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Composition and diversity of Diptera in temporary pond in southern Nigeria

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Abstract: Spatial and temporal variations in the density and diversity of Diptera were studied in a temporary pond in Okomu Forest Reserve, southern Nigeria during January 1988 to December 1989. Twenty six morphologically distinct taxa were identified, of which 14 were chironomids. The dominant taxa were *Polypedilum* (43%), *Alluaudomyia* (21%), *Culex* (11%), *Pentaneura* (10%) and *Chironomus* (5%). The overall density of Diptera differed significantly ($P<0.05$) among the four study stations, which were chosen from the bank towards the centre of the pond, and differentiated mainly by the degree of macrophyte cover, exposure to sunlight and nature of substratum. Chironomidae dominated at all stations except station 3 where Ceratopogonidae was dominant. In all stations, the highest densities were recorded in the dry seasons. There was a significant positive correlation between density and water temperature and a significant inverse relationship with water level. Shannon-Wiener diversity and evenness were significantly higher ($P<0.05$) at station 4. Faunal similarity analysis revealed a strong affinity between dipteran density and aquatic macrophyte cover.

Resumen: Se estudió la variación espacial y temporal de la densidad y la diversidad de Diptera en un estanque temporal en la Reserva Forestal Okomu, sur de Nigeria, de enero de 1988 a diciembre de 1989. Se identificaron 26 taxones morfológicamente distintos, de los cuales 14 fueron quironómidos. Los taxones dominantes fueron *Polypedilum* (43%), *Alluaudomyia* (21%), *Culex* (11%), *Pentaneura* (10%) y *Chironomus* (5%). La densidad global de los Diptera difirió significativamente ($P < 0.05$) entre las cuatro estaciones estudiadas, seleccionadas desde la orilla hacia el centro del estanque, las cuales difirieron principalmente por el grado de cobertura de macrofitas, la exposición a la luz solar y la naturaleza del sustrato. Los Chironomidae dominaron en todas las estaciones excepto en la estación 3, donde los Ceratopogodonidae fueron dominantes. En todas las estaciones, las mayores densidades fueron registradas en las épocas secas. Existió una correlación significativa y positiva entre la densidad y la temperatura del agua, y una relación significativa pero inversa con el nivel de agua. La diversidad de Shannon-Wiener y la equidad fueron significativamente mayores ($P < 0.05$) en la estación 4. El análisis de la similitud faunística reveló una fuerte afinidad entre la densidad de los dípteros y la cobertura de macrofitas acuáticas.

Resumo: A variação espacial e temporal na densidade e na diversidade dos Diptera foi estudada num reservatório temporário localizado na Reserva Florestal de Okomu, sul da Nigéria, durante o período que decorreu de Janeiro de 1988 a Dezembro de 1989. Foram identificados vinte e seis taxa morfologicamente distintos, dos quais 14 eram chironomididos. O taxa dominante foi o *Polypedilum* (43%), *Alluaudomyia* (21%), *Culex* (11%), *Pentaneura* (10%) e *Chironomus* (5%). A densidade global dos Diptera diferiu significativamente ($P<0,05$) entre as quatro estações estudadas, as quais foram escolhidas desde a margem ao centro do reservatório, e diferenciadas, principalmente, pelo grau de cobertura de macrófitas, exposição à luz solar e natureza do substrato. Os Chironomidae dominavam em todas as estações, excepto na estação 3 onde os Ceratogonidae eram dominantes. Em todas as estações, as maiores densidades foram registadas nas estações secas. Encontrou-se uma correlação positiva significativa entre a densidade e a temperatura da água e uma relação inversa significativa com o nível da água. A diversidade de Shannon-Wiener e a uniformidade, foram significativamente altas (P<0,05) na estação 4. A análise de similaridade faunística revelou uma forte afinidade entre a densidade em dipteros e a cobertura macrófita aquática.

Key words: Diptera, ecology, Insecta, macrophyte, Nigeria, pond, tropics.

