2.0 HISTORICAL OVERVIEW
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2.1 General Aspects

Human malaria is known to have contributed to the fall of ancient Greek and Roman empires. Troops in both the Civil war and the Spanish-American war were severely incapacitated by this disease. More than one quarter of all hospital admissions during these wars was malaria patients. During World War II, malaria epidemics severely threatened both the Japanese and Allied forces in the Far East. In fact the ultimate success of the United States in Asia may be credited to a large degree to the parasitologists, both civilian and military, who fought and conquered this ruthless enemy. To some degree, the same may be said of the military conflicts in Korea and Vietnam (Cheng, 1986).

The first detailed description of the clinical picture of malaria and its treatment with the Cinchona bark was presented by the Geneva physician Morton in 1696. In 1880, the French physician Laveran in Algeria identified the causative agent of human malaria. In 1885, Golgi established the presence of *Plasmodium vivax* and *Plasmodium malariae*, Sakharov in 1889, Marchiafava and Celli in 1890 described *Plasmodium falciparum* (Loban and Polozok, 1985).

Malaria still remains a very important disease of man. It created havoc in our country. The disease killed 8,00,000 people in India in 1953 out of nearly 75 million affected. Total loss of income due to malaria amounted to 500 million dollar per year (Hati, 2001). The scourge of malaria not only brings death in its wake; it continues to pester the living, weakening and demoralizing them every few days over a period of months and years. There is a marked deterioration, physical and mental, in a race, which suffers from malaria continuously. It saps the strength of the farmer, and he neglects agriculture; it saps the energy of the labour, and he proves to be inefficient worker; it saps the mental activity of an intellect, and he is reduced to a narrow groove, superstition, petty quarrels and general backwardness. Unborn children are throttled to death; women are rendered barren; youth is shriveled up into premature old age by the single curse of malaria. It brought about the debacle of the splendour that was Greece, the decline and fall of the Roman Empire, and the disappearance of the Egyptian civilization and the ancient culture of Ceylon (Sharma, V.P., 1995).

2.2 Malaria incidence in countries other than India

The global incidence of malaria is estimated to be on the order of 110 million clinical cases each year. Some 280 million people carry the parasite (WHO, 1991). Of the 4.7 million cases reported
to the WHO in 1990 by member countries other than those in Africa, 85 percent were concentrated in 9 countries (WHO, 1992). In these countries, malaria is clearly a local problem (WHO, 1990).

2.2.1 Africa

Between 1983 to 1987, the number of reported cases of malaria in countries north of the Sahara increased from 453 to 457. There were 1061 cases in 1988 and 1174 in 1989. On the basis of reported cases, 2-21 million cases of malaria per year have been estimated to occur in Sub-Saharan Africa. An extrapolation of data from surveys of fever incidence and parasitemia suggests that the incidence of clinical malaria in Sub-Saharan Africa is actually 80-90 million clinical cases annually in a population of 515 million. The prevalence of the infection is considered to be on the order of 260 million parasite carriers (WHO, 1989, 1991). The majority of deaths from malaria occur in Africa, where a figure of 1 million deaths of African children per year is often mentioned (WHO, 1991).

2.2.2 Southeast Asia

In Bangladesh, the number of cases of malaria dropped to 36,000; in Bhutan, the number dropped to 13,000 in 1987. However, cases increased to 51,000 and 19,000 respectively, in 1989. In Nepal, the programs for malaria control in the malarious areas are bearing fruit; there, the number of cases has been reduced from 42,000 in 1985 to 22,000 in 1989. Malaria incidence rose in Sri Lanka from 35,000 cases in 1982 to 676,000 in 1987, but the number of cases decreased to 259,000 in 1989 (WHO, 1989, 1991).

2.2.3 Eastern Asia and Oceania

An analysis of malaria cases reported in 1987 from eastern Asia and Oceania indicates a concentration of cases in China (2,11,000; 15% Plasmodium falciparum), Indonesia (19,000), the Philippines (1,64,000), the Solomon Islands (72,000) and Thailand (3,21,000), Mayanmar, Vietnam, and Laos reported 61,000, 1,30,000 and 35,000 cases respectively (WHO, 1989). The number of cases decreased in China to 1,38,000 in 1989. In that year, malaria also decreased in Thailand but levels remained stable in Indonesia (WHO, 1991).

2.2.4 Europe

Endemic Plasmodium vivax malaria occurred mainly in South-eastern Turkey but also to a lesser extent elsewhere in the country. The Annual Parasitic Incidence (API) in Turkey was
reduced from 0.75 per 1000 population in 1986 to 0.39 in 1987. The total numbers of cases were 12,000 in 1989. In the Common Wealth of Soviet States, malaria is limited to the Republics of Azerbaijan Tadjik. In 1987 and 1989, 338 and 285 cases of local transmission were registered, respectively (WHO, 1989, 1991).

2.2.5 The Americas

In 1974, the number of registered malarial cases in the 21 countries of the region with active malaria control program was 2,69,000. At the end of 1989, 1,099,436 cases were reported and the reported API was 2.72 per 1000. The 5 countries with the highest API per 1000 population during 1988 were French Guinea (69.2), Belize (29.5), Guyana (20.3), Nicaragua (12.3), and Honduras (9.2) (PAHO, 1990).

2.2.6 Malaria In India

Lal et. al. (2000) reported that in this country, during the year 1947 to 1952, average people suffered due to malaria was 7 crores 50 lakhs, whereas death results to 8 lakhs. After 1952, people from all over the World came forward to combat malaria. India came to the forefront in 1953 (Burman, 2000). In India, the control of malaria was given to priority and as a result of nationwide spraying of residual insecticides supported by case detection and treatment, malaria started to disappear (Sharma, 1995). National Malaria Control Programme (NMCP) was taken due to which in 1958, the number of people suffering from malaria comes down to 20 lakhs as compared to 7 crores 50 lakhs in 1952.

By the early 1960s progress in malaria control was simply spectacular. From an annual incidence of 75 million and 0.8 million deaths, malaria cases were reduced to 1 lakh and there were no deaths due to malaria (Sharma, 1995). Hati (2001) reported that the number of malaria cases rose to 3,50,000 in 1969 as compared to 1,00,000 in 1965. 19,30,273 and 31,67,658 cases were detected in 1973 and 1974 respectively. In 1975, 1976 and 1977 about 5.1, 6.4 and 4.7 million people respectively suffered from malaria.

