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Surveillance on Malaria and Dengue Vectors Fauna across in Angul District Of Odisha, India: An Approach to Determine Their Diversity and Abundance, Correlation with the Ecosystem

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Abstract
Frequently morbidity and mortality was caused due to dengue and malaria in Angul district of Odisha, India. The study was designed to perceive the mosquito fauna across the Angul district to generate information on the diversity and abundance of mosquitoes, correlation with the ecosystem. This study highlighted that, ten species of *Anopheline* and three species of *Aedine* were conquered across the Angul district. *Anophelines* coincided mainly with the monsoon; whereas, *Aedines* coincided mainly during the lateral of the monsoon and initial of the post-monsoon. Climatic and ecological changes are the major factors favored mass breeding and propagation of theses vectors and transmission of the infection around the year; suggest that, the Angul district of Odisha was becoming a hyper-endemic province in India for both dengue and malaria infection. Therefore, the vector control strategies in the district should target these thirteen species to control any epidemic/outbreak in the future.

Keywords: Mosquito fauna, Anopheline, Aedine, Rainfall, Temperature, Humidity

Introduction
Mosquitoes are small insects which can be found all over the world and they are important because of the effects on human as well as animal health due to the role they play in the transmission of protozoan and viral pathogens [1]. Mosquitoes can thrive in all types of environments associated with lentic aquatic habitats for breeding except in marine habitats with high-salt concentration and septic tanks [2]. The breeding habitat is crucial for mosquito population dynamics, because it is the location where many important life cycle processes are the development of larval, emergence of adults, resting, swarming and mating of adults [3].
Mosquitoes are unquestionably the most important vectors of diseases that can spread vector borne diseases, such as Dengue, Malaria, Filariasis, Yellow fever and Japanese encephalitis etc. In the tropics, infections from the dengue virus (DENV) and the protozoan malaria parasites of the genus *Plasmodium* species are transmitted by *Aedine* and *Anopheline* vectors respectively. *Aedine* mosquitoes belong to the family Culicidae of the order Diptera. *Aedes* mosquitoes occur around the world and there are over 950 species; amongst *Ae. aegypti* was the most potential vector, but other species such as *Ae. albopictus*, *Ae. vittatus*, *Ae. polynesiensis* and *Ae. niveus* have also been incriminated as secondary vectors [4]. The *Anopheline* vectors belongs to phylum Arthopoda, class Insecta, order Diptera, sub-order Nematocera, family Culicidae, sub-family Culicinae, genus *Anopheles*, and subgenus Cellia. There are approximately 460 *Anopheles* species reported worldwide, of which 100 species can transmit human malaria and in India, 58 species of *Anopheline*s have been reported, out of which nine species are established vectors of malaria, of which six are of primary importance. These species are: *An. culicifacies, An. fluviatilis, An. stephensi, An. sundaicus, An. minimus* and *An. dirus* [5].
Globally, an estimated 3.3 billion people were at risk of malaria in 2011 and in the SEAR, India alone contributes to nearly 80% (1.3 million) of malaria cases with the 753 deaths [6]; whereas, two-fifth of the world population approximately lives in areas at risk for dengue [7] and 52% of the global population are at the risk of contracting dengue fever (DF) or dengue hemorrhagic fever (DHF) lives in the SEAR. In India, DENV was first isolated in 1946 and DF was first reported in Calcutta, West Bengal in 1963 but dengue infection became a notifiable disease after the major epidemic of DHF from Delhi was reported in the year 1996 [8]. Particularly, Odisha state in India is considered as endemic for both dengue and malaria fevers.

In the state, malarial parasitic infection was documented since long, while DENV infection was first documented in 1998; and several epidemics due to DENV precipitated after 2005, causing an increase of the case fatality rate. For an instance in 2011, of the total 1846 detected dengue cases in Odisha, 33 death cases occurred with the epicenter at the Talcher coalmine area of Angul district; the maximum number of dengue positive cases (33.7%), with the CFR at 66.7% had been reported alone in the Angul district [9].

For the last few decades Odisha state in India is highly vulnerable to vector-borne diseases and there are numerous scientific studies on surveillance of mosquitoes' fauna were conducted in Coastal belt, North-western part and Chilika lake of Odisha state [10-12]. However, a systematic study on the association of climatic factors with the diversity and abundance of mosquitoes' fauna from this geographical region in Angul district of Odisha, India has yet not been attempted, except recording of prevalence/ epidemiological trends of both diseases, *i.e.* malaria and dengue in databases, there is no systematic study [9].

Keeping this view, the study was conducted in the different sites of Angul district of Odisha, India to generate information on the diversity and abundance of malaria and dengue vectors fauna, correlation with the ecosystems and also mapping the mosquito species presently conquered in this region.

2. Materials and methods

2.1. Study area

Centrally located Angul district with area 6232 sq. km. (20° 31′ N and 21° 40′ N latitude and 84° 15′ E and 85° 23′ E longitude) in the state of Odisha has the total population of 1,271,703 with males 654,898 and females 616,805, as per 2011-census. With a brief winter, the climate of the district is sub-tropical with the temperature range, 6 to 47° C (Figure 1).