Introduction

Aquatic dipterans are the most ubiquitous of all the macrobenthic invertebrate groups in the tropics (Ogbeibu & Egborge 1995; Ogbeibu & Victor 1989; Victor & Onomivbori 1996). Due to the eurytopic nature of dipterans larvae, they have been used as reliable bioindicators of aquatic pollution and related perturbations (Victor & Dickson 1985; Victor & Onomivbori 1996). However, only a few studies deal with dipterans in aquatic systems (Ogbeibu & Egborge 1995; Sharma *et al.* 1993; Victor & Victor 1997). The objectives of this study are to investigate (a) the distribution and diversity of Diptera, (b) the effects of aquatic macrophytes, substrate and water quality on the composition, distribution and density of dipteran fauna in a temporary pond in Okomu Forest Reserve in southern Nigeria.

Study area

Okomu Forest Reserve is located west of Benin City in Edo State, Southern Nigeria (6.5°N; 5.8°E). The Forest Reserve has the distinct feature of the humid tropical wet and dry seasons governed primarily by rainfall. Several streams originate in the reserve, flowing into the gullies of the Osse and Siloko Rivers, which border the Reserve on the eastern and western boundaries respectively. The Okomu River borders the Sanctuary on the western side. Treeless ponds and marshes abound within the Sanctuary (Jones 1955; Ogbeibu & Egborge 1995).

The present study was conducted in the largest pond located in Compartment 52 of the Wildlife Sanctuary within the Reserve (Fig. 1). The study pond has a maximum length of 892.70 m, width of 476.3 m, depth of 1.55 m, shoreline of 2,410.70 m and a volume of 659,196.82 m^3. Samples were taken from four sampling stations spread from the margin to the centre of the pond. Station 1 was located 30 m from the margin, and shaded by dense tree canopy. There were no true aquatic macrophytes; only forest floor vegetation submerged during heavy rains were present. The substratum was mainly leaf litter, with a small proportion of silt, fine and coarse sand.

Station 2, located about 150 m from the margin was also well shaded by the tree canopy without aquatic vegetation. The substratum was a mixture of leaf litter, other decaying organic matter and sticky mud.

Station 3 was about 250 m from the margin, and partially shaded. The water surface was covered by dense mat of floating *Salvinia nymphellula* and *Lemna* sp. Other macrophytes present during this study were *Nymphaea lotus, Panicum* sp. *Commelina* sp. and *Ceratopteris cornuta*. The substratum was composed of organic rich sticky mud with macrophytes fragments.

Station 4, which was innermost and exposed to direct sunlight, was located about 430 m from the margin. It was completely overgrown with rooted macrophytes, *Bacopa aquatica, Telanthera philoxeroides, Cyclosorus striatus, Dryopteris, Cyrtosperma senegalense* and the submerged *Ceratophyllum submersum* and *Spirogyra* sp. The bottom was an entangled mesh of roots and stems of macrophytes.

Materials and methods

Four stations were sampled fortnightly from January 1988 to December 1989 between 1000 and 1700 h. They were located at increasing distances from the shore so as to represent the range of macrophytes density and sediment types.

Samples of dipteran larvae were collected by the 'kick method' (Lenat *et al.* 1981; Victor & Ogbeibu 1985). All invertebrates were killed in the field using small quantities of 40% formaldehyde and later preserved in 70% ethanol for further ex-

