ROLE OF SOME ENVIRONMENTAL FACTORS IN MODULATING SEASONAL ABUNDANCE OF POTENTIAL JAPANESE ENCEPHALITIS VECTORS IN ASSAM, INDIA

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Abstract. Temporal changes in the abundance of host-seeking, potential Japanese encephalitis (JE) vector mosquitos and the role of some ecological factors that are modulating the abundance of vector mosquitos were studied. Vector surveillance was conducted for one year in 4 JE prone villages of Dibrugarh, Assam. Among potential JE vectors, the most abundant mosquito was *Culex vishnui s.s.* comprising about 22.32%. Maximum density of the mosquito was found during the month of April and another peak was observed in the month of September. The influence of meteorological factors on the abundance of JE vectors was found to vary from species to species. The final multiple regression equations (after variables were selected using STEPWISE procedure) consisted of a combination of linear, quadratic, cubic and interactive ecological variables and accounted for 25-98% of the variations in the abundance of JE vector mosquitos.

Complex interactions among environmental factors, such as minimum and maximum temperature, rainfall and flood level are involved in modulating the seasonal abundance of mosquitos. A time lag is involved before a cause and effect relationship is established between environmental parameters (independent variables) and entomological variables (dependent variables). Inundation caused by flooding is favorable for mansonioid mosquito species whereas it has an adverse effect on non-mansonioid mosquito species.

INTRODUCTION

Japanese encephalitis (JE) is a major public health problem in the north-eastern region of India, in Dibrugarh District, Assam and other parts of India, and in other south-eastern parts of Asia (Umenai *et al*, 1985).

Fourteen species of mosquitos have been incriminated as vectors of JE from different places all over India (Rodrigues, 1984) out of which eleven species are known to occur in Dibrugarh (RMRC, Dibrugarh, unpublished data). These are : *Culex vishnui s.s.*, *Cx. pseudovishnui*, *Cx. tritaeniorhynchus*, *Cx. gelidus*, *Cx. bitaeniorhynchus*, *Cx. whitmorei*, *Cx. fuscocephala*, *Cx. quinquefasciatus*, *Mansonia annulifera*, *Anopheles barbirostris* and *An. peditaeniatus*. Information regarding seasonal abundance of these potential vectors of JE is lacking in Assam. Knowledge of the seasonal abundance of JE vectors is very important to understand more fully the epidemiological aspects of JE transmission in an area where this disease has posed serious public health problems.

The purpose of the present study was to describe temporal changes in abundance of host seeking potential JE vector species of mosquitos and to evaluate the role of some ecological factors that are modulating the abundance of vector mosquitos.

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MATERIALS AND METHODS

Dusk collection of adult mosquitos in JE endemic areas

Vector surveillance was conducted regularly from May 1991 to April 1992 in four villages of Dibrugarh District endemic for JE, namely, Madhupur Mishing village, Jokai Panitola village, Padumoni village and Lapetkota Tea Estate, which reported JE cases regularly during the earlier outbreaks. The geographical coordinates of Dibrugarh District are : 94° 45' to 96° east longitude and 27° 15' to 28° north latitude.

Adult mosquitos were collected for 1 hour during dusk every fortnight from each locality. In all, 137 man-hours were spent. Mosquitos were collected by two trained persons from in and around cattle sheds by mechanical aspirators using torch lights. Mosquitos were identified and counted specieswise and monthly collections were pooled for analysis.

Meteorological data and Brahmaputra river flood level

Data on weather and flood level in the study area were collected from Toklai Tea Research Centre field unit, Dikom and flood control Department, Dibrugarh District, respectively. Dibrugarh District has a moderate climate with very high humidity throughout the year. During the study period, the total amount of rainfall recorded was 337.25 cm. Temporal variability in the rainfall and the number of rainy days per month are shown in Fig 1. Maximum rainfall was received from June with the arrival of southwest monsoons. Vernal showers from March to May also contributed 25.8% of the total rainfall received. November 1991 to January 1992 was a relatively dry period ~ 2.5-6.5 cm rainfall). In all there were 196 rainy days during the study period, with the maximum number of rainy days occurring from June to August (22-26 rainy days / month) and the minimum during November 1991 to January 1992 (3-9 rainy days / month).

