Malaria is considered as the most widely occurring disease affecting humans of the world which gets spread by the bite of female *Anopheles* mosquito. It is so severe that around 1 million people die annually, putting 3.3 billion (50%) population of the world at risk from 106 countries. Africa continent is the most worst sufferer where, in every 30 seconds a child dies from malaria. South-East Asia and Eastern Mediterranean Regions account for 6% and 2% death due to malaria respectively. In South-East Asia, India accounts for 55% cases reported to be due to malarial effect.

Malaria is endemic in India and active transmission has been reported from many areas of the country. During Independence of India the country reported 75 million cases of malaria with nearly 8 million deaths. With successive efforts taken by the governments, the malaria cases and deaths have been reduced greatly. By 1961 the cases had come down to 50,000 per year. But, due to factors like urbanization, industrialization, irrigation projects, the growing resistance of the parasites to chloroquine and other anti-malarial drugs and insecticides, the disease has spread significantly. In 1976 the cases were reported to be around 6.47 million. However, the constant efforts by the governments have been able to reduce the cases to around 2 million per year since 1984.
The transmission pattern of malaria in India is dominant in the North-Eastern states and large areas of Orissa, Chhattisgarh, Jharkhand and Madhya Pradesh. According to WHO, 80% of the malaria cases were registered from the forest fringe areas and the border areas of Nepal, Bhutan and Myanmar. It is endemic in the north-eastern part of India and is predominately affecting the entire population of this region with *Plasmodium falciparum* being the dominant parasite that has already attained drug resistance. With a total population accounting for only 3.7% of India, the North-East India records on an average about 8–12% of the total malaria cases of the country. Assam with 2.6% of the India’s total population alone registers 9% of the total cases of the country. Despite introduction of numerous control measures including DDT spray operation under National Anti-Malaria Programme (NAMP) recently renamed as National Vector Borne Disease Control Programme (NVBDCP), transmission of malaria continues to be uninterrupted caused by major vectors, namely *An. dirus*, *An. minimus* and *An. fluvatilis*.

Due to excessive and prolonged rainfall (annually 2000 to 3000mm), high humidity (60-90%) and warmer climates (22°-33°C), the Assam region encourages malaria vector breeding and proliferation. The poor socio-economic condition of the people (59.43% of the population below poverty line) and insufficient health care facilities in rural areas have worsened the situation. Sonitpur district of the state is one among the other highly endemic and malaria-affected districts like Karbi Anglong, NC Hills, Hailakandi, Kokrajhar, Chirang, Udalguri, Darrang, Lakhimpur, Nagaon, Morigaon, Cachar, Bongaigaon and Goalpara with Annual Parasitic Index (API) more than two.
8.1 Summary

The district of Sonitpur presents suitable and favorable conditions for mosquito breeding, which in turn facilitate the growth and spread of malaria in the entire district in general and the foothills and the forest fringe areas in particular. The favourable physical conditions like rainfall, temperature, humidity, surface water, vegetation cover etc. coupled with the socio-economic conditions like educational level, per capita income, way of living, occupational pattern, deforestation, poor surveillance activities and their coverage and improper planning and management in health sector have substantially contributed to the growth and diffusion of malaria incidence in the district.

The malaria disease is the outcome of the interaction among three elements, i.e. Man, Mosquito and the Parasite. The intensity of the disease is being regulated by the physical and the socio-economic determinants in the area which interact with these elements. The physical conditions of a region determine the growth and proliferation of mosquito and parasite, while the socio-economic conditions of the people determine the distribution of mosquito and parasite. This piece of research work has been devoted to the study of habitat ecology of mosquito vector species, spatio-temporal incidence pattern of malaria, i.e. parasitic load, physical and socio-economic determinants responsible for the spread of mosquito and parasite and risk factor assessment.

The research work has been organised in eight chapters. Chapter I deals with the introduction of the study which includes statement of the problem, study area, objectives, methodology and database etc. Chapter II presents the review of
literature related to the study. The physical and the socio-economic bases of the study have been discussed in chapter III. Meteorological conditions and different topographical characteristics of the study area are discussed so as to understand its physical base. Similarly under the head - socio-economic base, settlements distribution and locational factors, different population characteristics and social and economic conditions of the study area are covered. The chapter IV tries to elaborate the malaria incidence pattern, both spatially and temporally. The spatial pattern of malaria incidence has been analysed in the light of physiography, vegetation, prevalence of malaria parasite and its trend. The temporal distribution of malaria is examined based on both seasonal and annual pattern. The habitat identification and geo-environmental settings of habitats of malaria vector species are discussed in chapter V. This chapter also presents discussion on the breeding grounds and colonization of mosquito vectors in some selected survey sites. The chapter VI deals with various determinants of malaria endemicity based on the physical and socio-economic characteristics of the study area. Factor-combination and disease clustering, risk zonation, and issues relating to risk reduction and management etc. are addressed under risk factor analysis of malaria that has been discussed in chapter VII. The summary and conclusion along with the salient findings of the research work are systematically presented in chapter VIII.