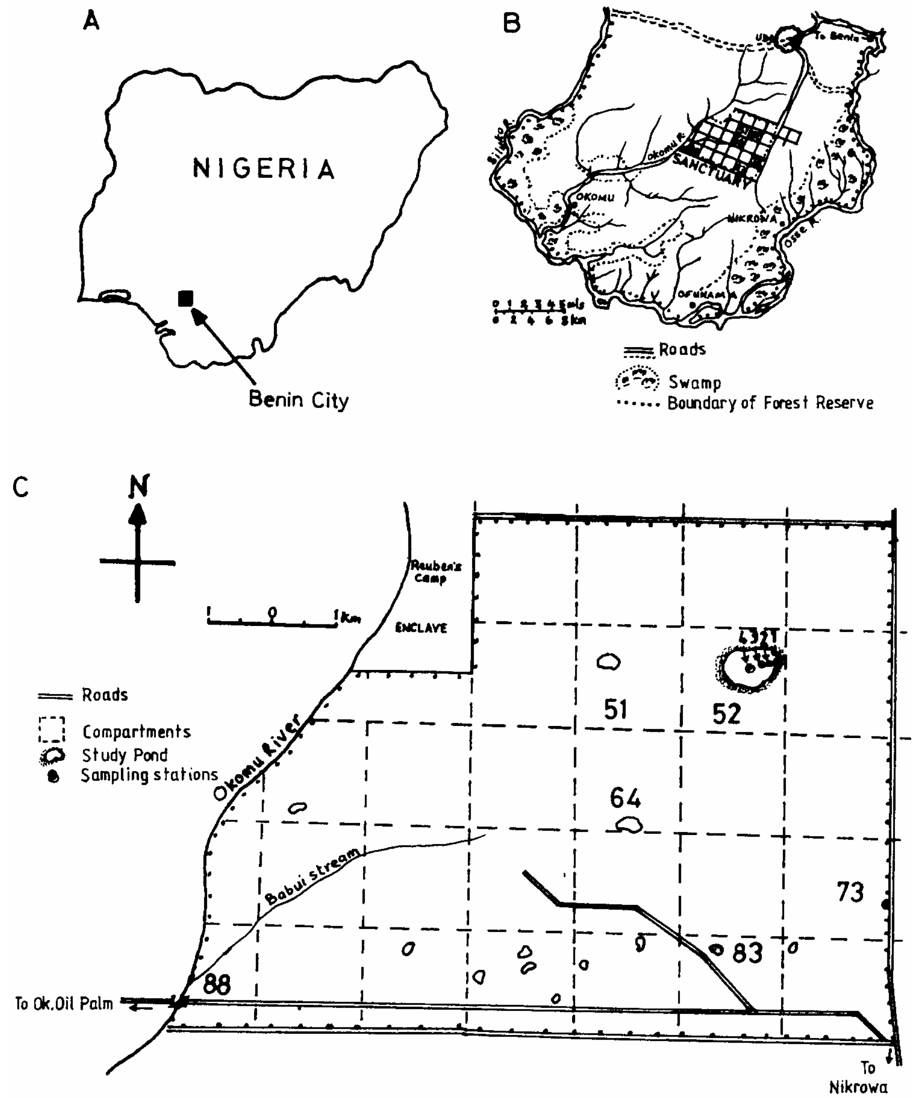

Fig. 1. Map of the study area. (A) Nigeria showing Benin City, Edo State; (B) & (C). Okomu Forest Reserve and the Wildlife Sanctuary showing the sampling stations in Compartment 52.

amination. Most dipterans were identified only to the generic level. The recognized taxa, however, were distinct morphological units. Members of the subfamilies Chironominae and Tanypodinae were, however, identified to the species level using the larval head capsules, antennae and labial plates (Petr 1972). The methods used for analysing the community structure and faunal similarities were according to (Ogbeibu & Egborge 1995). All appropriate statistical procedures for the calculation of diversity and similarity indices were adopted from Magurran (1988) and Zar (1984).

Results

Physical and chemical conditions

A summary of some physical and chemical conditions of the study stations is given in Table 1. All factors with the exception of air temperature and water level were not significantly different ($P>0.05$) among all the stations. The air temperature of stations 1 and 2 were significantly lower ($P<0.05$) than those of stations 3 and 4, which were not different ($P>0.05$) from each other. The water

Table 1. Summary of some physical and chemical conditions of the study stations.

