Previous investigators on Anopheles stephensi related to different aspect of malaria in Calcutta are James (1902), Stephens and Christophers (1902), Annandale (1907), Bose (1911), Paiva (1912), Iyenger (1920), De (1923), Basu (1930), Roy (1931), Covell (1928), Strickland et al. (1933), Senior White (1934), Knowles and Basu (1934), Ganguly (1935), Strickland and Roy Chowdhuri (1936), Sweet et al. (1937), Roy et al. (1938), Senior White (1940), Siddons (1943), Siddons (1943, 1946), Das et al. (1971), Mukhopadhyay (1980), Hati et al. (1988), Chatterjee K.K. et al. (1992).

Still only a few literature are available regarding the vectorial potential, man-vector contact, chromosomal study, water-analysis of the breeding sites of Anopheles stephensi in this metropolis.

Before going to take control measures for combating malaria in a locality it is essential to pin point the ecological characteristics of the vector mosquito (Samuel, 1926, Hati, 1979, WHO, 1974).

This is essentially an Indian species and has been recorded from outside the India mainly from Pakistan, Afghanistan, Arabia, Iraq and Iran. This species has a wide distribution throughout the whole of India and has been recorded from Kashmir and Jammu. It also occurs in Burma and Yunnan but has not been recorded from Ceylon. It is also collected from certain regions in China South of 25°N.L.

It is normally an urban mosquito though occasionally found in the rural areas. It is a highly efficient malaria-carrier and is responsible wholly or partly for malaria in cities like Bombay, Madras, Bikaner, Calcutta, Quetta, Sind, Kohat, Mysore etc.

It is an important rural vectors in western Pakistan, Bahrein and Iraq. It prefers to breed in small collections of water for oviposition such as pools, chowbchas, stream beds, springs and red pages.
Two broad palpal bands and the broad scaling on the mesothorax speckled legs. Two broad apical bands of equal and the palp speckled.

Chief character – At least 4 dark spots on the costa. Femora and tibiae speckled. Dark footed series (tip of hind legs definitely dark).

A. Three pale bands on the palp 3 or less than 3 dark spots on vein 6.

Distribution of *Anopheles stephensi* in Calcutta

In February 1900 Rogers studied the relationship of the drinking water, water logging and distribution of anopheline mosquitoes to the prevalence of malaria in north Calcutta along the bank of the Hooghly.

In 1900, Dr. Cook, Health officer of Calcutta, investigated the connection between the anopheline mosquitoes and malaria in the city of Calcutta.

*Anopheles stephensi* was first described only in 1901 by Liston. James in 1902 first recorded the presence of this species in Calcutta. B. Brahmachari in 1909 carried out investigations in 1906-1907 in Chitpur-Cossipore. He found four species of anophelines. Annandale reported by Theobold in (1908, 1910) and Brunetti (1907-1912 and 1920) found *Anopheles stephensi* in the garden of the Indian Museum.

In 1911, Bose found anopheline larvae and remarked ‘Burrabazar in Calcutta is very bad with malaria cases’.

Brahmachari in 1912 collected *Anopheles stephensi* larvae in Calcutta.

In 1912, Paiva conducted a mosquito survey and *Anopheles stephensi* larvae were obtained from Maniktala (North Calcutta), Beliaghata (East Calcutta) and Sealdah, Entally (Central Calcutta), Daimond Harbour Road (West Calcutta), Tiljala...
and Kajal (East Calcutta), Beckbagan, Hazra Road, Ballygunge, Tollygunge and Bhowanipore (South Calcutta).

The researches of Iyenger (1920) and of Basu (1930) have shown that *Anopheles stephensi* have shown that this species is exceedingly prevalent throughout Calcutta, even in the most central parts of the city. It is not found to occur under natural conditions in Lower-Bengal.

Distribution of *Anopheles stephensi* in different parts of the city. The distribution of this species corresponds with the sewered area of the city. In this connection it is advantageous to remember that only certain parts of Calcutta, comprising about one-fourth of the total area of the city, enjoy a water carriage system of sewage disposal and area provided with an unfiltered water supply. *Anopheles stephensi* is very prevalent in the sewered area, and the larvae were found mainly in the unfiltered water cisterns.

Basu in 1930 surveyed malaria mosquitoes i.e. *Anopheles stephensi* Liston in Calcutta, the area was bounded on the north by Machubazar Street, Cotton Street, LalBazar Street and Dalhousie Square North, on the east by Amherst Street and on the west by Charhock place and Clive Street.

In 1975-80, Mukhopadhyay et al. worked in central Calcutta, BowBazar and captured *Anopheles stephensi* mosquitoes.

In 1986-1990, Hati et al. surveyed nine areas of Calcutta namely Dharmatala, Bowbazar, Central Avenue, Sealdah, Tilgala Beliaghata, Garia, Bidhan Nagar, BaghBazar and obtained *Anopheles stephensi*.

*Anopheles stephensi stephensi* were distributed in central Calcutta (Siddons, 1946).
**World**

*Anopheles stephensi* is widely spread throughout the Indian Peninsula from the extreme North West to the extreme South and East (Krishnan, 1961)\(^2\). It is also distributed in Pakistan, Afghanistan, Iraq, Iran, Baharin, Oman, Saudi Arabia, Bangladesh, South China, Burma, Thailand.

*Anopheles stephensi* (type form) has been also found in Sinai Egypt, 1.5 Kms from the Suez Canal, the first record on the African continent (Gad, 1967)\(^3\). In Iran, this species is distributed on the Southern slopes and valleys of the Zagros chain up to 900 m altitude in Khuzestan, Fars Kerman, Abbas, Beluchistan and Southern Kerman shahans provinces\(^4\).

Synonyms of *Anopheles stephensi* are *Anopheles* (myzomyia) *stephensi*, Liston, *Anopheles metaboles* Theobold 1902; *Neocellia intermedia* Roth well 1907 and *Anopheles falquii* de Mello, 1918 (Covell, 1927).

Both the type form and variety are present in all mainland zones of the country. Outside India, it had been presumed that the variety *Anopheles stephensi mysorensis* did not occur beyond the Indo-Pakistan region, but it is now known that ‘mysorensis’ occurs widely in Iran also and is a malaria vector (T. Rama Rao, *Anophelines of India*).

**India**

According to Sweet and Rao, the type form was distributed in Bengal city, Mysore, Delhi, Pune, Calcutta and variety mysorensis was distributed in rural parts of Mysore state, Pune, Calcutta, Sukkar (Sind), Hyderabad (Sind).

In Decan plateau, *Anopheles stephensi mysorensis* were present\(^5\) (Viswanathan & Rao, 1980).
Anopheles stephensi was noticed in all mainland zones becoming rather scarce at high altitudes in India. It is not found in Andamans or Lakshadweep, Nepal and Sri Lanka.

Global Distributions of Malaria

The enormous area covered by India means that the malarious situations in various parts of the country are extremely diverse. In the foothills of the Himalayas, from Kashmir in the west to Arunachal Pradesh in the east, malaria was hyperendemic. In the west, in Jammu and Kashmir and Himachal Pradesh over 99% of infections are due to *P. vivax*. Whereas in the north, Assam 59% of the infections are due to *P. falciparum*. Slightly further South in the state of Maghyalaya, a *P. falciparum* infections rate of 82% occurred in 1978 (Pattanaik and Roy, 1980).

In western Rajasthan, the climate in desertic, but from Punjab and Harayana in the north, through eastern Rajasthan, Gujrat, Maharastra east of the Western Ghats to Karnataka, there is marked by seasonal malaria with particularly in the north, an eight yearly epidemic cycle, throughout this area, *P. vivax* infections predominate, varying from over 99% in the Punjab to 84% in Maharastra. East wards along the valleys of the Ganges and Brahmaputra, malaria endemic in the States of Uttar-Pradesh, Bihar and West-Bengal. In W.B. Hati and Mukhopadhyay (1980) observed *P. vivax* infections account for 89% of cases and that *P. malariae* has completely disappeared. On the western side of the Western Ghats from Bombay in the north to Trivandum in the South, there is a narrow strip of low-lying coastal land that is almost free from malaria but east of that in the foot-hills of Ghats malaria again becomes hyperendemic.

Saxena (2001) worked on eco-epidemiological characteristics of an unstable peri-urban focus of falciparum malaria. In Delhi, during post monsoon period i.e. Oct.-Nov. malaria reached a peak due to extensive breeding of 5 species of *Anopheles* mosquitoes including *Anopheles stephensi*. 
In urban areas in the built in portion of the township, *Anopheles stephensi* is the principal vector. The type form of *Anopheles stephensi* is predominantly urban, while *mysorensis* is mostly found in rural areas. The type form of *Anopheles stephensi* has been recorded from major cities like Delhi, Mysore, Bangalore etc. while both 'type’ form and *mysorensis* have been encountered in Pune, Calcutta etc. The distribution of type form or *mysorensis* requires precise mapping.

Tyagi et al. (1996)\(^7\) described the chronological and spatial distribution of anopheline vectors of malaria in the Thar desert.

Kochar et al. (1997)\(^8\) observed increase in the annual rainfall, collection of water in Indira Gandhi canal forestation of shrubs around it, adaptation of *Anopheles stephensi* to desert climate helped to increase malaria in Bikaner, Rajasthan.

**Seasonal Prevalence of *Anopheles stephensi* larvae**

During the four years (1928-1932) in the one square mile area around the STM (School of Tropical Medicine) in all 11,927 examinations for breeding places of *A. stephensi* were carried out, with 3,942 positive findings. This gives some idea of the density of *Anopheles stephensi* breeding in the city. The total number of *Anopheles stephensi* larvae captured was 68,055, the highest numbers being found in July and the lowest in April.

Rain water are stored in different types of containers which acts as a breeding sites of *A. stephensi*. Some of the earthen tubs are used as garden tubs in which rain water collects, some of the iron tubes are used as fire buckets in buildings from many of which larvae of *Anopheles stephensi* were collected (Tin mugs, wooden boxes, glass vials etc.)\(^6\).

After the use of pitch, barrels are left by in the roadside and rain water accumulate. Pucca drains – when blocked by dirt and with stagnant water in them form suitable breeding sites. Out of 21 examined – 10 showed larvae.
Iyenger (1920), Basu (1930), Covell (1932) and Strickland Roy and Chaudhuri (1933) have clearly shown that *A. stephensi* is exceedingly prevalent throughout Calcutta where it generally breeds in overhead cisterns and also in fresh water in artificial containers. Judging from the large no. of larvae of *A. stephensi* that can be obtained throughout the year, one would naturally believe that the number of adults would be sufficient to cause an outbreak of the disease.

The researches of Strickland Roy and Chaudhuri (1933) > that malaria transmission could easily take place at temperature varying from 62°F to 96°F, and at relative humidity ranging from 32 to 85% they further concluded that nearly cent percent of the mos. were infected . . . between 62°F and 87°F at relative humidity ranging from 32-70%. The ideal conditions for transmission of malaria in this city exist during late autumn and winter.

Paiva, 1912, Earthen pots in most cases proved to be the most usual breeding places. In some cases open drains were found to be equally suitable.

Larvae of every species found during the survey were taken from earthen pots, especially during the rainy season.

Ganguli’s (1935) observations on Malaria carrying Mosquito of Calcutta. *A. stephensi, A. sundaicus* and *A. varuna* are the only species transmitting malaria in Calcutta. *A. stephensi* is much more prevalent than the other two.

Mahesh et al. (1995) studied on underground tanks supported the breeding of *Anopheles stephensi* in Dun-valley, Dehra Dun districts especially at DAV & DBS College.

Mariappan et al. (1997) described the different kinds of breeding habitats of mosquitoes including *Anopheles stephensi* in Kochi.
Basu (1930) observed that the largest catches of larvae took place in July and lowest in December.

Knowles and Basu in 1934 showed that the peak of *Anopheles stephensi* breeding in Calcutta occurs in July and there after rapidly falls until December. Simultaneously the malaria cases through they start to rise in July reach their peak in November when adult density was less than half that of July.

Ramsay and Macdonald (1936) showed that *Anopheles stephensi* breeding was very low in the cold weather.

In 1980, Mukhopadhyay performed an ovitrap experiment in Calcutta, which showed larval density was highest in the month of the July that means in monsoon.

In 1992, Biswas et al. observed that larval density was highest in August and lowest in the month of December.

Toyon and Chakroborty observation (1998) behavioural factors of *Anopheles stephensi* the principle vector of malaria in Calcutta. They observed the density of *Anopheles stephensi* larva was maximum in July and November prolongation of monsoon that resulted to high larval density of *A. stephensi*. They bred in fresh and rain water.

Batra and Reuban in 1979 observed *Anopheles stephensi* in wells and cisterns in Salem, Tamil Nadu in Suramangalam, 20-37.5% of the wells were breeding. The highest percentage of breeding was obtained in June and the lowest in April, at a time when 6.9% of the wells were dry. Breeding density as shown by relative numbers of first instar larvae, pupae were high in December and January but fell to a low level in April. After some rain in May, breeding increased to high levels from May-July. Due to heavy rain after the month of June larval density were declined.
Bhatt et al. in 1991 observed that the larval densities of *Anopheles stephensi* in Kheda district Gujarat remained low in all the three physiographic areas i.e. canal irrigated, non canal irrigated and reverine area throughout the year.

But on the basis of adult densities it was noticed that the larval densities of *Anopheles stephensi* was highest in the month of August (monsoon) and lowest in winter i.e. January.

Kumar and Thavaselvam in 1992 conducted a longitudinal study on the breeding habitats of *Anopheles stephensi* in Panaji, Goa. They reached 67,360 breeding sites, among it 1.1% contained *Anopheles stephensi* immatures. Breeding sites of *Anopheles stephensi* larvae constituted 0-1.3% wells. 1.4-11.4% fountains, 0.8-6.1% masonry tanks, 0.1-4.0% overhead tanks curing water in construction sites 0.6-9.0% ground water tanks 0-1.4%, types 0-8.9%, barrels and tins 0-5.5% and intradomestic containers 0-1.9%.

