KWAME NKRUMAH UNIVERSITY OF SCIENCE AND

TECHNOLOGY, KUMASI

FACULTY OF SCIENCE

DEPARTMENT OF BIOLOGICAL SCIENCES

BIONOMICS OF THE CHIRONOMIDAE OF BAREKESE AND OWABI RESERVOIRS AS A BASIS FOR FORMULATING STRATEGIES FOR THE CONTROL OF THE NUISANCE SPECIES.

A thesis submitted to the Department of Biological Sciences, Faculty of Science, in partial fulfilment of the requirements of the examinations for the award of Doctor of Philosophy degree.

By

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JUNE, 2002

DECLARATION

This is to certify that this thesis has not been submitted previously to any other University for the award of a Ph. D. degree. It is entirely my own work and the study was undertaken under the supervision of Prof. Emmanuel Frempong. Due acknowledgement has been given for all help received by me.

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I wish to thank my supervisor, Prof. Emmanuel Frempong, for being patient with me throughout the study period. I thank my wife, Gladys, and my children- Michael, Doreen and Frederick for the encouragements that they gave me throughout the study period.

This study would not have been possible but for the dedicated services of the late Mr Seth Nortey (Driver, WRI) who ferried me from Accra to the sampling site, every week, at the peak of the study.

ABSTRACT

Chironomidae of two raw water reservoirs at Barekese and Owabi, in the Kumasi Metropolis, were studied over an 18-month period with the objective of identifying the nuisance species. Seasonal variations of the physico-chemical parameters of the two reservoirs were examined with respect to the abundance, diversity and production of the five common chironomid species, namely, *Nilodorum fractilobus, Nilodorum brevibucca, Nilodorum brevipalpe, Dicrotendipes schoutedeni* and *Kiefferulus chloronotus.* All together, seventeen chironomid species were recorded from the two reservoirs, three species more than previously reported by other workers. The large fluctuations observed in reservoir water level at Barekese were attributed to the higher rate at which raw water was extracted. Mean surface water temperature at Owabi and Barekese was 28.0°C and 27.9°C respectively. Surface water temperature exhibited seasonal fluctuations with the highest temperatures occurring in March, during the dry, humid season and the lowest in August during the rainy season, when the sky was heavily overcast. Water from both reservoirs was slightly alkaline (pH = ~ 7.0) and well buffered (alkalinity > 24.0 mg. l^{-1} $CaCO_3$). Concentration of nutrients in both reservoirs was high. Mean concentration of ammonia-nitrogen (NH_3-N) was equal to that of nitrate-nitrogen (NO_3-N) but was greater than nitrite-nitrogen (NO_2-N). Thus, the dominant pattern of nutrient concentration was of the order NH_3-N = NO_3–N > NO_2–N. Generally, the nutrients, major cations and anions followed a seasonal trend. Higher concentrations occurred at the start of, or during the rainy season whereas lower concentrations occurred during the dry season. In general, the concentration of calcium was greater than magnesium (i. e. $Ca^{2+} > Mg^{2+}$), and conformed to the pattern associated with fresh waters. Concentration of chloride in reservoir water was 19.5 mg. l^{-1} and 22.7 mg. l^{-1} for Barekese and Owabi respectively. Chloride concentration was higher than the limits (<10 mg l^{-1}) found in pristine waters. Sulphate

(SO_4^{2-}) was also higher than 10 mg l^{-1}. The reservoirs were, therefore, classified as receiving organic pollutants.

Chironomid production was estimated to be 170.66 ± 23.25 g m^{-2} yr^{-1} and 41.00 ± 55.40 g m^{-2} yr^{-1} in Barekese and Owabi reservoirs respectively. The production of Chironomidae in Barekese and Owabi reservoirs is also equivalent to 827.7 and 198.9 cal. of energy respectively that is locked up in the various species but is not utilised by the biocoenosis. The abundance of Chironomidae in the two reservoirs was related to thirteen physico-chemical variables, *viz.* dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), chlorides (Cl^-), Acidity, ammonia-nitrogen (NH_3-N), nitrite as nitrogen (NO_2 –N), nitrate as nitrogen (NO_3–N), phosphate (PO_4), chlorophyll *a* (Chl. A.), calcium (Ca^{2+}), Turbidity, Conductivity and Total Hardness. Nine significant prediction models described these relationships ($p < 0.05$). However, there was no significant model that related abundance of *Dicrotendipes schoutedeni* to the physico-chemical characteristics of the waters of Barekese. Based on the observations made, during the study, a strategic plan for the control of the nuisance species in both reservoirs is provided. The plan involved the use of chemicals, biocides, and the introduction of fish species to exploit the vast amount of energy locked up in the nuisance chironomid species. The plan also recommended better management of the watershed by controlling inputs of nutrients from point sources.

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LIST OF ABBREVIATIONS AND ACRONYMS USED

Taxonomic

N. f	*Nilodorum fractilobus*
N. brv.	*Nilodorum brevibucca*
N. brp.	*Nilodorum brevipalpe*
K.c.	*Kiefferulus chloronotus*
D.s.	*Dicrotendipes schoutedeni*

Physico-Chemical Features of Reservoirs

Alknity	Alkalinity
Chl. A	Chlorophyll A
Conduct	Conductivity
Hdness	Hardness
R.level	Reservoir level
Secchi	Secchi Disc Transparency
Turbid	Turbidity

Production

DM	Dry Mass
CPI	Cohort Production Interval

Other

APOC	African Programme for the Control of Onchocerciasis
GWCL	Ghana Water Company Limited

CHAPTER ONE

INTRODUCTION

1.1 Background to The Study.

Barekese and Owabi reservoirs are two water supply systems that serve Kumasi and its satellite communities. The growing population of Kumasi Metropolis has placed pressure on the installed capacity of the two headworks. In addition, there is unfettered encroachment of the watershed of the two reservoirs. Physical development within the catchments of the two reservoirs, recently, has led to pollution and eutrophication of the waters of the two reservoirs. The result is that the unit cost of production of potable water keeps increasing, by the year, as more water treatment chemicals are needed in order to achieve good- quality, potable water at the two plants. Alongside the deteriorating quality of the raw water is the infestation of the potable water by chironomid larvae (Ghana Water Company Limited (GWCL), pers. com.).

Consumers in the metropolis began to complain about the appearance of certain organisms in their potable water. The problem became widespread in 1997. Therefore, some communities, especially the peri-urban areas, reverted to their old sources of water supply that were mainly of doubtful quality. Such consumers stood high risks of contracting diarrhoeal diseases. GWCL contacted the Department of Biological Sciences of Kwame Nkrumah University of Science and Technology to investigate the source and cause of this contamination. The organisms were found to be larvae of Chironomidae.

Chironomidae occur in all zoogeographical regions of the world (Ashe, 1983). They live in various microhabitats ranging from ice to hot springs (Oliver, 1971). The adult can cause economic losses at recreational centres when they emerge in large numbers and become a

nuisance (Ali, 1980; Cranston *et al.*, 1990). Some species are of medical importance as they elicit allergic reactions, ranging from rhinitis to asthma, in humans (Freeman, 1950; Kay *et al.*, 1978; Cranston, 1980; Cranston *et al.*, 1981; Pinder, 1989) or damage rice crops (Darby, 1962 cited by Stevens, 1995; Stevens, 1995).

Berg (1995) reviewed the problem of infestations of water supply systems by chironomid larvae and the methods for their control or elimination. The control measures included re-designing or modification of the distribution system and the application of insecticides (Berg, 1995). However, because the chironomid larvae, in the present study, occurred in water supply reservoirs, GWCL was unwilling to use insecticides to control the nuisance flies because of the health implications and because of the cost involved. Instead, GWCL increased the amount of chlorine added to the potable water produced at the two headworks. Also, GWCL installed screens between the filters and the potable water reservoirs as a means of containing the problem of infestation by the larvae. The measures have largely failed to solve the problem.

Straškraba and Tundisi (1999) suggested that a way to achieving a sustainable management of reservoirs is to adopt an integrated reservoir management system involving watershed management and control of nuisance species (both plants and animals) through bio-manipulation of the species. To be able to achieve this the ecology of the reservoirs must be known.

1.2 Aims and Objectives.

The objectives of this study were to:

1. Investigate the extant species in the two reservoirs.

2. **Identify the nuisance chironomid species in the two reservoirs.**
3. **Investigate the seasonal abundance and production of the nuisance species.**
4. **Investigate the influence of the prevailing physico-chemical parameters on the abundance of the nuisance chironomid species.**
5. **Provide efficient and sustainable methods for the control of the nuisance chironomid species.**

CHAPTER TWO

PHYSICO-CHEMICAL CHARACTERISTICS OF THE WATERS OF BAREKESE AND OWABI RESERVOIRS

2.1 Introduction

The physico-chemical characteristics of a reservoir are a reflection of the geology of the basin in which the reservoir lies as well as the activities that go on within the basin (Straškraba and Tundisi, 1999). These characteristics include the depth of the reservoir, transparency, conductivity, water temperature, and cationic and anionic contents as well as nutrients of the reservoir water (Straškraba and Tundisi, 1999). They do not only indicate the suitability or otherwise of the reservoir water for production of potable water but also affect the aquatic ecosystems as a whole. Physico-chemical features of a reservoir also determine other uses to which a reservoir may be put such as: -

(a) The removal of impurities especially nutrients in tertiary oxidation ponds and in sewage treatment plants.

(b) Recreation centres.

(c) Fish farming and for irrigation.

(d) Conservation of endangered species (both Owabi and Barekese reservoirs have been designated as Ramsar sites).

The physico-chemical characteristics of reservoir or lake waters vary in time and space. They are influenced by climate and location of the lake or reservoir (Ruttner, 1963). Temperature is particularly important in this regard. Wide differences between summer and late autumnal surface water temperatures of reservoirs and lakes set off a series of chain reactions that affect the entire aquatic ecosystem in temperate locations (Ruttner, 1963). In the tropics, however,

seasonal variations in surface water temperatures are minute. However, because of the anomalous behaviour of water in relation to temperature, large differences in density of water occur on a diel and seasonal basis because of slight temperature variations (Ruttner, 1963). These slight changes in temperature of surface water and that at greater depths can trigger mixing of the reservoir water with consequent redistribution of the chemical constituents of the water (Straškraba and Tundisi, 1999).

Ansa-Asare and Asante (1998) observed that nutrients in Densu Reservoir, at Weija, increased considerably during the rainy season. Water Research Institute (1999) also reported an increase in the ionic content of the waters of Lake Volta during the rainy season.

The climate of Ghana and its effects on ambient temperatures have been described by Petr (1969) who recognised four seasons in the year. There are two rainy seasons. The major one lasts from April/May to September. The skies are overcast and reservoir and lake surface temperatures are low. It is followed by the hot weather (October-December) during which time temperatures rise. The harmattan then comes in at the end of December and persists until the end of February. At this time high surface evaporation combined with the north-easterly trade winds work together to reduce reservoir surface water temperatures. The last season lasts from February to March or April and is characterised by high ambient temperatures.

2.1.1 Description of Study Area

The study was undertaken in two reservoirs, Barekese and Owabi near Kumasi. The two reservoirs are the principal sources of water for the Kumasi Metropolis and its environs. Owabi lies at latitude 6°52'N and longitude 1°43'W whiles the co-ordinates of Barekese are

latitude 6°52'N and longitude 1°42'W.

Construction of Owabi Water Works was completed in 1928; and this resulted in the formation of a reservoir with a total surface area of about 700 hectares (GWCL, pers. com.) (Plate 1). The Barekese reservoir on the other hand was formed in 1970 (Frempong and Nijjhar, 1973). The impoundment covers 1600 hectares (GWCL, pers. com) (Plate 2). Both reservoirs lie in the closed-forest ecological zone of Ghana (Hall and Swaine, 1976). However, the watersheds of the two reservoirs are different. Barekese Reservoir is fed by the Ofin river system. The basin lies in predominantly arable lands. Owabi Reservoir, on the other hand, is fed by the Sukobri-Owabi-Pumpuna river system, which drains the central business and industrial areas of Kumasi.

Rainfall of the study area is high and ranges from 1500 to 1750 mm per annum (Hall and Swaine, 1976). The soils are therefore deeply weathered. Their humus content is low and they are poorly buffered (Hall and Swaine, 1976). Soil nutrients are, therefore, derived from decomposition of leaf fall that accumulates on the forest floor. The two reservoirs also lie in a basin with a high concentration of poultry farms. Urban run-off, domestic wastes, industrial effluents and discharges from the poultry farms contain high levels of nutrients, suspended solids, chlorides and sulphates. Inflows from these sources to the reservoirs are, therefore, expected to influence the chemistry of the reservoirs and consequently, the biological processes that occur there.

Although Whyte (1980) and Frempong and Nijjhar (1973) studied Barekese Reservoir, they did not follow the seasonal variations of the physico-chemical characteristics of the reservoir. There is, however, dearth of knowledge about the older Owabi Reservoir. The seasonal

variations of the physico-chemical characteristics of both the Owabi and Barekese reservoirs are thus poorly known. This study, therefore, examined the seasonal variations in the major cations and anions as well as the nutrients of the surface waters of the two reservoirs.

2.2 Materials and Methods

Water samples were collected from the surface of Barekese and Owabi reservoirs at weekly intervals. Sample collection started in March 1998 and continued until August 1999. Parameters assessed were temperature, pH, oxygen saturation, Biochemical Oxygen Demand (BOD), Alkalinity, Total Hardness (TH), Total Dissolved Solids (TDS), and Conductivity. In addition, the major cations – calcium and magnesium (Ca^{2+} and Mg^{2+}), anions - chloride, sulphate and silica (Cl^-, SO_4^{2-} and SiO_2^{2-}) and nutrients – ammonia-nitrogen, nitrate- and nitrite -nitrogen (NH_3 -N, NO_3- N, NO_2-N) and phosphates (PO_4^{3-}) were determined.

Reservoir water level was read from a river gauge installed at each of the reservoirs or the Ghana Water Company Limited (GWCL) provided it. Temperature, pH, TDS and conductivity of the water were measured *in situ* with the aid of portable meters (HACH or WTW kits). Transparency of the water was measured with a Secchi disc and was estimated as the depth of extinction of the Secchi disc (in cm).

Dissolved oxygen (DO) content of the water was estimated by using the azide modification of the Winkler Method. DO of the water sample was measured immediately after sample collection. The sample was then diluted when necessary and incubated in the dark for 5 days at 20°C after which residual oxygen in the incubated bottle was again measured for the determination of BOD. A wide-mouthed one litre, plastic bottle was filled with water and brought to the laboratory, in Accra, for estimates of the remaining parameters.

Plate 1: Barekese Reservoir (Looking in the Direction of the Barrage)

Plate 2: Owabi Reservoir (Looking in the Direction of the Barrage)

Samples were collected from ~10 cm below the surface around the centre of the reservoirs. Samples were kept refrigerated until ready for analysis.

Methods of analyses followed those outlined in 'Standard Methods for the Examination of Water and Wastewater' (Clesceri *et al.*, 1998). A summary of the procedures is provided below:

2.2.1 Total Hardness (TH)

TH was estimated by titration with EDTA against Erichrome Black T indicator. TH was measured as mg l^{-1} $CaCO_3$.

2.2.2 Alkalinity

Alkalinity is a measure of the buffering capacity of the water. It is usually a measure of the balance between HCO_3^-, CO_3^- and CO_2 and OH radicals. Alkalinity of the water was measured by double titration with acid against phenolphthalein and methyl orange indicators at pH of 4.5. Alkalinity was estimated as mg l^{-1} of $CaCO_3$.

2.2.3 Acidity

This was estimated by titration with sodium hydroxide (0.1 N NaOH) against phenolphthalein indicator. Acidity was estimated as mg l^{-1} of CO_2.

2.2.4 Calcium (Ca^{2+})

Calcium concentration was estimated by titration with EDTA against Murexide indicator at pH of 12 or 13. The concentration of Ca^{2+} was measured as mg l^{-1} $CaCO_3$.

2.2.5 *Magnesium (Mg^{+2})*

By principle, the difference between TH and calcium hardness multiplied by a correction factor (0.243) is a measure of Mg^{+2} concentration. Magnesium was measured in mg l^{-1}.

2.2.6 *Ammonia-Nitrogen (NH_3 - N)*

The 'Direct Nesslerisation' method was used in measurement of ammonia in samples. An intense colour formed after nesslerisation of the sample was measured on a spectrophotometer at 410 nm. The value of the spectrophotometric reading was then read off a calibration curve that gives concentration of ammonia as mg l^{-1} of nitrogen.

2.2.7 *Nitrate-Nitrogen (NO_3-N)*

'Hydrazine Reduction' method was used in estimating nitrate concentration of the reservoir water. Nitrate in the sample was reduced to nitrite with hydrazine phosphate followed by diazotisation and coupling with N (1-napthyl)-ethyl dihydrochloride to form an intense azo dye, which was then measured on a spectrophotometer at 520 nm. The value of the spectrophotometric reading was then read off a calibration curve that gives the concentration of nitrate in mg l^{-1} of nitrogen.

2.2.8 *Nitrite-Nitrogen (NO_2-N)*

Direct diazotisation of nitrite in the sample was the method used for estimation of concentration. Nitrite in the sample was made to form a di-azo compound in a strongly acidic medium by the addition of sulphanilic acid. The di-azo compound was then passed through the same procedure as for nitrates to form a red coloured azo dye and the intensity of the colour measured on a spectrophotometer at 540 nm. The value of the spectrophotometric reading was then read off a calibration curve to give the concentration of nitrite in mg l^{-1} of

nitrogen.

2.2.9 Phosphate-Phosphorus (PO_4- P)

Concentration of phosphates in samples was measured through the 'Ascorbic Acid' method. Ammonium molybdate was first added to the sample to form molybdophosphoric acid with the phosphate. The molybdophosphoric acid was then measured on a spectrophotometer at 810 nm. The value of the spectrophotometric reading was read off a calibration curve that gives the concentration of phosphate in mg l^{-1} phosphorus.

2.2.10 Chloride (Cl^-)

This was estimated as the amount of silver nitrate that was needed to form silver chloride using potassium chloride as an indicator. Chloride was measured in mg l^{-1}.

2.2.11 Sulphate (SO_4^{-2})

The absorbance of $BaSO_4$ was measured at 420 nm after the sulphate had been precipitated out of solution by addition of barium chloride to the sample. The concentration of SO_4^{-2} was then determined by reading the corresponding value from a standard curve. The concentration of sulphate was measured in mg l^{-1}.

2.2.12 Silicon (As SiO_2)

Concentration of silicates in sample was determined by adding ammonium molybdate to the sample to produce heteropoly acids. Oxalic acid was then added to the sample to remove molybdophosphoric acid that was formed in the previous process to give an intense yellow colour that was measured at 410 nm. The value of the spectrophotometric reading was then read off a calibration curve to determine the concentration of silicon in mg l^{-1} silica.

All spectrophotometric measurements were performed on a UV/Vis Ultraspec II spectrophotometer. All samples were kept refrigerated until ready for analysis. Chemical analyses were completed within 14 days of sample collection.

2.3 Results and Discussion

2.3.1 Reservoir Water Level

The hydrological cycles of the two reservoirs were similar (Fig. 2.1) and tended to be influenced by the rainfall pattern in the basin. The early rains, falling between April and July, contributed greatly to the filling-up of the reservoirs (Fig. 2.1). On the other hand, there was very little rise in reservoir water levels at Barekese and Owabi, during the minor season, which occurred between September and October. Mean reservoir water level at Barekese during the study period was 12.6 m and it fluctuated between 11.1 m and 13.2 m. Mean reservoir water level at Owabi was 6.6 m with a minimum level of 6.02 m and a maximum of 6.74 m. Fluctuation in reservoir water level was, therefore, higher in Barekese (2.1 m) than in the Owabi Reservoir (0.72 m). Straškraba and Tundisi (1999) have investigated reservoir hydrodynamics and observed that fluctuations in reservoir water level are a function of the depth of the reservoir, the watershed of the reservoir, the spill-rate as well as the rate of extraction of water. Barekese Reservoir has a bigger watershed than Owabi Reservoir. However, the rate of water extraction at Barekese (120 million litres a day) is four times that of Owabi. Thus, the large fluctuation in reservoir water level at Barekese could be due mainly to the rate of extraction.

2.3.2 Temperature

Variations in ambient (air) and surface water temperature at Barekese and Owabi during the study are shown in Fig. 2.2. Ambient temperature was lower than surface water temperature recorded at the two sites. Mean ambient temperature at Owabi, during the study, was 24.9°C and the temperature ranged between 21.9°C and 28.6°C. For Barekese the mean ambient temperature was 25.6°C with a minimum of 23°C and a maximum of 28.0°C. At Barekese, the mean surface water temperature was 27.9 ° C and ranged between a minimum of 26.1°C and maximum of 31.0 ° C. The mean surface water temperature at Owabi was, therefore, slightly higher than at Barekese. Chapman (1992) observed that the mean surface temperatures of natural waters, world wide, ranged from 20°C to 30°C. Temperatures recorded at Owabi and Barekese, therefore, fell within the reported range for natural waters. In general, variations in both ambient and surface water temperatures followed a seasonal trend and were similar to those observed in Lake Volta by Petr (1969) or Lake Weija (Ameka *et al.*, 2000). The highest surface water temperature was recorded in March 1998 during the dry humid season whilst the lowest temperatures were recorded in August when the skies were heavily overcast as was also, observed in Lake Volta and Lake Weija.

2.3.3 pH

The waters of the two reservoirs were slightly alkaline. However, the pH of the water in Barekese was similar to that in Owabi. In Barekese, pH ranged from 6.7 to 8.9 whereas it was 6.6 to 7.3 in Owabi. When the upper limits are considered, however, it can be said that Barekese had slightly more alkaline water than Owabi. Most natural waters have a pH that ranges from 6 to 9 (Her Majesty's Stationery Office, 1972; Stumm and Morgan, 1981). The pH^s recorded in both reservoirs were slightly higher than those recorded by Ameka *et al.*, (2000) in Lake Weija or from the surface waters of Lake Volta (pH – 7.0) at Akosombo

Gorge (Ofori-Danson and Antwi, 1994) (Table 2.1).

Eutrophic lakes and reservoirs tend to have alkaline waters (Straškraba and Tundisi, 1999). This is due to phytoplankton and submerged aquatic macrophytes that impart more H^+ ions to the water during daytime photosynthesis (Ruttner, 1963). Growth of phytoplankton and submerged aquatic plants especially *Ceratophyllum dermersum* in the Barekese and Owabi reservoirs could be responsible for the high pH observed.

2.3.4 Alkalinity

Chapman (1992) states that waters of low alkalinity have low buffering capacity. She considered waters with alkalinity <24.0 ml l^{-1} as poorly buffered. The buffering capacity of the water of Owabi Reservoir as evidenced by the alkalinity (92.7 mg l^{-1} $CaCO_3$) was nearly twice as high as that of Barekese Reservoir (51.5 mg l^{-1} $CaCO_3$). Both waters had alkalinity values above the limit stated by Chapman (1992). Surface waters at Barekese and Owabi, therefore, were well buffered.