Parameters	Stations							
	1		2		3		4	
	n = 21 X ± SE	CV %	n = 34 X ± SE	CV %	n = 36 X ± SE	CV %	n = 39 X ± SE	CV %
Air temperature (°C)	25.7 ± 35	6	26.4 ± 0.37	8	27.2 ± 0.46*	10	28.4 ± 0.45*	10
Water temperature (°C)	24.6 ± 0.20	4	24.9 ± 0.28	7	25.82 ± 0.35	8	27.1 ± 0.45	10
Water level (cm)	170.0 ± 0.03*	73	48.0 ± 0.04	48	52.0 ± 0.04	48	62.0 ± 0.05*	48
Conductivity (μ S cm^{-1})	40.2 ± 8.18	36	31.1 ± 0.14	26	32.1 ± 1.92	36	36.7 ± 2.36	40
Dissolved oxygen (mg l^{-1})	1.43 ± 0.30	97	1.46 ± 0.14	58	1.73 ± 0.15	53	3.61 ± 0.37	65
Dissolved oxygen % saturation	17.2 ± 3.63	97	17.6 ± 1.75	58	21.4 ± 1.88	53	45.8 ± 4.8	65
Total Alkalinity (mg l^{-1} $CaCO^3$)	15.4 ± 1.36	41	11.2 ± 0.72	38	10.3 ± 0.76	44	9.1 ± 0.72	50
PH	5.5 ± 0.09	7	5.4 ± 0.08	9	5.2 ± 0.08	9	5.1 ± 0.07	8
PO^4-P (mg l^{-1})	0.21 ± 0.05	108	0.37 ± 0.08	127	0.64 ± 0.321	300	0.32 ± 0.06	119
NO^3-N (mg l^{-1})	1.11 ± 0.13	53	1.06 ± 0.12	67	0.97 ± 0.07	40	1.45 ± 0.11	48

*Significantly different means (P<0.05)

level of station 1 was significantly lower (P<0.05) than those of the other stations; stations 3 and 4 were similar, but significantly higher (P<0.05) than that of station 2.

Faunal composition, abundance and distribution

Table 2 shows the taxa composition, density and distribution of dipterans in the study area. Twenty six taxa were identified from a total of 6, 486 individuals collected. Station 1 had 19 taxa, while station 2, 3 and 4 had 18, 22 and 21 taxa respectively. Of all the individuals collected, stations 1 and 2 accounted for 27.1 and 19.6% respectively while stations 3 and 4 contributed 22.3 and 32.0% respectively. The overall density was significantly different at the four stations (ANOVA, P<0.05). An a *posteriori* test for multiple comparison showed that the density at station 2 was significantly lower than those at stations 1, 3 and 4 (P<0.05), which were not different from each other (P>0.05).

A summary of the relative contribution of major dipteran families and species to the overall faunal density at the various stations is presented in Fig. 2 and Table 3. Ceratopogonidae was most important at station 3 where it contributed 46% of the total density. At station 1, its contribution was not significant. The dominant taxon in this family was *Alluaudomyia.*

The family Chironomidae dominated the samples at all stations, contributing 77% at station 1 and 64%, 49% and 62% respectively at stations 2, 3 and 4. It was represented by 10 taxa from three subfamilies, Chironominae (6), Orthocladiinae (5) and Tanypodinae (3). The most important taxa were *Polypedilum, Chironomus transvaalensis* Kieffer, *C. fractilobus* Kieffer (Chironominae), *Cricotopus* (Orthocladiinae) and *Pentaneura* (Tanypodinae). *Chironomus transvaalensis* and *Pentaneura* spp. recorded the highest abundance at station 4 while *Polypedilum* spp. and *Cricotopus* spp. were most abundant at station 1 (Fig. 2).

Culicidae was fairly represented at stations 1, 2 and 4, but insignificant at station 3. Two subfamilies, Chaoborinae and Culicinae were represented. *Chaoborus* was the only Chaoborinae while unidentified *Culex* spp. dominated the Culicinae. Stratiomyidae was not prominent; it contributed only 1% at stations 1, 2 and 3, but absent at station 4. Analysis of variance showed that the density of Chironomidae was significantly higher (P<0.05) than those of the other families.

Temporal dynamics in population density

The overall density of dipterans did not show any general pattern of fluctuation in the study stations (Fig. 3). In all stations, the highest densities were recorded during the dry season months (December in station 1, January in sta-

Table 2. The composition, density (No. of individuals 0.25 m^{-2}) and distribution of dipterans in the study stations.