*Anopheles stephensi* larvae also bred with *A. subpictus*, *A. vagus*, *A. barbirostris*, *Culien* sp. and *Aedes* sp.

Mishra and Singh (1997) observed that mosquito breeding are found in rice fields in two ecological terrains of district Jabalpur, M.P.

Sharma (1995) observed the seasonal variation in the density of larvae and adult of malaria vectors *Anopheles stephensi* and *Anopheles culicifacies*. Highest larval density was recorded in August. Breeding habitats are tanks, ponds and wells.

Haq, Kani, Sharma, Sharma (1998) observed that small number of *Anopheles stephensi* were collected from the sewage system plant site in Anand City, Gujarat. Larval density was maximum in monsoon (40/dip) and lowest in summer and winter (10/dip).

Kar, Eapen and Ravindram in 1996 worked on domestic breeding sources and their contribution in *Anopheles stephensi* breeding in Dindigul, Tamil Nadu. A study conducted between June 1994 to May 1995 in 10 different types of breeding habitats in 44
wards of Dindigul town, Tamil Nadu, India revealed that of 51785 habitats 225 (0.437) were found positive for immatures of *A. stephensi*. The overall positivity varied between 0.03 to 1.31% with peak density during July. The observed positivity per habitat was overhead tanks 0-7.07% wells 1-1.69% underground tanks 0-2.26% tappits (under ground tanks used for collecting drinking water supply) -0-2.26% tappits (under ground tanks used for collecting drinking water supply).

Outside tanks (permanent), 0-2.42% outside tanks (temporary), barrels (1-1.32%) inside permanent tanks 0-2.0% and others 0-25.01%. In 16.0% of habitats, larvae of *Anopheles stephensi* were found with *A. subpictus, Aedes aegypti, A. vittatus* and *Culex quique fascitus* in different combinations. Overhead tanks were found to be contribute minimum *Anopheles stephensi* larval site in this area.

Menon and Rajagapalan 197990. The proportion of wells breeding *Anopheles stephensi* ranged from 8.3% in January to 17.5% in October. *A. stephensi* were found breeding during rainy season.

Vector ecology on the basis of WHO observation – the larval micro habitat of some anopheles and culicine mosquitoes has been gathered, but many species required, intensive ecological study.

**Seasonal Prevalence of Adult *Anopheles stephensi***

Density of the vector is most important factors in the epidemiology of malaria. It determines the degree of contact between man and the vector and therefore the intensity of malaria transmission.

From the earliest days after Ross's discovery of the role of anophelines in malaria transmission, numerous attempts have been made to determine how this disease could be controlled.
One of the practical uses of the perman - hour method has been to estimate the \( \text{density (pmno)} \) of a vector, a concept developed by Ross in 1911, in his book on “Prevention of Malaria” (quoted from Wernsdorfer & McGregor).

In 1917, Sinton observed in Kohat district that \textit{Anopheles stephensi} began to appear in early part of May in a very few numbers and increased in abundance until July and August, up to October it was found but Nov.-April, \textit{Anopheles stephensi} were completely rare.

Ray, Chandra and Siddons (1938) observed \textit{Anopheles stephensi} was prevalent in May-September, the largest number was found in September in Calcutta i.e. maximum adult density was in monsoons.

White (1940) presented the following observations that out of 169 \textit{Anopheles stephensi} 53, 82 and 34 were collected in monsoon, summer and winter respectively.

Dey (1923) Adult \textit{Anopheles stephensi} density was maximum in rainy season and no appreciable decrease in their number is noticed even in Calcutta.

Observations of Ganguli in 1935 there was a marked increase in the number of \textit{Anopheles stephensi} in the rainy season and was reached a peak in August. After the rainy season the number gradually declined and the minimum was reached in December.

According to Siddons (1946) density of adult \textit{Anopheles stephensi} was maximum in October, therefore transmission was highest in November. Adult density is indirectly related with rainfall. Adult density was maximum in rainy season and the transmission season was from late July to late September, when rainfall was become well established, then adult density was gradually increased.

Ramsay and Macdonald in 1936 reported that in coastal towns like Bombay and Calcutta, it appeared to have a marked seasonal increase during the monsoon though it is to be found at all times.
In Madras city, Bhaskar Rao et al. in 1946 found 976 (48.4%), 678 (33.6%) and 363 (18%) Anopheles stephensi in winter, monsoon and summer respectively.

Singh et al. 1957\textsuperscript{91} observed 33.0 per 10 man – hours of both Anopheles stephensi stephensi and Anopheles stephensi mysorensis.

Bhatia et al. in 1958\textsuperscript{92} collected a total of 1924 Anopheles stephensi mosquitoes from near Delhi average 75, 66, 28.25 were collected in summer Monsoon and winter respectively.

From man landing collection, total twenty seven Anopheles stephensi were captured, among them 20, 5 and two were captured from rainy, winter and summer respectively (Mukhopadhyay, 1980).

Rao, 1981 explained that “Per man – hour” figure does not give any indication of the actual number biting man per day, but it was an important entomological parameter affecting malaria transmission.

Subbarao et al. in 1984\textsuperscript{93} captured the highest number of Anopheles stephensi in February in Mandora, Harayana.

In 1987, Hati et al. observed that in Calcutta, maximum collection (90.5%) of Anopheles stephensi was found during the monsoon June-October. The peak adult density was in July. In Nov. to May – adult density was very low, January and March, no adult was observed. PMHD of Anopheles stephensi was 0 in January and March (1986) and 1.1 in July (1986) and mean PMHD of vector species was 0.3. Neogy and Sen in 1962\textsuperscript{94} observed that PMHD of Anopheles stephensi was 1.1 in human – dwelling and C.S. In rural Bengal, March to June was dry period, July to September was rainy season and winter constitutes December, January and early part of February. Adult density was minimum in September.

Chaudhuri and Sen in 1987\textsuperscript{85} surveyed Anopheles stephensi both adult and larvae in Chetla area (Kolkata South) of the city on the basis of their observation, it was noticed that prevalence of Anopheles stephensi adult was maximum in the month
of September 1986, PMHD was 0.45 and least was in the month of March – PMHD – 0.03. Adult was very prevalent in rainy season, i.e. June-October.

According to Bhatt et al. 1991 – Adult *Anopheles stephensi* was maximum in riverine area (0.65%) followed by canal irrigation 32% and 0.19% on canal irrigated area. In Gujrat (Kheda district) adult densities remained below one per man hour throughout the year with minor fluctuations although adult density became slightly increased with the onset of monsoon and it almost stabilized from August to October.

In non canal irrigated area, MHD was one throughout the year.

In riverine area, PMHD of *Anopheles stephensi* was less than two throughout the year except Jan.-Aug. from 1985-1988 in above three areas.

Tiwari et al. (1997) worked on seasonality of indoor resting Anophelines species in stone quary area of District Allahabad, UP and *Anopheles stephensi* constitutes 0.01% of total anopheline collection.

Sharma (1994) worked on seasonal prevalence and resting density of *A. stephensi* and showed that adult densities was 7.09/man/h during Sept. in Gurgaon. Nala and pits were the most infested larval habitats.

Sharma (1995) observed the peak adult density for malaria vector *A. stephensi* (4.14 PMHD) was reported in August.

In January-March, *A. stephensi* density was high and it was gradually increased and monsoon peak was observed in August and from September, density became gradually declined upto November.

In 1992, Hati et al. observed that maximum collection of *Anopheles stephensi* occurred in rainy season and showed a peak in July. In June, PMHD was 0.8 in nature, from the beginning of the monsoon, its became drastically declined after September, very few are obtained in summer and winter season.
On the basis of observation of Chatterjee et al. (1986-1990) the density of adult *Anopheles stephensi stephensi* was found maximum in rainy season (July-October) i.e. 74.0% in temporary hutments, 70.1% in cattle-sheds and 86% in brick built houses with a peak in July that indicate that in Calcutta, rainy season is more conductive to the building up of adult population of this species than winter and summer. The PMHD of *Anopheles stephensi* were 0.42 (0-1.7) in temporary hutments, 0.68 (0-2.6) in cattle sheds and 0.01 (0-0.06) in brick built rooms. Prevalence of adults of the vector species was higher in both temporary hutments and cattle sheds than brick built rooms.

Tandon and Chakraborty in 1998, observed adult density of *Anopheles stephensi* was highest in Monsoon (PMHD = 0.8) in the morning and PMHD 0.6 in the evenings in human-dwelling in South Calcutta, followed by that in winter its were not encountered in summer and PMHD in cattle-shed was 0.9 in monsoon in the evening but during early hours of morning, there were no trace of adult *Anopheles stephensi* in indoor.

**WORLD**

*Anopheles stephensi* plays an important role as a vector of malaria in the coastal areas of the persian Gulf and Oman sea from Abadan to Bandar Abbas and Chahbahan. Here, *Anopheles stephensi* was active throughout the year with two peaks, one in April-May and other, which is higher in August-September.

In hilly areas of the Southern slopes and valleys of the Zargros chain or in Beluchistan, its activity started in May and reached its peak in August and then gradually declined. In cold weather, no *Anopheles stephensi* was obtained (Manouchchri et al. 1976)98.

Reisen, Mahmood and Parveen (1982)99 reported that the maximum *Anopheles stephensi* were found during November and December in rural Punjab province, Pakistan.
Chromosome

In medical entomology, species recognition is often carried out as a routine activity by which formal Latin names, are assigned to anopheline mosquitoes following morphological criteria and related taxonomic keys. However, anopheline species identification should be understood as the malariologists tool towards his actual task, namely the biological characterization and effective monitoring of vector populations in the context of epidemiological observations or control programmes.

The limits of the conventional morphological approach to species identification and the need for a genetical approach have been recognized in malaria entomology already in the 1930s in connection with the famous problem of “anophelism without malaria” in Europe and the related studies which led to the discovery of the *Anopheles maculipennis* complex.

Morphological features appear to be in many cases very useful tools for anopheline taxonomy, the genetical analysis of various groups of closely related species or species complexes shows that reproductive isolation may be acquired without or before morphological divergence, resulting in a speciation that is undetectable through morphological observation alone. The identification of such sibling species is not of minor malariological importance. Morphological similarity or identity generally implies close phylogenetic relationships and recent speciation processes but it does not imply similarity or identity of binomics especially when dealing with sympatric (co-existing) taxa. Biological diversity is the prerequisite for a species to achieve successful expansion into the range of a close relative and in groups of mosquitoes involving malaria vectors, biological diversity frequently results in a shift in the degree of contact with man and/or his environment.

Anopheline mosquitoes are a suitable material for cytotaxonomic applications. Following the pioneer work of Friggi (1947-1953) on the *A. maculipennis* complex chromosomal characters have been successfully utilized for the identification of sibling species. The low chromosome number (2n=6) of the genus *Anopheles* facilitates the recognition and comparison of the various karyotype elements on polytene (Giant)
chromosome complements. Polytene chromosomes were particularly exploited as a cytotaxonomic tool after it was shown that good preparations can be obtained not only from larval salivary glands but also from the adult female ovaries (Coluggi, 1972)\textsuperscript{100}.

Inversion (2) $R_1$ in \textit{Anopheles stephensi}, its distribution and relation to egg size was studied by Suguna (1981)\textsuperscript{101} studied on inversion in chromosome (2) $R_1$ is widely distributed in Indian populations of \textit{Anopheles stephensi}. From measurements of eggs, the populations reported here fit closely to the measurements of type form of \textit{A. stephensi}. The overall egg size and inversion $(2)R_1$ did not show any correlation, variation in the occurrence of this inversion in different areas and its place in answering the varietal status of \textit{Anopheles stephensi} are discussed.

Chromosomal arrangement of Pondichery and Swamapuri belong to the homozygous standard type\textsuperscript{8}. Cytological examination of the three stocks revealed the presence of inversion $(2)R_1$ in Salem. It has been suggested that \textit{Anopheles stephensi} included more than one biological species used for the standard and inverted arrangement respectively and the heterozygotes represented the hybrids.

\textbf{INDIA}

The marked difference in the habits of \textit{Anopheles stephensi} in many parts of India observed by early observers had led to the postulation of the existence of biological races. Mulligan and Baily in 1936\textsuperscript{102} in Quetta and Ramsey and Macdonald in 1936 in Bengal were observed this matter. Rao, Sweet and Rao in 1938\textsuperscript{304} worked in Mysore state noticed for the first time certain difference in the eggs both in measurements of length and breadth and in the number of ridges on the egg floats. They named one of the varieties as variety \textit{mysorensis}. The two forms were given a sub species by Puri (1949)\textsuperscript{104} and it was adopted by Stone \textit{et al.} in 1959\textsuperscript{105,106}, but Knight and stone in 1977\textsuperscript{116} have reduced it to just a synonym.

In 1937 Sweet and Rao measured\textsuperscript{109} two kinds of eggs, its length, breadth, length of the egg floats, the number of ridges on the egg float, they divided eggs into
classes on the basis of their measurements one was 'B' type i.e. *Anopheles stephensi stephensi* and other was 'M' type i.e. *Anopheles stephensi mysorensis*.

Sweet and Rao in 1937 measured ova which were collected from different corners of India.

The *Anopheles stephensi* of 'B' (type form) collected from Mysore state came from Bangalore and Mysore cities only. From Delhi, Major Afridi and Doctor Puri, Doctor Barber and Rice from Poona, Dr. B.C. Basu from Calcutta supplied 'B' (type form) *Anopheles stephensi*, and from Mysore state, 40 females, 1828 ova, from Delhi 21 females, 895 ova, from Poona one female, 45 ova, from Calcutta 6 females and 220 ova, were measured in microns so total 68 females were given 2988 ova.

