Transmission dynamics of diurnally subperiodic lymphatic filariasis transmitted by *Ochlerotatus (Finlaya) niveus* in the Andaman & Nicobar Islands

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**Background & objectives:** In India diurnally subperiodic filariasis is prevalent only in the Nicobar district of Andaman and Nicobar Islands, with significant health problem. Sample surveys indicated that this form of filariasis is restricted to a small region of Nancowry group of islands with *Ochlerotatus niveus* as the vector. We therefore carried out a comprehensive study to assess the transmission dynamics of LF in Teressa island in Nicobar district in view of its control and evaluation of interventions.

**Methods:** Entomological studies were carried out for a period of twelve months covering all the seasons in the year, by means of man landing catches in Teressa Island, an endemic island for this form of filariasis. Parameters *viz*., the annual biting rate (ABR), annual infective biting rate (AIBR), annual transmission index (ATI), risk of infection index (RII) and annual transmission potential (ATP), which reflect the dynamics and intensity of transmission of filariasis, were estimated. Host efficiency of *Oc. niveus* was also assessed.

**Results:** The number of vectors biting a person in a year was estimated to be 21851, of which 107 were harbouring infective parasite. Risk of infection intensity was 0.02332. Every person in this study area was at the risk of receiving an estimated number of 22 infective stage larvae per year. The host efficiency index of *Oc. niveus* indicated that over 40 per cent of the microfilariae ingested were able to develop into infective stages. The ATP was 169 with evidence of year round transmission. The pattern of monthly transmission potential suggested that the intensity of transmission was high during summer months.

**Interpretation & conclusions:** Perennial transmission of subperiodic *Wuchereria bancrofti* in the typical forest ecosystem was evident in Teressa Island with transmission parameters suggesting that summer is a high risk season for transmission. Personal protection measure is the method of choice to protect from the risk of infection, because of day biting, exophilic and exophagic behaviour of the vector and larvae are not amenable to larvicidal measures. An alternative method to control the transmission would be to use selective or periodic mass chemotherapy to reduce the parasite load in this community.

**Key words** Andaman Nicobar Islands - diurnally subperiodic filariasis - host efficiency - transmission dynamics - transmission indices - *Ochlerotatus niveus* - *Wuchereria bancrofti*
Lymphatic filariasis (LF) is widely distributed in tropical and subtropical countries and has been targeted by the World Health Organization for elimination as a public health problem by the year 2020\textsuperscript{1,2}. About 120 million people live in 83 countries in Africa, Asia and the Pacific are infected with LF, primarily by *Wuchereria bancrofti* and to a lesser extent, by *Brugia malayi* and *Brugia timori*\textsuperscript{3-5}. Of the three physiological races of *W. bancrofti*, nocturnally periodic and the diurnally subperiodic physiological races are prevalent in India. While the nocturnal form transmitted by *Culex quinquefasciatus* is prevalent in many parts on the mainland India, the diurnal form\textsuperscript{6} is prevalent only in the Nicobar group of Andaman and Nicobar Islands\textsuperscript{7-10} with overall microfilaraemia (mf) prevalences ranging between 8.7 and 20 per cent in different islands.

The diurnally subperiodic form of *W. bancrofti* in the Nicobar Islands is transmitted by *Ochlerotatus niveus*\textsuperscript{9,11}. This species was earlier known as Aedes (Finlaya) niveus. Consequent to the elevation of subgenus *Ochlerotatus* to generic rank and the reclassification of the other subgenera\textsuperscript{12}, *niveus* is now placed in the genus *Ochlerotatus* and is currently known as *Ochlerotatus (Finlaya) niveus*. Though studies on the prevalence, distribution, and assessment of endemicity status\textsuperscript{7,8}, incrimination of the vector\textsuperscript{9}, clinical epidemiology\textsuperscript{10} and host feeding activity\textsuperscript{11} of this infection have been reported, information on the transmission dynamics and the host efficiency is lacking. Moreover, these studies did not focus on long-term (intensive) observations to delineate the transmission dynamics. Information on transmission dynamics is crucial to devise targeted approach to control vector or prevent man vector contact. Host efficiency could provide indications of such level of microfilaraemia as a decision support tool to decide on cessation of MDA. Therefore, we carried out an extensive year long study (November 1999 to October 2000) with an objective of assessing the transmission parameters *viz.*, annual biting rate (ABR), annual infective biting rate (AIBR), annual transmission index (ATI), risk of infection index (RII) and annual transmission potential (ATP) of vector, which reflect the dynamics and intensity of transmission of filariasis.