Taxa	Stations			
	1	2	3	4
Family Ceratopogonidae				
Alluandomyia needhami Thomsen	36	241	663	419
Probezzia opaca Loew	-	5	-	11
Stilobezzia antennalis Coq.	1	-	3	18
Family Chironomidae				
Subfamily Chironominae				
Chironomus (Nilodorum) fractilobus Kieffer	19	4	-	100
Chironomus (Chironomus) trasnvaalensis Keiffer	29	30	10	135
Polypedium bipustulatum Freeman	917	591	376	549
Polypedilum deletum Goetghebuer	249	49	33	46
Stictochironomus caffrarius Kieffer	-	-	8	4
Tanytarsus balteatus Freeman	-	2	7	86
Subfamily Orthocladiinae				
Corynoneura sp 1	1	-	3	6
Corynoneura sp 2	2	3	5	-
Corynoneura sp 3	-	-	4	2
Cricotopus scotae Freeman	94	40	44	-
Cricopus sp	23	-	7	4
Subfamily Tanypodinae				
Clinotanypus maculatus Freeman	-	-	12	18
Pentaneura (Ablabesmyia) nilotica Kieffer	7	52	174	298
Pentaneura (Ablabesmyia) sp	3	2	25	48
Family Culicidae				
Subfamily Chaoborinae				
Chaoborus anomalus Edwards	60	18	13	31
Subfamily Culicinae				
Anopheles sp	17	8	3	28
Culex pipiens	167	83	34	89
Mansonia sp	-	-	-	16
Theobaldia sp 1	9	-	3	18
Theobaldia sp 2	106	64	7	147
Family Stratiomyidae				
Nemotelus sp	-	10	8	-
Odontomyia sp	10	3	-	-
Oxycera sp	11	2	5	-

tion 2, May in station 3, April and February in station 4). Lower densities were recorded during periods of high water level in September and October. The same trend was observed at the family level (Fig. 4), except for Ceratopogonidae which had lower densities in November/December in station 1, 2, 3 (1988) and 4 (1989). Pearson's correlation coefficient revealed a significant positive relationship between total dipteran density and water temperature $r = 0.51$ ($P<0.05$) and a significant inverse relationship with water level $r = 0.47$ ($P<0.05$) and pH $r = 0.27$ ($P<0.05$). Correlations with other chemical parameters were not significant ($P<0.05$).

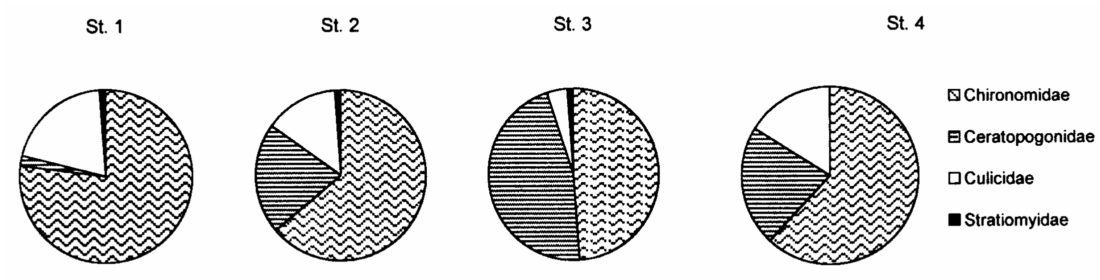

Fig. 2. Relative contribution of major dipteran taxa in the study stations.

Diversity and dominance

The diversity and dominance indices calculated for the four stations are summarized in Table 3. The taxon richness (d) was the highest in station 3 and the lowest in station 2. Station 4 had higher taxon richness than station 1. Shannon diversity (H) was significantly higher in station 4 than in the other stations (P<0.05), which were not different from one another. The. evenness index (E) followed the same trend. Simpson's dominance index was the highest in station 1 and the lowest in station 4; values for station 2 and 3 were not very different.