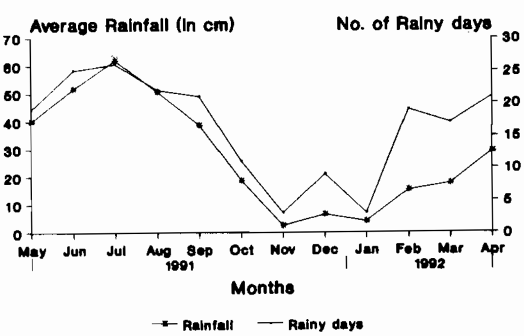

Fig 1–Temporal changes in average rainfall and number of rainy days.

The Brahmaputra river was in flood (flowing at 46 to 195 cm above danger level) in the study area from May 1991 to September 1991.

Temporal patterns of mean maximum and mean minimum monthly temperatures are shown in Fig 2. Maximum mean monthly temperatures ranged from 20.8°C to 32.1°C and mean minimum temperatures ranged from 8.5 °C to 24.7°C. December to February were the coldest months of the season with mean minimum temperature varying from 8.5°C to 11.1°C and mean maximum temperature ranging from 20.8°C to 22.7°C.

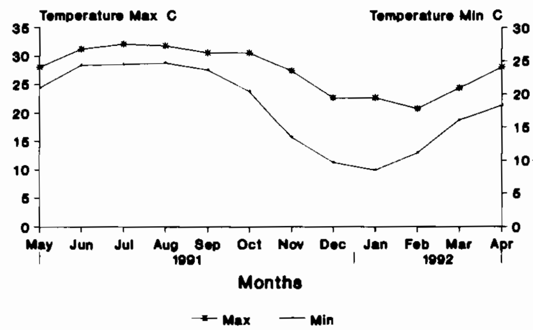

Fig 2–Temporal changes in average maximum and minimum monthly temperature.

Data analysis

Prior to employing parametric tests, the numbers of JE vector mosquitos collected per month at dusk from all the four sites were pooled and the collection effort was standardized to numbers per 10 man-hour density (10 MHD) (Table 1). Statistical techniques used in the present study to examine the interrelationship between entomological and meteorological variables were Pearson's correlation, cross correlation with time lags and multiple regression analysis using linear, quadratic, cubic and interactive combinations of variables.

Pearson's correlation coefficients were calculated between log abundances of each pair of mosquito vectors in order to get an estimate of the temporal relationship among mosquito abundances. High correlation will be expected for species closely related from an ecological point of view. Conversely, a low correlation for a particular pair of mosquito species may indicate that mosquito abundance is determined by different factors. Similarly, correlation coefficients were calculated between

Table 1
Monthwise densities of potential JE vectors expressed in 10 man hours (N) collected during dusk hour from study villages.

Mosquito species	1991									1992		
	May	June	July	August	September	October	November	December	January	February	March	April
Cx. fuscocephala	206(2.32)	81.7(1.92)	91(1.96)	95(1.98)	37(1.58)	20(1.32)	72(1.86)	16(1.23)	14(1.18)	220(2.35)	400(2.6)	690(2.84)
Cx. tritaeniorhynchus	154(2.19)	110(2.05)	-	71.7(1.86)	37.8(1.59)	60(1.79)	141(2.15)	33(1.53)	172(2.24)	85.5(1.94)	664(2.82)	457(2.66)
Cx. vishnui	292(2.47)	366(2.57)	170(2.23)	130(2.12)	180(2.04)	71.4(1.86)	22(1.36)	14(1.18)	60(1.79)	77.7(1.9)	465(2.67)	477(2.68)
Cx. pseudovishnui	234(2.31)	323(2.35)	431(2.64)	78.3(1.9)	69.2(1.85)	62.8(1.8)	15.7(1.22)	15(1.2)	29(1.48)	38.8(1.6)	150(2.18)	280(2.45)
Cx. whitmorei	2(1.32)	35(1.56)	74.4(1.88)	70.5(1.85)	9.2(1.0)	320(2.51)	-	-	-	1.6(0.4)	-	15(1.2)
Cx. gelidus	-	15(1.2)	-	12.5(1.13)	23.6(1.39)	28.5(1.47)	60.7(1.79)	71(1.86)	-	8.3(0.97)	-	1.2(0.34)
Cx. bitaeniorhynchus	-	-	32.2(1.52)	24.1(1.4)	17.1(1.26)	8.5(0.98)	-	4(0.7)	1(0.3)	3(0.6)	6.2(0.86)	23.1(1.38)
Cx. quinquefasciatus	-	10(1.04)	-	14.2(1.18)	4.2(0.72)	14.2(1.18)	31(1.5)	15(1.2)	4(0.7)	7.2(0.91)	6.8(0.9)	13.1(1.15)
An. hyrcanus s.l.	20(1.32)	76.7(1.9)	47.8(1.69)	85.8(1.94)	55(1.75)	110(2.04)	2(0.48)	6(0.84)	52(1.72)	36.1(1.57)	123(2.09)	139(2.15)
An. barbirostris	6(0.84)	1.7(0.43)	-	-	0.7(0.23)	-	-	3(0.6)	-	-	-	-
Ma. annulifera	-	16.7(1.25)	-	122(2.09)	178(2.25)	77.1(1.89)	22(1.36)	5(0.78)	-	1.1(0.32)	1.8(0.45)	0.06(0.2)