Average length - 554.92 Microns ± 0.30
Average Breadth - 204.44 ± 0.14
Length of float - 293.89 ± 0.29
No. of ridges - 18.06 ± 0.02
Proportion : Length of float : Length - 0.528 ± 0.004

*Anopheles stephensi*  *mysorensis*  
From Mysore  112 females  5258 ova
From Sukkur, Sind  11♀  535 ova
Hyderabad, Sind  7♀  303 ova
Poona  11 females  570 ova

Above all the ova were measured and found its average length of eggs 476.20 ± 0.20.

In 1987, Subbarao *et al.* surveyed in Delhi and around Delhi and measured eggs and found three kinds of eggs, type form, intermediate form and variety *Anopheles stephensi mysorensis*. All the three forms i.e. type form, intermediate, variety all found in semi urban areas and intermediate and variety are found in rural
areas. Based on the observation of Dr. S. Subba Rao et al. (1987b)\textsuperscript{110}, it was indicated that variation in ridge number is controlled by more than one genetic factor.

Studies on the genetic and cytogenetics of vector species were intensified in India in order to get a better understanding of their Biology. During 1970s work was limited to the description of karyotypes and preparation of line diagrams of salivary polytene chromosomes maps (Kitz-Miller, 1976)\textsuperscript{111} and formal genetic studies on phenotype markers (Subbarao Vasantha Sharma, 1981)\textsuperscript{112}. The discovery of species A and B by Green and Miles 1980\textsuperscript{113}, species C by Subbarao \textit{et al.} 1983 and species D by Vasantha \textit{et al.} (unpublished) of \textit{Anopheles culicifacies}, however, initiated the beginning of cytotaxonomic studies and their relationships to the epidermiology of malaria in India. Other vector species that have been studied though not, extensively are \textit{Anopheles stephensi}.

\textit{A. stephensi}, \textit{Anopheles culicifacies}, \textit{A. fluviatiles}, \textit{A. philippensis}, \textit{Anopheles subpictus} the cytotaxonomic studies carried out on these vectors species will be dealt with intense those paper.

\textit{Anopheles stephensi} is an established malaria vector and has a wide geographical distribution, the Indian subcontinent. It also plays an important role in the transmission of malaria.

**Calcutta**

Senior White (1940) examined the \textit{Anopheles stephensi} population of Calcutta city from the point of view of the possibilities of the existence of two races and stated that both the type form and variety (mysorensis) occurred and that in recent years the type form had suddenly became rare. It appeared that the fertility of the \textit{mysorensis} form in captivity was very low.

Studying chromosomal inversions in \textit{Anopheles stephensi}, White (1974)\textsuperscript{107} has pointed out that certain aspects of morphology and behaviour were associated with them.
Knight and Stone in 1977 published catalog of the 'Mosquitoes of the World' have now listed *mysorensis* as a synonym following the findings.

Stephens and Christophers (1902) who gave the measurement that the float ridges numbered 15 and the floats occupied the middle half of the ova or slightly less they were captured specimen from Lahore and Nagpur. These measurements are repeated by Christophers and Barraud in 1931 for *Anopheles stephensi* ova, as the specimens was named in 1937 by Sweet and Rao. Chaudhury, Mosquito Control Officer, CMC informed Senior White that type farm of Anopheles stephensi decreased rapidly in Calcutta city.

**WORLD**

Afridi and Aslamkhan *et al.* were able to differentiate the existence of the two races in Karachi Pakistan by egg measurements. A comparative study was held. Mosquito captured from India, Iraq, Iran. Rutledge (1970) made several experiments and also observed eggs and measured it, and found three strains of *Anopheles stephensi* with respect to egg length, width, number of ridges on egg-float and length of egg-float and oviposition.

The Iran strain resembled ‘mysorensis’ but the Iraq and Indian shrains were similar (i.e. Type).

Ashraf and Aslamkhan (1973) made a study of the measurements like the number of ridges to find out variation with in the eggs of a single female. 25-50 eggs of 50 individual females from the Karachi strain the so called *Anopheles mysorensis* were measured. On studying 1, 712 eggs it was concluded that both the type and variety were present here.

Detailed maps of salivary gland chromosomes have been made of *Anopheles stephensi* by Sharma *et al.* in 1969 but they describe only on the type form.
In 1973 Siddiqi and Aslamkhan\textsuperscript{125} seems to indicate that an inversion has been recognised in the polytenechromosome of \textit{Anopheles stephensi mysorensis}.

Torre and A. Della (1997)\textsuperscript{126} described the simple method for polytene chromosome preparation from Anopheline mosquitoes in U.K.

Polytene chromosomal studies were conducted different workers, in different places of the world.

Examination of the polytene chromosomes have shown that urban population are highly polymorphic having many (ten) floating inversions while rural populations are monomorphic except for 'b' inversion on chromosome arm 2.

Similar studies were done by Mahmood and Sakai in 1984\textsuperscript{114}, found that the rural and urban \textit{Anopheles stephensi} populations from Pakistan different in inversion frequencies.

Coluzzi \textit{et al.} (1973a)\textsuperscript{115} reported that 2Rb inversion homozygotes had \textit{mysorensis} type eggs. No such correlation was found by Suguna (1981) and Subbarao \textit{et al.} (1987b).

A total of 26 floating inversions have so far been identified by Coluzzi \textit{et al.} (1973b), Mahmood and Sakai 1984, Vasantha \textit{et al.}

Coluzzi and coworkers have been able to associate certain life-table characteristics and behavior traits in \textit{Anopheles stephensi} with the Karachi (2Rb) inversion (Coluzzi, 1972, 1973; Coluzzi and Dideco, 1974)\textsuperscript{116}.

They have described five other autosomal paracentric inversions from laboratory colonies of this species (Coluzzi \textit{et al.} 1970, 73).

According to Mahwood and Sakai, 1984, a preliminary survey of natural population of \textit{Anopheles stephensi} Liston in Pakistan has discovered the presence of 16 autosomal paracentric inversions. Twelve previously undescribed inversions were observed in the field populations and an additional new one was seen in a laboratory
colony. A comparison of urban and rural population showed striking difference in the kinds and frequencies of paracentric inversions. They also observed that mosquitoes which were captured from the two rural districts, no inversions were found among them.

Mahmood and Sakai (1985)\(^{119}\) prepared a polytene chromosome map of *Anopheles stephensi* from the ovarian cells of adult females.

Chhilar and Chaudhury (2004)\(^{117}\) collected *Anopheles stephensi* (Liston) larvae from the water pools in Sonipat (Haryana) and observed a total of 18 structural aberrations out of which 10 were heterozygous paracentric inversion, 2 translocations, 2 cases of ectopically paired bands, one deletion and one case of chromosomal break.

Choudhuri and Gupta (2004)\(^{118}\) studied the eggs of *Anopheles stephensi* which were collected from Chandigarh (SEM studies on the egg surface architecture) and observed 12-16 ridge numbers on the egg float of *Anopheles stephensi* which was corresponded with intermediate form.

**Sporozoite Rate, Infection and Infectivity**

*Anopheles stephensi* is one of the major vectors of malaria in India and in neighbouring countries of Pakistan, Iran, Iraq.

**CALCUTTA**

Mayne (1930)\(^{127}\) established that there were some influence of relative humidity on the life and infectibility of *Anopheles stephensi*.

Iyenger (1933)\(^{128}\) observed that positive results were obtained in every one of the batches of *Anopheles stephensi* fed on infective gametocyte carrier of *Plasmodium falciparum*. 
Total 122 mosquitoes were dissected, 32 were positive for sporozoite and 71 were positive for oocysts and 76 had either sporozoites or oocysts or both.

Strickland et al. (1933) dissected salivary glands of Anopheles stephensi and observed sporozoites in Calcutta under laboratory condition. The striking period of infection (i.e. 90%) was found in November to January and non-infection period was from March to July.

In 1943\textsuperscript{129}, Roy, under laboratory condition an experiment was made for calculating the infectivity rate and oocyst rate. 50.9 and 45.3 were oocyst and sporozoites rates respectively, indicating that Anopheles stephensi was the classical vector of malaria in Calcutta City.

In 1944\textsuperscript{130}, Knowles and Basu made a laboratory experiment for studying the sporozoite and oocyst rate in Anopheles stephensi in both controlled and uncontrolled situation of temperature and humidity. Infection of Anopheles stephensi was related with temperature and humidity.

In Calcutta, Anopheles stephensi had an important role as a vector was established by Siddons (1946)\textsuperscript{131}. From 1942-1945, there was a definite increase in the local transmission of malaria which was attributed to Anopheles stephensi type form. Out of 1052 Anopheles stephensi were dissected, 6 salivary gland and 3 gut infections were found. Total infection rate was found to be 0.85% of which, oocyst and sporozoite rates were 0.58 and 0.56 respectively.

Mukhoapdhyay in 1980\textsuperscript{60}, incriminated that Anopheles stephensi was the vector of malaria. The infectivity rate was found to be 1.56 in that year, only one mosquitoes was sporozoite positive out of 64 Anopheles stephensi dissected.

In 1987, Chaudhury and Sen\textsuperscript{95}, a total of 982 Anophelines were dissected and of these, gland infection in one specimen of Anopheles stephensi was found during the month of September.
In 1987, Hati et al.\textsuperscript{132} employing 1152 man hours in a year (Sept.'85 – Aug.'86), 516 female Anopheles were captured, among them 357 (69.1\%) were \textit{Anopheles stephensi}. It is interesting to note that 29.1\% (104) \textit{Anopheles stephensi} adults were collected in July, sporozoites positive \textit{Anopheles stephensi} were collected in July, sporozoites were detected in the salivary glands of one specimen in the same month and oocyst rate is nil.

According to Hati \textit{et al.} (1988)\textsuperscript{61} 28\% in \textit{A. stephensi} was achieved with \textit{P. vivax} infection.

\textbf{WEST BENGAL}

Negi and Sen in 1962\textsuperscript{32b} found one gland positive out of 193 dissected in Damodar Valley area of Burdwan District.

In Durgapur Steel plant in rural Bengal, they found \textit{Anopheles stephensi} as the vector, out of 1,613 dissected, they found one gland positive.

\textbf{INDIA}

In Bombay city, Bentley (1911)\textsuperscript{10} dissected 1228. Adult \textit{Anopheles stephensi}. Among them 91 gut and 30 gland positive infections were found.

In Delhi, Hadgson (1914)\textsuperscript{133} recorded two gut infections out of 17 specimens of \textit{Anopheles stephensi} dissected. In Kohat district in India Sinton (1917) examined 45 specimens of \textit{Anopheles stephensi} and one sporozoite positive specimen was obtained.

In 1927 Chalam observed that out of 151 mosquitoes, 5 were gland and 2 were gut positive infections (quoted from Covell, 1928).

Covell, 1928\textsuperscript{134} got twelve gland infections out of 671 \textit{Anopheles stephensi} dissected in Bombay.
In Andhra Pradesh, King and Iyer (1929)\textsuperscript{135} dissected 166 adult *Anopheles stephensi* and among them one was sporozoite positive and nine was oocyst positive specimen.

In 1930, Banerjee\textsuperscript{14} dissected 75 females *Anopheles stephensi* which were captured from Lucknow city among them five were sporozoite positive and two were oocyst positive.

In 1931, Sweet and Rao\textsuperscript{136} dissected 2,708 *Anopheles stephensi* in Mysore state and obtained two oocyst positive infections. No sporozoite infections were obtained.

Sur, Sarkar and Banerjee in 1932\textsuperscript{137} found 23.1\% oocyst rate in *Anopheles stephensi*.

In 1936, Ramsey and Macdonald\textsuperscript{130} observed sporozoite in the salivary glands of *Anopheles stephensi* in Bombay, in north west frontier province, the united provinces and Madras. Specimens with oocyst positive were obtained in Mysore, Sind and Delhi. It is probably an important vector in rural condition in the west parts of India and in urban conditions throughout most peninsular and northern India.

Afridi and Majid and Singh in 1938\textsuperscript{138} dissected 238 *Anopheles stephensi* adults collected from Vijaya Vilas Palace, Kothda, Baharampur, Durgapur and from Bhuj city in Kutch state and found five infected mosquitoes.

Roy, Chandra and Siddons in 1939 declared that the two varieties of *Anopheles stephensi* have different their vectorial-potential of malaria in nature.

In Ahmedabad, Singh and Jacob in (1944)\textsuperscript{139} observed infectivity rate of *Anopheles stephensi* was 1.4\%.

Basu in 1946\textsuperscript{140} carried out a series of experiments and observed black spore or abnormal oocyst of *Anopheles stephensi* in laboratory. In the first series of experiments, out of 173 of mosquitoes, two 'black spore' were observed. In the second
series, 61 mosquitoes were dissected, among them four abnormal oocyst or 'black spore' were observed. In the third series, survivals of mosquitoes fed on gametocyte carriers of *Plasmodium falciparum*, 354 were dissected/examined. Thirteen of the showed abnormal oocyst along with normal oocyst.

In Coastal Orissa, Senior white had made a statement that *Anopheles stephensi* was the chief vector in some of the coastal localities. In Vishakapatnam (North Andhra Pradesh), many positive dissections of *Anopheles stephensi* have been made.

In Bombay, Viswanathan 1950\cite{141}, as well as of Bhaskar Rao *et al.*, 1946\cite{142} in Ballery district (Karnataka) has shown that *Anopheles stephensi* was a vector, having some importance in rural areas of Decan. Here infection rate was very low. In Maharashtra Decan, *Anopheles stephensi mysorensis* acts as a vector of malaria as determined by T.R. Rao.

In Madras City (Salem, Erode town) where malaria was still persisting in 1978-1979, *Anopheles stephensi* is regarded as chief vector of malaria.