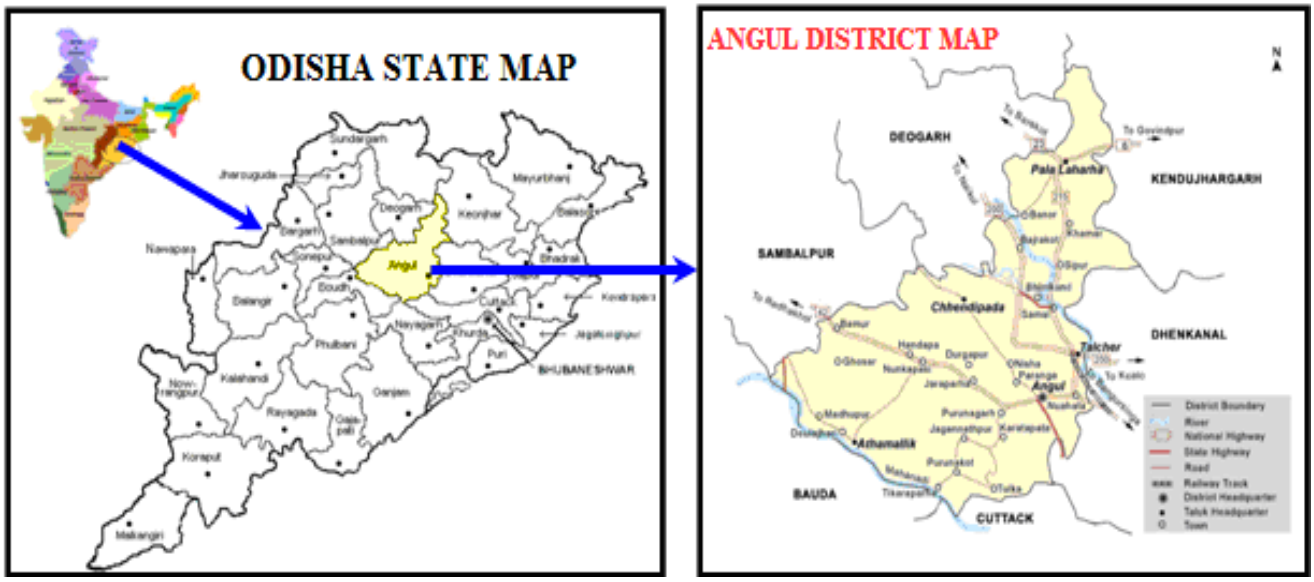

Fig 1: Map showing the study area of Angul district, Odisha.

2.2. Entomological studies

Entomological studies were conducted on the mosquitoes' fauna, specifically *Anopheline* and *Aedine* spp. in the study area periodically from January to December, 2013. A demographic map of the localities (plain and forest province) in rural, suburban and urban areas was prepared and houses to be examined in each survey were marked.

2.2.1. Larvae Survey

Anopheline and *Aedine* larval surveys were carried out in different parts of the study area periodically during the study period; both types of instar stages of larvae were collected from different breeding habitats using standard dippers (250 ml capacity) method (about 5–20 dips were taken from each breeding habitat according to its area) and the samples were brought to the laboratory and reared at room temperature (25°C) with the help of thermostat. Larvae and adults were preserved and identified [13]. Incidences of larval of *Anopheline* and *Aedine* species collections were recorded and the larval density was calculated using the following formula:

$$\text{Larval density (LD)} = \frac{\text{Total number of larvae}}{\text{Number of dip}}$$

To evaluate the distribution and density of the *Aedine* mosquito species in the study area, the parameters of three larval indices: *Aedes* Index (AI), Container Index (CI), and Breteau Index (BI) were calculated as per the standard WHO guidelines.

$$\text{House/ } \textit{Aedes} \text{ Index (AI)} = \frac{\text{Number of houses infested}}{\text{Number of houses inspected}} \times 100$$

$$\text{Container Index (CI)} = \frac{\text{Number of positive containers}}{\text{Number of containers inspected}} \times 100$$

$$\text{Breteau Index (BI)} = \frac{\text{Number of positive containers}}{\text{Number of houses inspected}} \times 100$$

2.2.2. Adult mosquito survey

Indoor resting adult female mosquitoes' of *Anopheline* and *Aedine* were collected from human dwellings (HD) as well as cattle sheds (CS) by hand catch aspirator method as per WHO, 1992 [14]. The collections were made fortnightly from fix and random catching sites during morning hours between 05:00 hrs. to 07:00 hrs. The collected mosquitoes were kept in cage, labeled properly and brought to the laboratory. The mosquitoes were anesthetized with ether, and identified morphologically [15-17]. Per man-hour density (PMHD) of each *Anopheline* and *Aedine* species was calculated as:

PMHD =	No. of each mosquito species (N) X *60*	X Total time spent in minutes (t)
	No. of person involved *(p)*	

2.3. Analysis of climatic data
Climate is one of the most important abiotic factors an ecosystem. The monthly climatic data, such as rainfall, temperature and relative humidity of the year, 2013 were obtained from the 'Meteorological Department of Angul district, Odisha'. The climatic data was divided into three periods, namely; pre-monsoon period: February – May, monsoon period: June – September and post-monsoon period: October – January and one-way analysis of variance (ANOVA) was used to analyzed the significant difference among the climate variables between the three seasonal periods.

2.4. Analysis of data
During the study (January to December, 2013), the statistical data's of the diversity and abundance of malaria and dengue vectors namely *Anopheline* and *Aedine* species (both adult and aquatic stages) were used as dependent variables and the climatic factors, *i.e.* rainfall, temperature and relative humidity were used as independent variables entered in the statistical programme 'Excel-2007' and retrospectively analyzed to find out the diversity and abundance of adult and aquatic stages of *Anopheline* and *Aedine* spp*.,* correlation with the ecological and climatic factors during the three seasonal periods. The statistics were used in this study as the following: Percentage (%), Mean and Standard Deviation (SD). The statistics graph was designed by the chart wizard of column with the line in 2 axes.