Resurgence of *Plasmodium falciparum* since early 1980’s has made the malarriogenic situations more complex. The Directorate Of National Anti-Malaria Programme, Govt. Of India, New Delhi, reported that the *Plasmodium falciparum* cases increases from 20.3% to 36.8% in the year 1980 to 1989. During the span of ten years, 2251 people died due to *Plasmodium falciparum* malaria. The situation became more complicated during nineties. During the year 1990 to 1999, 7424 people died due to *Plasmodium falciparum*. 
WHO (1996), reported that in South East Asia, more than 60 percent of malaria reported form India. Annually 25 lakhs people suffer from malaria (Dhillon et. al., 1999), amongst which 40 percent contributes by *Plasmodium falciparum*.

### 2.2.7 Scenario of Malaria in West Bengal

Malaria shows an increasing trend since 1990 in West Bengal. There were 27531, 40452, 28179, 46138, 74293, 91014, 80127, 79881, 132088 and 197259 malaria cases reported from West Bengal in the year 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998 and 1999 respectively. The corresponding figures of death due to malaria were 4, 13, 43, 37, 52, 87, 55, 74, 77, and 155 respectively (Hati, 2001). There were 32465 and 42566 *Plasmodium falciparum* cases during the year 2000 and 2001 in West Bengal. The corresponding figures of death due to the disease were 103 and 191 respectively (Health on the March, 2001-'02).

### 2.2.8 Scenario of Malaria in Calcutta

Malaria is endemic since the official inception of the city over 300 year’s back. Job Charnock landed here in 1690 with 1200 Englishmen amongst whom 460 died of malaria (O’Malley, 1914). Malaria was nearly eradicated in 1960’s. The resurgence of indigenous cases of *Plasmodium falciparum* malaria were, however, not reported in Calcutta before 1981 (Dutta et. al., 1982). In Calcutta from 1971 to April1985, altogether 75,342 people suffered from malaria. The disease is increasing in Calcutta which constituted 0.1-0.2% of total cases, occurring in Bengal, but in 1984, it comprised about 56.2% of total cases. From 1971 to 1985 (April), of all malaria cases, occurring in Bengal, 23.1% occurred in Calcutta. From 1971 to 1980, there were only 10 cases of *Plasmodium falciparum* and all of them were imported cases (Hati, 1985). Hati (1982), for the first time reported indigenous cases of *Plasmodium falciparum* in Calcutta. However, it may be recalled that in bygone days, *Plasmodium falciparum* malaria in Calcutta constituted about 56% of the total cases (Hati et. al., 1980). The death due to malaria were reduced to as 4, 7, 52, 17, in 1993, 1994, 1995 and 1996 respectively (Hati, 2001).

There were 13624, 15606, 17969, 19084, 18298, 36804, 44602, 34514, 88402 and 132367 malaria cases recorded in Calcutta during the year 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, and 1999 respectively. The corresponding figures of death were 0, 0, 0, 4, 7, 52, 17, 38, 53 and 79 respectively (Hati, 2001).
2.2.9 Changing Scenario of Malaria in India due to Climatological Changes

Malaria outbreak in India is well correlated with season and the epidemics occur mostly in the pre-monsoon season (May-June) in South India and the late monsoon and post-monsoon seasons (August to November) in other parts of the country. In peak summers in North and Central India and in winter the disease tapers off and epidemics rarely strike as the mosquito menace becomes least in this period (Bhattacharya et. al., 2002). Epidemics are increasing in the forests and malaria has become a major health hazard for the tribals (Prakash, 1997, 2000; Gyan Chand, 1997; Singh, 1999 & Shukla, 1999). About 25% of the total malaria cases and about 505 of the vector *Plasmodium falciparum* are reported form the tribal belt particularly from Orissa and Madhya Pradesh.

Monthly distribution of malaria cases in Assam (Prakash, 1997) with respect to monthly temperature and rainfall over the period during August 1995 to July 1996 indicate that the Slide Positivity Rate (SPR) is over 70% that occurred in November-December 1995 and second maximum of 65% in May 1996. Sen (1973) and Dutta (1991) reported that the number of malaria cases were minimum when the maximum temperature was below 30°C and the minimum temperature varied between 15-17°C.

As per Prakash (2000), there is a decrease in malaria profile in Jorhat, Assam from peak of 1995 to April 1999. A sudden rise was observed in May, which along with higher than average temperature (30-31°C) in February and March 1999 could have resulted in high density of the vector in hilly areas and forested region of Naga hills.

According to the recent reports, in the districts of Orissa, 190,794 samples were found to be carrying the cerebral malaria parasites, viz. *Plasmodium falciparum*. There are 23 species of mosquitoes in Orissa and over 400,000 people contacted the disease in 1999 with a death toll of 402. Recent work has shown that conditions in arid and semi-arid regions of India (Rajasthan and Gujrat), which were considered less vulnerable to malaria, have also become susceptible to malaria outbreaks (Akhtar and McMichael, 1996; Bansal, 1998; Kondrasen., 1998; Tyagi, 1998; and Batra et. al., 1999).
2.3 Composition of Mosquito Fauna especially Anopheles Fauna in some malaria endemic Areas

*Anopheles albimanus* and *Anopheles vestapennis* were the most abundant species and these species exhibited evening peak of biting activity in the fields of Dajabon Province of Dominion Republic (Mekuria, et. al., 1990). A survey was conducted to record Anopheles species of Western Province of Papua New Guinea using carbon-di-oxide baited light traps larval sampling (Cooper et. al, 1997).

In the Gambian village of Sanja, malaria is transmitted mainly by *Anopheles gambiae* complex (Jawara et al, 1998). Usage of carbon-di-oxide baited light traps and larval sampling of 12 species of Anopheles mosquitoes in Northern Australia was reported by Cooper et. al.,(1996).

Rathnanrithikul et. al., (1996) reported the seasonal prevalence and variation in the density of 21 species of Anopheles in Southern Thailand. Studies on the Anopheles fauna of Kheda district and species specific breeding habitats were carried out by Yadav et al (1989). Sixteen Anopheles species were recorded from canal irrigation area, followed from riverine area and non-canal irrigation area. Mosquito fauna of Sagar Islands include 20 species belonging to 5 genera; Aedes, Anopheles, Armigeres, Culex and Mansonia from the northern, middle and southern regions (Pramanik et. al., 1993). Prakash, et.al. (1998) recorded 31 species of mosquito fauna belonging to eight genera; Culex, Coquillenttidia, Malaya, Mansonia, Uranotaenia, Aedes, Anopheles and Armigeres in South Tripura District.

