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Records of the Zoological Survey of India

Population Ecology of benthic dipterans of the mangrove ecosystem of Sundarbans, India

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Zoological Survey of India

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By

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PREFACE

Sagar Island, a typical Gangetic delta, is situated in the Hooghly—Matla estuarine complex which by dint of its exciting mangrove ecosystem of the Indian part of the magnificent Sundarbans, has already made its deserving place in the global map. This ecosystem inspite of sheltering words most graceful game, also supports a luxuriant flora and fauna, micro—, meio— and macro—, in its hundreds of tributaries, salt marshes and sand and mud flats, in the form of plankton, nekton and benthic.

This Island has been chosen as the venue to study the seasonal population structure of littoral benthic dipterans in relation to the prevailing ecological parameters. It is being hoped that this study venture may pave the way and acceterate fresh investigations on the many other benthic insects fauna that abound the intertidal salt marshes of the deltaic Sundarbans of the Indian subcontinent.

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INTRODUCTION

Marine insects, specially those spend part of their life in the intertidal belt, have generally been ignored in standard entomological books. Even the text books on marine invertebrates only casually refer their existence. However, several lists of marine insects have been compiled by individuals or institutions viz., Buckland (1945), Marine Biological Association (1957), Smith and Carlton (1975) etc. Such lists seem to be far from complete and are generally regional, but they do really highlight the existence of potentially rich faunas of coastal marine insects that are often overlooked.

About 30,000 insect species are aquatic or have aquatic larval stages. Of these only a fraction, perhaps a few hundred species only, are marine and intertidal. Nevertheless, certain marine insects are of considerable interest and of economic importance being related with public health, directly or indirectly (Cheng, 1976). Informations related to marine benthic insects, available in literature are mainly from North America, Britain, Australia, Netherlands and Japan.

As no substantial work on this important areas has been dealt with in the eastern sector of the world so far, and the Indian subcontinent and South East Asia at large, this work has been done on the population ecology of marine benthic dipteran insects in the deltaic Sundarbans located in the Hooghly-Matla estuarine complex. This magnificant tropical estuary, supporting luxuriant mangrove swamps and salt marshes, is a good example of a couple system that achieves a good balance between physical and biotic components and high rate of biological productivity. It consists of several basic subsystems linked together ebb and flow of water that is driven by the hydrological cycle (river inflow) and the tidal cycle, both of which provide "energy subsidies" for the system as a whole.

The habitat gradient fluctuates back and forth with the tides and the gradient of salinity is dependent upon continuous inflow of fresh water. Influx of upstream fresh water and also monsoonal run off are the principal sources of dissolved and particulate nutrient inputs. In general this estuary belongs to that important class of "fluctuating water level ecosystem" where the physical conditions are often stressful and the species diversity correspondingly low, but the conditions are so favourable that the region is packed with life, and Sagar Island is no exception to that. Along with the varieties of planktonic and nektonic forms, a luxuriant benthic insect fauna is displayed in the intertidal belt of the island. Diptera, coleoptera and hemiptera appear to be predominant orders among the insect fauna in this habitat.

In the present work 17 species of dipteran insects comprising 5 families and 12 genera have been considered and studied their detailed interaction with everfluctuating environmental parameters.

HISTORY

The benthic dipterans are less studied biotic organisms. In fact, our knowledge of benthos in all enviroments is largely restricted to descriptive studies. Earlier investigations of benthic dipterans were directed only towards the discovery of species and enumerating them. During the biginning of present centurv, interest seemed to be moulded more on the benthic ecology with particular reference to benthos as food source or to control the medically important insects by destroying their larvae and pupae.

Quantitative assessment of bentnic diptera was first initiated by Muttkowski (1981). Subsequently, notable contributions on different aspects of benthic diptera. worthy of mention, are by different authors, which are as follows.

Important works on the biology and taxonomy were donc by Renn (1941), Kettle and Lawson (1952), Pennak (1953), Needham and Westfall (1955), Macdonald (1956), Kettle and Elson (1975), Howarth (1977), Gormostaeva (1978), Burger *et al* (1980), and Thier and Foote (1980).

Miall (1934) and Wolvekamp (1955) observed the respiratory adaptation of different benthic dipteran larvae.

A summary of literature reveals that works on the ecology have been carried out by Sprules (1940). Deevey (1941), Miller (1941), Shelford and Boesel (1942), Ball and Hayne (1952), Eggleton (1952), Wood (1956), Wilhm, (1967, Collins (1975), Angelovski (1977), Isaev (1977), Andrews and Minshall (1979), Jankovie (1979), Barton, (1980), Moore (1980), Reice (1980, 1985), Srokosz (1980), Winner *et al* (1980) and Hersher (1985).

Arndt (1914) first reported and recorded the existence of dipteran insects in the intertidal zones of marine environment, A review of the literature reveals that most of the works on marine and estuarine benthic diptera have been carried out on the North American coast. Besides this, some works also have been done in Europe (particulary in United Kingdom, Netherland, France, etc.) and Asia (only in Japan and recently in india).

Notable works on salinity tolerance and osmoregulation of marine benthic dipterans were performed by Wigglesworth (1963), Beadle (1939), Ramsay (1950) Sutcliffe (1960), Neumann (1961), Clements (1963) and Nicolson (1972).

A summary of literature reveals that some works on the biology, habitat and distribution of some marine benthic diptera have been carried out by Dyte (1959), who noticed some interesting habitats of larval dolichopodidae. Metcalf and Osborn (1920) and Cameron (1972) studied the distribution of insects between the tide zones.

Painter (1926), Jamnback *et al* (1958), Jamnback and Well (1958), Breeland (1960), Jones (1961), Reye and Lee (1962), Williams (1964), Davies and Linley (1965), Hair et al (1966), Davies (1967), Linley (1966, 1969, 1985), Lawrence and Mathias (1972), Linley and Adams (1972), Davies (1973), Cheng and Hogue (1974), Kline (1974) and Wirth *et al* (1974) studied biology, habitat, distribution and taxonomy of benthic ceratopogonids.

Hesse (1934), Tokunaga (1935), Hashimoto (1968, 1973), Neumann and Honegger (1969), Leader (1975) and Robles (1984) made notable contribution on the habitat, distribution and taxonomy of marine benthic chironomids.

The truly marine, or coastal ephydridae have been less well investigated than their inland counterparts. Significant contributions concerning biology and ecology have been made by Williams (1938), Henning (1943), Dahl (1959) and Simpson (1973).

Larval and pupal distribution of tabanids and their ecology in saline habitats were studied by some authors viz., Bailey (1947), Freeman (1962). Adams (1963), Rockel and Hansens (1970) and Dukes *et al* (1974a ; 1974b.)

The studies on marine benthic insects in our country are still rather meagre. Some works have been carried out only in Hooghly estuary, which are as follows.

Poddar and Choudhury (1985ab,) Ray and Choudhury (1985abc, 1986abc, 1988ab) studied different aspeats, such as salinity tolerance, ecology, community structure and diversity, etc., of some dipteran and coleopteron insects.

PHYSIOGRAPHY AND CLIMATE

The geographical location of the present investigation lies in the Hooghly - Matla estuarine complex, embracing the western sector of deltaic Sundarbans nearly 100 km south of Calcutta between 21°N and 21°53'N and meridians 88°02'E to 88°15'E. This estuarine complex of the tropics occupies an important place in the world map and can be categorised as a river delta estuary (formed at the mouth of large rivers) which has been advocated by Odum (1971) in addition to Pritchard's (1967) four categories of estuarine complex. There are seven major rivers in the Hooghly-Matla estuarine system, most of which are blind in the north except the river Hooghly in the extreme west that receives perennial supply of fresh water draining into the sea through the Hooghly estuary. This estuary is a positive estuary of mixohaline type. It has an approximately funnel shaped wide mouth spread over about 20 km stretch and probably due to the strong scouring action of the stream as well as tidal currents, a greater overall circulation is maintained. The tidal influence is felt in the upper reach of the river upto a distance of 290 km from the sea face. The estuary experiences vertical turbulence to a high degree and is reported to have no appreciable stratification of temperature and salinity, practically throughout its entire length (Bose, 1956) (Fig. 1).

The deltaic system of the estuary covers several islands of which Sagar Island was selected for the present works.

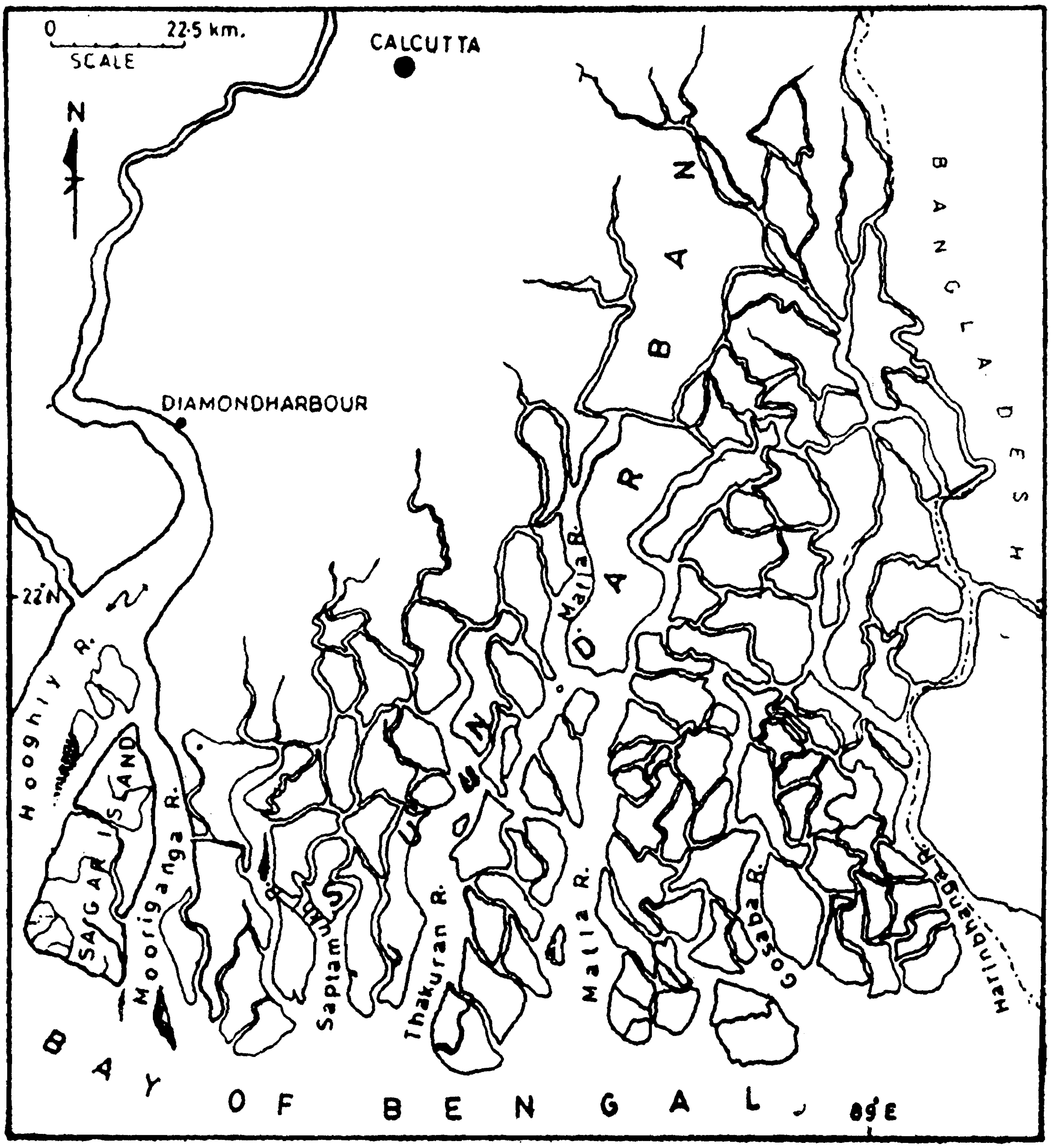

Fig. 1. Map of Hooghly-Matla estuarine complex.

Physiography of Sagar Island :

Sagar Island, the largest delta in the Hooghly-Matla estuarine complex, is surrounded by large bodies of water, the river Hooghly in the north and northwestern side and the river Mooriganga in the eastern side. The southern part of the island faces the open sea, Bay of Bengal, between 21°31'N to 21° 53'N and 88°02'E to 88°15'E (Fig. 2). Sagar Island, about 144.9 sq km in area and partially reclaimed, is criss-crossed by twelve large and small tidal creeks strewned with mangrove vegetation, all connected with the principal estuarine water, either on the east or on the west coast.

Wind :

The prevailing wind is from north and north-east from the beginning of October to the middle of March. The months January and February are relatively calm. It again commences to blow violently from south-west from about the middle of March and gradually subsides in September. Storms are common during spring and autum. Some of these often develop into cyclones of varying intensity usually accompanied by high (8 m) tidal waves and surges and cause much loss of life and damage to property and coastal features.

Seasons :

Seasons are pronounced in this estuarine system, each with four-month duration and the seasonal variations have been noted in accordance with the tidal regime (Pillay, 1958). The premonsoon (March to June) is the dry season with occasionally higher temperature. The monsoon season (south-west) is accompanied by heavy rainfall (annual average precipitation 1600 mm), and the postmonsoon (November to February) comprised partly the winter season, comparatively with lower temperature and lesser precipitation. With the change of seasons, tidal interactions in the Hooghly estuary also change (highest high tide 5.9 m and lowest low tide 0.5 m in the month of August/September).

Physiography of field stations :

Three stations in Sagar Island have been selected for the present investigation.

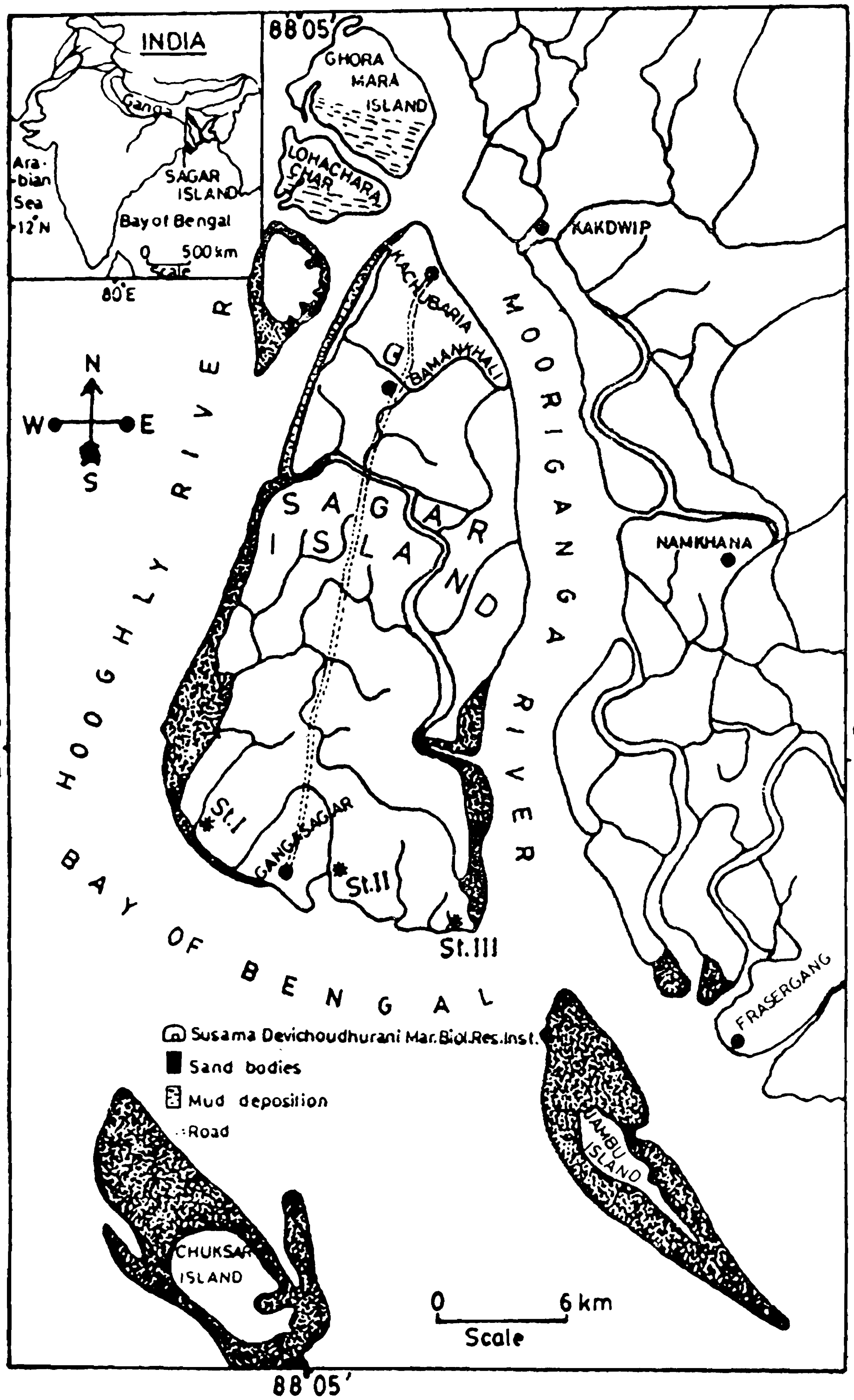

Fig. 2. Map of Sagar Island.

Station I : Beguakhali creek :

The sampling spot has been selected near the starting point of the Beguakhali creek in south-western part of the island originating from Bay of Bengal and extending upto 5 km in the northern sector of the island (Fig. 3). The substratum of this area is completely sandy and supported by scattered patches of mangrove vegetation and spiny grasses, comprising of *Phoenix peludosa, Ipoemea inermis, Salicornia brachiata, Suaeda maritima* and *Porteresia coarctata* The impact of the fresh water run off from the adjacent land areas (cultivated), renders a very unstable condition in the creek water environment.

Station II : Sagar creek :

The sampling area is also being located near the starting point of the Sagar creek in southern part of the island which originates from and ends in Bay of Bengal, traversing through the extreme supra-littoral zone of the southern part of this delta (Fig. 3). The length of this creek is about 3 km. This zone mostly formed of silty clay and little sand and covered with luxuriant but gradually declining mangrove patches (due to biotic interference) comprising of *Phoenix* sp., *Avicennia officinalis, Acanthus ilicifolius, Excoecaria agallocha, Ceriops decandra, Derris trifoliata, Ipoemea inermis, Salicornia brachiata, Suaeda maritima*, etc. This zone often experiences silting and desilting from time to time throughout the year and for this reason the elevation of the littoral zone is subjected to alternate change.

Station III : Dhablat :

This area is located in the south-eastern part of the island facing the open Bay and is landmarked by several sand dunes with extended sandy beaches (Fig. 3). The supra littoral zone of this area is traversed by a narrow tidal creek. Several tidal pools and man made tidal ditches are found on either side of the creek. During ebb tide, it is completely exposed and gets inundated during flowtide, depending upon the intensity of tide through lunar cycles. Inside tidal pools, silt is deposited gradully to make the substratum muddy. The soil substratum of this area is sandy-muddy and vegetation is poor being represented only by grass and sacculants e.g., *Porteresia coarctata, Salicornia brachiata* and *Suaeda maritima*. Dunes are covered by matting of *Ipoemea inermis.*

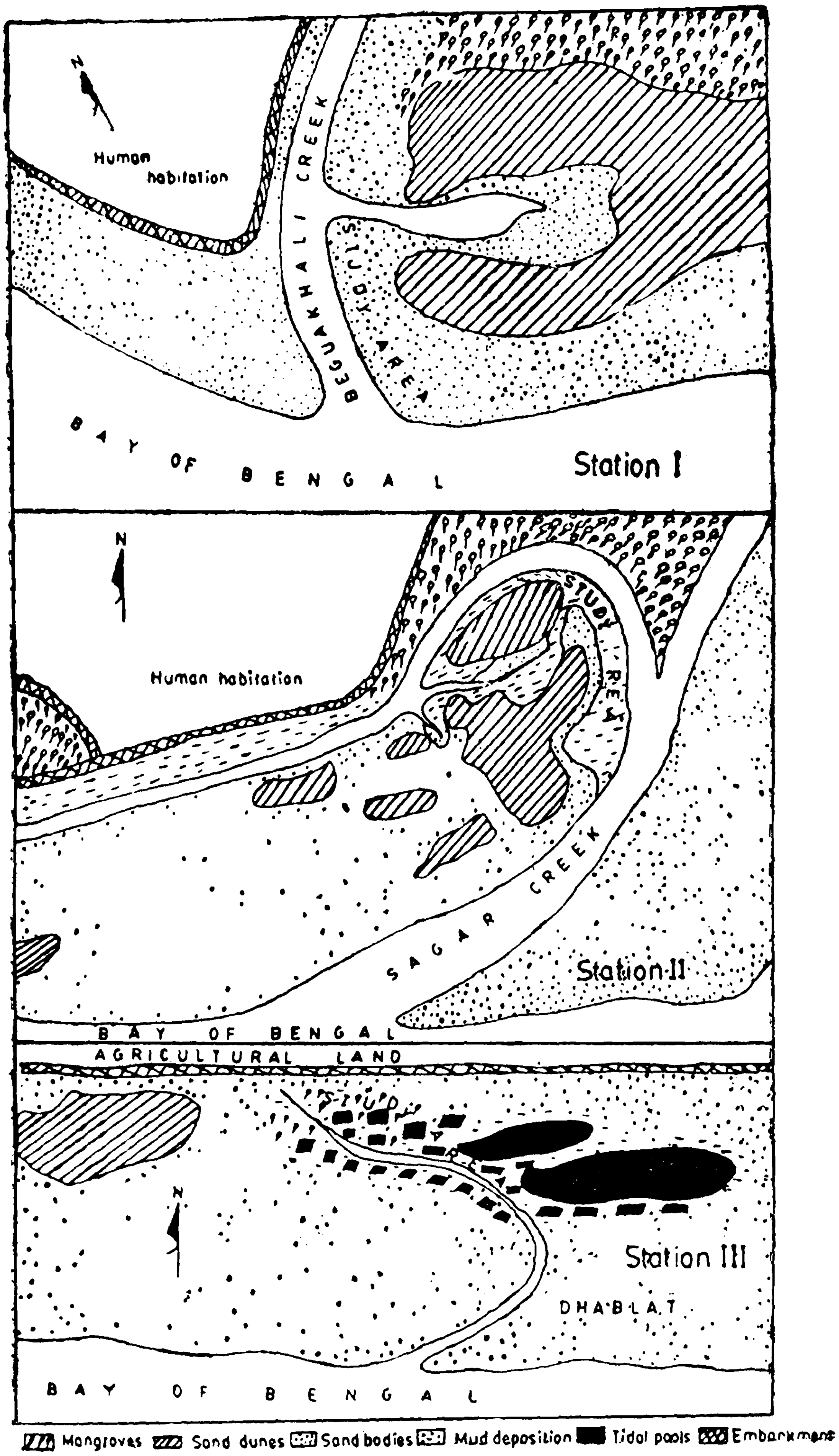

Fig. 3. Physiography of field stations (field sketch).

