should be reduced resulting in a decreased malaria incidence. Currently, great efforts go into the spraying campaigns, but timing may need to be improved to obtain a higher impact. More research is needed on the behavioural aspects of *An. culicifacies* sibling species in Sri Lanka. It is not unlikely that different sibling species show a non-uniform exposure pattern (9). The sensitivity of different vector populations to malathion should also be investigated.

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Dynamique des populations anophéliennes dans un village situé dans la zone intermédiaire du Sri Lanka et traité au malathion.


Dynamica van anopheles populaties in een dorp van de intermediate zone in Sri Lanka behandeld met malathion.


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