3. Result
During this surveillance, a total of 1576 different breeding sites in plain and forest area was inspected. Out of which, 1314 breeding sites were inspected in plain areas and 496 (37.7%) sites found positive; whereas, 262 breeding sites were inspected in forest areas and 85 (32.4%) sites found positive. Over the study months, the percentage of positive sites were significantly higher in November and lower in April for the larvae of *Aedine* species; whereas, the percentage of positive sites were significantly higher in August and lower in March for the larvae of *Anopheline* species was presented (Table 1).

The preferred positive breeding habitats for larval of *Aedine* and *Anopheline* species were identified and presented (Table 2). The results the larval compositions revealed that, a total of 53055 larvae was collected, belonging to 13 spp. in 2 genera: *Aedines* (3 spp., n=49650) and *Anophelines* (10 spp., n=3405). The *Aedines* (93.6%) were more dominant than the *Anophelines* (6.4%) during the year round. In the total *Aedines* species larvae were collected, *Ae. aegypti* (n=24856, 50.0%) and *Ae. albopictus* (n=24359, 49.1%) larvae were mostly found during the study. Similarly, amongst the larvae of *Anopheline* spp*., An. culicifacies* (n=1959, 57.5%) larvae was found most predominantly; whereas, the least number of larval percent value found in *An. minimus* (n=20, 0.6%) were presented (Table 3).

The larval indices of *Aedine* species by month wise were presented (Table 4). The result was shown that, the average Stegomyia indices were house index (HI) 26.1, container index (CI) 16.0 and breteau index (BI) 43.7. The larval density of *Aedine* spp. was highest during November, *i.e.* post-monsoon period; meantime the HI, CI and BI were calculated as 46.7, 30.5 and 83.3 respectively, whereas, the lowest larval density of *Aedine* spp. was observed in May, *i.e.* pre-monsoon period; meantime the HI, CI and BI were calculated as 7.3, 12.4 and 12.0 respectively.

The percent composition of adult *Aedine* and *Anopheline* species was presented (Table 7). The result revealed that, a total of 7949 adult mosquito was collected, belonging to 13 spp. in 2 genera: *Aedine* (3 spp., n=2261) and *Anopheline* (10 spp., n=5688). The *Anophelines* (71.6%) were more dominant than the *Aedines* (28.4%) during the year round. In the total adult *Aedines* species were collected, *Ae. aegypti* (n=1132, 50.1%) and *Ae. albopictus* (n=1067, 47.2%) species were mostly found. Similarly, amongst the adult of *Anopheline* spp*., An. culicifacies* (n=4385, 77.1%) was found most predominantly; whereas, the lowest number of adult % found in *An. minimus* (n=11, 0.19%). The resting preference of adult *Aedine* and *Anopheline* mosquito species was significantly found more in cattle sheds (n=5809, 73.1%) rather than in human dwellings (n=2140, 26.9%) after the host feeding was presented (Table 8).

Prevalence of larval of *Aedine* and *Anopheline* species by month wise was presented (Table 5 and Table 6). The result revealed that, the variation in the larval density of *Aedine* spp. and *Anopheline* spp. were ranges 7.3 – 36.2 and 0.50 – 1.76 respectively from the monthly collections. Amongst the total *Aedines* spp. larvae were collected, *Ae. aegypti w*as the most abundant species (10.4). Similarly, in connection with the total *Anopheline* spp. larvae were collected, *An. culicifacies w*as the most abundant species (0.54); whereas, the least abundant was recorded in *An. minimus* (0.01). However, the variation in the prevalence of adult *Aedine* spp. and *Anopheline* spp. accord to the man-hour density (MHD) were ranges 4.0 – 19.8 and 15.0 – 52.9 respectively from the monthly collections. Amongst the total adult *Aedines* spp. were collected, *Ae. aegypti w*as the most abundant species (5.6). Similarly, of the total adult *Anopheline* spp. were collected, *An. culicifacies w*as the most abundant species (21.9); whereas, the least abundant was recorded in *An. minimus* as well as *An. varuna* (0.1) were presented (Table 9 and Table 10).

The distribution of the prevalence of both larval and adult stage of *Aedine and Anopheline* species in association with seasonal and climatic factors in Angul district, Odisha during January to December, 2013 were presented (Figure 2). The result revealed that, the temperature variations were more amongst different months during the pre-monsoon and post-monsoon period as compared to the monsoon period. Between the three seasonal periods, the divergence in the rainfall and temperature as well as the divergence in the rainfall and humidity were found not significant ($p < 0.05$) (z value = -1.0112, 0.4295 respectively); whereas, the divergence in the temperature and humidity were found significant ($p < 0.05$, z value = -8.8144). The prevalence of larvae of *Aedine* spp. coincided mainly with the post-monsoon period from October to December, 2013 of subnormal rainfall (Cumulative rainfall = 25.9 mm) with the mean relative humidity was 69% and the mean ambient temperature of 26.0°C; while, the prevalence of larvae of *Anopheline* spp. significantly decreases and coincided very low; however, the prevalence of adult *Aedine* spp. coincided mainly with the lateral of the monsoon and initial of the post-monsoon period of normal rainfall (Cumulative rainfall = 143.5 mm) from September to November 2013; while, the prevalence of adult *Anopheline* spp. significantly decreases and coincided very low, but during the monsoon period from June to September, 2013 of relatively heavy rainfall (Cumulative rainfall = 266.7 mm) with the mean relative humidity was 83% and the mean ambient temperature of 29.8°C the prevalence of both larval and adult stage of *Anopheline* spp. coincided mainly; whereas,

the prevalence of both larval and adult stage of *Aedine* spp. slightly decreases. In the period of pre-monsoon from February to May, 2013 of subnormal rainfall (Cumulative rainfall = 33.4 mm) with the mean relative humidity was 74% and the mean ambient temperature of 32.5°C the prevalence of both larval and adult stage of *Anopheline* spp. significantly increases; whereas the prevalence of both larval and adult stage of *Aedine* spp. gradually decreases in comparison to the post-monsoon. In the month of May the larval density of both vectors was very low while the temperature was 46ºC, the humidity was 85% and the rainfall was 90.2 mm. the higher rates of adult mortality causing severe reduction of mosquito densities have frequently been associated with a rise in temperature.