MATERIALS AND METHODS

The quantitative assessment of littotal benthic dipteran fauna was conducted at the three well specified stations (I, II and III) during July, 1982 to June, 1984. The larval and pupal population were sampled at fortnightly intervals during neaptides in the morning hours (09-30 to 11-30 a. m.). Samples were removed from the sites at consistent position along transects traversing the beach. There were four transects on each site, each consisting of five samples, the transects were one metre apart, the samples, also one metre apart, so that a representative rectangle of the site was under observation. Each sample consisted of 25 cm^2 cut neatly to a depth of 9 cm by corer. The fauna inhabiting the soil were recovered by following standardised magnesium sulphate floatation technique (Davies and Linley, 1966). All samples were carried from the field to laboratory in polythene packets and were transferred in glass jars. Saturated magnesium sulphate solution was poured into the glass jars and the samples were stirred vigorously to bring the sand and mud into suspension. As the sand and mud began to settle at the bottom, the fluid containing the biotic materials was quickly decanted into a black painted pan set infront of a bright light. Dipteran larvae and pupae accumulated along the side of the pan set furtherest from the light and removed with clean eye droppers. The presence of larvae and pupae was finally checked by hand lens.

Vertical distribution of two species was studied from March, 1983 to February, 1984. Same methodology was followed as mentioned earlier. Each sample (25 cm^2) was divided vertically into three subsamples from 0-3 cm, 3-6 cm and 6-9 cm.

After recovering from the saturated solution of magnesium sulphate, the larvae and pupae were identified, counted and expressed as number/25 cm^2.

Larvae and pupae can be identified following two methods In the first method, larvae and pupae obtained from the eggs laid by identified females, may be reared on a medium, freed from other larvae and pupae. In the other method, larvae and pupae collected from nature, grouped on the basis of certain characters, can be kept until the adult emerged, in order to identify the species and to ensure that each group is homogeneous, cantaining one species (Kettle and Lawson, 1952). The later method was adopted to identify the larvae and pupae.

For vertical distribution studies, two measurements were made for each individual larvae, body length and head length in particular for instar determination, according to Dyar's law (Kettle and Lawson, 1952).

Surface vegetation and under growths were collected from the habitat spots for botanical identification.

Water samples for hydrological studies were collected fortnightly in the morning hours (09-30 to 11-30 a.m.) from all the three stations during neap tide by digging a twenty centimeter deep pit and collecting the interstitial water that percolates instantly into it. Temperatures were recorded in degree centigrade by using an ordinary thermometer. Air temperature was collected at 1.5 m adove the ground and soil temperatures at depths of 3, 6 and 9 cm respectively. Five readings were taken at different points and mean values were noted. The salinity for the sample water was estimated by employing 'Mohr-Knudsen method' (Stricland and Parsons, 1968). The correction factor was found out by titrating the silver nitrate solution against standard sea water (I. A P. O. standard sea water service, Charlottenlund Slot Denmark, chlorinity 19.376 ‰). Winkler's method was followed to estimate the dissolved oxygen content of the sample and pH was measured by using the Lovibond colour comparator disc in the field. Soil moisture was measured by following oven-dry method. Soil samples were brought to laboratory in air tight polythene packets. 100 gm of soil was kept overnight in an oven at 105°C for drying, after which the soil was again weighted and the moisture was expressed in percentage. Precipitation data were collected from Alipore Meteorological station. Analyses of different soil characteristics were based on the samples collected fortnightly from five different spots.

Organic carbon content of soil was determined following Walkley and Black's (1934) rapid titration method. Organic carbon content is calculated as Organic carbon (%) = titration value (ml) with soil x 0.3.

Available phosphorus was extracted from the soil by following Olsen *et al* (Jackson, 1967) using 0 5 $NaHCO_3$ solution along with pinch of carbon black. Phosphate content of the extracted solution was measured by "Chlorostannous reduced phosphomolybdic blue colour method", afer Dickmann and Bray (Jackson, 1967).

To The aliquot containing soil phosphorus, addi:ion of ammonium molybdate produces a complex, which on reduction by stannous chloride, gives blue colour. The optical density was measured at 660 m w in a spectrophotometer and the amount of phosphorus was calculated from the standard KH_2PO_4 solution. Available phosphorus content in the soil is calculated as following :

If the concentration of phosphorus in the solution (2 ml filtrate diluted to 50 ml) be X ppm.

Amount of available phosphorus (mg/100 gm soil) = X x 18.75.

The textural compositions of the soils were determined by following international pipette method, as elaborated by Banerjee and Chottopadhyay (1980). For this purpose, 20 gms of air dry soil was first digested with 6 % H_2O_2 till the sample was free of organic matter. The soil was then treated with dilute HCl to remove the free calcium carbonate, washed and shaken throughly with NaOH to bring complete dispersion. The suspension was transferred to a 1000 ml cylinder. After 4 minutes, 20 ml of sample was pipetted out from 10 cm depth and dried to constant weight to obtain the weight of silt and clay (X gm). The pipetting was repeated in the similar manner after 6 hrs to get the weight of clay alone (Y gm).

Percentage fo sand, silt and clay in the soil was determined by using the following calculation :

% of clay	$= Y \times 250$
% of silt	$- (X - Y) \times 250$
% of sand	$= 100 - (X \times 250)$

Statistical analysis :

Correlation coefficient :

To find out the relationship between differnt environmental factors, the relationship between different environmental parameters and different species and the relationship among different species, the following procedure was used :

Months	Variate (X)	Variate (X)	XY
1. July '82	X_1	Y_1	X_1Y_1
2. August '82	X_2	Y_2	X_2Y_2
3. September '82	X_3	Y_3	X_3Y_3
24. June '84	X_{24}	Y_{24}	$X_{24}Y_{24}$
Total	$\sum_{i=1}^{i=24} X_i$	$\sum_{i=1}^{i=24} Y_i$	$\sum_{i=1}^{i=24} X_iY_i$

$$\delta X^2 = \frac{\sum_{i=1}^{i=24} X_i^2 - \left[\overset{i=24}{\underset{i=1}{X_i}}\right]^2 \Big/ 24}{24-1}$$

$$Y^2 = \frac{\sum_{i=1}^{i=24} Y_i^2 - \left[\sum_{i=1}^{i=24} Y_i\right]^2 \Big/ 24}{24-1}$$

Correlation between X or Y or,

$$r = \frac{\left(\sum_{i=1}^{i=24} X_iY_i - \dfrac{\sum_{i=1}^{i=24} X_i \times \sum_{i=1}^{i=24} Y_i}{24}\right) \Big/ 24-1}{\sqrt{\delta X^2} \times \sqrt{\delta Y^2}}$$

All correlation coefficient analyses with sand, silt and clay were computed seasonally (where X and Y were X_1 ....X_6 and Y_1........Y_6).

Multiple regression :

Combined effect of eight environmental parameters (soil temperature X_1, soil moisture X_2, rainfall X_3, salinity X_4, dissolved oxygen X_5, pH X_6, organic carbon X_7, available phosphorus X_8) on different species and individual role of each parameter along with other parameters were ascertained by the following formula (Snedecor and Cochran, 1967).

$$\hat{Y} = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X$$

$$\text{Where } a = \overline{Y} - b_1\overline{X}_1 - b_2\overline{X}_2 - b_3\overline{X}_3 - b_4\overline{X}_4 - b_5\overline{X}_5 - b_6\overline{X}_6 - b_7\overline{X}_7 - b_8\overline{X}_8$$

($\overline{Y}$ = mean value of Y)

($\overline{X}$ = mean value of X)

b_1, b_2 .... b_8 were calculated according to the following model.

$$b_1\sum x_1^2 + b_2\sum x_1x_2 + b_3\sum x_1x_3 + b_4\sum x_1x_4 + b_5\sum x_1x_5 + b_6\sum x_1x_6 + b_7\sum x_1x_7 + b_8\sum x_1x_8 = \sum x_1y$$

$$b_1\sum x_1x_2 + b_2\sum x^2 + b_3\sum x_2x_3 + b_4\sum x_2x_4 + b_5\sum x_2x_5 + b_6\sum x_2x_6 + b_7\sum x_2x_7 + b_8\sum x_2x_8 = \sum x_2y$$

$$b_1\sum x_1x_3 + b_2\sum x_2x_3 + b_3\sum x_3^2 + b_4\sum x_3x_4 + b_5\sum x_3x_5 + b_6\sum x_3x_6 + b_7\sum x_3x_7 + b_8\sum x_3x_8 = \sum x_3y$$

$$b_1\sum x_1x_4 + b_2\sum x_2x_4 + b_3\sum x_3x_4 + b_4\sum x_4^2 + b_5\sum x_4x_5\, b_6\sum x_4x_6 + b_7\sum x_4x_7 + b_8\sum x_4x_8 = \sum x_4y$$

$$b_1\sum x_1x_5 + b_2\sum x_2x_5 + b_3\sum x_3x_5 + b_4\sum x_4x_5 + b_5\sum x_5^2 + b_6\sum x_5x_6 + b_7\sum x_5x_7 + b_8\sum x_5x_8 = \sum x_5y$$

$$b_1\sum x_1x_6 + b_2\sum x_2x_6 + b_3\sum x_3x_6 + b_4\sum x_4x_6 + b_5\sum x_5x_6 + b_6\sum x_6^2 + b_7\sum x_6x_7 + b_8\sum x_6x_8 = \sum x_6y$$

$$b_1\sum x_1x_7 + b_2\sum x_2x_7 + b_3\sum x_3x_7 + b_4\sum x_4x_7 + b_5\sum x_5x_7 + b_6\sum x_6x_7 + b_7\sum x_7^2 + b_8\sum x_7x_8 = \sum x_7y$$

$$b_1\sum x_1x_8 + b_2\sum x_2x_8 + b_3\sum x_3x_8 + b_4\sum x_4x_8 + b_5\sum x_5x_8 + b_6\sum x_6x_8 + b_7\sum x_7x_8 + b_8\sum x_8^2 = \sum x_8y$$

where $x_1 = X_1 - \overline{X}_1$, as usual

$y_1 = Y_1 - \overline{Y}_1$, as usual

(The part of the exercise has been computerised following FORTRAN programme).

'F' test was employed to study the statistical significance between eight environmental parameters and each species according to the following model.

'F' test :

Source of Variation	Degrees of freedom (d.f.)	Sum of squares (S.S.)	Mean square (M.S.)	'F'
Regression	8	$\sum \hat{y}^2$	$\frac{S.S.}{d.f.}$	M.S./ Deviation M.S.
Deviations	15	$\sum d^2 = \sum y^2 - \sum \hat{y}^2$	"	
Total	23	y^2	"	

Where $\hat{y}^2 = b_1 \sum x_1y + b_2 \sum x_2y + b_3 \sum x_3y + b_4 \sum x_4y + b_5 \sum x_5y + b_6 \sum x_6y + b_7 \sum x_7y + b_8 \sum x_8y$

$$y^2 = \sum Y^2 - \frac{(\sum Y)^2}{N}$$

Analysis of variance :

To find out the variation of different species populations in different months, years and stations and also between different instars of two species at different depths, seasons and stations, three way and four way of classifications were performed according to the following models.

A. Three way of classifications :

MODEL—I

	Station I		Station II		Station III		
Month	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Total
M_1	$X_{1.1}$	$X_{1.2}$	$X_{1.3}$	$X_{1.4}$	$X_{1.5}$	$X_{1.6}$	
M_2	$X_{2.1}$	$X_{2.2}$	$X_{2.3}$	$X_{2.4}$	$X_{2.5}$	$X_{2.6}$	
M_{12}	$X_{12.1}$	$X_{12.2}$	$X_{12.3}$	$X_{12.4}$	$X_{12.5}$	$X_{12.6}$	Grand Total (G.T.)

$$\text{Correction Factor (C.F.)} = \left(\sum_{\substack{i=1 \\ j=1}}^{\substack{j=6 \text{ or } 4 \\ i=12}} X_{ij} \right)^2 \Big/ (72 \text{ or } 48)$$

$$\text{Total Sum of Square (S.S.)} = \sum_{\substack{i=1 \\ j=1}}^{\substack{j=6 \text{ or } 4 \\ i=12}} X_{ij}^2 - (\text{C.F.})$$

MODEL – II

Month/Year	Y_1	Y_2	Total
M_1	y_1m_1	y_2m_1	$M1 = \sum_{i=1}^{i=2} y_i m_1$
M_2	y_1m_2	y_2m_2	$M_2 = \sum_{i=1}^{i=2} y_i m_2$
M_{12}	y_1m_{12}	y_2m_{12}	$M_{12} = \sum_{i=1}^{i=2} y_1 m_{12}$
Total	Y_1 $\sum_{j=1}^{i=12} y_1 m_j$	Y_2 $\sum_{j=1}^{i=12} y_2 m_j$	

$$\text{Month S.S.} = \sum_{j=1}^{j=12} m_j^2 \Big/ \left\{(6 \text{ or } 4) - (\text{C.F.})\right\}$$

$$\text{Year S.S.} = \left(\sum_{i=1}^{i=2} y_i^2\right) \Big/ \left\{(36 \text{ or } 24) - (\text{C.F.})\right\}$$

$$\text{Month x Year S.S.} = \sum_{\substack{i=1\\j=1}}^{\substack{j=12\\i=2}} y_i m_j^2 \Big/ \left\{(3 \text{ or } 2) - (\text{C.F.}) - (\text{Month S. S.} + \text{Year S.S.}\right\}$$

MODEL – III

Station/Year	Y_1	Y_2	Total
St_1	y_1s_1	y_2s_1	$S_1 = \sum_{i=1}^{i=2} y_i s_1$
St_2	y_1s_2	y_2s_2	$S_2 = \sum_{i=1}^{i=2} y_i s_2$
St_3	ls_3	y_2s_3	$S_3 = \sum_{i=1}^{i=2} y_i s_3$
Total	Y_1 $\sum_{j=1}^{j=3 \text{ or } 2} y_1 s_j$	Y_2 $\sum_{j=1}^{j=3 \text{ or } 2} y_1 s_j$	

$$\text{Station S.S.} = \left(\sum_{j=1}^{j=3 \text{ or } 2} s_j^2\right) \Big/ \left\{(24) - (\text{C.F.})\right\}$$

$$\text{Station x Year S.S.} = \left(\sum_{\substack{i=1\\j=1}}^{\substack{j=3 \text{ or } 2\\i=2}} y_i s_j^2\right) \Big/ \left\{(12) - (\text{C.F.}) - (\text{Station S.S.} + \text{Year S.S.})\right\}$$

MODEL – IV

Month/Station	St_1	St_2	St_3	Total
M_1	m_1s_1	m_1s_2	m_1s_3	$M_1 = \sum_{j=1}^{j=3 \text{ or } 2} m_1s_j$
M_2	m_2s_1	m_2s_2	m_2s_3	$M_2 = \sum_{j=1}^{j=3 \text{ or } 2} m_2s_j$
	. .	. . .	. .	
M_{12}	$m_{12}s_j$	$m_{12}s_j$	$m_{12}s_j$	$M = \sum_{j=1}^{j=3 \text{ or } 2} m_{12}sj$
Total	S_1 $\sum_{i=1}^{i=12} m_is_1$	S_2 $\sum_{i=1}^{i=12} m_is_2$	S_3 $\sum_{i=1}^{i=12} m_is_3$	

$$\text{Month x Station S.S.} = \left(\sum_{\substack{i=1\\j=1}}^{\substack{i=12\\j=3 \text{ or } 2}} m_is_j\right) \Bigg/ \left\{(2) - (\text{C.F.}) - (\text{Month S.S.} + \text{Station S.S.})\right\}$$

Error S.S. = (Total S.S.) -- (Year S.S. + Station S.S. + Month S.S.) + (Year x Station interaction S.S.) + (Year x Month interaction S.S.) + (Station x Month interaction S.S.)

ANOVA for character :				
Source of variation (S.V.)	Degree of feedom (d.f.)	Sum of Square (S.S.)	Mean sum of Square (M.S.) = (S.S.)/(d.f.)	Calculated 'F' = M.S. at each level /M.S. at zero level
Years (Y)	1			
Stations (St)	2 or 1			
Months (M)	11			
Year x Station	2 or 1			
Year x Month	11			
Station x Month	22 or 11			
Error (E)	22 or 11			
Total	71 or 47			

FOUR WAY OF CLASSIFICATIONS

MODEL – I

Station = St
Season = S
Depth = D
Instar = IS

Instar					St_1									St_2									St_3					Total
		S_1			S_2			S_3			S_1			S_2			S_3			S_1			S_2			S_3		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	
IS_1	$X_{1.1}$	$X_{1.2}$	$X_{1.3}$	$X_{1.4}$	$X_{1.5}$	$X_{1.6}$	$X_{1.7}$	$X_{1.8}$	$X_{1.10}$	$X_{1.11}$	$X_{1.12}$	$X_{1.13}$	$X_{1.13}$	$X_{1.14}$	$X_{1.15}$	$X_{1.16}$	$X_{1.17}$	$X_{1.18}$	$X_{1.19}$	$X_{1.20}$	$X_{1.21}$	$X_{1.22}$	$X_{1.23}$	$X_{1.24}$	$X_{1.25}$	$X_{1.26}$	$X_{1.27}$	
IS_2	$X_{2.1}$	$X_{2.2}$	$X_{2.3}$	$X_{2.5}$	$X_{2.5}$	$X_{2.6}$	$X_{2.7}$	$X_{2.8}$	$X_{2.9}$	$X_{2.10}$	$X_{2.11}$	$X_{2.12}$	$X_{2.13}$	$X_{2.14}$	$X_{2.15}$	$X_{2.16}$	$X_{2.17}$	$X_{2.18}$	$X_{2.19}$	$X_{2.20}$	$X_{2.21}$	$X_{2.22}$	$X_{2.23}$	$X_{2.24}$	$X_{2.25}$	$X_{2.26}$	$X_{2.27}$	
IS_5	$X_{5.1}$	$X_{5.2}$	$X_{5.3}$	$X_{5.4}$	$X_{5.5}$	$X_{5.6}$	$X_{5.7}$	$X_{5.8}$	$X_{5.9}$	$X_{5.10}$	$X_{5.11}$	$X_{5.12}$	$X_{5.13}$	$X_{5.14}$	$X_{5.15}$	$X_{5.16}$	$X_{5.17}$	$X_{5.18}$	$X_{5.19}$	$X_{5.20}$	$X_{5.21}$	$X_{5.22}$	$X_{5.23}$	$X_{5.24}$	$X_{5.25}$	$X_{5.26}$	$X_{5.27}$	Grand Total G. T.

$$\text{C.F.} = \left(\sum_{\substack{j=1\\ i=1}}^{\substack{j=27\\ i=5}} X_{ij}\right)^2 \Big/ 540$$

$$\text{Total S.S.} = \left(\sum_{\substack{j=1\\ i=1}}^{\substack{j=27\\ i=25}} X_{ij}^2\right) \Big/ - \text{C.F.}$$

MODEL – II

Instar/Season	S_1	S_2	S_3	Total
IS_1	slisl	$s_2$isl	$s_3$isl	$IS_1 = \sum_{i=1}^{i=3} s_i is_1$
IS_2	slis$_2$	s_2is_2	s_3is_2	$IS_2 = \sum_{i=1}^{i=3} s_i is_2$
IS_5	slis$_5$	s_2is_5	s_3is_5	$IS_5 = \sum_{i=1}^{i=3} s_i is_5$
Total	S_1 $\sum_{j=1}^{j=5} s_i isj$	S_2 $\sum_{j=1}^{j=5} s_i isj$	S_3 $\sum_{j=1}^{j=5} s_i isj$	

$$\text{Instar S.S.} = \left(\sum_{j=1}^{j=5} isj^2\right) \Big/ \left\{(108) - (\text{C.F.})\right\}$$

$$\text{Season S.S.} = \left(\sum_{i=1}^{i=3} si^2\right) \Big/ \left\{(180) - (\text{C.F.})\right\}$$

$$\text{Instar x Season S.S.} = \left(\sum_{\substack{i=1\\j=1}}^{\substack{j=5\\i=3}} s_i is_j^2\right) \Big/ \left\{(36) - (\text{C.F.}) - \text{Instar S.S.} + \text{Season S.S.}\right\}$$