At least 104 species of mosquitoes under the different genera have been recorded in Bengal since 1900 (Pramanik et. al. 1992). Hati, et.al. (1994) reported 3 species of Anopheles, namely *Anopheles stephensi, Anopheles vagus, Anopheles subpictus* in the urban area and five species namely, *Anopheles vagus, Anopheles subpictus, Anopheles annularis, Anopheles hyrcanus* and *Anopheles barbirostris* in the rural area of Bengal. Occurrence and distribution of 13 species of Anopheles of Siliguri Naxalbari block, Darjeeling were reported by Malakar et. al.(1995). Saha et. al.(2001) reported eight species of Anopheles during their study on urban Anopheline in the Himalayan foothills of Darjeeling district, West Bengal. Among the female specimens collected during the study, the most abundant species was *Anopheles vagus* (44%) followed by *Anopheles subpictus* (30%), *Anopheles culicifacies* (13%) and *Anopheles barbirostris* (7.4%), while others were very few in numbers.
Covell (1932) had recorded 13 species of Anopheles mosquitoes from Calcutta. These were *Anopheles vagus*, *Anopheles subpictus*, *Anopheles ludlonii*, *Anopheles culicifacies*, *Anopheles varuna*, *Anopheles aconitus*, *Anopheles tesseletus*, *Anopheles stephensi*, *Anopheles fuliginosus*, *Anopheles pallidus*, *Anopheles pseudojamesi*, *Anopheles sinensis* and *Anopheles barbirostris*. A large-scale survey was conducted in 1964 – 1965 to gather information about house frequenting mosquitoes of West Bengal and Calcutta (Ghosh, et. al. 1966). Altogether 18 species of mosquitoes were obtained. Pramanik et. al.(1992) reported 13 species of Anopheles from Calcutta, comprised of 60.54% of *Anopheles subpictus*, followed by *Anopheles vagus* with a frequency of 22.06%. Interestingly they found 23 specimens of *Anopheles sundaicus* from Salt Lake city and Eastern Bypass. Bhattacharya et. al(1999) reported 18 species of mosquitoes comprising of five genera, viz. Culex, Anopheles, Aedes, Armigeres and Mansonia, during their study, from Calcutta and adjoining suburbs. Amongst these, Culex (71.59%) topped the list, while Mansonia was the most scarce (0.86%). Bhattacharya and Mukherjee, (1996) collected 18,205 mosquitoes. Amongst the seven Anopheline species, *Anopheles subpictus* (36.10%), *Anopheles annularis* (22.10%) and *Anopheles stephensi* (19.65%) occupied the first, second and third position respectively.

### 2.3.1 Collection of Mosquitoes off Man Bait

**Calcutta**

Hati et. al(1971) recorded distribution of different species of nocturnal man-biting mosquitoes in Bagbazar and Fort William. In Bagbazar, *Culex quinquefasciatus* constituted 99.2% of nocturnal man biting mosquitoes and in Fort William this figure was 95.9%. Mean per hour contact of *Culex quinquefasciatus* was 5.30. The other mosquito species in Bagbazar were *Culex vishnui* complex, *Culex sitiens*, *Culex gelidus*, *Armigeres subalbatus*, *Anopheles stephensi* and *Anopheles aconitus*.

Similar study (Mukhopadhya et al, 1978) was conducted in Central Calcutta, where only 7 species of nocturnal man-biting mosquitoes were obtained, namely, *Culex quinquefasciatus* (97%), *Aedes aegypti* (2.5%), *Anopheles stephensi* (0.2%), *Armigeres subalbatus* (0.1%), *Anopheles subpictus* (0.017%), *Anopheles vagus* (0.017%), and *Culex gelidus* (0.008%). During the study period no *Culex sitiens*, *Culex vishnui*, *Mansonia indiana*, *Anopheles aconitus*, *Anopheles sundaicus* were caught off man baits, showing that there is some fluctuation in composition of mosquitoes. Hati et. al(1994) reported that in case of man-landing catches,
Anopheles stephensi (0.49%) and Anopheles vagus (0.05%) were available in Calcutta. During indoor resting catches, 3 species of Anophelines were detected in Calcutta, namely, Anopheles stephensi (0.36%), Anopheles subpictus (0.49%) and Anopheles vagus (0.89%). At Memari, 4 species were encountered, namely, Anopheles vagus (1.18%), Anopheles subpictus (2.17%), Anopheles annularis (0.27%) and Anopheles hyrcanus (0.06%). Chowdhury (1936) reported that Anopheles stephensi was most active night biting mosquitoes in Calcutta. Between July 1997 and June 1978, a total of 27 Anopheles stephensi mosquitoes were landed on human bait. Per man hour density was 0.023 (Mukhopadhyay, 1980).

2.3.2 Man-Biting activity of Anopheles stephensi Mosquitoes in Countries Other than India

Krishnan (1961) reported that certain observations in 1941 in Baghdad showed that biting time of Anopheles stephensi was over by midnight. Feeding of Anopheles stephensi occurred in the open at 09.00 hours (De Burca and Jacob, 1947). Reisen and Aslam Khan (1978) made a critical study on seasonal man and cattle landing Anopheles stephensi in Pakistan and concluded that Anopheles stephensi fed mostly before midnight being marked crepuscular during periods of low ambient temperature. They stated that during warmer months, biting rates on man was the highest during second quarter of night.

India

Sixteen and twenty Anopheles stephensi were collected indoors and outdoors respectively off human bait during September – October in South India (Samini, et.al, 1966). Nursing et. al.(1934) collected 33% Anopheles with fresh blood between 21.00 and 24.00 hours and 67% between 04.00 and 06.00 hours from the Mysore State. 3 and 1 Anopheles stephensi from cattle trap and Gorilapalem respectively were captured by Senior White et. al (1944) in Vishakhapatanam. The only female Anopheles stephensi at 04.00 and 01.00 hours respectively in April and May was captured by Senior White (1946) engaging himself in a series of night catches at various points in the Korea coal field, situated in the Hazaribagh ranges of Central India. Batra et. al. (1979) collected 44 and 65 Anopheles stephensi off man and cow bait respectively from September 1976 to October 1977.

