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EXECUTIVE SUMMARY

The Indian council of Medical Research (ICMR) under its Flagship Programmes initiated a Tribal Health Research Forum (THRF) at Regional Medical Research Centre for Tribals, Jabalpur on the International Day of the world’s indigenous people on 9th August, 2010. In the 3rd annual meeting of THRF at RMRC Bhubaneswar, it was decided to have comprehensive information on the biology and bionomics of malaria vectors as malaria is still a major health problem among various ethnic tribes. Because of local and focal nature of malaria, the vectors also show a wide diversity in their seasonal prevalence, distribution pattern of sibling species breeding, feeding and resting behavior, transmission potential and response to various insecticides used in the national programme.

Among malaria vectors Anopheles culicifacies and An. fluviatilis are the most prevalent species followed by An. annularis and An. minimus. Studies on these vectors at sibling species level revealed the prevalence of species A, B, C, D and E in MP with the predominance of species C (>80%). The sibling species C, D and E are incriminated as vectors in study areas and these species are primarily zoophilic. However, in the state of Odisha all the 5 sibling species are prevalent with the predominance of species B. Species E has been found an efficient vector and highly anthropophilic as compared to other sibling species. Species A, D and C are also incriminated. In Jharkhand, Chhattisgarh and peninsular India Species B and C are prevalent. Broadly, An. culicifacies has developed resistance to DDT and malathion but it is mainly susceptible to deltamethrin with some exception where verification is required. An. culicifacies has been found endophilic resting mainly in cattle sheds and predominant in monsoon and summer seasons. This species is now found as major vector in forested belt of M.P. in urban, rural and tribal areas of Odisha and even in north eastern states, it has been incriminated as vector.

An. fluviatilis complex comprises sibling species S, T, U and V. In M.P.state species T is predominant (>95%), mainly zoophilic, endophilic and incriminated as
malaria vector. However, species S is predominant in hill and foot hill areas of Odisha state and certain forest areas of Chhattisgarh and Andhra Pradesh states where this species is incriminated as major vector. Species S is highly anthropophagic and rests indoor. In plain areas of Odisha, foothill areas of Jharkhand and north Chhattisgarh, species T is predominant and mainly zoophilic. Species S is susceptible to DDT malathion and deltametherin, while species T is less susceptible to DDT and malathion but susceptible to deltametherin. An. fluviatilis is prevalent mainly during post monsoon and winter seasons.

An. annularis species A is prevalent as secondary vector in Odisha and Jharkhand states and incriminated in Odisha. The species is prevalent in monsoon and winter seasons and endophilic in nature. The species is resistant to DDT but susceptible to deltametherin.

Prevalence of An. stephensi is restricted to urban areas only. The species is found in beginning of monsoon season and incriminated as vector in urban area of Odisha along with An. culicifacies. An. minimus sensu stricto of Minimus Complex and An. baimaii of Dirus Complex, mainly found in north-eastern region are highly anthropophagic and efficient malaria vectors.

Finally, these studies only provides the gist of efforts carried by various ICMR Institutes in highlighting the bionomics of vectors and their role in malaria transmission in varied geo-climatic conditions.
## Acronyms

<table>
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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>HD</td>
<td>Human Dwelling</td>
</tr>
<tr>
<td>CS</td>
<td>Cattle Shed</td>
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<tr>
<td>DDT</td>
<td>Dichloro Diphenyl Trichloroethane</td>
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<tr>
<td>ITMNs</td>
<td>Insecticide Treated Mosquito Nets</td>
</tr>
<tr>
<td>LLINs</td>
<td>Long Lasting Insecticide Nets</td>
</tr>
<tr>
<td>CHC</td>
<td>Community Health Centre</td>
</tr>
<tr>
<td>IRS</td>
<td>Indoor Residual Spray</td>
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<tr>
<td>PCR</td>
<td>Polymerase Chain Reaction</td>
</tr>
<tr>
<td>R</td>
<td>Resistant</td>
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<tr>
<td>S</td>
<td>Susceptible</td>
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<tr>
<td>API</td>
<td>Annual Parasite Incidence</td>
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<tr>
<td>HBF</td>
<td>Human Blood Fed</td>
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<tr>
<td>ITN</td>
<td>Insecticide Treated Nets</td>
</tr>
<tr>
<td>SP</td>
<td>Synthetic Pyrethroids</td>
</tr>
<tr>
<td>GFATM</td>
<td>Global Fund for Aids Tuberculosis &amp; Malaria</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>VR</td>
<td>Verification require</td>
</tr>
<tr>
<td>CDC</td>
<td>Centre for Disease Control</td>
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<tr>
<td>SR</td>
<td>Sporozoite Rate</td>
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<td>EMCP</td>
<td>Enhanced Malaria Control Programme</td>
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<tr>
<td>EIR</td>
<td>Entomological Inoculation Rate</td>
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<tr>
<td>PF</td>
<td>Plasmodium falciparum</td>
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<tr>
<td>SPR</td>
<td>Slide Positivity Rate</td>
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<tr>
<td>GIS</td>
<td>Geographical Information System</td>
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<tr>
<td>MHD</td>
<td>Man Hour Density</td>
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<tr>
<td>BMC</td>
<td>Bhubaneswar Municipal Corporation</td>
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<td>HBI</td>
<td>Human Blood Index</td>
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</table>
1. Title of the study

Assessment of the effectiveness of intensive intervention measures on malaria control programme in tribal districts, Balaghat and Dindori of Madhya Pradesh

Study Area including Ecotype e.g. forest/plain:

Dindori (22N 40° latitude and 81E 48° longitude) and Balaghat (Longitude 80° 15' E; Latitude 21° 84' N) districts are among the malarious districts in Madhya Pradesh. The study area covering 3 CHCs in each district is forested (>37%) with undulating terrain and perennial streams near villages inhabited by one of the most primitive aboriginal tribe known as Baigas who live in dense evergreen forest. Average distance of the villages from CHC is 20 to 80 Km.

Fig 1: Map of India showing location of Dindori & Balaghat districts in M.P.

Type of Housing (Kaccha/pakka):

Houses in the study area are very scattered located in field, forest, in plain and on hilltop surrounded by small perennial streams. The houses are having tiled roof with mud walls and are dark and damp often without ventilation.
Vector species(s)/sibling species:

During the study, *An. culicifacies* and *An. fluviatilis* were found as the vectors. *An. culicifacies* sibling species C was predominant (80%) followed by species D, B, E and A. Species C, D and E were incriminated as vectors. However, *An. fluviatilis* species S and T were found and both were incriminated as vectors in Balaghat whereas in Dindori only *An. fluviatilis* species S was found as vector.

Seasonal prevalence (e.g. rainy, summer etc.):

In the region there are 4 seasons i.e. dry hot (March-May), Monsoon (June-Sep), autumn (Oct-Nov), winter (Dec-Feb). The anopheline fauna of this area consisted of 15 species, of which *An. culicifacies*, *An. subpictus*, *An. fluviatilis*, *An. annularis* and *An. vagus* were commonly prevalent species. Density of *An. culicifacies* was high throughout the year peaking in July-August during the rains. This species was mostly endophilic whereas other species were mostly seasonal. *An. fluviatilis* was mostly found in autumn. Its density was low throughout the year and it was mainly exophilic.

Resting behavior indoor/outdoor/HD or CS:

Most of the species were found to rest indoors in CS. Both the vectors were found in CS throughout the year. However in summer season *An. culicifacies* was found to rest preferably in HD.

Feeding Behaviour/Preference:

In all 1056 specimens of *An.culicifacies* were analyzed for human blood index (HBI) from Balaghat, of which 8 were found positive for human sera and 4 positive for both bovine and human sera. The HBI was found to be 1.1. While from Dindori the HBI for *An.culicifacies* and *An.fluviatilis* were 0.71 and 1.22 respectively.

Sporozoite rate:

Both *An. culicifacies* (25/3000) and *An. fluviatilis* (4/300) were incriminated by ELISA technique. *An. culicifacies* was found positive almost in every month of the year with the sporozoite rate ranging from 0.3% to 0.9%.
An. fluviatilis was found positive mainly in winter season with the average sporozoite rate of 1.3%.

**Insecticide susceptibility status (R or S):**

Monitoring of insecticide susceptibility status of An. culicifacies revealed that this species is resistant to DDT 4% and partially susceptible to malathion 5% in both the districts. However, in Dindori, this species was found resistant to Deltamethrin 0.05% whereas in Balaghat it was found partially susceptible to this insecticide. The corrected percent mortality to DDT, malathion and deltamethrin was 7.0, 83.0 and 92.0 respectively in Balaghat and 13.0, 80.0 and 71.0 in Dindori district.

