CHIRONOMIDAE COMMUNITY STRUCTURE AS BIOINDICATOR OF WATER QUALITY IN ERIORA RIVER, DELTA STATE, NIGERIA.

Arimoro, F.O.
Department of Animal and Environmental Biology,
Delta State University, P.M.B. 1, Abraka, Nigeria.
E-mail- fransarimoro@yahoo.com, Tel +2348035615424

ABSTRACT
Chironomid larvae and pupae were studied in selected sections of Eriora River, Delta State, Nigeria with the aim of identifying taxa assemblages and analyzing their response to water quality parameters. Macroinvertebrate samples were collected in four stations along a forested ecotone using the kick sampling technique over a six-month period. A total of 12 chironomid species comprising of 1081 individuals were collected. The most abundant taxon was *Cricotopus* sp., (23.5%) followed by *Orthocladius* sp. (20.0%). The chironomidae responses to environmental variables were evaluated by means of biological measures and canonical correspondance analysis (CCA). The abundance (numbers) of chironomidae differed significantly ($p<0.05$) both in space and time. Low abundance and diversity of chironomids were reported (both species and numbers) in station 3 and 4 while the highest number of taxa and individuals were recorded in both station 1 and 2. Conclusively, chironomid communities in Eriora River were deeply affected by organic nutrient enrichment, canopy cover and dissolved organic matter.

KEYWORDS: Canopy cover; chironomid assemblages; physical and chemical parameters; evenness; diversity indices.

INTRODUCTION

Chironomidae, the family of Diptera commonly called "non-biting" midges are ubiquitous in aquatic systems and often are the dominant group of the benthic invertebrate fauna of streams both numerically and in species richness (Coffman and Ferrington, 1984; Freimuth and Bass, 1994; Epler, 2001; Arimoro 2009; Marziali et al 2010; Arimoro et al 2011, Arimoro 2011). They are a useful group for exploring the abundance-distribution relationship due to their ecological importance as well as to the applied aspects of environmental health monitoring. Besides representing one of the most species-rich and abundant group in most aquatic environment, chironomids also present a range of life history that differs markedly, for example, in life-span, locomotion, feeding habits and physiological tolerance to oxygen deficit (Pinder 1986). Because of their abundance and known sensitivity to difference in water quality, chironomidae have long been used as bioindicators of water quality (Pinder 1995).

In this study, both the larval chironomid fauna of Eriora River and the efficiency of the physicochemical variables and substratum structure to distribution of the larvae were discussed. In the face of changing and intensifying human activity in the catchments draining into the river, there is a need to assess the current status of water quality in the river and to test protocols for future monitoring. This study was therefore designed to generate information that could strengthen management strategies for Eriora River in particular and similar streams in Delta State, Nigeria in general.

MATHERIA AND METHOD

Description of Study Area

The Eriora River is a short stream (about 60 km length) located in the Delta State Nigeria. It lies between latitude $5^0.25$□ and $5^0.35$□ N and longitude 6°.07□ and 6°.11□E (Fig. 1). The stream is fed principally by

ground seepage from an aquifer in the thick rainforest zone of Kwale axis of Delta State, Nigeria and also by precipitation, and surface run off from the riparian communities. It flows through the main town of Owhelogbo, Ozoro, Olomoro in Delta State and empties into the Atlantic Ocean via the River Niger. The climatic condition of the area is quite stable with two distinct seasons; wet (April to October) and dry (November to March), with average temperature of 28°C during the wet season and 32°C during the dry season. The river is an intermittent stream that dries up during the dry season.

Four sampling stations were chosen to cover the environmental gradient from reference to slightly impacted stations and care was taken to avoid strong altitudinal/ longitudinal gradients.

Station 1 is located about 5 km downstream from the source at Ozoro along the Owhelogbo-Ozoro road. The riparian vegetation at the station consists of *Symphonia globifena, Alstonia congesis, Oxystigma manni, Matrogyna ciliata, Fussiaera repens* and *Xylopia* species. Canopy cover here is dense with water flowing under narrow channel. The streambed consists predominantly of loam and silt with fallen leaves and wooden parts from fallen trees.

