Bionomics of Malaria Vectors in India

Extensive work on the bionomics of the main malaria vectors, namely *Anopheles culicifacies*, *An. fluviatilis*, *An. minimus*, *An. sundaicus* and *An. stephensi* has been carried out at different locations in the country by the National Institute of Malaria Research and is briefly described below.

Anopheles culicifacies

Anopheles culicifacies is a major malaria vector in the plains of India and is a complex of sibling species A, B, C, D and E, details of which have been given in the chapter "Species Complexes in Malaria Vectors" in this publication. Its bionomics was studied in Delhi, Nadiad (Gujarat), Haldwani (Uttarakhand) and Rourkela (Orissa).

Abundance and Seasonal Prevalence

In Delhi, the study was done in a riverine zone of the River Yamuna and in a non-riverine belt in northwestern area during 1989–91 and the *An. culicifacies* (3.16%) was the third most prevalent species in this area. In the riverine zone, a higher peak of An. culicifacies was observed in April followed by another peak in October and in the non-riverine area, the peak density was observed in May and August (Fig. 15). Generally its density was more in the non-riverine area due to shifting of preferred larval habitat from the riverbed pools to large lakes/ channels and pumping reservoirs. This may be due to extensive pollution of the river zone by sewage discharged by 17 major stormwater drains. Breeding of *An. culicifacies* was maximum in the northern part of the riverine zone where water pollution was at minimal level. In the non-riverine area, *An. culicifacies* breeding was not observed in the western Yamuna canal which at present is cement lined and allows fast-flow of water. Earlier this canal used to be the main source of *An. culicifacies* breeding. The preferences of breeding water for *An. culicifacies* were ponds, pools, ditches, pits and lake (Batra *et al* 2001).

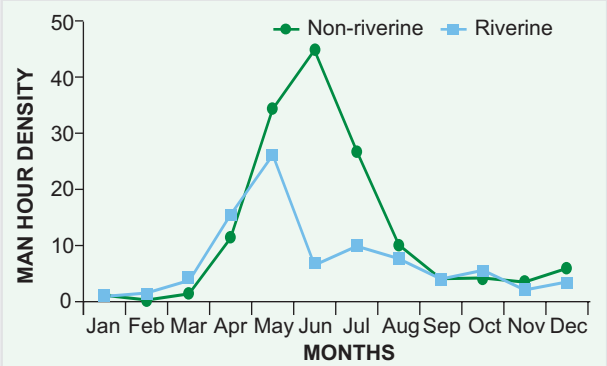

Fig. 15: Man hour density of *An. culicifacies* in Delhi

In a study carried out during 1989–91 in Gujarat, it was observed that *An. culicifacies* was most abundant in the villages situated on the bank of rivers (46%) followed by hilly (23%), canal irrigated (22%), coastal (7%) and non-canal-irrigated areas (2%) (Fig. 16). In general it was most abundant during the summer and monsoon months. In Orissa, stream and riverside villages had high densities.

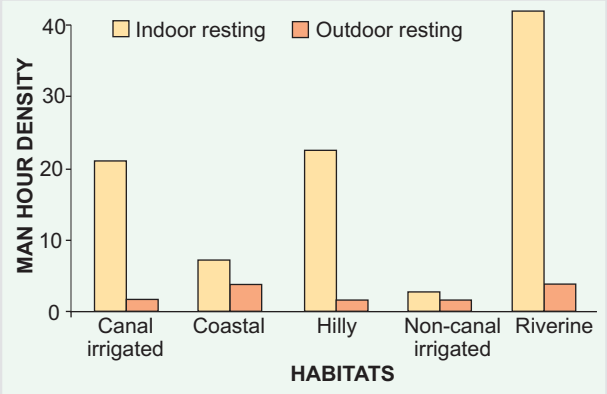

Fig. 16: Indoor resting density of *An. culicifacies* in various physiographical areas in Kheda, Gujarat

Resting Behaviour

Day-time resting preferences of *An. culicifacies* in human dwellings and cattlesheds in areas around Delhi did not differ significantly when subjected to ANOVA. Variations in the densities between the two zones (riverine and non-riverine) were observed which could be due to ecological factors. Though the two zones are in close proximity to each other, they are ecologically and physiogeographically distinct from one another. Thus, it is not the proximity and spatial continuity but the ecosystem which influences the prevalence and densities of *An. culicifacies*. *An. culicifacies* prefers to rest indoors and mainly in the cattlesheds than in the human dwellings in Gujarat and Orissa areas (Chand *et al* 1993). However, it has been observed to rest outdoors in natural shelters and artificial pit shelters as well in all the physiographic areas of Kheda district in Gujarat (Bhatt *et al* 1989).