(figures in parenthesis are log N+1)

some environmental variables and log abundance of mosquito species. As it was observed that there was a time lag involved before a cause and effect relationship was established between environmental variables and mosquito abundance, time series for the abundance of mosquito species (mosquito count + 1) were cross-correlated with flood level of the Brahmaputra river lagged by one month. Cross correlation coefficient was considered statistically significant at 95% confidence level when its value was more than ± 2/n with n paired data points. The above variable in the time series was also correlated synchronously for comparison (Chatfield, 1975).

For understanding the role of selected environmental factors in the seasonal abundance of different JE vector mosquitos in the study area, multiple regression analysis was used (SPSS). The dependent variable used was mosquito abundance (10 MHDs) and the independent variables used were maximum temperature, minimum temperature, evening relative humidity, flood level of Brahmaputra river, one month lagged flood level of the Brahmaputra river, rainfall and number of rainy days. The regression equations consisted of combinations of linear, quadratic, cubic and interactive explanatory variables. After preliminary analysis to verify assumptions for regression, mosquito abundances were transformed to log (10 MHD + 1). Similarly, the level of the Brahmaputra river above the danger mark was measured in cm and expressed as log (level in cm + 1). This was done to stabilize variance and to remove heterosecdacity (Dowdy and Wearden, 1983). STEPWISE Procedure (Draper and Smith, 1966) was used to select a sub-set of predictor variables in the multiple regression that best explained variations in the seasonal abundance of JE vector mosquitos. Multiple correlation coefficient was used to assess the goodness of fit to the data.

RESULTS

Species composition and mosquito abundance

A total of 19,789 female mosquitos were collected in the present study (during dusk hours) which comprised of 26 species and 5 genera (Table 2). After standardization of the collection effort to per man hour density (MHD) for each month, the relative abundance of each species was calculated. *Ma. uniformis* was the most dominant species comprising 19.27% of the total mosquitos collected. Among potential JE vectors, the most abundant mosquito was *Cx. vishnui* comprising 22.32%, followed by *Cx. tritaeniorhynchus* (19.65%), *Cx. fuscocephala* (19.22%), *Cx. pseudovishnui* (17.09%), *An. hyrcanus s. l.* (7.46%), *Cx. whitmorei* (5.4%), *Ma. annulifera* (4.21%), *Cx. gelidus* (2.18%), *Cx. bitaeniorhynchus* (1.18%), *Cx. quinquefasciatus* (1.18%) and *An. barbirostris* (0.11%).

Seasonal fluctuation in mosquito abundance

Temporal variations occurred in mosquito abundance during dusk hours in the study area. Maximum MHD of mosquitos collected was recorded in

Table 2

Adult female mosquitos collected from four JE prone areas (study villages) of Dibrugarh District over 137 man hours from May 1991 to April 1992.