Station 2 is located at Akiewe just by the boundary between Akiewe and Otor-Owhe along the Ozoro-Ughelli road. The stream substratum is covered with coarse sand with an average depth of 17.5cm and width of about 3.7cm. Canopy cover is about 65% consisting of mixed vegetation with in-stream vegetation comprising of *Pistia stratiotes, Nymphaea.* sp., *Commelina* and *Panicum repens*. The river flow is quite swift here and it is relatively free from human activities due to its location away from human settlement.

Station 3 is situated at Otor-Owhe some 3km downstream of station 2 and along the SPDC oil installation (flow station) road. The stream is dark in apperance here with a lot of fallen leaves and sticks. Flow rate here is reduced when compared to that of station 2. Canopy cover is about 60% and in-stream vegetation consists of *Azolla africana, Nymphaea.* sp, *Commelina.* sp, and *Bambusia.* sp.

Station 4 is located at Olomoro some 1.5km downstream of station 3 and very close to Olomoro Comprehensive Secondary School. The riparian vegetation cover is about 60% and is made up of mixed forest with the *Bambusia.* sp being the most predominant. Others are *Pandanus.* sp, *Elaeis guineensis*, and *Mitragyna ciliata*. The substratum consists of coarse sand mixed with mud and plenty of fallen leaves from the predominant *Bambusia* sp.

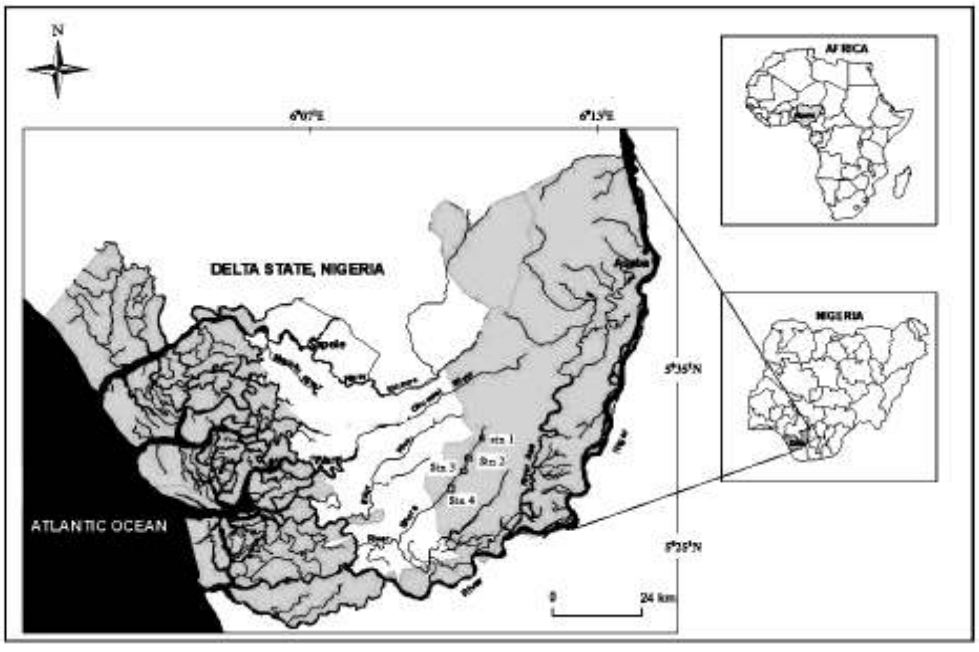

***Figure 1**. Map of Delta state showing the location of Eriora River and the sampling stations. Inset; map of Africa showing the location of Nigeria and map of Nigeria showing the location of Delta State.*

Physical and chemical variables

At each sampling station the following physical and chemical variables were measured: Dissolved oxygen (YSI 55 dissolved oxygen meter), temperature (0-100°c mercury in-glass thermometer), pH and conductivity (Hanna HI 991300/1), Water samples were taken for analysis of nitrates and phosphates were measured spectrophotometrically after reduction with appropriate solutions (APHA 1992).