**Material & Methods**

**Study site:** Approximately 500 islands in Andaman and Nicobar islands are grouped into Andaman district covering northern islands and Nicobar district, which includes the southern islands, respectively. The Nancowry group of islands in Nicobar district (8.5° - 9.5°N and 93° - 94°E) is a small region composed of seven remotely located islands (Bomoka, Chowra, Kamorta, Katchal, Nancowry, Teressa and Trinket) with a population of approximately 25,000 people, mainly Nicobarese tribe who are at the risk of acquiring *W. bancrofti* filarial infection. The present study was carried out in Teressa island (8° 20' N and 93° 7' and 93° 15' E) situated in Bay of Bengal. This island has an area of 87.04 km² and a population of 1,935 Nicobarese residing in 11 villages between November 1999 and October 2000. All these villages are scattered within the dense jungles interspersed with coconut and arecanut groves. The tribal population lives in huts raised on wooden stilts, commonly known as the Nicobarese hut\textsuperscript{11}.

Mean minimum temperatures on this island range between 22.97°C (January) and 25.44°C (March) and mean maximum temperature 28.31°C (January) and 32.36°C (March). The Relative humidity is high and ranged between 72.9 per cent (January) and 87.0 per cent (November). Rainfall is heavy from May to November, and is influenced by both the southwest and northeast monsoons. In the other months, rainfall is generally low, with February being the driest month. The rainfall ranged between 32.7 mm (March) and 351.1 mm (May) during the study period. The soil is porous coral sand, quickly absorbing the rainwater and leaving hardly any water stagnant. Tree holes are the major breeding habitats of *Oc. niveus* in the Nancowry group of islands\textsuperscript{10}.

**Classification of seasons:** The climate in Andaman and Nicobar Islands is moderate with small variations between months unlike north India, where climate has been extreme during summer and winter. However, for the interpretation of the results, the year could be divided into three seasons - summer (February to April), when temperature rises up to 29°C, monsoon (May to October), with substantial rain, and cold season (November - January) with temperature below 28°C.

The study protocol was reviewed and approved by the Scientific Advisory Committee as well as the Institutional Ethical Committee of the Regional Medical Research Centre (RMRC) in Port Blair. Verbal informed consent was obtained from the volunteers.

**Vector monitoring:** Human-landing collections were carried out in five randomly selected villages of the eleven. In all the randomly selected villages, meetings were organized with the tribal chieftains, pastors and other opinion makers of the Nicobarese community. The
objectives of the study and design were detailed to them and their support was sought to identify a volunteer from the respective village to be the prospective human bait for conducting man landing mosquito collections. At the start of the study, 24 h human landing collections were carried out in the selected villages. Since there were no *Oc. nivens* biting between 19:00 and 04:00 h, human landing collections were restricted to the period between 04:00 and 19:00 h. The collections were carried out once in a month in fixed catching stations in each of the selected villages for a period of one year. A human volunteer was made to sit on a raised wooden platform that forms a part of the Nicobarese hut, adjoining the forest fringe, wearing his normal clothing. Mosquitoes landed and attempting to bite on the exposed surface of the bait were collected using oral aspirators by an insect collector. While, insect collectors worked in shifts, the baits continued throughout the collection.

**Mosquito identification and dissection:** The female mosquitoes were transferred to test tubes and labeled. The hourly collections of mosquitoes were kept separately, brought them alive to the field laboratory, anaesthetized with ether and identified under a NIKON stereomicroscope. All the mosquitoes belonging to *Oc. nivens* were dissected to determine the parity status and infection with the filarial parasite. After removing the legs and wings, the mosquito was placed on a clean glass slide with a drop of normal insect saline and the ovaries were pulled out from the abdomen. Ovarioles were separated using a fine entomological needle under a stereomicroscope at 20X magnification. As many ovarioles as possible were examined under a compound microscope to record the number of dilatations to determine the physiologic age. Then the abdomen, thorax and head, of the mosquito were separately teased finely with a drop of saline under a stereomicroscope at 20X magnification. The teased parts were examined under a compound microscope at 100X magnification for the presence of *W. bancrofti* larvae. The filarial larvae present were categorized into microfilariae (mf), I stage (short, inactive sluggish and sausage shaped), II stage (longer and active compared to the stage I) and infective stage or L*$_3$* (long, very active, relatively thin and found in any part of the mosquito body). Mosquitoes positive for any filarial stage was considered as infected and those with L*$_3$* as infective. The total number of different stages of larvae present in different parts of the mosquito body was recorded.

**Calculation of indices:** The following indices, which reflect the changes in the intensity of transmission of filariasis, were computed from human-landing collection data.