Sl No.	Species	No. of mosquitos collected
1.	*An. (Ano.) barbirostris*	8
2.	*An. (Ano.) hyrcanus s. l.*	902
3.	*An. (Cel.) annularis*	91
4.	*An. (Cel.) karwari*	4
5.	*An. (Cel.) kochi*	21
6.	*An. (Cel.) maculatus*	1
7.	*An. (Cel.) vagus*	153
8.	*Ae. (Adm.) nigrostriatus*	1
9.	*Ae. (Adm.) vexans*	501
10.	*Ae. (Neo.) lineatopennis*	8
11.	*Ae. (Stg.) albopictus*	4
12.	*Ar. (Arm.) kuchingensis*	138
13.	*Ar. (Arm.) obturbans*	20
14.	*Ar. (Arm.) subalbatus*	2
15.	*Cx. (Cux.) bitaeniorhynchus*	147
16.	*Cx. (Cux.) fuscocephala*	2,686
17.	*Cx. (Cux.) gelidus*	250
18.	*Cx. (Cux.) pseudovishnui*	1,710
19.	*Cx. (Cux.) quinquefasciatus*	128
20.	*Cx. (Cux.) tritaeniorhynchus*	2,676
21.	*Cx. (Cux.) vishnui*	2,632
22.	*Cx. (Cux.) whitmorei*	438
23.	*Ma. (Man.) annulifera*	501
24.	*Ma. (Man.) indiana*	2,569
25.	*Ma. (Man.) uniformis*	3,880
26.	*Ma. (Man.) dives*	318
	Total	19,789

the month of April and minimum in the month of January. Two seasonal peaks of mosquito abundance were evident during the study period - one in the month of September and the other in the month of April. Seasonal variations of abundance of individual potential JE vectors were as follows:

1. *Culex vishnui* :

Cx. vishnui was present throughout the year and was most abundant in the months of May to June. The population steadily declined from July to December and from January, then began to rise gradually again (Fig 3).

2. *Culex tritaeniorhynchus* :

The temporal variations in the abundance of *Cx. tritaeniorhynchus* are depicted in Fig 4. These mosquitos were present almost throughout the year with the exception of the month of July when no specimens were found. The population showed a

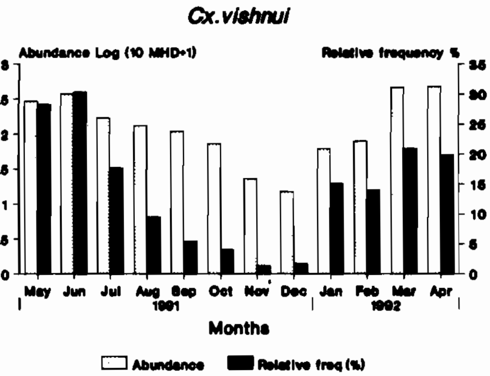

Fig 3

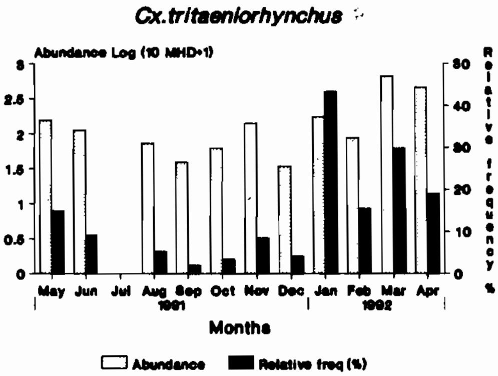

Fig 4

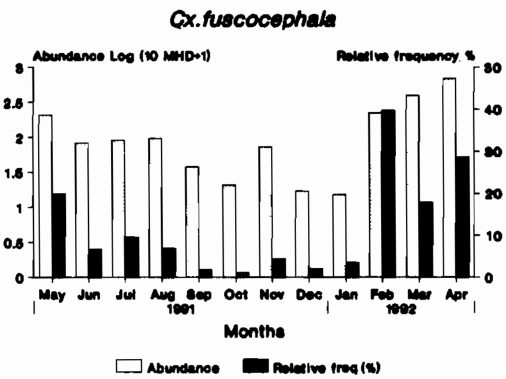

Fig 5

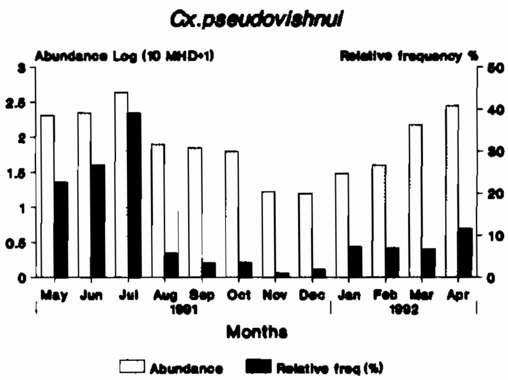

Fig 6

Fig 3-6–Temporal changes in the abundance and relative frequency of potential JE vector mosquitos.

rising trend from August onwards with the peak abundance in the month of March. However, the maximum relative abundance was observed in the month of January.