Chironomids sampling

Kick samples of chironomids were collected bimonthly (May–November 2010) with a D-frame net (500-µm mesh) within an approximately 25 m wadeable portion of the river. Four 3-min samples were taken on each sampling visit to include all different substrata and flow regime zones. The four samples were then pooled, representing a single sample for each station. Samples were sorted *in situ*, examining single quotes of material in white trays. A part of the sediment collected during the sampling, for each sample, was brought to the laboratory to further check for the presence of small taxa. This was preserved in 70% ethanol. In the laboratory, samples were washed in a 500- µ m mesh sieve to remove sand and macroinvertebrates were sorted under a stereoscopic microscope (magnification 10X). All animals were separated and enumerated and identified under a binocular dissecting microscope. Chironomids species were identified using relevant diagnostic keys (Merritt and Cummins 1996; Pennak 1978; Cranston 2000; Epler 2001; Day et al 2002).

Statistical analyses

The range, mean and standard error for each parameter and station were calculated. Physical and chemical features of stations were compared using one way ANOVA on log (x + 1) transformed data except for pH. Fixed effect ANOVAs were performed using dates as replicates. Significant ANOVAs ($P < 0.05$) were followed by post hoc {Tukey Honest (HSD)} tests to identify differences between station means. Canonical correspondence analysis (CCA) was used to evaluate relationships between chironomid communities and environmental variables with Environmental community analysis (ECOM) package (version 1.33, Pisces Conservation Ltd., 2000 http://www.ircHouse.demon.co.uk/index.html). CCA is a powerful tool for simplifying complex data sets and, being a direct gradient analysis, it allows integrated analysis of both taxa and environmental data (ter Braak and Smilauer 2002). Before using CCA, variables that covaried with other variables (Pearson correlation $r > 0.80$, $P < 0.05$) were removed. In addition, variables were log transformed {log (x + 1)} before the CCA analysis to prevent extreme values (outlier) from unduly influencing the ordination. Species-environment correlation coefficients provided a measure of how well variation in community composition could be explained by individual environmental variables. Taxa richness (Margalef & Menhinick indices), diversity (Shannon, & Simpson dominance indices) and evenness indices were calculated using the computer BASIC programme SP DIVERS (Ludwig and Reynolds, 1988).

RESULT

The physical and chemical status of Eriora River

The waters of Eriora River are, in general, somewhat dark coloured, acidic with low pH values ranging from 4.4 to 4.8, reasonably well oxygenated (10.4 - 12.0 mg/L), of low conductivity (<56.0 μScm^{-1}) except in station 3 where conductivity reached up to 88.2 μScm^{-1} during the peak of the rainy season (Table 1). Nitrates values ranged from 0.70 in station 3 to 1.6mg/L in station 4. Phosphates ranged from 0.1 in station 1 to 0.29 mg/L in station 4. Repeated measures ANOVA showed that air & water temperatures, flow velocity, dissolved oxygen, were not significantly different ($p > 0.05$) among the various stations sampled. Biochemical oxygen demand (BOD), nitrates and phosphates values were however significantly higher ($p < 0.05$) in station 4. Biochemical oxygen demand (BOD) values were highest in station 4, followed by station 3, 2 and 1 in decreasing order of magnitude.

Table 1: Summary of physicochemical properties of the study stations, Eriora River from May to No-