Cone bioassay test with alphacypermethrin 5% carried out in Balaghat showed 42% mortality on day 1 and 7.5 % mortality on day 30.

**Existing Control measures in the study area:**

Two rounds of indoor residual spray with alphacypermethrin 5% are carried out in both the districts. Long lasting insecticide treated bed nets are in use in Dindori. While in Balaghat ITMNs were given which were not re-impregnated.

**Applied Value:**

ITMNs and IRS which are so effective in other parts of world were not found effective in Balaghat perhaps because of outdoor life and forest based economy of the tribals. Thus there is a need to test the feasibility and effectiveness of other methods of control, for example complete coverage of population with LLINs or with new indoor residual insecticides which has longer residual life or both LLINs and IRS for effective vector control. A well designed case control study may be taken up to evaluate the efficacy of these malaria interventions systematically.

**Knowledge gap:**

Entomological indices lacked on human landing catches. Thus entomological inoculation rate (EIR) could not be determined.
2. Title of the study

**Efficacy of alphacypermethrin 5% by Cone Bio-assay tests in 9 districts of Madhya Pradesh**

Cone bio-assay tests were carried out in 9 districts during June-August 2012 for efficacy of alphacypermethrin 5% sprayed during routine spray (IRS) programme of M.P. state Govt. These tests were carried out on day one and day 30th after the spray in districts Shahdol, Sidhi, Panna, Chhindwara, Mandla, Balaghat, Jhabua, Dhar and Khargone following the method of WHO to determine the persistence and bioavailability of insecticide on the sprayed walls. Field collected *An. culicifacies* from unsprayed villages were used for these assays. Five mosquitoes were introduced in the plastic cones for an exposure of 10 minutes. Number of mosquitoes knocked down in 1 hr and mortality after 24 hrs holding (at standard temperature and humidity) was recorded. Four replicate assays were run on each sprayed house. Four such houses of the villages were tested at one time. Unsprayed houses were taken as control. Data was recorded and Abbott's formula was applied as per the criterion. The results are depicted in Table. The bio-efficacy of alphacypermethrin 5% showed 42 to 70% mortality in *An. culicifacies* on day one after the spray, however, on day 30th <22% mortality was observed.

![Map of India showing location of nine study districts in M.P.](image)
Table-1: Bioassay Test for efficacy of alphacypermethrin 5% in \textit{An. culicifacies} on day 1 and day 30\textsuperscript{th} after the spray in different districts of Madhya Pradesh (June-August 2012)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Districts*</th>
<th>% corrected mortality in day 1</th>
<th>%corrected mortality in day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shahdol</td>
<td>57.8</td>
<td>10.6</td>
</tr>
<tr>
<td>2</td>
<td>Sidhi</td>
<td>67.6</td>
<td>9.2</td>
</tr>
<tr>
<td>3</td>
<td>Panna</td>
<td>70.0</td>
<td>15.8</td>
</tr>
<tr>
<td>4</td>
<td>Chhindwara</td>
<td>66.3</td>
<td>21.6</td>
</tr>
<tr>
<td>5</td>
<td>Mandla</td>
<td>60.7</td>
<td>17.3</td>
</tr>
<tr>
<td>6</td>
<td>Balaghat</td>
<td>42.1</td>
<td>7.5</td>
</tr>
<tr>
<td>7</td>
<td>Jhabua</td>
<td>-</td>
<td>17.5</td>
</tr>
<tr>
<td>8</td>
<td>Dhar</td>
<td>-</td>
<td>14.2</td>
</tr>
<tr>
<td>9</td>
<td>Khargone</td>
<td>-</td>
<td>20.3</td>
</tr>
</tbody>
</table>

*Bioassay in Jhabua, Dhar and Khargone could not be carried out on day 1 after the spray due to non availability of sufficient numbers of mosquitoes.

**Applied value:**

The existing vector control measure in Madhya Pradesh is mainly insecticide residual spray (IRS) which requires the selection of effective insecticide time to time. The study on efficacy of alphacypermethrin 5% will help for changing pattern of IRS, as the existing alphacypermethrin 5% showed very less mortality of \textit{An. culicifacies} (7.5 to 21.6) even in a month.

**Knowledge gap:**

Before any IRS programme in each year, the insecticide should be checked for its efficacy in the state.
3. Title of the study

Vector mapping with its susceptibility status to insecticides in seven high-risk districts of Odisha state

Study area including ecotypes e.g. forest/plain:

Study area included following blocks of 7 districts that are at high risk of malaria transmission as identified by EMCP. These are Nuapara (Kharia), Keonjhar (Ghatgan), Kandhamal (Khajuipara), Gajapati (Mohana), Boudh (Adenigarh), Rayagada (Muniguda) and Nawarangapur (Papdahandi). All these seven districts represent hilly forest ecotype. Of these districts Nawarangapur and Boudh are densely forested areas.

Fig 1: Map of Odisha state showing study districts

Type of Housing (Kaccha/Pakka):

Houses in the seven districts are located in plain, foot hill and hilltop areas. In hill forest regions the villages were surrounded by perennial streams. Mostly the houses are made of mud walls and tiled/ thatched roof. Most of the
houses do not have any window and kitchen and living room are combined. In hill top villages mostly cattle sheds are open without walls.

**Vector species and sibling species:**

During the study the species recorded included *An. annularis*, *An. culicifacies*, *An. fluviatilis*, *An. minimus*, *An. philippinensis* and *An. varuna* which have been recognized as malaria vectors in India. *An. annularis*, *An. culicifacies* and *An. fluviatilis* were found as major vector species. The sibling species of *An. culicifacies* were identified as A, B, C & D and species B was most abundant. *An. annularis*, sibling species A, *An. fluviatilis* sibling species S, T & U, *An. minimus*, *An. philippinensis* and *An. varuna* were also collected in small numbers from study districts.

**Seasonal prevalence:**

All surveys were conducted during rainy and winter seasons in all the districts. The highest mosquito collection was made in post monsoon season followed by winter season. *An. culicifacies* and *An. annularis* were predominant vector species in seven districts. *An. culicifacies* density was found more during the monsoon and post monsoon seasons followed by *An. annularis* density. Maximum numbers of *An. fluviatilis* were collected during the winter season.

**Resting behavior indoor/outdoor/ HD or CS:**

*An. fluviatilis* were collected from indoor resting places mainly from cattle sheds. *An. culicifacies* and *An. annularis* were collected more from cattle sheds followed by mixed dwellings. Very less number of these species was collected from human dwellings indicating their preference to rest in cattle sheds/ mixed dwellings.

**Feeding behavior/ preference:**

In all, 4643 female anopheline specimens belonging to 5 species collected in the different study sites were processed for human blood index and *P. falciparum* infectivity by PCR. The highest anthropophilic index (47.8%) was found in the *An. fluviatilis* population while 5.8% of *An. culicifacies* and 2.7% of *An. annularis* were found fed on human blood. Generally the
mosquitoes particularly *An. fluviatilis* in the hilly area (Boudh) showed more preference for human blood rather than those in the plain area.

**Sporozoite rate /EIR:**

The vector mosquito species were detected with *P. falciparum* sporozoites. The overall sporozoite rate of vector mosquito species collected from different study sites was; *An. culicifacies* (SR-1.3%); *An. fluviatilis* (SR-1.5%) and *An. annularis* (SR=0.3%)

**Insecticide susceptibility status (R or S):**

Exposure of *An.culicifacies* to DDT sprayed surfaces reduced mortality in *An. culicifacies* from all study localities, implicating resistance according to established criteria. The highest resistance to DDT in *An. culicifacies* was recorded from Kandhamal followed by Keonjhar and Boudh. *An. culicifacies* showed 100% resistance to malathion, but no test was done with deltamethrin.

**Existing control measures in the study area:**

Two rounds of indoor residual spraying with DDT/ synthetic pyrethroids were provided in areas with API 5 and above due to scarcity of insecticides. Long Lasting Insecticide Nets (LLINs) were also distributed in some blocks of these districts, but all house hold were not covered.

**Applied value:**

Study of the vector fauna, their habits and density and vector infection rate in seven districts will help to implement a more selective approach for the vector control programme. As DDT was found to be resistant to *An. culicifacies* the major vector of Orissa, the changing pattern of IRS may be undertaken with distribution of LLIN for better control measure.