MODEL – III

Station/Season	S_1	S_2	S_3	Total
St_1	s_1st_1	s_2st_1	s_3st_1	$St_1 = \sum_{i=1}^{i=3} s_ist_1$
St_2	s_1st_2	s_2st_2	s_3st_2	$St_2 = \sum_{i=1}^{i=3} s_ist_2$
St_3	s_1st_3	s_2st_3	s_3st_3	$St_3 = \sum_{i=1}^{i=3} s_ist_3$
Total	$S_1 \sum_{j=1}^{j=3} s_1st_j$	$S_2 = \sum_{j=1}^{j=3} s_1st_j$	$S_3 = \sum_{j=1}^{j=3} s_1st_j$	

$$\text{Station S.S.} = \left(\sum_{j=1}^{j=3} st_j^2\right) \Big/ \left\{(180) - (\text{C.F.})\right\}$$

$$\text{Station x season S.S.} = \left(\sum_{\substack{i=1\\j=1}}^{\substack{j=3\\i=3}} s_ist_j^2\right) \Big/ \left\{(60 - (\text{C.F.})) - (\text{Station S.S.} + \text{Year S.S.})\right\}$$

MODEL – IV

Depth/Season	S_1	S_2	S_3	Total
D_1	s_1d_1	s_2d_1	s_3d_1	$D_1 = \sum_{i=1}^{i=3} s_id_1$
D_2	s_1d_2	s_2d_2	s_3d_2	$D_2 = \sum_{i=1}^{i=3} s_id_2$
D_3	s_1d_3	s_2d_3	s_3d_3	$D_3 = \sum_{i=1}^{i=3} s_id_3$
Total	$S_i = \sum_{j=1}^{j=3} s_id_j$	$S_2 = \sum_{j=1}^{j=3} s_2d_j$	$S_3 = \sum_{j=1}^{j=3} s_3d_j$	

$$\text{Depth S.S.} = \sum_{j=1}^{j=3} s_id_j^2 \Big/ \left\{(180) - (\text{C.F.})\right\}$$

$$\text{Depth} \times \text{Season S.S.} = \sum_{\substack{i=1\\j=1}}^{\substack{j=3\\i=3}} s_id_j^2 \Big/ \left\{(60) - (\text{C.F.}) - (\text{Depth S.S.} + \text{Season S.S.})\right\}$$

MODEL – V

Instar/Depth	D_1	D_2	D_3	Total
IS_1	is_1d_1	is_1d_2	is_1d_3	$IS_1 \sum_{i=1}^{i=3} is_1d_i$
IS_2	is_2d_1	is_2d_2	is_2d_3	$IS_2 = \sum_{i=1}^{i=3} is_2d_i$
IS_3	is_3d_1	is_3d_2	is_3d_3	$IS_3 = \sum_{i=1}^{i=3} is_3d_i$
IS_5	is_5d_1	is_5d_2	is_5d_3	$IS_5 = \sum_{i=1}^{i=3} is_5d_i$
Total	$D_1 = \sum_{j=1}^{j=5} is_jd_1$	$D_2 = \sum_{j=1}^{j=5} is_jd_2$	$D_3 = \sum_{j=1}^{j=5} is_jd_3$	

$$\text{Instar x Depth S.S.} = \sum_{\substack{i=1\\j=1}}^{\substack{j=5\\i=3}} d_i isj^2 \Big/ \left\{(36) - (\text{C.F.}) - (\text{Instar S.S.} + \text{Depth S.S.})\right\}$$

MODEL – VI

Station/Depth	D_1	D_2	D_3	Total
St_1	st_1d_1	st_1d_2	st_1d_3	$ST_1 = \sum_{i=1}^{i=3} d_i st_1$
St_2	st_2d_1	st_2d_2	st_2d_3	$ST_2 = \sum_{i=1}^{i=3} d_i st_2$
St_3	st_3d_1	st_3d_2	st_3d_3	$St_3 = \sum_{i=1}^{i=3} d_i st_3$
Total	$L_1 = \sum_{j=3}^{j=1} d_1 st_j$	$L_2 = \sum_{j=1}^{d_2 st_j} d_2 st_j$	$L_3 = \sum_{j=1}^{j=3} d_3 st_j$	

$$\text{Station x Depth S.S.} = \left(\sum_{\substack{i=1 \\ j=1}}^{\substack{i=3 \\ j=3}} d_i st_j^2 \right) \Big/ \Big\{ (60) - (\text{C.F.}) - (\text{Station S.S.} + \text{Depth S.S.}) \Big\}$$

MODEL – VII

Instar/Station	ST_1	ST_2	ST_3	Total
IS_1	st_1is_1	st_2is_1	st_3is_1	$IS_1 = \sum_{i=1}^{i=3} st_iis_1$
IS_2	st_1is_2	st_2is_2	st_3is_2	$IS_2 = \sum_{i=1}^{i=3} st_iis_2$
IS_5	st_1is_5	st_2is_5	st_2is_5	$IS_5 \sum_{i=1}^{i=3} st_iis_5$
Total	$ST_1 = \sum_{j=1}^{j=5} st_1is_j$	$ST_2 = \sum_{j=1}^{j=5} st_2isj$	$ST_3 = \sum_{j=1}^{j=5} st_3is_j$	

$$\text{Station x Instar S.S.} = \sum_{\substack{i=1\\j=1}}^{\substack{j=5\\i=3}} st_jisj \Big/ \{(36) - (\text{C.F.}) - (\text{Station S.S.} + \text{Instar S.S.})\}$$

Error S.S. = {(Total S.S.) – (Season S.S.) + (Depth S.S.) + (Instar S.S.) + (Station S.S.) + (Season x Instar interaction S.s.) + (Instar x Depth interaction S.S.) + (Depth x Season interaction S.S.) + (Station x Depth interaction S.S.) + (Station x Season interaction S.S.) + (Station x Instar interaction S.S.).}

ANOVA for characters:

Source of variation (S.V.)	Degree of freedom (d.f.)	Sum of square (S.S.)	Mean sum of square (M.S.)	Calculated 'F' =M.S. at each/ M.S. at error level
Seasons (S)	2			
Depths (D)	2			
Instars (IS)	4			
Stations (ST)	2			
(S × IS)	8			
(IS × D)	8			
(D × S)	4			
(ST × D)	4			
(ST × S)	4			
(ST × IS)	8			
Error	493			
Total	539			

OBSERVATION AND RESULTS

Ecological parameters :

Temperature :

The soil and air temperature recorded in the morning hours showed a more or less parallel trend of variation throughout the year in all stations (St. I, II, III). The air temperature varied from 21.5°C-35.2°C in St. I, 21.8°C-36.0°C in St. II and 21.3°C-34.5°C in St. III (Figs 4, 5 and 6). The soil temperature variables at all stations through seasons were also distinctly pronounced. During the course of study the maximum and minimum soil temperatures were 34.4°C and 20.8°C in St. I, 35.1°C and 21.6°C in St. II and in St III 33.7°C and 20.5°C. The range of variation during the years 1982-1983 and 1983-1984 has been presented in Figs. 4, 5 and 6. Variation of soil temperature was found satistically significant over months, year and also stations (Table 1).

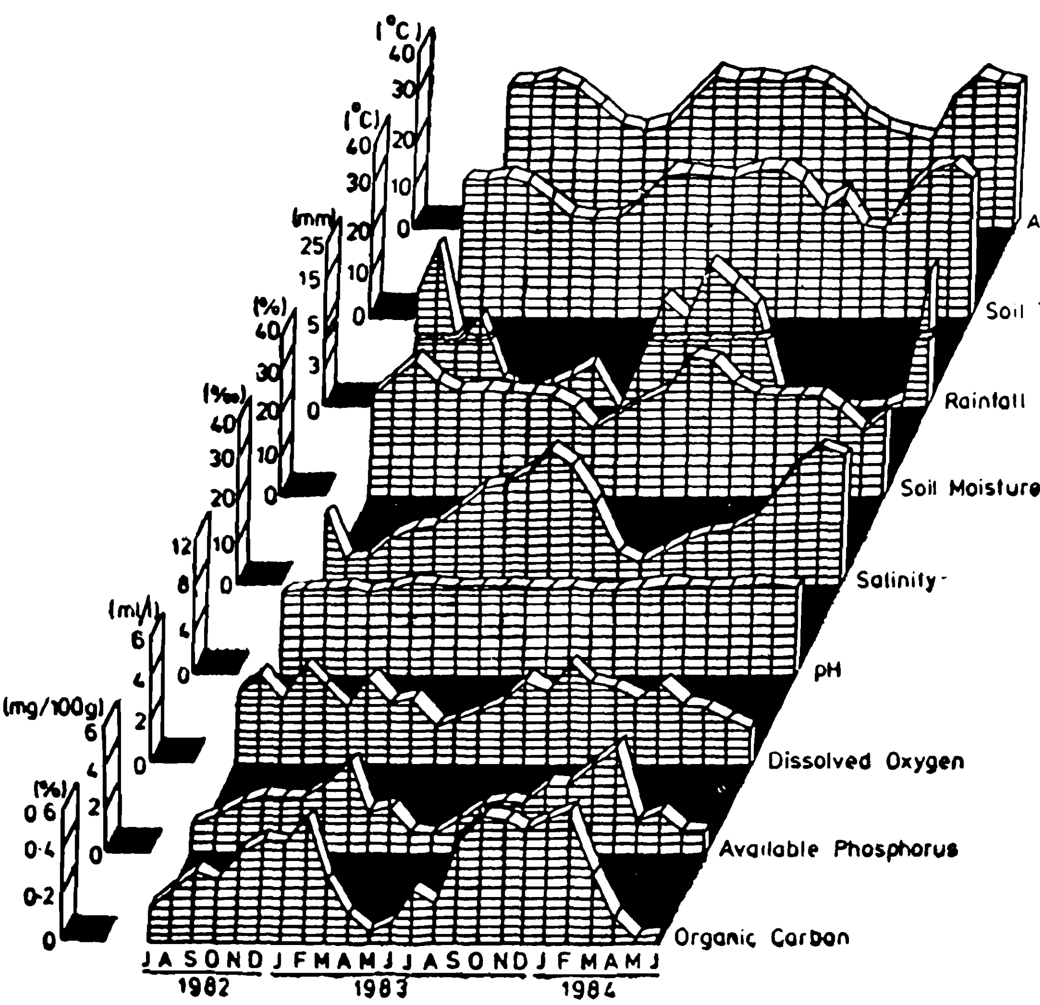

Fig. 4. Monthly fluctuations of different ecological parameters at station I.

Soil temperature of different depths (0-3 cm, 3-6 cm and 6-9 cm) in three stations during March 1983 to February 1984 was also documented (Fig. 7). Temperature record was always higher in the surface layer (0-3 cm) but showed a trend of gradual declination in subsequent depths at all stations. The maximum and minimum temperatures at all depths (0-3 cm, 3-6 cm and 6-9 cm) of three stations have been presented in Fig. 7.

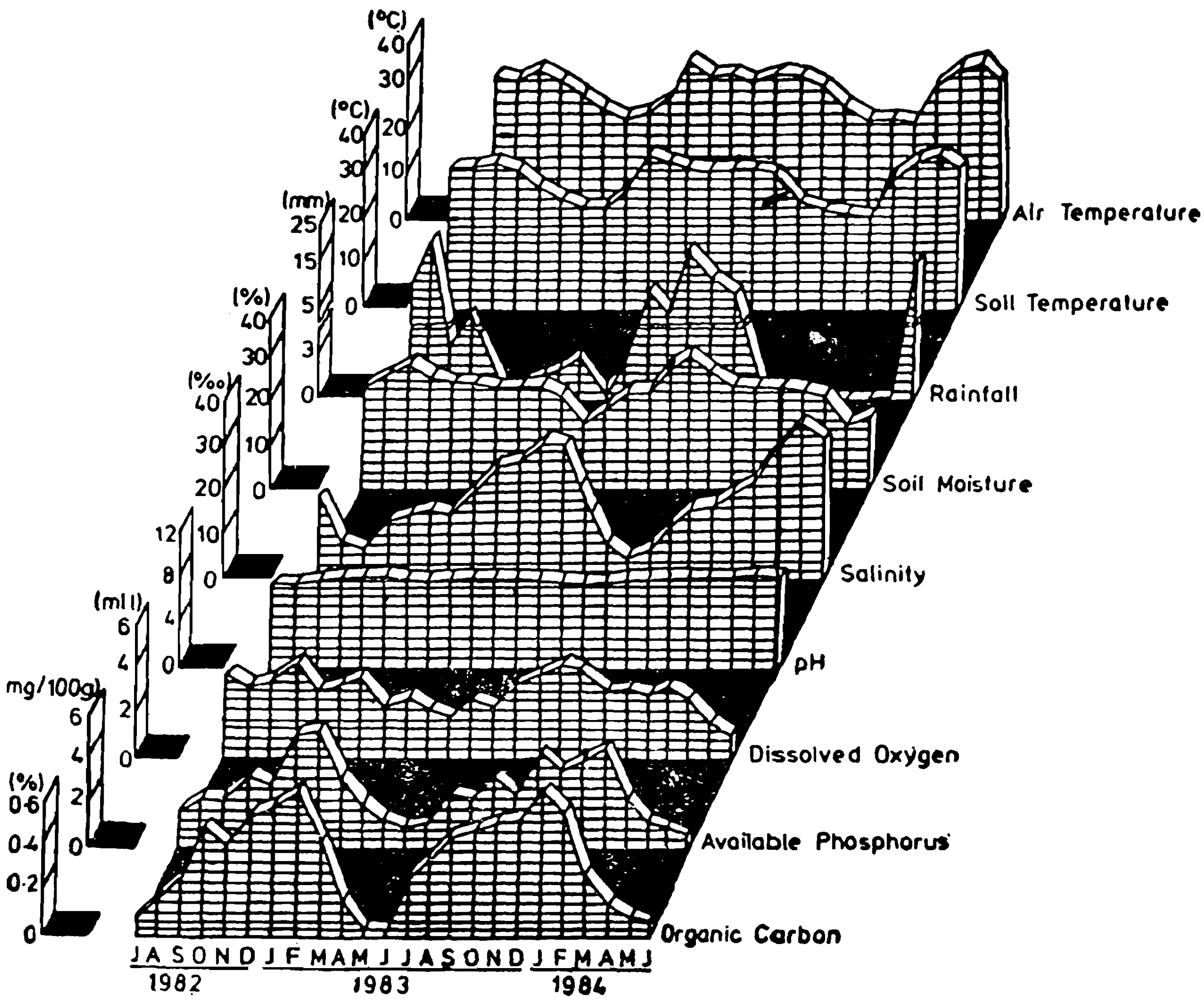

Fig. 5. Monthly fluctuations different ecological parameters at station II. (See also Table 1A)

Soil moisture :

Soil moisture of this dynamic environment is one of the most important factor which is subjected to profound variation (Figs 4, 5 and 6). In St. I it varied from 15%-31.8% in St. II it was 14.7%-30.0% and in St. III it was 15.3%-28.6% during the study period. The results of ANOVA test showed that this factor varied significantly over months and stations (Table 1).

Soil moisture of three depths (0-3 cm, 3-6 cm and 6-9 cm) in all stations were measured during March, 1983 to February, 1984 (Fig 7). It was maximum in September and minimum in May in all the depths. The recorded values were 33.7%, and 14.7%, 31.5% and 15.1%, 30.3% and 15.6% in St. I, 32.2% and 14.2%, 29.8% and

14.5%, 28.9% and 15.3% in St. II, and in St. III these were 34.4% and 15.0%, 26.9% and 15.8% and 24.6% and 16.0% respectively.

Salinity :

It is well known that the salinity in the open marine environment does not show any conspicuous variation. The factors affecting are minimum compared to its vast water masses. But in the estuarine environment, the salinity is affected greatly by additional freshwater efflux from the upstream river and surface run off during monsoon every year.

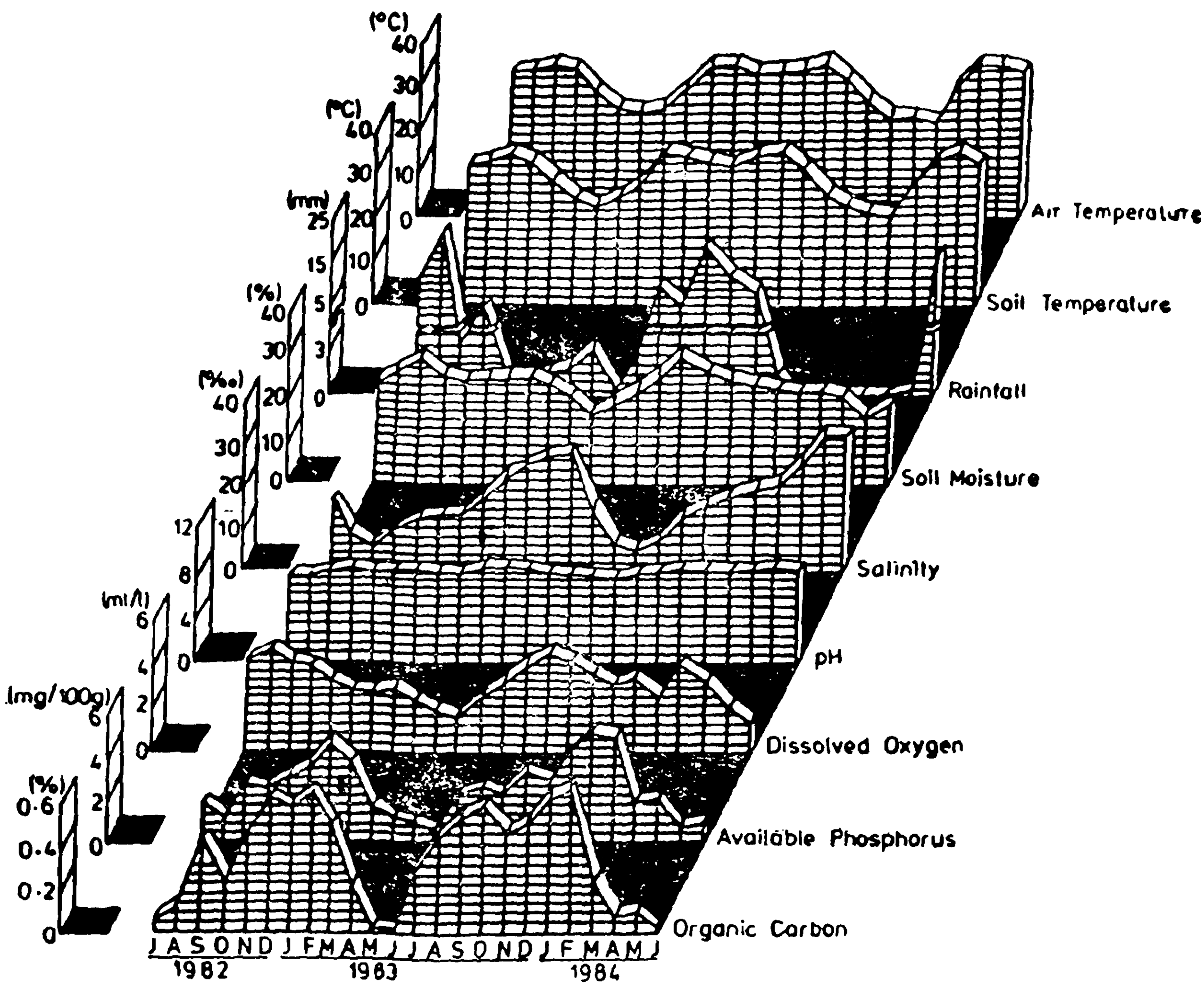

Fig. 6. Monthly fluctuations of different ecological parameters at station III. (See also Table 1A)

The maximum and minimum salinity record in St. I were 32.4‰ in may, 1984 and 5.0‰ in September, 1984 and in St. II 35.1‰ in May, 1984. In St. III the peak value 31.5‰ was attained also during May, 1984 and lowest value 5.0‰ in September, 1984 (Figs. 4, 5 and 6). Analysis of variance showed that salinity varied significantly over months and stations (Table 1).

The pattern of change in salinity was maximum in the premonsoon months which accounts no rain but higher temperature and evaporation, and was minimum in the monsoon months being affected by the south-west monsoon accompanied by heavy rains. The post-monsoon period may be considered a mixed period because the water is somewhat diluted with the just over monsoonal rain, followed by the winter months with minimum record of temperature and precipitation. During this period the salinity gradient kept a gradual rising trend and attained a maximum value through the premonsoon months.

The interstitial water showed higher salinity values than in the adjacent flood water of the estuary during the premonsoon and post-monsoon periods because of the evaporation of the capillary water during the dry seasons. During monsoon, the values were low due to the infiltration of excess fresh water.