3. *Culex fuscocephala* :

The seasonal pattern of *Cx. fuscocephala* is shown in Fig 5. *Cx. fuscocephala* was abundant almost throughout the year. Peak abundance was in the month of April. The population gradually declined from May onwards and minimum abundance was recorded in the months of December and January. The relative frequency of *Cx. fuscocephala* was maximum in the month of February.

4. *Culex pseudovishnui* :

The seasonal pattern in the abundance of *Cx. pseudovishnui* was more of less similar to that of *Cx. vishnui*. The abundance was maximum in the month of July, thence onwards, the population showed a gradual decline and minimum abundance was noticed in the months of November and December (Fig 6). Highest relative abundance was found in the month of July.

5. *Anopheles hyrcanus sensu lato* :

The seasonal abundance of *An. hyrcanus s.l.* is depicted in Fig 7. *An. hyrcanus* was almost uniformly abundant throughout the season except the months of November and December when their abundance was at the lowest.

6. *Culex whitmorei* :

The abundance of *Cx. whitmorei* showed a distinct peak in the month of October. From November to April, their abundance was almost negligible.

From May, their population showed a rising trend with the second major peak occurring in the month of June (Fig 8).

7. *Mansonia annulifera* :

The pattern of abundance of this species is depicted in Fig 9. This species was most abundant from August to October with peak abundance in the month of September. Its abundance gradually declined from September with minimum abundance in January. Two minor peaks were also noticed - one in the month of March and the other in the month of June.

8. *Culex gelidus* :

The abundance of this species showed a rising trend in the month of August and maximum density was reached in the month of December. From January to April the abundance was negligible. There was another major peak in the month of June (Fig 10).

9. *Culex bitaeniorhynchus* :

The peak density was found in the month of July and it gradually declined with minimum abundance in the period extending from November to January. From February onwards, the abundance of mosquitoes increased steadily (Fig 11).

10. *Culex quinquefasciatus* :

Cx. quinquefasciatus was abundant from October to December (Fig 12). Minor peaks were noticed in June and August.