Faunal similarity of sampling stations

Faunal similarities between sampling stations were evaluated by Bellinger's coefficient and McNemar's coefficient (Wallwork 1970; Zar 1984), and the results are given in Table 4. Bellinger's test showed that station 2 was significantly dissimilar (P<0.05) from stations 1 and 4; the other pairs of stations were similar. McNemar's test, however, did not reveal any significant dissimilarity between the pairs of stations, but it did show that stations 3 and 4 had the closest similarity.

Table 3. Diversity of Diptera in the study stations of Okomu forest pond, 1988-1989.

	Stations			
	1	2	3	4
	n = 11	n = 18	n = 18	n = 20
No. of taxa	19	18	22	21
No. of individuals 0.25 m^{-2}	1759	1207	1447	2073
Taxon richness (d)	2.41	2.40	2.89	2.62
General diversity (H)	0.74	0.75	0.73	0.98*
Maximum Possible Diversity (Hmax)	1.28	1.26	1.34	1.32
Evenness (E)	0.58	0.60	0.54	0.74
Dominance (C)	0.312	0.293	0.295	0.149

*Hutcheson's test-significantly different (P<0.01).

Table 4. Similarity coefficients for pairs of sampling stations, Okomu Forest Pond, 1988-1989.

	Bellinger's Coefficients				
	1	2	3	4	5
McNemar's Coefficients	1	0	3.857*	0.167	1.960
	2	0.357	0	0.360	19.000*
	3	1.429	1.700	0	2.670
	4	1.111	0.769	0.286	0

* Significant dissimilarity (P<0.05)

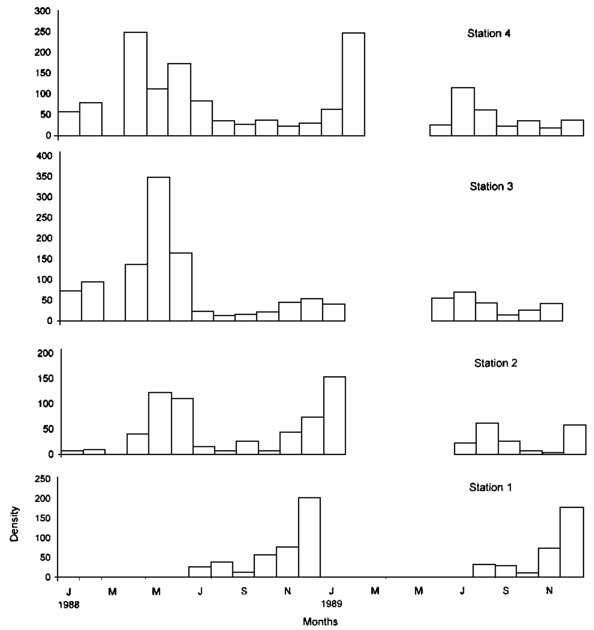

Fig. 3. Spatial and temporal variations in the density of Diptera, Jan. 1988-Dec. 1989, Okomu Forest Pond.

Discussion

Of the 26 taxa recorded in this study, 14 (54%) were chironomids, dominated mainly by the subfamily Chironominae in terms of species richness and density. Thus, further confirming the dominant position of chironomids among dipterans, a common phenomenon in both temperate and tropical waters (Bidwell & Clarke 1977; Bylmakers & Sabolvarro 1988; Lenat *et al.* 1981; Sharma *et al.* 1993; Towns 1979).

The total number of dipteran taxa reported here is high when compared with earlier studies by Victor & Ogbeibu (1985), Ogbeibu & Victor (1989), and Victor & Onomivbori (1996), which reported 10, 19 and 14 taxa respectively from a southern Nigeria fourth order stream. This may be due to the larger and more diverse littoral zone in the pond, encouraging high faunal diversity (Parkin & Stahl 1981). Related studies include those of McLachlan (1971), which reported 23 taxa comprising 17 chironomids from Lake Kariba, and Victor & Al-Mahrouqui (1996) in a perennial stream in southern Oman in which 5 out of the 10 taxa recorded were chironomids. The principal taxa, in the present study *Alluaudomyia, Chironomus transvaalensis, Polypedilum, Cricotopus, Pentaneura, Chaoborus* and *Culex* have earlier been reported in Nigerian waters.