**Knowledge gap:**

Susceptibility status of other vectors like *An. fluviatilis* could not be carried out extensively as more samples were not collected. EIR could not be calculated due to lack of man landing collection.
4. **Title of the study:**

**GIS based Micro Planning for Malaria Control in High Endemic Areas of Odisha state.**

**Study area including ecotypes:**

The study was conducted in three malaria endemic districts of Odisha namely Nawarangapur (Block Papdahandi), Khurda (Block Banpur) and Keonjhar (Block Ghatagaon). These three districts differ in their geophysical conditions, demographic pattern and socio-economic status and represent plain and forest ecotypes.

![Location Map of the Study Area](image)

**Fig 1:** Maps showing Odisha state in India & pilot blocks in study districts

**Type of housing (Kaccha/pakka):**

Houses in the study areas are clustered and both pakka and kaccha type of houses are found here. Kaccha houses with mud tiles (khapara) were mostly found in Nawarangapur and Keonjhar districts but in district Khurda most of the houses are made of cemented walls with thatched roof.
Vector species (S)/ Sibling species:

In selected blocks of 3 districts An. culicifacies, An. fluviatilis, An. annularis, An. varuna and An. philippinensis were recorded. An. culicifacies Complex comprised species A, B, C, D and E and species B was most abundant. An. annularis species A and An. fluviatilis species T and U were prevalent.

Seasonal prevalence:

During one year study period total three surveys were carried out in three seasons i.e. winter, summer and rainy in Papdahandi, Banpur and Ghatagaon blocks. The results indicated that the winter season is the most favorable period for malaria vectors followed by monsoon.

Resting behavior indoor/outdoor/HD or CS:

Vector species were indoor resting and were collected from both human dwellings and cattle sheds near to the households. An. culicifacies, An. fluviatilis and An. annularis found more in number from the cattle shed near to the household. Only An. culicifacies and An. fluviatilis was collected from human dwellings.

Sporozoite rate:

An. culicifacies E was reported for the first time in this study with 42% human blood fed percentage (HBF) from Nawarangapur district. Highest 19% sporozoite rate was observed in An. culicifacies E, followed by D, A and C as 10.8%, 10.3% & 1.8% respectively. An. annularis showed sporozoite rate of 0.5% and none of the An. fluviatilis was found with malaria sporozoites.

Existing control measures in the study area:

Ghatgaon block was totally covered by ITMNs and recently these have been replaced by LLINs in a phased manner. In other two blocks, NVBDCP uses IRS with DDT and synthetic pyrethroid.
**Applied value:**

The risk maps developed by monitoring environmental condition and overlying the composite parameters will help us to create an integrated early warning system where malaria may be an epidemic in future and early identification of potential epidemic situation timely and respond to it.

**Knowledge gap:**

More area requires to be validated. Validation was not done except one place.
5. Title of the Study

Investigation of an outbreak of malaria in a non endemic malaria block of Balasore district of Odisha state.

Study areas including Ecotype e.g. Forest/ Plain:
An outbreak of malaria occurred in 3 villages of a non endemic block Nilgiri of Balasore district during March 2010. The study villages represented foot hill ecotype.

![Districts of Orissa](image)

Fig 1: Map of Odisha state showing district Balasore

Type of the Housing (Kaccha/Pakka):
Most of the houses of the study area were kachha with mud plastered walls and thatched roof. The houses were in rows and few houses were scattered towards the periphery of the village. There is a stream flowing on the outer side of all the three villages. The villages are located in foot hill.

Vectors Species(s)/sibling species:
During the survey *An.culicifacies* species A, *An.annularis* and *An. subpictus* were found.
Seasonal prevalence (e.g. rainy, summer):

During the study period (summer season) *An. culicifacies* species A, *An. annularis* and *An. subpictus* were prevalent with MHD of 17, 14 & 10.8 respectively.

Resting behavior/preference:

The above mentioned species were collected from the human dwellings and cattle sheds. Majority of the *An. culicifacies* species A were collected from human dwellings.

Feeding behavior /preference:

Anthropophilic index of *An. culicifacies* s.l. was 10.5%.

Sporozoite rate/EIR:

*Plasmodium falciparum* (Pf) sporozoites were detected in two out of 58 *An. culicifacies* examined (SR- 3.45%). One specimen of *An. annularis* out of 40 examined was found with Pf sporozoites (SR is 2.5%)

Insecticide susceptibility status(R or S):

The vectors susceptibility tests showed that *An. culicifacies*, *An. annularis* and *An. subpictus* were resistant to DDT but susceptible to synthetic pyrethroid.

Existing control measures in the study area:

Since the above area is a non endemic for malaria therefore, no Govt. control programme is running there.

Applied value:

Sudden outbreak of the malaria in non endemic area requires collection and identification of vectors. Presence of sporozoite is also important parameter for the identification of vector. Spraying by synthetic pyrethroid may be undertaken for controlling the situation.

Knowledge gap:

An early detection method for epidemic of malaria is not known in non endemic areas. As the malaria cases and API is very low throughout the year the early warning of epidemic cannot be assessed.
6. Title of the Study:

Urban Mosquito Control in Bhubaneswar Municipality

Study areas including Ecotype e.g. Forest/Plain:

Bhubaneswar city is mostly a plain area having a small forest zone of 5 km radius. A river flows on the eastern side of the city. The city has 60 wards which have been divided into five zones. All the zones are malarious. From each ecozone one slum and one non slum area were taken for study.

Fig 1: Map of Odisha state showing Bhubaneswar city

Type of the housing (Kaccha/Pakka/Apartment):

In the city various type of houses are there. Mostly in slum areas more kaccha houses with few pakka houses are seen. In the non-slum areas apartments and cemented pakka houses are present.

Vectors Species(s)/ sibling species:

The following three vectors i.e. An. culicifacies, An. annularis and An. stephensi were collected during the surveys.
Seasonal prevalence (e.g. rainy, summer etc.):

Out of six anopheline species, three known vectors, viz, *An. annularis*, *An. culicifacies* and *An. stephensi* were prevalent in the city. None of the above vector species were prevalent throughout the year but were prevalent during February, June, July and December. All the three species showed one peak in July and *An. stephensi* showed a second peak in December, *An. culicifacies* in January and *An. annularis* in February.

Resting behavior/preference:

All the species were collected from houses and cattle sheds. *An. culicifacies* was collected more from houses than cattle sheds.

Feeding behavior/preference:

All three vector species were primarily zoophagic. Anthropophilic index of *An. culicifacies*, *An. annularis* and *An. stephensi* was 2.8%, 3.4% and 3.8% respectively.

Sporozoite rate/EIR:

Sporozoite rate (SR) of *An. culicifacies* was found to be 0.03% and for *An. stephensi* the SR was 0.01%.

Insecticide susceptibility status(R or S):

All the three species were found to be susceptible to deltamethrin.

Existing control measures in the study area:

The city has not been covered under urban malaria scheme but the National filarial control program is running in the city.

Applied value:

In India few cities were covered under urban malaria scheme. The upcoming of large number of town leads to spread of malaria into urban localities. The situational analysis is required in every town for control of malaria.

Knowledge gap:

More number of cities should be taken for situation analysis.
7. Title of the Study

Comprehensive integrated vector control for co-existing infection of Malaria, Filariasis and Chikungunya in Odagaon block of Nayagarh district of Odisha.

Study areas including Ecotype e.g. Forest/ Plain:

Malaria, filariasis, chikungunya and dengue were reported from Odagaon block of Nayagarh district. Two villages with more than 3000 population were selected for the study. Half of the study area is surrounded by paddy fields and rest of the area is adjacent to forest.

![Fig. 1: Maps showing district Nayagarh in Odisha & its Odagaon block.](image)

Type of the Housing Kaccha/Pakka:

Both Kaccha and Pakka house are present in the study area. Houses are situated on the both the side of village road and some areas have concentrated household of kaccha houses in the centre of the village.

Vectors Species(s)/ sibling species:

An. culicifacies and An. annularis the, known vectors were present in the study villages. The average per man hour density of An. culicifacies and An. annularis was 12.9 and 8.9 respectively.
Seasonal prevalence (e.g. rainy, summer etc.):
Density of *An. culicifacies* was (MHD 18.3) highest during rainy season, *An. annularis* showed highest density in winter. (MHD was 9.3).

Resting behavior/preference:
The high proportion of unfed & freshly fed (90.6%) population indicates that the vector breeds nearby to the houses and prefer to rest inside human dwelling.

Feeding behavior/ preference:
The anthropophilic index of *An. culicifacies* was 7.8% whereas for *An. annularis* it was 5.2%.

Sporozoite rate/EIR:
The sporozoite rate of *An. culicifacies* and *An. annularis* were 1.2% and 0.31% respectively conforming the indigenous transmission of malaria.