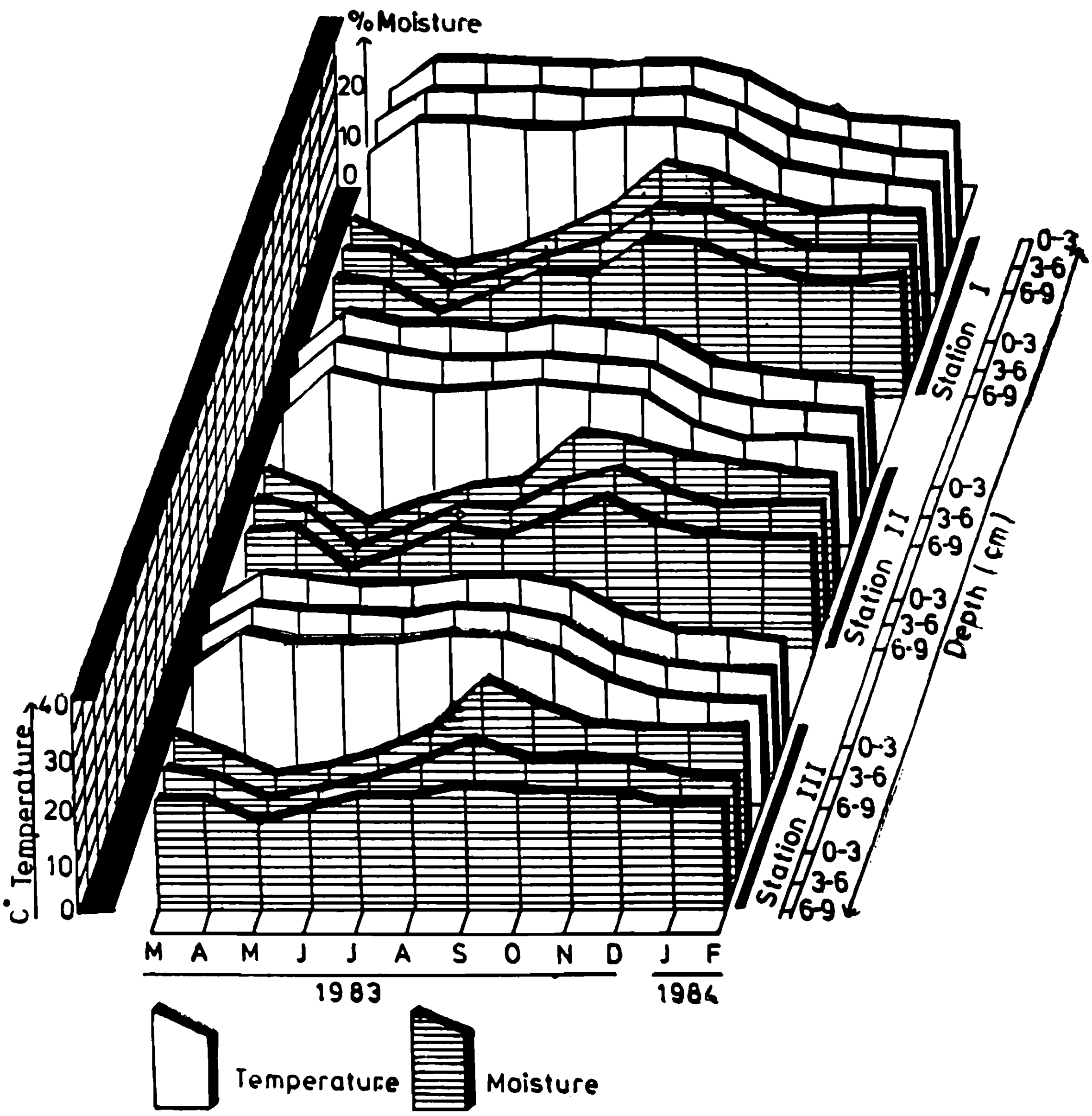

Fig. 7. Monthly fluctuations of soil temperature and moisture in different depths at station I, II and III.

Precipitation :

The data obtained from Alipore meterological station revealed that during the study period the rainfall at Sagar Island was maximum during monsoon months which gradually decreased towards the postmonsoon months and then there was a sporadic fall during the premonsoon months (except June) (Figs. 4, 5 and 6).

Maximum value (659.4 mm) was recorded in August, in the first year. During the second year the highest value (560.4 mm) was also obtained in August.

Analysis of variance (Table 1) shows that there is a significant and sharp variation of rainfall over months but not over the years.

Dissolved Oxygen :

The dissolved oxygen did not show any sharp range of fluctuation during the period 1982-1984. The concentration of dissolved oxygen in the tidal flats showed a variation range from 1.7 ml/l to 4.7 ml/l, 1.1 ml/l to 4.3 ml/l and 1.3 ml/l to 4.6 ml/l in St. I, St. II and St. III respectively (Figs 4, 5 and 6).

ANOVA results display that the values are significant only over months (Table 1).

pH :

pH remained almost constant throughout the year with minor fluctuation in the monsoon months when the dilution brought pH to a minimum (7.7) to the fresh water level. The maximum values at St. I, St. II and St. III were 8 3, 8.4 and 8.4 respectively and minimum 7.7 in all stations (Figs. 4, 5 and 6).

The values of analysis of variation showed a significant result over the months (Table 1).

Organic carbon :

The pattern of change in the organic carbon content of the soil at all the three stations was very distinct as is evident from the figures (Figs. 4, 5 and 6). During the course of study from July, 1982 to June, 1984 the maximum and minimum organic carbon in the soil at St. I, St. II and St. III were 0.60% and 0.03%, 0.66% and 0.03%, 0.64% and 0.02% respectively.

Analysis of variance (Table 1) shows that there was a significant and sharp variation in concentration of organic carbon over different months and years.

Available phosphorus :

This soil nutrient was also subjected to profound variation, every year the nutrient increased to a maximum during postmonsoon and decreased during premonsoon. At St. I it varied from 0.89 mg/100 gm-4 95 mg/100 gm, at St. II 0,76 mg/100 gm-5.31 mg/100 gm and at St III it was 0.68 mg/100 gm-5.12 mg/100 gm during the study period (Figs. 4, 5 and 6).

The analysis of variance showed significant distinction over the months and years (Table 1)

Soil texture :

Textural condition of soil at all stations remained almost constant throughout the year with minor fluctuation due to cyclonic action and tidal overwash (Fig 8).

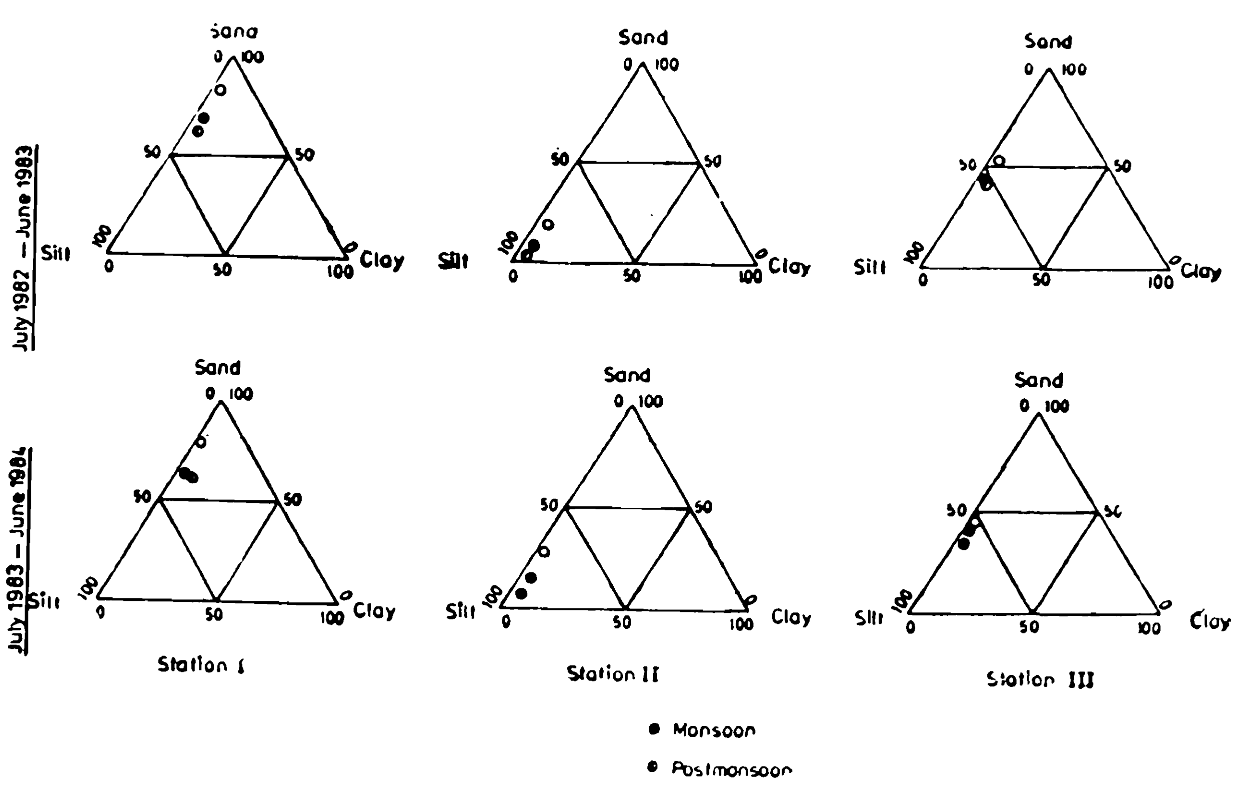

Fig. 8. Percentage of sand, silt and clay during different seasons at station I, II and III.

At St. I sand was the major constituent of soil followed by silt and clay, sand percentage was recorded maximum during premonsoon period, values were 82.6% and 78.3% during 1982-1983 and 1983-1984 respectively. Maximum and minimum percentage of silt in this station were 33.5% during postmonsoon and 15.5% during premonsoon respectively. Clay was found to be minimum in the soil of this station ; the maximum and minimum recorded values were 4.8% and 0.9% during postmonsoon and premonsoon respectively.

Soil texture of St. II was composed mainly by silt and followed by sand and clay. The highest and lowest values of silt content were observed during postmonsoon and premonsoon respectively. The silt content of this field showed a variation range from 69.1% to 93.2%. The maximum and minimum ranges of sand and clay were 27.4% to 2.9% and 4.6% to 3.5% respectively.

At St III the texture of the soil was composed of sand and silt ; clay percentage was minimum. The higher percentage of sand was noticed during the premonsoon month, and during postmonsoon the silt percentage was maximum. The range of varation of sand, silt and clay were 35.5%-53.7%, 43.1%-61.2% and 0.8%-4.3% respectively.

Correlation among ecological parameters :

The results are shown in table 2. Correlation ccefficient among the different parameters documented at the three stations display that soil temperature is significantly (at 5% level) correlated with rainfall at all stations ; soil temperature with organic carbon and available phosphorus of soil are always negatively correlated (significant at 1% level).

The relationship of soil moisture with salinity and pH is also significantly high and negative (at 1% level) but positive (at 1% level) with dissolved oxygen and organic carbon at all the stations. Positive correlation between soil moisture and available phosphorus was observed only in St. II and St III.

So far rainfall and pH are concerned, they always show negative correlation at all stations Negative correlation (at 5% level) of rainfall with available phosphorus was also noticed at St. I and St. III.

Both positive and negative correlation were observed between salinity and different parameters ; with pH was highly positive (at 1% level), but negatively correlated with dissolved oxygen, organic carbon and available phosphorus at all the stations.

Dissolved oxygen was found to be negatively correlated (at 1% level) with pH at all the stations and positively with organic carbon and available phosphorus at St. I and St. II,

Significant (at 1% level) positive correlation was registered at all stations between organic carbon and available phosphorus.

Quantitative assessment of benthic dipterans :

The population of estuarine littoral dipterans experience a peculier and varying seasonal conditions due to various physical and biological phenomena. The present observation was based on the seasonal or episodic changes, composition and abundancc of littoral dipteran insects in relation to important ecological variables in three stations of Sagar Island, during July, 1982 to June 1984,

Dipterans inhabiting the littoral zones of these stations displayed conspicuous monthly variation in their faunistic structure as well as in abundance. Besides this, some species showed their occasional appearance and few were transient.

In total, 17 species belonging to 5 families and 12 genera have been quantitatively assessed in the present investigation.

At St, I, 14 species of dipterans have been recorded of which eight species viz., *Culicoides pelilíouensis*, *Culicoides oxystoma*, *Culicoides similis*, *Bezzia albicornis*, *Alluaudomyia formosana*, *Forcipomyia murina*, *Dasyhelea* sp. 1, sp. 2 under the family ceratopogonidae, one species each viz., *Chironomus barbatitarsis* and *Psychoda nigripennis* under the family chironomidae and psychodidae, two species viz., *Notiphila* sp. and *Brachydeutera longipes* under the family ephydridae and *Atylotus agrestis* and Tabanus striatus under the family tabanidae.

A total of 14 species have been recorded in St. II. All species as mentioned in St. I are also present in St. II except *Dasyhelea* sp. 2 and *Culicoides similis* but in this station *Alluaudomyia maculosipennis* and *Dasyhelea* borbonica are the new representatives of the famiiy.

In St III species have been recorded other than *Dasyhelea* spp. and *Alluaudomyia maculosipennis*, all species under the family ceratopogonidae as recorded in St. I and St. II are present in this station but *Nilobezzia* sp. is the new addition to the list. Species of other families have also been recorded as in St. I and St. II.

In all stations, ceratopogonids constitute the most dominant faunal component and followed by ephydrids, tabanids, chironomids and psychodids

Assessment of different dipteran species at different stations :

Culicoides pelilioueusis

This species was the most dominant one which was recorded throughout the year and maximum number were counted during post-monsoon and minimum during premonsoon. The range of minimum and maximum number of this species in St. I, II and III were 18,0 to 71.6, 8.1 to 62.3, 13.5 to 57.2 during 1982, 1983 and 9.1 to 87.0, 6.5 to 90.2, 6.2 to 82.4 during 1983, 1984 respectively (Figs, 9, 10 and 11).

The results communicated above established the concept that the veriations of this species were found to be statistically significant over months and stations (Table 3).

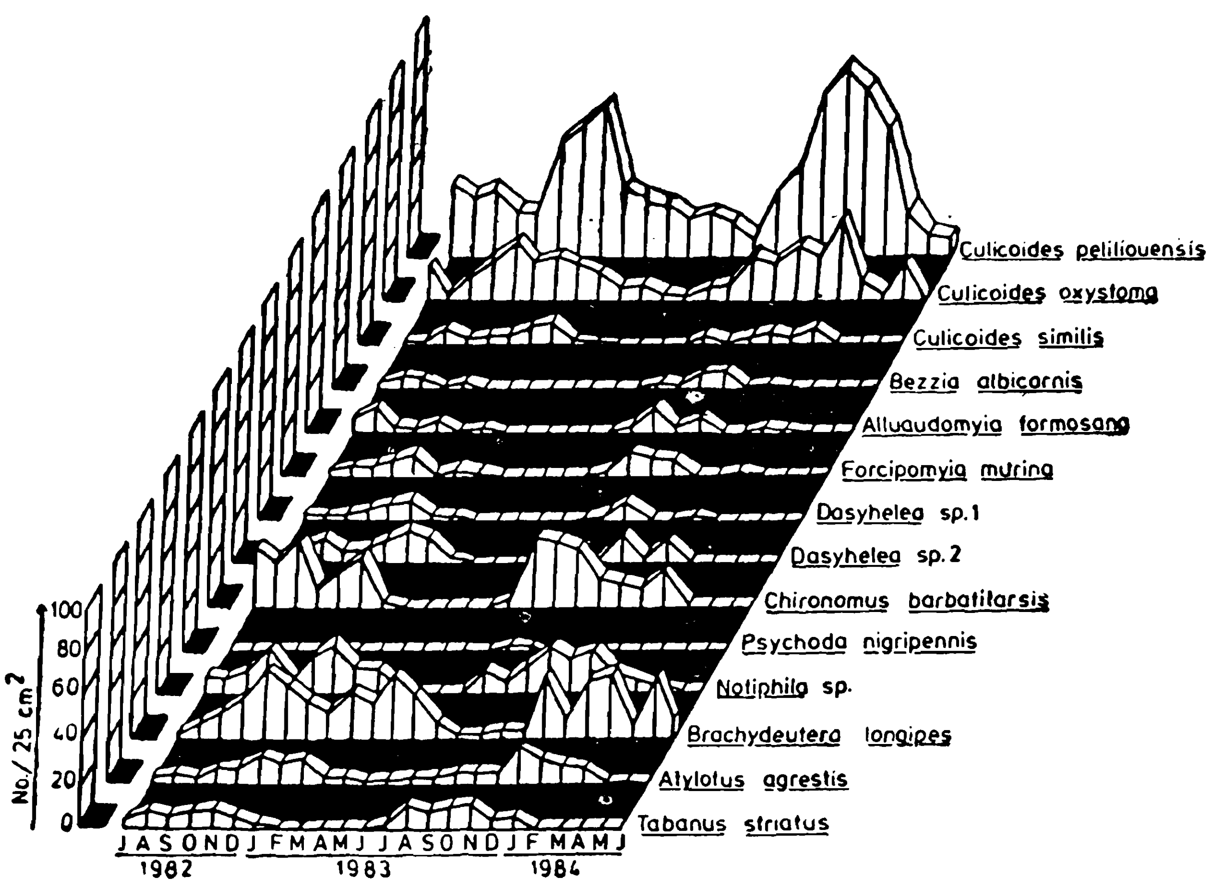

Fig. 9. Monthly fluctuations of different dipteran species at station I.

Culicoides oxystoma

This was also a dominant species recorded almost throughout the year, maximum and minimum range in numbers at the St. I, II and III were 41.2 to 1.5, 46.1 to 0 and 55.5 to 2.5 respectively (Figs 9, 10 and 11). During the study period the rise of population was recorded higher in the postmonsoon and lower during the premonsoon months.

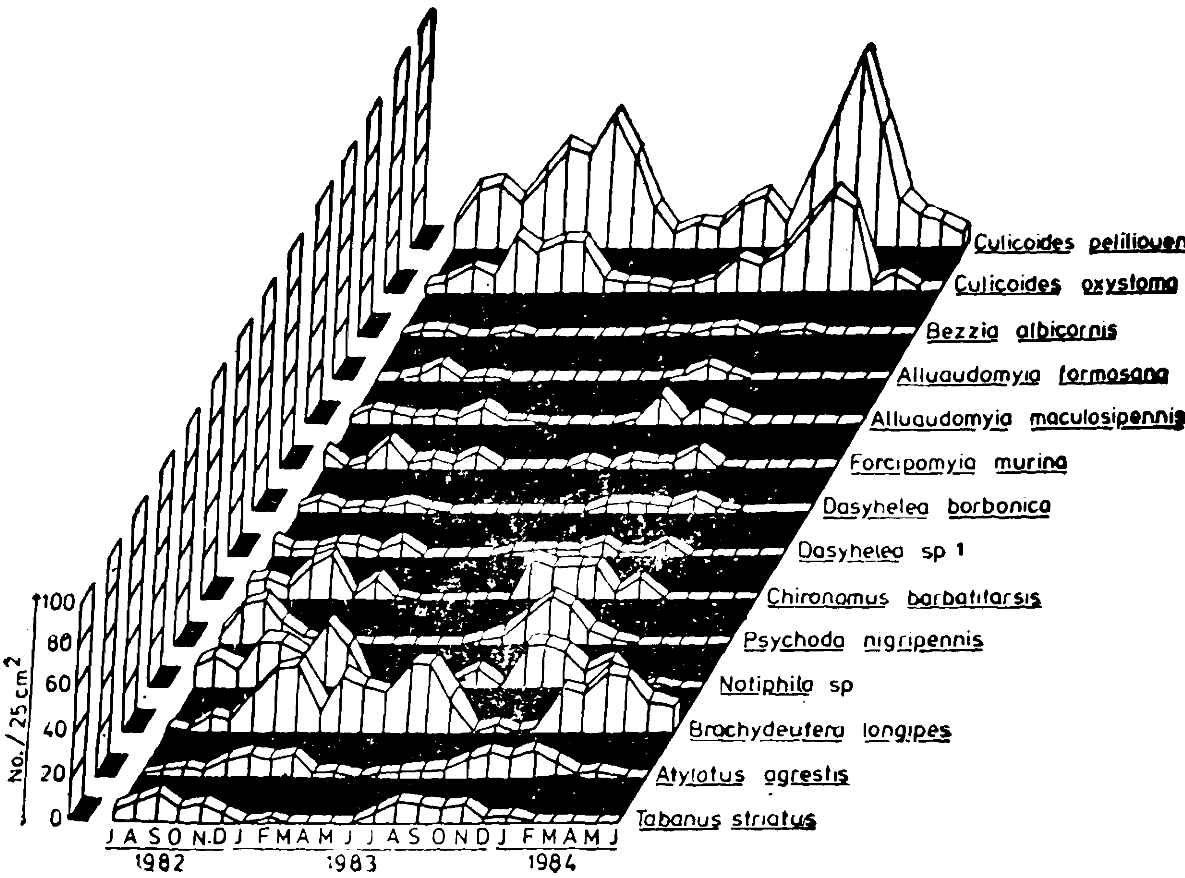

Fig 10. Monthly fluctuations of different dipteran species at station II. (See also Table 2A)

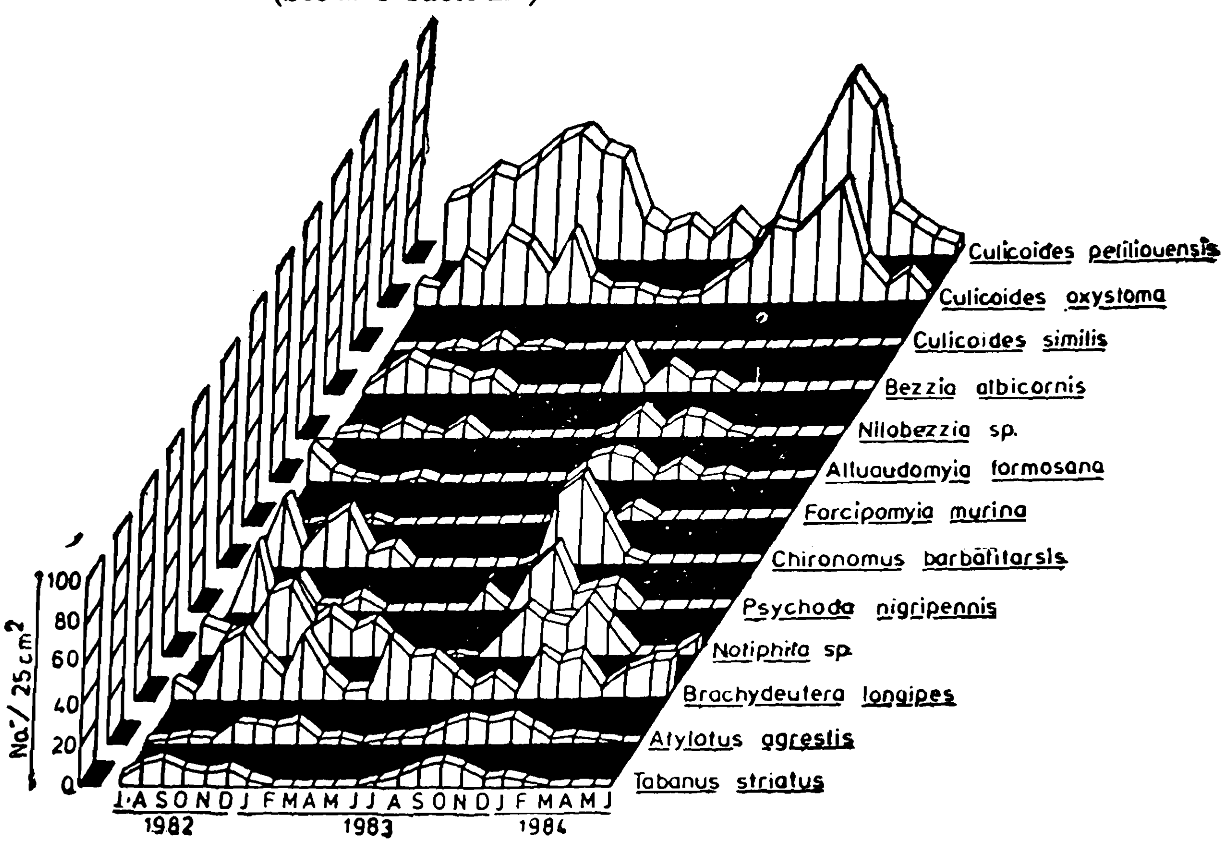

Fig. 11. Monthly fluctuations of different dipteran species at station III. (See also Table 2A)

Results of ANOVA test showed that the population of this species varied significantly over months, years and stations (Table 3).