2.3.3 Some important vectors of Malaria and their distribution in India

Anopheles sundaicus was established as the malaria vector around Chilka Lake in Orissa (Senior White and Adhikari, 1939; Covell and Singh, 1942). Rao, (1984) reported Anopheles annularis, Anopheles culicifacies, Anopheles stephensi and Anopheles sundaicus as the established
malaria vectors in India. *Anopheles annularis* was incriminated as malaria vector by Ghosh et al. in (1985) in Gurap village of Hoogly district (West Bengal). With regard to *Anopheles philippinensis*, another established vector of malaria, a team of research workers from Malaria Research Centre, Delhi found them during September and October 1986 in Birbhum and Burdwan districts.

Rao (1981) reported that in hills and foothills, *Anopheles fluviatilis* is very efficient with high anthropophily while in plains as in Deccan Plateau it acts as a moderate vector with high zoophily. Christophers (1902), Bose (1911), Paiva (1912), De (1923), Basu (1930), Covell (1932), Senior White (1934), Ganguly (1935), Strickland, Roy and Chowdhuri (1936), Roy et. al. (1938) and Mukhopadhyay (1980) incriminated *Anopheles stephensi* as the vector of malaria in Calcutta. In Bitra (Lakshadweep Islands) *Anopheles subpictus* and in Chetlet (Lakshadweep Islands) either *Anopheles subpictus* or *Anopheles varuna* or both are stated to be suspected vectors, though not incriminated by dissection (Roy et. al., 1978). In an outbreak of malaria in a few villages near Pondichery, similar circumstantial but inconclusive evidence has been cited in form of *Anopheles subpictus* (V.C.R.C., 1977). Panicker et. al. (1981) and Kulkarni (1983) noted *Anopheles subpictus* as a suspected vector of malaria in India. Hati (2002), in his book, 'Medical Parasitology' also mentioned *Anopheles subpictus* as a suspected vector of malaria in India. The distribution of some suspected vectors of malaria in India, Pakistan and Bangladesh are given in (Table - 1). Chatterjee et. al. (2003) during their study found *Anopheles subpictus* to be the carrier of natural sporozoite infection. *Anopheles minimus* in foothill areas and Sunderbans and Salt Lake, near Calcutta, are the principal vectors in the bygone days, when malaria was rampant in West Bengal (Hati, 1979). *Anopheles maculatus* was established as a vector in the foothill region of the Himalayas (Rao et. al.1973).

### 2.3.4 Infection and infectivity rates of some important malaria vectors, viz. *Anopheles stephensi, Anopheles subpictus* and *Anopheles annularis*

1412 wild *Anopheles stephensi* were caught and dissected by Afridi and Majid in (1938) and they found 8 gut and 1 gland infections. The percentage of infection was 0.7% in Bahrain Islands in the Persian Gulf. Krishnan (1961) found only one *Anopheles stephensi* infected when troops were concerned in and around Baghdad and there was an epidemic of malaria. Rahaman and Muttali (1967) found only one female *Anopheles stephensi* with sporozoites in the salivary gland, among 204 examined. A number of investigators obtained naturally infected *Anopheles*
<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Anopheles stephensi</em></td>
<td>In cities like Calcutta, Mumbai, Delhi, Chennai etc.</td>
</tr>
<tr>
<td>2. <em>Anopheles culicifacies</em></td>
<td>Madhya Pradesh, Bihar, Adjacent Parts of West Bengal, Rajasthan, Punjab, Kashmir, Nainital area, West-Pakistan.</td>
</tr>
<tr>
<td>3. <em>Anopheles Philippinensis</em></td>
<td>West-Bengal, Assam, North Bihar, Bangladesh.</td>
</tr>
<tr>
<td>5. <em>Anopheles varuna</em></td>
<td>Calcutta area, Jeypore hills, Singbhum hills, Satpura range.</td>
</tr>
<tr>
<td>6. <em>Anopheles sundaicus</em></td>
<td>Chilka lake area, Coastal Orissa, Vishakhapatnam, Ganjam, Chennai area, Coastal parts of West Bengal and Bangladesh.</td>
</tr>
<tr>
<td>7. <em>Anopheles minimus</em></td>
<td>Assam dooars, West Bengal, the foot hills of the Himalayas in M.P. &amp; South India.</td>
</tr>
<tr>
<td>8. <em>Anopheles dirus</em></td>
<td>Assam, Arunachal, Nagaland, Meghalayas, Mizoram, Tamilnadu, Tripura, West-Bengal, Karnataka, Andaman Islands, Bangladesh etc.</td>
</tr>
<tr>
<td>9. <em>Anopheles maculatus</em></td>
<td>Assam (Shillong), Northwest-Himalays, South India.</td>
</tr>
<tr>
<td>10. <em>Anopheles annularis</em></td>
<td>West Bengal, Orissa.</td>
</tr>
<tr>
<td>11. <em>Anopheles subpictus</em></td>
<td>Tamilnadu, Bitra and Chetlet (Laks hadweep Islands), Pondicherry, West Bengal.</td>
</tr>
</tbody>
</table>

* Suspected vector.
**Stephensi mysorensis** in Abadan, Bandar Abbas, Kazerum and Dezful in Southern Iran. The sporozoite rate was 0.2% to 0.7%. They further stated that in 1962, 298 *Anopheles stephensi* mysorensis were collected and kept in an insectary of Kazerum Medical Research Station for 12 days. 283 of those were dissected and 14 specimens were found positive for sporozoite in their salivary glands and two contained oocyst in their guts (Manouchchri et al., 1976).

### Indian Scenario

Bentley (1911) dissected 1228 *Anopheles stephensi* in Bombay City, of which, 30 and 91 were, found with gut and gland infections respectively. Hodgson (1914) reported 2 gut infections, out of 110 specimens of *Anopheles stephensi* dissected in Delhi. Sinton (1917) examined 45 specimens of *Anopheles stephensi* in Kohat district and found sporozoites in the salivary gland of one specimen. As per Covell (1928), Chalam (1926), they found 5 gland and 2 gut infections out of 151 mosquitoes dissected in Bombay. Covell in (1928) dissected 2511 *Anopheles annularis* out of which 4 (0.16%) were infective. 12 gland infections out of 671 *Anopheles stephensi* dissected were found in Bombay (Covell, 1928). King and Iyer (1929) observed one gland and nine gut infections out of 166 *Anopheles stephensi* dissected in Andhra Pradesh.