2.3.5 Nutrients

Concentrations of inorganic, nitrogenous compounds (or nutrients) in the surface waters of the two reservoirs are presented in Figs. 2.3 and 2.4. The dominant pattern of nutrients at both Barekese and Owabi was of the order NH_3-N = NO_3-N > NO_2-N. Mean NH_3-N concentration in Barekese Reservoir was 0.3 mg l^{-1}; concentration of NH_3-N ranged from a minimum of 0.09 mg l^{-1}, in October 1998, to a maximum of 0.75 mg l^{-1} in July 1998. In Owabi Reservoir, however, the mean concentration was 0.3 mg l^{-1}; but NH_3-N concentration fluctuated between a minimum of 0.2 mg l^{-1} recorded in March 1998 and August 1999 and a maximum

concentration of 0.73 mg l^{-1} recorded in July 1999. Variations in concentration of NH_3-N closely followed the rainfall pattern within the basin (Figs. 2.3 and 2.4). In general, higher concentrations of nutrients were detected in the surface waters during the periods of high rainfall (March – September) whereas lower concentrations were detected during the dry season between October and February. The concentrations detected in both reservoirs were much higher than the 0.15 mg l^{-1} limit set for natural reservoirs (Straškraba and Tundisi, 1999). Also, the mean concentration of NO_3-N detected in the Barekese and Owabi reservoirs was six times higher than the concentration recorded in Lake Volta by Ofori-Danson and Antwi (1994) or what Gordon observed in the Kpong Head pond (Gordon, 1998). Straškraba and Tundisi (1999) observed that when concentrations of NH_3 -N and other nitrogenous compounds in reservoirs exceed the permissible level, then these nutrients were obtained from within the watershed and were usually the result of inputs from sewage plants, large-scale breeding farms and run-off from farmlands.

Both reservoirs lie in the Atwima District of Ashanti where there are many large-scale poultry farms. Thus, effluents from the poultry farms could be responsible for the high concentrations of nitrogenous compounds observed in the surface waters. High concentrations of NH_3 -N tended to coincide with periods of low DO levels in the surface waters of the reservoirs (Figs. 2.5 and 2.6). It is generally agreed that ammonia is derived mainly from the decomposition of organic nitrogenous compounds (Chapman, 1992; Straškraba and Tundisi, 1999). Thus, when the floodwaters enter the reservoirs, during the rainy season, they bring into the reservoir surface waters organic, nitrogenous compounds that use up some DO during the process of decomposition.

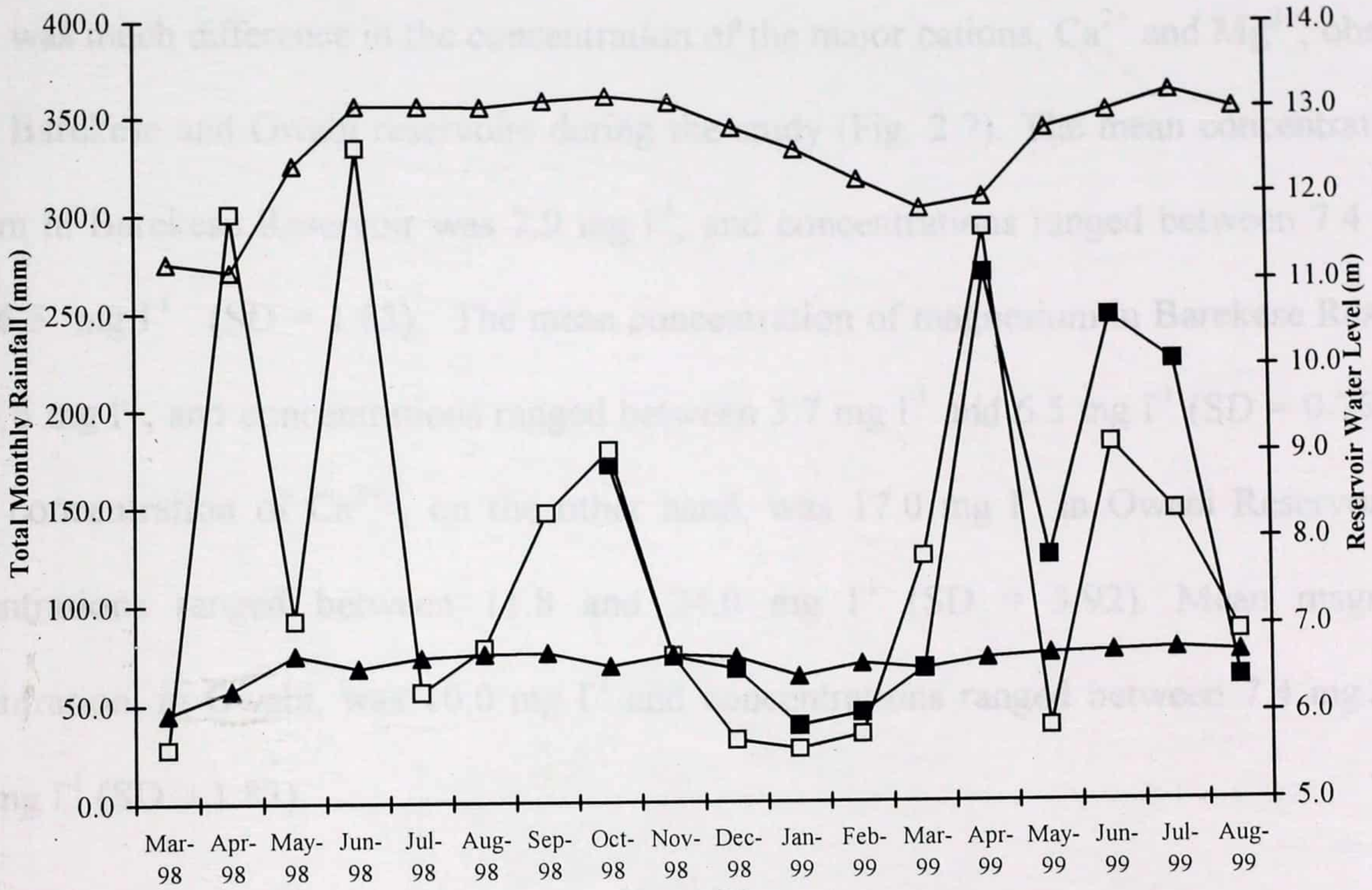

Fig. 2.1 :Seasonal Variation in Reservoir Water Level at Barekese and Owabi During Study Period (March 1998 - August 1999)

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2.3.6 *Major Cations (Ca^{2+} and Mg^{2+})*

There was much difference in the concentration of the major cations, Ca^{2+} and Mg^{2+}, observed in the Barekese and Owabi reservoirs during the study (Fig. 2.7). The mean concentration of calcium in Barekese Reservoir was 7.9 mg l^{-1}; and concentrations ranged between 7.4 mg l^{-1} and 16.5 mg l^{-1} (SD = 1.83). The mean concentration of magnesium in Barekese Reservoir was 4.6 mg l^{-1}; and concentrations ranged between 3.7 mg l^{-1} and 6.5 mg l^{-1} (SD = 0.75). The mean concentration of Ca^{2+} , on the other hand, was 17.0 mg l^{-1} in Owabi Reservoir; and concentrations ranged between 11.8 and 24.0 mg l^{-1} (SD = 3.92). Mean magnesium concentration, in Owabi, was 10.0 mg l^{-1} and concentrations ranged between 7.4 mg l^{-1} and 16.5 mg l^{-1} (SD = 1.83).

Generally, higher concentrations of the major cations were detected in surface waters during the rainy period (April to June/July) than during the dry period (December to March). The concentrations of both cations in the Owabi Reservoir were twice as high as in Barekese Reservoir. The pattern of dominance of the two cations was $Ca^{2+} > Mg^{2+}$. This is in agreement with the pattern of dominance found in fresh waters (Burton, 1976).

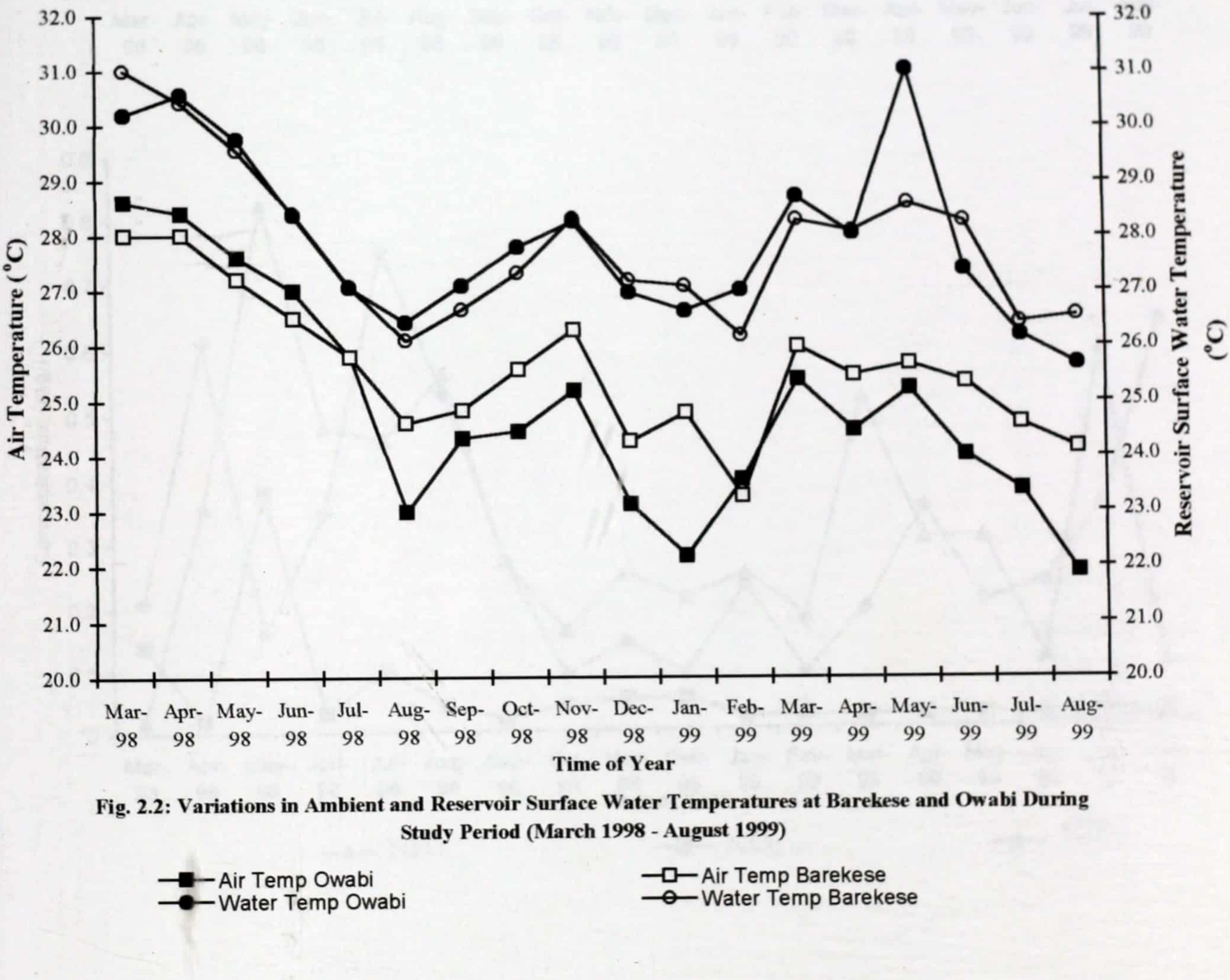

Fig. 2.2: Variations in Ambient and Reservoir Surface Water Temperatures at Barekese and Owabi During Study Period (March 1998 - August 1999)

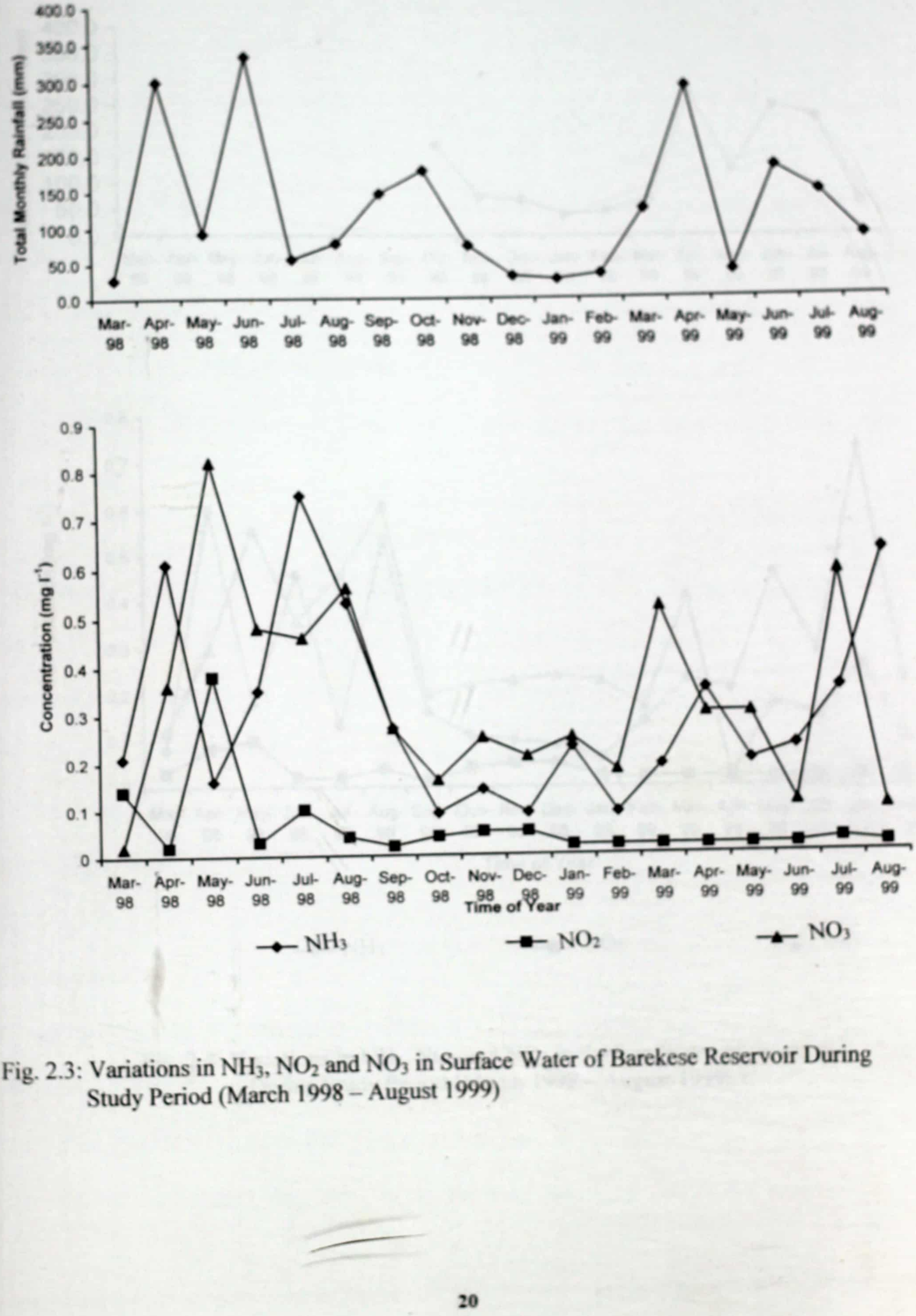

Fig. 2.3: Variations in NH_3, NO_2 and NO_3 in Surface Water of Barekese Reservoir During Study Period (March 1998 – August 1999)

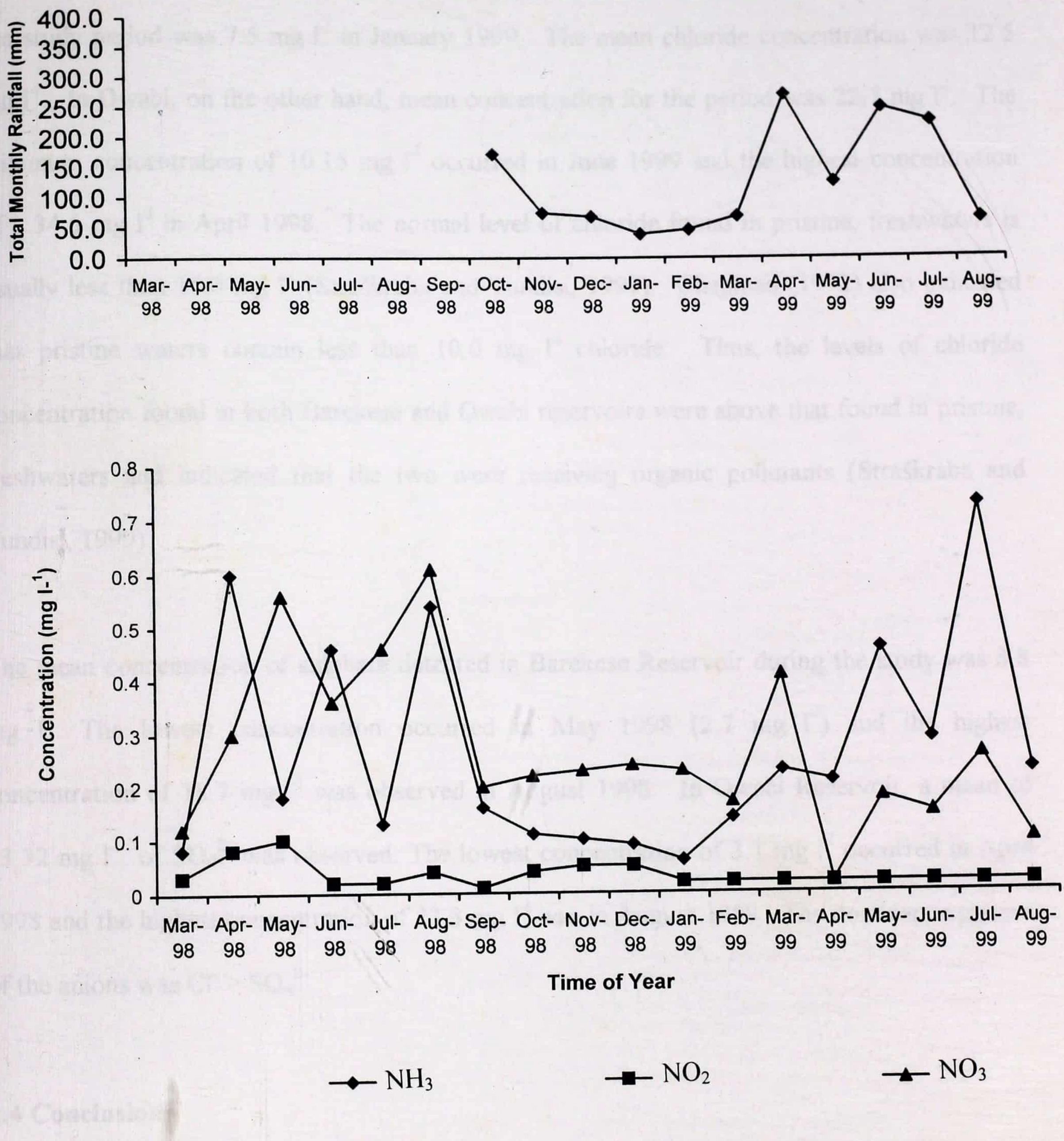

Fig. 2.4: Variations in NH_3, NO_2 and NO_3 in Surface Water of Owabi Reservoir During Study Period (March 1998 – August 1999)

2.3.7 *Major Anions (Cl^- and SO_4^{2-})*

Maximum chloride concentration of 19.5 mg l^{-1} in the surface water of Barekese Reservoir was observed in April 1998 (Fig. 2.8). The lowest concentration of chloride detected during the study period was 7.5 mg l^{-1} in January 1999. The mean chloride concentration was 12.5 mg l^{-1}. In Owabi, on the other hand, mean concentration for the period was 22.7 mg l^{-1}. The minimum concentration of 10.15 mg l^{-1} occurred in June 1999 and the highest concentration of 34.6 mg l^{-1} in April 1998. The normal level of chloride found in pristine, freshwaters is usually less than 10.0 mg l^{-1} (Straškraba and Tundisi, 1999). Chapman (1992) also indicated that pristine waters contain less than 10.0 mg l^{-1} chloride. Thus, the levels of chloride concentration found in both Barekese and Owabi reservoirs were above that found in pristine, freshwaters and indicated that the two were receiving organic pollutants (Straškraba and Tundisi, 1999).

The mean concentration of sulphate detected in Barekese Reservoir during the study was 8.8 mg l^{-1}. The lowest concentration occurred in May 1998 (2.7 mg l^{-1}) and the highest concentration of 18.7 mg l^{-1} was observed in August 1998. In Owabi Reservoir, a mean of 13.32 mg l^{-1} of SO_4^{2-} was observed. The lowest concentration of 3.1 mg l^{-1} occurred in April 1998 and the highest concentration of 23.3 mg l^{-1} was in August 1998. The dominance pattern of the anions was $Cl^- > SO_4^{2-}$.

2.4 Conclusions

A summary of the physico-chemical characteristics of Barekese and Owabi reservoirs is provided in Table 2.1. In general, it can be said that although the two reservoirs lie close to each other, on the same geological formation and have similar weather, the chemistry of the two reservoirs is different. The levels of the chemical constituents of Owabi Reservoir were

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about twice as those found in Barekese Reservoir. The different ages of the reservoirs and the impact of human activity within the watersheds of the reservoirs are contributory factors. Owabi Reservoir is about twice the age of Barekese. It is shallower and its watershed lies in the industrial and business areas of Kumasi. It also receives a lot of waste and storm waters from Kumasi. Thus, the water of Owabi receives more anthropogenic impacts than Barekese.