Vertical distribution of larval and pupal stages of the two species, *Culicoides pelilíouensis* and *Culicoides oxystoma* :

Different stages of larvae and pupae were sampled from March, 1983 to February, 1984 from three depths (0-3 cm, 3-6 cm and 6-9 cm). They were encountered througout the year from 0-3 cm depth at all the three stations except during summer months (April, May and June) (Table 4 and Figs. 12 and 13).

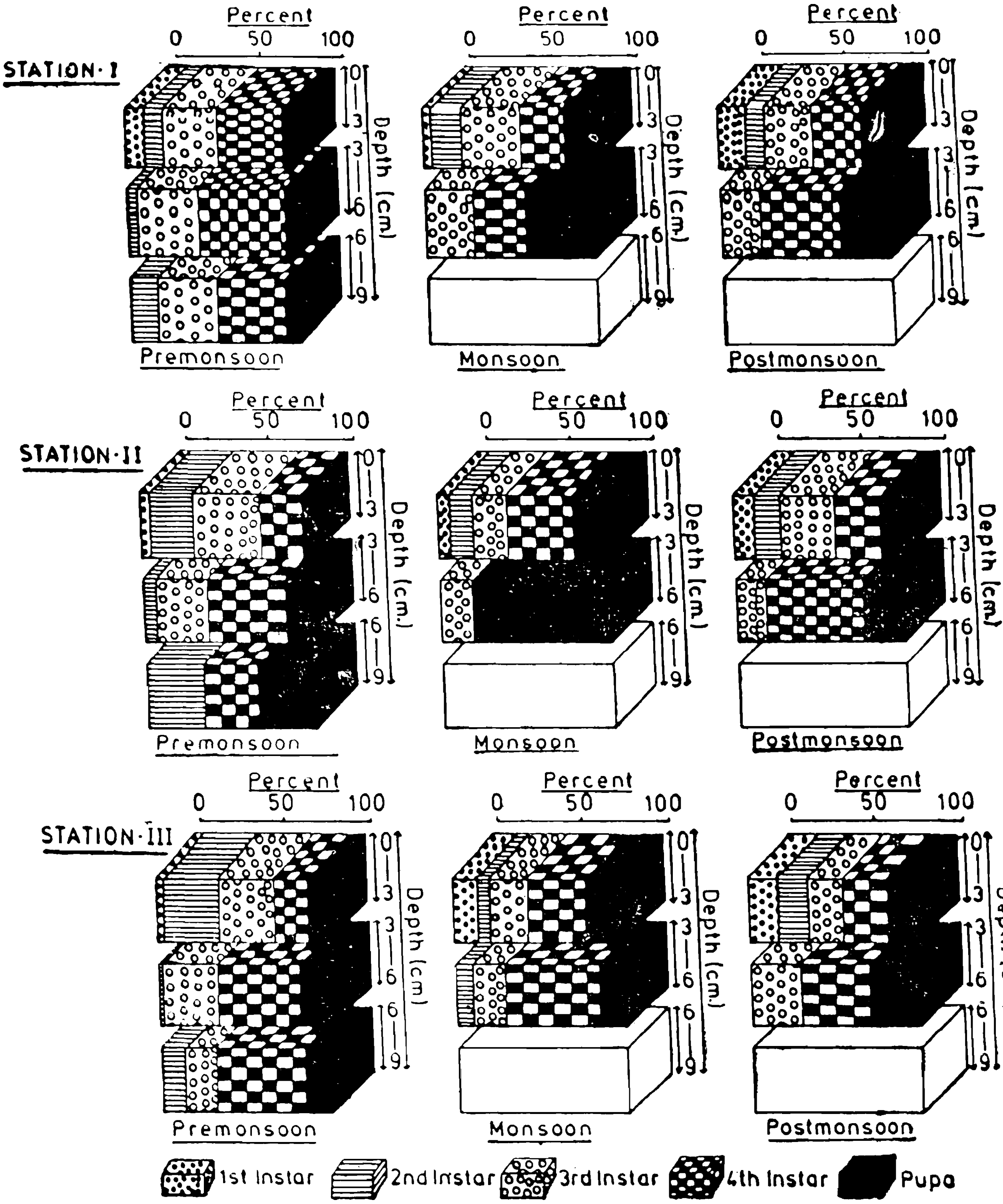

Fig. 12. Vertical distribution of different immature stages of *Culicoides pelilíouensis* during different seasons at station I, II and III.

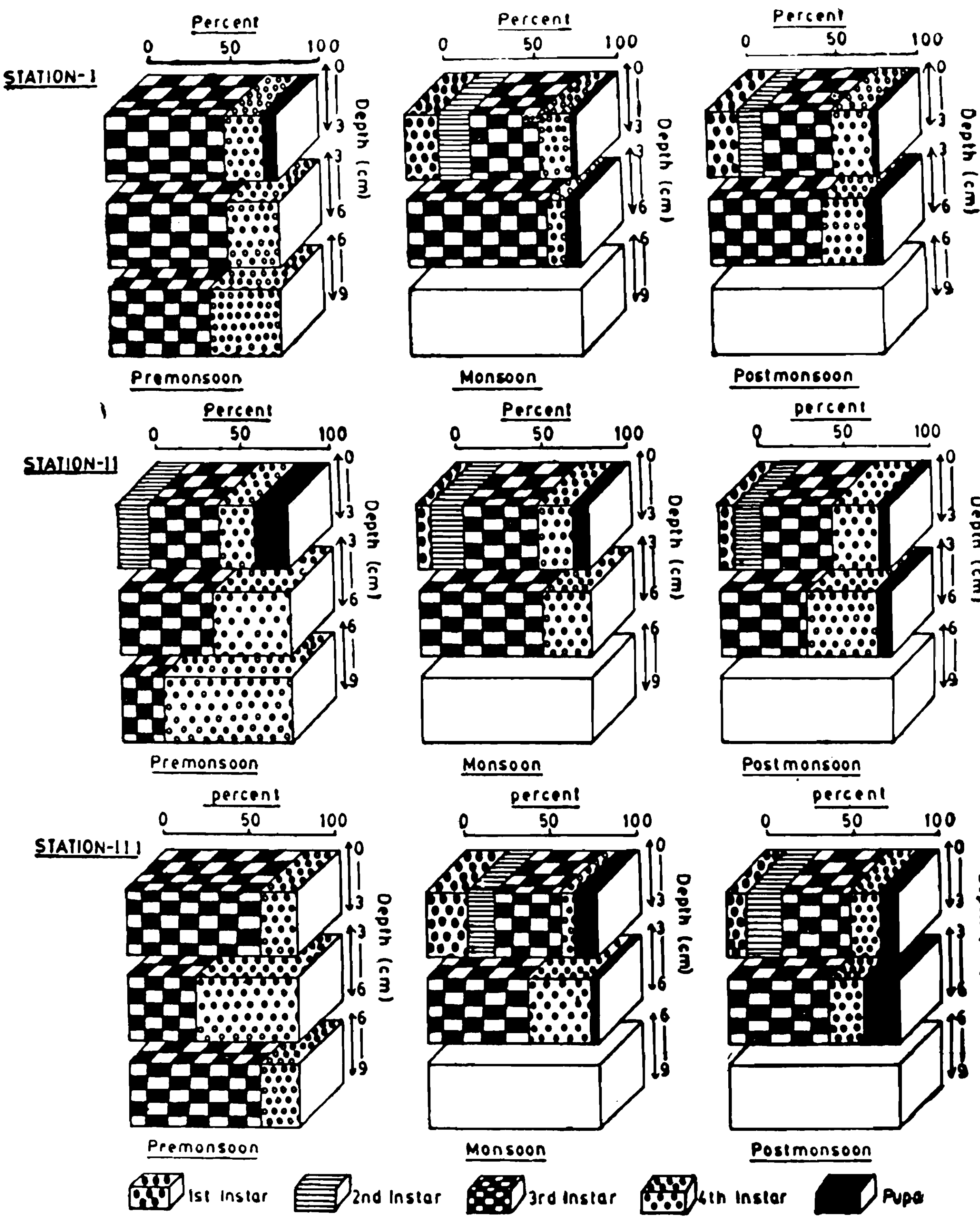

Fig. 13. Vertical distribution of different immature stages of *Culicoides oxystoma* during different seasons at station I, II and III.

First instar larvae were the most limited ones in their distribution, exclusively examined from the surface soil (0-3 cm).

Second instar larvae of both the species were also observed in 0-3 cm depth but on some rare occasion few 2nd instar larvae of *C. pelilioueusis* were collected below the the surface soil (3-6 cm).

The number of 3rd and 4th instar larvae of these species were maximum in the collected samples more or less throughout the year and they were distributed in all depths, maximum in 0-3 cm, followed by 3-6 cm and 6 9 cm. But during summer they were absent in the sarface soil.

Pupal abundance of both the species wéře also maximum in 0-3 cm depth except in summer months, when their occurrence were recorded only from samples of greater depths (3-6 cm and 6-9 cm), though in lesser numbers.

ANOVA results display that the population values of both the species vary significantly over seasons, depths and instars but this trend was not noticed over the stations (Table 5).

Culicoides similis

This species was recorded from St. I during monsoon and post-monsoon but they were totally absent during premonsoon. Maximum number recorded was 10.5 in February, 1983 (Fig. 9), Few larvae were encountered at. St. III during postmonsoon in 1982 and 1983 but rest of the year they were totally absent (Fig 11). At St. II they were totally absent.

Analysis of variance showed that *C. similis* varies significantly over months, years and stations (Table 3).

Bezzia albicornis

They were recorded only during the monsoon and early post-monsoon months at all the stations. Maximum number of the insects recorded in St. I, II and III were 8.0 in November, 1983, 4.5 in November, 1983, and 21.2 in July, 1983 respectively (Figs. 9, 10 and 11).

Analysis of variance (Table 3) demonstrates that there is a significant variation of this species over months and stations but the trend did not follow over the years.

Nilobezzia sp.

Documented only from St. III during monsoon and postmonsoon and its maximum number recorded was 13.2 in September, 1983 (Fig. 11).

From ANOVA results it is clear that this species varies significantly neither over months nor over the years (Table 3).

Alluaudomyia formosana

This insect population was found to occur at all the stations during the monsoon and postmonsoon months. Maximum numbers recorded at St. I, II and III were 13.2 in September, 1983, 9.5 in October, 1983 and 17.3 in July, 1982 respectively (Figs. 9, 10 and 11).

Results of ANOVA display that the number of this species varies significantly over months and stations but not over the years (Table 3).

Alluaudomyia maculosipennis

Present were only at St. II during the monsoon and postmonsoon months and totally absent in other stations. The maximum number recorded was 16.0 in September, 1983 (Fig 10).

Analysis of variance showed that they varied significantly over months but not over the years (Table 3).

Forcipomyia murina

During monsoon and postmonsoon all the three stations were represented by this species. Their maximum numbers were 11.3 during September, 1983 at St. I, 14.3 during October, 1982 at St II and 8.4 during November, 1983 at St. III (Figs 9, 10 and 11).

The values of analysis of variance, as usual, showed a significant result over months and stations but not over the years (Table 3).

Dasyhelea borbonica

Recorded only from St. II during monsoon and postmonsoon. Their maximum number recorded was 7.0 in January, 1984 (Fig 10).

ANOVA results indicated that the variation of the number of species was insignificant over every aspects (Table 3).

Dasyhelea sp. 1

Other than the premonsoon months this dipteran species, supposed to be new to science, occurred througout the year at St. I and II. Maximum numbers recorded were 9.0 and 9.2 in October, 1983 at the Sts. I and II respectively (Figs. 9 and 10).

ANOVA test showed that the population of this species varies significantly over months, years and stations (Table 3).

Dasyhelea sp. 2

This dipteran species, also supposed to be new to science, was collected only from the St. I during monsoon and postmonsoon months. During premonsoon they were totally absent. Their maximum number recorded was 15.4 in January, 1983 (Fig. 9).

Results of ANOVA display that this species did not vary significantly over months and years (Table 3).

Chironomus barbatitarsis

This insect was the dominant species during monsoon at all the stations and was totally absent in premonsoon. Their maximum numbers recorded were 32 1 in September, 1982, 21.5 in November, 1982 and 42.6 in October, 1983 from the Sts I, II and III respectively (Figs. 9, 10 and 11).

From the ANOVA results it is clear that the number of this species varies significantly only over months but not over the years and stations (Table 3).

Psychoda nigripennis

Recorded during monsoon and postmonsoon months from the Sts. II and III. At St. I they were almost absent, few larvae were encountered during August and September, 1983. Maximum larvae counted were 22.2 in October, 1983 and 32.4 in August, 1982 from the stations II and III respectively.

ANOVA results indicated that the variation of this species was significant over months and years but not over the stations (Table 3).

Notiphila sp.

This insect, supposed to be new to science, was recorded almost throughout the year and from all the stations. They were abundant during postmonsoon and minimum in premonsoon. Maximum numbers recorded were 23.0 in January, 1983 and November, 1983, 31.1 in January, 1983 and 32.0 in November, 1982 from the stations I, II and III respectively (Figs. 9, 10 and 11).

ANOVA showed that this species varied significantly over months and years but not over the stations (Table 3).

Brachydeutera longipes

This species was collected throughout the year from all the three stations, maximum in late postmonsoon and early premonsoon seasons, the range of minimum and maximum numbers being 2.5 to 31.0 at St. I, 0 to 33.5 at St. II and 2.5 to 33.4 at St. III respectively (Figs. 9, 10 and 11).

ANOVA results display that this species varies significantly over months and years but not over the stations (Table 3).

Alylotus agrestis

Its presence was observed almost throughout the year at all the three stations, maximum during postmonsoon and minimum during premonsoon. Their maximum numbers were 16.0 in December. 1983 at St. I, 12.6 in November, 1983 at St. II and 12.0 in January, 1984 at St. III (Figs. 9, 10 and 11)

The results of ANOVA indicated that this species varied significantly only over months (Table 5).

Tabanus striatus

During monsoon and postmonsoon they were recorded at all the stations, but during premonsoon they were totally absent. Maximum numbers documented from Sts. I, II and III were 10.5 in November, 1983, 11.5 in September, 1982 and 13.0 in September, 1982 respectively (Figs. 9, 10 and 11).

From ANOVA test it is clear that this species varies significantly only over months but not over years and stations (Table 3).

Associated fauna :

The dominant among benthic associates were coleopteran insects and polychaetes. Among the coleopteran insects, staphylinids and carabids were the representative fauna. Four families, viz., capitalidae, neridae, glyceridae and lumbrineridae of polychaet were present.

Amphipods were recorded only from St. I. On rare occasions some siphunculids were encountered at St. II.

Algal forms :

Various algal species were found to occur at all the stations, viz., *Ulva* sp., *Enteromorpha* sp., *Vaucheria* sp., *Oscillatoria* sp., *Lyngbya* sp., *Catenella* sp., *Chaetomorpha* sp., and *Xenococcus* sp., These algae were recorded maximum during the postmonsoon months followed by monsoon and premonsoon.

Correlation coefficient among the different dipteran species :

Results showed both negative and positive correlation values (Table 6). The relationships among *Culicoides pelilouensis, C. oxystoma, C. similis, Dasyhelea* sp. 2., *Notiphila* sp., and *Atylotus agrestis* were always significantly positive at all the three stations.

The results also show more or less significant positive relationship among some species viz,, *Bezzia albicornis, Alluaudomyia formosana, A. maculosipennis, Forcipomyia murina, Dasyhelea borbonica, Dasyhelea* sp. 1., *Chironomus barbatitarsis, Psychoda nigripennis* and *Tabanus striatus.*

Significant positive results of *Brachydeutera longipes* with any other species were not found from any station.

Correlation coefficient of different dipteran species with different ecological parameters :

The results showed both positive and negative relation at all the stations (Table 7)

The relationship of soil temperature with *Culicoides pelilouensis, C. oxystoma, Notiphila* sp. and *Atylotus agrestis* are always negatively correlated (significant both at 1% and 5% level), but highly significant positive correlations are found with soil nutrients (organic carbon and available phosphorus) at all the stations.

The dipteran insects, *Bezzia albicornis, Nilobezzia* sp., *Alluaudomyia formosana, A. maculosipennis, Forcipomyia murina, Chironomus barbatitarsis, Psychoda nigripennis, Atylotus agrestis* and *Tabanus striatus* at all the stations, showed positive correlation with soil moisture and negative correlation with salinity, significant both at 1% and 5% levels.

Positive significant correlations between dissolved oxygen and some species have been recorded. Negative significant correlations have been observed between some species and pH.

Some species showed either positive or negative significant correlation between sand, silt and clay at all the stations.

Multiple regression analysis :

Combined effects of all ecological parameters on each species were almost always positive and significant at all the stations (Table-8) Combined effects on each species at all the stations were explained by the following equations.

Culicoides peliliouensis

(St. I) $\hat{Y} = -114.13-7.06X_1+4.79X_2-0.67X_3-0.04X_4-3.32X_5+36.47X_6-125.67X_7+2.65X_8$

(St. II) $\hat{Y} = 344.05-3.88X_1-1.01X_2-0.59X_3-0.73X_4-3.31X_5-18.35X_6+41.53X_7-6.60X_8$

(St. III) $\hat{Y} = 37.43-8.78X_1+2.33X_2-0.37X_3-3.59X_4-6.09X_5+34.31X_6-103.46X_7-28.92X_8$

Culicoides oxystoma

(St. I) $\hat{Y} = 290.22+0.75X_1-2.50X_2-0.52X_3+0.07X_4+5.77X_5-34.48X_6+43.99X_7+3.26X_8$

(St. II) $\hat{Y} = 49.22-2.20X_1-0.50X_2-0.51X_3-0.97X_4-1.82X_5+8.99X_6+9.93X_7-3.50X_8$

(St. III) $\hat{Y} = 97.77-4.07X_1+0.70X_2-0.42X_3-0.40X_4+2.15X_5+5.25X_6-13.20X_7-5.03X_8$

Culicoides similis

(St. I) $\hat{Y} = -34.04-0.89X_1+1.29X_2-0.11X_3+0.12X_4-0.35X_5+4.55X_6-28.96X_7+2.12X_8$

(St. III) $\hat{Y} = -41.71-0.20X_1+0.01X_2+0.02X_3-0.22X_4-0.46X_5+6.82X_6+2.22X_7-1.20X_8$

Bezzia albicornis

(St. I) $\hat{Y} = 66.59+0.64X_1-0.68X_2+0.08X_3-0.03X_4+0.58X_5-9.38X_6+26.09X_7-0.82X_8$

(St. II) $\hat{Y} = 21.48+0.13X_1+0.20X_2+0.03X_3-0.06X_4-0.99X_5-9.38X_6-1.09X_7+0.44X_8$

(St. III) $\hat{Y} = -131.98-0.26X_1+1.02X_2-0.78X_3-1.67X_4-8.30X_5-8.46X_6-50.48X_7+0.79X_8$

Nilobezzia sp.