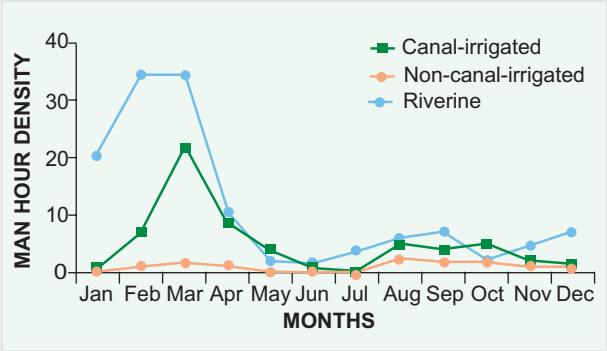

Fig. 17: Seasonal prevalence of *An. culicifacies* in Kheda district, Gujarat

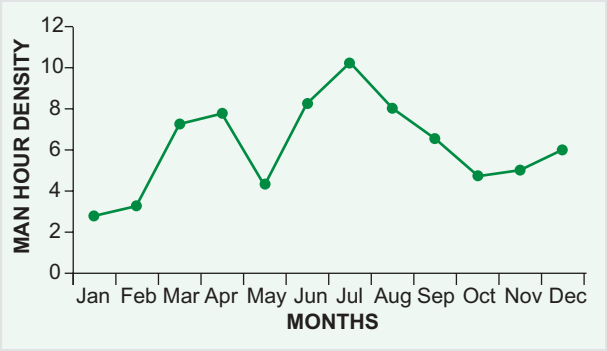

Fig. 19: Indoor resting density of *An. culicifacies* in Sundargarh, Orissa

Seasonal Prevalence

An. culicifacies is found throughout the year in the Kheda district in varying proportions. In the canal-irrigated areas, its density starts to build-up from February and reaches peak in March and thereafter it declines gradually till July. The rise during February is associated with the cultivation of the first crop of paddy. The second rise in the density though less pronounced, is associated with the onset of monsoon and it gets stabilized from August to October and thereafter it further declines in December. In the non-canal-irrigated areas, the density of *An. culicifacies* remains low throughout the year with less wider fluctuations. In the villages situated on the bank of the river, *An. culicifacies* is represented by nearly 67–75% of the all anophelines (Fig. 17). In *Bhabar* area of Uttarakhand in northern India, *An. culicifacies* density remains low during January to June and October to December (Fig. 18). It increases during monsoon reaching a peak in August. In *terai* its density picks up in March, remains high during April to August. In northern Orissa, *An. culicifacies* density shows a small peak in March–April and another in July (Fig. 19).

Host Preferences

Results of blood meal analysis showed that anthropophilic index (AI) of *An. culicifacies* in the riverine zone was 3.7% and in the non-riverine area it was 2.7%. Maximum AI was 5.7% in Mukundpur and 4.8% in Rithala locality of riverine and non-riverine zones in Delhi respectively. *An. culicifacies* is mainly a zoophilic species. Its anthropophilic index was found to be 0.62% which shows little variation between various physiographic areas in Kheda, Gujarat. In certain situations where there were few cattle to divert the vectors, its anthropophilic index has been observed to be considerably high (12.3%) (Bhatt *et al* 2002). In the forest area of Uttarakhand its human blood index was 0.01%.

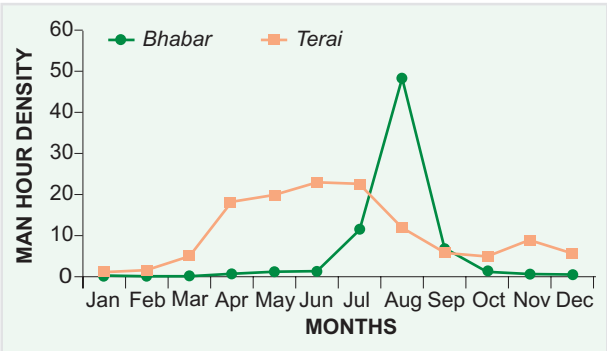

Fig. 18: Seasonal prevalence of *An. culicifacies* in *Bhabar* and *Terai* regions of Uttarakhand

Biting Behaviour

In Delhi, man biting rates of *An. culicifacies* was 0.07 only and a gross probability of biting a man was 0.0011 only. In Gujarat, biting activity of *An. culicifacies* starts in early part of the night from January to April, shifting by one hour from between 1800 and 1900 hrs in January to 2100 and 2200 hrs in April. About 70–90% of *An. culicifacies* population caught during the whole night was found to feed prior to midnight during these months. Bimodal activity was seen during June and July indicating a further shift towards the second and third quarters of the night. During August–September, most biting takes place in the later part of the night. Biting activity was positively correlated with temperature during January ($r = 0.762$; $p < 0.001$) and February ($r = 0.888$; $p < 0.001$) months. However, the biting activity was negatively correlated with the relative humidity during these months ($r = -0.734$ and -0.895; $p < 0.001$). For the rest of the months of the year, the biting activity was negatively correlated with both the parameters.

Human landing collections during the cold season in 1991–92 in a riverside settlement showed that *An. culicifacies* biting activity starts soon after dusk. More biting was recorded outdoors (26.7/man/night) compared to indoors (13.4/man/night), particularly during the early hours and in the last quarter of the night. During the hot season no definite biting rhythm was observed indoors or outdoors. The activity picks up only at the end of the first quarter (1800 to 2100 hrs) of the night and continues till dawn. More activity was observed in indoors (19.8/man/night) than in outdoors (11.7/man/night). In monsoon more activity was observed in indoors (23.5/man/night) than in outdoors (11.9/man/night). The mean indoor landing rates for the cold, hot and rainy seasons varies considerably ($F = 4.7$; $p = 0.0163$),

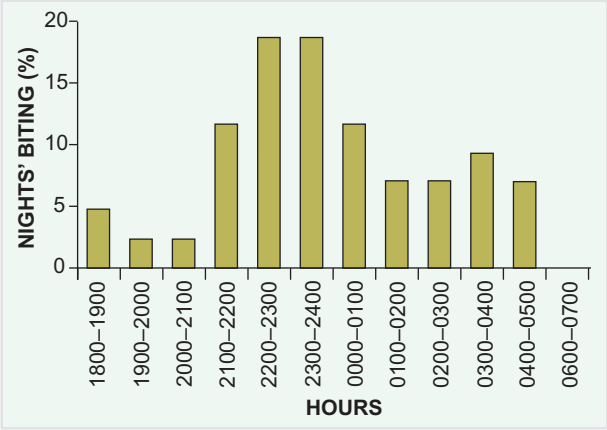

Fig. 20: Biting rhythm of *An. culicifacies* in northern Orissa

while the differences in outdoor landing rates were statistically non-significant (F = 0.4; p = 0.6).