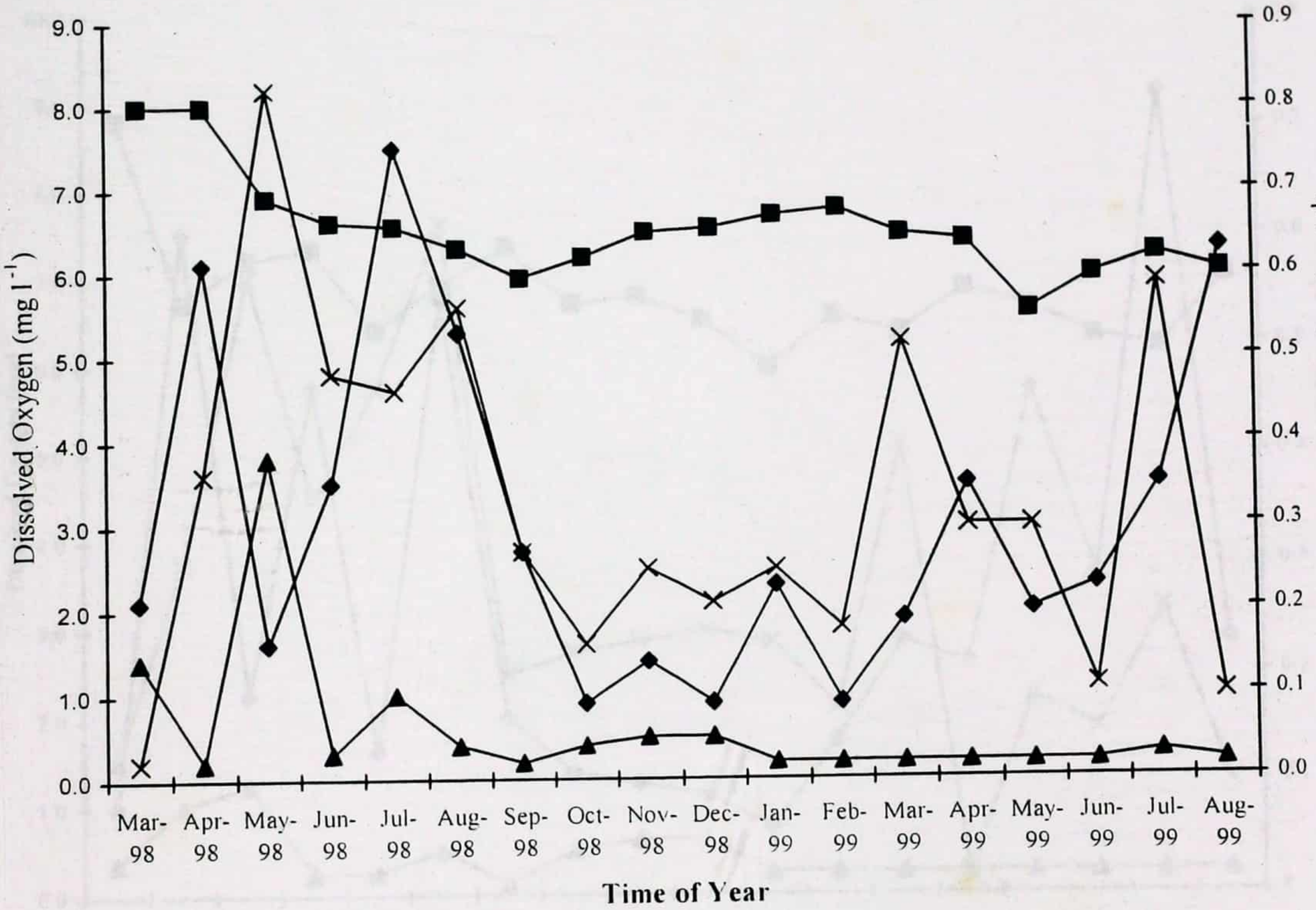

Fig. 2.5 :Relationship Between Nutrients and Dissolved Oxygen in Surface Water of Barekese Reservoir During Study Period (March 1998 - August 1999)

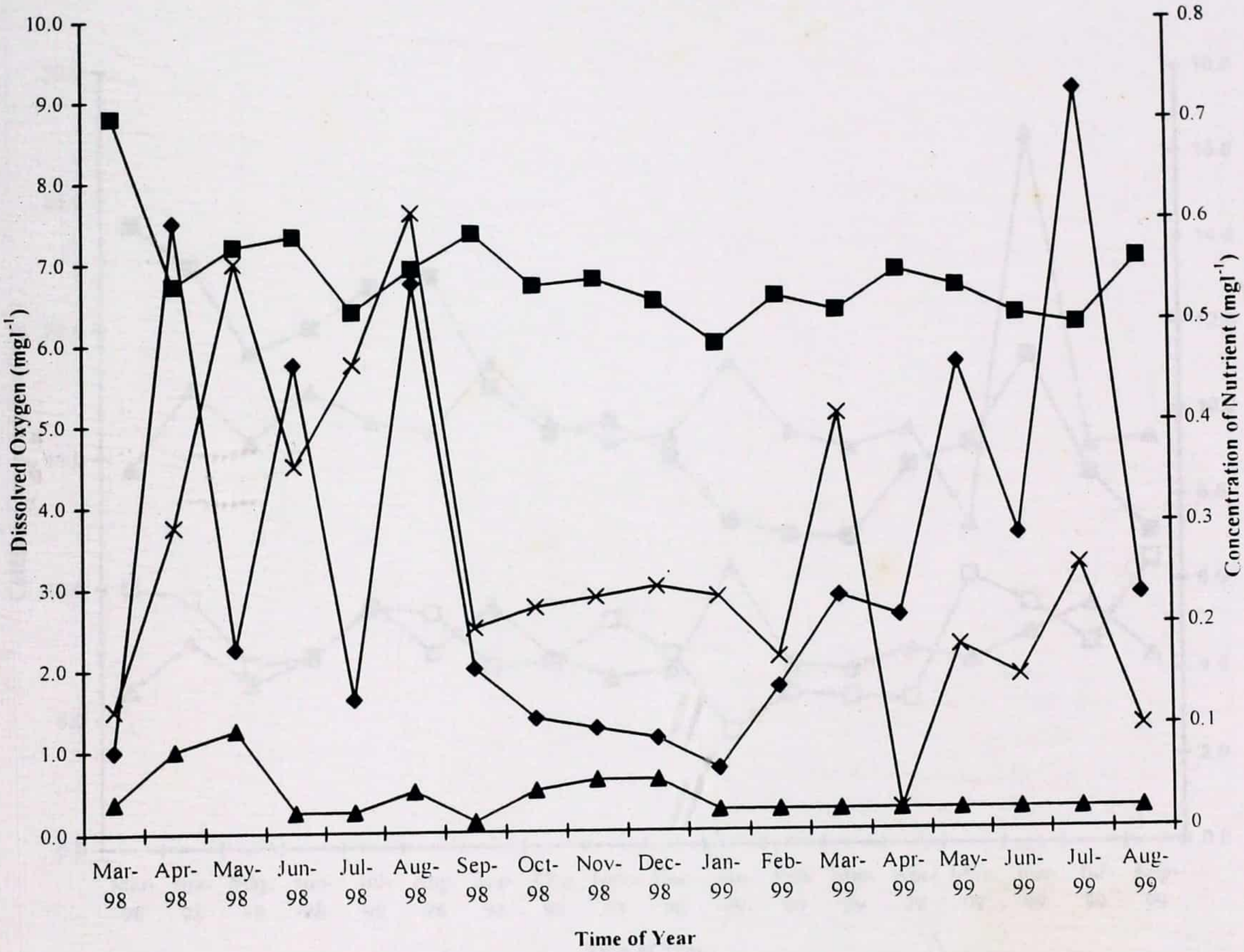

Fig 2.6 :Relationship Between Nutrients and Dissolved Oxygen in Surface Water of Owabi Reservoir During Study Period (March 1998 - August 1999)

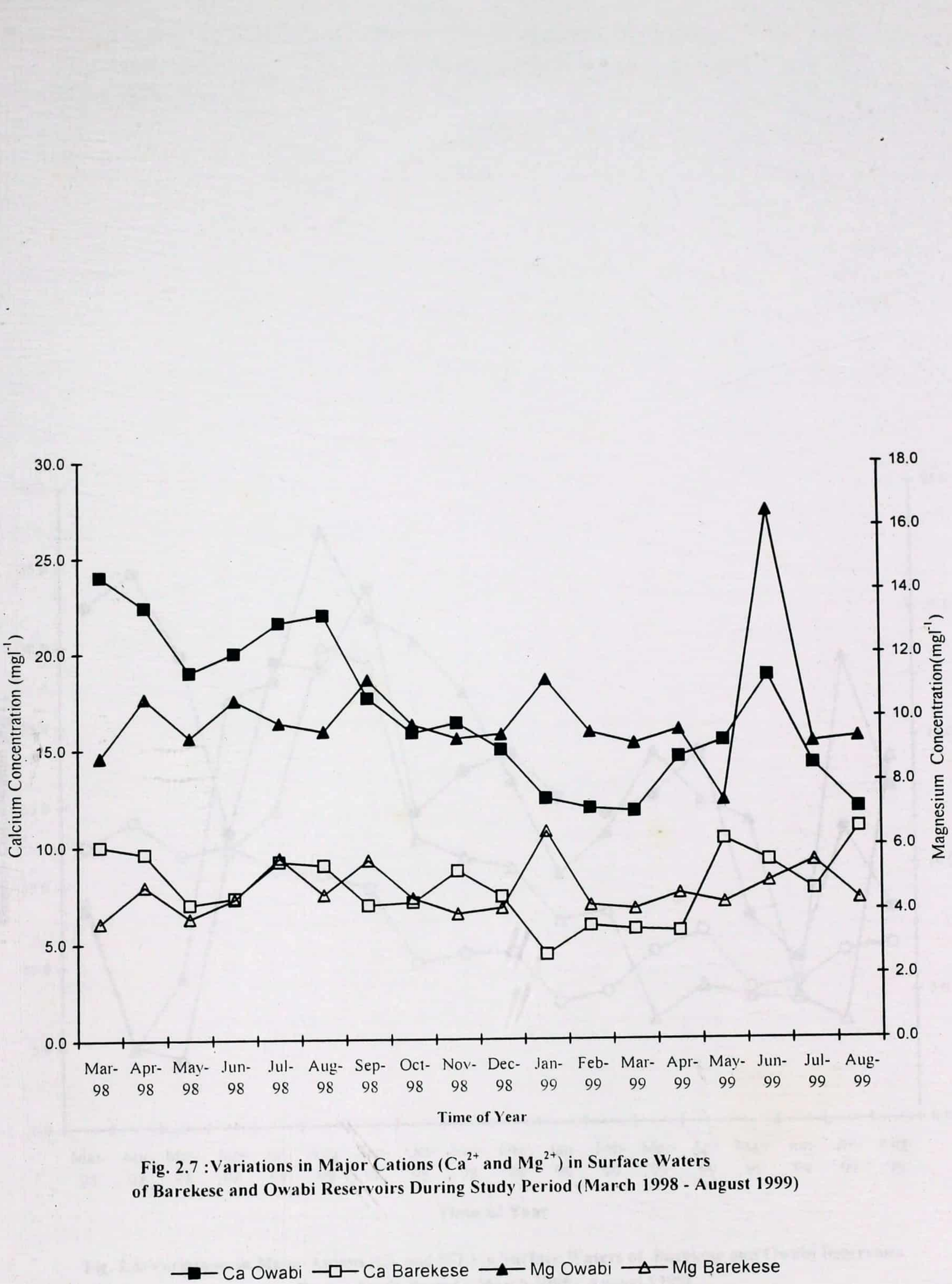

Fig. 2.7 :Variations in Major Cations (Ca^{2+} and Mg^{2+}) in Surface Waters of Barekese and Owabi Reservoirs During Study Period (March 1998 - August 1999)

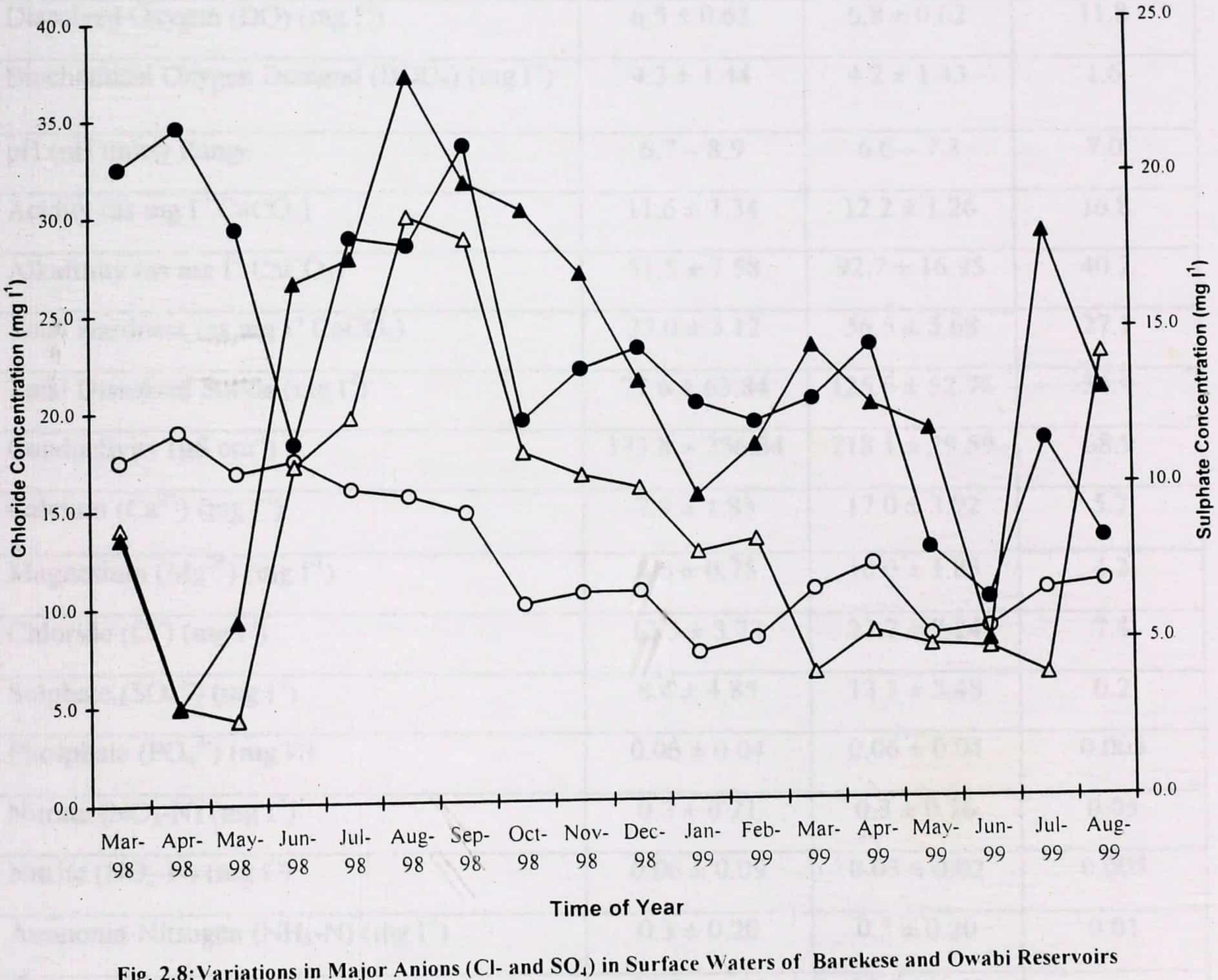

Fig. 2.8: Variations in Major Anions (Cl- and SO_4) in Surface Waters of Barekese and Owabi Reservoirs During Study Period (March 1998 - August 1999)

—○— Cl^- Barekese —●— Cl^- Owabi —△— SO_4 Barekese —▲— SO_4 Owabi

Table 2.1: Comparison of Physico-Chemical Characteristics of Surface Waters of Barekese and Owabi Reservoirs with Surface Waters of Lake Volta at Akosombo Gorge.

Characteristics	**Barekese**	**Owabi**	**Volta Lake Akosombo Gorge[#]**
Reservoir Water Level (m)	12.75 ± 0.66*	6.59 ± 0.18*	70.0
Surface Water Temp (°C)	27.9 ± 1.41	28.0 ± 1.56	29.1
Dissolved Oxygen (DO) (mg l^{-1})	6.5 ± 0.63	6.8 ± 0.62	11.8
Biochemical Oxygen Demand (BOD_5) (mg l^{-1})	4.3 ± 1.44	4.2 ± 1.43	1.6
pH (pH units) Range	6.7 – 8.9	6.6 – 7.3	7.0
Acidity (as mg l^{-1} $CaCO_3$)	11.6 ± 1.34	12.2 ± 1.26	16.8
Alkalinity (as mg l^{-1} $CaCO_3$)	51.5 ± 7.58	92.7 ± 16.95	40.2
Total Hardness (as mg l^{-1} $CaCO_3$)	27.0 ± 3.12	56.5 ± 5.68	27.1
Total Dissolved Solids (mg l^{-1})	77.6 ± 63.84	125.6 ± 52.76	34.9
Conductivity (µS cm^{-1})	173.8 ± 256.34	218.1 ± 29.59	68.9
Calcium (Ca^{2+}) (mg l^{-1})	7.9 ± 1.83	17.0 ± 3.92	5.7
Magnesium (Mg^{2+}) (mg l^{-1})	4.6 ± 0.75	10.0 ± 1.83	4.2
Chloride (Cl^-) (mg l^{-1})	12.5 ± 3.73	22.7 ± 7.24	7.4
Sulphate (SO_4^{2-}) (mg l^{-1})	8.4 ± 4.85	13.3 ± 5.48	0.2
Phosphate (PO_4^{3-}) (mg l^{-1})	0.06 ± 0.04	0.06 ± 0.04	0.003
Nitrate (NO_3-N) (mg l^{-1})	0.3 ± 0.21	0.3 ± 0.16	0.05
Nitrite (NO_2-N) (mg l^{-1})	0.06 ± 0.09	0.03 ± 0.02	0.005
Ammonia-Nitrogen (NH_3-N) (mg l^{-1})	0.3 ± 0.20	0.3 ± 0.20	0.01
Chlorophyll a (mg l^{-1})	19.9 ± 4.32	18.9 ± 4.49	--
Turbidity (NTU)	4.70 ± 3.37	4.86 ± 2.04	--
Secchi Disc Transparency (cm)	72.3 ± 15.15	101.6 ± 20.73	220.0

* Mean ± S.D., n = 18 months for all values unless otherwise stated.

[#] Ofori-Danson & Antwi (1994)

CHAPTER THREE

SPECIES COMPOSITION, DIVERSITY, SEASONAL ABUNDANCE AND PRODUCTION OF FIVE COMMONLY OCCURRING CHIRONOMIDAE IN BAREKESE AND OWABI RESERVOIRS.

3.1 Introduction

Larvae of Chironomidae are microphagagous; they feed on small plants, algae, bacteria and detritus (Oliver, 1971). They represent a critical link in the trophic pathways of the freshwater habitat. They are, therefore, linked to the energy flows within aquatic habitats (Coffman and Ferrington Jr., 1984). The juveniles of many carnivorous fishes, for example, consume the larva and pupa of Chironomidae. Bryce and Hobart (1972) observed that, as much as 80% of the food items in stomachs of carnivorous fish, in River Thames, was chironomid larvae and pupae. In Ghana, Amakye (1996) observed that majority of the fish caught from the Yeji area of Lake Volta depended on autochthonous material, especially chironomid larvae, algae and planktonic Microcrustacea as food. However, larvae of some chironomid species may become pests in agriculture by causing large-scale damage to rice crops in both temperate and tropical countries (Barrion and Litsinger, 1984 cited by Stevens, 1995). Occasionally, Chironomidae may invade enclosed water supply systems and infest drinking water with their larvae (Berg, 1995). The quality of drinking water then may become degraded and cause significant losses at drinking water production plants.

Over 5000 chironomid species have been described worldwide (Oliver, 1971; Ashe, 1983). However, many species, especially those from Africa, are unknown in their immature stages or poorly described (Oliver, 1971; Amakye, 1993; Cranston and Hare, 1995). Also, the

taxonomy of Chironomidae and the number of recognised species from Ghana are in a state of flux. Coffman *et al.*, (1992) reported 299 species from West Africa. Thomas (1966) reported of seventeen chironomid species from a small man-made lake, in the Accra plains. Also, Whyte (1971) collected 69 species from a small man-made lake – Danfa. Whyte (1980) again recognised 34 species of Chironomidae from reservoirs in a nationwide survey. Petr (1970) collected 52 species from light-traps on Lake Volta. A literature search conducted by Amakye (1993) showed that there were 87 recognised chironomid species in Ghana. Since then, some 32 new chironomid species have been added to the chironomid species list of Ghana (Adam, 1995; Kyerematen, 1995; Billa, 1997; Oyewo, 1997; Sæther and Sundal, 1999). Amakye (1995) described a new species from the dry semi-deciduous forest in southeastern Volta Region of Ghana, while Ekrem (1999) added three new Tanytarsini species. About 123 chironomid species have thus been described, currently, from Ghana.

The recent additions to the list of chironomids from Ghana have been collected mostly from rivers and streams. However, a greater proportion of the Ghanaian Chironomidae was reported from reservoirs (Amakye, 1993). Even so, the chironomid fauna of most of the large reservoirs in Ghana has not been studied. In particular, little attempt has been made to estimate production of Chironomidae in Ghana despite their importance to the productivity and hence energy flows within the freshwater habitats.

Benke (1993) reviewed the methods for estimation of aquatic macro-invertebrate production. Three broad methods are available for estimation of production, depending on whether the cohort population can be followed or not.

They are:

(i) Methods that follow the growth of the individuals in the cohort population.

(ii) Methods that depend on analysis of Size Frequencies (SF).

(iii) Methods that measure Instantaneous Growth (IG).

Methods under (ii) and (iii) are especially useful when the growth and development of the species are non-seasonal or when several indistinguishable generations are present simultaneously in the habitat (Benke, 1993). However, estimation of production under the Size Frequency or Instantaneous Growth method requires that the duration of the aquatic stage or the Cohort Production Interval (CPI) be established. This implies a good knowledge of the life history of the species under consideration (Benke, 1993).

In practice, however, the conditions stated above are usually not met; the immature, aquatic stages of species under consideration may not be accessible, during field-based studies, if there is profuse growth of weeds in the reservoir such as was the case in Barekese and Owabi. Illies (1971, 1975) and Castro (1975) have suggested, therefore, that emerging adult insects from aquatic habitats could be used to estimate production of macro-invertebrates of rivers and streams. Böttger, (1975) and Lehman (1979, 1981) used the method, successfully, to estimate chironomid production in some rivers in the Democratic Republic of the Congo (Zaire). Also, Spier and Anderson (1974) showed that emergence data alone could provide an approximate estimate of production in aquatic habitats. In addition, models have been developed that estimate production of macro-invertebrates of both lentic and lotic habitats, empirically, by relating biomass to mean annual temperature of the reservoir or river (Plante and Downing, 1989; Morin and Bourassa, 1992 cited by Benke, 1993).

Whyte (1971) attempted estimating production of Chironomidae, in Ghana, when he investigated five chironomids, during an ecological study of the Danfa Reservoir in the Accra plains. Whyte based his estimate on data obtained from larvae collected from the field supplemented by laboratory determination of the growth rates of the different species.

Prior to the present investigation, Frempong and Nijjhar (1973) and Whyte (1980) had studied the Chironomidae of Barekese Reservoir as part of a general faunal survey. Whyte found eleven chironomid species at Barekese whereas Frempong and Nijjhar reported the presence of seven species from the same habitat. Unfortunately, very little information was found on the chironomid fauna of Owabi Reservoir despite the fact the reservoir lies close to Barekese Reservoir and it is the older of the two reservoirs. No study on the production of chironomids of the two reservoirs had been undertaken previously. The present study, therefore, examined aspects of the ecology of five chironomid species in Barekese and Owabi reservoirs. Trapped, emerging adults were used to estimate the seasonal abundance, diversity and production of *Nilodorum fractilobus*, *N. brevipalpe*, *N. brevibucca*, *Kiefferulus chloronotus* and *Dicrotendipes schoutedeni* in the two reservoirs.

3.1.1 Study Area

The study was carried out on two reservoirs, Barekese and Owabi, in the Kumasi Metropolis. Description of the sites has been provided in chapter two of this thesis.

3.2 Materials and Methods

3.2.1 Estimation of Density and Production of Chironomidae

The method used by Illies (1971) was followed. Four emergence traps of the model 'Week' (LeSage and Harrison, 1979) as modified by Singh and Harrison (1984) were deployed on

each of the reservoirs (Plate 3). The emergence trap consisted of a square, wooden base measuring 35 cm x 35 cm (A). A pyramidal tent (B), with a base equal to the wooden frame, was fixed to the wooden base. The tent was made of polyester-cotton material. The apex of the tent was directed to a wooden board measuring 15 x 15 cm with a window measuring 7 x 5 cm cut in the centre of the board (C). The tent material was then affixed to the board on one side such that the window was completely sealed from the outside. A window of the same dimensions as that of the board was then made in the broad side of a 500 ml rectangular plastic bottle (D). The tops of two of these plastic bottles were then joined, the septa separating the two tops removed and then screwed onto the mouth of one of the bottles. The bottle was then fixed to the other side of the window of the board with the mouth pointing downwards. Brass screws were used in fixing the bottle to the board to ensure resistance to rust. Ten-centimetre thick Styrofoam sheets (E) were attached to the base frames to buoy the traps up.