													F-Anova	P-value
	Station 1			Station 2			Station 3			Station 4				
Parameter	min	Max	X±S.E	min	Max	X±S.E	Min	max	X±S.E	min	max	X±S.E		
Air Temperature (°C)	30.00	33.03	31.5±0.64[a]	30.60	33.05	31.5±0.64[a]	30.07	33.07	31.56±0.64[a]	30.1	33.09	31.5±0.64[a]	0.0	0.999
Water Temp (°C)	28.50	30.10	29.3±0.34[a]	29.00	32.00	30.5±0.65[a]	28.00	31.00	29.5±0.65[a]	29.0	32.00	30.5±0.65[a]	1.3	0.330
Flow Velocity (m/s)	0.05	0.63	0.31±0.13[a]	0.06	0.54	0.26±0.11[a]	0.06	0.43	0.21±0.08[a]	0.05	0.45	0.25±0.09[a]	0.2	0.920
Water Depth (cm)	24.00	30.00	27.75±0.31[a]	13.50	20.50	17.5±1.50[b]	44.20	50.00	47.88±1.28[c]	70.3	78.40	75.0±1.78[d]	274*	0.000
DO (mg/L)	10.40	11.00	10.73±0.13[a]	10.90	11.40	11.35±0.24[a]	10.20	11.50	10.78±0.28[a]	10.8	12.00	11.3±0.26[a]	3.5	0.160
BOD (mg/L)	7.00	7.40	7.18±0.09[a]	7.80	8.20	8.00±0.09[a]	7.80	8.40	8.08±0.13[a]	9.20	10.00	9.73±0.18[b]	71*	0.000
Nitrates (mg/L)	1.00	1.40	1.23±0.09[a b]	1.00	1.20	1.08±0.05[a]	0.70	0.90	0.78±0.05[b]	1.30	1.60	1.45±0.06[b]	19.6*	0.0001
Phosphate (mg/L)	0.10	0.16	0.14±0.01[a]	0.15	0.20	0.18±0.01[a]	0.20	0.26	0.24±0.01[b]	0.24	0.29	0.26±0.02[a]	13.4*	0.0004
pH	4.5	4.6	4.6	4.7	4.8	4.8	4.3	4.5	4.4	4.5	4.7	4.6		
Conductivity (µS/cm)	47.60	48.20	47.9±0.13[a]	56.00	56.20	56.1±0.04[b]	87.80	88.20	87.9±0.10[c]	55.9	56.20	58.3±2.23[d]	244*	0.0000

Note: Values are mean ± SE, minimum and maximum values. Different superscript letters in a row show significant differences ($P < 0.05$) indicated by Tukey Honest (HSD) significant difference tests. * Indicates significantly calculated F-value detected by ANOVA. DO, Dissolved Oxygen, BOD, Biochemical oxygen demand

Distribution and composition of chironomid community in the study area

There were 12 different chironomid taxa at the four stations with richness at individual stations ranging from 4 to 8 taxa. Two chironomid taxa, *Chironomus transvaalensis,* and *C. fractilobus* species were found in all the four stations (Table 2). Some sensitive chironomid species, *Polypedilium* and *Clinotanypus* were restricted to station 1, while on the other hand, somewhat tolerant species *Cladotanypus* was restricted to station 4 only. *Cricotopus* sp. was the major taxa with a relative composition of 23.5% followed by *Orthocladius* sp. (20.0%) and *Chironomus transvaalensis* (18.7%). Others were *Chironomus fractilobus* with 14.8% and *Paratrichocladius* sp. with 11.7% of the total chironomidae abundance. *Ablabesyia* sp. and *Tanytarsus* sp. were sporadically present with 1.8% and 1.3% in relative composition respectively.

Influence of environmental parameters on abundance of chironomids

The total extent of variation or total inertia (TI) in chironomid assemblage composition in the studied stations of Eriora River was equivalent to 1.15 eigenvalues of which the six physical and chemical parameters could explain 63.2% (total variance explained, TVE). All canonical axes were significant (Monte-Carlo test, $p<0.05$). The first canonical axis distinguished group of species found at most stations *Chironomus transvaalensis, Cricotopus* and *Corynoneura*. This corresponded to high phosphate and nitrate values. The second group included the tolerant species namely *C. fractilobus, Tanytarsus*) that corresponded to high DO, pH and water depth values (Figure 2). Temperature did not play a major significant role in structuring the chironomid abundance and distribution.

Temporal variation in macroinvertebrate abundance

Total chironomid abundance (no. of individuals) varied significantly among months and inversely with depth suggesting strong seasonal effects. It increased progressively from May to November with a peak in November in all the stations sampled.