In the forested area of Uttarakhand, it was found active throughout the night and indoor and outdoor landing rates were 0.5 and 1.4/man/night, respectively. In the plain area, *An. culicifacies* outdoor landing rate was 0.4/man/night. The average landing rate of *An. culicifacies* was recorded as 0.95 and 0.2/man/night in forest and dam areas, respectively. In Orissa, the mean landing rate was 0.86/man/night. Its biting rhythm is shown in Fig. 20.

Sporozoite Rate and Vectorial Capacity

In the riverine zone in Delhi, among 197 *An. culicifacies* dissected, the sporozoite rate was 0.5%. In the non-riverine zone, the sporozoite rate was 0.53% among 186 specimens dissected. A total of 59 *An. culicifacies* were assayed from the riverine area by IRMA technique and one specimen of *An. culicifacies* was found positive for CS antigen of *P. vivax*, giving a sporozoite rate of 1.69%.

Previous studies on incrimination of *An. culicifacies* in Delhi carried out in areas adjoining the River Yamuna and in south Delhi showed that *An. culicifacies* plays a role in malaria transmission in these areas but no infected specimen was detected in the non-riverine area of northwest Delhi. *An. culicifacies* plays a role in malaria transmission in the non-riverine area too. On the basis of these results it was found that in the riverine zone, *An. culicifacies* played a greater role in malaria transmission in only the north part of the zone where water pollution is at minimal level.

In a study carried out during 1991–92 in Galteshwar (Gujarat), the overall sporozoite rate was found to be 0.6% (10/1568), but in October the observed rate was 3.25 (4/125). In north Gujarat, the sporozoite rate of *An. culicifacies* during 2001–04 was found to be 1.74% (23/1319) by ELISA test. In this area maximum infective mosquitoes were found in October. The vectorial capacity (VC) estimates for *An. culicifacies* ranged between 0.0005 and 0.5649 for *Plasmodium vivax* and between 0.00001 and 0.3928 for *P. falciparum*. It was highest during November and lowest during January for both parasites. The combined VC for *Pv* and *Pf* showed positive correlation with the slide positivity rate (r = 0.0928; df = 10; p < 0.05). In a study carried out in Uttarakhand the sporozoite rates were recorded as 0.79, 2.4 and 6.0% during September, October and November 1982, respectively.

Ecology

In areas around Delhi, empty lands/marshy swamps, ponds and river water which were contaminated with open sullage/sewage pourings, did not support *An. culicifacies* breeding. Influence of *An. culicifacies* is restricted to northern areas of the riverine zone where water was not polluted with sewage pouring in the river compared to southern part of the riverine area. The changes were attributed mainly due to ecological changes, pollution of the Yamuna River and rapid developmental activities which contribute to the anopheline vector breeding habitats and malaria transmission.

Survey of breeding habitats in Gujarat have shown that *An. culicifacies* prefers to breed mostly in the canals, rivers, irrigation channels, riverbed pools and freshly inundated paddy-fields (Yadav *et al* 1989). Sample positivity rate of different habitats showed that *An. culicifacies* was present in 60.7% samples of immatures from river, 53.1% from irrigation canal, 34.8% from riverbed pools, 28.1% from paddy-fields, 19.8% from irrigation channels, 14.1% from wells, 12.4% from ponds and between 5 and 6% in domestic containers. Positive breeding association of *An. culicifacies* was observed with *An. annularis* in ponds and small pools, with *An. stephensi* and *An. barbirostris* in irrigation channels and with *An. stephensi* in paddy-fields in canal-irrigated areas of Kheda district. *An. culicifacies* was also observed breeding in water bodies infested with aquatic vegetation (Hydrilla).

In *Bhabar* area of Uttarakhand, it breeds predominantly in cemented tanks, pokhars (small pools) and paddy-fields throughout the year. In *terai* its breeding was observed in streams for the greater part of the year. In Orissa, main habitats are streams, riverbed pools, rainwater pools, and freshly inundated rice-fields. It does breed in treeholes filled with rainwater in the forest (Yadav *et al* 1997).

Anopheles stephensi

Anopheles stephensi is an important vector of malaria in urban areas. *An. stephensi* was first incriminated as a malaria vector from Bombay (now Mumbai), Maharashtra in 1911. Subsequently, it was also incriminated from Kutchch (Gujarat) and Madras, (now Chennai) Tamil Nadu in 1938, Ahmedabad City in 1943 and from Broach (now Bharuch) town in 1967. *An. stephensi* exists as two forms, the type form and the variety *mysorensis*, which are distinguished by differences in the egg length and width and by the number of ridges on the egg-float. The type form was

reported to be an efficient vector of urban malaria, whereas var. *mysorensis* was considered to be a rural species and a poor vector. Recent works have indicated yet another variant; the intermediate form with reference to the ridge number on the egg-floats. National Institute of Malaria Research has undertaken several studies on some bioecological aspects of this vector in the rural area of Kheda and Kutchch districts, and Ahmedabad and Surat cities in Gujarat, Chennai City (Tamil Nadu), Panaji (Goa) and desert areas of Rajasthan.