75 female *Anopheles stephensi* caught from the city of Lucknow and found 7 of them were infected (Banerjea, 1930). From Mysore State 2,708 *Anopheles stephensi* were dissected, amongst which 2 gut infections were reported (Sweet and Rao, 1931). Sur, Sarkar and Banerjea (1932) found 23.1% oocyst in the stomach of *Anopheles stephensi*. Ramsay and McDonald (1936) stated that sporozoites of *Anopheles stephensi* had been reported in the salivary glands in Bombay, the North-West Frontier Province, the United Province and Madras. Specimens with oocysts only were found in Mysore, Sind and Delhi. Amongst 238 *Anopheles stephensi* collected from Vijaya Villas Palace, Kothda, Baharampur, Durgapur and from Bhuj city in Kutch State, 5 were found to be infectious (Afridi, Majid and Singh, 1938). Singh and Jacob, (1943) reported the infectivity rate of *Anopheles stephensi* in Ahmedabad was 1.4%. Amongst 6133 *Anopheles subpictus* which were dissected, 52 had oocysts (0.85%) and 4 had sporozoites (0.07%) (V.C.R.C., 1981).

### Scenario in West Bengal

Out of 34,041 *Anopheles annularis* dissected, Timber in 1935 found the gland infection in 8 (0.02%) cases. Neogi and Sen (1962) dissected 193 *Anopheles stephensi* from Oyaria district, Burdawan and found one gland infection (0.51%). Dash et. al. (1982) detected sporozoites in
the glands of one *Anopheles annularis* out of 174 dissected in Keonjhar district, Orissa which neighbours West Bengal. During the period of August 1979 to July 1983, altogether 5428 *Anopheles annularis* collected from both cowsheds and human habitations in Hooghly were dissected, out of which the salivary glands of one *Anopheles annularis* were infective with sporozoites of *Plasmodium vivax* malaria. The infectivity rate was 0.018% (Ghosh et al., 1985). Chatterjee et al. (2003) reported that during their survey between March 2002 and February 2003 to study the distribution and prevalence of mosquitoes in the rural areas of Hooghly district, West Bengal, total 9 species of mosquitoes were collected. Amongst 9 species of mosquitoes *Anopheles subpictus* was found to be the carrier of natural sporozoite infection. Average sporozoite rate was 0.32%.

**Scenario in Calcutta**

Iyenger (1933) observed that positive results were obtained in every one of the batches of *Anopheles stephensi* fed on infective gametocyte carrier of *Plasmodium falciparum*. Out of 122 mosquitoes examined, 71 were positive for oocysts, 32 for sporozoites in the salivary glands and 76 had either sporozoites or oocysts or both. The results showed that *Anopheles stephensi* is very susceptible to experimental infection with *Plasmodium falciparum*. Out of total number of 112 mosquitoes dissected after the infective feed, 69 showed an infection either with oocysts or sporozoites or both. Sporozoites were observed in the salivary glands in 48 out of 112 specimens examined.

The salivary glands of *Anopheles stephensi* for the presence of sporozoites in Calcutta under laboratory condition was examined. The striking period of infection (90%) was found in November to January and a striking period of non-infection (0.7%) from March to July (Strickland et al., 1933). Roy (1943) made an experiment in laboratory for calculating the infectivity rate of *Anopheles stephensi* in Calcutta. The total oocyst and sporozoites rates were found to be 50.9% and 45.3% respectively, indicating that *Anopheles stephensi* was the classical vector of malaria in the city of Calcutta. Knowles and Basu (1944) carried out laboratory experiment for studying the infectivity rate of *Anopheles stephensi* in both controlled and uncontrolled situation of temperature and humidity. Out of 45% survival rate 42 and 38 infections in gut and gland respectively were found in *Anopheles stephensi* under uncontrolled condition. On the other hand, amongst 64% survival rate 33 and 27 gut and gland infections respectively were found in *Anopheles stephensi* during monsoon under controlled conditions. Amongst 53% survival rate
50 and 0.4 gut and gland infections respectively were found in *Anopheles stephensi* during post-monsoon period under controlled conditions. The available literatures regarding natural infection of *Anopheles stephensi* in Calcutta has been consulted Siddons (1946) first incriminated *Anopheles stephensi* as the vector of malaria in Calcutta. Out of 1052 *Anopheles stephensi* 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. The infectivity rate was found to be 1.56, only one infection was found, out of 64 *Anopheles stephensi* dissected in Calcutta (Mukhopadhyay, 1980). Out 357 *Anopheles stephensi* dissected, sporozoites were detected in the salivary glands of one *Anopheles stephensi* in the month of July (Hati et.al, 1986). *Anopheles sundaicus* was the potential vector of malaria in Salt Lake and Budge-budge, adjacent to Calcutta during the period between 1880 – 1936 (Hati, 1991).

2.3.5 The Resting sites of *Anopheles stephensi*

Global Scenario

Christophers and Shrott (1921) found that in Mesopotamia *Anopheles stephensi* was of retiring habit and its presence was therefore oversighted. Mulligan and Bailey (1936) reported that *Anopheles stephensi* (total catch 1200) of Huda village, Quetta, Beluchistan showed a marked preference for resting places which are in close proximity to human and animal dwelling shelters hastily erected by refugees. Few catches were made from outdoors. 1142 *Anopheles stephensi* were captured from huts, barrack-rooms and family quarters in Bahrain island by Afridi and Majid (1938). Rafi (1955) obtained resting *Anopheles stephensi* throughout the height of the wall inside rooms in Punjab (Pakistan). Quraishi (1965) collected a total of 2083 adults from a pet shelter (outdoors) but all of them were mysorensis variety.

In Iran, *Anopheles stephensi* was found in thatched human habitations and animal sheds (Kapar or Kumesh) and it preferred to rest on lower part of the wall or on the ground of unoccupied shelters (Monochchri et.al, 1976). *Anopheles stephensi* was found to rest underground shelters, such as "Quanats" (built on sloping land to bring underground water to the surface) in Bandar Abbas of Iran. Mahmud et. al. (1982) stated that during the pre monsoon season in Pakistan, mosquitoes typically seek suitable microhabitats within indoor resting sites lowering sampling proportion at this time.
Resting sites of *Anopheles stephensi* in India

In Mysore, *Anopheles stephensi* had a decided preference in human habitations for daytime resting places (Nursing et al, 1934). Sweet and Rao (1937) selected eight buildings in each state of three different villages of the same state for study. Percentage catches were 1.0, 0.4 and 0.9 of the total Anopheline found. Afridi et. al (1938) experienced great difficulties in collecting *Anopheles stephensi* in Kutch state. This species was frequently found to hide itself in the concave surface of the cut bamboo pieces, which support the tile roofs in most poor habitations and cattle sheds. Barbar and Rice (1938) in Poona and its vicinity collected 55 *Anopheles stephensi*. 19 from dwellings, 30 from buildings and 6 under culverts were found. In their two-year survey, Russel and Rao (1941) captured only 11 female *Anopheles stephensi* from Puttakkottai area, Madras, by searching thatched roofs (human, animal and mixed).