Table 2: The occurrence, relative abundance of macroinvertebrate species at the four stations of Eriora River, Delta State, Nigeria from May to November, 2010.

	TAXA	Code	Station I	Station II	Station III	Station IV	Total	%
	Sub family Chironominae							
1	*Tanytarsus* sp.	Tan	0	14	0	0	14	1.3
2	*Polypedilum* sp.	Pol	9	0	0	0	9	0.8
3	*Crytochironomus* sp.	Cry	0	0	9	0	9	0.8
4	*Cladotanytarsus* sp.	Cla	0	0	0	5	5	0.5
5	*Chironomus transvaalensis*	ChiT	28	52	56	66	202	18.7
6	*Chironomus fractilobus*	ChiF	56	9	42	52	160	14.8
7	*Corynoneura* sp.	Cor	42	5	0	14	61	5.6
	Sub family Tanypodinae							
8	*Ablabesyia* sp.	Abl	0	19	0	0	19	1.8
9	*Clinotanypus* sp.	Cli	5	0	0	0	5	0.5
	Sub-family orthocladiinae							
10	*Cricotopus* sp.	Cri	66	127	0	61	254	23.5
11	*Orthocladius* sp.	Ort	136	52	28	0	216	20.0
12	*Paratrichocladius* sp.	Par	103	24	0	0	127	11.7
	No of species (s)		8	8	4	5		
	No of individual (N)		445	302	135	198	1081	

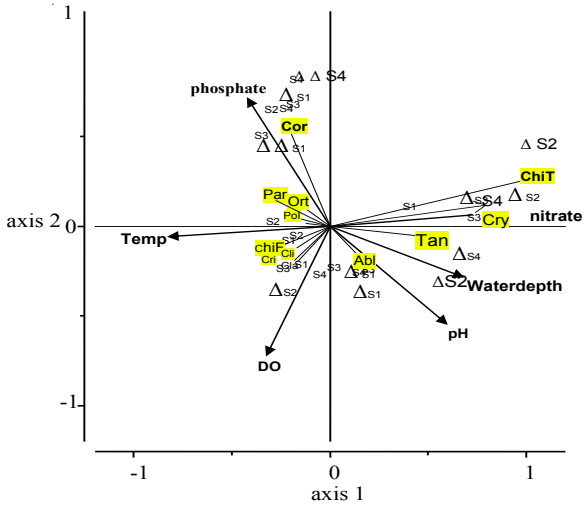

Figure 2: *Triplot of first and second CCA axes of chironomid taxa, environmental variables and their corre-*

sponding sampling stations. The scale in SD units is -1 to 1 for both the invertebrate and environmental variable scores. Full names for abbreviation codes of invertebrate taxa are given in Table 1. → environmental variable, Δ- samples codes, Stations numbers: S1, S2, S3 andS4.

Taxa richness, Diversity, Evenness and Dominance Indices

Taxa richness calculated as Margalef's index, *Shannon-Weiner,* evenness and Simpson's indices for the four stations are depicted in Table 3. The *Shannon-Weiner* index (H) was significantly lower in station 3. Similarly, station 2 recorded the lowest evenness index. It was higher in station 3 followed by station 1 and then station 4. Taxa richness was higher in station 1 followed by station 2, station 4 and then station 3.

Table 3. Taxa richness, diversity, evenness and dominance indices of the sampling stations of Eriora River

	Station 1	Station 2	Station 3	Station 4
Species Richness Indices				
Margalef's index(d):	1.148	1.226	0.612	0.756
Menhinick's index(d):	3.240	3.348	1.806	2.174
Diversity Indices (Information Theory Indices)				
Shannon-diversity Index (H'):	1.771[a]	1.660[a]	1.235[b]	1.360[b]
Shannon and Wiener Index (H):	0.769[a]	0.721[a]	0.536[b]	0.591[b]
Evenness Index(E'):	0.852	0.798	0.891	0.845
Simpson's Dominance Index (C):	0.198	0.250	0.316	0.281