(St. III) $\hat{Y} = -3.35-0.30X_1+0.98X_2-0.06X_3-0.27X_4-1.84X_5+0.95X_6-11.48X_7+0.02X_8$

Alluadomyia formosana

(St. I) $\hat{Y} = 82.83+0.34X_1+0.39X_2+0.39X_3+0.48X_4+0.82X_5-14.54X_6+14.74X_7+0.31X_8$

(St. II) $\hat{Y} = -67.25+0.36X_1+0.20X_2+0.04X_3+0.07X_4+1.89X_5+5.48X_6+11.19X_7-0.72X_8$

(St. III) $\hat{Y} = 117.80+0.35X_1-0.52X_2+0.24X_3+0.27X_4+2.66X_5-16.62X_6+2.88X_7+2.66X_8$

Alluaudomyia maculosipennis

(St. II) $\hat{Y} = 6.39+0.27X_1+0.26X_2+0.05X_3-0.16X_4-0.68X_5-2.02X_6-9.01X_7+2.67X_8$

Forcipomyia murina

(St. I) $\hat{Y} = 27.31+1.04X_1-0.66X_2+3.28X_3-0.03X_4+2.17X_5-6.77X_6-32.86X_7-0.76X_8$

(St. II) $\hat{Y} = 10.34-0.12X_1+0.27X_2-0.13X_3-0.23X_4-0.99X_5+1.38X_6-9.23X_7+0.94X_8$

(St. III) $\hat{Y} = 8.28-0.22X_1+0.31X_2-0.15X_3-0.11X_4-0.31X_5-2.17X_6-5.70X_7-0.62X_8$

Dasyhelea borbonica

(St. II) $\hat{Y} = -16.86 - 0.15X_1 + 0.14X_2 + 0.08X_3 - 0.06X_4 + 0.53X_5 + 2.38X_6 - 1.97X_7 + 0.37X_8$

Dasyhelea sp. 1

(St. I) $\hat{Y} = 60.03 + 0.31X_1 - 0.43X_2 - 0.03X_3 + 0.02X_4 + 0.78X_5 - 7.79X_6 + 21.70X_7 - 1.72X_8$

(St. II) $\hat{Y} = -23.1 - 0.10X_1 - 0.09X_2 + 0.04X_3 - 0.15X_4 + 2.21X_5 + 3.15X_6 - 0.51X_7 - 0.44X_8$

Dasyhelea sp. 2

(St. I) $\hat{Y} = -152.54 - 1.94X_1 + 2.54X_2 - 0.24X_3 - 0.05X_4 - 0.84X_5 + 21.86X_6 + 21.70X_7 - 1.72X_8$

Chironomus barbatitarsis

(St. I) $\hat{Y} = 422.57 + 2.48X_1 - 3.39X_2 + 0.25X_3 - 1.50X_4 - 3{,}43X_5 - 48.32X_6 + 69.74X_7 + 1.63X_8$

(St. II) $\hat{Y} = -85.98 - 0.16X_1 - 1.28X_2 + 0.11X_3 - 0.10X_4 + 5.27X_5 + 16.65X_6 + 15.14X_7 - 3.94X_8$

(St. III) $\hat{Y} = 165.74 - 0.26X_1 + 1.43X_2 - 0.15X_3 - 0.73X_4 - 1.87X_5 - 19.33X_6 - 6.39X_7 - 2.12X_8$

Psychoda nigripennis

(St. I) $\hat{Y} = -9.47 + 0.16X_1 - 0.22X_2 + 0.06X_3 - 0.13X_4 - 0.24X_5 + 1.41X_6 + 2.80X_7 + 0.26X_8$

(St. II) $\hat{Y} = -54.37 - 0.33X_1 + 1.12X_2 - 0.09X_3 - 0.69X_4 - 0.38X_5 + 8.40X_6 - 14.98X_7 - 2.55X_8$

(St. III) $\hat{Y} = 146.37 - 0.05X_1 - 0.31X_2 + 0.26X_3 - 0.26X_4 - 0.38X_5 + 17.03X_6 - 4.38X_7 + 1.58X_8$

Notiphila sp.

(St. I) $\hat{Y} = -323.06-7.52X_1+10.04X_2-1.22X_3+0.34X_4+4.33X_5+47.91X_6-289.65X_7+4.61X_8$

(St. II) $\hat{Y} = 383.22-0.87X_1-11.48X_2-0.93X_3-3.58X_4+19.22X_5-7.71X_6+53.03X_7-10.01X_8$

(St. III) $\hat{Y} = 80.02-1.06X_1+1.55X_2-0.28X_3-0.58X_4-4.77X_5-5.10X_6-24.98X_7+1.60X_8$

Brachydeutera longipes

(St. I) $\hat{Y} = 53.35-0.76X_1-1.52X_2-0.87X_3-0.47X_4+2.03X_5+4.79X_6-2.02X_7-4.70X_8$

(St. II) $\hat{Y} = -65.93+1.17X_1-0.34X_2-0.23X_3+0.73X_4-1.47X_5+3.76X_6-2.13X_7+7.18X_8$

(St. III) $\hat{Y} = -175.04+0.93X_1-1.10X_2-0.23X_3-1.48X_4-5.27X_5+28.15X_6-30.27X_7+5.24X_8$

Atylotus agrestis

(St. I) $\hat{Y} = -91.39-0.69X_1+0.98X_2-0.10X_3-0.03X_4-0.29X_5+12.26X_6-7.74X_7-0.21X_8$

(St. II) $\hat{Y} = -16.04-1.10X_1+0.18X_2-0.18X_3-0.33X_4+0.24X_5+7.67X_6-1.59X_7-2.17X_8$

(St. III) $\hat{Y} = -75.37+0.08X_1+1.11X_2-0.05X_3+0.05X_4-0.82X_5+6.42X_6-2.59X_7+1.86X_8$

Tabanus striatus

(St. I) $\hat{Y} = 23.12+0.82X_1-1.32X_2+0.08X_3-0.66X_4+0.55X_5-1.20X_6+29.49X_7-1.22X_8$

(St. II) $\hat{Y} = 0.21+0.01X_1-0.17X_2-0.05X_3-0.65X_4-0.20X_5+2.98X_6-5.93X_7-0.84X_8$

(St. III) $\hat{Y} = 54.85+0.07X_1-0.39X_2-0.02X_3-0.51X_4+0.48X_5-0.58X_6-0.47X_6+0.17X_7$

TABLE—1 ANALYSIS OF VARIANCE FOR ECOLOGICAL PARAMETERS OVER MONTHS, YEARS AND STATIONS.

Source of variation	d.f.	Soil temp.		Soil Moisture		Rainfall		Salinity		Dissolved Oxygen		pH		Organic carbon		Available phosphorus	
		M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Months (M)	11	126.60	844**	81.26	239**	82.15	8.71**	418.57	152.76**	3.29	19.35**	0.12	12**	0.24	40**	7.8	52**
Years (Y)	1	7.03	46.86**	0.14	0.41	0.06	0.006	1.18	0.43	0.06	0.35	0	0	0.05	8.3*	1.70	11.33**
Station (S)	2	1.02	6.8**	10.85	31.91**	—	—	20.57	7.51**	0.31	1.82	0.005	0.5	0.005	0.83	0.44	2.93
Interaction (M × Y)	11	2.39	15.93**	3.95	11.62**	—	—	7.78	2.84	0.59	3.47**	0.04	4**	0.01	1.67	0.16	1.07
Interaction (M × S)	22	0.18	1.2	1.08	3.18**	—	—	2.97	1.08	0.20	1.18	0	0.6	0.002	0.33	0.75	5.0**
Interaction (Y × S)	2	0.04	0.27	0.64	1.88	—	—	4.45	1.62	0.12	0.71	0	0.5	0.005	0.83	0.33	2.2
Error	22	0.15		0.34		9.43		2.74		0.17		0.01		0.006		0.15	
Total	71	20.22		13.97		43.80		68.54		0.73		0.03		0.04		1.45	

In case of rainfall d.f. for error and total are 11 and 23 respectively.

*Significant at 5% level.

**Significant at 1% level.

TABLE—1A SEASONAL RANGE AND MEAN (IN PARENTHESIS) OF DIFFERENT ECOLOGICAL PARAMETERS (STATIONS I, II, III)

	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Air temperature (C°)						
Monsoon	33.2-34 6 (33.4)	31.5-34.6 (33.6)	32.4-34.1 (33.0)	31.2-33.4 (32.4)	32.1-33.5 (32.7)	31.0-34 0 (32.6)
Postmonsoon	23.4-28.5 (25.0)	21.5-25.7 (23.2)	23.4-29.0 (25.6)	21.8-25.7 (23 6)	23.0-28.4 (24.9)	21.3-25.7 (22.8)
Premonsoon	28.5-35.1 (32.9)	30.0-35.2 (33.3)	28.2-36.0 (32.7)	30.5-35.0 (33.1)	28.0-34.3 (32.1)	29.5-34.5 (32.9)
Soil temperature (C°)						
Monsoon	31.8-33.9 (32.6)	30.9-33.1 (32.3)	31.8-33.6 (32.4)	30.8-32.6 (31.8)	31.6-33.2 (32.2)	30.5-33.0 (32.0)
Postmonsoon	22.5-27.5 (24.1)	20.8-25.1 (22 6)	22.7-28.1 (24.8)	21.6-25.0 (23.3)	22.5-27.2 (24.3)	20.5-25.0 (22.1)
Premonsoon	27.8-34.4 (32.2)	29.2-33.9 (32.2)	27.4-35.1 (31,9)	29.7-34.5 (32.5)	27.4-33.7 (31.6)	28.5-33.7 (31.9)

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	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Soil moisture (%)						
Monsoon	23.3-30.1 (26.7)	22.2-31.8 (27.3)	23.4-28.2 (25.7)	22.0-30.0 (25.6)	21.1-27.6 (24.8)	20.4-28.6 (24.3)
Postmonsoon	23.6-24.3 (24.0)	23.3-26.6 (24.2)	23.4-24.0 (23.7)	23.0-26.2 (23.9)	22.8-23,5 (23.0)	21.4-24.3 (22.8)
Premonsoon	15.1-22.9 (19.3)	15,0-23.0 (19.1)	14.7-23.3 (19.5)	15.4-22.4 (19.1)	15.6-22.1 (19.1)	15.3-21.2 (18.6)
Rainfall (mm/m)						
Monsoon	83.1-659.4 (323.7)	152.4-560.4 (339.4)	83.1-659.4 (323.7)	152.4-560.4 (339.4)	83.1-652.4 (323.7)	152.4-560.4 (339.4)
Postmonsoon	0-39.3 (24.38)	0.3-11.4 (0.25)	0-39.3 (24.38)	0.3-11.4 (0.25)	0-39.3 (24.38)	0.3-11.4 (0.25)
Premonsoon	0.9-335.1 (116.3)	0-456.0 (126.6)	0.9-335.1 (116.3)	0-456.0 26.6)	0.9-335.1 (116.3)	0-456.0 (126.6)

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	St. I		St. II		St. III	
	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84	July '82- June '83	July '82- June '84
Salinity (%o)						
Monsoon	7.2-17.3 (10.9)	5.0-19.8 (10.2)	7.3-19 0 (12.3)	5.0-18.0 (9.5)	5.9-16.8 (10.4)	5.0-13.8 (8.3)
Postmonsoon	12.6-22.0 (16.6)	11.6-15.7 (13.2)	13.7-19.8 (16.2)	11.2-19.7 (15.6)	11.7-17.8 (14.0)	13.6-19.5 (16.3)
Premonsoon	23.0-30.2 (26.9)	21.4-32.4 (28.0)	25.0-31.0 (28.2)	22.7-35.1 (30.2)	22.5-26.7 (25.1)	20.0-31.5 (26.9)
Dissolved oxygen (ml/l)						
Monsoon	3.1-4.7 (3.8)	2.8-4.6 (3.7)	3.2-4.3 (3.7)	2.3-4.3 (3.5)	3.8-4.6 (4.2)	3.3-4.4 (3.9)
Postmonsoon	2.7-4.1 (3.4)	3.0-3.9 (3.6)	2.2-3.8 (3.1)	2.8-4.1 (3.2)	2.7-3.2 (2.9)	2.6-3.8 (3.2)
Premonsoon	1.8-3.1 (2.4)	1.7-2.7 (2.3)	1.8-2.7 (2.3)	1.1-3.3 (2.2)	1.7-2.5 (2.2)	1.3-4.1 (2.7)

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Contd. Table 1A

	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
pH						
Monsoon	7.7-8.1 (7.9)	7.9-8.1 (8.0)	7.8-8.2 (8.0)	7.7-7.9 (7.8)	7.7-8.2 (7.9)	7.7-8.0 (7.9)
Postmonsoon	7.9-8.3 (8.1)	8.0-8.2 (8.1)	8 0-8.2 (8.2)	8.0-8.1 (8.1)	8.1-8.2 (8.2)	8 0-8.3 (8.2)
Premonsoon	8.1-8.3 (8.2)	8.2-8.3 (8.2)	7.9-8.2 (8.1)	8.2-8.4 (8.3)	8.0-8.3 (8.2)	8.1-8.4 (8.3)
Organic carbon (%)						
Monsoon	0.15-0.33 (0.25)	0.18-0.58 (0.37)	0.09-0.51 (0.26)	0.27-0.48 (0.39)	0.06-0.42 (0.21)	0.30-0.57 (0.45)
Postmonsoon	0.42-0.57 (0.47)	0.51-0.60 (0.56)	0.42-0.66 (0.56)	0.51-0.66 (0.57)	0.45-0.63 (0.56)	0.45-0.64 (0.54)
Premonsoon	0.03-0.27 (0.12)	0.03-0.33 (0.130)	0.03-0.42 (0.17)	0.06-0.29 (0.16)	0.02-0 48 (0.19)	0.02-0.24 (0.12)

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	St. I		St. II		St. III	
	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '83
Available phosphorus (mg/100g)						
Monsoon	1.29-2.44 (1.89)	1.61-2.44 (2.15)	1.61-3.19 (2.28)	2.21-3.51 (2.59)	1.15-2.55 (2.01)	2.01-3.19 (2.49)
Postmonsoon	2.44-4.24 (3.08)	3.15-4.95 (3.87)	2.79-5.31 (4.06)	3.51-4.44 (4.02)	2.76-4.34 (3.54)	2.89-5.12 (4.22)
Premonsoon	0.89-2.12 (1.48)	1.12-2.12 (1.51)	0.99-2.15 (1.39)	0.76-2.19 (1.28)	0.68-1.61 (1.12)	0.71-2.16 (1.48)

TABLE—1B TEXTURAL CONDITIONS AT DIFFERENT STATIONS THROUGH THE SEASONS DURING 1982-84

	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Sand (%)						
Monsoon	69.2	63.5	8.1	14.7	44.3	47.6
Postmonsoon	62.4	61.7	2.9	6.0	41.2	35.5
Premonsoon	82.6	78.3	18.1	27.4	53.7	41.2
Silt (%)						
Monsoon	27.5	32.4	87.8	81.5	55.3	51.2
Postmonsoon	33.4	33.5	93.2	89.4	54.5	61.2
Premonsoon	15.5	20.8	77.6	69.1	43.1	58.0
Clay (%)						
Monsoon	3.3	4.1	4.1	3.8	2.4	1.2
Postmonsoon	4.2	4.8	3.9	4.6	4.3	3.3
Premonsoon	1.9	0.9	4.3	3.5	3.2	0.8

TABLE—1C MEAN SOIL TEMPERATURE AND MOISTURE AT DIFFERENT DEPTHS DURING MARCH, 1983 TO FEBRUARY, 1984 (STATIONS I, II, III)

	St. I			St. II			St. III		
Depths	0-3 cm	3-6 cm	6-9 cm	0-3 cm	3-6 cm	6-9 cm	0-3 cm	3-6 cm	6-9 cm
Soil temperature (°C)									
Premonsoon	29.0-34.9 (32.9)	27.9-34.5 (32,3)	26.5-33.8 (31.2)	28.7-36.9 (33.0)	27.5-35,2 (31.9)	26.0-34.1 (30.6)	28.5-34.5 (32.3)	27.2-33.5 (31.3)	26,5-33.0 (30,5)
Monsoon	31.6-34.3 (33.2)	30.8-32.2 (32.3)	30.2-32.3 (31.8)	31.7-34.2 (33.1)	30.7-32.1 (31.8)	30.7-31.5 (30.8)	31.7-33.7 (32.7)	30.2-33.0 (31.9)	29.7-32.3 (31.2)
Postmonsoon	21.7-26.1 (23.4)	20.5-25.3 (22.6)	20.2-23.9 (21.7)	22.5-26.0 (24.0)	21.5-25.0 (23.0)	20.7-24.0 (22.0)	21.2-26.0 (23.1)	20.5-25.0 (22.1)	19.7-24.0 (21.2)
Soil moisture (%)									
Premonsoon	14.7-22.9 (18.7)	15.1-23.1 (19.2)	15.6-22.7 (19.8)	14,2-23.9 (19.1)	14.5-23.7 (19.4)	15.3-23.0 (19.7)	15.0-24.0 (18.8)	15.8-22.5 (19.3)	16.0-21.0 (19.3)
Monsoon	21.4-33.7 (28.2)	21.4-31.5 (27.1)	21.4-30.3 (26.5)	21.2-32.2 (26.7)	21.9-29.8 (25.3)	21.7-28-9 (24.7)	19.8-34.4 (27.1)	19.8-26.9 (23.3)	21.4-24.6 (22.5)
Postmonsoon	21.7-26.1 (25.6)	20.5-25.3 (24.1)	21.7-25.2 (23.0)	24.0-27.5 (25.5)	22.5-26-5 (23.7)	21.5-24.5 (22.4)	24.1-25.7 (24.7)	20.1-24.8 (22.4)	20.0-22.4 (21.0)

TABLE—2 CORRELATION COEFFICIENT AMONG THE ECOLOGICAL PARAMETERS AT ALL THE STATIONS

	Soil moisture	Rainfall	Salinity	Dissolved Oxygen	pH	Organic Carbon	Available phosphorus
STATION—I							
Soil temperature	−0.134	0.486*	0.242	−0.280	−0.086	−0.783**	−0.811**
Soil moisture		0.210	−0.913**	0.706**	−0.691**	0.660**	0.367
Rainfall			−0.255	0.210	−0.461*	−0.349	−0.413*
Salinity				−0.794**	0.722**	−0.645**	−0.413**
Dissolved oxygen					−0.526**	0.564**	0.410*
pH						−0.228	0.027
Organic carbon							0.842*

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	Soil moisture	Rainfall	Salinity	Dissolved Oxygen	pH	Organic Carbon	Available phosphorus
STATION—II							
Soil temperature	−0.225	0.431*	0.229	−0.189	−0.051	−0,810**	−0.824**
Soil moisture		0.077	−0.879**	0.806**	−0.609**	0.576**	0.518**
Rainfall			−0.258	0.090	−0.412*	−0.373	−0,341
Salinity				−0.784**	0.649**	−0.567**	−0.565**
Dissolved oxygen					−0.456*	0.485*	0.552*
pH						−0.144	−0.070
Organic carbon							0,885**
STATION—III							
Soil temperature	−0.175	0.493*	0.113	0.048	−0.251	−0.734**	−0.851**
Soil moisture		0.184	−0.989**	0.787**	−0.683**	0.576**	0.430*
Rainfall			−0.253	0.238	−0.621**	−0.363	−0.413*
Salinity				−0.812**	0.706**	−0.545**	−0.425**
Dissolved oxygen					−0.654**	0.231	0.227
pH						−0.142	0.073
Organic carbon							0.841**

* Significant at 5% level. ** Significant at 1% level.

TABLE—2A RANGE AND MEAN OF OCCURRENCE OF SPECIES THROUGH SEASONS AT STATIONS I, II AND III

	St. I		St. II		St. III	
	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84
Culicoides peliliouensis						
Monsoon	22.0-34 2 (28.95)	9.0-31 2 (19.65)	11.0-30.9 (22.5)	10.6-24.0 (16.0)	28.3-41.0 (34.78)	8.1-19 02 (13.55)
Postmonsoon	21.4-71.6 (51.5)	43.3-87.0 (71.33)	33.0-62.3 (46.25)	36.0-90.2 (60.75)	43.0-57.2 (50.55)	43.0-82.4 (63.63)
Premonsoon	18.0-33.0 (25.85)	9.1-61.2 (25.83)	8.1-43.0 (20.25)	6.6-23.0 (14.0)	13.5-47.0 (24.63)	6.2-21.5 (13.33)
Culicoides oxystoma						
Monsoon	2.5-21.0 (13.25)	1.5-21.0 (9.13)	4.3-13.2 (8,25)	2.5-16.5 (9.38)	8.5-24.3 (15.65)	2.5-21.0 (10.05)
Postmonsoon	17.5-28.5 (21.33)	18.5-41.2 (26 63)	18.6-27.5 (23.38)	18.5-46.1 (33.58)	11.2-34.1 (26.83)	32.0-55.5 (41.1)
Premonsoon	3.5-14.0 (8.0)	3.0-19.0 (8.9)	1.0-7.2 (4,8)	0-7.5 (2.68)	3.3-11.5 (7.08)	3.1-21.0 (11.33)

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	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Culicoides similis						
Monsoon	1.4-8.4	0-4.2	—	—	0-2.0	0-0
	(3.6)	(1.06)	—	—	(0.5)	(0)
Postmonsoon	3.5-10.5	3.5-8.5	—	—	0.03-7.1	0-0
	(6.93)	(5.63)	—	—	(2.41)	(0)
Premonsoon	0-1.5	0-0	—	—	0-0	0-0
	(0.38)	(0)	—	—	(0)	(0)
Bezzia albicornis						
Monsoon	0.03-7.0	0-7.2	0-4.2	0.03-3.3	1.0-18.0	1.5-21.2
	(3.76)	(2.63)	(1.93)	(2.85)	(10.93)	(10.43)
Postmonsoon	0-3.3	0-8.0	0-1.5	0-4.5	0.03-11.0	0-6.0
	(0.83)	(2.26)	(0.38)	(1.75)	(6.18)	(1.63)
Premonsoon	0-0	0-0	0-0	(0-0)	0-0	0-0
	(0)	(0)	(0)	(0)	(0)	(0)

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	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '82-June '84
Nilobezzia sp.						
Monsoon	—	—	—	—	1.2-7.0	0-13.2
	—	—	—	—	(3.68)	(4.63)
Postmonsoon	—	—	—	—	0-9.6	0.5-9.2
	—	—	—	—	(3.45)	(4.68)
Premonsoon	—	—	—	—	0-0	0-0
	—	—	—	—	(0)	(0)
Alluaudomyia formosana						
Monsoon	2.0-11.5	0-13.2	0-9.4	0-9.5	0-17.3	2.0-12.6
	(5.73)	(4.68)	(3.0)	(2.65)	(5.83)	(8.45)
Postmonsoon	0-4.5	0-7.5	0-3.0	0-3.7	0-2.1	0.03-7.3
	(1.43)	(2.26)	(1.06)	(0.93)	(0.54)	(2.11)
Premonsoon	0-0	0-0.5	0-0	0-0	0-0	0-0
	(0)	(0.1)	(0)	(0)	(0)	(0)

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Contd. Table 2A

	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Alluaudomyia maculosipennis						
Monsoon	—	—	2.2-7.5	0-16.0	—	—
	—	—	(5.03)	(7.13)	—	—
Postmonsoon	—	—	1.5-9.3	0-8.3	—	—
	—	—	(4.53)	(3.39)	—	—
Premonsoon	—	—	0-1.2	0-0	—	—
	—	—	(0.68)	(9)	—	—
Forcipomyia murina						
Monsoon	2.5-9.3	0-11.3	0-14.3	0.5-5.1	0.5-3.0	0-2.2
	(5.1)	(5.53)	(6.45)	(2.91)	(1.75)	(0.93)
Postmonsoon	0-11.1	0-8.5	2.6-8.2	0-11.4	0-2.7	0-8.4
	(3.75)	(2.38)	(4.88)	(3.9)	(0.8)	(2.23)
Premonsoon	0-0	0-0	0-0	0-0	0-0	0-0
	(0)	(0)	(0)	(0)	(0)	(0)