Abraham and Samuels (1944) collected few adult mosquitoes in some villages of Bombay and Hyderabad cities, where *Anopheles stephensi* are the chief carrier of malaria. 388 specimens from town and 304 specimens from rural areas of Vizagapatnam are collected by Subba Rao and Appa Rao (1945) and found that the adults were rare in pucca houses but plentiful in thatched huts and cattle sheds. Senior White (1946) obtained a total of 189 specimens and reported that both the type and mysorensis variety of *Anopheles stephensi* was available in Eastern Satpura Ranges of Central Provinces. Bhaskar Rao et. al (1946) got 3646 *Anopheles stephensi* in a 27 month duration study period from Madras. Maximum preference of resting of *Anopheles stephensi* was found in mixed dwellings (1842) followed by cattle sheds (1154) and human dwelling (650) respectively. The density of *Anopheles stephensi* adults in human dwellings in North Madras coast and coastal areas around Vizagapatnam was measured and per man-hour density of the mosquito was found to be 0 in 1944, 1946 and 1948 (Adhikari and Ganguly, 1949).

The houses treated with DDT invariably showed a striking reduction both in day time and night catches of *Anopheles stephensi* (Pal and Sharma, 1952). From March to July 1981, total 86 *Anopheles stephensi* were collected, of which, 35 were collected by hand before pyrethrum spraying and 51 after pyrethrum spraying in Poona district (Vishwanathan et. al., 1952). Majority of *Anopheles stephensi* was obtained from pucca houses in Salem, Tamilnadu, as reported by Batra et.el. (1979). The resting specimens were also found in huts, godowns, fire wood depots, cattle sheds and walls of the wells and so on. A total of 761 *Anopheles stephensi* were collected from two villages of rural Rajasthan. Per man--hour density in the post-monsoon season (August-
September) was 0.15 (10) indoor and 0.4(4) outdoors. The corresponding data were 18.24 (727) and 2.0 (20) respectively in the premonsoon season (March – April) as reported by Rahman et. al.,(1979). Subba Rao et. al.,(1984) found that per man-hour collection of *Anopheles stephensi* was 20.8 with a peak in February in Mandora, Haryana. After surveying nine talukas of Kutch State in morning and evening hours, Singh et. al., (1985) found a high density (6729) of *Anopheles stephensi* starting from May 1982 to December 1983, per man-hour density of *Anopheles stephensi* in Delhi were 4.00, 2.00, 10.50, 24.50, 33.50, 40.50, 19.50, 9.50, 0, 0, 0, 1.00, 0, 0, 5.00, 13.75, 17.50, 8.25, 0 and 0 respectively (Sharma et. al,1985). Mahesh et. al.(August 1999 to July 2000) reported that *Anopheles stephensi* preferred cattle sheds for resting than the human and mixed dwellings.

### 2.3.6 Habitat Preference scenario of *Anopheles stephensi* in Calcutta and adjoining areas

The existence of *Anopheles stephensi* in Calcutta was first recognised by Stephens and Christophers in 1902 (Senior White, 1940). Annandale (1907) as cited by Basu (1930) noticed the presence of *Anopheles stephensi* in the gardens of Indian Museum. Out of a total collection of 1460 Anophelines, *Anopheles stephensi* comprised only 1% (De, 1923). After his three years of extensive study, Senior White (1934) collected 1256 Anophelines, of which, *Anopheles stephensi* comprised of only 1.2%(14). Specimens were mainly captured from ground levels of Bengal – Nagpur railways head quarters colony. From his observation on resting habitat of *Anopheles stephensi* in Calcutta, Senior White concluded that the apparent rarity of *Anopheles stephensi* in the check catches was not due to its absolute paucity of numbers, but in fact its daytime resting-places were unknown in Calcutta. Knowles and Basu (1934) stated “in spite of the fact that larvae of *Anopheles stephensi* are to be found in profusion throughout the city, yet adults of this species are curiously difficult to capture in Calcutta”. Due to some unaccountable reasons the adults of *Anopheles stephensi* were difficult to catch in Calcutta (Ganguly, 1935).

According to Strickland, Roy and Chowdhuri (1936), the prevalence of *Anopheles stephensi* in this metropolis was considerable. Out of a total of 8564 adult anopheles comprising of 13 different species, 177 *Anopheles stephensi* were caught by hand. The distribution of female *Anopheles stephensi* from pucca bungalow, pucca cow sheds, kutcha cow sheds, pucca servant quarters, kutcha servant quarters, school, bustee huts and flats were 27, 0, 1, 77, 1, 3, 14 and 24 respectively. No significant variation was found between male and female *Anopheles stephensi* caught both in the morning and evening hours. Not a single *Anopheles stephensi* was obtained from several villages lying on either bank of the river Hooghly from Calcutta to Falta and
Uluberia for a year as cited by Sen (1937). Daytime resting *Anopheles stephensi* were collected from a house in central Calcutta (Roy et. al., 1938). The resting sites includes dark blue dressing gown and its folds, leather bands, inside hats, underneath a small parapet, projecting from the top of a almirah. The room from where the mosquito captured was situated on the first floor of pucca building. A cattle shed was situated within 30 yards (27 m) was demolished, catches were found to be lower. Finally they concluded “while *Anopheles stephensi* is comparatively easy to collect a large number of adults in other cities (Bombay, Delhi), it is by no means so in Calcutta”. Senior White (1940) collected 297 (1.8%) *Anopheles stephensi* spending 28 months. 111 from houses, 13 from cowsheds, 170 from cow traps and only 3 from human trap. After the long-term investigation, the author remarked “Daytime places of this species are obscure in Calcutta”.

Siddons (1943) stated that Senior White in 1940 had closed the investigation of *Anopheles stephensi* because of its rarity to make the cost of collection prohibitive, Siddons (1943) himself did not establish the actual resting places and concluded “Until the problem of its daytime resting places is solved, no real progress can be expected”. Also in the year 1946, Siddons was not able to pinpoint the daytime resting places of *Anopheles stephensi* in Calcutta. Only 14 and 24 *Anopheles stephensi* were obtained from indoors and outdoors respectively from a pucca house in Calcutta (Mukhopadhyay, 1980). Employing 1152 man-hours in a year, a total of 17109 mosquitoes of 8 species were captured. *Anopheles stephensi* comprised 2.1% of the total catch. Out of 516 female anophelines, 357 (69.1%) were *Anopheles stephensi* (Hati et. al., 1987).