Abundance and Resting Behaviour

Study on bionomics of *An. stephensi* was carried out in riverine and non-riverine areas of Delhi. Among anophelines, *An. stephensi* proportion was 15.7%. The densities of *An. stephensi* observed in riverine and non-riverine areas are shown in Fig. 21. *An. stephensi* was found throughout the year in both the areas. Mean man hour densities and peaks of *An. stephensi* showed wide variation over months in both the zones and thus it could be considered that *An. stephensi* density was regulated by seasonal factors. Dry summer conditions were found favourable for *An. stephensi* as also reported earlier. In a study carried out in rural areas of Kheda district between 1989 and 1991, it was observed that *An. stephensi* was most abundant species in the villages situated in hilly area followed by coastal, non-canal-irrigated, canal-irrigated and riverine areas (Fig. 22).

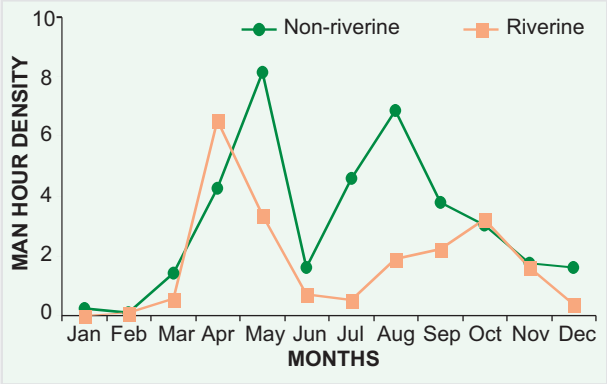

Fig. 21: Man hour density of *An. stephensi* in Delhi

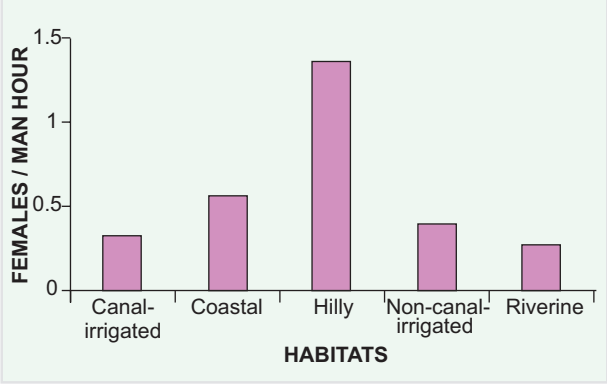

Fig. 22: Man hour density of *An. stephensi* in different physiographic areas of Kheda district, Gujarat

In a study carried out between 1985 and 1988 in the villages of Kheda district, it was observed that *An. stephensi* comprised 0.65% (270/41280) of the total anophelines collected indoors in the riverine villages followed by 0.32% (434/136495) in canal-irrigated and 0.19% (130/69678) in non-canal-irrigated villages. *An. stephensi* mainly rests indoors. However, a good proportion also rests outdoors in natural shelters as well as artificial pit shelters throughout the year. In a study during 1987–88 in five canal irrigated villages of Kheda district, *An. stephensi* proportion among all anophelines collected in outdoor shelters was observed to be 0.28% (14/4998) whereas, in the indoor collections it was 0.24% (98/40681).

In urban areas in Ahmedabad City, *An. stephensi* comprised 9.4% of all anophelines collected indoors by pyrethrum spray collections in five municipal zones between April 1997 and December 2000. In Surat City, collections made from July 1999 to December 2000 revealed that *An. stephensi* population comprised 4.8% of all anophelines collected by pyrethrum spray collection method in human dwelling rooms. Its proportion in the light-trap collections during the same period was 3.3%. A study in Panaji showed that *An. stephensi* rested between 30 cm and 2.4 m height indoors but one-third of these rested above 1.2 m height from the ground level (Sumodan *et al* 2002).

Seasonal Prevalence

In rural areas of Gujarat, *An. stephensi* is prevalent round the year in canal-irrigated, non-canal-irrigated and riverine villages. Its density in riverine villages remains <2 per man hour whereas, in the canal-irrigated and non-canal-irrigated villages it remains <1 per man hour throughout the year (Fig. 23). In urban areas it is collected throughout the year in varying proportions and is most abundant between June and August, which coincides with the onset of transmission season. In Surat City (Fig. 24), it was also collected in light-trap collections throughout the study period and followed a similar trend observed in pyrethrum spray collections. In Kutchch, pyrethrum space spray and

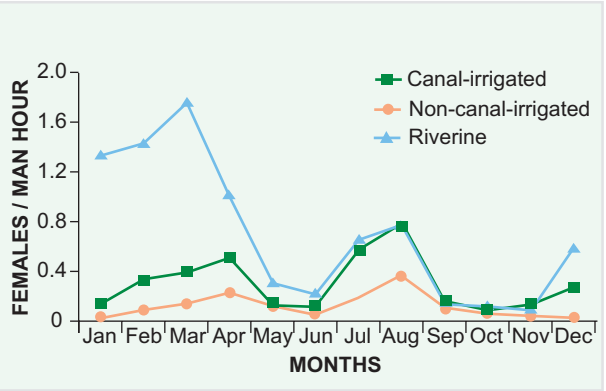

Fig. 23: Density of indoor resting *An. stephensi* in villages of Kheda district, Gujarat

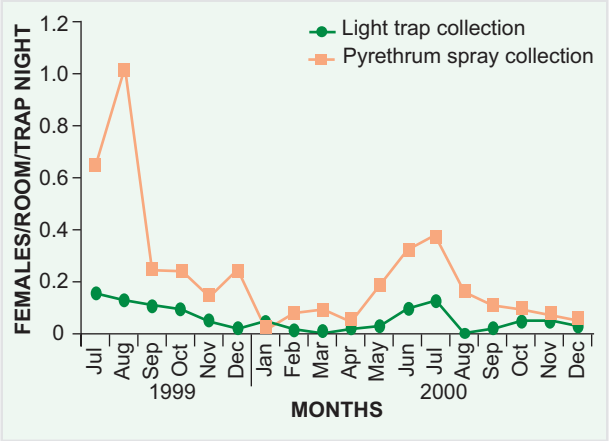

Fig. 24: Seasonal abundance of *An. stephensi* in Surat City, Gujarat

light-trap collections during 2006–2007 of the species showed a high peak in March–April soon after the winters were over and relatively lower prevalence during the wet season.