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	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Dasyhelea borbonica						
Monsoon	—	—	1.5-6.1	0-4.5	—	—
	—	—	(3.35)	(2.19)	—	—
Postmonsoon	—	—	0.02-5.0	1,5-7.0	—	—
	—	—	(2.46)	(4.0)	—	—
Premonsoon	—	—	0-0	0-0	—	—
	—	—	(0)	(0)	—	—
Dasyhelea sp. 1						
Monsoon	1.5-4.1	0-9.0	3.5-7.9	2.5-9.2	—	—
	(2.58)	(0.58)	(5.5)	(4.58)	—	—
Postmonsoon	1.4-8.0	0-1.2	0-7.6	0-7.2	—	—
	(4.6)	(0.3)	(4-33)	(2.65)	—	—
Premonsoon	0-0	0-0	0-0.5	0-0	—	—
	(0)	(0)	(0.13)	(0)	—	—

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	St. I		St. II		St. III	
	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84
Dasyhelea sp. 2						
Monsoon	0-12.0 (5.43)	0-1.5 (0.83)	— —	— —	— —	— —
Postmonsoon	6.5-15.4 (11.35)	0.13.5 (6.73)	— —	— —	— —	— —
Premonsoon	0-2.1 (0.53)	0-0 (0)	— —	— —	— —	— —
Chironomus barbatitarsis						
Monsoon	8.4-32.1 (22.53)	4.1-32.0 (23.78)	7.3-17.5 (11.38)	0-18.5 (11.75)	0-53.5 (15.9)	0-42.6 (19.78)
Postmonsoon	0.05-23.5 (11.06)	9.0-17.1 (12.85)	2.2-21.5 (9.58)	0-15.5 (7.88)	0.05-28.5 (11.71)	0.5-22.5 (7.55)
Premonsoon	0-0 (0)	0-0 (0)	0-0.03 (0.007)	0-0 (0)	0-0 (0)	0-0 (0)

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	St. I		St. II		St. III	
	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84
Psychoda nigripennis						
Monsoon	0-0 (0)	0-3.3 (1.33)	4.0-21.3 (13.63)	2.1-22.2 (10.58)	0-32.4 (13.1)	0.05-31.1 (15.14)
Postmonsoon	0-0 (0)	0,0 (0)	0-3.4 (0.86)	0.05-18.6 (7.19)	0.5-8.0 (3.73)	0-11.7 (7.05)
Premonsoon	0-0 (0)	0-0 (0)	0 0 (0)	0-0 (0)	0-0 (0)	0-0 (0)
Notiphila sp.						
Monsoon	8.5-21.2 (12.65)	0.05-15 6 (8.46)	9.5-22.2 (14.75)	2.0-21.4 (9.43)	9.0-27.3 (15.88)	0.02-21.2 (8.31)
Postmonsoon	7-7-23.0 (15.58)	10.1-23.0 (17.9)	14.5-31.1 (21.95)	9.2-21.3 (15.6)	11.0-32.0 (19.0)	13.5-27.0 (17.98)
Premonsoon	0-13.5 (4.4)	0-7.3 (2.63)	0-2.1 (1.23)	0-1.5 (0.38)	0-16.5 (4.95)	0-7.1 (2.28)

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	St. I		St. II		St. III	
	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84	July '82- June '83	July '83- June '84
Drachydeutera longipes						
Monsoon	3.1-19.1 (10.48)	2.5-7.0 (4.5)	1.2-9.5 (5.08)	0-33.3 (13.73)	3.1-33.4 (18.15)	5.5-22.1 (12.78)
Postmonsoon	13.5-31.0 (22.0)	4.2-29.4 (17.98)	12.0-33.5 (24.8)	0-5-21.4 (10.43)	11.5-31.3 (18.83)	2.5-22.6 (11.35)
Premonsoon	18.4-31.0 (22.85)	7.0-31.0 (19.63)	19.5-32.0 (25.43)	13.0-29.1 (21.43)	4.5-30.0 (14.9)	18.0-21.0 (17.4)
Atylotus agrestis						
Monsoon	2.1-7.5 (4.43)	2.5-6.0 (4.23)	1.1-4.3 (2.7)	2.0-8.5 (4.13)	1.0-4 0 (2.5)	2.0-8.5 (4.13)
Postmonsoon	6.5-12.7 (9.8)	5.5-16.0 (10.25)	8.5-10.5 (9.65)	8.0-12.6 (10.53)	8-5-10,5 (9.63)	8.0-12.0 (10.38)
Premonsoon	1.1-3.0 (2.03)	0-7.8 (1.96)	0-3.1 (1.68)	0-3.4 (1.35)	0-3.0 (1.63)	0-3.0 (1.25)

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Contd. Table 2A

	St. I		St. II		St. III	
	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84	July '82-June '83	July '83-June '84
Tabanus striatus						
Monsoon	2.6-8.0 (6.03)	1.0-10.0 (7.15)	5.0-11.5 (7.88)	4.0-10.0 (7.63)	4.0-13.0 (9.38)	1.0-12.5 (7.25)
Postmonsoon	0.02-8.5 (4.13)	0-10 5 (5.0)	0-7.5 (3.25)	0-8.5 (3.75)	0-7.5 (4.13)	2.0-9.0 (5.13)
Premonsoon	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)

TABLE—3 ANALYSIS OF VARIANCE FOR DIFFERENT SPECIES OVER MONTHS, YEARS AND STATIONS

Source of variation	d.f	*Culicoides pelilIouensis* +		*Culicoides oxystoma* +		*Culicoides similis* +		*Bezzia albicornis* +		*Nilobezzia* sp. +++		*Alluaudomyia formosana* +	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
Months (M)	11	2462.55	32.62**	694.58	28.25**	13.98	4.08*	42.27	3.35**	16.08	1.11	24.09	5.28**
Years (Y)	1	11.52	0.15	130.14	5.29*	16.94	4.95*	2.00	0.16	3.16	0.22	2.91	0.64
Stations (S)	2_{+}, 1_{++}	313.42	4.15*	171.15	6.96**	71.83	21.00**	105.29	8.36**	—	—	15.23	3.34
Interaction (M×Y)	11	309.12	4.09**	113.48	4.61**	1.07	0.31	12.38	0.98	—	—	25.00	5.48**
Interaction (M×S)	22_{+}, 11_{++}	43.25	0.57	38.95	1.58	0.12	0.04	13.52	1.07	—	—	17.38	3.81**
Interaction (S×Y)	2_{+}, 1_{++}	157.83	2·09	20.27	0.82	0.59	0.17	8.01	0.64	—	—	4.47	0.98
Error	22_{+}, 11_{++}, 11_{+++}	75.49		24.59		3.42		12.60		14.55		4.56	
Total	71_{+}, 47_{++}, 23_{+++}	479.64		152.11		8.24		19.78		14.79		15.00	

Source of variation	d.f	*Alluaudomyia maculosipennis* $_{+++}$		*Forcipomyia murina* $_{+}$		*Dasyhelea borbonica* $_{+++}$		*Dasyhelea* sp. 1. $_{++}$		*Dasyhelea* sp. 2. $_{+++}$		*Chironomus barbatitarsis* $_{+}$	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
Months (M)	11	23.50	2.20	35.65	7.89**	6.82	1.87	17.73	8.82**	39.68	2.63	498.18	8.53**
Years (Y)	1	1.69	0.16	5.14	1.14	0.10	0.03	15.27	7.60*	62.73	4.16	0.45	0.01
Stations (S)	2_{+}, 1_{++}	—	—	31.05	6.87**	—	—	15.73	7.83*	—	—	146.00	2.52
Interaction (M×Y)	11	—	—	6.79	1.50	—	—	6.31	3.14*	—	—	66.75	1.14
Interaction (M×S)	22_{+}, 11_{++}	—	—	10.36	2.29*	—	—	8.06	4.01**	—	—	59.37	1.02
Interaction (S×Y)	2_{+}, 1_{++}	—	—	4.62	1.02	—	—	0.59	0.29	—	—	3.47	0.06
Error	22_{+}, 11_{++}, 11_{+++}	10.67		4.52		3.65		2.01		15.07		58.39	
Total	71_{+}, 47_{++}, 23_{+++}	16.41		12.23		5.01		5.73		28.91		128.24	

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Contd. Table 3

Source of variation	d.f	*Psychoda nigripennis*		*Notiphila* sp.		*Brachydeutera longipes*		*Atylotus agrestis*		*Tabanus striatus*	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F	M.S.	F
Months (M)	11	122.27	4.88**	366.18	12.62**	158.91	3.76**	94.40	55.20**	88.20	56.18**
Years (Y)	1	12.42	0.50	167.72	5.78*	246.42	5.82*	3.84	2.25	1.38	0.88
Station (S)	2	45.74	9.80**	8.23	0.28	9.33	0.22	1.95	1.44	0.01	0.01
Interaction (M×Y)	11	46.63	1.86	21.68	0.75	183.23	4.33**	4.45	2.60*	3.39	2.16
Interaction (M×S)	22	42.88	1.71	17.73	0.61	110.33	2.61*	3.35	1.96	1.69	1.08
Interaction (S×Y)	2	0.7	0.03	15.52	0.53	2.33	0.06	0.73	0.43	0.68	0.43
Error	22	25.07		29.02		42.31		1.71		1.57	
Total	71	54.34		77.61		367.75		17.01		15.24	

*Significant at 5% level.
**Significant at 1% level.

TABLE—4 SEASONAL RANGE AND MEAN (IN PARENTHESIS) OF DIFFERENT LARVAL INSTARS AND PUPAE OF TWO SPECIES IN ALL THE STATIONS

Species	Station	Depths	Premonsoon (March, 1983—June, 1983) Immature stages I	II	III	IV	P	Monsoon (July, 1983—October, 1983) Immature stages I	II	III	IV	P	Postmonsoon (November, 1983—February, 1984) Immature stages I	II	III	IV	P
Culicoides peliliouensis	St. I	0-3 cm	0-4.0 (1.5)	0-3.0 (1.25)	0-9.0 (4.0)	0.18.0 (4.5)	0-2.0 (1.0)	0-4.0 (1.0)	1.0-6.0 (3.0)	3.0-8.0 (5.25)	2.0-9.0 (4 25)	2.0-3.0 (2.5)	8.1-15 9 (10 25)	3 0-12.0 (6.75)	8.0-27.1 17.0)	11 0-27 0 (18.0)	0-21 0 (8.75)
		3-6 cm	0-0 (0)	0-2.0 (0.5)	0-9.1 (2.53)	1.0-9.0 (4.0)	0-1 0 (0.5)	0-0 (0)	0-0 (0)	0-4.0 (1.0)	0-2.0 (1.0)	0-3.0 (1.5)	0-0 (0)	0-0 (0)	1.0-4.0 (2.58)	4.0-6.0 (4 75)	0-5 0 3.25)
		6-3 cm	0-0 (0)	0-4.3 (1.08)	0-8.0 (2.0)	0-10.0 (2.5)	0-2.0 (0.5)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 0)	0-0 (0)
	St. II	0-3 cm	0-3.1 (0.78)	3.2-9.0 (3.05)	8.1-10.9 (4.75)	0-10.2 (3.25)	0-1 9 (0.48)	0-4.0 (1.0)	1.0-2.2 (1.8)	2.0-4.0 (2.75)	0-5.0 (4.75)	2.0-5.0 (2.95)	4 1-11 0 (6 25)	6 0-13 0 (8.05)	7.0-29.0 16-75)	9.0-22 0 (16.25)	1.0-18.0 7.75)
		3-6 cm	0-0 (0)	0-2.0 (0.5)	1.0-4.0 (3.0)	1.0-6.2 (3.15)	0-2.0 (1.0)	0-0 (0)	0-0 (0)	0-1.0 (0.5)	2.1-3 0 (2.25)	0-0 (0)	0-0 (0)	0-0 (0)	0-2 0 0 5)	2.0-7 0 4 0)	0-4.0 1 0)
		6-9 cm	0-0 (0)	0-2.0 (0.5)	0-0 (0)	0-2.0 (0.5)	0-2.0 (0.5)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 0)
	St. III	0-3 cm	0-2.0 (0.5)	3.0-12-0 (3.75)	4.0-11.0 (3.8)	2.0-8.1 (2.54)	0-4.1 (1.03)	0-3.0 (1.25)	1.0-2.0 (0-75)	0-3.0 (2.0)	2.4-6.0 (2.83)	0-4.1 (1.78)	6.1-11.9 (9 25)	7 8-12 0 9 95)	8.1-15.0 (11.55	11.1-17 2 12.83)	1.0-5.0 (9 75)
		3-6 cm	0-0 (0)	0-1.0 (0.25)	2.2-3.0 (2.05)	3.0-5.0 (4.25)	0-2.0 (1,25)	0-0 (0)	0-2.0 (0.5)	0-2.0 (1.0)	1.0-5.2 (2.8)	0-1.0 (0.73)	0-0 (0)	0-0 0)	1.0-6 0 3.25)	2.0-7 0 4 0)	1 0-8.0 (3 08)
		6-9 cm	0-0 (0)	0-2.3 (0,58)	0-3.0 (1-75)	0-6.1 (2.05)	0-1.9 (0.48)	0-0 (0)	0-0 (0)	0-0 (0)	0-2 0 (0.5)	0 0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 0)	0-0 (0)
Culicoides oxystoma	St. I	0-3 cm	0-0 (0)	0-0 (0)	0-7.1 (2.05)	0-3.0 (0.55)	0-1.0 (0.05)	0-5.0 (1 5)	0-1.6 (1.15)	0-6.1 (2.75)	0-4 0 (1 5)	0-0 5 (0 25)	1 0-11.2 (4 25)	2 9-5 0 (2 75)	5.0-13.0 (8 75)	3 0-8 0 (5 0)	0-2 0 (0 75)
		3-6 cm	0-0 (0)	0-0 (0)	0-2.9 (1.50)	0-6.0 (2.00)	0-0 (0)	0-0 (0)	0-0 (0)	0-3.5 (1 63)	0-1 2 (0.3)	0-0 (0.13)	0-0 (0)	0-0 (0)	2 0-4 5 (3 38)	0-2 2 (1 25)	3-1 0 (0 5)
		6-9 cm	0-0 (0)	0-0 (0)	0-3.5 (1.15)	0-2.0 (0.70)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0 0 (0)
	St. II	0-3 cm	0-0 (0)	0-1.0 (0.25)	0-2.0 (0.5)	0-1.0 (0.25)	0-1.0 (0.25)	0-2.0 (0.5)	0-4.3 (1.38)	0-6.8 (2.75)	0-3 0 (1.25)	0-1.0 (0 5)	1 0-6 0 (3 0)	0 9-8 0 (4.5)	2 0-20 0 (10 75)	4 3-11 9 (6 75)	0 5-3 0 (1.63)
		3-6 cm	0-0 (0)	0-0 (0)	0-3.1 (1.25)	0-2.0 (1.0)	0-0 (0)	0-0 (0)	0-0 (0)	1.4-3 0 (2.13)	0-1.0 (0 75)	0-0 (0)	0 0 (0)	0-0 (0)	1 0-4 5 (3 5)	1 0-7 5 (2 88)	0-1 0 (0 5)
		6-9 cm	0-0 (0)	0-0 (0)	0-0.9 (0.23)	0-1.0 (0 75)	0.0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0 0 (0)	0 0 (0)
	St. III	0-3 cm	0-0 (0)	0-0 (0)	0-2.0 (0.5)	0-0.5 (0.13)	0-0 (0)	0-4.0 (1.5)	0-2 0 (0.5)	0-4.0 (2.25)	0-1 0 (0 5)	0-2 5 (0.75)	3.0-6 0 (3 75)	3.5-8 0 (5 88)	8 0-18 0 (12 25)	3.0 9 0 (5 63)	2 0-4 0 (3 13)
		3-6 cm	0-0 (0)	0-0 (0)	0-3 0 (1.5)	1.0-3.0 (2.25)	0-0 (0)	0-0 (0)	0-0 (0)	1.0-5.0 (2.38)	0-5.0 (1.5)	0-0.5 (0 13)	0-0 (0)	0-0 (0)	4 0-10 0 (6 13)	1 0-4 0 (2 25)	0 3 5 (2 0)
		6-9 cm	0-0 (0)	0-0 (0)	1.0-3.0 (2.0)	0-1.0 (0-63)	0-0 (0)	0-0 (0)	9-0 (0)	0-0 (0)	0-0 (0)	0 0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)	0-0 (0)

TABLE—5 ANALYSIS OF VARIANCE FOR TWO SPECIES POPULATION OVER SEASONS, DEPTHS AND STATIONS

Source of variation	d f	*Culicoides pelliliouensis* M S	*Culicoides pelliliouensis* F.	*Culicoides oxystoma* M S	*Culicoides oxystoma* F
Seasons (S)		637.45	94.02**	174.34	99.06**
Depths (D)		1406.07	207.38**	160.96	91.45**
Instars (I)	4	140.65	20.74**	91.60	52.05**
Stations (St)	2	6.93	1.02	4.12	2.34
Interaction (I × D)		37.59	5.54**	32.42	18.42**
Interaction (S × I)	8	15.64	2.31*	14.37	8.16**
Interaction (St × I)	8	4.26	0.63	0.47	0.27
Interaction (D × S)		538.29	79.39**	160.06	90.94**
Interaction (St. × S)		1.00	0.15	6.26	3.56**
Interaction (St × D)	4	5.89	0.87	28.22	16.03**
Error	493	6.78		1.76	
Total	539	19.75		5.69	

*Significant at 5% level. **Significant at 1% level.

TABLE—6 CORRELATION COEFFICIENT AMONG THE SPECIES POPULATIONS AT ALL THE STATIONS

	Culicoides oxystoma	Culicoides similis	Bezzia albicornis	Nilobezzia sp.	Alluaudomyia formosana	Alluaudomyia maculosipennis	Forcipomyia murina	Dasyhelea borbonica	Dasyhelea sp. 1	Dasyhelea sp. 2	Chironomus barbatitarsis	Psychoda nigripennis	Notiphila sp.	Brachydeutera longipes	Atylotus agrestis	Tabanus striatus
STATION—I																
Culicoides pelliliouensis	0.698**	0.612**	−0.125	—	−0.264	—	−0.283	—	−0.052	0.463*	−0.086	−0.293	0.591**	0.251	0.814**	−0.109
Culicoides oxystoma		0.604**	0.037	—	0.221	—	0.233	—	−0.342	0.310	0.292	−0.234	0.561**	0.237	0.928**	0.158
Culicoides similis			−0.004	—	0.062	—	0.130	—	0.067	0.700**	0.187	−0.118	0.545**	0.103	0.631**	0.067
Bezzia albicornis					0.640**	—	0.602**	—	0.343	0.291	0.588**	−0.020	0.287	−0.485*	0.525**	0.713**
Alluaudomyia formosana						—	0.700**	—	0.193	0.095	0.849**	0.333	0.100	−0.496*	−0.093	0.611**
Forcipomyia murina									0.568**	0.219	0.528**	0.183	0.314	−0.274	0.064	0.753**
Dasyhelea sp 1										0.219	0.493*	−0.088	0.324	−0.005	0.328	0.526**
Dasyhelea sp 2											−0.048	−0.182	0.712**	−0.060	0.518**	0.339
Chironomus barbatitarsis												0.073	0.293	−0.438*	0.127	0.741**
Psychoda nigripennis													−0.020	−0.400*	−0.138	0.423*
Notiphila sp.														−0.100	0.721**	0.529**
Brachydeutera longipes															0.277	−0.396*
Atylotus agrestis																0.246
STATION—II																
Culicoides pelliliouensis	0.881**	—	−0.037	—	−0.145	0.101	−0.105	0.110	0.096	—	0.093	−0.074	0.408*	0.014	0.773**	−0.038
Culicoides oxystoma			0.023	—	−0.006	0.204	0.224	0.128	0.237	—	0.519**	0.040	0.524**	−0.091	0.856**	0.079
Bezzia albicornis					0.911**	0.413**	0.013	0.125	0.411*	—	0.318	0.740**	0.118	−0.376	0.067	0.676**
Alluaudomyia formosana						0.166	0.474*	0.095	0.513**	—	0.482*	0.609**	0.450*	−0.340	0.224	0.374
Alluaudomyia maculosipennis							0.306	0.120	0.348	—	0.585**	0.589**	0.406*	−0.491*	0.237	0.604**
Forcipomyia murina								0.073	0.371	—	0.318	0.250	0.530**	−0.437*	0.309	0.258
Dasyhelea borbonica									0.156	—	0.138	0.135	0.123	−0.101	0.135	0.124
Dasyhelea sp. 1										—	0.729**	0.448*	0.608**	−0.240	0.335	0.512**
Chironomus barbatitarsis												0.570**	0.615**	−0.462	0.363	0.759**
Psychoda nigripennis													0.366	−0.715**	0.180	0.794**
Notiphila sp.														−0.301	0.696**	0.329
Brachydeutera longipes															−0.227	−0.571**
Atylotus agrestis																0.173
STATION—III																
Culicoides pelliliouensis	0.813**	0.261	−0.244	−0.066	−0.192	—	0.078	—	—	—	−0.033	−0.068	0.638**	0.031	0.677**	0.182
Culicoides oxystoma		0.193	−0.086	0.324	−0.159	—	0.283	—	—	—	0.113	0.006	0.557**	−0.019	0.749**	0.234
Culicoides similis			0.349	−0.044	−0.105	—	−0.022	—	—	—	−0.018	−0.061	0.151	0.039	0.250	0.144
Bezzia albicornis				0.424*	0.101	—	0.322	—	—	—	0.536**	0.515**	0.266	0.290	0.344	0.618**
Nilobezzia sp.					0.357	—	0.561**	—	—	—	0.671**	0.530**	0.442*	−0.167	0.352	0.529**
Alluaudomyia formosana							0.105	—	—	—	0.335	0.494*	0.073	−0.427*	−0.011	0.386
Forcipomyia murina								—	—	—	0.516**	0.211	0.427*	−0.204	0.226	0.513**
Chironomus barbatitarsis												0.821**	0.519**	−0.198	0.263	0.789**
Psychoda nigripennis													0.398*	−0.132	0.121	0.692**
Notiphila sp.														0.086	0.613**	0.492*
Brachydeutera longipes															0.180	−0.109
Atylotus agrestis																0.417*

* Significant at 5% level. ** Significant at 1% level.