Because the traps were unstable and capsized in the slightest storm, the members of the base were increased in width from 10 cm to 25 cm. This improved stability of the traps so that they could even stand squalls. Traps were kept at the same location by dropping stone anchors to the bottom of the reservoir. Another 500 ml rectangular bottle was filled with 150 ml of 70% ethanol and screwed to the one fixed permanently to the trap and left in place (F). Traps were emptied at weekly intervals.

Male individuals belonging to the same taxa were sorted out by examination of the samples under a dissecting microscope. The lower half of a Petri dish was used to press aluminium foil into the top of 30 mm Ø Petri dish.

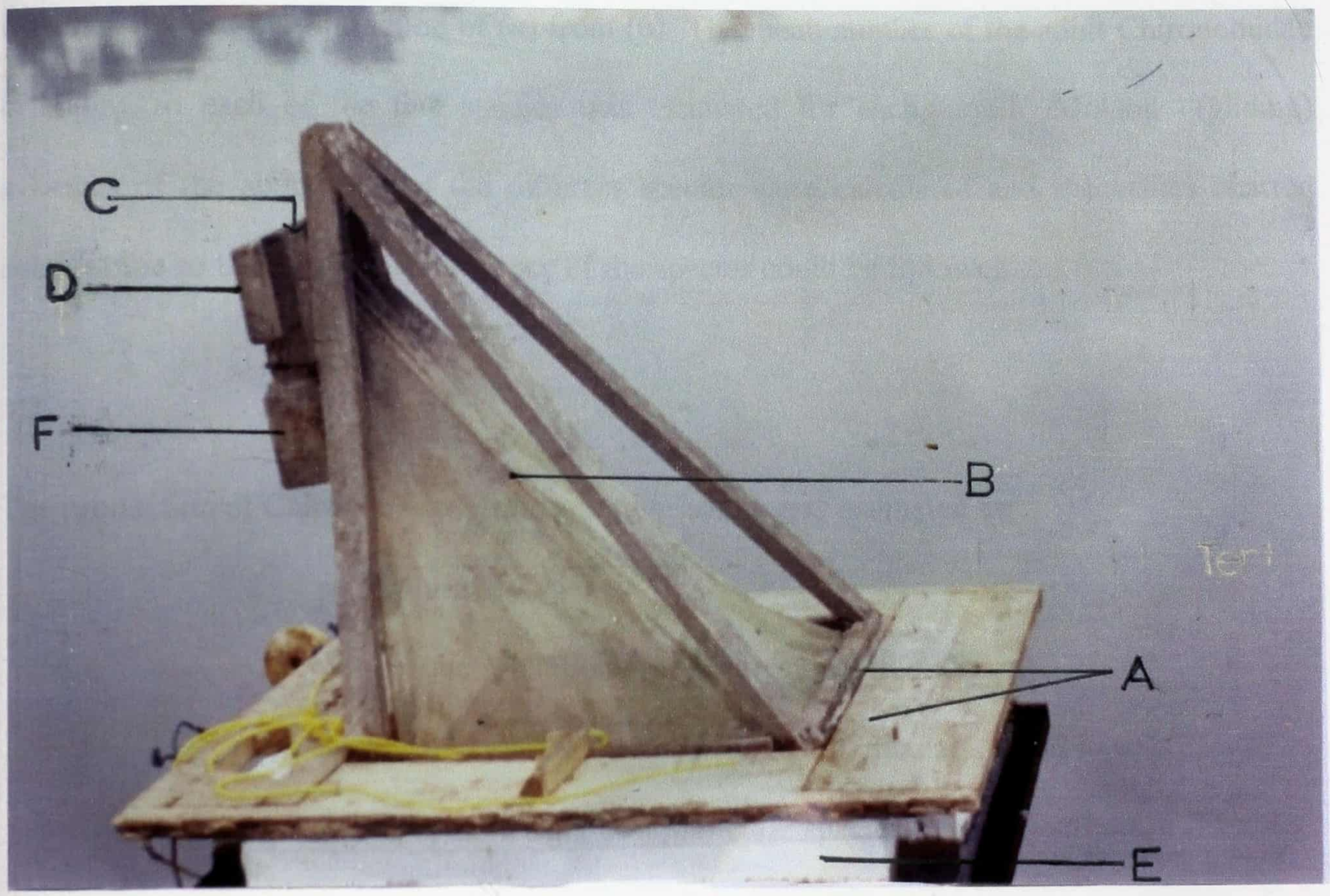

Plate 3: Close-up of Emergence Trap in Position over Owabi Reservoir (See text for description).

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The edges of the aluminium foil were trimmed off the Petri dish so that the foil formed a weighing pan. The mass of the weighing pan was determined on an electronic balance to the nearest 0.0001 g (*a*). Individual Chironomidae belonging to the same taxon were then put in a pre-weighed pan and the sample dried in an oven at 60C for at least 24 hr. The sample was then cooled in a desiccator for at least one hour after which the sample was re-weighed together with the aluminium pan (*b*). The dry mass (DM) of the different taxa in each sample was then derived by subtraction of (*a*) from (*b*). The mean number of the adult Chironomidae belonging to each of the five species was estimated for each month. Moving (gliding) averages of the abundance of the different species were calculated and the values charted against time so that trends in abundance of the species could be followed.

The production of Chironomidae from emerging adults was estimated as:

$$p = d \; x \; w \; x \; k$$

Where p = production (Biomass for the month in question)

d = mean number of individuals of a particular species in trap

w = specific weight of a particular species for the month in question

k = is a constant (the reciprocal of area of the window at base of trap (i. e. 8.1633).

Specific weight of a species was obtained as:

$$w = \frac{\text{Mean biomass of a species}}{\text{Mean number of individuals of a species in trap}}$$

3.2.2 Species Diversity

The diversity of the Chironomidae collected on each sampling occasion was determined from the mean number of individuals from the four emergence traps. The Shannon-Wiener diversity index (H') was used to estimate diversity of the chironomid fauna. It was calculated as:

$$H = \sum_{i=1}^{s} [(ni/n)\ln(ni/n)] \qquad \text{(From Brower and Zar, 1977)}$$

Where n_i = number of individuals belonging to a species

n = total number of individuals in the sample

s = number of taxa in the sample

3.2.3 Identification of Chironomid Species.

Male adult characters were used for identification of species. Microscopic slides of the adult males were prepared following the recommendations of Pinder (1989). The procedure that was followed is as illustrated in Fig. 3.1. Chironomidae were identified to the genus level with the help of keys provided by Wiederholm (1989). Identification of specimens to species level was based on keys provided by Freeman (1955 – 1958) and Harrison (1970, 1978). Only keys for adult males were available for identification of species except in *Kiefferulus chloronotus* when the females could be matched with the males from the coloration of the body.

The following working key was used for identification of the five common Chironomidae from Barekese and Owabi reservoirs (Adapted from Freeman, 1957 and Cranston *et al*., 1990):

1. Large insect; maxillary palps reduced or normal; inferior volsella bulbous, more or less racquet shaped.....(*Nilodorum Kiefferulus**).....2

1. Large insect; maxillary palps normal (Fig. 3.2a) inferior volsella long and cylindrical directed dorsad. Apex of Inferior Volsella distinctly shaped like a claw (Fig 3.2d).....*Dicrotendipes schoutedeni*#

2. Scutum with a long, wide dorso-medial mark; maxillary palps not reduced (Fig 3.2c;Fig. 3.2b).....*Kiefferulus chloronotus*

2. Scutum with no such mark, maxillary palps reduced (Fig. 3.2e).....(*Nilodorum) 3*

3. Distal half of Inferior Volsella partly obviate; maxillary palps reduced.....4

3. Distal half of Inferior Volsella entire reduced (Fig. 3.2h).....*Nilodorum brevibucca*

4. Inferior Volsella with proximal half about the same width as distal half (Fig. 3.2g).....*N. fractilobus*

4. Inferior Volsella with proximal half about twice as large as distal half (Fig. 3.2f).....*N. brevipalpe*

#Epler *et al*. ,(2000) believed that this species does not fit into the genus *Dicrotendipes* and have therefore raised a new genus *Acinoretracus* for this and some other related African species.

* Cranston *et. al*. , (1990) made *Nilodorum* synonymous with *Kiefferulus*. By precedence, *Nilodorum* is now *Kiefferulus*.

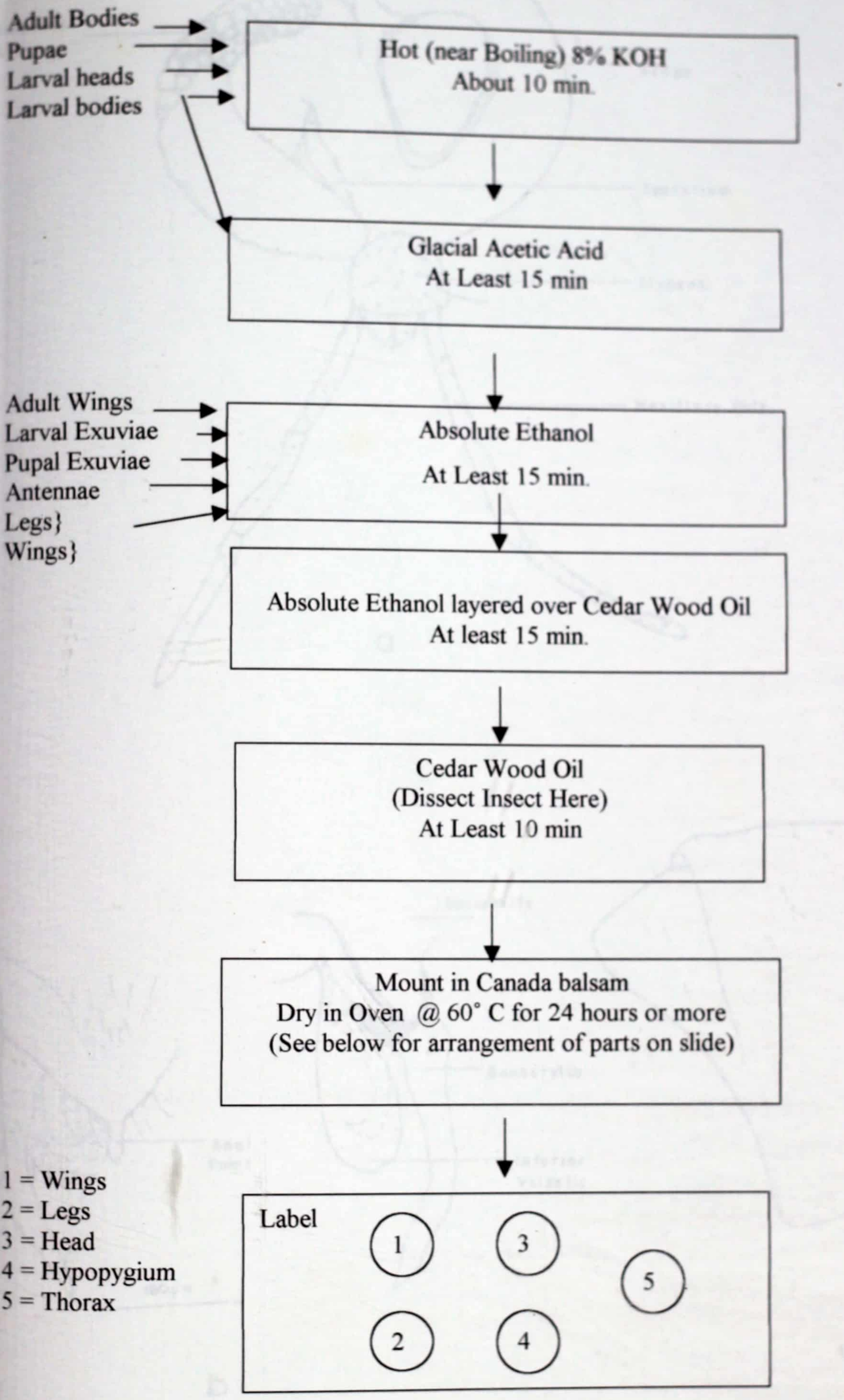


Fig. 3. 1: Steps in Preparation of Microscopic Slides for Taxonomic Identification

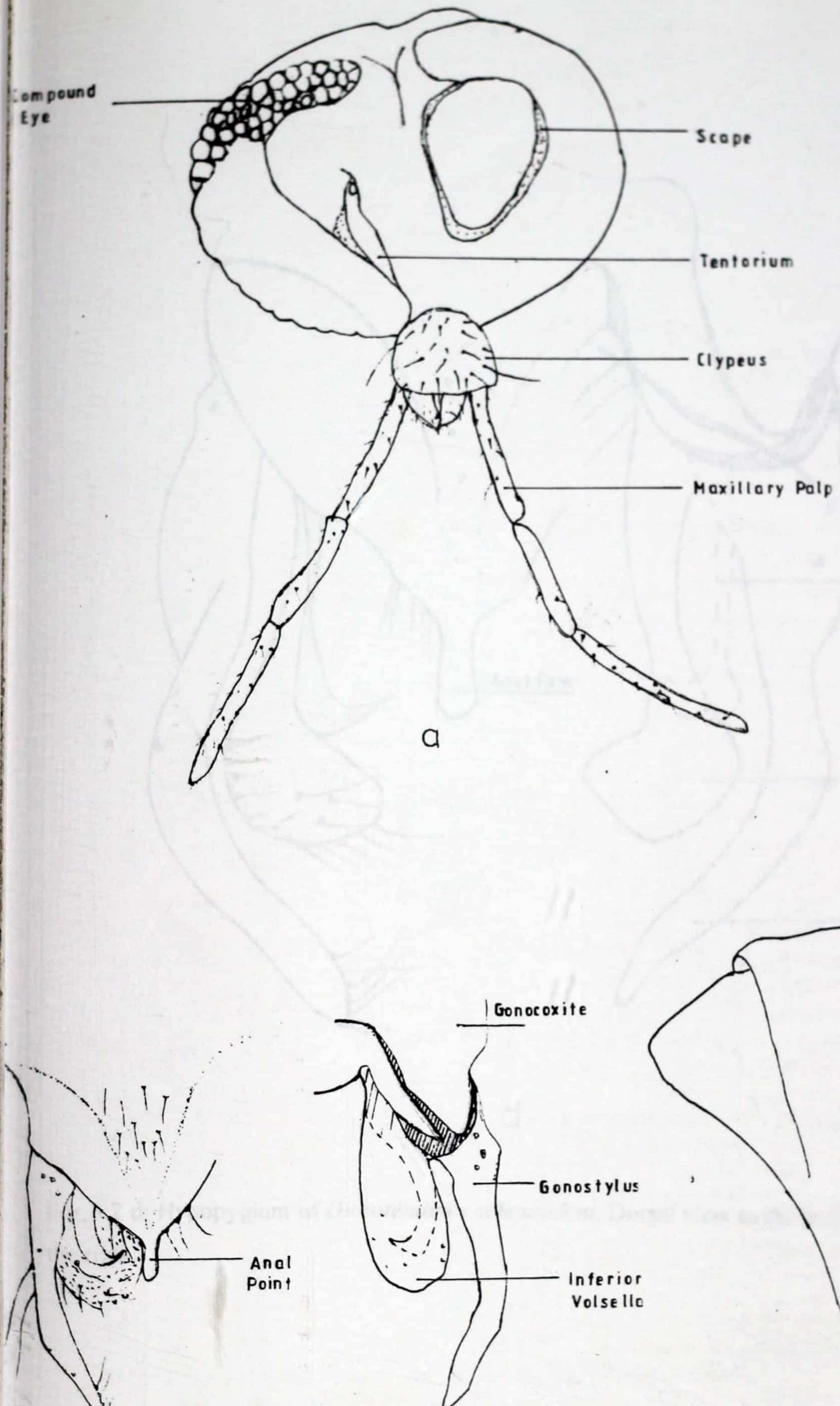


Fig. 3.2 a–c: *Kiefferulus chloronotus* Male imagine: (a) Frontal view of head

(b) Hypopygium (dorsal view to the left, ventral view to the right) (c) Thorax, side view

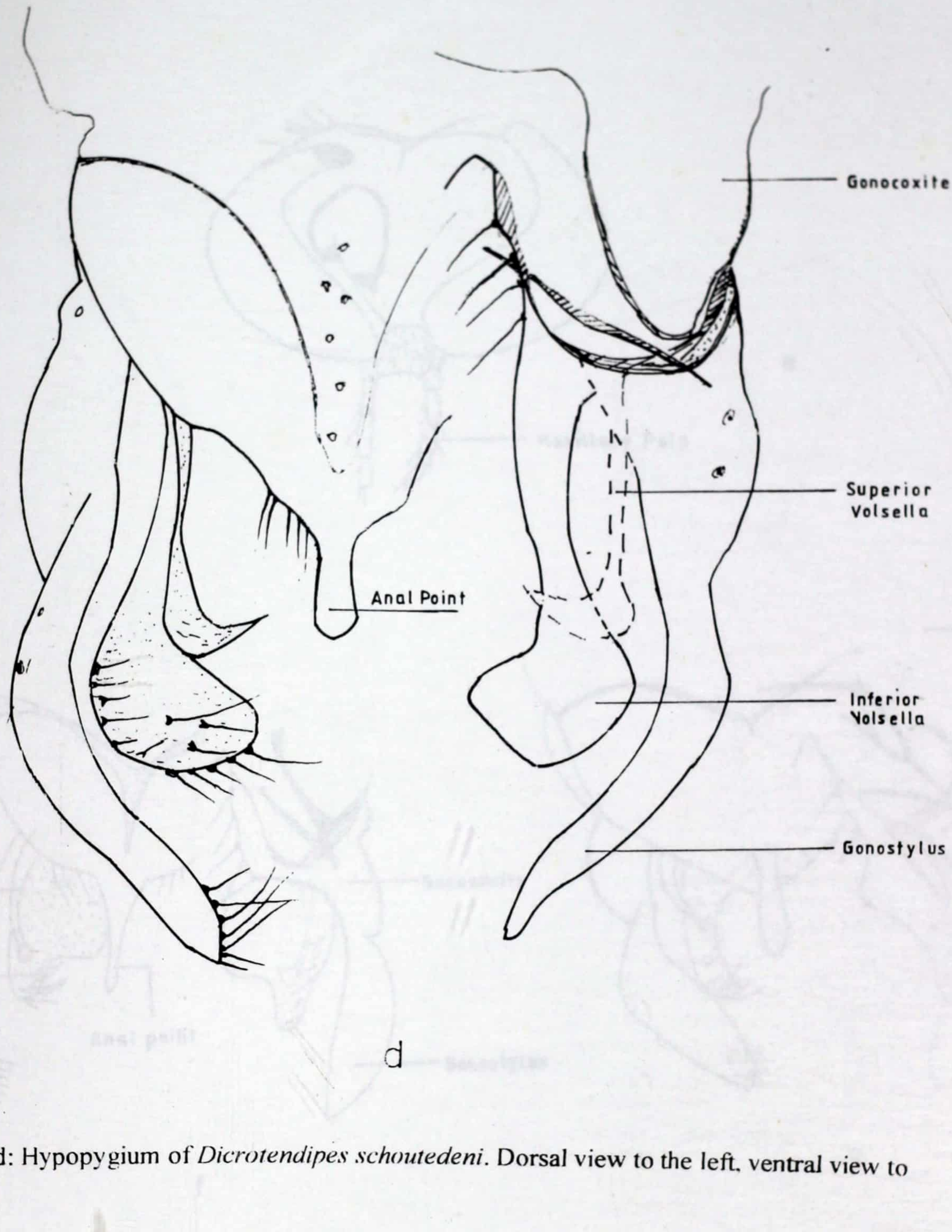
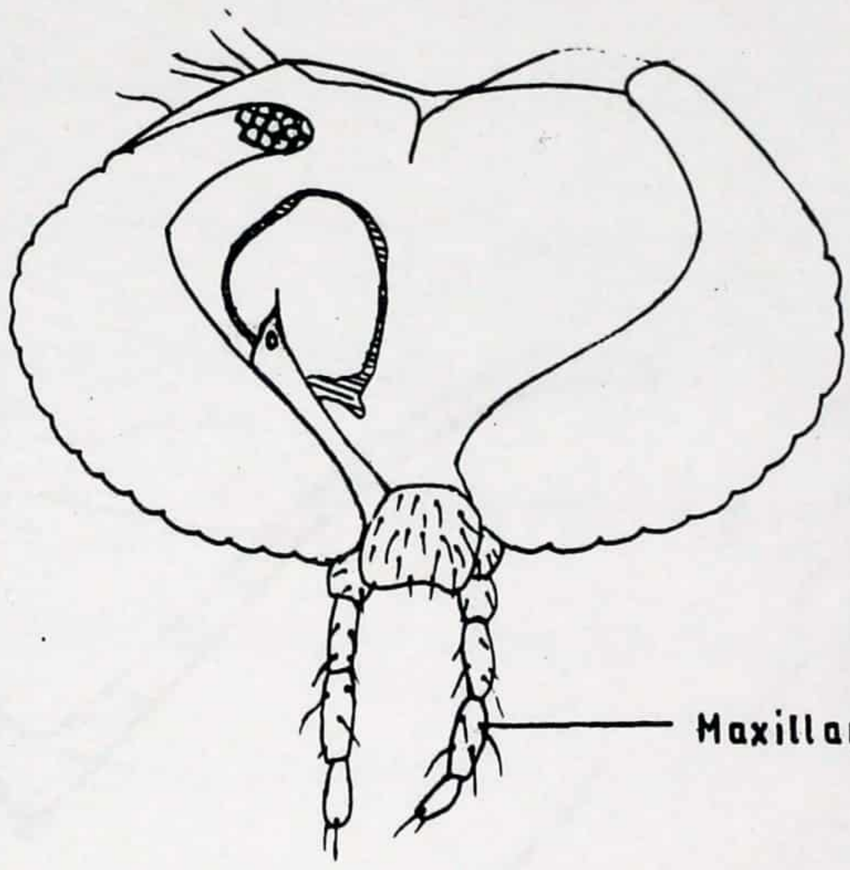


Fig. 3.2 d: Hypopygium of *Dicrotendipes schoutedeni*. Dorsal view to the left, ventral view to the right.