**Annual biting rate (ABR):** ABR is the number of mosquito contacts a person receives during one year period. The ABR is the sum of 12 monthly biting rates (MBR), which were computed by multiplying the number of mosquitoes contacting, a man per day with number of days in a month in the respective month.$^{15}$

**Annual infective biting rate (AIBR):** It is the estimated number of mosquitoes with infective filarial larval stage (infective bites) contacting a person during one year period.$^{15}$ It is calculated by multiplying the ABR with proportion of mosquitoes with infective larvae in the population under feeding phase.

**Annual transmission index (ATI):** ATI as proposed by Beye and Gurian$^{16}$, is the estimated number of infective larvae to which a person is exposed during a period of one year, and is widely used in the measurement of density, parity status and parasite load. The formula to calculate this index is given below.

\[
\text{Biting density} \times \text{Proportion of parous mosquitoes out of total dissected} \times \text{Proportion infective to total parous mosquitoes}
\]

**Annual transmission potential (ATP):** ATP proposed by Walsh et al$^{18}$, to evaluate the impact of *Simulium* control in reducing the transmission of onchocerciasis. The basic index to calculate the ATP is monthly transmission potential (MTP), which indicates the level of transmission of infective larvae to humans, during a month. The MTP is calculated by using the following formula.

\[
\text{Monthly biting rate} \times (\text{Total number of infective larvae/Number of mosquitoes dissected})
\]

The sum of 12 MTPs gives the ATP. During the act of feeding infective larvae present not only in the head region and proboscis but also from the thorax and abdomen migrate towards proboscis, from where they get deposited on human skin.$^{19,20}$ Hence, the total number of larvae present in the mosquito body was
considered for the calculation of MTP. A similar procedure was adopted elsewhere.

**Host efficiency of Oc. niveus:** The ratio of the mean number of infective larvae (L₃) to the mean number of microfilariae (mf) per female mosquito i.e., average number of L₃/average number of mf was described as ‘host efficiency index’. This index was calculated from the parasite counts observed by pooling the data on the biting mosquitoes from the five randomly selected villages.

**Statistical analysis:** One way Analysis of variance (ANOVA) was used to test the significance of means of biting rates between seasons and the P value denoted the significance at 95 per cent CI.

**Results**

The biting density of *Oc. niveus* was found to range between 2.0 (females per man hour) during the month of December and 8.1 in February. The mean number of L₃ dissected mosquito ranged between 0 and 1.75 during different months of the year. During the study period, the overall ABR was observed to be 21851, while the AIBR was 107. ATI, the number of infective stages of parasites to which a person was exposed in a year was estimated to be 169. The RII was 0.02332 in the study area.

The MBR was found to be significantly different between the seasons (*P*<0.05). Highest MBR was recorded during monsoon (May-October) followed by summer (February-April) and cooler months (November-January) (Table). A similar trend in MTP was observed. This indicated that MBR was the key determinant of the MTP. The risk of receiving infective stage of the parasite through vector population existed throughout the year except the months of March, July and August (Fig.). Transmission was observed to be low during the monsoon months (May-October) as compared to the summer (February-April) and cooler months (November-January) of the year. The transmission potential was relatively higher in the summer months. In general, the rise and fall in the transmission potential corresponded to the MBR of the vector. The host efficiency index of *Oc. niveus* was found to be 0.43, indicating that a little over 40 per cent of the microfilariae ingested, could be supported by the vector mosquito to develop into infective stages.

**Discussion**

In this study we estimated the transmission parameters through a year long study in Teressa island of the Nancowry region of the Nicobar district of the Andaman and Nicobar Islands, and also attempted to understand the host efficiency of *Oc. niveus* in natural setting. Human landing collection is the method of choice to sample adult population for assessing transmission parameters, as this species does not lend to carry out resting collections in the diffuse sylvan setting due to its exophilic (resting outside human dwellings) behaviour.

Monthly analysis of biting density of *Oc. niveus* showed that the biting was year round with seasonal variations. An estimated number of 107 mosquitoes with 169 infective parasites were available with the vector population for infecting an individual during the study period. De Meillon *et al* hypothesized that a proportion of only 0.414 of infective stages in the