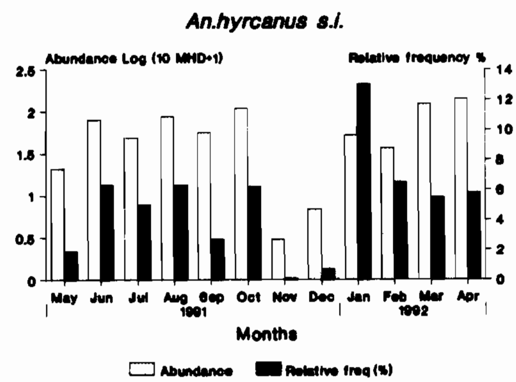

Fig 7

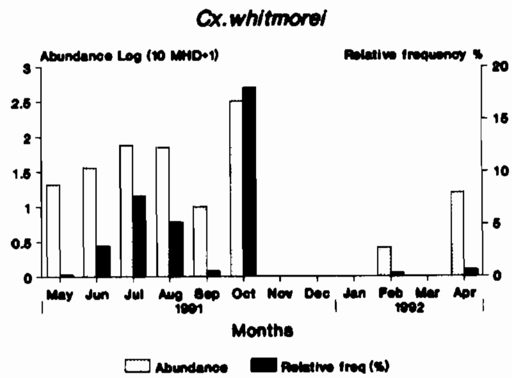

Fig 8

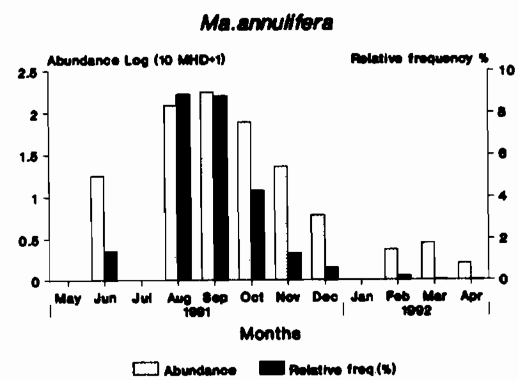

Fig 9

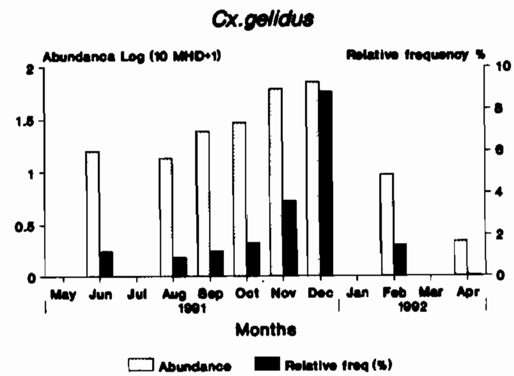

Fig 10

Fig 7-10–Temporal changes in the abundance and relative frequency of potential JE vector mosquitos.

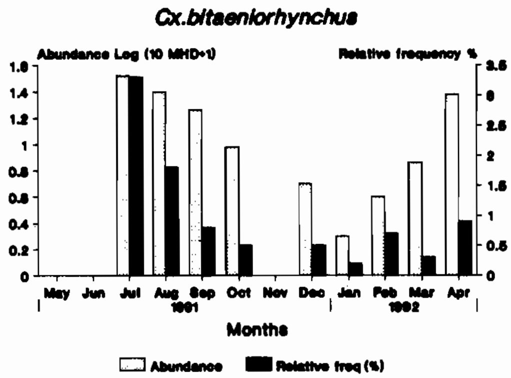

Fig 11

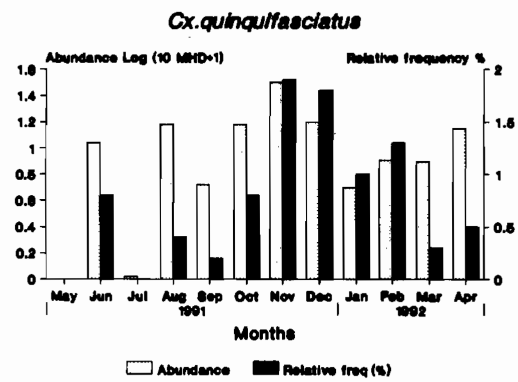

Fig 12

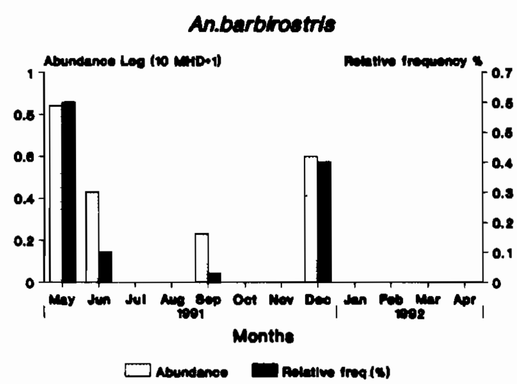

Fig 13

Fig 11-13–Temporal changes in the abundance and relative frequency of potential JE vector mosquitos.

11. *Anopheles barbirostris* :

An. barbirostris was less numerous and sporadically present with peak abundance in the month of May. Two mino peaks were noticed in the months of September and December (Fig 13).

Temporal relationship among mosquito abundances collected during dusk hours

Examination of patterns of correlation (Table 3) revealed that *Cx. vishnui* and *Cx. pseudovishnui* had a highly significant correlation (r=0.9; df=10; p<0.001). *Cx. vishnui* was also significantly correlated with *An. hyrcanus s. l.* (r=0.75; df=10; p<0.01). Similarly, significant correlation was obtained between *Cx. gelidus* and *Cx. quinquefasciatus* and between *Ma. annulifera* and *Ma. uniformis* (r=0.8; df=10; p<0.01).

Lack of temporal correlation among different mosquito species may be attributed to habitat diversity and asynchronous breeding.

Influence of some environmental factors on the abundance of JE vectors

The results of multiple regression analysis and summarized in Table 4.

Culex vishnui : Multiple regression model (for variable abbreviations see Table 4) showing relationship of *Cx. vishnui* abundance are environmental variables is :

$$\log(10\,\text{MHD}+1) = 1.00335 + 0.03696\,(\text{T} \times \log \text{RF}) - 0.08680\,(\log \text{Fl}_{t-1})^3.$$

This equation shows that maximum temperature, rainfall and one-month lagged flood level have a significant effect (multiple R=0.83: p<0.0048) on the abundance of *Cx. vishnui.* Maximum temperature and rainfall interacted with each other and had a positive effect on the abundance of *Cx. vishnui* whereas one-month lagged flood level decreases the abundance of the above species.