Many towns in Gujarat, *Anopheles stephensi* is still very active in transmission of malaria. Nair and Samnotra in 1967\cite{143} was studied/dissected, 87 females adult *Anopheles stephensi* in 1963-64, 1967 of which only a specimen was infected both gut and gland.

Batra *et al.* (1999)\cite{144} their entomological studies showed that *Anopheles stephensi* was abundant in Jodhpur, Rajasthan and the factors responsible for the persistence of malaria in the area were resistance of malaria vectors to insecticides, poor surveillance and treatment of patients with inadequate suppressive agents.

In an experimental study Raghavan and Krishnan in 1949\cite{145} found that *Anopheles stephensi* was refractory to infections by *Brugia malayi* but Lahiri *et al.* in 1972 were able to demonstrate the development of *Brugia ceylonensis*.
Afridi and Majid in 1938\textsuperscript{146}, captured and dissected 1,142 wild female *Anopheles stephensi* and obtained one gland and 8 gut infections. The infection rate was 0.7\% in Baheren islands in the Persian Gulf.

In 1941, in and around Bagdad, there was an epidemic of malaria, only an *Anopheles stephensi* was observed infected (Krishna, 1961).

Rahaman and Muttali in 1967\textsuperscript{147} captured and examined 204 female *Anopheles stephensi*, here only a female was positive for sporozoite infection.

Muttali and Akiyama (unpublished WHO document 1967, 1968) collected 505 *Anopheles stephensi* from Karachi city (Pakistan) and dissected and also observed that 6 are positive for sporozoite infections (1.18\%).

Manouchehri \textit{et al.} 1976\textsuperscript{148} stated that a number of investigators obtained naturally infected *Anopheles stephensi mysorensis* in Abadan, Bandar, Abbas, Kagerum and Dezful in Southern Iran. The sporozoite infection rate was 0.2-0.7\%. They further stated that in 1962, 298 *Anopheles stephensi mysorensis* were collected and kept in an insectary of Kagerum Medical Research station for 12 days, 283 females *Anopheles stephensi* were dissected, among them 14 specimens were positive for sporozoite infections and two were positive for oocyst infections (delayed sporozoites rate about 5\%).

Ponnudurai \textit{et al.} (1991)\textsuperscript{149} in Russia worked on feeding behaviour and sporozoite ejection by infected *Anopheles stephensi*.

Noden \textit{et al.} (1995)\textsuperscript{150} in Baltimore, USA described the effect of temperature on early *Plasmodium falciparum* development was examined in *Anopheles stephensi*.

Sharma \textit{et al.} (1995)\textsuperscript{185} studied on adult densities, vector incremination and breeding habitats of *Anopheles culicifacies* and *Anopheles stephensi*. *Anopheles stephensi* showed gland infection in south region only.
Mariappan et al. (1992)\textsuperscript{151} described about the malaria vector \textit{Anopheles stephensi} in Cochin.

Reisen, Milby (1986)\textsuperscript{152} worked on population dynamics of some Pakistan mosquitoes and observed, \textit{Anopheles stephensi} are endophilic in nature.

**Vectorial Capacity**

A concept of vectorial capacity has been developed by Garret Jones 1964. It is the same as the basic reproduction rate of malaria but expressed on a daily basis to determine the force of infection in a particular epidemiological situation (WHO 1975 "Manual of Practical Entomology")\textsuperscript{153,159}

Sporozoite possess a thin surface coat (15 mm) of fibrillar material surrounding the outer sporozoite membrane. This surface coat plays a role in the sporogoite response to the immune reaction of the host (Cochrane \textit{et al.} 1976)\textsuperscript{155}.

White (1974) described that whether or not malaria is actually being transmitted in terms of vectorial capacity, as proposed by Garrett-Jones (1964)\textsuperscript{156} on the basis of the Macdonald model for malaria reproduction.

Relative risks of malaria transmission are calculated as values of $C$. \textit{Theoretically 0.01 is the critical vectorial capacity for multiplication} of malaria, assuming that the mean period for human recovery is 100 days. Thus, the case multiplication rate, $C \times 100$, must exceed in order to cause increasing malaria and transmission will decline at lower values. From field experience, notable the Garki project in Nigeria (Molineaux and Graicca, 1980\textsuperscript{157}, Molineaux, 1978)\textsuperscript{158}. We find that V.C. values of at least (0.03) are necessary for transmission to continue in practice presumably to off set the inefficiency of malaria inoculation by the vectors and some failures of sporozoites to induce infection. The assessment of vectorial capacity can still provide a continuing index of malaria receptivity as a guide to the risks of resumed transmission if parasite carriers re-enter malaria free areas.
Menon and Rajagopalan (1979) observed that few microsporidian infected *Anopheles stephensi* develop fewer oocysts and sporozoites of plasmodium and the sporogonic cycle is not completed in most of the infected adults due to the reduced longevity.

Mulligan and Baily stated that *A. stephensi* as a vector, the following localities have yielded positive gland dissections of *Anopheles stephensi* (Covell, 1927, 1931, Mulligan and Baily)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Number dissected</th>
<th>Sporozoite rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bombay</td>
<td>2039</td>
<td>2.3</td>
</tr>
<tr>
<td>Lucknow</td>
<td>75</td>
<td>6.6</td>
</tr>
<tr>
<td>Kohat</td>
<td>45</td>
<td>2.2</td>
</tr>
<tr>
<td>Quetta</td>
<td>719</td>
<td>0.3</td>
</tr>
<tr>
<td>Mopod</td>
<td>166</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Senior White (1940), natural infections have been recorded from the east side of non-peninsular India and from Bengal there are only 21 negative dissections by Sur & Sur quoted by Covell (1931) of the 297 females captured during the investigation in Calcutta, 285 have been dissected. All have proved negative both for gut and for glands. This number is quite insufficient for valid conclusions to be drawn from the results the findings accord with the very low malaria rate of Calcutta other than in the wards affected by *A. sundaicus*. Sporozoite or oocyst positivity actually show the infection and infectivity.

**In 1987** (Chaudhury & Sen)

A total of 982 anaphelines were dissected and of these gland infection in one specimen of *A. stephensi* was found during the month of September.

A concept of vectorial capacity has been developed (Garret Jones, 1964). It is the same "as the basic reproduction rates of malaria but expressed on daily basis to
determine the force of infection in a particular epidemiological situation (WHO, 1974, Manual of Practical Entomology).

In other sense, vectorial capacity is "the number of potentially infective contacts and individual person makes, through the vector population per unit time."

Critical vectorial capacity is the minimum value of 'C' below which malaria cannot maintain itself at an endemic level.

The main use of vectorial capacity concept is in attempting to monitor transmission potential in areas where no transmission is taking place, but which are both vulnerable and receptive.

Deitz et al. (1974)\(^{160}\) have tested the idea of vectorial capacity in an African savannah, in Karo State, N. Nilgeria including studies on the role of super infections.

Batra et al. (1978)\(^{81}\) have estimated the vectorial capacity in *Anopheles stephensi* in Salem Town, Tamil Nadu with *P. vivax* infections.

Shevpet - 0.09 to 0.43 (corresponding) to biting rates of 0.08 to 1.0 per main per night.

Trasipalayam - 0.07 to 0.50 (corresponding to biting rates of night 0.2 to 1.1 per individual per night.

Reisen and Boreham (1982)\(^{161}\) estimated the vectorial capacity of *Anopheles culicifacies* and *Anopheles stephensi* in rural Punjab.

They said that it was difficult to determine accurately the critical vectorial capacity.

Attempts to understand and express malaria epidemiology in mathematical terms have been made by N.R. Rao and co-workers (Rao, N.R. et al., 1974, 1975, 1976, 1977)\(^{162}\). They have found critical levels of mosquitoes to man required for
malaria transmission to be higher than those obtained by Macdonald\textsuperscript{163} possibly explaining the phenomenon of anophelism without malaria.

**Genotrophic cycle**: Blood meal was taken by mosquito, digested development of and oviposition of eggs.\textsuperscript{163}

1\textsuperscript{st} genotro cycle
- taken time: 48-72 hours

2\textsuperscript{nd}, 3\textsuperscript{rd}
- warmer: 48 hours
- cold: 96 hours

**Anopheles stephensi**: Results of vector incrimination studies\textsuperscript{164}.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Year</th>
<th>Author</th>
<th>Locality</th>
<th>No. dissected</th>
<th>Gut</th>
<th>Gland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1911</td>
<td>Benty</td>
<td>Bombay, Maharastra</td>
<td>2445</td>
<td>91</td>
<td>30</td>
<td>121\textsuperscript{1}</td>
</tr>
<tr>
<td>2.</td>
<td>1914a</td>
<td>Hadgson</td>
<td>Delhi</td>
<td>110</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>1921</td>
<td>Christophers &amp; Short</td>
<td>India</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>1927</td>
<td>Covell</td>
<td>Bombay, Maharastra</td>
<td>2445</td>
<td>91</td>
<td>30</td>
<td>121\textsuperscript{1}</td>
</tr>
<tr>
<td>5.</td>
<td>1927</td>
<td>Challam</td>
<td>Bombay, Maharastra</td>
<td>151</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>6.</td>
<td>1928</td>
<td>Covell</td>
<td>Bombay, Maharastra</td>
<td>671</td>
<td>17</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>7.</td>
<td>1929</td>
<td>King and Gyer</td>
<td>Mopad, Madras</td>
<td>166</td>
<td>9</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tamil Nadu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>1930</td>
<td>Banerjee</td>
<td>Lucnnow, U.P.</td>
<td>75</td>
<td>7</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>9.</td>
<td>1931</td>
<td>Sweet &amp; Rao</td>
<td>Mysore, Karnataka</td>
<td>27</td>
<td>10</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>10.</td>
<td>1934</td>
<td>Nursing \textit{et al.}</td>
<td>Mysore, Karnataka</td>
<td>277</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>11.</td>
<td>1938</td>
<td>Afridi \textit{et al.}</td>
<td>Kutch, Gujrat</td>
<td>238</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>12.</td>
<td>1938</td>
<td>Roy \textit{et al.}</td>
<td>Madras Prov</td>
<td>166</td>
<td>9</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tamil Nadu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>1941</td>
<td>Rao</td>
<td>Bihar Prov. Bihar</td>
<td>423</td>
<td>5</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>14.</td>
<td>1943</td>
<td>Sing &amp; Jacob</td>
<td>Ahmedbad, Gujrat</td>
<td>155</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>15.</td>
<td>1943</td>
<td>Senior White &amp; Rao</td>
<td>Vigagapatanam</td>
<td>225</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Andhra Pradesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>1945</td>
<td>Subbaroal Apparao</td>
<td>Madras Prov. T. Nadu</td>
<td>692</td>
<td>1</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>
28. 1980 Hati & Mukhopaday
29. 1982 Sharma et al. Alwar Rajasthan 179 0 1 (1)
30. 1983 Annual Report Arthala 119 0 1 (1)
31. 1983- Annual Report Delhi Union territory 131 0 1 1
32. 1983 Choudhury Delhi Union Territory 866 0 1 1
33. 1984- Annual report MRC Delhi, Union territory 2165 0 1 (1)
34. 1985- Delhi Union Annual Report 469 0 1 (1)
35. 1987 Choudhury & Sen Cal / West Bengal 982 0 1 10%
36. 1987 Hati et al. Cal / W.B. 104 0 1 (1) = 96%

**WORLD**

Rahman and Muttali (1976) found one female *Anopheles stephensi* with sporozoites in the salivary glands among 204 examined. Muttali and Akiyama (unpublished who document 1967, 1968) dissected 505 *Anopheles stephensi* obtained from Karachi city and 6 gland are infected and (1.18%). Manoucheri et al. (1976)
stated that a number of investigators obtained naturally infected *Anopheles stephensi mysorensis* in Abadan, Bandar Abbas, Kazerum and Dezful in Southern Iran. The sporozoite rate was 0.2 to 0.7%. They further described that in 1962, 298 *Anopheles stephensi mysorensis* were collected and kept in laboratory condition of Kazerum Medical Research Station for 12 days. 283 *Anopheles stephensi mysorensis* were dissected and 14 were sporozoite positive in their salivary glands and two were oocyst positive (gut). According to Hati *et al.* (1980) 28% in *Anopheles stephensi* was achieved with *P. vivax* infection.

Noden *et al.* (1995)\(^{150}\) studied in the salivary glands of a non infections sporozoites to evaluate minimally susceptible anopheline mosquito vector malaria parasite relationships.

Yaming *et al.* (2001)\(^{165}\) in China observed the sporozoites in the salivary glands of *Anopheles stephensi* at 14 days post infection.

Wu (1996)\(^{166}\) in China studied on the factors influencing the sporogonic multiplications of *Plasmodium vivax* in mosquito vector i.e. *Anopheles stephensi*.

Reisen, Mahmood and Parveen (1982)\(^{167}\) in Pakistan, vectorial capacity on the number of malaria infections a given vector mosquito would distribute per case per day was determined using a modification of the formula of Garrett-Jones (1974) suggested by Molineaux *et al.* (1978).

\[
V_C = (HB_a)(e^{-\beta E})
\]

**Nature and Kind of Breeding Habitat of Vector Species**

Detailed ecological knowledge concerning the larval habitats of arthropod vectors is essential for an understanding of their product and control.
Calcutta

Calcutta in 1912, Paiva observed the larval breeding sites of *Anopheles stephensi* in Calcutta metropolis and found that earthen pots in most case proved to be the most usual breeding places, open drains were also acted as breeding place.

Basu in 1930 observed that *Anopheles stephensi* larvae was increased due to change of breeding places, kitchen was shifted to roof their results in an increased demand for filtered water on the roof, but as the pressure of the filtered water supply is only a few feet in the city, people collect filtered water in a choubacha in the ground floor and this acts as a breeding sites of *Anopheles stephensi*. Breeding sites are wooden barrels, earthen handis, earthen tubs, earthen jars etc.