Host Preferences

Results of blood meals of specimens collected in Delhi showed that anthropophilic index (AI) of *An. stephensi* in the riverine zone was 0.45% and in the non-riverine area it was 1.4%. *An. stephensi* in rural areas is essentially a zoophilic species. There is little variation in the anthropophilic indices between the various physiographic areas of Kheda district. In a study carried out between 1989 and 1991, its anthropophilic index was found to be 1.03% (1/97). In cities, it is the main malaria vector and has shown an increased tendency to feed on man than on cattle unlike in rural areas. In Ahmedabad City, the anthropophilic index of *An. stephensi* was recorded as 8.6% (75/875) and that in Surat City it was 4.9% (15/306). In north Gujarat, it showed an anthropophilic index of 0.8%.

Biting Behaviour

Experiments on mosquito landing collections of the animal baits in villages of Kheda district have shown that the species remains most abundant between February and April (75%) and was encountered throughout the year in low numbers except in July, October and December. Biting occurs mostly before midnight and maximum activity was observed in the first quarter of the night (1800–2100 hrs). Biting activity has been observed till third and fourth quarters of the night, though at a low rate. In all night mosquito landing collections on human baits from July 1999 to August 2000 involving 134 man nights in Surat City, average human landing rate of *An. stephensi* was found to be 0.4% and it represented 54% of all anophelines collected. *An. stephensi* was active throughout the night and 39% population fed before midnight. More activity was observed in outdoors (0.46/man night) as compared to indoors (0.34/man night). Studies on the biting rhythms of *An. stephensi* type form in Chennai (Tamil Nadu) indicated that there was no seasonal variation in the peak biting time during different months indoors, but there was a significant shift in the peak biting time outdoors during different months and the maximum biting occurred during the third quarter of the night and was more pronounced during all the months as compared to that in indoor collections.

Sporozoite Rate

In the non-riverine area in Delhi, the sporozoite rate was 0.78% and in the riverine area it was 0.53%. Samples of *An. stephensi* collected from July 1999 to August 2000 by all methods in Surat City were analysed by ELISA for the detection of sporozoites. In all, 1660 samples were tested and 29 were found positive giving a sporozoite rate of 1.75%. Experimental infection to study the infectivity rate of *An. stephensi* var. *mysorensis* was carried out using blood isolates from 13 patients in Chennai City. The gametocyte count of the patients ranged between 200/µl and 2520/µl. Gut and gland positivity was observed from 7th and 10th day onwards. Gut positivity rates observed on the 7th, 9th, 10th and 13th day were 33.3, 78.57, 50 and 80% respectively. Sporozoites were observed on the 10th and 13th day and the sporozoite positivity obtained was 33.3 and 25% indicating delayed infectivity. In a study in Kutchch, *An. stephensi* was also incriminated from a rural area by ELISA method where its sporozoite rate was 0.07%. The study clearly established the species as a potential vector of malaria in semi-arid zone where thousands of man-made water bodies are being created for water conservation and irrigation.

Ecology

An. stephensi was found mainly in clear water, except in some polluted, blocked cemented drains with grass growth in the non-riverine zone near Delhi (Batra *et al* 2001). In cities and towns, it breeds in all kinds of contained waters in houses, at construction sites, industries, cattle troughs, in sluice valve chambers with water-supply leakages, and ornamental waters. Observations carried out in Ahmedabad City revealed that it prefers to breed in curing chambers at the construction sites and sluice valve chambers. Nearly 36% of all anophelines emerged from the larval samples collected from these two sites were contributed by *An. stephensi*. A small proportion of its breeding was also detected from ponds and pools. In a survey of breeding habitats carried out in rural areas, between 1985 and 1988, it was found that *An. stephensi* prefers to breed mainly in wells and domestic water storage containers. Of the total adults emerged in the samples from wells, this species accounted for 48.3% and from domestic containers for 69.5%. Except wells, other peridomestic habitats were not preferred by it, though its breeding was recorded from river, riverbed pools, irrigation canal, irrigation channel, ponds, small pools and hoof prints.

In Chennai City, an increase in the abundance of type form and intermediate form during post-monsoon was observed in general suggesting that it might be governed by the availability of the types of breeding sites that result from monsoon rains. Oviposition in type form was confined to the period of 1800 to 0100 hrs while in var. *mysorensis* it was prolonged from 1800 to 0600 hrs. The egg-hatching rate was 76.5% being maximum in *mysorensis*. The time required for eggs of the three variants to hatch was found significantly different. Variety *mysorensis* showed higher mortality rate than type form. Studies on the immature stages of type form under ambient conditions in different seasons indicated that throughout the year, larval mortality was significantly higher in IV instar and instar-wise larval mortality did not differ through different seasons. A study in Kutchch, Gujarat showed profuse breeding of *An. stephensi* in irrigation farm ponds and concrete tanks throughout the year.

