Summary and Conclusions
6 Summary and Conclusions

It was for the first time that a detailed study on An. stephensi was done in Kerala. The study was taken up at a time when ‘urban malaria’ emerged as a major public health problem in the state and An. stephensi was implicated in the transmission of the disease. Therefore, a detailed study on An. stephensi was found to be relevant. Studies on ecology, biology, behaviour and variant composition of An. stephensi were carried out in Thiruvananthapuram City during the period from September 1999 to August 2004. Mosquito fauna of the area was also studied during the course of the work with a view to understand the species composition, mosquito biodiversity and prevalence of other mosquito vectors.

The mosquito fauna of Thiruvananthapuram City is rich and diverse with 32 species under 11 genera. Culex was found to be the predominant genus with 10 species followed by Anopheles with 8 species and Aedes with 4 species. There were two species each under the genera Mansonia and Mimomyia. All other genera, namely Armigeres, Coquillettidia, Ficalbia, Malaya, Toxorhynchites and Uranotaenia were represented by one species each.
Indoor resting collection was made in all the eco-regions in the study area for a period of 2 years from September 1999. A total of 23 species under 5 genera were collected. *Anopheles* and *Culex* were found to be the predominant genera with 8 species each. *Aedes* and *Mansonia* were represented by 4 and 2 species respectively while *Armigeres* consisted of only one species.

The outdoor resting collection yielded 12 species under 7 genera. The following species were found to be more abundant in the survey: *Cx. tritaeniorhynchus*, *Cx. gelidus*, *Ae. albopictus* and *Ar. subalbatus*.

An extensive larval survey was undertaken in the study area covering all the seasons during September 2001 to August 2003. The larval survey revealed that the study area is highly mosquitogenic with diverse kinds of breeding habitats. Out of the total 32 species, 31 were collected from the larval survey. *Coquillettidia crassipes* was collected exclusively in the adult survey. Among the major breeding habitats, pools were found to support 21 species followed by ponds and wells with 14 and 12 species respectively. Pits / ditches and seepage water collections supported 8 species each.

The following seven vector mosquitoes other than *An. stephensi* were found to be prevalent in the area: *An. varuna,*
*Cx. quinquefasciatus, Cx. tritaeniorhynchus, Ae. aegypti, Ae. albopictus, Ma. annulifera and Ma. uniformis.*

The biodiversity indices such as man-hour total density, species richness and Shannon evenness showed significant variations over the months in each eco-region in both years. However, the variations in the indices between the different eco-regions were not found significant. This showed that seasons had an influence on the species composition rather than the difference in the ecological characteristics of the area.

The density and richness showed an increasing trend in the monsoon season while evenness was found to be high during the other two seasons (pre-monsoon and post-monsoon). It became evident from the seasonal fluctuation that climatic factors had a bearing on the species composition in this area.

When the diversity indices were correlated with various climatic factors, it was observed that maximum temperature had a negative impact on the density and richness while it favoured evenness. Relative humidity, rainfall and number of rainy days were found to increase the density as well as the richness but these factors did not seem to favour evenness. It was because of these reasons that density and richness were high during the monsoon and post monsoon seasons and low in the summer seasons.
The breeding of *An. stephensi* was encountered in a wide range of habitats such as wells, overhead tanks, cisterns, roof gutters, earthen pots, tins, seepage pits, curing waters, buckets and plastic containers. Among the different types of habitats, the contribution of wells to the breeding of *An. stephensi* was found significantly higher than all other sources. Wells contributed 50.92% of the total habitats positive for the breeding of *An. stephensi*. Tanks/cisterns were the next major breeding habitats which formed 22.09%. It was followed by roof-gutters and curing waters (13.50%), barrels/tins/pots (12.27%) and seepage pools (1.22%). From these observations, wells were found to be the most preferred and the prime sources of the breeding of *An. stephensi* in this area. The ability of this vector species to breed in a wide variety of habitats in all seasons, showed its adaptive capabilities and breeding potential.

The density of immature stages of *An. stephensi* showed marked fluctuations over the months. The density of immature stages in wells varied between 1.17 and 4.83 per dip, while in tanks/cisterns it ranged from 1.73 to 3.47 per dip. The highest and lowest densities in wells were observed in May and October respectively. In tanks/cisterns, the highest density was noticed in May but the lowest density was in November.
The physico-chemical analysis of the water from the breeding places of *An. stephensi* showed that the pH varied from 7.1 to 7.7, alkalinity from 66 to 224 ppm, chlorides from 22 to 66 ppm, nitrates from 0 to 20 ppm and sulphates from 10 to 50 ppm in different seasons. Salinity was found to be too low in all the samples. The correlation analysis showed that higher level of pH was not favourable for the development of larval stages.