Covell (1932) noticed that larval breeding sites were deep wells, it has a wide tolerance with regarded to the temperature of the water, it does not breed in ponds or tanks.

Basu also noted that the reservoirs of filtered and unfiltered water in the centre of Calcutta city are the main source of the *Anopheles stephensi* breeding in the city. He searched 560 cisterns, out of 560, 162 are examined during the year. Rain water was collected in different containers which acts as a breeding places. Some of the earthen tubs are used as garden tubs in which rain water was collected, some of the iron tubs are used as fire buckets in which their species breed. Pucca drains and garden fountains are also played a role as a breeding habitat.

In 1935, Ganguly showed the following breeding places of *Anopheles stephensi* made up of iron-cisterns. Total 12,053 cisterns were examined, of these 2893 were found breeding *Anopheles stephensi* i.e. 24% were positive, *Anopheles stephensi* larvae have been found in fire buckets, garden fountains and also in drain containing fairly clear water. He collected 4,307 samples of *Anopheles stephensi* from different kinds of breeding sites like masonary cisterns, fountains and fire buckets.

Knowles and Basu (1934) studied the breeding sites of *Anopheles stephensi* and observed that they especially bred in masonry tanks, overhead galvanized iron
cisterns on the roofs for the filtered and unfiltered water supply. They observed that *Anopheles stephensi* preferred earthen containers to oviposit and breed.

In 1920, Iyenger observed the presence of breeding habitats such as shallow pits, garden tubs, unused cisterns of *Anopheles stephensi* throughout the entire city of Calcutta.

In Calcutta city, Roy in 1931 observed the presence of *Anopheles stephensi* larvae in open earthen drains and ponds, full of aquatic lillies. Permanent breeding sites were overhead tanks, masonary vats for soaking bricks, tanks and temporary breeding sites were small water puddles in the park, maidans and tanks.

Roy and Brown (1931) observed that *Anopheles stephensi* prefers to breed in small collection of water for oviposition such as chowbachas, pools, stream beds, springs and seepages.

Siddons, 1940 observed the breeding sites of *Anopheles stephensi* and its were in cisterns on the roof, vats made by masons for soaking new bricks.

In 1943, De worked on *Anopheles stephensi* in Calcutta and observed the breeding places of the vector species in cemented tanks where drinking water was stored.

In 1980, Mukhopadhyay organised a natural survive in and around 100 brick houses in Central Calcutta and observed the presence of *Anopheles stephensi* larvae in 202 water holding containers of which 158, 18, 11 and 15 were found on ground, first, second and third floors respectively.

Choudhuri and Sen (1987) observed the breeding sites of *Anopheles stephensi*. Larvae were found in masonry tanks, cisterns, lowlying land, ponds, empty artificial containers depressions, shallow wells, drains, nullahs of a total of 59, 762 sites checked 10,592 were found positive for breeding.
In 1992, Biswas et al.\textsuperscript{88} surveyed larvae of *Anopheles stephensi* in Chetla areas of South Calcutta from July 1990 – June 1991. They observed different kinds of breeding sources. The vector species had a greater preference for outdoor water bodies than indoors.

In 1998, Chakrabarty and Tandon observed that *Anopheles stephensi* preferred earthen pots as a breeding sites followed by stone-cemented container.

**West Bengal**

Neogy and Sen in 1962 observed 3.1% larvae in empty containers, ditches or neglected pits in Oyaria, Burdwan.

**India**

Hadgson in 1914 reported that in Delhi larvae were generally breeding in wells and they were also found in the pools of Bela one very unusual breeding place for this mosquito was found in April, 1913, a slowly moving shallow stream called the ‘Khudsia creek’. In this position, the larvae were numerous.

In Kohat district Sinton in 1917\textsuperscript{168}, observed that *Anopheles stephensi* mosquitoes were found to breed in almost any collection of water.

Various kinds of breeding habitats were found in India such as

(i) Old tins and broken pots
(ii) In tins and vessels used to store water
(iii) In parous earthen were pots which is called ‘Jala’
(iv) In the square brick tanks used to store water for gardens
(v) In rain rater puddles and in little pools of water left after irrigation
(vi) In grass-grown ditches and irrigation channels
(vii) In borrow pits.
Covell in 1928 described in his monograph ‘Malaria in Bombay’ that *Anopheles stephensi* was bred with equal facility in dark places and in those exposed to the direct sunlight, larvae flourished in any depth. The breeding place may be situated below the level of the ground or on the roof of a building 80-100 ft (24.4-30.5 m) in height. The roof cisterns is the permanent breeding sites in Bombay along with the improperly graded roof gutters and terraces. Large roof cisterns which were found in mills and railways, were acted as a good breeding habitats.

In 1923, De worked on *Anopheles stephensi* in Calcutta and observed the breeding places of the vector in cemented tanks where drinking water was stored.

In 1946, Siddons worked on *Anopheles stephensi* and breeding of *Anopheles stephensi* was observed in water which had collected under a cistern on the roof and cisterns, vats made by masons for soaking new bricks.

Banerjea in 1930, discovered the breeding habitat of *Anopheles stephensi* larvae in wells in Lucknow. During rainy season larvae became numerous in number in wells.

In Kutch state, Afridi *et al.* in 1938 reported that *Anopheles stephensi* bred actively in trough, siphons, reservoirs and wells in Vijaya Villa place while in Bhey it was almost bred in well.

In Puttukkottai, Madras, the larvae of *Anopheles stephensi* were found to be restricted in wells (Russel and Rao, 1941).

Bana in 1943 reported that in Bombay *Anopheles stephensi* bred in the salt pans in September and October, when these were used for rearing fish, and *Anopheles stephensi* also bred in A.R.P. tanks and drums filled with sea water which had become diluted with rain water, and also bred occasionally when specific gravity was high as 1030 (equal to that of sea water).

Senior White and Rao in 1944 observed *Anopheles stephensi* bred in pucca wells (14.9%) and kaccha (7.0%) wells and also in nalas (78.1%) in Visagapatnam.
Krishna in 1961, Dhir in 1970 observed larvae of *Anopheles stephensi* at the floor of newly constructed rooms where the water being kept to moisture the cement layer.

Batra and Reuben in 1979 reported that *Anopheles stephensi* breeds mainly in wells in Salem, Tamil Nadu, Madras. *Anopheles stephensi* preferred sunlit breeding places in rural areas where as Krishnan thought that no preference was shown for dark as for well breeding sites. Larvae were always found in deeply shaded wells.

Kaur and Reuben in 1981 surveyed *Anopheles stephensi* larvae in 20 wells in after 14 months study a malarious town in South India and did not observe any direct relation between rainfall and larval density of *Anopheles stephensi*.

Bhatt *et al.* in 1991 described the breeding habitats of *Anopheles stephensi* in canal irrigated, non-canal irrigated and riverine area of Kheda district, Gujarat.

Canal-irrigated area included irrigation canals and channels, drains seepage water pools, ponds and paddy fields and non canal irrigated and riverine area constituted ponds, small pools, river and river bed pools were considered as the major breeding sources wells and intradomestic water storage containers also provided breeding opportunities throughout the year in all the three areas. In the canal irrigated area, breeding habitats were after infested with aquatic vegetation like eichhornia, Hydrilla, Trapa and gpomea and paddy fields were sometimes played an important role as a breeding habitats.

Ashwani Kumar and Thavaselvam (1992) observed the seasonal prevalence of *Anopheles stephensi* larvae in 1992, in Panaji, Goa they showed that in the wells, larval positivity of *Anopheles stephensi* was highest in June (1.3%) and there was no breeding from October till December and the data showed that the overall positivity in wells declined from 8.3% in January to 1.6% in August but in 19 ornamental fountains, larval density was highly fluctuated the highest positively (11.4%) was detected in February and lowest (1.4%) in August.
In Panaji, Goa Anopheles stephensi were found in overhead tanks along with Aedes aegypti and Culex quinquefasciatus.

Kar, Eapen and Ravindran in (1996)\(^8\) worked on domestic breeding sources and their contribution in Anopheles stephensi breeding in Dindugal, Tamil Nadu. They observed ten different types of breeding habitats, larval density was maximum in overhead tanks. Anopheles stephensi larvae were found with Aedes and Culex larvae in different combinations.

In rural areas, Anopheles stephensi mysorensis (variety) has a much wider ranges of breeding habitats. It breeds in streams, channels, tanks, ponds, seepages irrigation wells etc. They also bred in borrow pits followed by rivers and streams (Vishwanatan, 1950) in Bijapur district.

In the Nira canal area of Pune and Sholapur district. Anopheles stephensi mysorensis bred in seepage filled i.e. nulla (streams) overgrown with bull-rush.

**WORLD**

Gad in 1967 observed Anopheles stephensi larvae near Gulf of Suez.

Zulueta in 1968\(^17\), also described the presence of larvae in saline water at Fao, Iraq (quoted from Monouechri, 1976).

In Burma, Khin-Maung-Kyi in 1971 as quoted by Rao in 1984 reported that Anopheles stephensi larvae were found in the foot hill areas where they bred in pools, in river beds, in seepages and rocky hill streams.

Manouchchari in 1976 reported that Anopheles stephensi bred in all kinds of water, mainly in wells and garden ponds in southern Iran. The larvae of Anopheles stephensi were even detected in hoof prints of animals around the seepages of marshy areas. Anopheles stephensi also bred readily in rice fields specifically in nurseries and newly planted rice fields.
In rural area of Southern Iran, this species was also found in small amount of water which leak from the ‘mask’ – the goat skin bag used to hold drinking water or hoof prints of animals.

At the time of the study period, Sweet & Rao had felt that only the type form was an efficient vector, it has now been found, *Anopheles stephensi mysorensis* was also a vector in several areas particularly in the Decan plateau. In Iran, it acts an important role as a vector.

**Water Analysis**

The physico-chemical factors of water and the larval density have been reported for *Aedes aegypti* by Babu et al. (1983)\(^{175}\), *Culex quinquefascioatus* by Thavaselvam and Kalyanasundaram (1991)\(^{176}\), *Anopheles stephensi* by Saxena et al. (1992)\(^{178}\) and *Armigeres subal batus* by Rajavel (1992)\(^{177}\).

Malhotra and Mahanta in 1996\(^ {179}\), studied the physico-chemical factors of water supporting various mosquito species, bred singly or in association in different habitat, around Guwahati, Assam. *Anopheles stephensi* showed maximum larval density at 27°-30°C.

The average 8.3 pH of water was suitable for development of Anopheles in Delhi (Sehgal and Pillai, 1970)\(^{180}\). However, pH swing was noticed between 6-9 by Bhatt et al. (1993)\(^{181}\)

Saxena et al. (1992) also noted that *Anopheles stephensi* preferred a less turbid water, a very moderate salinity (2.5%) and most of the Indian *Anopheles* breed in fresh non-saline water. Slightly alkaline pH is essential for higher population density. Lower the salinity, higher the population density and higher amount of free ammonia in the water is accounted for the higher population density of *A. stephensi*.

Bio-chemical oxygen demand (BOD) was generally higher in the 14 breeding waters of *Culex fatigans* tested and ranged from 46-655 mg/litre, where as in one non
breeding habitats. BOD was 21.5 mg/litre. Higher larval density was observed in a breeding sites where BOD value was 505 mg/litre. They also reported that there was a distinct relationship between BOD and the larval density of *Culex fatigans*, when BOD was high larval density was also innumerable.

A preliminary studies on the chemical nature of mosquito breeding water were studied by Sehgal and Pillai in 1970. They observed the pH values of larval breeding sites ranged between 7.75-8.5 and pH influenced the species specificity, *Anopheles* preferred more turbid water with a much lower oxygen content. Although individually the breeding habitats of Culex and Anopheles were chemically distinct in a few cases those species were also found to breed along with *Aedes* sp. where the chemical make up of the water was somewhat different. The chemical nature of the water influenced the ovipositional preference of the mosquitoes. Although *Anopheles stephensi* generally prefers clean water, it was not averse to breed in highly polluted water. Roy (1931) shown that in Calcutta, it was breeding in waters actually contaminated by sewage.

Williamson (1949) reported the ability of *Anopheles* species to transmit malaria, could be influenced by the chemical contents of the water in which they grew up.

Russel and Mohan (1939) reared *Anopheles stephensi* larvae in various types of waters including one contaminated by sullage water and found no difference in the ability of the adults to transmit malaria. *Anopheles stephensi* bred even in brakish or salt water (Chalan, 1926; observed) *Anopheles stephensi* was found breed in slightly saline water in pits with salinity ranging from 0.13% to 0.27% (Afridi and Majid, 1938).

In Bombay city, Anopheles species occasionally adapted itself to breed in salt water (Bana, 1943).
The *Anopheles stephensi* larvae were also able to feed on suspended matter even at the bottom or on the sides of the water in large containers. Therefore they are well adapted for breeding in deep waters such as in wells (Ray, 1931).47

The *Anopheles stephensi* larvae are shade lovers as they breed by preference in deep wells permanently shaded and also in cisterns and overhead tanks (Rao, 1981).

Herrel *et al.* (2001)184 collected the larvae of *Anopheles stephensi* from different breeding sites and also studied the temperature, dissolved oxygen, electro-conductivity and pH of the water in the breeding sites.

Senior White (1926)185 also studied the physical factors of water in the breeding sites of mosquitoes.

Haq *et al.* (1998)86 worked on mosquito breeding associated with urban sewage system in Anand city (Gujarat). They observed 0.11%. *Anopheles stephensi* bred in urban sewage system plant and it showed high organic contents in the water and the pH of the water was found to be 8.0-8.5.