Bio-ecology of Ecological Variants of *An. stephensi*

Studies on the bio-ecology of two ecological variants—*An. stephensi* type form and var. *mysorensis* were carried out in different seasons—pre-monsoon, monsoon and post-monsoon in an arid zone (Jodhpur, Rajasthan). The study brought out that: (i) two varieties of *An. stephensi* are sympatric in rural areas; (ii) the type form breeds indoor in domestic and peridomestic containers and also rests indoor on unsprayed hanging objects, throughout the year while var. *mysorensis* co-breeds and rests indoors during the summer for lack of breeding waters but moves out with the onset of rain as feral species (Fig. 25); and (iii) it is only type form which is involved in the transmission of malaria. The *An. stephensi* var. *mysorensis* may not be involved in the transmission, basically because of largely zoophagic feeding behaviour and low parity rate during the transmission season. The findings have obvious implication for control of *An. stephensi* transmitted malaria by residual spraying as the species select hanging objects for resting. In Kutchch, >90% population of *An. stephensi* had egg float ridge counts of 12–14 while the remaining had 16 ridges.

Anopheles sundaicus

In India, this species has now disappeared from the main land except for a small focus in the Kutchch area of Gujarat (Singh *et al* 1985) and is found abundantly and widely only in Andaman and Nicobar Islands. Mosquito fauna survey in Car Nicobar Island revealed that *An. sundaicus* was the most predominant species comprising 58% of the total

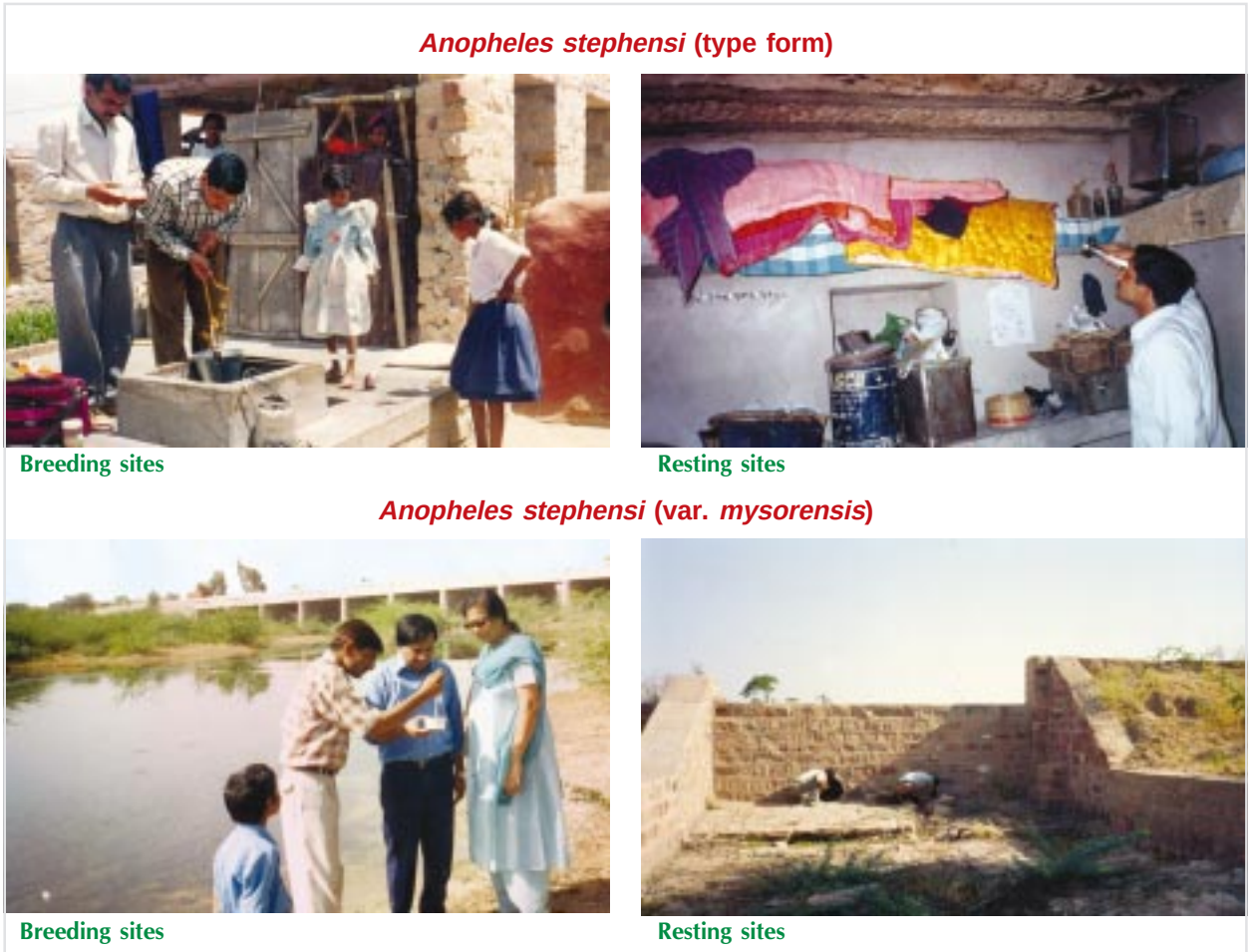

Fig. 25: Breeding and resting places of two variants of *An. stephensi* in Jodhpur, Rajasthan

mosquitoes collected (Das *et al* 1998). A wide variation in the resting and feeding behaviour of *An. sundaicus sensu lato* has been reported on this Island. Although substantial number of *An. sundaicus* rests outdoors, still the species prefers to rest indoors (Kumari and Sharma 1994). Studies on host-feeding behaviour showed that it was primarily a zoophagic species, however, a human blood index of 0.18 was observed in mosquitoes collected from the human dwellings (Kumari *et al* 1993). Indoor human landing rates were comparatively higher than the outdoor landing rates and the species showed bimodal biting rhythm with a peak activity observed between 2230 and 2330 hrs and second peak between 0130 and 0230 hrs (Kumari and Sharma 1994). The species prefers to breed in brackish waters such as creeks, mangrove swamps and marshy areas with a salinity range of 2–14 g/l but its breeding has also been reported from fresh waters such as ponds, wells and rainwater collections having salinity below 0.1 g/l (Sharma *et al* 1999). The wide variations in feeding and resting behaviour and breeding habits suggest that *An. sundaicus* is well-adapted to island ecosystem.