The studies on the density, abundance and frequency of *An. stephensi* clearly indicated that the vector species is prevalent in all the eco-regions (urban, peri-urban and coastal settings) in the study area. It was invariably prevalent in all the months in the urban and coastal settings. But its prevalence was erratic in the peri-urban area. The man-hour density, abundance and absolute frequency fluctuated markedly over the months in both years. The density, abundance and frequency were generally high during the monsoon and pre-monsoon seasons. The different eco-regions did not have any influence on the prevalence of this species. The pooled data of the monthly means of the three eco-regions for two consecutive years showed that the man-hour density fluctuated from 0.12 (January) to 0.49 (September), the abundance from 0.67 (January and February) to 1.69 (September) and absolute frequency (%) from 16.67 (December) to 37.50 (October). A more or less similar seasonal trend was observed in the density, abundance and frequency in the individual years as well. This showed
that this vector mosquito had a marked preponderance in the pre-
monsoon and monsoon seasons. The prevalence was found to be low in
the cold months of the post-monsoon season.

The correlation analysis showed that man-hour density of
An. stephensi had significant positive relationship with minimum
temperature. It was due to this reason that highest densities of
An. stephensi were observed during pre-monsoon and monsoon seasons.

The analysis of the collections made from indoor and outdoor
habitats and abdominal conditions of the adults clearly indicated that
An. stephensi was predominantly endophilic in the area.

The proportion of An. stephensi collected from cattle sheds was
83.75% which was more than two times that in human dwellings. It
suggested that cattle sheds were the preferred resting places of this
species.

The animal landing collections showed a bimodal biting rhythm
with marked peaks between 2000 and 2200 hours and between 0200 and
0400 hours. Since the number of mosquitoes collected landing on human
was very small, a definite peak could not be observed in this case. The
peaks in the frequency of landing did not show any significant seasonal
shift.
A detailed morphometric analysis of eggs obtained from females of *An. stephensi* collected from different areas was made with a view to identify the variants of the species in the study area. The length and breadth of the egg, the mode number of the ridges on the egg float and the proportion of egg covered by the float were determined. The mean length and breadth of the egg varied from 474.06 μ to 535.46 μ and from 177.25 μ to 194.52 μ respectively. The mode number of ridges on one side of the egg float ranged from 13 to 15 which indicated that the intermediate form of *An. stephensi* was prevalent in the study area.

The mean duration of tanning of egg was found to be 86 minutes (70 to 105 minutes). The eggs were found to be capable of withstanding mild desiccation for short periods.

The incubation period at room temperature ranged from 42 to 45 hours (mean 43.2). The duration of first, second, third and fourth instar larvae in the laboratory varied from 29 to 37 hours (mean 32.8), 35 to 40 hours (mean 37), 39 to 49 hours (mean 43) and 62 to 67 hours (mean 63.7) respectively. The pupal duration ranged between 31 and 44 hours (mean 34.2).

The growth rate of larvae was determined by morphometric analysis of the head capsule of different instars. The mean geometric progression ratio of the length of head capsule was 1.45 and that of
breadth of head capsule was 1.55. The ratios indicated that the growth of larval instars was in accordance with Dyar’s law.

The hatchability of eggs varied from 74.59% to 95.16% (mean 86.34%). The larval survival ranged from 54.24% to 85.14% (mean 76.4%) and the pupal survival rate was between 81.63% and 96.88% (mean 93.17%). The male-female ratio was found to be 1:1.02. It was found from survival rates that larval stages were more vulnerable than other stages in the aquatic cycle of this mosquito.

The duration for the complete rotation of male genetalia varied from 12 to 16 hours the average being 14.29 hrs. The insemination was observed from the second day of emergence. The insemination rate increased progressively and more than 60% insemination was observed on the fifth day.

Oviposition in the laboratory was observed from 1800 to 0500 hours with a peak between 1900 and 2200 hours. The mean number of eggs laid by the gravid females collected from the field and that of the females reared in the laboratory were 106.70 and 82.41 respectively.

The duration of the first and subsequent gonotrophic cycles in the laboratory were found to be 5 days and 2 days respectively.

The adult susceptibility tests showed that An. stephensi was resistant to DDT 4% but susceptible to malathion 5% and deltamethrin
(pyrethroid) 0.025%. The percent mortality against malathion and
deltamethrin were 98.33 and 100 respectively. Larvae were found to be
susceptible to temephos at a dose of 0.25 mg per litre, the mortality
being 100%.

The study clearly showed that An. stephensi had high adaptive
capability and immense reproductive potential in this area and
therefore, it could invade to nearby new areas rapidly and unplanned
urbanisation will aggregate the situation. Indoor application of
malathion or pyrethroids and treatment of breeding places with
temephos would be one of the best solutions for the interruption of
transmission of malaria. Integrated Environmental Management with
people’s participation on a sustainable basis shall be suggested as an
effective method of mosquito control. Introduction of larvivorous fishes
in the wells and mosquito-proofing of overhead tanks and other water
storage containers would prove to be a long-term solution for the control
of An. stephensi and urban malaria in Kerala.