Insecticide susceptibility status(R or S):
Both *An. culicifacies* and *An. annularis* were found to be resistant to DDT but susceptible to synthetic pyrethroid (Cyfluthrin).

Existing control measures in the study area:
At present no vector control programme is running in the study area.

Applied value:
Integrated vector control was carried out throughout the world for vector control programme of malaria, dengue etc. This study will give a new direction of integrated vector control for comprehensive management of malaria, filaria, chikungunya and dengue.

Knowledge gap:
The study was carried out in one village. More villages with a buffer zone is required for accurate result.
8. Title of the Study:

Risk factors associated with the spread of malaria in the Rengali left Bank Canal system of Odisha.

Study areas including Ecotype e.g. Forest/Plain:

In Dhenkanal district, a canal is being constructed in two blocks viz., Parjanga and Kamakhya Nagar. The water has been released in the canal of Parjang block which is a plain area whereas in Kamakhya Nagar block, the canal is under construction and this area is mostly forested.

![Maps showing district Dhenkanal in Odisha & study areas Parjang and Kamakhya Nagar blocks therein.](image)

Type of the Housing (Kaccha/Pakka):

Both the blocks have pakka and kaccha houses with predominance of pakka in Parjang area and Kaccha in Kamakhya Nagar area. The houses were made up of mud walls with thatched roof in Kamakhya Nagar.

Vectors Species(s)/sibling species:

The survey revealed prevalence of *An. culicifacies* (species A, B, C, &D), *An. annularis* (species A) and *An. fluviatilis* (species S) along with *An. subpictus*. *An. fluviatilis* (species S) was found only in Kamakhya Nagar.
Seasonal prevalence (i.e. rainy, summer etc.):

Parjang area (Canal with water):
All the sibling species of *An. culicifacies* (A, B, C, & D) were found in the study area. Density was more in rainy season followed by winter and summer seasons. *An. annularis* also showed the same trend. *An. fluviatilis* could not be collected in this area.

Kamakhya Nagar (Canal without water):
As observed in Parjang, *An. culicifacies* (A, B, C, & D) showed highest density in rainy followed by winter and summer. *An. annularis* unlike Parjang showed highest density in rainy followed by winter and summer season where as density of *An. fluviatilis* was highest in winter followed by rainy season. No specimen could be collected during summer.

Resting behavior/preference:
Most of the species were found resting inside the houses and cattle sheds. *An. culicifacies* was found to rest inside human dwellings during the summer season.

Feeding behavior/preference:
Among the members of *An. culicifacies* complex the anthropophilic index of *An. culicifacies* species A (Parjang-4.7%, Kamakhya Nagar-5.5%) was highest followed by species C (Parjang-3.5%, Kamakhya Nagar-2.8%), species B (Parjang-1.8%, Kamakhya Nagar-1.7%), species D (Parjang-0, Kamakhya Nagar-1.1%). In case of *An. annularis* the AI was found to be 11% in Parjang area and in Analabereni area it was 14%. The anthropophilic index of *An. fluviatilis* was found to be 65%.

Sporozoite rate/EIR:
Sporozoite rate of *An. culicifacies* species A was highest (Parjang-1.2%, Kamakhya Nagar-1.3%) followed by species C (Parjang-0.6%, Kamakhya Nagar-0.4%). The sporozoite rate in *An. annularis* In the Parjang area was 0.1% where as it was 4.4% in Analabereni area. The sporozoite rate of *An. fluviatilis* was found to be 4%. 
**Insecticide susceptibility status (R or S):**

In Parjang area *An. culicifacies* species D showed highest mortality (50%) to DDT and species C showed highest (66.7%) to malathion and 100% to deltamethrin. Species A was found to be less susceptible among A, C, D, i.e., 20% to DDT and malathion. In Kamakhaya Nagar area, *An. culicifacies* species B showed highest mortality (50%) to DDT, 40% to malathion and 100% to Deltamethrin. In both the study areas species C was found to be more susceptible to malathion compare to DDT. However all the species showed 100% mortality to Deltamethrin. *An. annularis* species A showed 30-45% susceptibility to DDT and malathion whereas it showed 100% susceptibility to Deltamethrin. *An. fluviatilis* species S showed 100% mortality to deltamethrin and malathion and 90% to DDT.

**Existing control measures in the study area:**

In both the areas Parjang and Kamakhya Nagar block bed nets were distributed.

**Applied value:**

Situation of malaria increases due to irrigation canal system. The risk factors analysed were seepage in canal system. Formation of temporary pond and breeding places in side canal increases the breeding potential of vectors. This situation can be taken care during canal construction in the country.

**Knowledge gap:**

Intervention was not done.
9. Title of the Study:

**Studies on vector prevalence and bionomics in relation to transmission of malaria and its containment using evidence based intervention measures in southern districts of Odisha State**

**Study Area including Ecotype e.g. forest/plain:**

The study area included ten southern districts of Odisha State: Malkangiri, Koraput, Rayagada, Nowrangpur, Kalahandi, Nuapada, Bolangir, Kandhamal, Gajapati and Ganjam (Figure 1). A systematic study on entomological and parasitological aspects of malaria transmission, covering the three seasons, was carried out in 128 villages which were selected representing the three major ecotypes viz., hill-top, foot-hill and plain following the grid sampling method.

![Fig. 1: Maps showing Odisha state in India and 10 southern districts of Odisha.](image)

**Type of Housing (Kaccha/pakka):**

In all the southern districts, both kaccha and pakka houses were present; overall, 30% were pakka houses and 70% katcha houses.

**Vector species (s) /sibling species:**

Both *An. culicifacies* and *An. fluviatilis* were prevalent in study district. The relative proportion of sibling species of Fluviatilis complex was *An. fluviatilis* S -72.1% and T-24.9%; *An. fluviatilis* S was predominant in hill-top and foot-hill villages and T was predominant in plain ecotype. The
Culicifacies Complex comprised species B - 52.9%, C - 0.9%, & E - 43.9%. Both the predominant sibling species of *An. culicifacies* (Species B and E) were more abundant in plain ecotype.

**Seasonal prevalence (e.g. rainy, summer etc.):**

*An. fluviatilis* was prevalent in rainy and winter seasons and *An. culicifacies* was predominant in summer and rainy seasons.

**Resting behavior indoor/outdoor /HD or CS:**

*An. fluviatilis* - Indoor- HD & CS; *An. culicifacies* - Indoor- HD & CS. Although, both the vector species were found resting in both HD and CS, *An. fluviatilis* was predominantly rests in HD and *An. culicifacies* predominantly rest in CS.

**Feeding behavior /preference:**

While *An. fluviatilis* was predominantly anthropophagic (HBI- 0.62); *An. culicifacies* was primarily zoophagic (HBI - 0.008)

**Sporozoite rate/EIR:**

Not available

**Insecticide susceptibility status (R or S):**

*An. fluviatilis* s.l. was susceptible to DDT, malathion and deltamethrin in all the southern districts. *An. culicifacies* was resistant to DDT in all the districts. It was also resistant to malathion in all the districts except Gajapati and Kalahandi where this species was under ‘verification required category’. *An. culicifacies* was susceptible to deltamethrin in five districts viz., Rayagada, Nowrangpur, Nuapada, Kandhamal and Koraput while it was under ‘verification required’ category in Balangir, Ganjam, Gajapati, Kalahandi and Malkangiri districts.

**Existing control measures in the study area:**

Two rounds of indoor residual spraying with DDT is done in districts Nowrangpur, Balangir, Nuapada, Ganjam, Gajapati, Koraput and Malkangiri whereas both DDT and SP are used in Rayagada Kalahandi, Kandhamal and LLIN have also been distributed in above mentioned districts.
**Applied value:**

The study has shown that *An. fluviatilis* is the main vector of malaria in all the southern districts of Odisha State. The vector density and the risk of malaria transmission depend on the ecotype of the villages. Therefore, micro-stratification of villages will be useful in prioritizing and optimizing implementation of vector control measures.

The main vector is still susceptible to DDT, malathion and deltamethrin in all the southern districts. Therefore, optimal implementation/utilization of the ongoing interventions such as indoor residual spraying using DDT and distribution of LLINs will have significant impact on the reduction of malaria transmission in these tribal areas. There is no need to change the insecticides in use now.

The outcome of the study has already been shared with the NVBDCP, disseminated to the district programme managers through workshop for implementation.