Anopheles minimus

With the resounding success in malaria control during 1960s using DDT as the residual insecticide, it was commonly believed that *Anopheles minimus* had disappeared from the northeastern states. Subsequently, the role in malaria transmission played by other vectors—*An. philippinensis* and *An. dirus* was highlighted. However, owing to persistent transmission of the disease in the region, studies were initiated by NIMR to identify the vectors and establish disease relationships in the changed ecological context. Under this initiative, detailed entomological investigations were conducted in malaria endemic pockets of the region. *An. minimus* was re-recorded in many districts of Assam and adjoining states. Data were collected *de novo* on its ecobiological characteristics including seasonal prevalence, sporozoite infection rates, feeding behaviour and breeding habitats. Its bionomics has been reported by Dev (1996).

Seasonal Prevalence and Resting Behaviour

In the day resting catches during 0900 to 1200 hrs from human dwellings indoor, *An. minimus*, was recorded in the non-intervention malaria endemic villages, and constituted fair proportion of the fauna (40%). They were found to rest on the darker corner of the house, hanging clothes and other articles, underside of beds/tables, *etc*. This species was recorded throughout the year, yet peak densities were observed during the months of March till August corresponding to wet season.

Sporozoite Infection Rates

From the day resting catches, *An. minimus* was reincriminated as vector by detection of sporozoites in the salivary glands. In the year 1990, sporozoite infections were recorded practically for all months of the year except August/September. Infection rate was lowest (0.7%) in March and highest in October (8.5%).

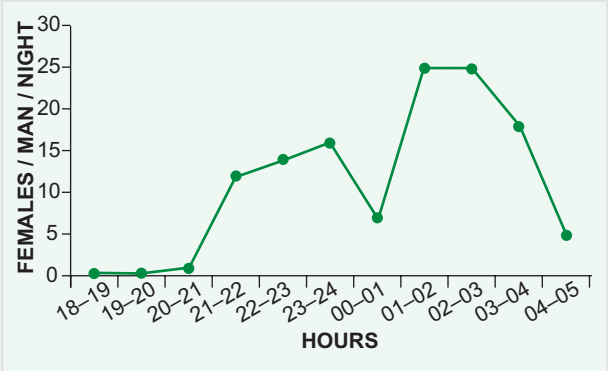

Fig. 26: Hourly landing pattern of *An. minimus* on human host in Assam

Feeding Behaviour

An. minimus was recorded to be highly anthropophagic (AI = 93%) based on hosts blood meal analysis. These mosquitoes landed all through the night on human host but landing was more pronounced between 1200 and 0400 hrs, and biting rate per person per night was 13.72. The hourly landing patterns based on nine all-night landing catches are shown in Fig. 26.

Ecology

Breeding of *An. minimus* was recorded throughout the year in slow-flowing seepage water streams with grassy banks in Assam.

Anopheles fluviatilis

Abundance and Seasonality

It is a main vector of malaria in the forested areas in central India, Himalayan foot hills and in eastern India (Nanda *et al* 2000). It is also found in other parts such as in Gujarat but its role in malaria transmission is doubtful. Studies in Orissa recorded that the species shows a small peak in its density in April just after the winter season when temperature rises, and a second higher peak in October during monsoon (Fig. 27). In *Bhabar* area of Uttarakhand, the adult *An. fluviatilis* density was observed to be low ranging from 0 to 1/man hour (PMH) but high during the month of October (1.7 PMH) and November (2.3 PMH). In the *terai* area, *An. fluviatilis* density was observed high in October (10.7 PMH) and March (9.7 PMH) whereas in rest of the months its density varied from 0.3 to 5.6. Average density of *An. fluviatilis* in the forest area ranged from 13.3 to 82.2. Adult resting catches revealed endophilic behaviour of this species.

In an entomological study, carried out in various

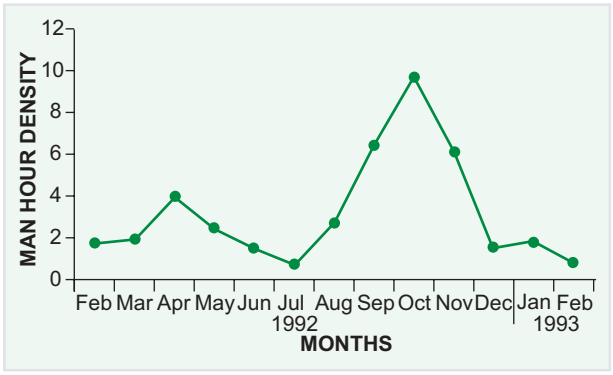

Fig. 27: Seasonality of *An. fluviatilis* in mining areas of Orissa

physiographic areas of District Kheda in Gujarat from 1989–91, the indoor resting density of *An. fluviatilis* was maximum in hilly area 0.57 PMH, followed by canal-irrigated area 0.03 PMH, coastal area 0.02 PMH and riverine area 0.01 PMH. Considerable resting was observed in outdoor natural shelters as well as artificial pit shelters. In the natural shelters, maximum density was recorded from hilly area 0.73 PMH and 2.48 PMH in artificial pit shelters. In a study carried out in the Sardar Sarovar Narmada Project area in Gujarat, indoor resting density of *An. fluviatilis* was high at the dam site than surrounding villages. Variable density was found in both areas throughout the year with two peaks, first during February–April and second in October. Density of *An. fluviatilis* ranged from 0.5 to 12 PMH at the dam site and 0.2 to1.8 PMH in the adjoining villages which reflects high breeding potential at the dam site. Further, it was observed that prevalence of *An. fluviatilis* was higher during winter season (Fig. 28).