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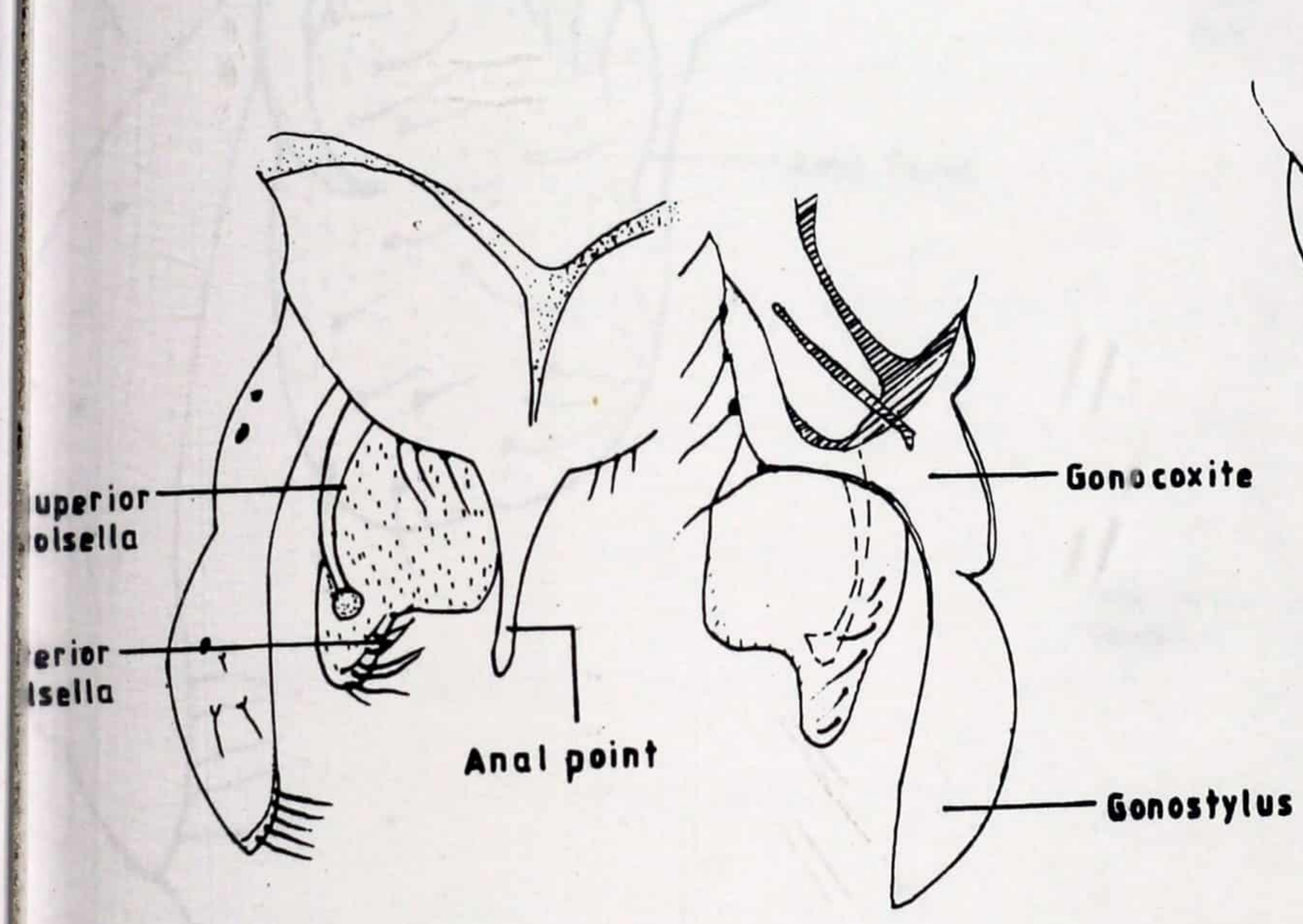

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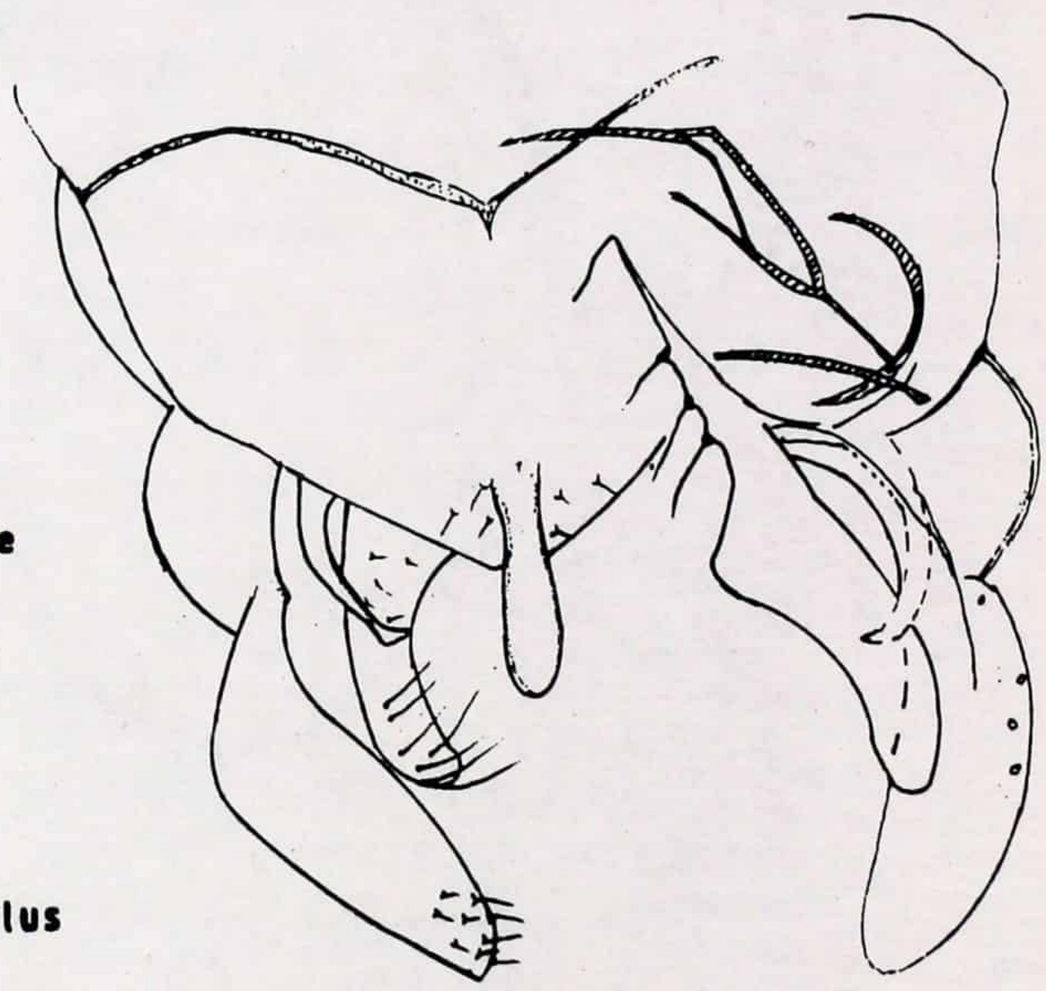

g

Fig. 3.2 e–g. Male Imagines *Nilodorum spp*. (e) Frontal view of head. (f) Hypopygium *Nilodorum brevipalpe* (g) Hypopygium *Nilodorum fractilobus*.

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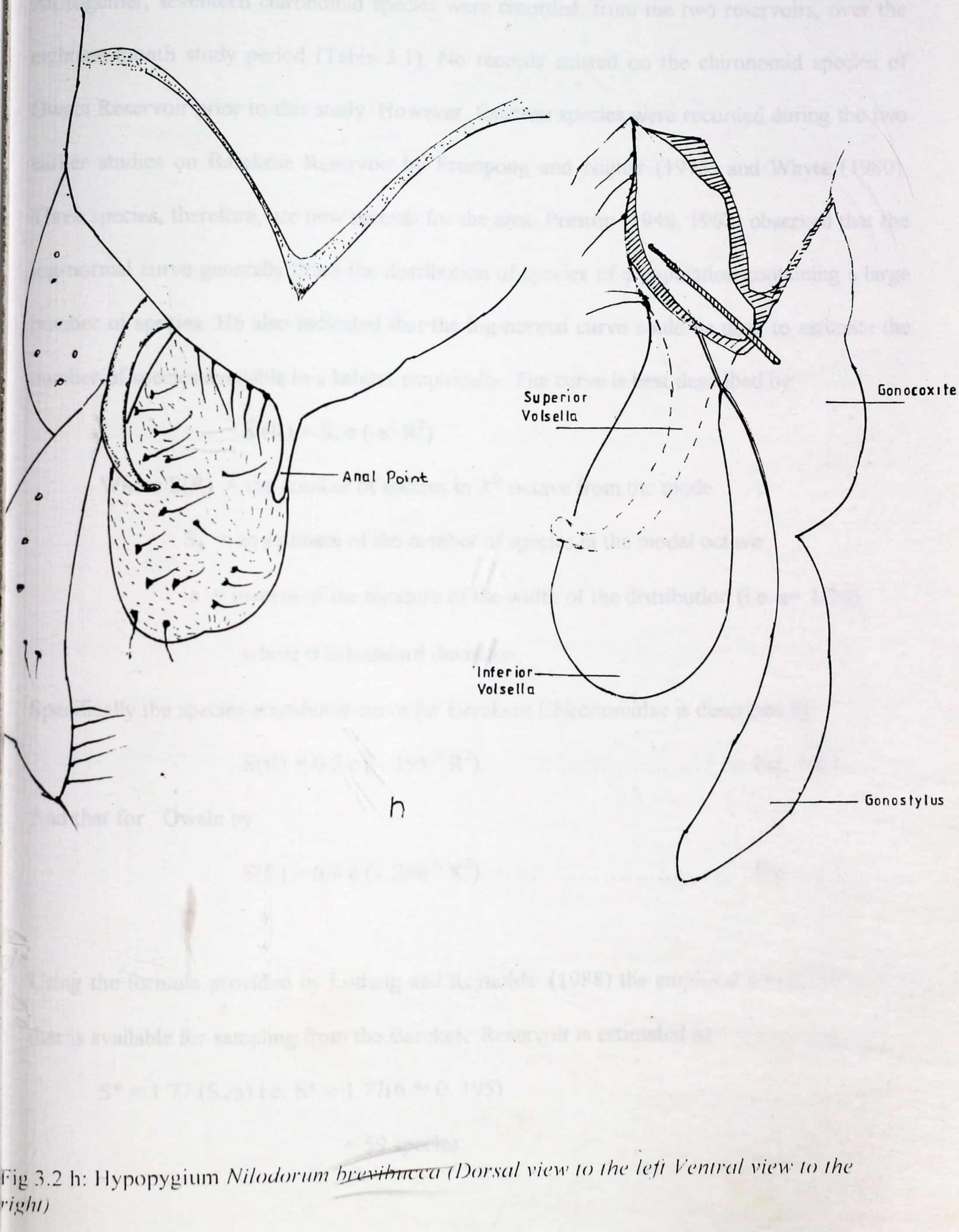

Fig 3.2 h: Hypopygium *Nilodorum brevibucca (Dorsal view to the left Ventral view to the right)*

3.3 Results and Discussion

3.3.1 Species Composition

All together, seventeen chironomid species were recorded, from the two reservoirs, over the eighteen-month study period (Table 3.1). No records existed on the chironomid species of Owabi Reservoir prior to this study. However, fourteen species were recorded during the two earlier studies on Barekese Reservoir by Frempong and Nijjhar (1973) and Whyte (1980). Three species, therefore, are new records for the area. Preston (1948, 1962) observed that the log-normal curve generally fitted the distribution of species of a population containing a large number of species. He also indicated that the log-normal curve could be used to estimate the number of species available in a habitat empirically. The curve is best described by:

$$S(R) = S_o\, e^{(-a^2 R^2)}$$

Where $S(R)$ = the number of species in R^{th} octave from the mode

S_o = an estimate of the number of species in the modal octave

a = inverse of the measure of the width of the distribution (i.e. $a = 1/2\sigma$)

where σ is standard deviation.

Specifically the species abundance curve for Barekese Chironomidae is described by:

$$S(R) = 6.5\, e^{(-.195^2 R^2)}. \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Fig. } 3.3.1$$

And that for Owabi by:

$$S(R) = 6.0\, e^{(-.268^2 R^2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Fig. } 3.3.2$$

Using the formula provided by Ludwig and Reynolds (1988) the empirical number of species that is available for sampling from the Barekese Reservoir is estimated as:

$$S^* = 1.77\,(S_o/a) \text{ i.e. } S^* = 1.77(6.5/\,0.\,195)$$

$$= 59 \text{ species.}$$

And for Owabi $S^* = 1.77\ (6.0/\ 0.\ 268)$

$= 40$ species.

The traps, therefore, sampled 29% and 43% of the available species at Barekese and Owabi respectively.

The number of chironomid species recorded from some African lakes and reservoirs overlap the number of species that was recorded from Barekese and Owabi reservoirs (See Table 3.3). An examination of Figs. 3.3.1 and 3.3.2 shows that the curve is truncated on the left side. This indicates that the traps were not efficient in sampling the rare species in the habitat (Ludwig and Reynolds, 1988). The use of the present traps, therefore, could have led to an underestimation of the number of species outside the commonly occurring species when the log-normal model is considered (See Table 3.3.1 and Table 3.3.2).

The large differences between the observed and predicted models (as indicated by the log-normal models (Model 1) for Barekese and Owabi (Figs.3.3.1 and 3.3.2) were minimised by subjecting the data to an algorithm provided by Ansa–Asare *et al.*, (1999) as ff:

$$E = \tfrac{1}{n} - p(\sum n_{I=1}(S(R') - S(R))^2$$

Where S (R') = Expected abundance

n = number of observed occurrences

S(R) = the observed abundance

Table 3.1: Chironomid Species Recorded from Barekese Reservoir Area.

Frempong & Nijjhar (1973)	**Whyte (1980)**	**Present Study**
Ablabesmyia sp.	*Cricotopus bizonatus*	*Ablabesmyia nilotica*
Clinotanypus sp	*Clinotanypus claripennis*	*Clinotanypus claripennis*
Chironomus SP	*Ablabesmyia melaleuca*	*Dicrotendipes pennicilatus*
Dicrotendipes sp.	*Ablabesmyia nilotica*	*Dicrotendipes kribiicola*
Nilodorum brevibucca	*Dicrotendipes fusconotatus*	*Dicrotendipes fusconotatuss/ pilosimanus*
Polypedilum sp	*Dicrotendipes sudanicus*	*Dicrotendipes schoutedeni*
Cryptochironomus sp	*Nilodorum brevibucca*	*Kiefferulus chloronotus*
(as Cryptochironomus forcipatus)	*Nilodorum fractilobus*	*Nilodorum fractilobus*
	Polypedilum (P) deletum	*Nilodorum brevibucca*
	Microchironomus tener	*Nilodorum brevipalpe*
	Harnischia acuta (as Cryptochironomus acuta)	*Polypedilum (Uresipedilum) sp.*
	Chironomus sp. 1	*Harnischia (Microchironomus) tener*
	Chironomus sp. 2	*Chironomus sp 1 (nr. transvalensis)*
	Chironomus sp. 3	*Chironomus sp 2*
		Chironomus sp 3
		Chironomus sp. 4
		Chironomus sp. 5

Table 3.3.1: Goodness of fit test for the lognormal models to observed Chironomidae Counts from Barekese Reservoir (March 1998 – August 1999).

Octave	R	a = S_o= Observed S(R)	0.195 6.5 Expected S(R) Model 1	χ^2	0.789 6.5 Expected S(R) Model 2	χ^2
1	-1	5.5	6.26	0.09	3.49	1.16
2	0	6.5	6.5	0.00	6.5	0.00
3	1	2.0	6.26	2.90	3.49	0.64
4	2	0	5.58	5.58	0.06	0.06
5	3	0	4.62	4.62	0.02	0.02
6	4	1	3.54	1.82	0.00	1.00
7	5	0	2.51	2.51	0.00	0.00
8	5	1	1.65	0.26	0.00	1.00
9	7	1	1.01	0.00	0.00	1.00
Total		17	37.93	17.85	13.56	4.88

Table 3.3.2: Goodness of fit test for the lognormal models to observed Chironomidae Counts from Owabi Reservoir (March 1998 – August 1999).

Octave	R	a = S_o= Observed S(R)	0.268 6.0 Expected S(R) Model 1	χ^2	0.553 6.0 Expected S(R) Model 2	χ^2
1	-1	5.5	5.58	0.001	4.42	0.26
2	0	6.0	6.0	0.00	6.0	0.00
3	1.0	0.5	5.58	4.62	0.60	0.12
4	2	2	4.50	1.30	1.76	0.03
5	3	1	3.14	1.46	0.38	1.06
6	4	1	1.90	0.43	.04	23.04
7	5	1	0	0.00	0.00	1.00
Total		17	27.7	7.81	13.2	24.51

The optimised models (Model 2) are shown in Figs. 3.3.3*a* and b and 3.3.4*a* and *b* for Barekese and Owabi reservoirs, respectively.

For Barekese $\chi^2 = 4.88$ therefore P_2 (v =7)>> 0.05 (Table 3.3.1).

The corresponding value for Owabi was χ^2 =24.51 << 0.001 (Table 3.3.2).

The parameters for the optimised model for Barekese Reservoir were:

$a = 0.789$

$S_o = 6.5$

The corresponding values for Owabi Reservoir were:

$a = 0.553$

$S_o = 6.0$

The log-normal curve provides a good fit to populations that contain a large number of species (Ludwig and Reynolds, 1988). In populations with log-normal distribution, ***a*** varies between 0.13 and 0.3 (Ludwig and Reynolds, 1988). The optimised curves for Barekese and Owabi reservoirs, therefore, did not fall within the constraints of the log-normal curve. However, it is worth noting that the coefficient of determination of the regression between the expected and the observed number of chironomid species for the optimised models was high in both reservoirs. R^2 was 0.82 and 0.96 for Barekese and Owabi reservoirs respectively (Figs. 3.3.3 b and 3.3.4 b).

Table 3.3: Number of Chironomid Species Recorded from Some African Lakes and Reservoirs

Lake/Reservoir	No of Chironomid Species	Source of Information
Chad	41	Wright and Cranston (2000)
Kariba	30	- do -
Chilwa	22	- do -
Opi	46	Hare and Carter (1987)
Central Ethiopian Rift Valley	17 – 27	Harrison (1987)
Volta	45	Petr (1970)
Barekese	7	Frempong and Nijjhar (1973)
Barekese	14	Whyte (1980)

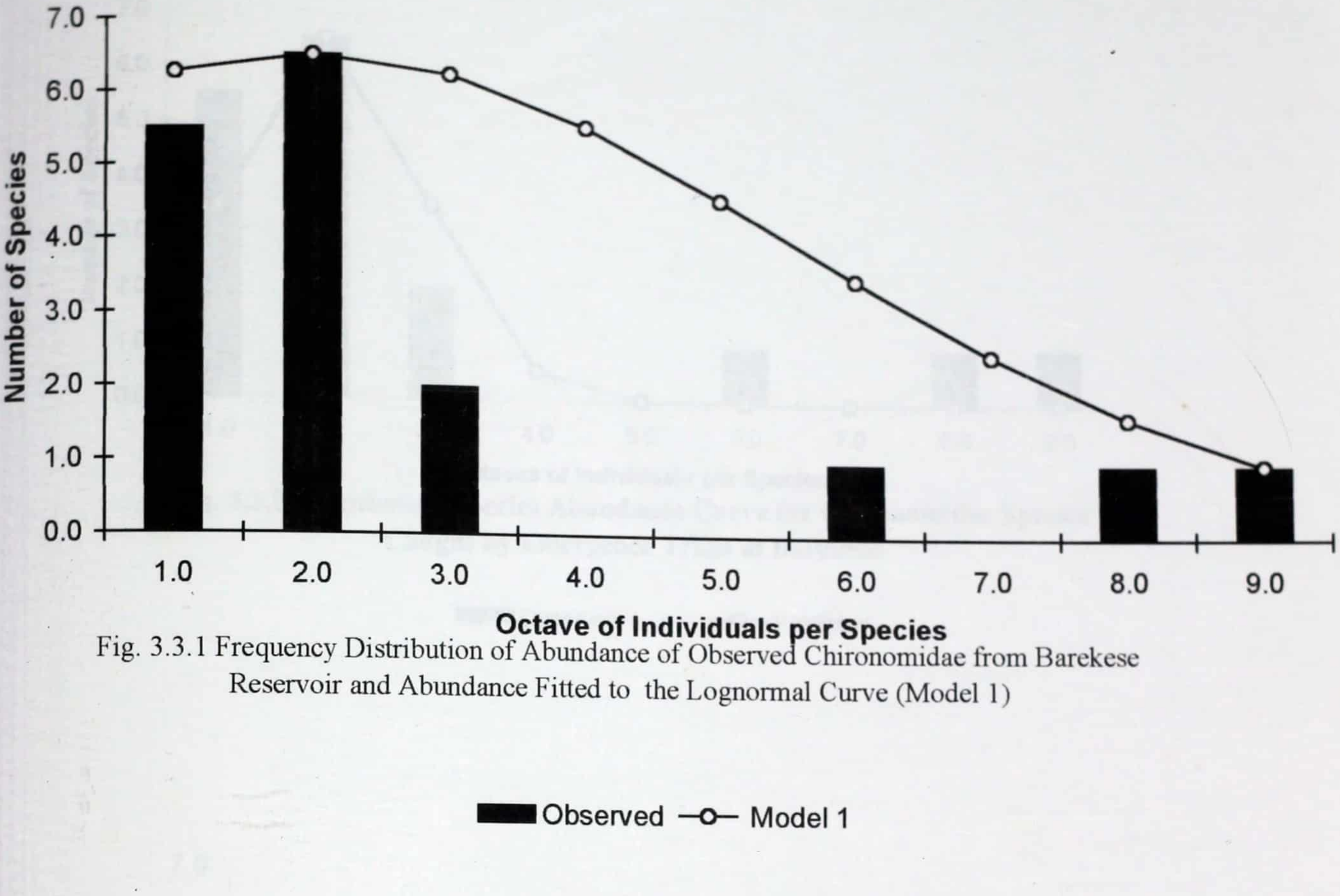

Fig. 3.3.1 Frequency Distribution of Abundance of Observed Chironomidae from Barekese Reservoir and Abundance Fitted to the Lognormal Curve (Model 1)

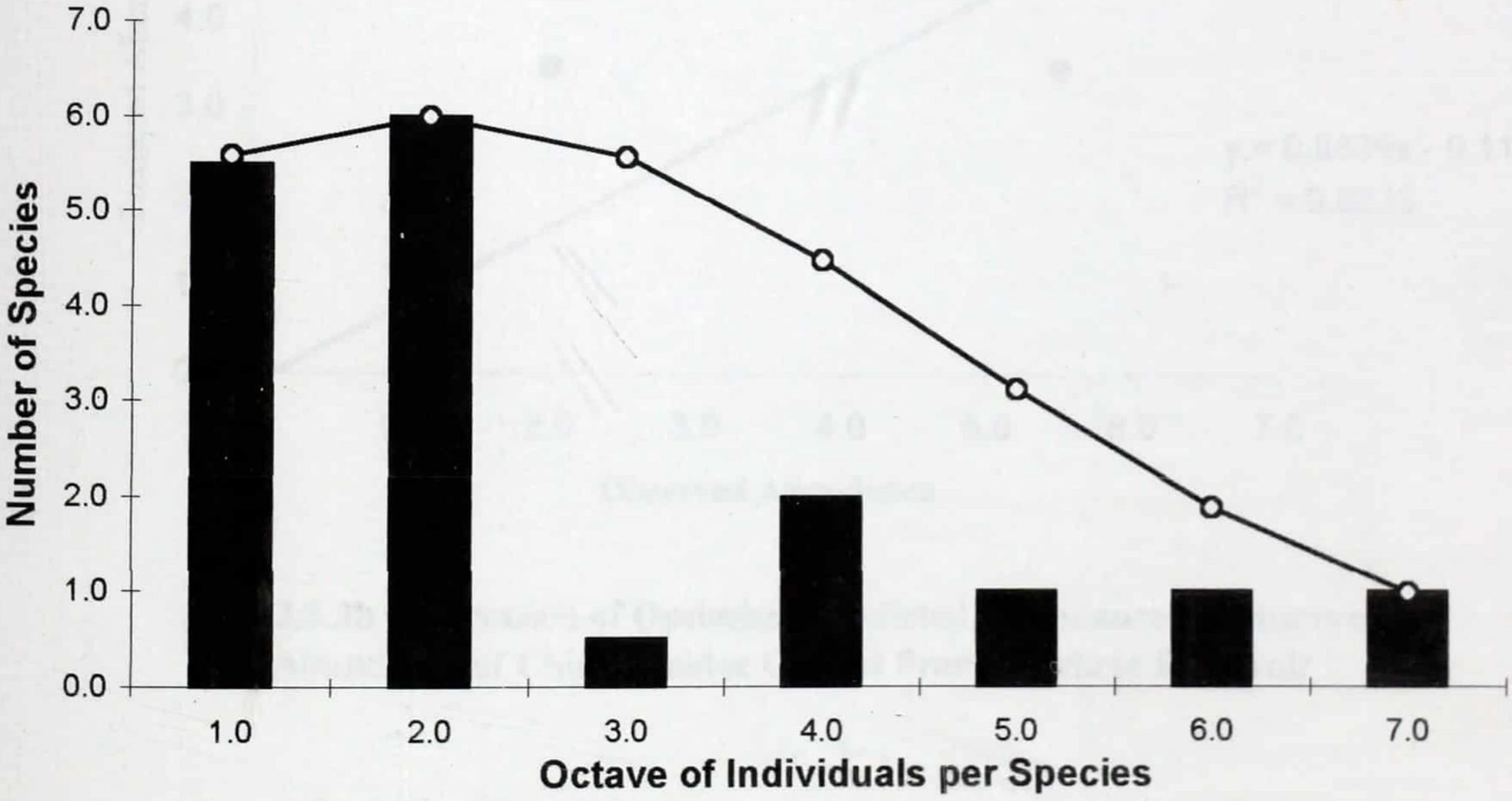

Fig3.3.2 :Freguency Distribution of Abundance of Observed Chironomidae from Owabi Reservoir and Abundance Fitted to the Lognormal Curve (Model 1)