Hati et. al. (1993) reported 285 and 87 adult *Anopheles stephensi* from temporary hutments and cattle sheds whereas only 7 were obtained from brick-built rooms. The adults were collected from hanging objects, i.e. Umbrellas, nylon strings, cobwebs, mosquito nets, clothes, gunnybags, etc.(37%) ; 19% from furniture, 25% from ceiling ,11% on room's materials, i.e. in and outside earthen pitchers, inside empty tin drums, iron pillars, etc, 6% on walls and 2% on the miscellaneous objects. Hanging objects seemed to be preferred resting sites of *Anopheles stephensi* in both temporary hutments and brick-built rooms; but in cattle sheds, mosquitoes preferred taking shelter on ceiling.

A total of 19,988 anophelines Cattle sheds and Human dwellings (CS 83.91%, HD 16.08%) distributed over 14 species were collected during monsoon (July – October 1991) in a survey
conducted indoors in 22 blocks (divided into northern, central and southern zone) of district South 24 Parganas (Tandon and Tandon, 1994). In cattle sheds (CS) (with plastered walls and cemented floors) in south and central Calcutta, female *Anopheles stephensi* were found resting on the walls and ceiling in the evening only (Tandon et. al., 1998).

### 2.3.7 Breeding sites of *Anopheles stephensi*

*Anopheles stephensi* larvae found by Gad (1967) near Gulf of Suez. Zuluesta et. al. (1968) also reported the presence of *Anopheles stephensi* larvae in saline water of Fao, Iraq (Quoted from Manouchchri, 1976). “In the foothill areas from which the species have mainly recorded the larvae been found in pools, in river beds, in seepages and along edges or rocky hill streams” – reported in Burma by Khin-Maung-Kyi (1971) as quoted by Rao (1984). *Anopheles stephensi* breed in all sorts of water mainly in wells and gardens ponds in Southern Iran. The larvae *Anopheles stephensi* were even detected in hoof prints of animals around the seepages in marshy areas. *Anopheles stephensi* also breed readily in rice fields, especially 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 ‘mashk’ – the goat skin bag used to hold drinking water or hoof prints of animals (Manouchchri, 1976).

The larvae of *Anopheles stephensi* were never found in large numbers in any part of the district of Delhi, but their universal distribution in wells, not only in the city but also throughout the countryside seemed to be extraordinary. *Anopheles stephensi* larvae were found in fair numbers 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 (Hodgson, 1914). In Kohat district Sinton (1917) found that *Anopheles stephensi* mosquitoes were found to breed in almost any collection of water. In 1914, the larvae of *Anopheles stephensi* were first recognised at the end of May and were very common in July and August. *Anopheles stephensi* generally breeds in old tins and broken pots, tins and vessels used to store water, porous earthenware, pots buried beside little trees; and filled with water to water the roofs in hot weather, square brick tanks, rain water puddles and in little pools of water left after irrigation, grass-grown ditches and irrigation channels and burrowpits.

In his monograph “Malaria in Bombay” Covell (1928) reported that *Anopheles stephensi* will breed with equal facility in dark places and in those exposed to the direct sunlight and 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 to 100 ft. (24.4 – 30.5 m) in height. The roof cisterns are the permanent breeding sites in Bombay along with the improperly graded roof gutters and terraces. Generally, large roof cisterns connected with mills and railways (touching a great height) were invariably found breeding places of *Anopheles stephensi*. After a break in the rains in the month of August 1929, the wells of Lucknow seemed to be active source of larvae of *Anopheles stephensi* (Banerjea, 1930).

According to Afridi (1938), in Kutch state, *Anopheles stephensi* used to breed in troughs, siphons, reservoirs and wells in Vijaya villa place while in Bhuj it was almost exclusively well breeders. *Anopheles stephensi* larvae were found to be restricted in wells in Puttukkottai, Madras (Russel & Rao, 1941). According to Bana (1943) *Anopheles stephensi* bred in the salt pans in September and October, when these were used for rearing fish. In addition to salt pans, *Anopheles stephensi* was also found breeding in tanks and drums filled with sea water which had become diluted with rain water. In Vizagapatnam, *Anopheles stephensi* was found to breed in pucca (14.9%) and kutch (7.0%) wells as well as nalas (78.1%). (Senior White and Rao, 1944). Abraham and Samuel (1944) reported that *Anopheles stephensi* used to breed in rivers and wells. According to Covell (1944), *Anopheles stephensi* larvae were also found in wells, cisterns, fountains, garden tanks and tubs, cement floors, reservoirs, roof gutters, tins, pools, stream, irrigation channels and reservoirs. The larvae of *Anopheles stephensi* were also found at the floor of newly constructed rooms, where the water being kept to moisten the cement layer (Krishnan, 1961 and Dhir, 1970). *Anopheles stephensi* larvae were also found from wells and cisterns in Salem (Batra & Reuben, 1979). The collection was done from December to November in old Suramingalam and Shevapet. The direct-effect of rainfall on survival or density of *Anopheles stephensi* larvae was not found by (Kaur & Reuben, 1981) after 14-months survey in 20 wells in a malarious town in South India. Nagpal & Sharma (1995) reported that *Anopheles stephensi* larvae were found to breed in dirty water.

**Scenario in Calcutta**

*Anopheles stephensi* was found to breed in garden tubs, old unused cisterns and shallow pits throughout the entire city of Calcutta (Iyenger, 1920). Out of 4119 spots examined, 27.45% (1131) spots were found to be positive with *Anopheles stephensi* larvae in an area, one square mile in extent in Central Calcutta bounded by Machu Bazar and Cotton Street in the North, Bowbazar, Lalbazar, Dalhousie Square North on the South, Amherst Street on the east and Charnock place and Clive Street on the West. Larvae of *Anopheles stephensi* were found both
in the filtered and unfiltered water (Basu, 1930). Roy (1931) observed the presence of Anopheles larvae in open earthen drains and ponds, full of aquatic weeds and lilies, in Calcutta. Knowles and Basu (1934) by conducting four year larval survey (July 1928 to June 1932) detected Anopheles larvae in 33.05% (3942), of 11,927 spots searched. The prevalence of positive containers was reported to be higher in the month of July and lower in April. The distribution of positive containers were earthen handis (29.3%), earthen tubs (26.4%), jars (30.0%), kerosine tins (29.2%) and iron tubs (28.3%).