Host Preference and Biting Behaviour

In Orissa, *An. fluviatilis* species S comprises nearly 98% and is mainly anthropophilic (Nanda *et al* 1996) whereas it has been found predominantly zoophagic in study areas of Nainital district, Uttarakhand (Shukla *et al* 1998). Its biting rhythm is shown in Fig. 29 indicating that most biting takes place during 2100 to 0400 hrs when most people are asleep. In the forest area in Uttarakhand, *An. fluviatilis* activity was recorded throughout the night with peak activity observed between 2100 and 2400 hrs. Indoor and outdoor landing rates on human host were found to be 1.1 and 3.0/man/night respectively. *An. fluviatilis* was not found in landing collections in the dam and plain areas. At the Sardar Sarovar Project site in Gujarat, the landing rate of *An. fluviatilis* was recorded as 0.28/man/night.

Sporozoite Rate

In the mining areas of District Sundargarh (Orissa), sporozoite rate based on dissections was 1.8%. In Uttarakhand, the sporozoite rates were 1.4, 0 and 62% during September, October and November in 1982, respectively (Choudhury *et al* 1983).

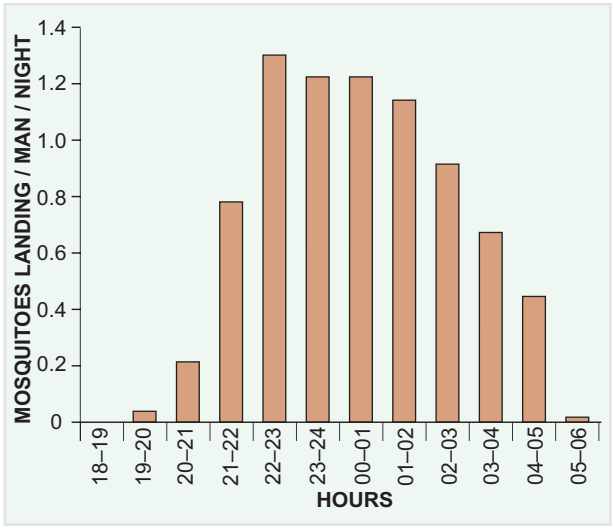

Fig. 29: Biting rhythm of *An. fluviatilis* in mining areas of Sundargarh, Orissa

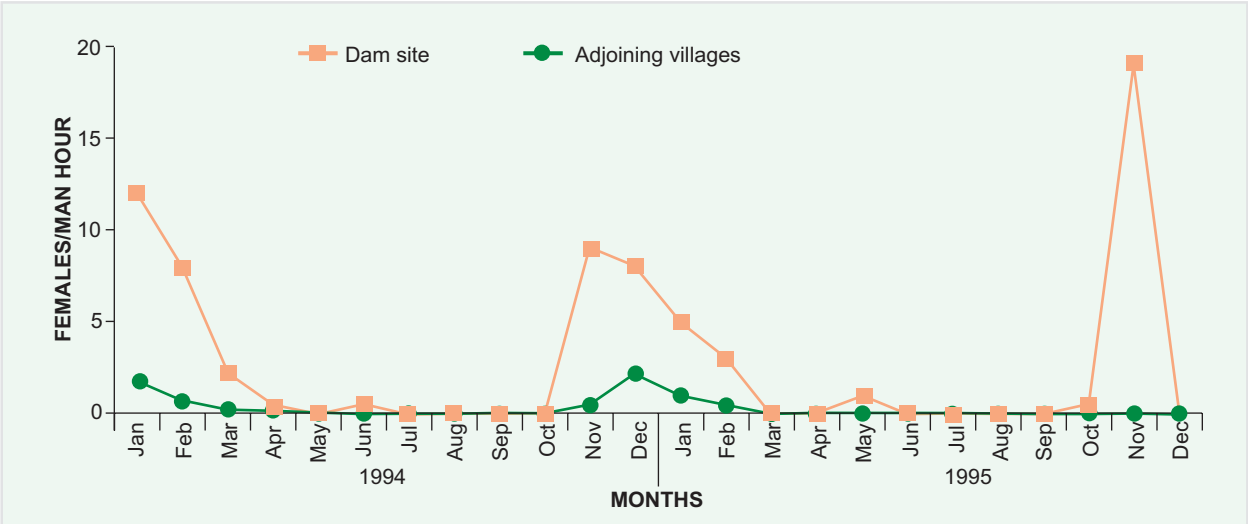

Fig. 28: Seasonal prevalence of *An. fluviatilis* at the Sardar Sarovar Project site and adjoining villages, Gujarat

Ecology

In the forested areas in Orissa, it breeds in sunlit slow running streams and freshly inundated paddy-fields. In Uttarakhand, *An. fluviatilis* was found breeding in artesian (irrigation) drains, streams and ponds (Shukla *et al* 1998). In districts of Orissa, *An. fluviatilis* was found resting predominantly in human dwellings. The preferred resting sites in foothill areas in Uttarakhand were cattlesheds.

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