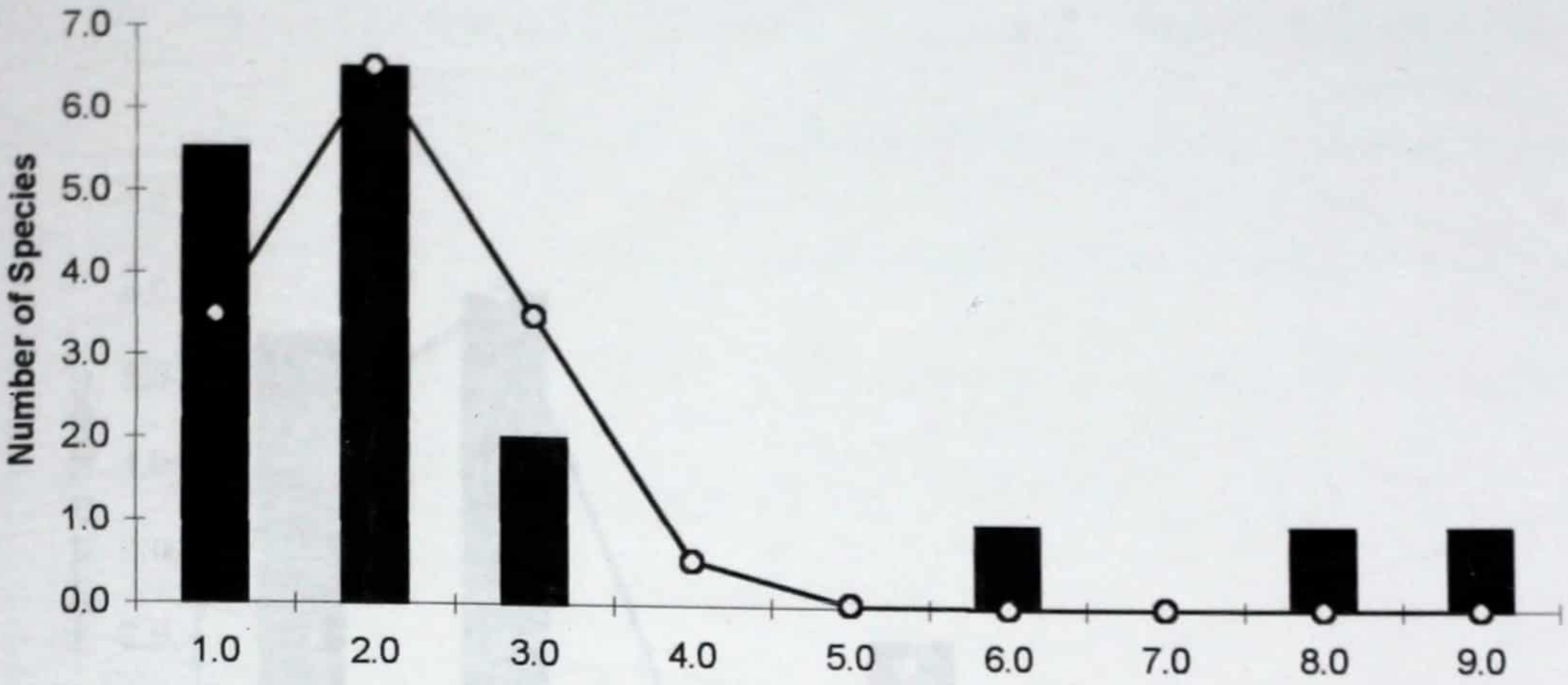

Fig. 3.3.3a :Optimised Species Abundance Curve for Chironomidae Species Caught by Emergence Traps at Barekese

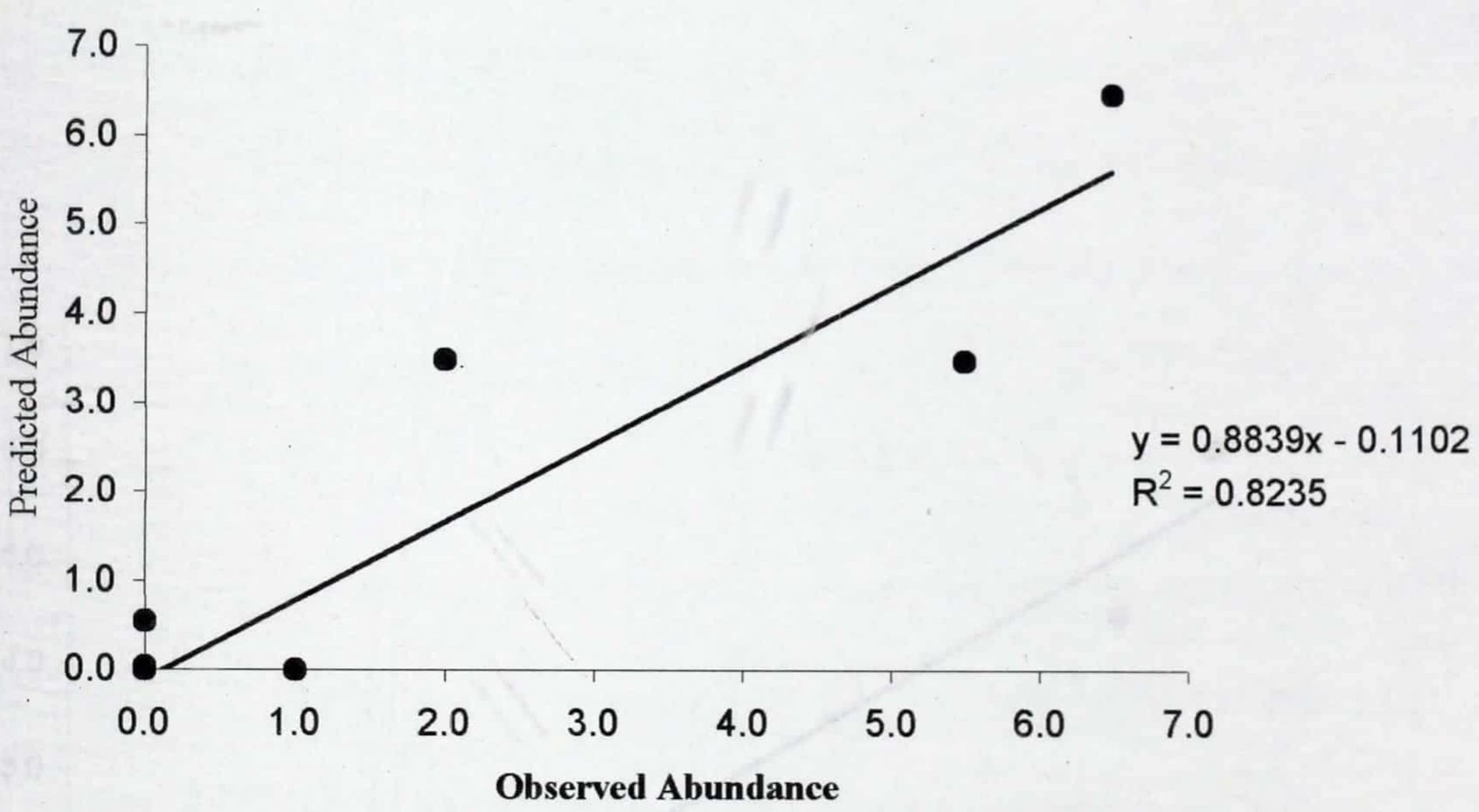

Fig. 3.3.3b :Regression of Optimised Predicted Abundance on Observed Abundance of Chironomidae Caught From Barekese Reservoir

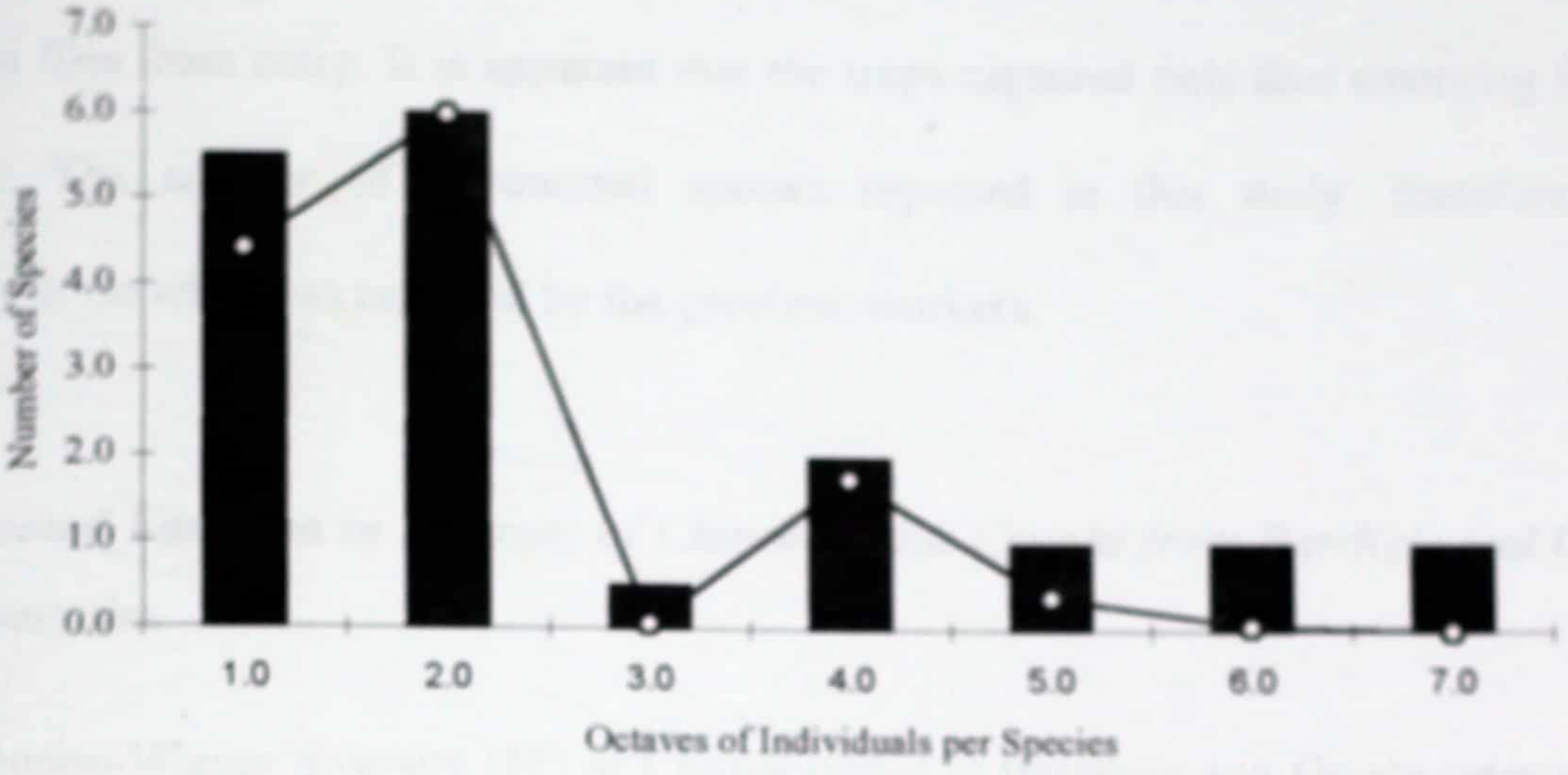

Fig. 3.3.4a :Optimised Species Abundance Curve for Chirinomidae Species Caught by Emergence Traps at Owabi

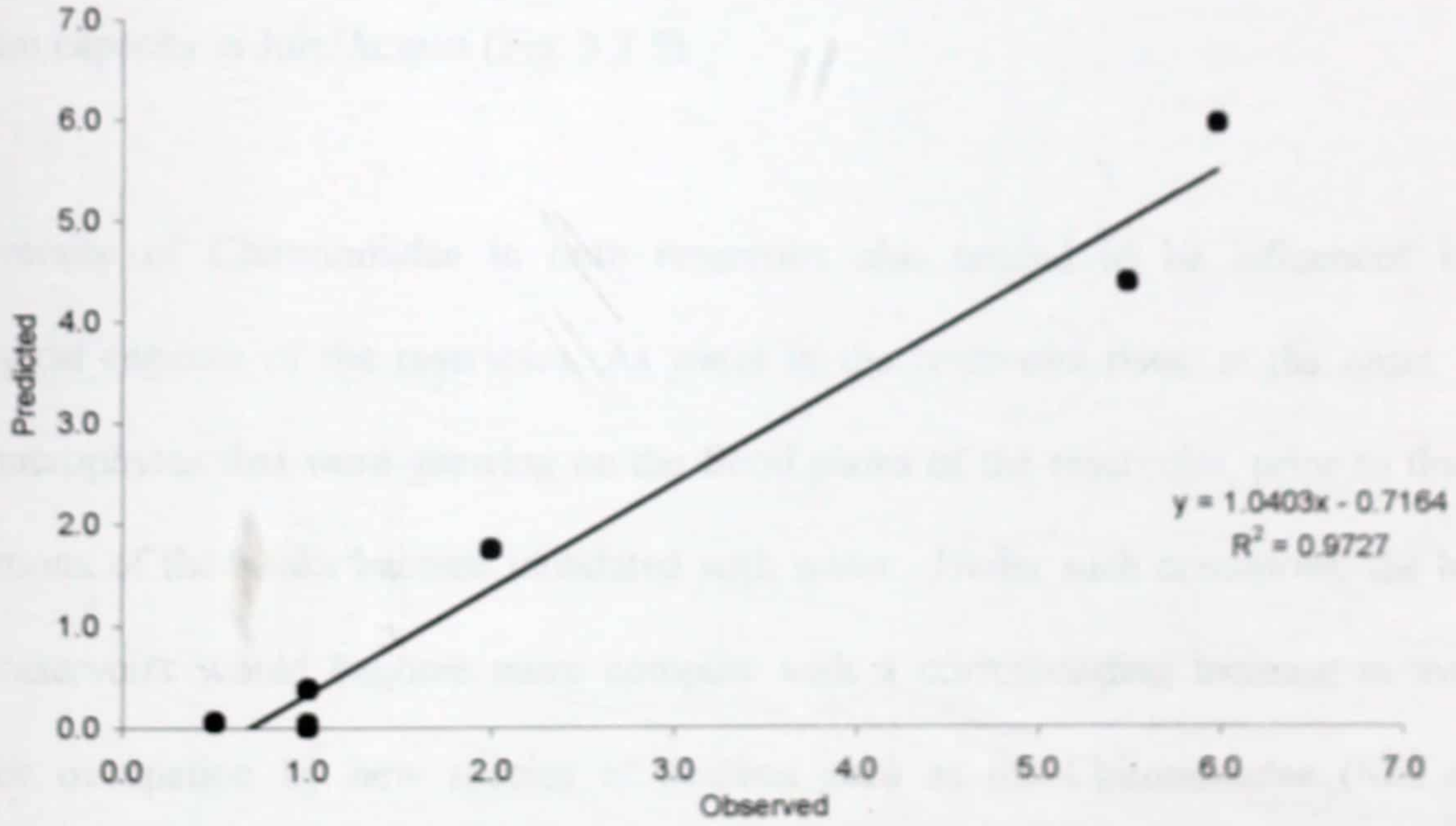

Fig. 3.3.4b :Regression of Optimised Predicted Abundance on Observed Abundance of Chironomidae Caught From Owabi Reservoir

Illies (1971), Lehman (1979, 1981) and Hare and Carter (1987) observed that some of the Chironomidae that were captured by them had entered their traps from the adjoining landmasses. In the present study, however, the architecture of the emergence trap excluded land-based flies from entry. It is apparent that the traps captured only flies emerging from the reservoirs. The number of chironomid species reported in this study, therefore, is an improvement on what was reported by the previous workers.

3.3.2 Seasonal Variation in Diversity of Chironomidae Caught from Barekese and Owabi Reservoirs.

Mean Shannon-Wiener diversity (H') of Chironomidae in Barekese and Owabi reservoirs was 1.22 ± 0.22 and 1.31 ± 0.22 respectively. Diversity of the chironomid fauna in Owabi was slightly higher than that of Barekese. However, there was no significant difference between diversity of Chironomidae in the two reservoirs ({|t| = 0.6558}; $P_{(2\,v=25)} >> 0.05$). Shannon – Wiener diversity in Owabi Reservoir was highest at the start of the rainy season (April/May) of the year whereas in Barekese this occurred at the time when the reservoir was reaching maximum capacity in July/August (Fig. 3.3.5).

The diversity of Chironomidae in both reservoirs also tended to be influenced by the hydrological regimes of the reservoirs. As water in the reservoirs rises, at the onset of the rains, macrophytes that were growing on the flood plains of the reservoirs, prior to flooding, and portions of the banks become inundated with water. Under such conditions, the bottom of the reservoirs would become more complex with a corresponding increase in available niche for occupation by new species of benthos such as the Chironomidae (McLachlan, 1969b). Thus, the diversity of Chironomidae increased, in the present study, when the reservoirs were filling up.

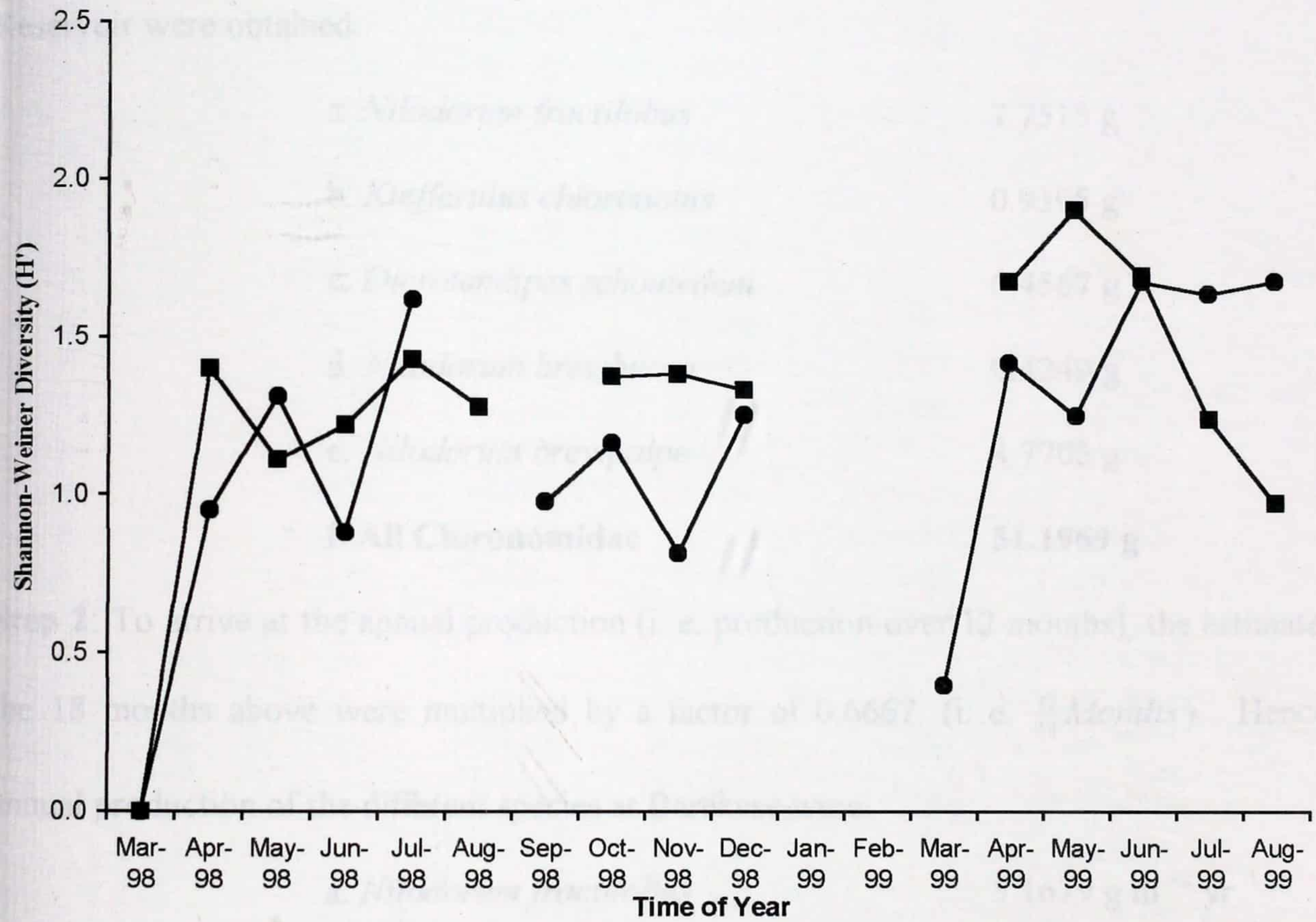

Fig.3.3.5 :Changes in alpha Diversity of Chironomid Fauna in Barekese and Owabi Reservoirs (March 1998 - August 1999)

3.3.3 Production of Chironomidae in Barekese and Owabi Reservoirs

The parameters that were used in estimating production of Chironomidae in Barekese and Owabi reservoirs are indicated in Appendices A and B respectively. Summaries of the monthly biomass of Chironomidae obtained for Barekese and Owabi are presented in Tables 3.4a and 3.4 b respectively.