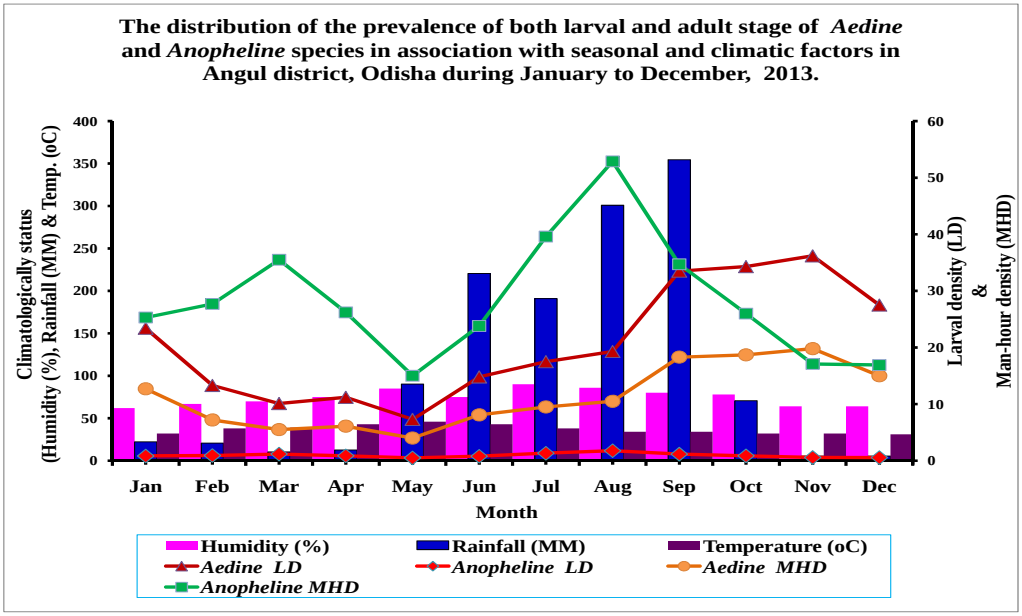

Fig 2: The distribution of the prevalence of both larval and adult stage of Aedine and Anopheline species in association with seasonal and climatic factors (Rainfall, temperature and relative humidity) in Angul district, Odisha during January to December, 2013.

Table 1: Distribution of breeding sites was inspected for larval collection of *Aedine* and *Anopheline* species, according to the catching locations in plain and forest areas by month wise in Angul district, Odisha (January – December, 2013).

Month	Breeding sites inspected for larval collection								
	Plain area			Forest area			Total		
	Total no. inspected	Positive		Total no. inspected	Positive		Total no. inspected	Positive	
		No.	%		No.	%		No.	%
January	105	25	23.8	20	5	25.0	125	30	24.0
February	95	30	31.6	25	8	32.0	120	38	31.7
March	112	64	57.1	18	10	55.6	130	74	56.9
April	120	54	45.0	26	8	30.8	146	62	42.5
May	122	37	30.3	15	1	6.7	137	38	27.7
June	140	41	29.3	20	4	20.0	160	45	28.1
July	112	68	60.7	30	14	46.7	142	82	57.7
August	107	72	67.3	24	15	62.5	131	87	66.4
September	104	30	28.8	22	6	27.3	126	36	28.6
October	105	28	26.7	22	5	22.7	127	33	26.0
November	90	23	25.6	20	5	25.0	110	28	25.5
December	102	24	23.5	20	4	20.0	122	28	23.0
Total	1314	496	37.7	262	85	32.4	1576	581	36.9

Table 2: The identification of positive breeding habitats for larval collection of *Aedine* and *Anopheline* species in Angul district, Odisha (January – December, 2013).

Sl. No.	Breeding habitat	Type of habitat	Types of mosquito species emerge from larvae
1	Irrigation canals	Natural BH	*An. culicifacies* and *An. vagus.*
2	Ponds	Natural BH	*An. culicifacies, An. annularis, An. varuna, An. aconitus, An. subpictus, An. vagus, An. splendidus* and *An. pallidus.*
3	Water collection near the pumps	Natural BH	*An. culicifacies.*
4	Streams	Natural BH	*Ae. vittatus, Ae. albopictus, An. minimus* and *An. fluviatilis.*
5	Riverbeds	Natural BH	*Ae. albopictus, Ae. vittatus, An. culicifacies, An. annularis, An. varuna* and *An. aconitus.*
6	Tree holes	Natural BH	*Ae. aegypti, Ae. albopictus*
7	Water coolers	Artificial BH	*Ae. aegypti*
8	Flower pots	Artificial BH	*Ae. aegypti, Ae. albopictus*
9	Storage tanks	Artificial BH	*Ae. aegypti and An. culicifacies.*
10	Un used well	Artificial BH	*Ae. aegypti, Ae. albopictus*
11	Plastic containers	Discards BH	*Ae. aegypti, Ae. albopictus*
12	Glass bottles	Discards BH	*Ae. aegypti, Ae. albopictus*
13	Drum	Discards BH	*Ae. aegypti, Ae. albopictus*
14	Tyres	Discards BH	*Ae. aegypti, Ae. albopictus*
15	Others	Discards BH	*Ae. aegypti, Ae. albopictus*

Table 3: Larval percent composition of *Aedine and Anopheline* species was collected in Angul district, Odisha (January – December, 2013).