***Note**. Values with the same letter of superscript in a row do not vary significantly using Tukey posthoc test*

Discussion

The physico-chemical parameters of Eriora River that is, low phosphate and nitrate values and high dissolved oxygen content portend that the water is of fairly good quality. However, water conditions were significantly better in the upstream stations (station 1 and 2) as compared with downstream stations (stations 3 and 4). The slightly higher nutrient values and BOD values at the downstream stations may be as a result of increase in organic matter from anthropogenic sources, although the values are far from constituting pollution or environmental health hazards. A total of 12 chironomid taxa were recorded in the river. Chironomids are one of the most abundant macroinvertebrate group and they often account for the majority of aquatic insects in freshwater environment (Freimuth and Bass, 1994, Epler, 2001). Due to adaptability of larvae to extreme environmental conditions of temperature, pH, salinity, depth, flow velocity and productivity, they can be found in many different aquatic environments (Armitage, et al, 1995). Although there were minimal differences in chironomid assemblage along the different sampling stations in the study area, the highest diversity and abundance was recorded in station 1 which corresponded to the station with the greatest percentage of canopy cover. It is assumed that stations with dense canopy cover usually lead to incidences of fallen leaves and trees (Price et al. 2003). This increased habitat heterogeneity, at least in terms of velocity and substrate coarseness, resulted to increase in chironomid abundance and diversity. The high diversity and taxa richness at station 1 can also be attributed to good habitat quality and high water quality at the reach. Also, species compositions of chironomids differ qualitatively and quantitatively among microhabitats, and larvae are highly selective in their choice of a station (Marziali *et al.,* 2010). In this study, station 1 recorded the highest abundance and diversity of chironomids especially members from the sub family Orthocladiinae which have been earlier classified as facultative species usually absent from heavily polluted streams (Pinder 1995; Arimoro et al 2007). The forests surrounding station 1 were a good source of allochthonous organic matter for stream biota which is broken down to fine particulate organic matter and utilized as food by most chironomids which are collector-gatherers and filterers (Merritt and Cummins 1996).

Overall, this study revealed that chironomid communities responded to changes in water quality along the river. Despite little apparent change in taxon richness observed at the different stations, there were marked shifts in dominance and composition. Station 1 and 2 were dominated by taxa associated with detritus, *Polypedilium* sp., *Orthocladius* sp., and *Paratrichocladius* sp. In general, *Cricotopus* sp. was the most dominant species followed by *Chironomus transvaalensis*. In all, *Chi-*

ronomus species (*C. transvaalensis* and *C. fractilobus*) were ubiquitous in the study stations. They were collected in high number showing their ability to tolerate any given water condition. Ikomi *et al*. (2005), Arimoro *et al*. (2007) and Arimoro and Ikomi (2008) had earlier reported the high abundance of these chironomids in some forest streams in Delta State. The reason for the high abundance of the Family Chironomidae is being especially related to the amount of detritus which is abundant in forested streams from allocthonous input.

From this study, the chironomid species, *Ablabesyia* and *Clinotanypus* (subfamily -Tanypodinae) were completely absent from stations 3 and 4. These species can be used as indicators of water quality in the Niger Delta as they were absent from waters having a BOD value of more than 8mg/L and nitrate value of above 1.0mg/L.

In conclusion, although this study was based on a single forested stream in the Niger delta, the results clearly demonstrate the assemblage dynamics of chironomids as related to the water quality status of the different sampling station and the amount of canopy cover available at each site thus we can infer that physical habitat is a primary factor influencing the structure and composition of stream faunal communities. The mosaic of streams in tropical forest provide an excellent system to gain better understanding of important processes affecting community assembly, and thus factors controlling chironomid diversity.

REFERENCES

APHA (1992). American Public Health Association. Standard Methods for the Examination of Water and Waste Water, 18th ed. APHA, Washington, DC.

Arimoro FO, Ikomi RB, Iwegbue CMA (2007). Water quality changes in relation to Diptera community patterns and diversity measured at an organic effluent impacted stream in the Niger Delta, Nigeria. *Ecol. Ind*. 7, 541–552.