The overall composition and density of fauna varied both spatially and temporary in response to physical, chemical and biological factors of the environment. The overriding influence of substrate composition in the distribution and abundance of benthic fauna (McLachlan & McLachlan 1971) can explain the significantly lower density in station 2, the macrophyte-free zone. The presence of macrophytes and the decomposition of accumulated plant materials provided the right conditions for the higher density of dipterans in stations 1, 3 and 4. Association between chironomid larvae and organic matter and particle size have been demonstrated by Wene (1940) and reviewed by Cummins & Lauf (1969).

The varied ecological requirements of individual taxa also affected their spatial distribution and abundance. Among the ceratopogonids, *Alluaudomyia* was more abundant in stations 3 and 4. These larvae are common among aquatic plants (Petr 1968) as adults are occasionally attracted to light.

Among the Chironominae, *Chironomus fractilobus* and *C. transvaalensis* seem to have the same ecological requirement in the form of high organic matter content, abundance of organic detritus and a broad oxygen tolerance. They also seem to prefer muddy bottoms to sandy substrata (Petr 1972). *Polypedilum* spp. were more abundant in station 1. Their presence or absence seems to be determined more by high oxygen and shallow water preference than substratum. Petr (1972) collected them predominantly from the well-oxygenated shallow zone of Lake Volta and attributed their abundance to the presence of rich food supply rather than a suitable substratum or oxygen concentration. Tanytarsini are typical of oligotrophic lakes, and their abundance has been correlated with permanently high oxygen saturation of water (Thienemann 1922). However, the larvae of *Tanytarsus* were more prominent in station 4, which although not permanently high in oxygen saturation, could be described as the zone with the higher oxygen saturation among the study stations (Table 1). A muddy substrate has been described as typical for these larvae, which are known to construct tubes of sand and organic detritus (McLachlan 1969).

Orthocladiinae is the least common subfamily of Chironomidae with high preference of oxygen-