**Knowledge gap:**

Changing trend in the vectors’ role, their behavior and susceptibility status to the insecticides in use over time, if any, needs to be monitored.
10. Title of the Study:

Demonstration and evaluation of integrated vector management (IVM) in a malaria endemic tribal area of Odisha State, India.

Study Area including Ecotype e.g. forest/plain:

Laxmipur community health centre (CHC) of Koraput district in Odisha State. The study was conducted in three major ecotypes, top-hill, foot-hill and plain.

Fig. 1: Maps showing Koraput districts and Laxmipur CHC

Type of Housing (Kaccha/ pakka):

Both kaccha (80%) and pakka (20%) houses; this proportion was almost same in all ecotypes.

Vector species (s) /sibling species:

The prevalent vector species were *An. fluviatilis* and *An. culicifacies*. Information on sibling species is not available.
Seasonal prevalence (e.g. rainy, summer etc.):

*An. fluviatilis* was prevalent in rainy and winter; *An. culicifacies*-summer and rainy.

Resting behaviour indoor/outdoor /HD or CS:

*An. fluviatilis*- Indoors, HD & CS, *An. culicifacies*- Indoors, HD & CS. however, *An. fluviatilis* was predominantly resting in HD and *An. culicifacies* predominantly in CS.

Feeding behaviour /preference:

Not available

Sporozoite rate/EIR:

Not available

Insecticide susceptibility status (R or S):

*An. fluviatilis* s.l. was susceptible to DDT, malathion and deltamethrin. *An. culicifacies* was resistant to DDT and malathion. To deltamethrin, *An. culicifacies* was found susceptible.

Existing control measures in the study area:

Two rounds of indoor residual spraying with DDT 50% and distribution of LLINs in all the villages of Laxmipur CHC.

Applied value:

This was a pilot study in which the efficacy and the feasibility of implementation of an environmental measure (construction of a minor irrigation dam with sluice gate) was demonstrated in controlling the malaria vector breeding in its preferential habitat through inter-sectoral collaboration. This strategy can be integrated with the ongoing ‘minor irrigation scheme’ implemented by the Agriculture Department, wherever feasible, in the tribal area.

Knowledge gap:

The replicability of the measure needs to be demonstrated in the context of implementing IVM for malaria control in the tribal areas.
11. Title of the study:

Studies on distribution and biological characteristics of the members of *Fluviatilis-Minimus* group for effective vector control strategies in tribal areas of India.

Study Area including Ecotype e.g. forest/plain:

Tribal dominated malaria endemic areas representing hilly and foothill forest ecotype with stream channels and prevalence of *An. fluviatilis* and *An. minimus* were selected in the following 22 districts belonging to 10 states. Districts Gumla, Simdega and West Singhbhum (Jharkhand state), Surguja, Dantewada and Bastar (Chhattisgarh state); Keonjhar, Deogarh and Mayurbhanj (Odisha state); Vizianagaram and Visakhapatnam (Andhra Pradesh state); Nilgiri (Tamil Nadu state); Waynad and Idduki (Kerala state); Jalpaigudi (West Bengal state); Nalbari, Chirang, Kamrup and Cachar (Assam state); Changlang (Arunachal Pradesh state) and Lung lai (Mizoram state). (fig.1)

![Map showing selected districts](image)

**Fig 1:** Districts selected for studies on *An. fluviatilis* and *An. minimus* sibling species.

Type of Housing (Kaccha/pakka):

Mostly kaccha with thatched or tilted roof and mud walls without proper ventilation and scattered in study areas of east-central and peninsular
India. In study areas of north – eastern states the houses are kaccha, made up of bamboo and mud with thatched roof and are sparsely distributed.

**Vector species (s)/ sibling species:**

Species S and T of Fluviatilis Complex were found prevalent in study areas of selected districts of east central and peninsular India. Species S was predominant (72-99%) in districts Dantewada and Bastar (Chattisgarh state), Keonjhar, Deogarh and Mayurbhanj (Odisha state) and Vizianagaram and Visakhapatnam (Andhra Pradesh state) and sympatric with species T. Only species T of Fluviatilis Complex was prevalent (100%) in districts Gumla, Simdega and west Singbhum (Jharkhand state); Surguja (Chhattisgarh state) and in districts Nilgiri and Waynad in peninsular India. Only *An. minimus sensu stricto* (formerly known as species A) of the Minimus Complex was prevalent in study districts of NE states and *An. harrisoni* (species C) was not found. *An. culicifacies* found co-existing with *An. fluviatilis / An. minimus* in study districts comprised species B and C (Figs. 2 & 3).

![Fig 2 & 3: Distribution pattern of *An. fluviatilis / An. minimus / An. culicifacies* sibling species in the districts surveyed](image)
Seasonal prevalence (e.g. rainy, summer etc.):

The peak prevalence period of *An. fluviatilis* was during winter months Nov –Dec and its densities were observed up to Feb-March in study districts. *An. minimus* were collected during March-April to Sept-Oct in study districts of north–eastern states which is considered favorable period for *An. minimus* prevalence.

Resting behavior indoor/ outdoor/ HD or CS:

*An. fluviatilis* species S was found to be resting indoors and the preferred resting site was human dwellings whereas species T was collected mainly from cattle sheds and mixed dwellings in areas of their prevalence in study districts. In study districts of N.E. states, *An. minimus* were found to be resting in human dwellings in very low densities and partially exophilic behavior of this species is strongly suspected. *An. culicifacies* species B and C found co existing with *An. fluviatilis / An. minimus* in study areas were found resting mainly in cattle sheds or mixed dwellings.

Feeding behavior/ preference:

Species S of Fluviatilis Complex was found to be highly anthropophagic in areas of its prevalence in Odisha, Chhattisgarh and Andhra Pradesh states with Human Blood Index (HBI) >0.9, whereas species T was primarily zoophagic in areas of its distribution (HBI ranging from 0.0-0.13). *An. minimus* in NE states was found to be highly anthropophagic (HBI 0.97) *An. culicifacies* species B and C co existing with *An. fluviatilis / An. minimus* in study areas were found to be primarily zoophagic.

Sporozoite rate/ EIR:

High sporozoite rates were observed in species S of Fluviatilis Complex ranging from 1.56-2.51 in study areas of districts Dantewada, Bastar, Keonjhar, Deogarh, Vizianagaram and Visakhapatnam. *An. minimus sensu stricto* was incriminated as vector in Chirang district of Assam state (SR- 1.49). *An. culicifacies* species C was found positive for malaria sporozoites in district Dantewada of Chhattisgarh state (SR-0.90).
Insecticide susceptibility status (R or S):

Insecticide susceptibility test revealed that resistance / tolerance to DDT has precipitated in An. fluviatilis in species T dominated areas (districts Gumla, Simdega and Surguja) where % corrected mortality observed ranged from 70% to 77.6% but this species was found completely susceptible to malathion 5% and deltamethrin 0.5%. Whereas An. fluviatilis was found susceptible / under verification required category to DDT% in species S dominated areas (districts Keonjhar, Bastar and Vizianagaram) with % corrected mortality ranging from 94.7-100 and it was completely susceptible to malathion and deltamethrin in above mentioned districts. An. culicifacies sensu lato was found resistance of DDT in study areas of districts Gumla, Simdega, Dantewada and Chairang whereas this species was under verification required category for malathion in districts Simdega and Chirang and resistant in Dantewada. Observations revealed that tolerance has developed in An. culicifacies to deltamethrin in district Dantewada (% corrected mortality 83.4-89.0)

Existing Control measures in the study area:

In selected districts of Odisha state two rounds of indoor residual spraying with DDT 50%/ SP (Deltamethrin) are being carried out and distribution of LLINs in high risk areas. In study districts of Jharkhand state 2 rounds indoor residual spray with DDT 50% and sporadic spray of pyrethroids and distribution of LLIN in high risk area. In Chhattisgarh state two rounds of indoor residual spray with synthetic pyrethroids are carried out. Vector control measures in study districts of NE states includes 2 rounds of indoor residual spray with DDT and selective distribution of LLIN/ ITN in high risk areas.

Applied value:

A comprehensive picture of the distribution pattern and biological attributes of the members of Fluviatilis and Minimus Complexes has been obtained in malaria endemic, tribal dominated districts of 10 states in central, north eastern and peninsular India. The study has delineated malarious areas that are primarily under the influence of highly efficient vector species.
like *An. fluviatilis* species S and *An. minimus sensu stricto*. The information generated on the biology and behavior of these species would be useful in planning effective vector control measures in such areas.