Roberts (1996)186 observed that the larvae of *Anopheles stephensi* preferred and survive mostly in fresh water but somewhere able to tolerate upto 50% sea water. The females had a ovipositional preference did not correspond with larval survival for *Culex quinquefasciatus* but did compare well in *Anopheles stephensi* and *Anopheles culicifacies*. Yasyukevich (1997)185 showed that *Anopheles stephensi* females prefer fresh water for their oviposition and avoid high salinity. Eggs do not survive beyond 2% salinity.

Iasiuukevich (1997) in terms of H2O salinity, the following developmental ranges were established for the larvae of 5 mosquito species. 1.5% in *A. stephensi* salinity demonstrated to affect the survival of larvae to the greatest extent and the duration of their development and weight to a much lesser one.
Life Cycle

The period of life cycle varies greatly with temperature and with the species of mosquito. In tropical areas where the mean temperature is approximately 27°C, the minimum time from egg to adult appears to be about 10-12 days in the laboratory but some times it will be nine days or perhaps even less, in the field. Anopheles needs more water surface for healthy development (Wernesdorfer,

The egg stage occupies between one and two days, the larval stage was completed between 7-8 days and pupal stage ranged one-two days. The minimum time taken from egg to adult was 10-12 days in laboratory and 9 days in the field.

From the first blood meal to egg-laying (i.e. first gonotrophic cycle) requires probably 2-4 days. Sometimes two blood meals are needed to mature the first batch of eggs, the complete cycle from egg to adult took a minimum two weeks.

Eugane, et al. in 1968\textsuperscript{188}, followed the mass rearing techniques of Anopheles stephensi in the laboratory and observed their life-cycle.

The female laid eggs within 48 hours (2 days) after taking blood meal, approximately with in 72 hours (3 days) hatching is completed.

Larval development was completed in six to nine days. The larval food was dog chow mixed with porcine liver powder in 1:1 ratio.

Pupation occurred over a 4 days period with approximately 5% pupation on 6\textsuperscript{th} day at 7\textsuperscript{th} day 35%, 50% on day eight and 10% on the nineth day. The adults emerged within 36-48 hours at a temperature of 27°C, and sex ration of male and female was 1:2 respectively.

Reisen and Mahmood (1980)\textsuperscript{189} Pakistan they established a laboratory colony of Anopheles stephensi in spring, 1978 and observed that life expectancy at emergence for female Anopheles stephensi was 8.1 days and for male was 8.0 days. The net
reproductive rates was 45.2, mean generation times was 19.9 and instantaneous rates of increase were 0.190 for *Anopheles stephensi*. The duration of the 1st and 2nd genotrophic cycles decreased with increasing temperature. Unexpectedly the duration of the 2nd genotrophic cycle at 18°C and 22°C was significantly shorter than the duration of the 1st cycle (Mahmood and Reisen, 1980).

Reisen (1975) studied anopheline biology and observed emergence times of 50% female was 9.80 days and for males 9.49 days. Survival rate was 66.7% (14 days) and life expectancy was 8.8 days for females and 8.7 days for males.

These survival rate and life expectancy was also observed by Reisen and Aslam Khan (1979) in Pakistan. Survivorship from first instar through emergence was 0.946. Studies of adult longevity and survival have been made under insectary conditions by Meller (1962), Stahler and Black (1970) and Reddy (1976) under field condition by Quraishi *et al.* (1966) and Reisen and Aslamkhan (1979).

Meller in 1962, observed E50 for adult male and female were 13 to 25 days and survivorship from first instar through emergence was 0.898 and adult (50%) survivorship of female was 15 days and male was 10 days. While Reddy (1976) found E50 for adult *Anopheles stephensi* as 17 days and average age specific survivorship was 0.573 and 20% survival of the adult was 0.518.

Quraishi *et al.* (1966) described that median *Anopheles stephensi* adult longevity was 3.0-3.5 days, survivorship of females 0.09 and males 0.64 days.

Reisen and Aslamkhan (1979) reported the mean longevity of female *Anopheles stephensi* was 3.24 days and males 3.26 days, survivorship of females 0.81 and males 0.74 days.

Mayne (1936) observed caged mosquitoes and found that at 55% relative humidities adult *Anopheles stephensi* could live upto 32 days.
According Sweet, Rao and Subba Rao (1938), type females (*Anopheles stephensi stephensi*) and mysorensis males (*Anopheles stephensi mysorensis*) were crossed, the females refused to lay eggs in spite of blood meals but after some attempt few female laid eggs. They also tried to cross the *mysorensis* females and type males. The *Anopheles stephensi mysorensis* (variety) has proved to be extremely difficult to rear in captivity (as distinguished from the type form) and they have never succeeded in getting 3 colony beyond the F1 generation. After third attempt, females laid eggs, few eggs were sterile, few were transformed into larvae.

In 1936, Stockland and Roy described that longevity of adult mosquitoes was 36 days in *Anopheles stephensi*. They also observed that at summer temperatures, the life cycle took 4-11 days to mature a batch of eggs under laboratory condition, the gonotrophic cycle took 2-3 days.

Quraishi (1966), studied on the colony of *Anopheles stephensi mysorensis* and estimated everyday mortality was 30%. The first gonotrophic cycle was completed in 3-4 days and the second in 6-8 days after eclosion. In Broach town, Gujrat, Nair and Samnotra (1964) showed that at least 19% were living upto the epidemiologically dangerous age.

Clements (1963) reported that eggs, larvae and pupae of *Anopheles stephensi* were killed by prolonged exposure to 8°C. Longevity of *Anopheles stephensi* at 25°-35°C increased with rising relative humidity upto 70% but at 90% relative humidity, longevity was reduced.

Schlein and Gratz (1973) determined age of *Anopheles stephensi* by noting daily growth layers of skeletal apodems in the laboratory bred specimens of the mosquito. According to their observation, it was possible to count upto 10 daily growth layers of Phragmata of 25% of those bred in laboratory and of 85% of the wild caught mosquitoes.
Suleman (1990) studied the interspecific variation in the reproductive capacity to *Anopheles stephensi* females was studied under laboratory condition. Maximum nine ovipositions was possible for a female *Anopheles stephensi*.

**INDIA**

Menon and Rajagopalan (1979) recorded a very high mortality of all larval instars and pupae in well. In April, first instar mortality was lowest and pupal mortality was highest. The pupation rate and the adult emergence rate was found to fluctuate at a low level in all the months. The adult emergence rate or immature survival rate varied from 1.9% in September, 10.4% in August with an average of 5.6%. In Salem town, the survival rate was higher (VCRC, Annual Report, 1978) and ranged from 4.4% to 16.1% with an average of 11.2%.

In September, due to increase in rainfall and maximum number of rainy days, survival rate of larvae was very low. Roy (1931) observed that in laboratory colony of *Anopheles stephensi*, the maximum time taken by larvae to pupae were 8-9 days.

Russell and Mohan (1939, 1941) maintained a laboratory colony in Madras (Chennai) and found that development from ovum to adult took 5-9 days and the period of gestation in females was 5-6 days. During Dec.-Jan., the time taken for the completion of one generation of the mosquitoes seem to be only a little longer than other months. Madras is tropical and the annual average temperature was 75°F-90°F and humidity ranged from 60%-70%.

Reisen and Aslamkhan (1979) found that longevity of *Anopheles stephensi* male and female was 13 and 12 days respectively (mean longevity 3.26 days to 3.24 days respectively) and survivorship was, in females 0.81 and males 0.74.

Russell and Mohan (1941) established an insectary colony of *Anopheles stephensi mysorensis*. They noted that the type *Anopheles stephensi* was easily colonized but the variety (mysorensis) failed to established a colony. The mysorensis females could not be induced to oviposit. After the failure of two attempt, third lot of
'mysorensis' were colonised in the laboratory and extended up to 9 generations. In case of type, they maintained 60 generations in laboratory.

Ansari et al. (1978) established a colony of *Anopheles stephensi* in laboratory temperature, maintained at 28±1°C and RH was 70%-80%. Eggs were hatched after 48 hours. There was about 95% egg hatch. In cyclic colony, average number of eggs hatched per female was 63.5.

Menon and Sharma (1981) studied on the four populations of *Anopheles stephensi* originated from widely different geographic areas and colonised in the laboratory showed variation in their life table attributed. The type forms were collected from Pondichery, Okhla (Delhi), Arthala (UP) and the variety *mysorensis* from Bhuj (Gujrat). Pondichery type showed significant variation from the other types. Arthala and Okhla populations were homogeneous. *Anopheles stephensi* var. *mysorensis* were similar to Arthala and Okhla type. This study did not give any evidence of two races of *Anopheles stephensi*.

**CALCUTTA**

De (1923) studied the life-cycle of *Anopheles stephensi* and showed that eggs hatched into larvae within 2 or 3 days. Larvae developed into pupae after three weeks that mean larvae continued up to the last three weeks, and pupal stage was short being up to 3 days (in case of the big larva it was as long as 6 days). After three days, adult emerged.

Knowles and Basu (1944) conducted three series of experiments in laboratory and also induced *Anopheles stephensi* to breed continuously but failed to rear them beyond the third generation.

Hati et al. (1980) observed in laboratory condition, adult *Anopheles stephensi* to survived 33 days (range 2-91 days).
White (1940) stated that there is a marked difference in fertility between the type form and variety *mysorensis* of 32 layings of the former, 68% hatched. Of 24 of the latter only 5% including females which died without laying at all.

Knowles and Basu (1934) maintained two colony M 'type' and B type (*Anopheles stephensi stephensi* and *Anopheles stephensi mysorensis*) at a temperature between 50°F-100°F and the relative humidity ranged between 50%-100%. Longevity of 73% *Anopheles stephensi* was 14-20 days in cold weather, 27% of 7 days. In summer 51% of *Anopheles stephensi* lived within 7-13 days and in monsoon, 63% of 8-14 days and 50% was 7-9 days.

In the non-cyclic colony average number of eggs hatched per female was 2.5 to 5.4. It was, therefore, concluded that cyclic colony was better than non-cyclic colony.

From larvae, 82.4% pupae were obtained and maximum time was 2-3 days (from 4th instar larvae to pupae).

D.N. Roy et al. (1938) observed that *Anopheles stephensi* can be kept alive for a long time in the laboratory, provided the atmosphere was not too dry and the temperature was not so high.

**Biting-activity of *Anopheles stephensi***

**CALCUTTA**

Early observation of Choudhury (1936) indicate that *Anopheles stephensi* adults were most active in biting before mid-night in Calcutta.

Strickland et al. (1936) used trap such as tea-box but no *Anopheles stephensi* were entered in these traps. They concluded that there appeared to be a very marked preference in *Anopheles stephensi* for biting natives of India than Europeans.

Senior White (1940) captured 3 *Anopheles stephensi* mosquitoes in the following three respective months such as July, August and December by using a trap.
net where he acted himself as the bait. But when cow-bait was used in a modern house of Calcutta, 170 female and one male *Anopheles stephensi* were captured. He concluded that both the type form i.e. *Anopheles stephensi stephensi* and 'variety' i.e. *Anopheles stephensi mysorensis* have showed affinities towards bovine-blood than human-blood.

Das *et al.* (1971) worked in Bag-Bazar area of North Calcutta and collected several species of mosquitoes including only a *Anopheles stephensi* of human-bait.

Mukhopadhyay (1980), caught 27 *Anopheles stephensi* mosquitoes on human-bait due to their Anthropophilic nature.

During the period of September-August (1986-87), Hati *et al.* organised a man-bait collection of *Anopheles stephensi* and captured 54 *Anopheles stephensi*, 42 were caught from indoor and 12 were from outdoor.

Maximum no of *Anopheles stephensi* were collected in the month of August at 11 p.m. to 4 p.m. yielded maximum number of mosquitoes with a peak between 12.00 mid-night to 11 a.m.

Mukhopadhyay and Hati (1978) caught *Anopheles stephensi* from 18.00 hours to 6.00 hours on man baits places indoors and outdoors in Central Calcutta during July 1977 to June 1978. They observed only 0.023 *Anopheles* mosquito, comes in contact with man per hour and per man hour contact in indoor is 0.04 and in outdoor it is 0.003 at outdoor. Per man hour contact of *Anopheles stephensi* in indoor is maximum in August which is 0.146. *Anopheles stephensi* mosquitoes come to bite man between 23.00 and 4.00 hours with a peak between midnight and 02.00 A.M. They preferred to bite below the waist line of the human bait.

**India**

In state of Mysore, Nursing *et al.* in 1934, collected 33% *Anopheles stephensi* between 21.00 and 24.00 hrs. and 67% between 04.00-6.00 hours.
In 1946, Senior White\textsuperscript{205} captured the only female \textit{Anopheles stephensi} at 4.00 and 01.00 hours respectively in the month of April and May at different locations in the Jorea Coalfields, situated in the Hazaribagh ranges of central India.

Batra \textit{et al.} (1979)\textsuperscript{206}, collected 44 and 65 \textit{Anopheles stephensi} off man and cow-bait respectively. These mosquito collections was done in urban and rural areas during September 1976 to October 1977.

\textit{Anopheles stephensi} were collected per man per night in Shenapet (urban) area were 1.0 (Sept.), 0.4 (Oct.), 0.08 (Nov.), 0.03 (Dec.), 0 (Jan.), 0 (Feb.), 0 (March and April), 1.0 (May), 0.2 (June), 0.3 (July), 0.3 (Aug.), 0 (Sept.) and 0.2 (Oct.). But in rural areas, \textit{Anopheles stephensi} were nil in the above respective months, except in the month of June 1977 where biting rate was 0.3.

In South India, Samimi \textit{et al.} (1966)\textsuperscript{206}, reported that 16 and 20 \textit{Anopheles stephensi} were captured from indoors and outdoors respectively off man-bait during September-October in South Iran.