8.2 Conclusion

The Sonitpur district records high incidence of malaria. The predominant parasite *Plasmodium falciparum* is considered vital for causing considerable morbidity and mortality in the district. The ecological and environmental factors
along with the land use land cover pattern altogether create congenial conditions for proliferation of mosquito species favouring vector longevity and rapid multiplication. Predominance of *Plasmodium falciparum* having resistance to antimalarial drugs, suitable mosquito vectors, innumerable mosquito breeding sites and favourable ecological conditions provide scope for intense malaria incidence in the district both spatially and temporally. Occurrence of high vector density and high percentage of parasitic load (asymptomatic carriers of malaria parasites) among the communities are the prime causes responsible for the recurrent and continuous transmission of malaria in the district. Socio-economic factors like educational level, economic status, house type, cooking fuel, electricity, source of water, use of bed nets and preventive measures adopted significantly determine the incidence pattern of malaria. Repeated infections and non-clearance of parasites from the blood lead to development of immunity and asymptomatic carriers of parasite in the community (Das et al. 2002). Therefore, awareness and thorough monitoring is needed for complete eradication of parasitic load from the communities in general and asymptomatic carriers in particular. The areas identified as malaria hot spots should get preference with prompt, effective and sustainable intervention for complete eradication of malaria. Since the population in general lack awareness about malaria, it is pertinent to achieve community compliance in the public health programmes. Unlike other parts of the country, the major malaria vectors are still susceptible to DDT in Assam (Barkakati and Narasimham, 1992; Dev and Phookan, 1998). Therefore, reasonable coverage and methodical indoor residual spraying of DDT in the affected areas may be recommended. The use of impregnated bed nets as personal protection measures
recommended by WHO should be strictly implemented. Requisite efforts to reduce parasitic load among the communities through proper surveillance, timely therapeutic measures and organizing malaria awareness camps can certainly improve the present situation of malaria in the district and achieve the goal of complete eradication of malaria from the society.

In conclusion, the following findings of the study along with suggestions are mentioned.

1. The seasonal temperature and rainfall patterns constitute the major factors that determine the prevalence and distribution of mosquitoes in the study area. The average maximum and minimum temperature suitable for the proliferation of mosquito is found to range from 20°C to 35°C during the months of April to October. The peak transmission period of malaria extends from May to August when the difference between the maximum and minimum temperature remains almost uniform.

2. The rainy months from April to September, the mosquito breeding gets intensified when rainfall occurs on the average in the range from 160 mm to 325 mm per month. It is the period of the year when the monthly average cases of malaria have been recorded more than 500 since 1991 up to 2010. The humidity suitable for mosquito breeding well coincides with rainfall pattern, as more than 70% humidity is observed from May to November.

3. The Anopheles mosquitoes are dominant in the northern periphery of the district, which is mostly densely vegetated. The places where Anopheles mosquitoes are recorded more than 40% of the total collected mosquito
species are Mainangshree (69.64%), Rihajuli (71.64%), Misamari (46.15%) and Aamlaiguri (44.54%). The areas, where the primary vectors of *Anopheles* are dominant are Mainangshree, Rihajuli, Misamari, Seijosa, Pavoi and Chapai Raumari. On the other hand, the areas where secondary vectors are mostly dominant are Rihajuli, Misamari, Chapai raumari, Aamlaiguri and Seijosa. The variations in distribution of primary, secondary and non vectors of *Anopheles* mosquito reveal that the primary vectors are dominant in areas of dense forest, while the secondary vectors are found to be prevalent in all the areas except the flood plains of Brahmaputra river.

4. Correlation between percentage of land use land cover and percentage of mosquito genus in different survey sites has been carried out and positive correlation is found in the case of wetlands, marshy lands and agriculture fields which are generally characterized by slow flowing as well as stagnant water-bodies. The *Anopheles* in general show positive correlation with the agriculture fields, where the *anopheles* primary vectors show a positive correlation with vegetation and dense forest.

5. The number of malaria cases increases as one moves towards the northern belt of the district which generally covered by forests. Roughly around 2090 km² of area (39.25% of the total district area) comes under different types of forest cover in the district.

6. The *Plasmodium falciparum* malaria being dominantly observed in the northern part of the district accounts for 63.89% of total malaria cases. The
western and north-central parts of the district are more affected by the disease, whereas some isolated pockets are also found towards the eastern part of the district. The malaria cases numbering more than 200 were registered in 20 sub-centres during the period from 2006 to 2010. Sonajuli sub-centre under Rangapara PHC recorded a highest of 673 cases of *Plasmodium falciparum* during 2006-2010 period.