**Knowledge gap:**

Longitudinal studies in malaria endemic zones to ascertain the relative role of species complexes of malaria vectors in different ecotypes (forest, rural plain, reverine etc.) would enhance the existing knowledge of bionomics and transmission potential of malaria vectors in different ecological settings. This would greatly help in formulating appropriate vector control strategies in ecologically diverse malarious areas. Such studies are proposed to be taken up under ICMR Task Force on biology and bionomics of vectors.
12. Title of the study

Monitoring of Insecticide Resistance in Malaria Vectors in India.

Study areas including Ecotype e.g., forest/plain:

Selection of the study areas were broadly classified based on various eco-epidemiological settings and distribution of mosquito vectors area is stated below:

(i) A group of administrative districts in the states in each of the region were designated as zones based on the similar eco-topography and vector prevalence and distribution.

(ii) In each of such zones, broadly, few prominent ecotypes were identified, such as plain area (riverine & non-riverine); foot-hill and hilly- forested; undulating terrain, arid and semi-arid and are termed as units. Based on the history of the insecticide use and vector prevalence, study villages were selected in the given study unit with emphasis on mosquito productivity and influence of the factors such as insecticide use in agriculture, soil types, altitude, rainfall etc. were considered where feasible for better selection and interpretation. Selected districts for the work include districts under the GFATM and World Bank project work. A total of 75 units were designated for study from 156 districts in 13 states for the proposed work. Each unit comprised of ~ 2-3 districts. All the districts in a given unit of study, which may be present in different congruent states, were considered as a single unit for the study.

(iii) Each study site comprised of about 3-4 villages, or as required. Thus broadly, areas in the state were stratified into zones based on certain defined ecotypes. Each zone was surveyed in a minimum of three study sites situated in different directions and considering other criterion which were further stratified.

Type of Housing (Kaccha/pakka):

Both kaccha and pakka with predominance of kaccha houses.
Vector species(s)/sibling species:
The vector species tested in study districts of each state are given in Table 1. Study was not carried out at sibling species level.

Table 1: Study districts:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>States (No. of Districts)</th>
<th>Districts</th>
<th>Vector Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Andhra Pradesh (5)</td>
<td>E.Godavari, Khammam, Srikakulam, Vishakhapatnam, Vizainagaram</td>
<td>An. culicifacies</td>
</tr>
<tr>
<td>2</td>
<td>Chhattisgarh (10)</td>
<td>Bilaspur, Korda, Korea, Dantewada, Bastar, Kanker, Dhamtari, Raipur, Jashpur, Raigarh</td>
<td>An. culicifacies, An. fluviatilis</td>
</tr>
<tr>
<td>3</td>
<td>Jharkhand (4)</td>
<td>Gumla, Ranchi, East &amp; West Singhbhum</td>
<td>An. annularis, An. culicifacies, An. fluviatilis</td>
</tr>
<tr>
<td>4</td>
<td>Madhya Pradesh (9)</td>
<td>Balaghat, Mandla, Dindori, Chhindwara, Betul, Guna, Jhabula, Shahdol, Sidhi</td>
<td>An. culicifacies</td>
</tr>
<tr>
<td>5</td>
<td>Odisha (19)</td>
<td>Angul, Keonjhar, Bolangir, Nuapada, Dhenkanal, Sonepur, Gajapati, Rayagada, Jharsuguda, Sundargarh, Kalahandi, Phulbani, Mayurbhanj, Sambalpur, Cuttak, Jagatsinghpur, Ganjam, Kurda, Baragarh</td>
<td>An. culicifacies, An. fluviatilis</td>
</tr>
<tr>
<td>6</td>
<td>West Bengal (4)</td>
<td>Bankura, Midnapur, Purulia, Birbhum</td>
<td>An. culicifacies</td>
</tr>
<tr>
<td><strong>N.E. States</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Assam (6)</td>
<td>Chirag, Lakhimpur, Dhemaji, Goalpara, Dhubri, Udalguri</td>
<td>An. culicifacies, An. minimus, An. nivipes</td>
</tr>
<tr>
<td>8</td>
<td>Meghalaya (2)</td>
<td>East &amp; West Garo Hills</td>
<td>An. minimus</td>
</tr>
<tr>
<td>9</td>
<td>Tripura (3)</td>
<td>Dhalai, West &amp; South Tripura</td>
<td>An. minimus, An. nivipes</td>
</tr>
</tbody>
</table>
Seasonal prevalence (e.g. rainy, summer etc.):
No specific information generated.

Resting behavior indoor/outdoor /HD or CS:
Susceptibility tests with different insecticides were performed using indoor resting mosquito species.

Feeding behavior /preference:
No information generated.

Sporozoite rate:
No information generated.

Insecticide susceptibility status (R or S):
Results of the susceptibility of vector species against DDT (4%), malathion (5%) and deltamethrin (0.05%) are given state-wise for the respective species (Fig. 1). Classification of the data is made according to WHO criteria for susceptible/ resistant status (R - 0-80% mortality; VR- 81-97% mortality; S - 98-100% mortality).

Based on the results of the survey carried out in the areas of the selected districts, following are the observations.

*An. culicifacies*, the major vector for malaria influencing in the rural plains of the country was tested for susceptibility to insecticides, DDT, malathion and deltamethrin, in different districts of the states of Andhra Pradesh, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha & West Bengal. The species was found resistant to DDT in all the above states. To malathion and deltamethrin the species was found resistant in the states of Andhra Pradesh and Chhattisgarh, while in other states it was mostly tolerant.

The susceptibility status of another important malaria vector, *An. fluviatilis*, prevalent in foothills and forested regions of the country was determined in Chhattisgarh, Jharkhand and Odisha states. This species was found resistant to DDT in Chhattisgarh, tolerant/ resistant in Jharkhand but
was susceptible in Odisha. In Jharkhand this species was mostly susceptible to malathion and deltamethrin.

Other anophelines, *An. annularis*, the secondary malaria vector in Jharkhand was found resistant to DDT, tolerant to malathion and susceptible to deltamethrin. *An. minimus*, the major vector of malaria in the north-eastern region was susceptible to DDT in the study areas of Assam, Meghalaya and Tripura. While in Assam it was also susceptible to malathion and deltamethrin. *An. nivipes*, another important vector in north-east region was also found susceptible to malathion in Assam and Tripura. In some areas of Assam during our studies, *An. culicifacies* was found in very low densities and was resistant to DDT as in other states. The study in north-eastern states are not conclusive owing to prevalence of mosquitoes in very low densities and work in some other north-east states was not conducted due to this reason.

This study in the mainland states has thus brought out clearly that there is a trend to develop resistance against SP in *An. culicifacies* in areas where pyrethroids are being used. Presently there is no clear evidence to assess the impact of pyrethroid resistance in vector species on the transmission of the disease in relation to the effectiveness of ongoing vector control interventions.

These observations clearly indicated that there is a need for implementing insecticide management strategies for vector control, where feasible. However, in areas where deltamethrin resistance is reported in malaria vectors and is not so intense and widespread could still be managed by rational use of insecticides in rotation with caution, till new vector control tools become available. Recently, studies are in progress in laboratory and field to assess the efficacy of insecticide molecules with different mode of action from the existing ones and are also gaining utmost importance for vector management.
Fig. 1: Insecticide resistance status of anophelines in different states of India

Susceptibility/Resistant as per WHO criteria: R - 0-80% mortality; VR - 81-97% mortality; S - 98-100% mortality

Existing control measures in the study area:

The surveys were conducted in areas which received IRS and reportedly endemic for malaria. Generally indoor residual spraying with DDT/pyrethroids and distribution of LLINs in high risk areas.
13. Title of the study

Ecological Succession of Anopheline and other mosquitoes in North-Eastern states of India

Study Area including Ecotype e.g. forest/plain:

The study area included four states of North-East viz. Assam, Meghalaya, Manipur and Sikkim. During the study period, 8 districts belonging to Assam (Lakhimpur, Nagaon, Sonitpur, Golaghat, Goalpara, Kamrup, Dibrugarh, Cachar); 2 districts belonging to Meghalaya (East Khasi hill & East Garo hill); 2 districts belonging to Manipur (Chandel, Imphal East) while 4 districts belonging to Sikkim (East, West, North, South) were covered (Fig-1) and plain, hilly, forested and semi urban ecotypes were covered districts of Assam, Meghalaya, Manipur and Sikkim states (Fig-2 & 3).

Fig 1: Selected sites for ecological succession of Anophelines
Fig 2 & 3 Showing forest and deforested areas in state of Assam

Type of Housing (Kaccha/pakka):
Houses in the study area are located in plain, inside the forest and on hilltop, surrounded by small streams and rivers. Houses are generally made up of bamboos and some houses are having tiled roof with mud walls.