Kumar, Thavaselvan-Sharma (1995)\textsuperscript{207} studied on biting behaviour of disease vectors in Goa. In 1991, a longitudinal study on the biting behaviour of vector species \textit{i.e. Anopheles stephensi} was conducted with human baits from 18.00 h – 6.00 h in 15 nights in Goa, weather condition also influenced the biting behaviour.

Bhatt and Kohli (1996)\textsuperscript{208} caught 4,552 anopheline mosquitoes including \textit{Anopheles stephensi} in Kheda district, Gujarat. Most feeding occurred during the early night.

\textbf{WORLD}

In Bagdad, 1941, it was observed that biting time of \textit{Anopheles stephensi} was after mid-night.

De Burca and Jacob (1947)\textsuperscript{209} found that the feeding of \textit{Anopheles stephensi} occurred in the open at 9.00 hours.
In Pakistan, Reisen and Aslam Khan (1978)\textsuperscript{210} made a critical observation on seasonal landing of *Anopheles stephensi* on man and cattle bait and concluded that "*Anopheles stephensi* feed mostly before midnight being markedly crepuscular during periods of low ambient temperature". They observed during warmer months of June to November, biting rates on both man and cattle were highest during the second quarter of the night. In January and February, there was practically no biting after 19.00 hours and the biting was actually crepuscular, but in November and December some biting took place also in late night. They stated that they have made similar observations in Karachi also.

Zahar (1973)\textsuperscript{214} studied the ecology as well as biting activity of malaria vectors *Anopheles stephensi*.

According to Nagpal and Sharma (1995)\textsuperscript{219}, peak biting time of *Anopheles stephensi stephensi* was generally between 22.00 and 24.00 hrs. but varies from area to area and also from season to season.

Manouchehri, Janbakhsh and Eshghj (1975)\textsuperscript{212} worked on the biting cycle of *Anopheles dthali, Anopheles fluviatilies* and *Anopheles stephensi* in Southern Iran and observed. Most of the bites of *Anopheles stephensi* takes place between 18-24 h.

Kampen et al. (2002)\textsuperscript{213} in Berlin (Germany) exhibited that *Aedes aegypti* and *Anopheles stephensi* at the same age took human blood.

**Host – Preference**

Estimation of biting habits to determine whether the *Anopheles stephensi* have fed on human or animal blood is a means of distinguishing between anthropophilic and zoophilic species and an important parameter in the epidemiology of a disease.
Attempts to determine the preferential feeding habits of *Anopheles stephensi stephensi* in connection with the possible role they might play in the carriage of *Plasmodium vivax* and *Plasmodium falciparum* were made by Roy et al. (1938)\(^5\) when they carried out blood meal analysis of 172 female *Anopheles stephensi* by micro precipitation test, of which 33.1% (57) species were found to be disintegrated. They also identified the blood contained in *Anopheles stephensi stephensi* by specific antisera that *Anopheles stephensi stephensi* fed on cows i.e. 95.5% in preference to human blood 3.4%.

Hati et al. (1979)\(^2\) observed that *Anopheles stephensi stephensi* preferred both human (50%) and bovine blood (50%) among the specimen (20) collected from Calcutta.

Mukhopadhyay (1980)\(^6\) tested a total of 10 stomach contents from female *Anopheles stephensi* by immuno precipitation. All mosquitoes blood showed sharp preference to human blood.

Chatterjee & Hati (1986)\(^2\), blood meal analysis of 423 *A. stephensi* was performed of which 225 were taken from human habitat and 198 from cattle sheds.

Chakraborty et al. in (1995)\(^2\) showed that *Anopheles stephensi* preferred bovine blood with respect to human blood.

Totally 76.1% were positive to human antisera and 19.6% were anti human blood index of *Anopheles stephensi* was 76 using Garabat, Jones formula.

Chandra G. et al. (1996)\(^2\) worked on the feeding behaviour of *Anopheles stephensi* in Calcutta and in Calcutta HBI of *Anopheles stephensi* is i.e. 76.1. Hence *Anopheles stephensi* are anthropophilic.

During the study of 1993-94, Chakraborty et al. (1995)\(^2\) concluded that *Anopheles stephensi* was boviphilic.
India

Barber and Rice (1938) noted that *Anopheles stephensi* were boviphilic in Poona. They tested 43 blood smear, human positive (Anthropophilic Index) was found to be nil.

Afridi et al. (1939) observed 1.19 (4) human blood index of *Anopheles stephensi* in an urban area of Delhi and in 1938 HBI was 4.16 (I) in same area of Delhi.

Human Blood Index (HBI) of *Anopheles stephensi* throughout the Globe

<table>
<thead>
<tr>
<th>Species</th>
<th>Places</th>
<th>Authors</th>
<th>Years</th>
<th>HBI</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anopheles stephensi</em></td>
<td>Calcutta</td>
<td>Roy <em>et al.</em></td>
<td>1938</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Calcutta</td>
<td>Hati <em>et al.</em></td>
<td>1979</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Calcutta</td>
<td>Mukhopadhyay</td>
<td>1980</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Poona</td>
<td>Barbar and Rice</td>
<td>1938</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Delhi, an urban area</td>
<td>Afridi <em>et al.</em></td>
<td>1938</td>
<td>4.16</td>
</tr>
<tr>
<td></td>
<td>Delhi</td>
<td>Afridi <em>et al.</em></td>
<td>1939</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Madras</td>
<td>Bhaskar Rao <em>et al.</em></td>
<td>1946</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Vizagapatam</td>
<td>Senior White</td>
<td>1947</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>Hyderabad state</td>
<td>Krishnan (1961) as</td>
<td>1961</td>
<td>41-47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>quoted by Brucechwatt</td>
<td>1966</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gujrat</td>
<td>Nair and Summnotra</td>
<td>1964</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td>Iraq, Pakistans, Iran, and Saudi Arabia</td>
<td>Bruce-Chwatt</td>
<td>1964</td>
<td>0.3-5.3</td>
</tr>
<tr>
<td></td>
<td>Iran</td>
<td>Zahar</td>
<td>1974</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td>Pakistan</td>
<td>Reisen and Boreham</td>
<td>1982</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Pakistan</td>
<td>Garrett-Jones</td>
<td>1964</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tamil Nadu (India)</td>
<td>Reuben <em>et al.</em></td>
<td>1971</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tamil Nadu</td>
<td>Batra <em>et al.</em></td>
<td>1979</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tamil Nadu</td>
<td>Galaun, R.</td>
<td>1985</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tamil Nadu</td>
<td>Bhasin <em>et al.</em></td>
<td>1984</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calcutta</td>
<td>Hati <em>et al.</em></td>
<td>1988</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calcutta</td>
<td>Chakraborty <em>et al.</em></td>
<td>1995</td>
<td></td>
</tr>
</tbody>
</table>
Rao et al. (1946) collected 97 blood smear of *Anopheles stephensi* and 'gel-diffusion techniques' was done in Madras, of which 8 and 67 were found to be positive far human and bovine blood respectively.

In Vizagapatnam, 80 blood smear of *Anopheles stephensi* were analysed, among which 12 (15.07%) were observed to be positive with human blood (Senior White, 1947).

In Bombay, Macdonald (1957) noted that *Anopheles stephensi* was highly zoophilic.

Anthropophilic Index was 37.5 in Broach Town (Gujrat) were analysed by Nair and Samnotra (1967).

Sharma (1995) worked on the host feeding pattern of *Anopheles stephensi* in 2 districts of Haryana and 6 districts of Himachal Pradesh during 1990-92. They showed *A. stephensi* was zoophilic.

Reisen and Boreham (1982) carried out blood meal analysis of 439 *Anopheles stephensi*. Among which 4 were positive to human blood So HBI was 0.9%.

Rao (1981) observed that anthropophilic index have ranged from 1.0% sometimes upto 47%. They type form is more anthropophilic than var. *mysarenensis*. The variety *mysar. ensis* is predominantly zoophilic.

Thapar et al. (1998) observed that *Anapheles stephensi* are still zoophilic in nature by using microdot ELISA techniques in vector mosquitoes.

Macdonald stated (1957)*Anopheles stephensi* is highly zoophilic and in the country side of Bombay state conveys a highly unstable malaria.
World

Bruce-Chawatt et al. (1966)²²⁴ performed 'precipi test' of *Anopheles stephensi* and observed 0.3%-5.3% HBI in Iraq, Iran, Saudi Arabia and Pakistan.

Rahman & Muttalib (1967)²²⁵ investigated the malaria situation in Karachi city, reported that *Anopheles stephensi* was anthropophilic.

Zahar (1974) reported 24% HBI of *Anopheles stephensi* in Iran²²⁶.

Briegel et al. (1993)²²⁵ in Switzerland worked on multiple blood meals as a reproductive strategy in *Anopheles*. They showed that *Anopheles stephensi* (Liston) fed multiply but fecundity was less affected.

Nalin (1985)²²⁸ observed that *Anopheles stephensi* are main vector in Karachi. They were feeding chiefly on buffaloes in periurban area.

Ten years study (1955-64)²²⁶ of host selection by Anopheline mosquitoes were performed by L.J. Bruce Chawatt, Garret-Jan es and B. Weitz. The data were obtained from 41,000 blood smear collected from 79 species of *Anopheles* from Ceylon, India and Nepal.

1,24,000 precipitation tests on 92 Anopheles species and they preferred human blood than others although sample size is very low.

Garrett Jones et al. (1980) reviewed the feeding habits, host selection pattern of *Anopheles* mosquitoes and also calculated HBI of *Anopheles stephensi*.

Susceptibility Status of *Anopheles stephensi*

The control of *Anopheles stephensi* has, received considerable attention from quite early days after Ross's²³⁰ discovery of the role of *Anopheles* mosquitoes in the transmission of malaria. Malaria in the major cities of India being known to be caused by *Anopheles stephensi*. Before the variety 'mysorensis' was recognized, it had been
assumed that *Anopheles stephensi* was predominantly an urban mosquito with predilection for breeding in man-made breeding habitats.

First control programme for *Anopheles stephensi* has been introduced in Bombay city and larval breeding sites i.e. wells were highly checked and preventive control measures have been taken in wells.

The successful programme in Bombay has been followed with good work in several other cities such as Delhi and Bangalore.

**INDIA**

In India, 1944 DDT was introduced as a residual insecticide for the control measures. *Anopheles stephensi* has also developed resistance to the insecticides being sprayed. The first instance of malathion resistance in *Anopheles stephensi* was detected in Haryana by Subbarao *et al.* 1984.

From 1946 onwards, malaria control demonstration projects using residual insecticides were started with the help of WHO in U.P., Terai, Rayagada Malnad and Wynad. Later, other pilot projects in Karnataka, Maharashtra, West Bengal, Assam etc. were also taken up. By 1952, a population of 30 million was being protected with residual insecticides spraying. The results of the pilot projects were highly encouraging and prompted the country for launching a nation wide National Malaria Control Programme in 1953.

For continuous control of malaria National Malaria Eradication Programme was launched in 1958 recommended by WHO with the commencement of the phase of NMEP, the spray operations were started from 1958-59. The surveillance operations were later on introduced in the year 1960-61.

The lowest incidence of malaria in the country was recorded in 1965 (99,667). The incidence of malaria started, increasing years to years and reached peak numbers (6.4 million) in 1976. Thereafter, as a result of the modified plan of operations (MPO),
1977 the incidence of malaria started declining and lowest incidence was recorded in 1983.

The National Malaria Control Programme (NMCP) was in operation for five years (1953-1958). By 1957-58 there was 63%-79% reduction in epidemiological indices (Narasimham et al., 1987). The progress of malaria control was so spectacular that in 1958 NMCP was re-designated as the National Malaria Eradication Programme (NMEP) with malaria eradication as the final goal to be achieved in a phased time schedule of 7 to 9 years (Rao, 198-).

After the introduction of DDT residual spray under National Malaria Eradication Programme (NMEP), the incidence of malaria in India declined from an estimated 75 million cases and 0.8 million deaths in 1952 to an all time low of 0.1 million cases with no death in 1965 (Das, 1997). From 1965 onwards the number of malaria cases started rising and reached a peak 6.4 million cases in 1976 (Das and Amalraj, 1997).

Epidemic situations were widespread in the country. To combat malaria the Government of India, based on the recommendations of the "In depth evaluation committee" constituted in 1970 and consultative committee of Experts in 1974. Implemented Modified Plan of Operation (MPO) for NMEP in 1976. The objectives of MPO are to prevent mortality, reduce morbidity due to malaria and maintain both agricultural and industrial progress (Narasimham, 1988).

In 1977, modified plan of operations was launched (Pathanayak and Ray, 1980) and the malaria decreased to 2-3 million cases in 1984 and was maintained at the same level. In 1994, after large scale epidemics were experienced, deaths due to malaria increased (Shiv et al. 1998).

WHO recommended a process-based approach to malaria control involving community with decentralized planning in the Global Malaria control strategy.

The resistance to DDT in Anopheles stephensi adults was observed in Salam, Bhavani and Kumarapalyam (Bhombre, Roy and Samson, 1963).
DDT resistance was also found in Andhra Pradesh in 1962, at Guntur, Visakhapatnam and Hyderabad city (WHO tech report series 1963 Rao, Sitaraman, 1964).245

Karnataka, Maharashtra, Gujrat, Rajasthan, Madhya Pradesh and Tamil Nadu have reported resistance either to DDT or to HCH, but double resistance was also observed in Gujrat and Maharastra (Sharma, 1986).246

Resistance to HCH has also been recorded from Calcutta and Kotah in Rajasthan (Bhatnagar and Wattal, 1979).247

Singh & Bansal in 1996 reported the susceptibility status of Anopheles stephensi in Thardesert, Rajasthan. They surveyed in three districts i.e. Barmer, Jodhpur and Pali. Anopheles stephensi was found resistant to DDT, dieldrin, partially resistant to malathion and susceptible to fenitrothion, propoxur and permethrin.