**Table.** Monthly biting rates (MBR) and monthly transmission potential (MTP) in Teressa island

<table>
<thead>
<tr>
<th>Seasons</th>
<th>No. dissected (a)</th>
<th>Monthly biting rate (b)</th>
<th>no. of infective larvae (c)</th>
<th>d=bcx</th>
<th>MTP (d/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monsoon (May-Oct)</td>
<td>1607</td>
<td>9826</td>
<td>8</td>
<td>78608</td>
<td>48.92</td>
</tr>
<tr>
<td>Cold (Nov-Jan)</td>
<td>674</td>
<td>4105</td>
<td>9</td>
<td>36945</td>
<td>54.81</td>
</tr>
<tr>
<td>Summer (Feb-April)</td>
<td>1344</td>
<td>7920</td>
<td>11</td>
<td>87115.6</td>
<td>64.82</td>
</tr>
<tr>
<td>Total</td>
<td>3625</td>
<td>21851</td>
<td>28</td>
<td>611816.8</td>
<td>168.78</td>
</tr>
</tbody>
</table>

Fig. Comparisons of monthly transmission potential (MTP) during the study period with rainfall and monthly biting rate (MBR).
mosquito body will be deposited on the skin during the act of feeding. Assuming this, the number of infective larvae releasing from the mosquito would be 70. Various microclimatic factors play an important role in the survival of the infective stages deposited on the skin. Experimental studies involving cats and Brugia pahangi concluded that only 32 per cent of the deposited larvae could be able to penetrate the host skin. Assuming these deductions in the process of transmission of infective larvae from invertebrate host to the vertebrate host for W. bancrofti, the number of infective stages that would have been deposited on host skin and penetrated into the human body would be 22 in the current study.

The ABR or the total number of Oc. niveus contacting a single person in a year was estimated to be 21851. The AIBR was 107, indicating that a person was at the risk of receiving 107 infective bites. The number of infective stages to which a person was exposed in a year was estimated to be 169. Studies on transmission parameters from Samoa, a persisting endemic focus of diurnally subperiodic filariasis transmitted by Ae. Polynesiensis, have shown very high values of ABR (150268), AIBR (968) and the ATP (3433). Both biting density of Oc. niveus and biting density with infective larvae in our study were only about one seventh of that with Ae. polynesiensis. But the number of infective larvae available with vector population to infect human host was only about one twentieth. Thus, our study area had a relatively high parasite load (11.83%) and low transmission parameters vis-a-vis the South Pacific Islands with relatively low parasite load (5.6%) and high transmission parameters. This probably could be due to higher efficiency of the vector, the Ae. polynesiensis compared to Oc. niveus. Since data on host efficiency are not available for Ae. polynesiensis this could not be confirmed.

The present study also showed that though RII was lower, ATP was well above the threshold level reported for Cx. quinquefasciatus, vector of periodic form of filariasis in Pondicherry (now Puducherry). The host efficiency index for Oc. niveus suggested that more than 40 per cent of the microfilariae ingested were able to develop into infective stages. This figure was higher compared to Cx. quinquefasciatus (0.3 and 2.8) indicating its higher efficiency in supporting the development of parasite in Oc. niveus. For Oc. niveus - W. bancrofti combination, in the absence of any control measure, it is expected that the transmission of infection would continue unabated.

In Teressa island, the major proportion of the Nicobarese population, spends significant part of the day working in coconut plantations for harvesting the copra crops and other forest produces situated in deep forests. As plantation/forests workers constitute the predominant group with the highest mf rates in the Nancowry group of islands and they frequently visit the forests plantations, it is evident that transmission of diurnally subperiodic filariasis occurs in sylvan ecosystem. Elsewhere, variance over the sites of transmission have been reported vis-a-vis, villages in Pacific wild ecological niche, in Western Samoa and Fiji transmission occurred in plantations and along paths leading to the water points.

Vector control is one of the means of LF control. Prolonged vector control for about 5-8 yr have shown sharp decline in the prevalence of mf in the community for the elimination of Anopheles-borne filariasis. A five-year programme to control bancroftian filariasis, through the control of the vector, Cx. quinquefasciatus, implemented in Pondicherry (Puducherry) greatly reduced the quantum of transmission. In filariasis transmitted by Cx. gelidus, near eradication of the vector for 10 yr resulted in the decline of mf prevalence from 14.0 to 0.5 per cent and mf density from 79.1 to 12.0.

From the perspective of vector control programme, which may reduce or eliminate transmission in endemic tracts, it is a difficult proposition and could prove to be cost-prohibitive. Vector control measures are very difficult owing to their exophily and diurnal feeding behaviour of this mosquito. Further, the larvae are not amenable to larvicidal control because of many scattered, peculiar and inaccessible breeding habitats of the mosquitoes. Personal protection measures (use of repellent creams) may be useful for protecting from the risk of transmission. But the community at the risk is tribal; therefore affordability will be a major limitation. In such epidemiological settings, the potential alternative method of containing this infection may be the use of microfilaricidal drugs to liquidate the parasite load in the community, either through selective chemotherapy or periodic mass chemotherapy.

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