Vector species (s)/sibling species:
During the study, An. culicifacies was predominant vector species found in high density as compared to An. dirus & An. minimus recorded as main vectors in North-Eastern states in earlier surveys. In the current study An. culicifacies was found in good number in all the surveys and also incriminated as a vector of malaria. Analysis of sibling species composition revealed, prevalence of species B and C of An. culicifacies complex in study areas and few specimens of An. minimus analyzed revealed prevalence of An. minimus sensu stricto (formerly known as An. minimus A).

Seasonal prevalence:
In Assam during pre-monsoon and post-monsoon seasons, An. culicifacies was predominant species (1981 specimens & 311 specimens) followed by An. minimus (25 specimens & 44 specimens), An. dirus (1 specimen & 35 specimens) and An. fluviatilis (20 specimens & 1 specimen) respectively similarly in Meghalaya, during pre-monsoon and post-monsoon seasons, An. culicifacies predominance was observed (929 specimens & 103 specimens) followed by An. minimus (1 specimen & 0 specimen) and An. fluviatilis (10 specimens & 0 specimen) were collected. In Manipur
during pre-monsoon season, *An. culicifacies* (24 specimens) *An. minimus* (10 specimens) and *An. fluviatilis* (1 specimen) were collected, while in Sikkim during pre-monsoon season, *An. culicifacies* (597 specimens) followed by *An. fluviatilis* (1 specimen) were collected. *An. culicifacies* was prevalent mainly in deforested plain areas of study districts.

**Resting behavior indoor/outdoor/HD or CS:**

*An. culicifacies* was found resting indoor (human dwellings and more in cattle sheds) whereas *An. minimus, An. dirus & An. fluviatilis* were mainly collected in landing collection and CDC light trap collections, indoor and outdoor.

**Feeding behavior/preference:**

*An. culicifacies* was found to prefer feeding on cattle as out of 155 specimens only one specimen was found positive for human blood. Few specimens of *An. minimus* analyzed revealed this species to be highly anthropophagic.

**Sporozoite rate:**

*An. culicifacies, An. minimus, An. dirus & An. fluviatilis* collected from 16 districts viz, Sonitpur, Nagaon, Golaghat, Lakhimpur, Dibrugarh, Goalpara, Kamrup, Cachar (Assam), East khasi hill, East garo hill (Meghalaya), Chandel, East Imphal (Manipur), East Sikkim, West Sikkim, North Sikkim & South Sikkim (Sikkim) are in process for vector incrimination. Result obtained so far revealed sporozoite positive specimens of *An. culicifacies* in the study areas.

**Insecticide susceptibility status (R or S):**

Not done

**Existing control measures in the study area:**

Two rounds of indoor residual spray with DDT and distribution of ITMN and LLINs in high risk areas in four states.
Applied value:

Due to change in landuse pattern in NE region *An. minimus* is being replaced by *An. culicifacies* which is a zoophilic and zoophagic species therefore there would a need for change in vector control strategy.

Knowledge gap:

Micro level studies on the bioecology of *An. culicifacies* and its role in malaria transmission in NE regions should be taken up.
14. Title of the study

Malaria–risk maps and prioritizing interventions in Tripura, Northeast India

Study Area including Ecotype e.g. forest/plain

The study was undertaken in South Tripura district (reporting highest morbidity and malaria attributable death cases in the state). Malaria endemic villages were selected in 3 Primary Health Centers. These included Hrishyamukh (Belonia subdivision), Manubankul (Sabroom subdivision) and Silachari (Karbook subdivision) sharing an international border with Bangladesh (Fig. 1). The study areas represented foothill forest ecotype with streams, rivers beds, paddy fields and ponds as major breeding sites for different mosquito species.

Type of Housing (kaccha/ pakka):

The houses in study areas were mostly made up of bamboo and mud with thatched roof and are sparsely distributed.

Fig. 1: Map of Tripura showing study locations (●) and geographical proximity to Bangladesh. Inset map shows geographical location of the state of Tripura in India.
**Vector species (s)/ sibling species:**

*An. minimus* and *An. baimaii* (a member species of the *An. dirus* complex) were the vector species prevalent in study areas. Analysis of sibling species revealed prevalence of *An. minimus* sensu *stricto* (formerly known as Minimus A) and *An. baimaii*, the only member of Dirus Complex that is prevalent in northeast India.

**Seasonal prevalence (e.g. rainy, summer etc.):**

During peak transmission season (June – September), as many 15 different anopheline mosquito species were collected. Among these, *An. vagus*, *An. subpictus* and *An. minimus* were major anophelines prevalent in human dwellings; however the densities of *An. minimus* and *An. baimaii* the proven vector species, were low to dismal in dry season (Nov–Dec). Density of different mosquito species was comparatively low in all study sites and *An. minimus* as well as *An. baimaii* were not recorded to occur.

**Resting behavior indoor/ outdoor/ HD or CS:**

*An. minimus sensu stricto* were collected from indoors (in human dwelling) by hand catch method in very low densities (per man hour density 0.46) and few specimens were collected outdoors by CDC light trap. Indoor resting density of *An. baimaii* was extremely low (MHD 0.01) and most of the *An. baimaii* were collected in human landing collections indoor/outdoor.

**Feeding behavior/ preference:**

*An. minimus sensu stricto* was found to be highly anthropophagic (AI - 0.92). Similarly few specimens of *An. baimaii* analyzed for blood meal source revealed strong preference to feed on humans (AI - 0.80).

*An. minimus*, however, was mostly endophagic (mean mosquito landing rate 6.33 per person night), and biting activity occurred during 21:00–03:00 hours but it was more pronounced midnight onwards till 03:00 hours. In contrast, *An. baimaii* searched human host equally both indoors and outdoors and mean mosquito landing rate was 3.83 and 3.50 respectively, and peak biting activity occurred during 21:00 till midnight hours.
Sporozoite rate:

Out of 61 An. minimus sensu stricto mosquitoes examined, 3 were found with sporozoites in the salivary gland (sporozoite rate 4.92%) where as none of the An. baimaii specimens analyzed was found sporozoite positive.

Insecticide susceptibility status (R or S):

The field collected specimens of An. minimus and An. baimaii were tested for susceptibility to DDT (4%), the commonly used insecticide in the program specific to northeast India. For both these mosquito species, 100% mortality was observed to given diagnostic concentration, and assessed to be fully susceptible.

Existing Control measures in the study area:

Two rounds of indoor residual spraying with DDT and selective distribution of LLIN / ITN in high risk areas.

Conclusions and scope of future work:

Anopheles minimus and An. baimaii were observed to be abundant and highly anthropophilic (HBI 80–90%). Of these An. minimus were incriminated by detection of sporozoites in salivary glands, and infection rate was recorded to be 4.9%. Both An. minimus and An. baimaii species were highly susceptible to DDT, the residual insecticide used in vector control. Molecular identification techniques confirmed that prevalent An. minimus is An. minimus sensu stricto (species A) and An. baimaii is the only species of the An. dirus complex prevalent in northeast India. In addition, there is possibility that An. jeyporiensis might as well be probable vector in this region for having indoor resting characteristics and biting preferences similar to that of An. baimaii calling for additional investigations. There is scope of work to generate similar data to ascertain relative risk and prioritizing interventions for remaining districts of Tripura to help formulate situation specific intervention strategies to avert impending disease outbreaks and spread of drug-resistant malaria.
S & T benefits accrued:

The study clearly established that DDT is still effective and should remain insecticide of choice for control of mosquito vector populations specific to Tripura. The study results have direct relevance for benefit of the state malaria control programme in scaling up interventions and prioritizing interventions in communities those most at risk, and saving costs. For effective control of malaria in the state, it is recommended that disease surveillance should be intensified to ensure early case detection and effective treatment, and DDT spray and/ or alternative interventions, i.e., mass distribution of insecticide-treated nets/ long-lasting insecticidal nets should be reinforced prioritizing population groups most at risk to avert spread of drug-resistant malaria.
15. Title of the study

Sibling species profiling of \emph{An. dirus} complex, the forest malaria vector in NE of \emph{An. dirus} complex mosquitoes

Study Area including Ecotype e.g. forest/plain:

57 Forest/Fringed areas in hills/foothills/ plains areas of 41 districts of all 8 NE states for sibling species study. Longitudinal vector bionomics study in a plain forest fringed village of Dibrugarh district, Assam.

Type of Housing (Kaccha/pakka):

Mostly kuccha, made of split bamboo & mud-plastered.