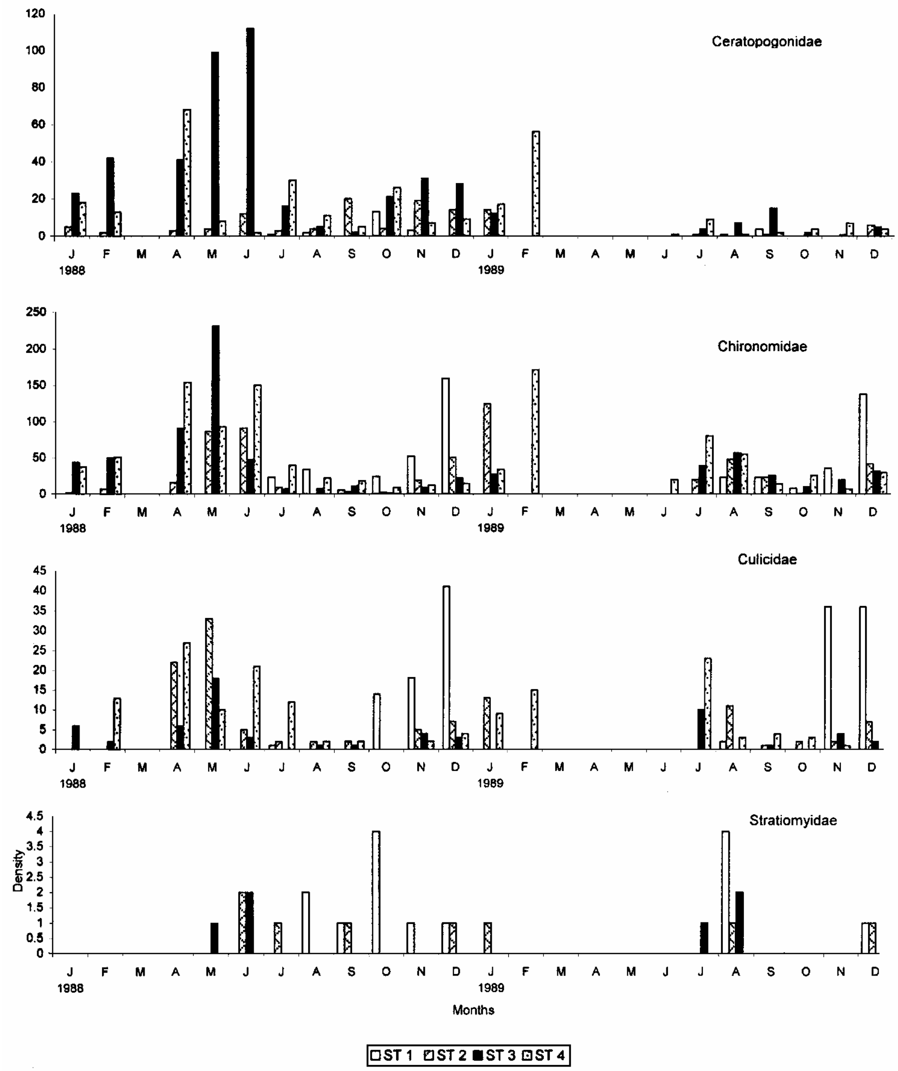

Fig. 4. Spatial and temporal variations in the density of dipteran families in Okomu forest Pond, 1988-1989.

rich environment (Petr 1972; Parkin & Stahl 1981). Species of the genus *Cricotopus* are often associated with vegetation (Hirvenoja 1973). Their high abundance in the marginal station 1 and poor representation in station 4 may be due to factors other than vegetation. The larvae of Tanypodinae represented in this study mainly by *Pentaneura (Ablabesmyia)* are predators commonly found in places such as the roots of aquatic plants, which offer an abundance of prey organisms including oligochaetes and other chironomid larvae (McLachlan 1969). Their high density in station 3 and 4 supports the above claim.

The larvae of *Chaoborus* were more abundant in station 1. It is known that chaoborid larvae can exist for a considerable period in deoxygenated conditions and have been found in high densities in lakes in which the deeper water becomes depleted of oxygen (Stahl 1966). Since deoxygenation was a constant phenomenon in the study stations, the chief reason of their abundance in station 1 is most likely the nature of the substratum. The mosquito *Culex* has been reported from grossly polluted shallow waters (Hynes 1960), and is presumably favoured by the rich supply of particulate organic matter on which it feeds. The stratiomyids, though not an important component of fauna in this study, are associated with organically polluted environments.

The overall density of fauna also varied temporally. Higher faunal densities were recorded during periods of low water level. Pearson's correlation coefficients calculated to assess relationship between density and physical/chemical parameters confirmed an inverse relationship between density and water level and pH. However, a positive relationship existed between density and water temperature.

The diversity and evenness of species calculated by Shannon-Wiener function varied among the study stations. The significantly higher diversity in station 4 is a reflection of its ecological heterogeneity and stability. The high evenness and low dominance index justify this situation, since the higher the evenness the higher the diversity, and the lower the dominance index, the higher the diversity (Victor & Ogbeibu 1985). If overall diversity is used as a measure of community and ecosystem stability, the dipteran community of station 4 must be considered more stable than other stations.

The faunal similarity analysis of the four stations succinctly showed that station 2 was significantly dissimilar from stations 1 and 4. Bellinger's coefficient detects significant discontinuities in the horizontal distribution of individual species populations (Wallwork 1970). McNemar's test ignores the number of taxa either present or absent in a pair of compared stations because it contributes no information about the differences in stations. Therefore, the number of taxa present only in one of the stations is useful in drawing a conclusion about the null hypothesis, which states that the two stations are similar (Ogbeibu & Victor 1989).

Although temporal variations in the density of dipterans was influenced by water level, temperature and pH, the chief factors responsible for the disparity in the density and spatial distribution of species were the nature of the substrate, exposure to sunlight and the presence of aquatic macrophytes.

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