Roop Kumari et al. in 1998 described the current insecticide status of Anopheles stephensi in different states of India. Resistance to DDT in adults was reported in Salem, Bhavani and Kumar Palyam. DDT resistance was also observed in Andhra Pradesh in 1962 at Guntur, Visakhapatnam and Hyderabad.

Latest NMEP reported that (till 1997) Anopheles stephensi has developed of double resistance to DDT, dieldrin in all districts where susceptibility tests were made.

Anopheles stephensi become resistant to DDT, Dieldrin and malathion in Chennai of Tamil Nadu, Belgaum and Dharward district of Karnataka and Banaskantha and Amreli districts of Gujrat.

In Andhra Pradesh Anopheles stephensi was highly resistant to dieldrin (30% mortality) in Waramgal district.
In Pune (Maharastra, 1980), double resistance of DDT and dieldrin became
grow among Anopheles stephensi.

Bansal and Singh (1996) conducted a insecticide susceptibility tests of
Anopheles stephensi in Rajasthan, this vector species is recorded to be resistance to
DDT and Dieldrin and 100% susceptible to fenitrothion and permethrin in Bikaner
district in Rajasthan. Triple resistance of Anopheles stephensi to DDT dieldrin and
malathion for the first time was reported from Goa in 1993 by Thavaselvam et al.

In Delhi, Verma and Rahman (1984) performed several experiment on
comparative to synthetic pyrethoids, natural pyrethrins, and DDT against mosquito
larvae.

Anopheles stephensi resistance to DDT was first observed in erode (Madras
state) in 1956 (Rajagapalan et al.) since then, resistance in this species to DDT and
gamma HCH or DDT alone has been recorded from many localities in the status of
Andhra Pradesh, Gujrat, Madras, Mysore and Rajasthan. In Salem, DDT and HCF
were applied both as adulticide, and larvicide.

Sharma, Jain and Sharma (1994) studied on seasonal prevalence and
susceptibility status of the some important Anophelines in Himachal Pradesh and
Harayana State, India. They observed that the mortality of Anopheles stephensi against
DDT ranged from 33%-100% in 1993.

In Kuruksetra adult Anopheles stephensi is susceptible to fenitrothion and
propoxur and resistant to Malathion.

Mathur (1992) studied on the epidemic of malaria in Barmer district (Thar
desert) of Rajasthan and the results revealed that adult Anopheles stephensi have a high
degree of resistance to DDT and dieldrin.

Sharma (1999) described the current scenario of malaria in India.
Malcom Netherland (1988)\textsuperscript{255}, observed that \textit{Anopheles stephensi} were susceptible to permethrin and its larvae are resistant to DDT in central Gujarat.

Manouchehri \textit{et al.} (1988)\textsuperscript{256}, described that in Southern India, adults of \textit{Anopheles stephensi}, the main vector of malaria are resistant to DDT, dieldrin and malathion and susceptible to propoxur.

Omerl \textit{et al.} (1980)\textsuperscript{265} worked on fourth instar larvae of \textit{Anopheles stephensi} and they were resistant to 4\% DDT and susceptible to permethrin.

Rathor (1980)\textsuperscript{258} observed the susceptibility status of six anopheline mosquitoes from nine localities in Punjab province to DDT, dieldrin, malathion, fenitrothion, fenitrothion and propoxur and DDT resistance was found in \textit{Anopheles stephensi} and also showed incipient malathion resistance.

Sharma \textit{et al.} (1997)\textsuperscript{259} studied on biological control of \textit{Anopheles stephensi} and other mosquitoes. Trials of \textit{Gambusia affinis} to control larvae of \textit{Anopheles stephensi}, \textit{A. annularis, Culex} were conducted in different habitats of Faridabad, Haryana, India in 1996.

Dhingra \textit{et al.} (1998)\textsuperscript{260} also studied on various process indicators for malaria control in Delhi.

Ansari \textit{et al.} (1998)\textsuperscript{261} observed relative efficacy of synthetic pyrethroid – impregnated fabrics against mosquitoes i.e. \textit{Anopheles stephensi} under laboratory conditions. Results revealed that deltamethrin was significantly superior than lambda cyhalothrin and cyfluthrin.

Sharma and Mehrotra (1986)\textsuperscript{262} discussed about the analysis of the pattern of malaria resurgence revealed that malaria outbreaks preceded the true problem of insecticide resistance.

Thanvaselvam, Kumar and Sumodan (1993)\textsuperscript{250} conducted adult and larval insecticidal tests of \textit{Anopheles stephensi} in Panaji, Goa and observed that adults of
Anopheles stephensi were resistant to DDT (4%), 0.4% dieldrin and 5% malathion. The larvae of Anopheles stephensi were also resistant to DDT 2.5 mg/l) and malathion (3.125 mg/l).

Chakraborty and Kalyansundaran (1992) conducted a test in the laboratory strain of the Anopheles stephensi and observed. LD$_{90}$ level of them with permethrin upto five generations. The development of cross resistance to 4% DDT was also noticed.

Basker and Shetty (1992) studied the status of Anopheles stephensi to various insecticides.

Das (1997) studied on the behavioural responses of Anopheles stephensi to residual application of DDT. Results of the irritability test demonstrated highest irritated behaviour of Anopheles stephensi to DDT.

Calcutta

Wu, Ghosh, Moelymont and Roy in 1946 described a preliminary report on some laboratory and field experiment on Anopheles stephensi both adult and larvae in Calcutta to pyrethrum, D.D.T. and Gammexane. The results of this experiments revealed that 5% DDT in road dust (it is a mixture containing 0.1%, 0.5% and 1.5% pyrethrum, DDT and Gammexane, respectively) tack 2 hours to paralyse the larvae and complete kill was effected only after 96 hours.

In Calcutta Chakroborty and Tandon (1998-2001) worked on the insecticides susceptibility status of Anopheles stephensi (Liston) both larvae and adult in Calcutta, W.B. Adult Anopheles stephensi stephensi were resistant to 4% DDT and susceptible to 1% fenitrothion and larvae are partially resistant to Temephos, susceptible to malathion, fenthion and fenitrothion at WHO recommended dosages.
Anopheline larvae were noticed to be equally affected by Pyrethrum D.D.T. and Gammexane, the effectiveness of D.D.T. and Gammexane lasted much longer than pyrethrum.

Sen (1957)\textsuperscript{286} made an experiment for the detection of susceptibility status of \textit{Anopheles stephensi} to D.D.T. (5\%) gammexane (5\%), pyrethrum (1\%) insecticides used as sprays. He observed that knock down effect of pyrethrum was more powerful than other two insecticides and after 24 hours mosquitoes were killed more in numbers by the effect of gammexane than DDT.

In larvicidal effect against mosquitoes – breeding DDT and gammexane lasted longer than pyrethrum. In room spray, the residual effect of D.D.T lasted much longer.

In 1957, Sen and Dasgupta\textsuperscript{287} studied on the susceptibility status of \textit{Anopheles stephensi} in Calcutta and showed that \textit{Anopheles stephensi} at Calcutta was highly susceptible to 2\% and 1\% dosages of the insecticides although mortality was observed at different exposure periods.

Very little study was done on susceptibility status of \textit{Anopheles stephensi} to DDT from eastern region of India with special reference to Calcutta though resistance in this species to DDT has been reported from Andhra Pradesh, Rajasthan (Pal, 1974)\textsuperscript{224}.

Sen in 1957 observed 100\% mortality of \textit{Anopheles stephensi} with 2\% DDT.

Hati \textit{et al.} in 1977\textsuperscript{288} performed an experiment to detect the susceptibility status of \textit{Anopheles stephensi} with 4\% DDT in Calcutta and observed that \textit{Anopheles stephensi} was partially resistant to DDT (mortality 90\%) in Calcutta.

Mukhopadhyay \textit{et al.} in 1997\textsuperscript{289} made an experiment for determination of susceptibility status of \textit{Anopheles stephensi} in Calcutta and reported that \textit{Anopheles stephensi} adults were found resistant to DDT, Propuxor, Malathion but susceptible to Fenthion (Beytex) and Deltamethrin and \textit{Anopheles stephensi} larvae of Calcutta have developed resistance to 3.125, Malathion and susceptible to fenitrothion and fenthion

\textsuperscript{286}Sen (1957)

\textsuperscript{287}Sen and Dasgupta

\textsuperscript{288}Hati \textit{et al.}

\textsuperscript{289}Mukhopadhyay \textit{et al.}
(125 mg/lt) and Sharma, Jain and Sharma, Nov 1994 described the susceptibility status of *Anopheles stephensi* in Himachal Pradesh and Haryana state. *Anopheles stephensi* was resistant to 5% Malathion in Karnal, Ambala and Kurukshetra and susceptible to fenitrothion and propuxur in Kurukshetra.

**WORLD**

*Anopheles stephensi* is widely resistant to DDT and dieldrin (WHO, 1976)\(^{264}\). *Anopheles stephensi* was resistant to DDT and HCH in Afghanistan, Iran, Iraq, Pakistan, Saudi Arabia.

They worked on Fourth instar larvae of *Anopheles stephensi* and they were resistant to 4% DDT and susceptible to permethrin.

Pal (1974)\(^{266}\) WHO (vector Biology and Control), the present status of insecticide resistance in Anopheline mosquitoes.

Bang (1985)\(^{267}\), nine member countries of WHO Southeast Asia Region (SEAR) have made extensive and intensive use of residual insecticides for the control and eradication of malaria for over past three decades. *Anopheles stephensi* is distributed from eastern Arabia and southern Iraq, east Geneva and south across India and Burma, Thailand and South China. In this region this is the major urban vector only in India. In western and north western India, this species (Variety mysorensis) is also an important vector under rural conditions.

Adult *Anopheles stephensi* was multiresistant (i.e. resistant to DDT, dieldrin, HCF etc. in South East Asian Region (SEAR) and EMR (Eastern Mediterranean Region).

Davidson and Zahar (1973)\(^{268}\) (WHO) described on DDT resistance in *Anopheles stephensi* in different country of the world.
The first indications that DDT was failing to control malaria transmitted by *Anopheles stephensi* were given by epidemiological observations made by Daggy 1957 in Saudi Arabia.

Kondrachine and Trigg (1997) in Switzerland discussed on ‘Global Review of Malaria’. Malaria continues to be one of the main public health problems in the world. Main public health problems in the world especially in the majority of frical countries. To overcome the malaria challenge, there is a need for concerted efforts by the health services, the private sector, the communities themselves, including the international community.

Zahar studied on malaria vectors in the eastern Mediterranean (WHO). In Iraq, Iran, Saudi Arabia *Anopheles stephensi* is resistant to DDT/dieldrin. The status resistance in this vector and its operational significance were reviewed by change. The susceptibility status of *A. stephensi* to DDT was checked periodically and routine estimation of house resting density by spray capture and larval mortality rate was low in November, 1966.

Continuous evaluation of DDT spraying in 1967 showed that resistance of *Anopheles stephensi* in DDT was increasing.

Hewitt et al. (1995) studied in Pakistan. In tents sprayed on the interior surface with permethrin 0.5 mg/m² with deltamethion 0.03 mg/m², the biting rate of *Anopheles stephensi* was reduced.

Bragdon et al. in Atlanta (1992) discussed about the insecticide bioassays and biochemical microtitre assays were compared for detection of resistance to malathion and fenitrothion using inbred laboratory strains of malaria vectors, *Anopheles stephensi* and other Anophelines.

Scott and Georghiou (1986), a strain of *Anopheles stephensi* from Pakistan was 8.7 fold resistant to malathion and no cross resistance to fenitrothion and permethrin.
Magesa et al. (1994) detected that Anopheles stephens was resistant to permethrin (at least 1 hour exposure to permethrin insecticide).

Malcom (1988) in Netherlands worked on reduced susceptibility to permethrin and its relationship to DDT resistance in larvae of Anopheles stephensi. Some evidence for an additional tolerance to DDT was found to be associated with reduced larval susceptibility to permethrin.

Romi et al. (1997) described that in Italy Anopheline populations were fully susceptible to deltamethrin, malathion and DDT, reduced susceptibility to permethrin and propoxur.

Curtis (1999) suggested that pyrethroid treated bed nets are the most promising available method of controlling malaria in the tropical world.

Boase (2001) worked on vector control. For control of the vector species i.e. Anopheles stephens use of insecticide treated plastic sheeting and bed nets and alliances to provide effective vector control programmes.

Jong and Ross (1999) discussed about the importance of interrupting malaria transmission in the eradication of malaria in the advent of increasing prevalence of insecticide i.e. DDT and drug resistant Plasmodium sp.

Ghavami and Ladonni (2000) in Iran a study was conducted to determine the discriminative dose of 5 pyrethroid insecticides against two strain of female Anopheles stephensi and they are susceptible to pyrethroid insecticides.

Mehrooyan and Ladonni (2000) observed the irritability level of Anopheles stephensi strain collected from Bandar Abbas. Iran was evaluated in nets impregnated with five different pyrethroid.

Vatandoost and Moinvaziri (1999) studied on the current response of Anopheles stephensi larvae to 4 WHO recommended larvicides i.e. malathion,
temephos, chlorpyrifos and fenitrothion at diagnostic conc. of larvicidae and they are susceptible to malathion and resistant to other three insecticides.

Malcolm and Robinson (2001)\textsuperscript{282} studied that susceptibility to DDT decreased from the first to fourth instar in the susceptible strain by 443 fold for knockdown and 15 fold for mortality and in the resistant strain by 8.5 fold for knockdown and 491 fold for mortality.

Ladonni \textit{et al.} (1995)\textsuperscript{284} have done a comparative study on susceptibility of the larvae of two wild strains of Anopheles stephensi to eight insecticides in South of Iran. The larvae of \textit{A. stephensi} of Bandar Abbas strain and kazeroan strain showed that \textit{A. stephensi} mosquitoes are susceptible to 4\% DDT.