Vector species (s) /sibling species:

Almost all (266/267) individuals of \emph{An. dirus} s.l. collected were identified by molecular tools as \emph{An. baimaii} (earlier sp. D). Only 1 individual from the N. C. Hills district of Assam was assigned the status of \emph{An. dirus} species X found in China suggesting the presence of at least 2 member species of the \emph{An. dirus} complex in north-eastern region of India. \emph{An. dirus} s.l. was found absent in the state of Sikkim.

Seasonal prevalence (e.g. rainy, summer etc.):

March – October

Resting behaviour indoor/outdoor /HD or CS:

Exclusively exophilic. Rest during day time outdoor in the forest area on tree trunks

Feeding behaviour /preference:

Endophagic as well as exophagic. Highly anthropophagic (HBI 90%). Take rest briefly (3-21 mts) on walls after entering in to the human dwelling before biting on humans.
Sporozoite rate/EIR:
Sporozoite rate of An. baimaii was found 1.9% (95% CI 1.1-2.9), parous rate was 58.7% (95% CI 55.3 – 62.0). Effective entomological inoculation rate was highest (0.249 positive bites/person/night) during 21.0 to 24.0 hrs. suggesting that the 2nd quarter of night is the most risky period for malaria transmission by An. baimaii. Vectorial capacity of An. baimaii recorded was 0.119 and 0.82 for P. vivax and P. falciparum.

Insecticide susceptibility status (R or S):
100% susceptible to DDT.

Existing control measures in the study area:
IRS with DDT and insecticide treated nets.

Applied value:
The study has brought out the distribution of the member species of the An. dirus complex in north-east India along with various features of the biology and bionomics of An. baimaii, the major malaria vector in South-east Asia including north-east India. This knowledge is important for advancement of science and for devising effective control strategy against this vector species.

Knowledge gap:
This study has shown the presence of at least 2 member species of the An. dirus complex in north-eastern region of India. Of these 2 species, the biology and bionomics of An. bamaii has been thoroughly studied. The distribution and bionomics of An. dirus species X (found in NC Hills area of Assam in this study) need to be studied.
16. Title of the study

**Morphological variation and molecular characterization of *An. minimus* species complex in Assam and Arunachal Pradesh**

**Study Area including Ecotype e.g. forest/plain:**

Foot hills/plains areas of Tezpur, Kamrup, Golaghat & Dibrugarh districts (Assam) and Khonsa district (Arunachal Pradesh).

**Type of Housing (Kaccha/pakka):**

Mostly kaccha, made of split bamboo & mud-plastered

**Vector species (s)/sibling species:**

Only 1 species of Minimus complex i.e. *An. minimus* SS (species A) was identified from the two states. No variations in the wing characters among the *An. minimus species A* individuals collected from Assam and Arunachal Pradesh was found.

**Seasonal prevalence (e.g. rainy, summer etc.):**

March/April – October/November.

**Resting behaviour (indoor/outdoor /HD or CS):**

Generally considered endophilic species, resting on lower half of the mud-plastered walls of the human-dwellings. Distribution patchy, not uniform in all houses with in a village. However, now-a-days it has become very difficult to collect indoor resting *An. minimus* s.l., though in light traps/human bait collections these mosquitoes are easily trapped, suggesting induced exophilic behavior in *An. minimus* s.l. in many areas.

**Feeding behaviour /preference:**

Endophagic as well as exophagic but more endophagic. Highly anthropophilic (HBI ~ 70-80%). Relatively more biting occurs during 2\textsuperscript{nd} & 3\textsuperscript{rd} quarters of the night.
**Sporozoite rate/EIR:**

Varies from place to place. 2-3% sporozoite rates common.

**Insecticide susceptibility status (R or S):**

100% susceptible to DDT in Assam.

**Existing control measures in the study area:**

RS with DDT and insecticide treated nets (ITNs)

**Applied value:**

The study established the presence of only one species of *An. minimus* complex i.e. *An. minimus ss* (earlier species A) in Assam and Arunachal Pradesh. The information on distribution of member species of a complex is important for advancement of science and for formulating effective vector control strategy.

**Knowledge gap:**

Though *An. minimus* is considered endophilic in nature yet the indications about the emergence of exophily in this species, at least in some areas of north-east India, has come from the study. This aspect need to be investigated in future studies.
17. Title of the study

Molecular and morpho-taxonomic studies on *An. philippinensis/nivipes* group mosquitoes: species distribution, vectorial status in different ecotypes of north-east India

**Study Area including Ecotype e.g. forest/plain:**

Hilly / Foothills / Plain Forested / forest fringed / plain villages in 38 districts of 6 NE states viz. Assam, Arunachal Pradesh, Mizoram, Meghalaya, Nagaland & Tripura.

**Type of Housing (Kaccha/pakka):**

Mostly kaccha, made up of split bamboo & mud-plastered.

**Vector species (s) /sibling species:**

Overall, *An. nivipes* was found dominant with relatively higher prevalence in Nagaland followed by Assam and Tripura. In Meghalaya, both *An. nivipes* and *An. philippinensis* were equally prevalent, whereas in Arunachal Pradesh and Mizoram *An. philippinensis* was found dominant. Two specimens of *An. nivipes* (one from Jorhat district of Assam and another from Dimapur district of Nagaland) were found positive for *P. falciparum* infection indicating its role in malaria transmission in Nagaland & Assam.

**Seasonal prevalence (e.g. rainy, summer etc.):**

June to Oct/Nov

**Resting behaviour indoor/outdoor /HD or CS:**

Predominantly outdoor resting.

**Feeding behaviour /preference:**

Equally exophagic as well as endophagic. More zoophilic than anthropophilic; Bites throughout the night no clear pattern.
Sporozoite rate/EIR:
Among *An. nivipes* (n=272) and *An. philippinensis* (n=64), 2 specimens of *An. nivipes*, one from Jorhat district of Assam and another from Dimapur district of Nagaland, were found positive for *P. falciparum*.

Insecticide susceptibility status (R or S):
No data available. Reported resistant to DDT from Tripura in a old study.

Existing control measures in the study area:
IRS with DDT and insecticide treated nets.

Applied value:
The study has conclusively brought out the distribution of *An. philippinensis* and *An. nivipes*, the two morphologically similar species, in the north-eastern states along with incrimination of *An. nivipes* as a vector proving that it is the *An. nivipes* and not *An. philippinensis* which is involved in malaria transmission in at least Assam and Nagaland. Moreover, this species acts as important secondary vector and a bridge species.

Knowledge gap:
The lead given by the study on the involvement of *An. nivipes* in malaria transmission in Assam and Nagaland should be further expanded in other north-eastern states along with targeted bionomics studies targeted on *An. nivipes*. 
18. Title of the study:

Cluster-Randomized Village-scale (Phase III) Evaluation of Deltamethrin SC 62.5 g ai/L for Indoor Residual Spraying against An. minimus s.l.

Study Area including ecotype e.g. forest/plain:

9 Foot hill/plain villages near forest areas in Golaghat and Karbi Anglong districts, Assam.

Type of Housing (Kaccha/pakka):

Mostly kaccha, made of split bamboo & mud-plastered.

Seasonal prevalence (e.g. rainy, summer etc.):

March/April – October/November.

Resting behaviour indoor/outdoor /HD or CS:

Only a few individuals of An. minimus were collected resting indoors but sufficient nos. of An. minimus s.l., were captured in light traps/human baits collections suggesting suspected exophilic behavior in An. minimus s.l.

Feeding behaviour /preference:

Endophagic as well as exophagic. More endophagic. Highly anthropophilic (HBI ~ 70-80%). Relatively more biting occurs during 2nd & 3rd quarters of the night.

Sporozoite rate/EIR:

During August – April the mean parous rate in An. minimus was 60.2%, the mean human blood feeding rate was 67.6%. No sporozoite positive An. minimus was found during the study.

Insecticide susceptibility status (R or S):

Susceptible to deltamethrin.

Existing control measures in the study area:

IRS with DDT and insecticide treated nets.
**Applied value:**

The study has shown that Deltamethrin SC 62.5 g, a new long lasting formulation of deltamethrin insecticide, is effective for about 5 months as indoor residual spray for malaria vector control. This is an alternate IRS tool and has the potential to ultimately replacing DDT. Further, in malaria endemic areas of north-east India only one round of spray with this insecticide @ 20-25 mg ai/m2 may be sufficient for vector control instead of current practice of 2 rounds of DDT, as practiced at present under NVBDCP, resulting in huge savings on insecticide and man-power.

**Knowledge gap:**

This formulation should be evaluated in different eco-epidemiological conditions of the country under influence of different vector species.