Culex tritaeniorhynchus : Multiple regression model is :

$$\log(10\ \text{MHD} + 1) = 2.25990 - 0.01377\ (\text{T} \times \log^{\text{Fl}}{}_{t-1}).$$

The maximum temperature and flood level (one-month lagged) interacted significantly (multiple R=0.61: p<0.05) and had an antagonistic effect on the abundance of *Cx. tritaeniorhynchus.*

Table 3

Correlation matrix showing temporal relationship among abundances of potential JE vector mosquitos

Cx. fuscocephala	1											
Cx. tritaeniorhynchus	2	0.37										
Cx. vishnui	3	0.72*	0.26									
Cx. pseudovishnui	4	0.59	-0.16	0.9**								
Cx. whitmorei	5	0.01	-0.39	0.37	0.58							
Cx. gelidus	6	-0.47	-0.07	-0.65	-0.63	-0.01						
Cx. bitaeniorhynchus	7	0.14	-0.39	0.21	0.34	0.41	-0.1					
Cx. quinquefasciatus	8	-0.13	0.45	-0.37	-0.57	-0.22	0.7*	-0.06				
An. hyrcanus s.l.	9	0.31	0.15	0.75*	0.64	0.51	-0.46	0.52	-0.14			
An. barbirostris	10	-0.1	0.01	-0.02	0.05	-0.02	0.07	-0.47	-0.34	-0.35		
Ma. annulifera	11	-0.37	-0.03	-0.23	-0.28	0.34	0.74*	0.19	0.52	0.04	-0.12	
Ma. uniformis	12	-0.12	0.07	-0.02	-0.18	0.25	0.45	0.57	0.53	0.26	-0.49	0.79*
	1	2	3	4	5	6	7	8	9	10	11	12

* Significant at $p < 0.0001$

** Significant at $p < 0.01$

Table 4

Multiple regression analysis showing relationship between important potential JE vectors and some environmental variables.

sl No.	Species	Variables*	B	SE-B	Beta	T	Sig T
1.	*Culex vishnui*	Tx log RF	0.03696	8.28606×10^{-3}	1.25276	4.461	0.0016
		$(\log Fl_{t-1})^3$	-0.08680	0.03046	-0.80016	2.849	0.0191
		constant	1.00335	0.25112		3.995	0.0031
2.	*Culex tritae-niorhynchus*	Tx log Fl_{t-1}	-0.01377	5.68757×10^{-3}	-0.60776	-2.420	0.0360
		constant	2.25990	0.22620		9.991	0.0000
3.	*Culex fusco-cephala*	Tx RD	2.098596×10^{-3}	5.43665×10^{-4}	1.02911	3.860	0.0038
		Tx log Fl_{t-1}	-0.01601	4.54994×10^{-3}	-0.93833	-3.520	0.0065
		constant	1.37402	0.21856		6.287	0.0001
4.	*Anopheles hyr-canus s.l.*	Tx log Fl	-0.01727	6.70256×10^{-3}	-1.04775	-2.577	0.0298
		Tx log RF	0.04609	0.01270	1.47599	3.630	0.0055
		constant	0.39184	0.34099		1.149	0.2801
5.	*Culex whit-morei*	T^3	4.248307×10^{-5}	2.02559×10^{-5}	0.49771	2.097	0.0654
		Tx log RF	0.02386	0.01276	0.44376	1.870	0.0943
		constant	-0.78122	0.34802		-2.245	0.0514
6.	*Mansonia annulifera*	log Fl_{t-1}	0.54296	0.20934	0.63416	2.594	0.0268
		constant	0.42958	0.26545		1.618	0.1367

* Variables : T = Maximum temperature (°C); RD = No. of rainy days

log RF = log of rainfall (cm); log Fl = log of Brahmaputra flood level above its danger mark (cm)

log Fl_{t-1} = log Fl lagged by one month

Culex fuscocephala : Multiple regression model is :

$$\log(10MHD^{+1}) = 1.37402+2.09859\times10^{-3}(TxRD)-0.01601(TxlogF1_{t-1}).$$

Maximum temperature alone had no significant relationship with the abundance of Cx. fuscocephala (r=0.01). Maximum temperature interacted with number of rainy days and flood level (lagged by one-month) significantly (multiple R=0.80; p<0.0092). The number of rainy days interacted with maximum temperature having a positive influence on mosquito abundance. However, one-month lagged flood level and synchronous maximum temperature had a negative effect on the abundance of the above species.