TABLE—7 CORRELATION COEFFICIENT OF DIFFERENT SPECIES WITH ALL ECOLOGICAL PARAMETERS AT ALL THE STATIONS

	Soil temperature	Soil moisture	Rainfall	Salinity	Dissolved oxygen	pH	Organic carbon	Available phosphorus	Sand	Silt	Clay
Station—I											
Culicoides pelihouensis	−0.887**	0.114	−0.508**	−0.184	0.174	0.169	0.670**	0.732**	−0.570	0.552	0.617
Culicoides oxystoma	−0.712**	0.194	−0.490	−0.294	0.452	−0.121	0.667**	0.707**	−0.713	0.697	0.732
Culicoides similis	−0.682**	0.337	−0.348	−0.370	0.312	−0.021	0.679**	0.762**	−0.754*	0.739	0.764*
Bezzia albicornis	0.102	0.609**	0.324	−0.593**	0.510**	−0.079	0.294	0.005	−0.604	0.591	0.617
Alluaudomyia formosana	0.185	0.639**	0.522**	−0.512**	0.450**	−0.730**	0.203	−0.022	−0.550	0.544	0.533
Forcipomyia murina	0.090	0.697**	0.202	−0.650**	0.650**	−0.561**	0.388	0.120	−0.757*	0.753	0.712
Dasyhelea sp 1	−0.116	0.465*	0.020	−0.441*	0.410*	−0.481*	0.371	0.068	−0.484	0.489	0.071
Dasyheleo sp 2	−0.570**	0.382	−0.299	−0.373	0.280	0.036	0.582**	0.525**	−0.679	0.669	0.671
Chironomus barbatitarsis	0.055	0.740**	0.412*	−0.827**	0.548**	−0.873**	0.349	0.137	−0.803*	0.778*	0.782*
Psychoda nigripennis	0.243	0.259	0.495*	−0.385	0.231	0.211	−0.040	−0.009	0.873*	−0.785*	−0.435
Notiphila sp.	−0.667*	0.544**	−0.237	−0.611**	0.657**	−0.159	0.526**	0.634*	−0.847*	0.823*	0.894**
Brachydeutera longipes	−0.267	−0.493*	−0.545**	0.401**	−0.255	0.439*	−0.064	−0.001	0.416	−0.422	−0.348
Atylotus agrestis	−0.687**	0.475*	−0.397*	−0.450*	0.383	0.025	0.794**	0.704**	−0.824*	0.812*	0.836*
Tabanus striatus	−0.033	0.728**	0.325	−0.853**	0.712**	−0.632**	0.437*	0.178	−0.851*	0.840*	0.833*
Station—II											
Culicoides pelihouensis	−0.870**	0.258	−0.425*	−0.272	0.139	−0.008	0.785**	0.692**	−0.749	0.738	0.647
Culicoides oxystoma	−0.829**	0.347	−0.423*	−0.381	0.249	−0.027	0.795*	0.745**	−0.766*	0.757*	0.598
Bezzia albicornis	0.179	0.622**	0.440*	−0.672**	0.366	0.626**	0.103	0.076	−0.367	0.367	0.175
Alluoudomyia formosana	0.075	0.538**	0.024	−0.445*	0.604**	−0.114	0.308	0.212	−0.452	0.463	−0.013
Alluoudomyia maculosipennis	−0.108	0.601**	0.211	−0.677	0.557**	−0.435*	0.313	0.432*	−0.616	0.629	0.032
Forcipomyia murina	−0.224	0.394	−0.080	−0.469*	0.309	−0.189	0.305	0.365	−0.850*	0.858*	0.257
Dasyhelea borbonica	−0.091	0.143	0.029	−0.154	0.146	−0.068	0.122	0.137	0.188	0.838	0.506
Dasyhelea sp 1	−0.124	0.570**	0.186	−0.626**	0.691**	−0.311	0.334	−0.375	−0.735	0.749	0.056
Chironomus barbatitarsis	−0.081	0.590**	0.308	−0.771**	0.718**	−0.330	0.393	0.367	−0.743	0.753	0.113
Psychoda nigripennis	0.141	0.745**	0.318	−0.737**	0.618**	−0.549**	0.153	0.130	−0.384	0.384	0.208
Notiphila sp	−0.583**	−0.123	−0.085	−0.603**	0.590**	−0.102	0.670**	0.714**	0.949**	0.958**	0.292
Brachydeutera longipes	−0.077	−0.434*	−0.384	0.476*	−0.334	0.516*	−0.044	0.020	0.355	−0.330	−0.303
Atylotus agrestis	−0.898**	0.484	−0.454*	−0.457*	0.385	−0.026	0.851**	0.801**	−0.789*	0.787*	0.459
Tabanus striatus	0.154	0.685**	0.435*	0.849**	0.609**	−0.601**	0.170	0.183	−0.518	0.522	0.065
Station—III											
Culicoides pelihouensis	−0.880**	0.319	−0.439*	−0.237	0.078	0.194	0.687**	0.891**	−0.635	0.467	0.797*
Culicoides oxystoma	−0.947**	0.298	−0.509**	−0.220	0.133	0.168	0.688**	0.778**	−0.832*	0.710	0.560
Culicoides similis	−0.268	0.099	−0.189	−0.146	−0.069	0.199	0.300	0.195	0.211	0.073	0.651
Bezzia albicornis	0.214	0.565**	0.161	−0.671**	0.489*	0.474*	0.017	0.020	0.077	0.0 0	−0.095
Nilobezzia sp	−0.175	0.623**	0.122	0.575**	0.444*	0.383	0.319	0.299	0.445	0.427	0.044
Alluaudomyia formosana	0.186	0.416*	0.527**	−0.469*	0.541**	0.687**	0.032	0.017	0.132	0.017	0.401
Forcipomyia murina	0.060	0.426*	0.046	−0.371	0.396*	−0.295	0.127	0.080	0.596	0.592	0.273
Chironomus barbatitarsis	0.075	0.670**	0.313	0.674**	0.576**	0.660**	0.257	0.099	0.064	0.124	−0.037
Psychoda nigripennis	0.048	0.544**	0.405*	−0.601**	0.576**	0.628**	0.176	0.138	−0.022	0.148	0.283
Notiphila sp	0.508**	0.464*	0.148	−0.438*	0.257	0.157	0.517**	0.562**	0.156	0.098	0.579
Brachydeutera longipes	0.047	0.260	0.207	0.090	0.190	0.432*	0.124	0.092	0.066	0.025	0.113
Atylotus agrestis	0.599**	0.630**	0.322	−0.521**	0.351	0.040	0.726**	0.783**	0.661	0.494	0.666
Tabonus striatus	0.036	0.718**	0.313	0.779**	0.724**	0.685**	0.345	0.243	0.085	0.155	0.112

* Significant at 5% level ** Significant at 1% level

TABLE—8 ANOVA VALUES OF THE INTERACTION OF INDIVIDUAL SPECIES WITH DIFFERENT ENVIRONMENTAL PARAMETERS AT DIFFERENT STATIONS

Source of variation		d.f.	*Culicoides pelilIouensis*		*Culicoides oxystoma*		*Culicoides similis*		*Bezzia albicornis*		*Nilobezzia* sp.		*Alluaudomyia formosana*		*Alluaudomyia maculosipennis*		*Forcipomyia murina*	
			M. S.	F.	M. S.	F.	M. S.	F.	M. S.	F.	M. S.	F.	M. S.	F.	M. S.	F.	M. S.	F.
St. I	$\sum \hat{y}^2$	8	1326.21	9.43**	226.84	9.48**	24.50	5.05**	12.91	3.63*	—	—	31.35	6.66**	—	—	37.55	8.73**
	$\sum d^2$	15	140.62		24.71		4.85		3.56		—		4.71		—		4.30	
	$\sum y^2$	23	552.99		95.01		11.68		6.81		—		13.98		—		15.87	
St. II	$\sum \hat{y}^2$	8	1105 43	9.71**	357.25	6.98**	—	—	4.73	5 37**	—	—	12.72	2.72**	26.01	2.30	11.23	0.61
	$\sum d^2$	15	113.90		51.21		—		0.88		—		4 67		11.30		18.30	
	$\sum y^2$	23	458.78		157.66		—		2.22		—		7.47		16.41		15.84	
St. III	$\sum \hat{y}^2$	8	1092.47	10.37**	562.13	57.19**	2.62	1.88	122.04	283.81**	19.71	2.49*	41,22	4.49**	--	—	3.44	1.53
	$\sum d^2$	15	105 28		9.83		1.39		0.43		7.93		9.19		—		2.25	
	$\sum y^2$	23	448.65		201.94		2.31		42.87		14.79		23.53		—		3.45	

Source of variation		d.f.	*Dasyhelea borbonica*		*Dasyhelea* sp. 1		*Dasyhelea* sp. 2		*Chironomus barbatitarsis*		*Psychoda nigripennis*		*Notiphila* sp.		*Brachydeutera longipes*		*Atylotus agrestis*		*Tabanus striatus*	
			M.S.	F.	M S.	F.	M.S.	F.	M.S.	F.	M.S.	F	M S.	F.	M.S	F.	M.S	F	M.S	F.
St. I	$\sum \hat{y}^2$	8		—	9.90	1.58	55.75	3.80*	402.73	30.30**	1 02	2 74*	128.49	5.63**	164.89	2 36	38.42	5.56**	39.11	13 30**
	$\sum d^2$	15	—		6.25		14.65		13.29		0.37		22.84		69.77		6 91		2.94	
	$\sum y^2$	23	—		7.52		28 91		148.75		0.60		59.58		102.86		17.87		15.52	
St. II	$\sum \hat{y}^2$	8	7.73	2.16	14.16	2.02	—		123 99	8.36**	126.97	5 61**	227.03	17.49**	158.4	1.32	48.21	104.80**	40.33	14.99**
	$\sum d^2$	15	3 57		7.00		—		14.83		22.62		12.98		119.88		0.46		2.69	
	$\sum y^2$	23	5 01		9.49		—		52.80		58.92		87.43		133.28		16.78		15.78	
St. III	$\sum \hat{y}^2$	8	—	—		—	—	—	284.22	3.44*	127.21	2.63	124.59	2.57	132.38	3.45*	34.24	11.30**	43.82	8.44**
	$\sum d^2$	15							82.74		48.45		48.46		38.38		3.03		5.19	
	$\sum y^2$	23					—		181.60		92.70		91.79		84.43		14.94		20.43	

* Significant at 5% level ** Significant at 1% level.

ΓAL PARAMETERS AT DIFFERENT STATIONS

Sou var		*Alluaudomyia formosana*		*Alluaudomyia maculosipennis*		*Forcipomyia murina*	
		M. S.	F.	M. S.	F.	M. S.	F.
St. I		31.35	6.66**	—	—	37.55	8.73**
		4.71		—		4.30	
		13.98		—		15.87	
St. II		12.72	2.72**	26.01	2.30	11.23	0.61
		4 67		11.30		18.30	
		7.47		16.41		15.84	
St. III		41,22	4.49**	--	—	3.44	1.53
		9.19		—		2.25	
		23.53		—		3.45	

Sou var	p.	*Brachydeutera longipes*	*Atylotus agrestis*	*Tabanus striatus*

DISCUSSION

The mangrove salt marshes of the deltaic Sundarbans at the land-sea interface in the month of Hooghly estuary contain a number of unstable habitats. The general pattern of damage creeks experiencing tides twice 24 hours is more or less stable, but the detailed topography of creek margins is continually changing, and eroded creek banks are a familiar feature of salt marshes of Sundarbans, supporting a variety of salt addicted vegetation. The instability of edge region is of fundamental importance, since it is to such region that a number of soil living species are largely confined (Foster and Treherne, 1976).

The pattern of tidal coverage on littoral salt marshes is complex and variable. Regular tidal inundation is the major factor that distinguishes them from other areas of angiospermic vegetation. The duration of submergence and exposure of the concerned habitats can vary widely. In some salt marshes the duration of normal tidal submergence and exposure may be very prolonged. The duration of submergence experienced by salt marsh insects can also depend upon the type of vegetation with which they are associated.

Salt marsh soils are extremely varied in structure and composition i.e., sand, silt and clay proportion, their grain size and pore spaces, and in the content of organic matter (Ranwell, 1972). In the edge regions, the soil has an enlarged pore structure which are suitable for colonization by insects and other micromarine invertebrates,

A majority of the intertidal benthic fauna prefers such brackish water situations where environmental conditions are markedly different from those of terrestrial and fresh water habitats. Animals in such habitats acquire a certain degree of euryhalinity as an insurance against fluctuating environmental conditions (Delamare-Deboutteville, 1960). Of all the factors salinity, perhaps, is the most variable components of the ecosystem which really exerts perceptable impact on the behaviour of the littoral community. During the present investigation this has been aptly demonstrated by the different dipteran larvae considered in this discussion. Marine and estuarine insects exhibit a wide range of tolerance to environmental salinity. This range is well established by the larvae of some aquatic dipterans found in various saline situations. Species such as *Chironomus aprilinus* and *C. halophilus* are able to cope with brackish water conditions. Some species (e.g., *Chironomus* *salinarius*, *Crocotopus vitripennis Aedes caeniorynchus Culcx sitiens* and *Culicoides oxystoma)* can tolerate prolonged exposure to sea water, whereas othcrs (e.g , *Ephydra riparia*, *Aedes caspius. A detritns* and *Opifex fuscus)* can withstand to hypersaline conditions (Clements, 1963 ; Macan, 1974 ; Ray and Choudhury, 1988a ; 1988b).

The salinity regime of the study area under communication undergoes gradual but conspicuous fluctuations through seasons ranging from 5.0‰ to 35.1‰. The presence of *Culicoides pelilioensis*, *C oxystoma*, *Notiphila* sp. and *Brachydeutera longipes* in this changing environment throughout the seasons at all the stations indicate that these species are typically euryhaline But the remaining 13 dipteran species were found to occur in these habitats only during the less saline period. Hence salinity plays a decisive factor in seasonal occurrence and abundance of the benthic insect species in this complex environment.

Importance of temperature as a factor, like salinity for animal distribution in a particular area or niche is also emphasized by the eeologists. The most obvious impact of temperature on animal distribution so far as brackish water zone is concerned, is th exclusion of species in areas with unsuitable temperature conditions. Such effects could have important influences on estuarine insect population (Duff and Teal, 1965). The range of temperature tolerated in the state of active life is smallest in marine benthic insects and largest in brackish water forms. Organisms that can tolerate wide range of temperature are called eurytherm (Kinne, 1963). In fine, the dis ribution of benthic fauna in estuaries is based on the complexity of periodically changing parameters that limit colonization of animals to restricted numbers of organisms with wide range of ecological adaptations and tolerance.

The distribution and abundance of *Culicoides pelilioensis*, *C. oxystoma*, *Notiphila* sp. and *Brachydeutera longipes* were inversely proportional to temperature (Table 5) (Ray and Choudhury, 1988b).

From the observations recorded by the authors it was also evident that the larvae and pupae of *Culicoides oxystoma* were absent in the desired depth (0-3 cm) of the soil when the temperature exceeded 34.9°C.

It is contended from the present investigation that temperature acted as one of the important factor to control the vertical distribution of larvae nnd pupae of this species (Ray and Choudhury 1985b). Similar observations were also made by Linley and Adams (1972) on the larval and pupal movement of *Culicoides melleus* which were found to be controlled by this factor.

Soil moisture and precipitations are also important environmental factors for several benthic fauna, Moisture content of the sand and mudflats is considerabiy influenced by seasonal precipitation resulting from surface run off and the tidal interplay.

Positive correlation coefficients between soil moisture and the diptera species viz , *Culicoides similis, Bezzia albicornis, Nilobezzia* sp,, *Alluaudomyia formosana, A. maculosipennis, Forcipomyia murina, Dasyhelea borbonica, Dasyhelea* sp. 1, *Dasyheiea* sp. 2, *Chironomus barbatitarsis, Psychoda nigripennis, Atylotus agrestis* and *Tabanus striatus* indicate that moisture may be a causative factor exerting impact on the differential distribution and abunda··ce of these species.

Breeding of some ceratopogonids viz., *Leptoconops becquaerti, Culicoides melleus, C. phlebotomus* were also found to be closely dependent upon the moisture content of the surface soil (Painter, 1926; Linley, 1968 ; Linley and Adams, 1972.

Throughout the length of the investigation the data on moisture so generated helped to evaluate the verticle distribution pattern of the arvae aud pupae of *Culicoides peliliouensis* and *C oxystoma* at a desired depth (0-3 cm) of the soil in all the three stations. When the moisture content lowered to a level less than 19.8%, larvae and pupae of *C. oxystoma* became completely absent but larvae and pupae of *C. peliliouensis* were still found to occur at that depth of the substratum. When the amount of moisture was further lowered to a level less than 14.8%, the later species was found to disappear completely (Ray and Choudhury, 1985b).

So, it it pertinent to infer that any alteration in the soil microclimate in relation to moisture seems to have substantial impact on the vertical distributlon of larvae of insect species.

The change in the population densities of some species *Culicoides similis, Bezzia albicornis, Alluaudomyia formosana,*, *A. maculosipennis, Forcipomyia murina, Dasyhelea* sp 1 and sp. 2, *Chironomusbar batitarsis, Psychoda nigripennis, Notiphila* sp., *Atylotus agrestis* and *Tabanus striatus*) documented mainly during the monsoon and postmonsoon months seems to be directly associated with dissolved oxygen and inversely associated with pH.

Littoral zones of mangrove ecosystem are rich in organic nutrients (Heald and Odum, 1970 ; Cameron, 1972). These nutrients help to grow different types of algae in these areas (Nandi. 1986), which provide a novel food source for insect intruders (cf. Chapman, 1960). Insects of those particular habitats are either detritus-algal feeders or carnivorous, specially feeding on nematodes, protozoa, bacteria, etc. (Teal, 1962; Linley and Hinds 1976; Kettle, 1977; and Koch and Axtell, 1978). The distribution and abundance of dipteran larvae in this environment are regulated by the available organic nutrients that help directly or indirectly to grow the algal as well as meofaunal populations.

Correlation coefficient results indicate the direct relationship between organic nutrients (organic carbon and available phosphorus) and the numeridabundance of dipteran species i.e one factor being related to the other (Ray and Choudhury, 1988b).

Soil substratum is also an important and proven facror for benthic dipterans. Different species prefer different types of substratum; some are well adapted in all types of moderate and mixed textural conditions and some favour either sandy or silty natures only (Majori *et al*, 1971 ; Kline, 1974 ; Ray and Choudhury, 1988b).

The occurrence and availability of *Culicoides pelilliouensis, C. oxystoma, Bezzia albicornis, Alluaudomyia formosana Forcipomyia murina, Dasyhelea* sp. 1, *Chironomus barbatitarsis, Psychoda nigripennis, Notiphila* sp , *Brachydeutera longipes, Atylotus agrestis* and *Tabauus striatus* at all the stations could be explained by their ability to adapt in different textural conditions of the soil. Non availability of *Culicoides similis, Nilobezzia* sp. and Dasyhelea sp. 2 at St. II seemed mainly due to their inability to adapt in muddy substratum. *Alluaudomyia maculosipennis* and *Dasyhelea borbonica* were restricted only in St. II for their exclusive preference for muddy substratum. The presence of Nilobezzia sp. in St. III only indicates its possible preference for moderate textural conditions.

Correlation coefficient results indicate that sand alone is negatively correlated with almost all species but in case of silt and clay the results are just opposite.

The content of the present work is but a modest initiation of the investigation on the problem thats deals with the ecological study of the marine benthic dipteran insects and is certainly not a complete one. On entering into the environment the vastness of the field was realised by the authors which demands a multidisciplinary approach and probing.

With a limited capacity and resource the authors could project in the present communication only the population ecology of dipteran fauna and their interaction with the prevailing environmental parameters. But this comprises only a fragment of the whole benthic community of the delta that includes many other non dipteran insects and non-insect invertebrate benthic biota displaying varying degrees of trophic levels and ecological interactions.

SUMMARY

This works deals with the population ecology of marine benthic dipterans in the mud and sandflats of Sagar Island, Sundarbans, India.

The objective of the research conducted during July, 1982 to June, 1984 is to assess the population dynamics in relation to different environmental parameters at the three well specified stations viz., Beguakhali creek (St. I), Sagar creek (St. II), and Dhablat (St. III) in Sagar Island.

The seasonal variation of different environmental parameters, viz., air and soil temperature, soil moisture, rainfall, salinity, dissloved oxygen, sand, silt and clay of the soil substratum in particular, have been documented.

In total 17 dipteran species belonging to 5 families and 12 genera have been assessed quantitatively. The various statistical analyses such as, simple correlation coefficient, multiple regression analysis, analysis of variance have been computed to study the relationship within the species, within the parameters and with the species and parameters.

Ceratopogonidae was the predominant family in the community. *Culicoides peliliouensis* appears as the master component in the environment followed by *Culicoides oxystoma* and *Brachydeutera longipes*.

Maximum number of species and their numerical abundance were encountered during monsoon followed by postmonsoon and premonsoon.

Temperature, moisture, salinity and soil nutrients appear to be the major factors controlling the distribution and abundance of different species.

Combined effects of all parameters on each species was almost always positive as evident from multiple regression analysis.

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