Sl. No.	Genus	Species	TLC*	Abundance (%)
1	*Aedes*	*aegypti*	24856	46.85
		albopictus	24359	45.91
		vittatus	435	0.82
2	*Anopheles*	*culicifacies*	1959	3.69
		fluviatilis	138	0.26
		annularis	461	0.87
		varuna	24	0.05
		aconitus	441	0.83
		subpictus	109	0.21
		vagus	79	0.15
		splendidus	82	0.15
		pallidus	92	0.17
		minimus	20	0.04

* *TLC = Total No. of larvae collected.*

Table 4: The larval indices of *Aedine* species by month wise in Angul district, Odisha (January – December, 2013).

Month	Total no. of house inspected	House's infested		Total No. of container checked	Container's found positive		HI / AI	CI	BI
		No	%		No	%			
January	150	34	22.7	410	60	14.6	22.7	14.6	40.0
February	150	20	13.3	410	29	7.1	13.3	7.1	19.3
March	150	22	14.7	410	30	7.3	14.7	7.3	20.0
April	150	29	19.3	410	42	10.2	19.3	10.2	28.0
May	150	11	7.3	410	18	4.4	7.3	4.4	12.0
June	150	24	16.0	410	32	7.8	16.0	7.8	21.3
July	150	40	26.7	410	69	16.8	26.7	16.8	46.0
August	150	44	29.3	410	75	18.3	29.3	18.3	50.0
September	150	58	38.7	410	118	28.8	38.7	28.8	78.7
October	150	68	45.3	410	114	27.8	45.3	27.8	76.0
November	150	70	46.7	410	125	30.5	46.7	30.5	83.3
December	150	49	32.7	410	75	18.3	32.7	18.3	50.0
Total	1800	469	26.1	4920	787	16.0	26.1	16.0	43.7
Mean	150	39.1	26.1	410	65.6	16.0	26.1	16.0	43.7
SD	0.0	19.2	12.8	0.0	37.4	9.1	12.8	9.1	24.9

* *HI = House Index, AI = Aedes Index, CI = Container Index, BI = Breteau Index.*

Table 5: Distribution of larval density of *Aedine* species by month wise in Angul district, Odisha (January – December, 2013).

Month	Identified larvae of *Aedine* species							
	TLC	LD	*aegypti*		*albopictus*		*vittatus*	
			TLC	LD	TLC	LD	TLC	LD
January	4670	23.4	2347	11.7	2298	11.5	25	0.13
February	2652	13.3	1417	7.1	1215	6.1	20	0.10
March	2012	10.1	1008	5.0	986	4.9	18	0.09
April	2243	11.2	1113	5.6	1098	5.5	32	0.16
May	1453	7.3	745	3.7	696	3.5	12	0.06
June	2960	14.8	1466	7.3	1446	7.2	48	0.24
July	3501	17.5	1718	8.6	1731	8.7	52	0.26
August	3866	19.3	1920	9.6	1900	9.5	46	0.23
September	6700	33.5	3337	16.7	3311	16.6	52	0.26
October	6868	34.3	3428	17.1	3382	16.9	58	0.29
November	7232	36.2	3568	17.8	3612	18.1	52	0.26
December	5493	27.5	2789	13.9	2684	13.4	20	0.10
Total	49650	20.7	24856	10.4	24359	10.1	435	0.18
Mean	4137.5	20.7	2071.3	10.4	2029.9	10.1	36.3	0.18

[*] *TLC = Total no. of larvae collected, LD = Larval density, Total no. of dips = 200.*

Table 6: Distribution of larval density of *Anopheline* species by month wise in Angul district, Odisha (January – December, 2013).