*Anopheles stephensi* larvae were very common in the sewered area of Calcutta (Senior White, 1934 and Ganguly 1935). Mukhopadhyay (1980) conducted a natural survey in and around 100 brick houses in Calcutta (central) and detected the existence 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. A larval survey of anophelines shows that out of 786 (20.6%) occupied habitats, 13.7% (108), 20.5% (161), 14.6% (115) and 51.1% (402) containing the abundance of the larvae of *Anopheles stephensi, Aedes aegypti, Anopheles subpictus* and *Culex quinquefasciatus* respectively (Chatterjee and Hati, 1990). *Anopheles stephensi* was found to breed in association with *Aedes aegypti* and *Aedes albopictus* larvae in almost all kinds of (temporary and permanent) breeding sites, provided they contained water in the study area (Chakraborty et al., 1998).

2.3.8 *Fish as a biocontrol agent of Vector Mosquitoes*

**World Scenario**

The most effective species of the 17 established exotic larvivores in Hawaii appears to be *Gambusia affinis, Lebistes reticulatus* and *Tilapia mossambica* mainly against *Culex quinquefasciatus* and *Aedes vexans nocturnus* (Nakagawa et. al, 1969). According to Hoy et. al., (1972), biological control of *Culex tarsalis* in a California rice field is highly appreciated. Stocking with 200-fish/ acre produced 95% mosquito larval reduction; stocking with 1000 fish/ acre produced 99% reduction. Stocks of Gumbusia should be prepared for early distribution for increased efficiency. Mathias (1972) reported that *Culex pipiens fatigans* larvae could be controlled in Rangoon, Burma, utilizing both fish and insecticide. Successfully combined use of larvivorous fish (*Poecilia reticulata*) and the larvicide fenthion at 0.01 p.p.m controlling *Culex pipiens fatigans* developing in a ditch. *Poecilia reticulata* can be used in controlling *Culex*
pipiens fatigans in Bangkok, Rangoon and Taipei, but there is very limited range of habitats in which they were used (Bay et. al., 1972).

Fish were placed in tanks ("birikas") along coastal towns several centuries ago by the Arabs to control Aedes aegypti and Culex quinquefasciatus. After the Second World War, Lebistes were used in the same type of breeding places (Bang et. el., 1973). Gambusia fish were used as a means of biological control of Anopheles sacharovi in Greece (Hadjinicolaou et. al., 1973).

Gambusia acts as a biocontrol agent to improve the control of malaria vectors, Anopheles hyrcanus and Anopheles pulcherrinus in northeastern Afghanistan (Dukharina et. al., 1974).

Three indigenous species of fish were evaluated as mosquito larvivores in Sri Lanka. Laboratory and field experiments proved Aplocheilus dayi more effective than Rasbora daniconius or Oryzias melastigma as indigenous mosquito larvivores (Costa et. al., 1977). Guppy (Poecilia reticulata) is used for mosquito control in California. The use of Guppy is considered for sewage treatment ponds and polluted waters where Gambusia will not survive (Hiscox, 1980).

Scenario in India

The tolerance of Guppy, a natural enemy of mosquito larvae to the septic pollution of water is studied (Kurihara et. al., 1973). Hydrogen sulphide in distilled water was toxic to fish at concentrations above 1 p.p.m. and ammonia at concentrations above 11 p.p.m. Toxicity to the fish can be minimized providing aeration. A study was done in Greater Hyderabad City, India to observe on the use of Gambusia affinis to control Anopheles stephensi breeding in wells. The number of wells containing larvae fell from 1173 in May 1967 to 287 in June 1969. Fish lived for 1-12 months, bred and increased in many of them. (Sitaraman et. al., 1975). Apocheilus panchax in the North and Apocheilus lineatus, indigenous to South India, were found to be good larvivorous (Jhingran, 1975). Biological control of Anopheles stephensi Liston larvae in wells by Poecilia reticulata in Greater Hyderabad city, India was reported by (Sitaraman, 1976). Gambusia affinis was more efficient than Poecilia reticulata in wells except when the latter was stocked at very high density.

Screening of some indigenous fishes on predatory activity against Culex pipiens fatigans larvae was done. Studies of six indigenous Indian species of fish and Gambusia affinis preying on third and fourth instar larvae of Culex pipiens fatigans wied showed these were biologically unsuited by size but Esomus danricus out performed even Gambusia in larvae consumed (Chakravertty et. al., 1976). Joshi et. al, (1978) studied the efficiency of larvivorous fish Poecilia
_Poecilia reticulata_ for the control of _Culex pipiens fatigans_, in a rural area of Delhi. Control of mosquito breeding in wells by using _Gambusia affinis_ and _Apocheilus blockii_ in Pondichery town is reported by Menon et. al., (1978). In wells, where _Gambusia affinis_ could not survive, _Apocheilus blockii_ was introduced, the latter is having a higher tolerance of salinity and PH. A laboratory observation on source species of larvivorous fishes shows _Trichogaster trichopterus_ was the most and _Glossogobius giurus_ the least larvivorous. _Apocheilus panchax_ apparently preferred eating larvae and pupae (Yuwono et. al., 1979). Dixit et. al., (1981) reported that _Gambusia affinis_ controlled all larvae of _Anopheles stephensi, Aedes albopictus, A. vittatus_ and _Culex quinquefasciatus_ under simulated field conditions, tanks, ponds and wells. Sunny conditions enhanced fish activity. _Poecilia reticulata_ has been extensively used in Kheda District, Gujarat, under bioenvironmental control of malaria vectors (Sharma et. al., 1986). Easy availability of _Mystus kelitus_ and its good predatory behaviour may be used for the bio-control of mosquito larvae (Radhakrishnan, 1986). Uma rani (1987) observed that goramy feeds on mosquito larvae thirty days after hatching.

**Scenario in Calcutta**

Guppy have been found extremely used in polluted water for the control of _Culex fatigans_ larvae (Tandon, 1985) in Calcutta. Saha et. al., (1986) reported that Guppy can be used as a bio-control agent for both the larval and pupal densities of _Culex quinquefasciatus_ in Calcutta. _Lebistes reticulatus_ is a voracious larval feeder with very high reproductive potential. Recently application of _Xenentodon cancilla_ fry has been found very effective against mosquito larvae (Chandra, 2000).