Culex pseudovishnui : In the case of *Cx. pseudovishnui*, STEPWISE multiple regression analysis failed to select a statistically significant subset of environmental variables which could explain variations in the seasonal abundance of this species. However, a highly significant relationship of *Cx. pseudovishnui* was observed with rainfall (r=0.85; p<0.001), minimum temperature (r=0.72; p<0.01) and evening relative humidity (r=0.7; p<0.01).

Anopheles hyrcanus sensu lato : the regression model is :

$$\log(10\ MHD\ +^{1}) = 0.39184 - 0.01727\ (T \times \log F1) + 0.04609\ (T \times RF).$$

In the case of *An. hyrcanus s.l.* maximum temperature interacted significantly with flood level, having a decreasing effect on the abundance of this species. Unfavorable conditions in the study area were flood level above 40 cm and mean monthly maximum temperature above 29°C. On the other hand, macimum temperature interacted with rainfall in such a way that there was an increase in the abundance of this species (multiple R=0.78; p<0.01). Favorable conditions were rainfall between 17-30 cm and maximum temperature between 24-28°C.

Culex whitmorei : The regression model is :

$$\log(10MHD+1) = -0.78122+4.248307\times10^{-5}(T)^{3}+0.02386(TxRF).$$

In case of *Cx. whitmorei*, maximum temperature above 28°C and average monthly rainfall above 30 cm were found to be highly favorable (multiple R=0.88; p<0.001).

Mansonia annulifera : The regression model is :

$$\log(10\ MHD+1) = 0.42958+0.54296\ (\log Fl_{t-1}).$$

Abundance of *Ma. annulifera* seemed to depend upon one-month lagged flood level (r=0.6; p<0.05). Mean monthly maximum temperature interacted positively with flood level. Temperature above 29°C seems to be favorable for *Ma. annulifera*.

The abundances of the remaining four potential JE vectors viz, *Cx. gelidus, Cx. gitaeniorhynchus, Cx. quinquefasciatus* and *An. barbirostris* were very low in the study area. Therefore, the influence of environmental factors on their abundances could not be studied. In some mosquito species, complex interactions among environmental factors contribute to the inconsistent relationship among environmental parameters and seasonal abundance of mosquitos.

DISCUSSION

Temporal variations occurred in adult mosquito abundance in the study area. Maximum per man hour density of total mosquitos collected was recorded in the month of January. Two seasonal peaks of mosquito abundance were evident during the study period.

The influence of meteorological factors on the abundance of JE vectors was found to vary from species to species. The abundance of mansonioid mosquitos was found to be related to flood levels. The large scale inundations during floods in Brahmaputra river led to elevated abundance of *Ma. annulifera* and *Ma. uniformis* possibly by increasing the breeding surface. On the other hand, increase in flood levels was found to be unfavorable for those non-mansonioid species including *Cx. vishnui s.l.* whose breeding habitats are associated with riparian sources, possibly because the larvae of these mosquitos are washed away. In contrast, mansonioid mosquitos withstand the washing away effects of floods because their larvae remain attached to the roots of aquatic plants.

The *Cx. vishnui* group of mosquitos were found to be most predominant during the study period.

Similar results were obtained by Reuben (1971) in north Arcot District of Tamil Nadu: seasonal abundance of *Cx. vishnui* group of mosquitos was found to be related to rainfall pattern. However, she further pointed that the effect of rainfall pattern on *Cx. vishnui* group deserves further study. In the present study, rainfall, flood level and maximum temperature were found to interact and modulate the seasonal abundance of the *Cx. vishnui* group. Rainfall and temperature were found to interact with each other in having a positive effect on the abundance of this group. On the other hand, increase in flood level decreased the abundance of this group. In the present study, peak abundance of the *Cx. vishnui* group of mosquitos towards premonsoon season was found to be related to premonsoon showers which created temporary water pools, thereby providing extensive breeding habitats. However, excessive rainfall in the monsoon season, although favorable initially, leads to flooding which in turn has a negative effect on the abundance of these mosquitos.

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