Month	Identified larvae of *Anopheline* species																					
	TLC	LD	*culicifacies*		*fluviatilis*		*annularis*		*varuna*		*subpictus*		*vagus*		*splendidus*		*aconitus*		*minimus*		*pallidus*	
			TLC	LD	TLC	LD	TLC	LD	TLC	LD	TLC	LD	TLC	LD	TLC	LD	TLC	LD	TLC	LD	TLC	LD
Jan	253	0.84	165	0.55	10	0.03	28	0.09	2	0.01	7	0.02	4	0.01	5	0.02	27	0.09	1	0.00	4	0.01
Feb	277	0.92	180	0.60	6	0.02	39	0.13	1	0.00	4	0.01	3	0.01	3	0.01	36	0.12	1	0.00	4	0.01
Mar	355	1.18	189	0.63	16	0.05	50	0.17	4	0.01	12	0.04	11	0.04	10	0.03	48	0.16	3	0.01	12	0.04
Apr	260	0.87	138	0.46	10	0.03	44	0.15	1	0.00	8	0.03	6	0.02	7	0.02	42	0.14	0	0.00	4	0.01
May	150	0.50	96	0.32	7	0.02	20	0.07	0	0.00	4	0.01	2	0.01	3	0.01	18	0.06	0	0.00	0	0.00
Jun	237	0.79	129	0.43	9	0.03	43	0.14	0	0.00	6	0.02	3	0.01	3	0.01	42	0.14	0	0.00	2	0.01
Jul	396	1.32	219	0.73	20	0.07	47	0.16	1	0.00	16	0.05	12	0.04	12	0.04	45	0.15	4	0.01	20	0.07
Aug	529	1.76	288	0.96	22	0.07	68	0.23	8	0.03	18	0.06	14	0.05	15	0.05	66	0.22	6	0.02	24	0.08
Sept	347	1.16	195	0.65	14	0.05	44	0.15	4	0.01	14	0.05	10	0.03	10	0.03	42	0.14	3	0.01	11	0.04
Oct	260	0.87	150	0.50	10	0.03	35	0.12	2	0.01	9	0.03	7	0.02	8	0.03	33	0.11	1	0.00	5	0.02
Nov	172	0.57	96	0.32	8	0.03	24	0.08	1	0.00	6	0.02	4	0.01	4	0.01	24	0.08	1	0.00	4	0.01
Dec	169	0.56	114	0.38	6	0.02	19	0.06	0	0.00	5	0.02	3	0.01	2	0.01	18	0.06	0	0.00	2	0.01
Total	3405	0.95	1959	0.54	138	0.04	461	0.13	24	0.01	109	0.03	79	0.02	82	0.02	441	0.12	20	0.01	92	0.03
Mean	283.75	0.95	163.25	0.54	11.5	0.04	38.42	0.13	2.00	0.01	9.08	0.03	6.58	0.02	6.83	0.02	36.75	0.12	1.67	0.01	7.67	0.03

**TLC = Total no. of larvae collected, LD = Larval density, Total no. of dips = 300*

Table 7: Percent composition of adult *Aedine* and *Anopheline* species were collected in Angul district, Odisha (January – December, 2013).

Sl. No.	Genus	Species	TMC*	Abundance (%)
1	*Aedes*	*aegypti*	1132	14.24
		albopictus	1067	13.42
		vittatus	62	0.78
2	*Anopheles*	*culicifacies*	4385	55.16
		fluviatilis	96	1.21
		annularis	471	5.93
		varuna	13	0.16
		aconitus	500	6.29
		subpictus	79	0.99
		vagus	40	0.50
		splendidus	40	0.50
		pallidus	53	0.67
		minimus	11	0.14

* *TMC = Total No. of adult mosquito spp. collected.*

Table 8: Distribution of adult *Aedine* and *Anopheline* species were collected in accordance to their resting preferences (indoor) in Angul district, Odisha (January – December, 2013).

Sl. No.	Genus	Species	Adult mosquito resting preferences					
			HD		CS		Total	
			No	%	No	%	No	%
1	*Aedes*	*aegypti*	421 (19.7)	5.3	711 (12.2)	8.9	1132	14.2
		albopictus	398 (18.6)	5.0	669 (11.5)	8.4	1067	13.4
		vittatus	24 (1.12)	0.3	38 (0.65)	0.5	62	0.8
2	*Anopheles*	*culicifacies*	1000 (46.7)	12.6	3385 (58.3)	42.6	4385	55.2
		fluviatilis	22 (1.03)	0.3	74 (1.3)	0.9	96	1.2
		annularis	107 (5.0)	1.3	364 (6.3)	4.6	471	5.9
		varuna	3 (0.14)	0.0	10 (0.17)	0.1	13	0.2
		aconitus	114 (5.33)	1.4	386 (6.6)	4.9	500	6.3
		subpictus	18 (0.84)	0.2	61 (1.05)	0.8	79	1.0
		vagus	9 (0.42)	0.1	31 (0.53)	0.4	40	0.5
		splendidus	9 (0.42)	0.1	31 (0.53)	0.4	40	0.5
		pallidus	12 (0.56)	0.2	41 (0.71)	0.5	53	0.7
		minimus	3 (0.14)	0.0	8 (0.14)	0.1	11	0.1
Total			2140	26.9	5809	73.1	7949	100.0

* *HD = Human dwellings, CS = Cattle sheds.*

Table 9: Distribution of adult *Aedine* species density (MHD) by month wise in Angul district, Odisha (January – December, 2013).

Month	Identified adult *Aedine* species.							
	TMC	MHD	*aegypti*		*albopictus*		*vittatus*	
			TMC	MHD	TMC	MHD	TMC	MHD
January	212	12.7	106	6.3	99	5.9	7	0.4
February	121	7.2	61	3.7	56	3.4	4	0.2
March	92	5.5	46	2.8	41	2.5	5	0.3
April	102	6.1	51	3.1	48	2.9	3	0.2
May	66	4.0	33	2.0	32	1.9	1	0.1
June	135	8.1	68	4.1	66	4.0	1	0.1
July	159	9.5	80	4.8	78	4.7	1	0.1
August	176	10.5	88	5.3	86	5.1	2	0.1
September	306	18.3	153	9.2	143	8.6	10	0.6
October	312	18.7	156	9.3	147	8.8	9	0.5
November	330	19.8	165	9.9	156	9.3	9	0.5
December	250	15.0	125	7.5	115	6.9	10	0.6
Total	2261	11.3	1132	5.6	1067	5.3	62	0.3
Mean	188.4	11.3	94.3	5.6	88.9	5.3	5.2	0.3

**TMC = Total No. of adult mosquito spp. collected., MHD = Man-hour density.*

Table 10: Distribution of adult *Anopheline* species density (MHD) by month wise in Angul district, Odisha (January – December, 2013).