Annual production of the five, chironomid species could be obtained in two ways:

A. From the sum of the monthly biomass over the 18-month period:

Step1: From Table 3.4.a the following estimates of chironomid biomass in Barekese Reservoir were obtained:

a. *Nilodorum fractilobus*	7.7515 g
b. *Kiefferulus chloronotus*	0.9395 g
c. *Dicrotendipes schoutedeni*	0.4567 g
d. *Nilodorum brevibucca*	0.4249 g
e. *Nilodorum brevipalpe*	4.7705 g
f. All Chironomidae	**51.1969 g**

Step 2: To arrive at the annual production (i. e. production over 12 months), the estimates for the 18 months above were multiplied by a factor of 0.6667. (i. e. $\frac{12}{18} Months$). Hence the annual production of the different species at Barekese were:

a. *Nilodorum fractilobus*	5.1679 g m^{-2} yr^{-1}
b. *Kiefferulus chloronotus*	0.6264 g m^{-2} $yr.^{-1}$
c. *Dicrotendipes schoutedeni*	0.3046 g m^{-2} $yr.^{-1}$
d. *Nilodorum brevibucca*	0.2833 g m^{-2} $yr.^{-1}$
e. *Nilodorum brevipalpe*	3.1805 g m^{-2} yr^{-1}
f. **All Chironomidae**	**34.1329 g m^{-2} yr^{-1}**

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Table 3.4a: Estimates of Monthly Biomass of Five Species of Chironomidae in Barekese Reservoir {g m^{-2} (Males only unless otherwise Indicated)}

	Species					
Time	*Nilodorum fractilobus*	*Kiefferulus chloronotus*	*Dicrotendipes schoutedeni*	*Nilodorum brevibucca*	*Nilodorum brevipalpe*	Total (All Chironomidae)
Mar-98	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Apr-98	0.0024	0.0000	0.0000	0.0000	0.0017	8.8870
May-98	1.9004	0.0155	0.0465	0.0029	0.2457	4.8611
Jun-98	0.0445	0.0000	0.0298	0.0033	0.1118	4.3737
Jul-98	0.4844	0.0041	0.0242	0.0039	0.0849	4.7446
Aug-98	0.0000	0.0000	0.0000	0.0000	0.0000	0.0588
Sep-98	0.1561	0.0943	0.0139	0.0000	0.7426	4.4434
Oct-98	0.9276	0.1412	0.0155	0.0000	0.3331	2.7557
Nov-98	2.6298	0.1478	0.0114	0.0000	0.7427	5.7707
Dec-98	0.1688	0.0727	0.0020	0.0012	0.0088	0.6534
Jan-99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Feb-99	0.0158	0.0044	0.0024	0.0000	1.3611	2.0723
Mar-99	1.1820	0.1371	0.0653	0.4136	1.0196	9.9828
Apr-99	0.0424	0.2939	0.0669	0.0000	0.0000	0.4660
May-99	0.0518	0.0090	0.0589	0.0000	0.0357	0.6293
Jun-99	0.0518	0.0090	0.0589	0.0000	0.0357	0.6293
Jul-99	0.0600	0.0004	0.0588	0.0000	0.0357	0.6090
Aug-99	0.0337	0.0101	0.0024	0.0000	0.0114	0.2598
Total Production	**7.7515**	**0.9395**	**0.4569**	**0.4249**	**4.7705**	**51.1969**
Mean	0.4306	0.0522	0.0254	0.0236	0.2650	2.8443
95%C.I.	0.3766	0.0405	0.0131	0.0484	0.2063	1.5497

Table 3.4b: Estimates of Monthly Biomass of Five Species of Chironomidae in Owabi Reservoir {g m^{-2} (Males only unless otherwise Indicated)}

	Species					
Time	*Nilodorum fractilobus*	*Kiefferulus chloronotus*	*Dicrotendipes schoutedeni*	*Nilodorum brevibucca*	*Nilodorum brevipalpe*	Total (All Chironomidae)
Mar-98	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Apr-98	0.0253	0.0041	0.2323	0.0005	0.4266	7.7919
May-98	0.1502	0.0048	0.0041	0.0000	0.0527	0.2530
Jun-98	1.1524	0.0522	0.1924	0.0000	0.8141	2.2111
Jul-98	0.0007	0.0007	0.0017	0.0004	0.0003	0.0049
Aug-98	0.0796	0.0220	0.0110	0.0000	0.1122	0.4621
Sep-98	0.0048	0.0000	0.0000	0.0000	0.0000	0.0137
Oct-98	0.0000	0.0016	0.0000	0.0000	0.0004	0.0022
Nov-98	0.0418	0.0000	0.0098	0.0000	0.0000	0.0946
Dec-98	0.0022	0.0000	0.0193	0.0000	0.0030	0.0320
Jan-99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Feb-99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mar-99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Apr-99	0.0007	0.0000	0.0004	0.0000	0.0007	0.0047
May-99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0294
Jun-99	0.0369	0.0269	0.0414	0.0000	0.0061	0.1584
Jul-99	0.1429	0.0269	0.0143	0.0000	0.0061	1.0362
Aug-99	0.0498	0.0000	0.0046	0.0000	0.0000	0.2125
Total Production	**1.6873**	**0.1392**	**0.5713**	**0.0009**	**1.4222**	**12.3069**
Mean	0.0937	0.0077	0.0317	0.0001	0.0790	0.6837
95%C.I.	0.1335	0.0073	0.0335	0.0001	0.1043	0.9234

Similarly, estimates of annual production of Chironomidae in Owabi Reservoir, based on the Table 3.4.b, yielded the following results:

a. *Nilodorum fractilobus*	1.1249 g m^{-2} $yr.^{-1}$
b. *Kiefferulus chloronotus*	0.0928 g m^{-2} $yr.^{-1}$
c. *Dicrotendipes schoutedeni*	0.3809 g m^{-2} $yr.^{-1}$
d. *Nilodorum brevibucca*	0.0006 g m^{-2} $yr.^{-1}$
e. *Nilodorum brevipalpe*	0.9482 g m^{-2} yr^{-1}
f. **All Chironomidae**	**8.2049 g m^{-2} $yr.^{-1}$**

B. By using the mean biomass estimates for the 18-month study period.

Step 3: In this case, the mean biomass for the different species was multiplied by 12.

The annual estimates of production for the five species in Barekese Reservoir by this procedure were:

a. *Nilodorum fractilobus*	5.1360 ± 4.5276 g m^{-2} $yr.^{-1}$
b. *Kiefferulus chloronotus*	0.6264 ± 0.4860 g m^{-2} $yr.^{-1}$
c. *Dicrotendipes schoutedeni*	0.3049 ± 0.1572 g m^{-2} $yr.^{-1}$
d. *Nilodorum brevibucca*	0.2832 ± 0.5808 g m^{-2} yr^{-1}
e. *Nilodorum brevipalpe*	3.1800 ± 2.4756 g m^{-2} $yr.^{-1}$
f. **All Chironomidae**	**34.1316 ± 18.5964 g m^{-2} yr^{-1}**

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The corresponding estimates for Owabi were:

a. *Nilodorum fractilobus*	1.1244 ± 1.6020 g m^{-2} $yr.^{-1}$
b. *Kiefferulus chloronotus*	0.0924 ± 0.0876 g m^{-2} yr^{-1}
c. *Dicrotendipes schoutedeni*	0.3804 ± 0.4020 g m^{-2} yr^{-1}
d. *Nilodorum brevibucca*	0.0012 ± 0.0012 g m^{-2} yr^{-1}
e. *Nilodorum brevipalpe*	0.9480 ± 1.2516 g m^{-2} yr^{-1}
f. **All Chironomidae**	**8.2044 ± 11.0808 g m^{-2} yr^{-1}**

Thus, both methods used in estimating production yielded essentially the same results. The procedure under method ***B***, however, tended to overestimate total chironomid production by about 0.04 %.

Step 4: Only the fourth weekly emergence samples, in each month, were used in estimating annual production. However, estimates of production based on adult emergence entail the summation of the biomass of all emerging adult Chironomidae during the entire period of study (Illies, 1971). The estimates listed in Step 2 and Step 3 above, therefore, need to be adjusted upwards by multiplying the estimates obtained in this way by four (4) to take care of the number of weeks in a month. There is also the need for adjusting the estimates upward to compensate for losses occasioned by preservation in alcohol. Illies (1971) adjusted his values by 25 %. Lehman (1981) also applied a 25% factor to the production estimates. A 25% upward adjustment, therefore, was made in the present study thus bringing the final estimates of production of Chironomidae in Barekese Reservoir to:

a. *Nilodorum fractilobus*	25.6800 ± 22.6380 g m^{-2} $yr.^{-1}$
b. Kiefferulus chloronotus	3.1320 ± 2.4300 g m^{-2} $yr.^{-1}$
c. *Dicrotendipes schoutedeni*	1.5245 ± 0.7860 g m^{-2} $yr.^{-1}$
d. *Nilodorum brevibucca*	1.4160 ± 2.9040 g m^{-2} $yr.^{-1}$
e. *Nilodorum brevipalpe*	15.900 ± 12.3780 g m^{-2} $yr.^{-1}$
f. **All Chironomidae**	**170.6580 ± 23.2455 g m^{-2} $yr.^{-1}$**

The corresponding estimates for Owabi were:

a. *Nilodorum fractilobus*	5.6220± 8.0100 g m^{-2} $yr.^{-1}$
b. *Kiefferulus chloronotus*	0.4620 ± 0.4380 g m^{-2} $yr.^{-1}$
c. *Dicrotendipes schoutedeni*	1.9020 ± 2.0100 g m^{-2} $yr.^{-1}$
d. *Nilodorum brevibucca*	0.0060 ± 0.0060 g m^{-2} $yr.^{-1}$
e. *Nilodorum brevipalpe*	4.7400 ± 6.2580 g m^{-2} $yr.^{-1}$
f. **All Chironomidae**	**41.0022 ± 55.4040 g m^{-2} $yr.^{-1}$**

Figures 3.4.1 and 3.4.2 show trends of biomass of the five, chironomid species, in absolute terms, in Barekese and Owabi reservoirs respectively. *Nilodorum brevipalpe* and *N. fractilobus* had the highest biomass, in Barekese Reservoir, during the study. The highest biomass for *N. brevipalpe*, in Barekese Reservoir, occurred in April 1998 whereas that of *N. fractilobus* was in November 1998. The two species also contributed the highest biomass to production of Chironomidae in Owabi Reservoir. In Owabi Reservoir, however, the highest biomass of the two species occurred between June and July 1998. In regard of the two years, chironomid production was higher in 1998 than in 1999, in absolute terms.

In addition, there was a trend towards seasonality in the biomass observed at Owabi. Higher chironomid biomass was observed during the rainy season (March/April to August, than in the dry season (September to March). No clear trend towards seasonality, however, was observed in the case of chironomid production in Barekese Reservoir.

The relative importance of the five commonly occurring chironomid species to production of Chironomidae in Barekese and Owabi reservoirs is presented in Fig. 3.5.1 and Fig. 3.5.2 respectively. A 15% threshold of total production was arbitrarily set by the author in deciding

on which species were important contributors to the overall chironomid production in the two reservoirs (Tables 3.5a and 3.5b). In this regard, two species, *Nilodorum fractilobus* and *N. brevipalpe* were important contributors to production in Barekese Reservoir. In Owabi Reservoir, on the other hand, all species excépt *N. brevibucca* were important contributors to chironomid production. The mean percentage contribution (geometric mean) of *N. fractilobus and N. brevipalpe* in Barekese was 8.4% and 7.1% respectively (Table 3.5a). Corresponding figures in Owabi, for *N. fractilobus*, *Kiefferulus chloronotus*, *Dicrotendipes schoutedeni* and *Nilodorum brevipalpe* were 15.1 %, 3.8%, 7.3% and 9.1% respectively (Table 3.5b).

3.3.4 Seasonal Abundance Pattern

Fig. 3.6.1 and Fig. 3.6.2 show densities of Chironomidae caught by the floating emergence traps from Barekese and Owabi reservoirs respectively. The traps caught Chironomidae throughout the year. Mean density of adult Chironomidae captured from Barekese was estimated at 3851.5 ± 2233.3 individuals m^{-2} (Mean ± 95% C.I.). It was 2207.4 ± 1918.6 individuals for Owabi. Density of Chironomidae in Barekese Reservoir, therefore, was 1.7 times that of Owabi. Two species, *Nilodorum fractilobus and N. brevipalpe* were dominant in the catches from both Barekese and Owabi reservoirs. Also, the peaks of abundance of the two species tended to follow the rainfall pattern in lag-time. And abundance of the Chironomidae also reflected the pattern that was observed in the case of production of the species.

3.4 Conclusions

The abundance of the species of chironomids in Owabi was strongly seasonal. It was related to the hydrological conditions of the reservoir. In contrast, the Chironomidae in Barekese did

not show a clear seasonality. Two chironomid species, *Nilodorum fractilobus* and *N. brevipalpe* were the most abundant and therefore constituted the immediate nuisance species. However, the other three species, *N. brevibucca, Kiefferulus chloronotus* and *Dicrotendipes schoutedeni* could also interfere with production of potable water at the two headworks.

Table 3.5a: Biomass of Males as Percentage of Total Chironomid Production at Barekese

	Species				
Month	*Nilodorum fractilobus*	*Kiefferulus chloronotus*	*Dicrotendipes schoutedeni*	*Nilodorum brevibucca*	*Nilodorum brevipalpe*
Mar-98	0.0000	0.0000	0.0000	0.0000	0.0000
Apr-98	12.6351	0.0000	0.0000	0.0000	32.1013
May-98	39.0940	0.3189	0.9566	0.0597	5.0544
Jun-98	1.0175	0.0000	0.6814	0.0755	2.5562
Jul-98	10.1347	0.0858	0.5063	0.8139	1.7763
Aug-98	0.0000	0.0000	0.0000	0.0000	0.0000
Sep-98	3.5131	2.1222	0.3128	0.0000	16.7124
Oct-98	33.6611	5.1239	0.5625	0.0000	12.0877
Nov-98	45.5716	2.5612	0.1975	0.0000	12.8702
Dec-98	25.8341	11.1264	0.3061	0.1837	1.3468
Jan-99	0.0000	0.0000	0.0000	0.0000	0.0000
Feb-99	0.7656	0.2132	0.1163	0.0000	65.9512
Mar-99	11.8533	1.3749	0.6548	10.2247	4.1477
Apr-99	9.0987	63.0687	14.3562	0.0000	0.0000
May-99	1.2016	4.8064	3.9786	0.1068	0.0000
Jun-99	8.2327	1.4304	9.3452	0.0000	5.6739
Jul-99	10.0000	0.0667	9.8000	0.0000	0.0000
Aug-99	12.9715	3.8876	0.9238	0.0000	4.3880
Geometric Mean	**8.4**	**1.6**	**1.0**	**0.3**	**7.1**

Table 3.5b: Biomass of Males as Percentage of Total Chironomid Production at Owabi

	Species				
Month	*Nilodorum fractilobus*	*Kiefferulus chloronotus*	*Dicrotendipes schoutedeni*	*Nilodorum brevibucca*	*Nilodorum brevipalpe*
Mar-98	0.0000	0.0000	0.0000	0.0000	0.0000
Apr-98	1.8719	0.2654	1.6065	0.0359	30.8470
May-98	18.7477	6.0002	36.3252	0.0000	8.4402
Jun-98	41.5635	18.8183	7.0524	0.0000	30.9842
Jul-98	2.5474	4.3333	7.0509	1.3469	14.4512
Aug-98	25.3168	7.0284	3.4425	0.0000	35.7877
Sep-98	34.7826	0.0000	0.0000	0.0000	0.0000
Oct-98	0.0000	0.0000	0.0000	0.0000	66.6667
Nov-98	37.9655	0.0000	8.9010	0.0000	11.8983
Dec-98	3.7866	0.5164	33.2186	0.0000	0.5164
Jan-99	0.0000	0.0000	0.0000	0.0000	0.0000
Feb-99	0.0000	0.0000	0.0000	0.0000	0.0000
Mar-99	0.0000	0.0000	0.0000	0.0000	0.0000
Apr-99	20.5479	0.0000	13.3562	0.0000	9.3607
May-99	35.3966	23.4159	8.6865	0.0000	1.2799
Jun-99	19.7221	6.4137	7.6430	1.6569	26.9375
Jul-99	13.2782	2.4995	3.8469	0.0000	0.5668
Aug-99	23.8620	0.0000	2.2041	0.0000	0.0000
Geometric Mean	**15.1**	**3.8**	**7.3**	**0.4**	**9.1**

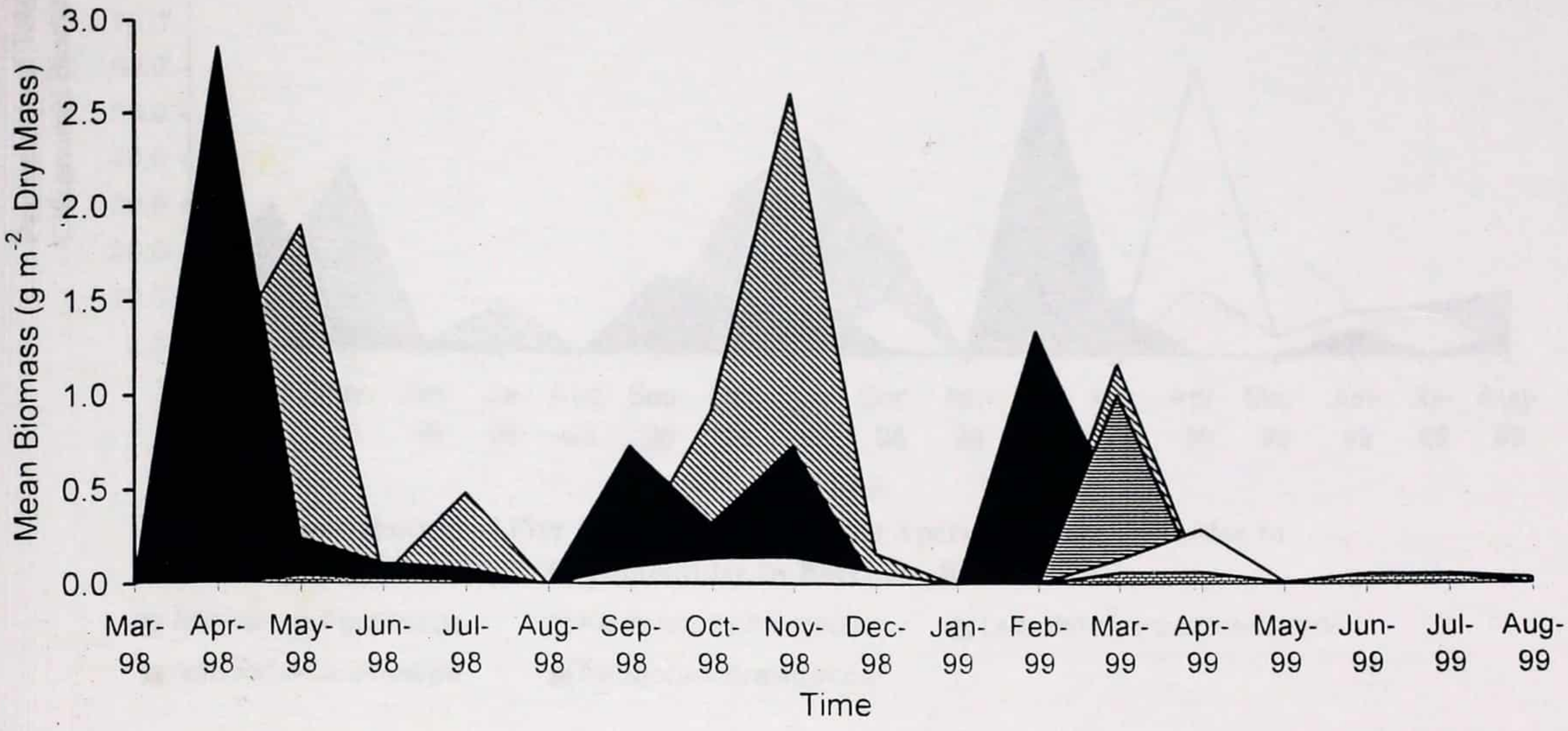

Fig. 3.4.1 Production of Five Commonly Occurring Species of Chironomidae in Barekese Reservoir

▨ *Nilodorum fractilobus* ■ *Nilodorum brevipalpe* ▤ *Nilodorum brevibucca*
□ *Kiefferulus chloronotus* ▦ *Dicrotendipes schoutedeni*

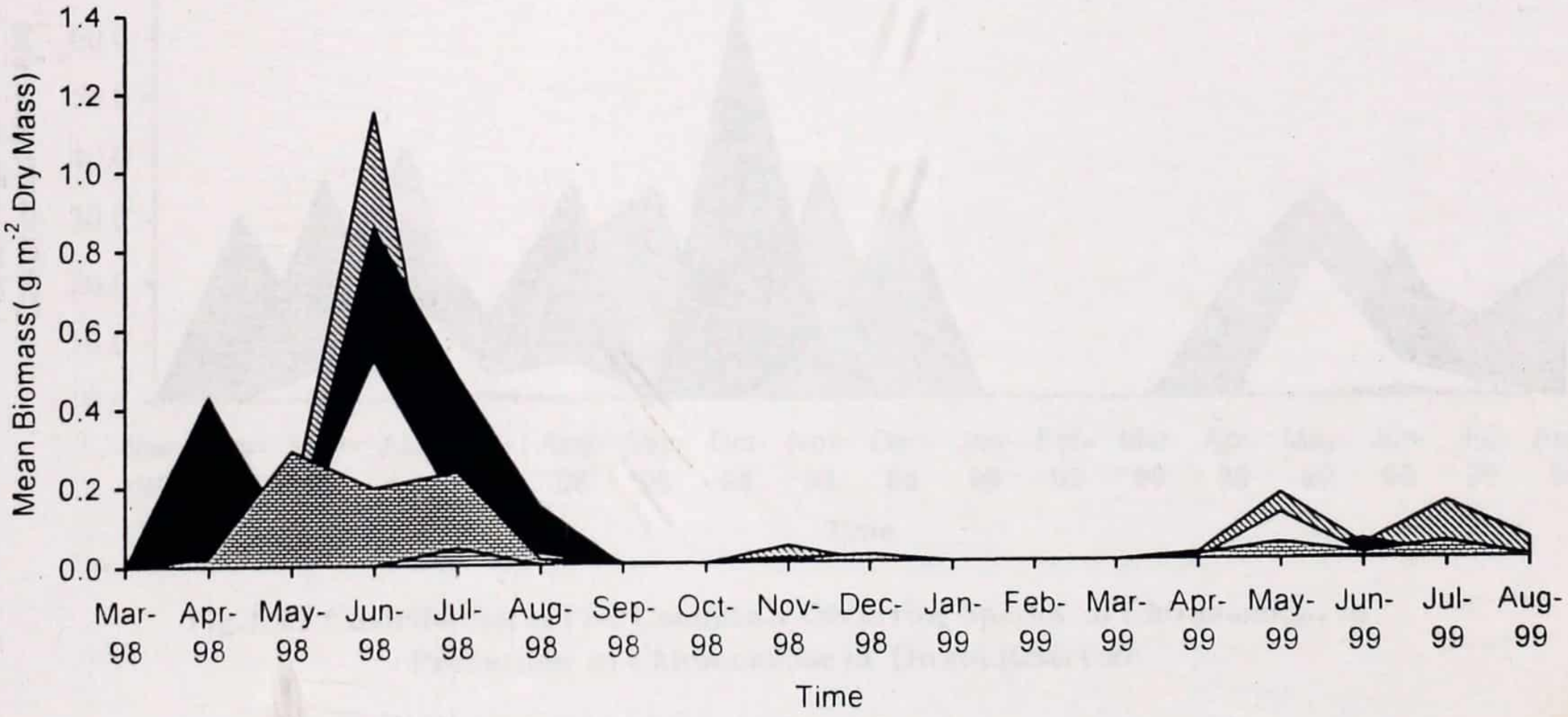

Fig. 3.4.2 Production of Five Commonly Occurring Species of Chironomidae in Owabi Reservoir

▨ *Nilodorum fractilobus* ■ *Nilodorum brevipalpe* □ *Kiefferulus chloronotus*
▦ *Dicrotendipes schoutedeni* ▤ *Nilodorum brevibucca*