7. The concentration of *Plasmodium vivax* is observed in the north central part and also in some patches in the western and eastern parts of the district. Nine sub-centres recorded more than 200 cases of *Plasmodium vivax* malaria in the district during 2006-2010. The highest numbers of *plasmodium vivax* cases were being registered from Kadamani sub-centre under Biswanath Chariali PHC.

8. Five numbers of sub-centres recorded both *falciparum* and *vivax* with cases more than 200 each. These sub-centres are Tinisuti, Dhuli, Sonajuli, Amloga and Panbari chanimari.

9. The number of sub-centres without a single case of malaria has increased from 72 to 177 during 2006-2010 thereby suggesting improvement in the health sector. Overall trend since 1991 of malaria incidence suggests decrease in the number of cases. The total number of malaria cases has come down from 25092 in 1994 to 2622 in 2010 which measures ten times reduction of cases in 16 years.
10. The analysis of epidemiological data since 1994, of 24 highly malaria endemic villages located in the forest fringed areas show an increasing trend in the incidence of malaria in the population due to ongoing deforestation. The NDVI analysis suggests that the north-western part of the district has been undergoing massive destruction of forest cover from 2000 to 2005. The total forest cover in this part was 23.6% in 2000 which was reduced to 15.4% in 2005.

11. The knowledge about malaria and the measures taken by educated families play important role to reduce malaria incidences than that of illiterate families.

12. The pattern of house type is an important factor that decides the occurrence pattern of malaria. The houses with open ventilation are more prone to mosquito attack than in closed ventilation. The chi square test indicates the significance of house type with malaria risk with $\chi^2$ value of 19.669 and p value less than 0.0001 at 0.05 significance level.

13. Knowledge and awareness about malaria by an individual is always considered and thought as an important precautionary measure in combating malaria, but from the study area it was revealed that it does not necessary helps in reduction of malaria. The $\chi^2$ value of 0.5872 with P value of 0.2947 suggest the non significance of knowledge on high and low risk malaria areas.
14. Basic needs like the use of domestic cooking fuel, electricity and bed nets observed in the study areas show the significance in influencing malaria.

15. Superimposing malaria cases for a period of 5 years from 2006 to 2010 with 3km buffer from sub-centres suggest that large areas of the district, particularly the northern part is uncovered by the reach of health centres which is a part prone to high incidence of malaria.

16. Analysis of data on malaria incidence since 2006-2010 shows a decreasing trend in the number of malaria cases which has come down from 9421 cases in 2006 to 1199 cases in 2010. Based on malaria cases from 2006-2010, thirty four sub-centres are highlighted for effective control measures.

17. Decreasing trend in Annual Parasitic Index (API) has been observed in the district as the API has come down from 5.52 to 0.64 during 2006-2010. Twenty four sub-centre records higher API suggesting for indoor residual spray operation.

18. The Annual Blood Examination Rate (ABER) that should be 10% of the total population in an area as per norm indicates poor surveillance in most of the sub-centres of the district. There are only 24 (8.3%) sub-centres in the district having more than 10% ABER found consistently for five years, whereas 85 (29.5%) sub-centres could not reach the 10% norm of ABER in any of the five years under study.

19. The weighted values for *Plasmodium falciparum*% indicate the concentration of the *Pf* cases mostly in two areas. One is in and around the
northern part of Dhekiajuli PHC and the other is in the northern part of Behali PHC. The satellite image depicts that the sub-centres with high weighted values for Pf % are located within the reach of forest areas thereby strongly advocating the close association of forest and malaria.

20. The areas with higher API and higher Pf % indicate high risk of malaria incidence. In 2006 such high risk sub-centres were 94 in number and the number came down to 20 in 2010. Nine sub-centres with following criteria consistently came since 2006 which are areas for intervention. An area with high API and less blood collection represents areas for immediate intervention. Such sub-centres in the district were twenty three in numbers during last five years.

21. High risk areas for three years, i.e. 2008, 2009 and 2010 were identified based on the conditions laid down by National Anti Malaria Program of India and it has been found that the number of sub-centres with higher weighted values with the conditions was reduced to 4 in 2010 from 17 in 2009 and 30 in 2008. The malaria hot spots of the district were identified by integrating the already identified high risk areas of 2008, 2009 and 2010 and the results shows that 136 (47.2%) out of 288 sub-centres are prone to malaria risk. Ten sub-centres identified as hotspots having extremely high risk of malaria incidence are Hograjuli, Narayankati Bengali and Labari under Dhekiajuli PHC, Phulaguri, Jogibil and Mainowsree under Rangapara PHC, Sonitpur under Balipara PHC, Tinisuti and Dhuli under Biswanath Chariali PHC and Bihmari Bongaon under Behali PHC.
22. Malaria incidence has come down since last few years due to control efforts at various levels which include upgrading health centres facilities, recruitments of health staff, new drug policies for malaria, use of rapid diagnosis kits and awareness on malaria.