Month	Identified adult *Anopheline* species																					
	TMC*	MHD	*culicifacies*		*fluviatilis*		*annularis*		*varuna*		*aconitus*		*subpictus*		*vagus*		*splendidus*		*pallidus*		*minimus*	
			TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD	TMC	MHD
Jan	422	25.3	325	19.5	7	0.4	35	2.1	1	0.1	37	2.2	6	0.4	3	0.2	3	0.2	4	0.2	1	0.1
Feb	462	27.7	356	21.3	8	0.5	38	2.3	1	0.1	41	2.5	6	0.4	4	0.2	3	0.2	4	0.2	1	0.1
Mar	593	35.5	457	27.4	10	0.6	49	2.9	1	0.1	52	3.1	8	0.5	5	0.3	4	0.2	6	0.4	1	0.1
Apr	437	26.2	336	20.1	7	0.4	36	2.2	1	0.1	38	2.3	6	0.4	3	0.2	6	0.4	4	0.2	0	0.0
May	251	15.0	192	11.5	4	0.2	21	1.3	1	0.1	22	1.3	4	0.2	2	0.1	2	0.1	3	0.2	0	0.0
Jun	397	23.8	306	18.3	7	0.4	33	2.0	1	0.1	35	2.1	6	0.4	2	0.1	2	0.1	4	0.2	1	0.1
Jul	661	39.6	511	30.6	11	0.7	55	3.3	1	0.1	58	3.5	9	0.5	5	0.3	4	0.2	6	0.4	1	0.1
Aug	884	52.9	681	40.8	15	0.9	73	4.4	2	0.1	78	4.7	12	0.7	6	0.4	7	0.4	8	0.5	2	0.1
Sept	579	34.7	449	26.9	10	0.6	48	2.9	1	0.1	51	3.1	8	0.5	4	0.2	3	0.2	4	0.2	1	0.1
Oct	435	26.0	336	20.1	7	0.4	36	2.2	1	0.1	38	2.3	6	0.4	3	0.2	3	0.2	4	0.2	1	0.1
Nov	285	17.1	220	13.2	5	0.3	23	1.4	1	0.1	25	1.5	4	0.2	1	0.1	2	0.1	3	0.2	1	0.1
Dec	282	16.9	216	12.9	5	0.3	24	1.4	1	0.1	25	1.5	4	0.2	2	0.1	1	0.1	3	0.2	1	0.1
Total	5688	28.4	4385	21.9	96	0.5	471	2.4	13	0.1	500	2.5	79	0.4	40	0.2	40	0.2	53	0.3	11	0.1
Mean	474.0	28.4	365.4	21.9	8.0	0.5	39.3	2.4	1.1	0.1	41.7	2.5	6.6	0.4	3.3	0.2	3.3	0.2	4.4	0.3	0.9	0.1

**TMC = Total No. of adult mosquito spp. collected., MHD = Man-hour density.*

5. Discussion

The present study was undertaken in plain and forested areas, which are situated at almost similar ecotypes and the percentage of positive sites were found significantly higher in plain area incomparable in the forest area amongst the total breeding sites was inspected for larval collection of *Aedine* and *Anopheline* species. Among the resting preferences of the adult *Aedine* and *Anopheline* mosquito species, a higher density was obtained from cattle sheds than the human dwellings after the host feeding. The reason was observed in the present study that, both the species avoided resting on light exposed portions such as roof, eaves and hanging objects in human dwellings and preferred to rest on cattle sheds which is relatively darker.

Thus, our collections showed that, both adult and aquatic stages of mosquito species diversity differed with the location. Of the 13 species in 2 genera was recorded in the present study, 10 species of *Anopheline* genera are incriminated vectors of malaria infection and 3 species of *Aedine* genera are incriminated vectors of dengue infection. Among these vectors, the potential vectors of malaria and dengue *viz*. *An. culicifacies, An. fluviatilis, An. annularis, An. varuna, An. aconitus, An. subpictus, Ae. aegypti* and *Ae. albopictus* were predominant, suggesting that all of these species may play an important role in the epidemiology of malaria as well dengue in Angul district. These findings are not found significant in the studies were carried out by Rozilawati *et al*., 2011 and Tan *et al*., 2011 that *Aedes albopictus* was found to be predominant and found positive for the Dengue virus [18, 19]. Among the collected species, *An. culicifacies, An. fluviatilis,* and *An. vagus,* are known malaria vectors in India [20]. *An. subpictus* is a human filariasis vector [21] and also suspected vector for malaria in India [19] and main malaria vector in Sri Lanka [22]. *An. pallidus* and *An. vagus* are considered as non-vectors [21]. *Ae. aegypti* and *Ae. albopictus* are known dengue vectors and widely distributed in India; whereas, *Ae. vittatus* is considered as non-vectors [23, 24].