Arimoro FO, Ikomi R.B (2008). Response of macroinvertebrate communities to abattoir wastes and other anthropogenic activities in a municipal stream in the Niger Delta, Nigeria. *Environmentalist* **28**, 85–98.

Arimoro F.O (2009). Impact of rubber effluent discharges on the water quality and macroinvertebrate community assemblages in a forest stream in the Niger Delta, Nigeria. *Chemosphere* **77**, 440-449

Arimoro F.O, Ikomi R.B, Ajuziego I. O, Nwadukwe F.O (2011) Temporal and spatial variability in the structure of benthic communities and environmental variables of a Niger delta creek *African Journal of Aquatic Science* **36**, 57-66.

Arimoro F.O. (2011). Head capsule deformities in *Chironomus transvaalensis* (Diptera: Chironomidae) as an indicator of environmental stress in an industrial effluent impacted stream in southern Nigeria. *Fresinius Environmental Bulletin* **20(6)**, 1360-1365.

Armitage, P., Cranston, P. S. and Pinder, L.C.V. (1995). The Chironomidae. The biology and ecology of non-biting midges. Chapman and Hall, London, 572pp.

Coffman, W. P. and Ferrington Jr. L. C. (1984). Chironomidae, chapter 25, in R. W. Merritt and K. W. Cummins (eds), *An Introduction to the Aquatic Insects of North American,* 2nd edn, Kendall/Hunt Publishing Co. Dubuque, Lower, 722pp.

Cranston, P.S. (2000). Electronic guide to the Chironomidae of Australia. http://entomology.UCdavis.edu/Chiro page. assessed on 12/03/2005

Day, J.A., Harrison, A.D., De Moor, I.J., (2002). Guides to the Freshwater Invertebrates of Southern Africa, Vol. 9. Diptera TT 201/02, Pretoria: Water Research Commission 200pp.

Epler J. H. (2001). Identification manual for the larval chironomidae (Diptera) of North and South Carolina. Version 1.0 Crawford Wille, 53pp

Freimuth, P. and Bass, D. (1994). Physicochemical conditions and larval chironomidae (Diptera) of an urban pond. *Proc. Okla, Acad. Sic.* **74**, 11-16.

Ikomi R.B, Arimoro F.O, Odihirin O.K (2005). Composition, distribution and abundance of macroinvertebrates of the upper reaches of River Ethiope, Delta State, Nigeria. *The Zoologist* **3**, 68-81.

Ludwig, J.A., Reynolds, J.F. (1988). Statistical Ecology. A Primer on Methods and Computing. Wiley Interscience, Wiley, New York, pp. 337.

Marziali L., Armanini, D.G., Cazzola, M. Erba, S., Toppi, E., Buffagni A., and Rossaro B. (2010). Responses of chironomid larvae (Insecta, Diptera) to ecological quality in Mediterranean River mesohabitats (South Italy). *River Research and Application* **26**: 1036–1051.

Merritt R.W, Cummins K.W (1996). An Introduction to the Aquatic Insects of North America, third ed. IOWA, Kendall-Hunt, Dubuque. 862pp.

Pennak, R.W., (1978). Freshwater invertebrates of the United States. John Wiley, New York, pp. 801.

Pinder, L. C. V. (1986). Biology of freshwater chironomidae, *Annual Review of Entomology,* **31**:1-23.

Pinder, L. C.V. (1995). The habitats of chironomid larvae. In the chironomidae, biology and ecology of non-bitting midges, Armitage PD, Cranston PS, Pinder LCV (eds). Chapman and hall, Londong, 107-135.

Price K, Suski A, Magarne J, Beasley B, Richardson JS (2003). Communities of aquatic insects of old-growth and clearcut coastal headwater streams of varying flow persistence. *Can. J. For. Res*. **33**:1416-1432.

Ter Braak CJK, Smilauer P (2002). CANOCO Reference Manual and Canoco Draw for Windows User's Guide: Software for Canonical Community Ordination (Version 4.5). Microcomputer Power, Ithaca, NY, USA, pp. 1 – 500.