The main breeding habitats for *Aedes* species in these areas were not significantly different. *Aedes aegypti* was commonly bred inside the home dwellings as well as outdoors, while *Aedes albopictus* and *Aedes vittatus* is more common in outside areas. The *Aedes albopictus* was a container breeder, and it breeds in both natural and man-made habitats. *Aedes aegypti* was fed inside houses, *Aedes albopictus* was more common outside, in open spaces with shaded vegetation and suitable breeding sites such as tyres and garbage dumps. This finding is similar to the report of WHO, Geneva 1986 [25]. *Ae. albopictus* is more likely to be found in outdoor man-made habitats containing a greater amount of organic debris. This finding is similar to the study of Rattanarithikul and Panthusiri 1994 [26]. Previous work had shown that *Aedes aegypti* larvae was always found in indoor conditions, in contrast with what is revealed in this current work where *Aedes aegypti* was found mostly in indoors as well as outdoors with *Aedes albopictus*. This finding is supported by the study of Isaacs 2006, where *Aedes aegypti* was found breeding in natural receptacles such as tree holes, but always near human habitation [27]. A similar result was found by Chareonviriyaphap *et al*. 2003, where both species *Aedes albopictus* and *Aedes vittatus* was found to breed outside, rather than inside home dwellings [28]. Whereas, the *Anopheline* species was commonly bred in outdoors and the main breeding habitats were irrigation canals, riverbeds, ponds, water collection near the pumps and storage tanks; whereas, *An. culicifacies, An. annularis, An. varuna, An. aconitus, An. subpictus, An. vagus, An. splendidus* and *An. pallidus* larvae were found in ponds, but *An. minimus* and *An. fluviatilis* were found only in the streams throughout the year. The findings are not found significant in the studies were carried out by Rao 1984, that the abundance throughout the year might be due to the presence of perennial streams, which was the preferred breeding habitat of these vector species [29]. In Assam also, *An. minimus* was reported to rest predominately in human dwellings [30, 31]. *An. fluviatilis* though collected from cattle sheds; a significantly higher number was obtained from human dwellings. Contrary to this finding, a study conducted in Jeypore hills in Orissa state [32].

The findings of the Stegomyia indices in this study is to resemble a little relief in accord to the study of Sharma *et al*. 2005 that in India, all dengue/DHF outbreaks are associated with a higher container index of more than 20 *Aedes aegypti* larvae [33]. Previous work of the Katyal *et al*. 2003 had shown that, in Delhi, the container index reduced in August which is lower than July and September [34] and Sharma *et al*. 2005 studied the prevalence of *Aedes aegypti* in defense area of Delhi Cantonment the data show that the total containers positive in August are lower than July and September [33], which is not significant to the findings of the present study. Our findings in this present study corroborate the study was carried out in Gurgaon in the year 1991during June, July and August; in 1992 during April that the larval density was nil because of the variation in the incidence of temperature and rainfall, fluctuation in larval density happens [35].

In the present study, it is observed that the centrally located Angul district in the state of Odisha, India is a very popular tourist, industrial and plant area fall in the deciduous, dry and wet climatic zone. The temperature remains high during the pre-monsoon period. It is continuous rain pouring for a couple of days that brings down the temperature during the monsoon period, which may also be responsible for an increase in the relative humidity and decrease in the evaporation rate thus maintaining secondary reservoirs containing rain water. An in-depth analysis of these three factors, thus led to a proposal that optimum temperature with high relative humidity and abundant stocks of fresh water reservoirs generated due to rain developed optimum conditions conducive for mass breeding and propagation of vectors and transmission of the virus throughout the year. The prevalence of *Aedines* and *Anophelines* spp. ultimately resulting in causing dengue viral infection as well malaria parasitic infection and an epidemic or outbreak of dengue or malaria. The pressure of urbanization, improper management of the domestic and other neglected water collections are also the other causative factors in the budding up of enormous breeding sites with *Ae. aegypti*, *Ae. albopictus, Ae. vittatus, An. culicifacies, An. fluviatilis, An. annularis, An. varuna, An. aconitus, An. subpictus, An. vagus, An. splendidus, An. pallidus* and *An. minimus* across the Angul district in the state of Odisha, India. Seven *Anopheles* species reported by Dash *et al*. 2000 [36] was not found in the present collections, along with *An. sundaicus*. Previous studies indicated a higher diversity of the *Anophelines* than those of *Culicines* across the Chilika lake area of Odisha state [10, 36], whereas, in the present study, a higher diversity of the *Anophelines* than those of *Aedines* species occurrence was observed across the Angul district of Odisha, India.

In this study, we have observed that despite the increasing prevalence of vectors namely *Anopheline* and *Aedine* species due to the major ecological changes and climatic factors, *i.e.* the optimum temperature with high relative humidity and abundant stocks of fresh water generated due to rain suggest that the Angul district of Odisha was becoming a hyper-endemic province in India for both dengue and malaria infection. Hence the outcome was good and satisfactory.

6. Conclusion

This prospective study was highlighted that, ten species of *Anopheline* and three species of *Aedine* were predominant and conquered across the Angul district of Odisha were described as; the prevalence of both larval and adult stage of *Anopheline* spp. coincided mainly with the monsoon period and the prevalence of larvae of *Aedine* spp. coincided mainly with the post-monsoon period; however, the prevalence of adult *Aedine* spp. coincided mainly with the lateral of the monsoon and initial of the post-monsoon period. The present study provides useful information on the mosquito population dynamics of *Aedine* and *Anopheline* species across the Angul district of Odisha state. The major ecological changes, climatic factors, increased industrial development, natural calamities and other factors favored mass breeding and propagation of vectors and transmission of the infection, the basal level of which is present around the year; suggests that, the Angul district of Odisha was becoming a hyper-endemic province in India for both dengue and malaria infection. It, therefore, suggests that the dengue and malaria vector control in the district should target these thirteen species and a large-scale monitoring on the bionomics of these two vector species in different seasons with climatic factors was highly required to draw a definite conclusion about the vector species conquered in the whole state of Odisha, which would help to forecast possible epidemic or outbreak in the future, well in advance with considerable accuracy and formulating the strategies and plans with the greater emphasis on vector control methods for reducing the transmission of infection to new areas in the state of Odisha, India to control any epidemic or outbreak in the future.

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