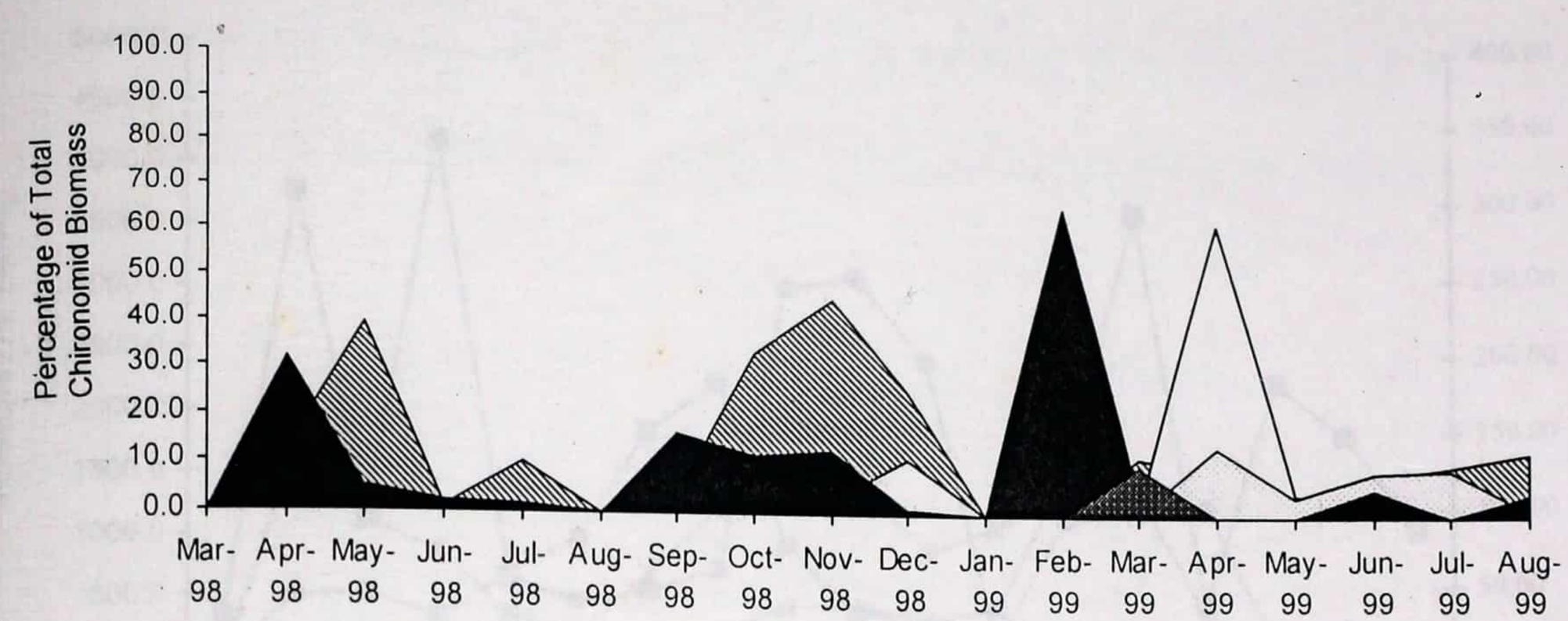

Fig. 3.5.1 Contribution of Five Commonly Occurring Species of Chironomidae to Production of Chironomidae in Barekese Reservoir

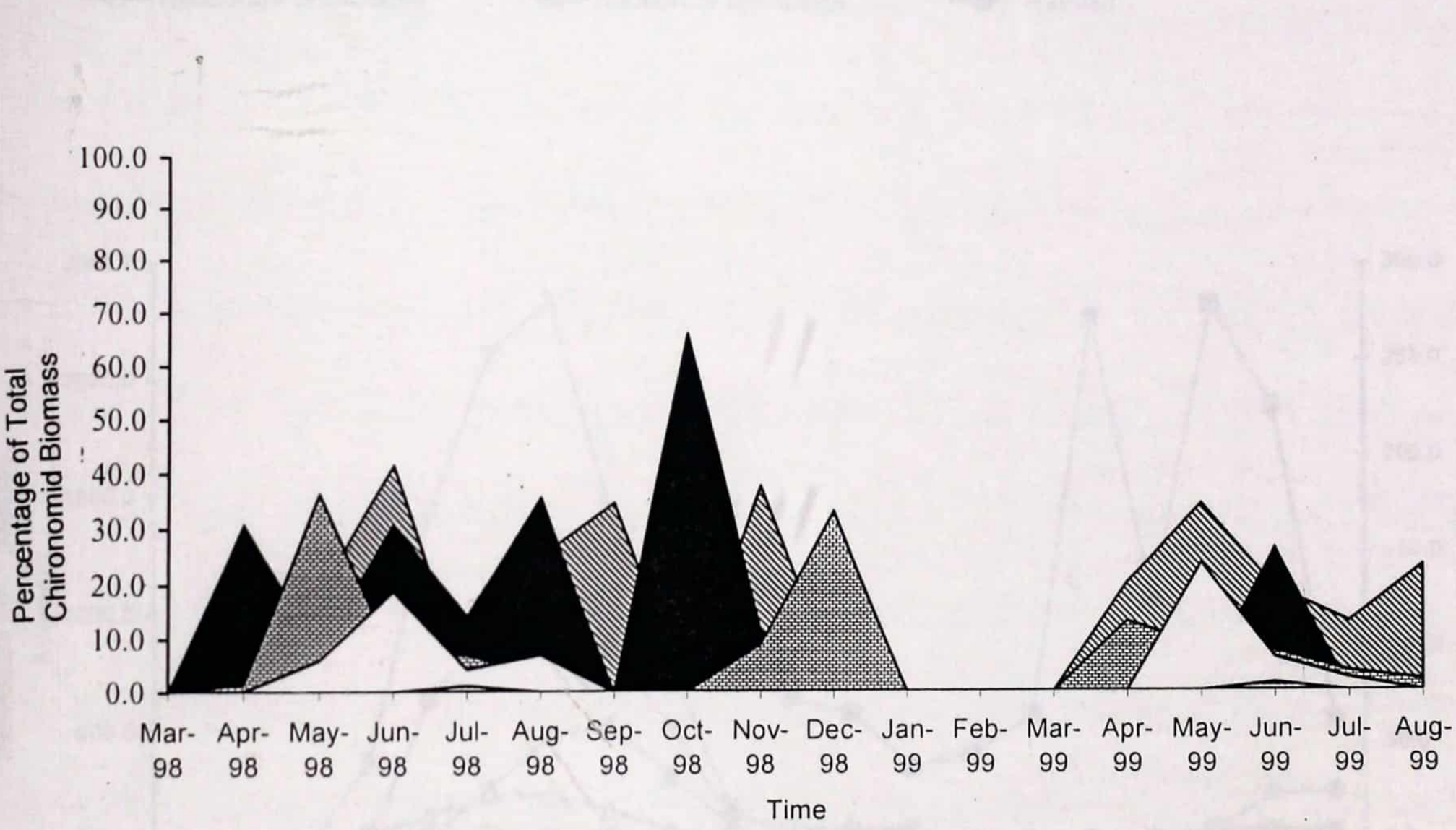

Fig.3.5.2 Contribution of Five Commonly Occurring Species of Chironomidae to Production of Chironomidae in Owabi Reservoir.

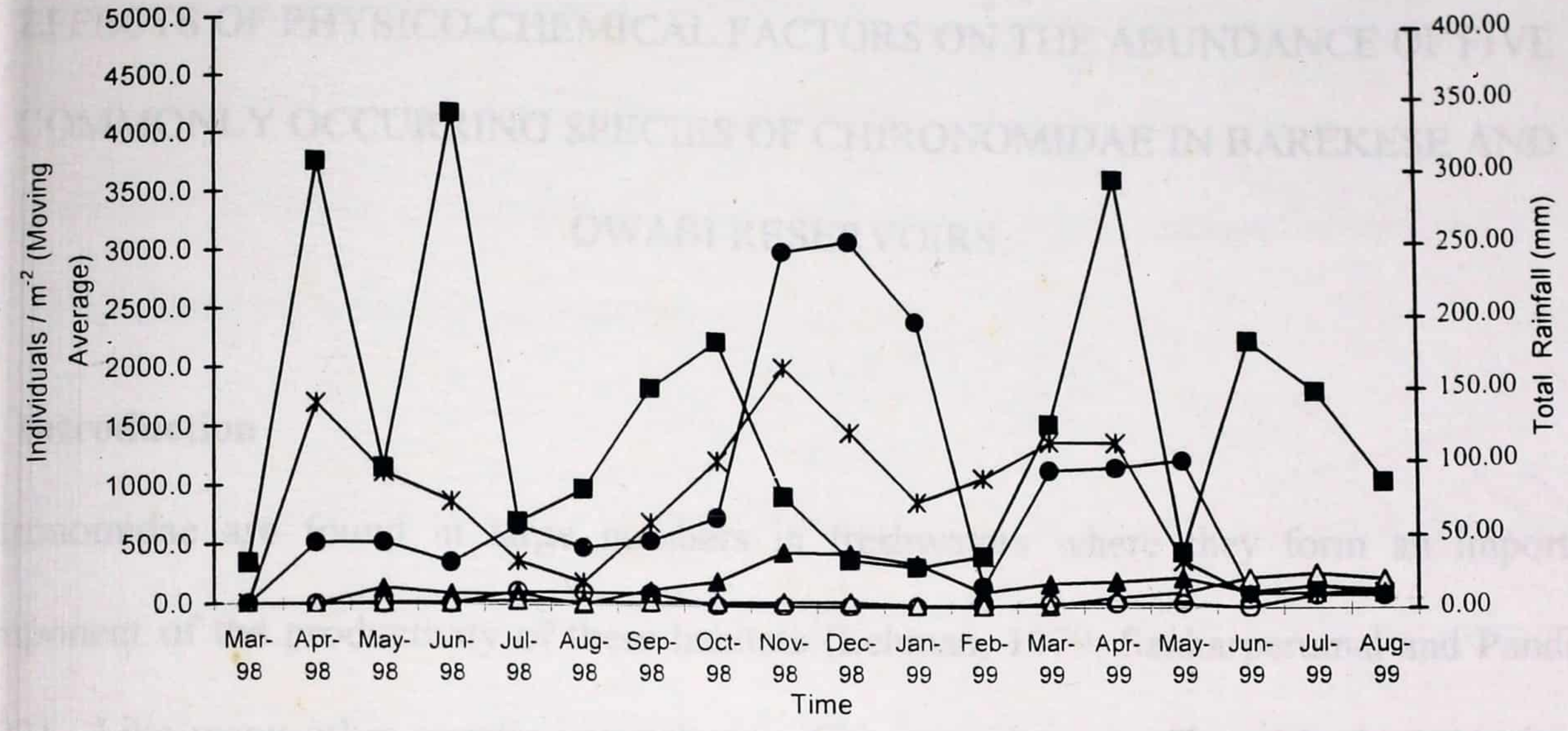

Fig.3.6.1 Variations in Abundance of Five Commonly Occurring Species of Chironomidae Caught by Floating Emergence Traps Deployed on Barekese Reservoir.

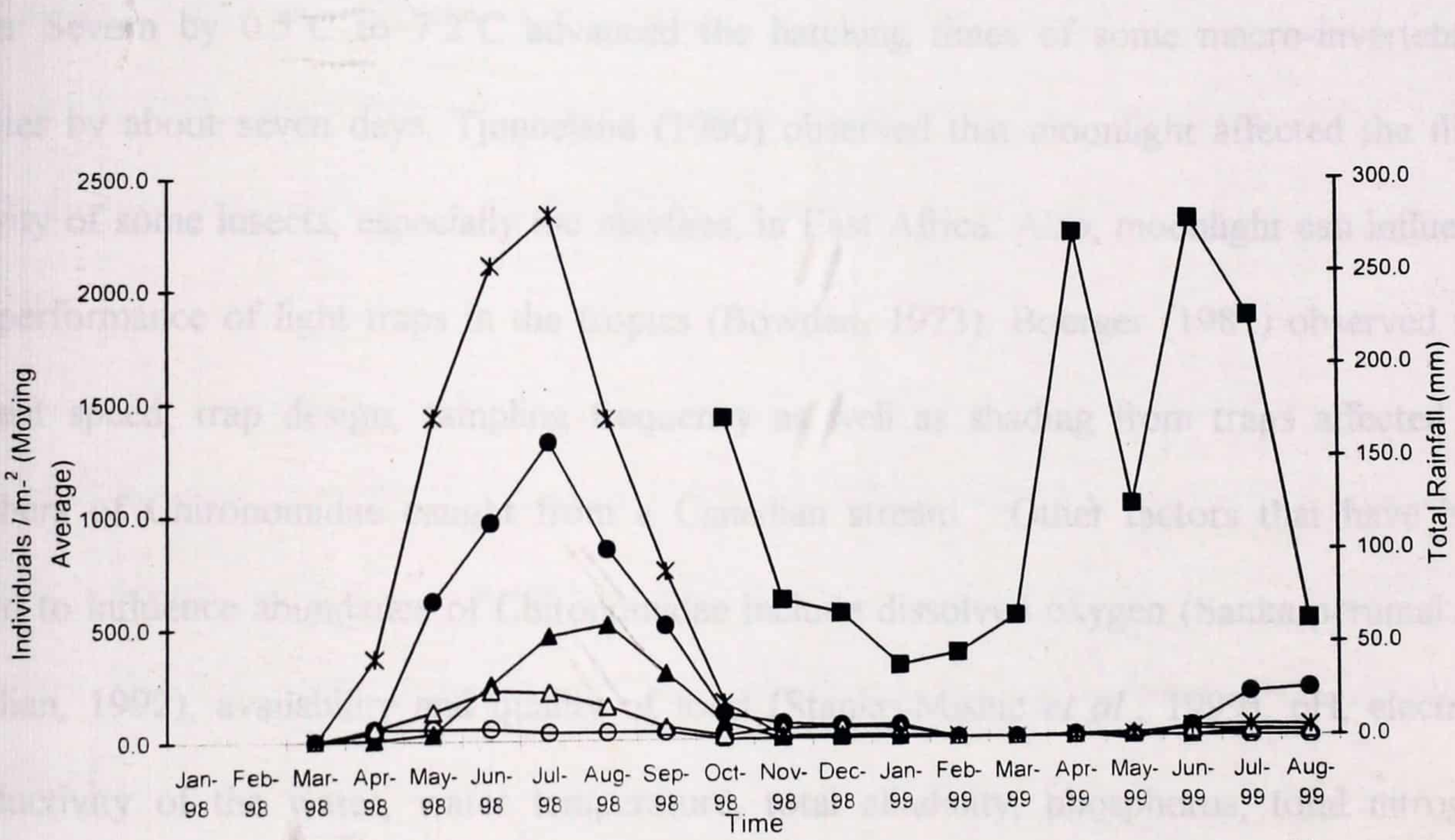

Fig. 3.6.2 Variations in Abundance of Five Commonly Occurring Species of Chronomidae Caught by Floating Emergence Traps Deployed on Owabi Reservoir

CHAPTER FOUR

EFFECTS OF PHYSICO-CHEMICAL FACTORS ON THE ABUNDANCE OF FIVE COMMONLY OCCURRING SPECIES OF CHIRONOMIDAE IN BAREKESE AND OWABI RESERVOIRS.

4.1 Introduction

Chironomidae are found in large numbers in freshwaters where they form an important component of the productivity of these habitats (Lehman, 1979; Sankarperumal and Pandian, 1992). Like many other aquatic invertebrates, Chironomidae are affected by both biotic and abiotic factors that prevail in the environment (Mackay, 1969; Clifford, 1978; Armitage *et al.*, 1987; Aldridge *et al.*, 1998). Langford (1971) observed that increased temperature of the River Severn by 0.5°C to 7.2°C advanced the hatching times of some macro-invertebrate species by about seven days. Tjønneland (1960) observed that moonlight affected the flight activity of some insects, especially the mayflies, in East Africa. Also, moonlight can influence the performance of light traps in the tropics (Bowden, 1973). Boerger (1981) observed that current speed, trap design, sampling frequency as well as shading from traps affected the numbers of Chironomidae caught from a Canadian stream. Other factors that have been found to influence abundance of Chironomidae include dissolved oxygen (Sankarperumal and Pandian, 1992), availability and quality of food (Stanko-Mishic *et al.*, 1999), pH, electrical conductivity of the water, water temperature, total alkalinity, phosphorus, total nitrogen, nitrite and nitrate contents of the water (Janeck, 1995; Chessman, 1999). McLachlan (1969a) and McLachlan and McLachlan (1971) observed that *Nilodorum brevibucca* preferred fine particles infused with organic matter to coarse sand in Lake Kariba. In temperate regions, variations in temperature and photoperiod have been recognised as the major factors influencing the seasonal appearance of Chironomidae (Danks and Oliver, 1972; LeSage and

Harrison, 1980; Singh and Harrison, 1984). Lehman (1979) found that emergence of Chironomidae in the Democratic Republic of Congo was seasonal. He also observed that the rainfall pattern and the hydrological cycle of the rivers studied affected the seasonal abundance of Chironomidae. However, he could not attribute seasonal abundance of the Chironomidae to the influence of photoperiod.

Chironomidae from the same habitat react differently to the same environmental variables. Multivariate statistical methods have been developed that relate the presence and abundance of Chironomidae and other macro-invertebrates to the environmental variables as well as the quality of the water (Norris and Georges, 1993; Johnson, 1995). They include specialised multivariate methods such as RIPVACS (Moss *et al.*, 1987; Armitage *et al.*, 1987), Discriminant Function Analysis – DFA (Wright *et al.*, 1989) and TWINSPAN (Hill, 1979). Also, multiple regression analysis is used in development of models that can predict the state of chironomid communities in a habitat with two or more environmental variables (Norris and Georges, 1993).

Ponce-Palafax and Arredondo-Figueroa (1995) concluded from a study in Mexico that alkalinity, nitrite, ammonia and phosphate content of waters of ponds in Mexico were important variables that could be used in multiple regressions to predict phytoplankton productivity. Sankarperumal and Pandian (1992) used multiple regression techniques to predict the abundance of larvae of *Chironomus circumdatus* in some sewage ponds and canals in India. Downing (1986) used similar methods to predict invertebrate populations in some lakes in Canada. Dinsmore *et al.*, (1999) also applied multiple regression methods to predict the biomass of macro-invertebrates in twenty-six lakes in Alberta, Canada by using a set of trophic, water chemistry and morphometric variables. In spite of its frequent use elsewhere,

multiple regression analysis has not been used frequently in models to predict abundance of macro-invertebrate communities of freshwater habitats in Africa.

In this study, prevailing physico-chemical factors were related to communities of five chironomid species namely *Nilodorum fractilobus, Kiefferulus chloronotus, Dicrotendipes schoutedeni, Nilodorum brevibucca* and *Nilodorum brevipalpe* in Barekese and Owabi reservoirs. The species were common to both reservoirs. The five chironomid species were also the more abundant species caught by emergence traps deployed on the two reservoirs. Multiple linear regression analysis was used to set up models that predicted the abundance of the five Chironomidae in Barekese and Owabi reservoirs from environmental variables.

4.1.1 Study Area

A brief description of the study areas has been provided in chapter two of this thesis.

4.2 Materials and Methods

4.2.1 Field Sampling

A description of the method for sampling of adult Chironomidae, used in this study, has been provided in chapter three (Paragraph 3.2.1) of this thesis.

Various physico-chemical parameters including pH, reservoir water level, transparency of the water, water temperature, dissolved oxygen content and conductivity of the water were measured *in situ* at the time of emptying the emergence traps. Water samples collected from the centre of the reservoirs were analysed for other chemical parameters in the laboratory. In all twenty-eight physico-chemical parameters were monitored over an eighteen-month period (See Tables 4.1 and 4.2, also Appendices C and D).

4.2.2 Statistical Analysis

The abundance of five commonly occurring species namely *Nilodorum fractilobus, Nilodorum brevibucca, Nilodorum brevipalpe, Kiefferulus chloronotus* and *Dicrotendipes schoutedeni* were related to prevailing physico-chemical parameters through multivariate statistical analysis. Data obtained from the field were subjected to double square root ($\sqrt{\sqrt{x}}$) transformations (Tables 4.1 and 4.2), fed into a statistical programme, Microstat version 2.0 (Ecosoft, 1981) and subjected to multiple regression analysis based on the least square method. Clarke and Warwick (1994) recommended that a double square root transformation of data is a suitable transformation method to apply to data when rare species occur in samples or scarce species occur alongside those with large numbers. Such transformations stabilise the variance and ensure compliance with theoretical assumptions associated with multiple linear regression (Prien, Undated; Zar, 1984; Chessman, 1999).

The exploratory data analysis method (EDA) was followed (Pauly and Hopkins, 1983; Zar, 1984; Van Dam, 1990). The decision as to which factors were included in a model was based on the outcome of correlation established between the chironomids and the physico-chemical parameters. Multiple regression analysis incorporated all independent variables that had significant correlation with specific Chironomidae ($p \leq 0.05$). Independent variables that showed a partial regression coefficient (b) that was different from zero (t-test) were discarded until majority of predictors with significant partial regression coefficient remained ($p \leq 0.05$) or when only a single predictor remained in the model. A model was deemed adequate if overall ANOVA of the relationship yielded $p \leq 0.05$.

The Durbin-Watson statistic (***d***) was calculated on the residuals of the ANOVA to determine if serial auto-correlation existed amongst the factors admitted into the significant model.

Durbin and Watson (1951) provide a table that was used for setting the significant points. In order to estimate the relative importance of the physico-chemical factors (predictors) that affected the abundance of the species standardised partial regression coefficients, ***b* (*beta weights or primers***) were estimated for models as follows:

$$beta = b\,(S.D._x/S.D._y)$$

Where:

b = coefficient of regression (associated with the predictor).

$S.D._x$ = Standard deviation of the predictor (physico-chemical variable).

$S.D._y$ = Standard deviation of the dependent variable (species of Chironomidae) (Blalock, 1972; Yamane, 1973 cited by Van Dam, 1990).

Table 4.1

a. Barekese Variables for Multiple Regression Analysis

Time	N.fr	K.c	D.s	N. brv.	N. brp.	R.Level	Temp.	pH	Acidity	Alkalinity	Ca	Mg	Hdness	Cl	DO	BOD	ChlA	Secchi	NH3	NO2	NO3	SO4	PO4	SiO2	SS	Turbid.	Conduct.	TDS
Mar-98	1.00	1.00	1.00	1.00	1.00	11.2	31	6.65	10	50	10	3.65	25	17.5	8	4.68	25	70	0.21	0.07	0.02	8.79	0.01	9.06	10.9	12	136.8	42
Apr-98	63.75	1.00	1.00	1.00	208.50	11.3	29.55	6.7	10	61	9.6	4.76	29.2	19	6.8	4.2	18	70	0.61	0.02	0.36	3.13	0.04	9.81	12.5	14.22	105	42
May-98	49.75	22.00	28.50	4.50	4.50	11.9	28.4	7.31	11.25	57.5	7	3.77	22.5	16.9	6.9	4.15	12.26	70	0.16	0.11	0.82	3.47	0.06	2.67	6	6.58	93.63	195
Jun-98	2.00	1.00	1.75	1.00	25.25	13.02	27.08	7.08	11.67	50	7.33	4.37	25.33	17.5	6.61	2.88	15.55	70	0.35	0.03	0.48	9.14	0.04	10.57	7.33	4.4	106.7	186.5
Jul-98	178.50	3.25	9.00	39.00	5.50	13.02	26.1	6.95	12	61	9.2	5.64	32.4	16	6.56	3.04	16.42	67.2	0.75	0.1	0.46	34.28	0.08	12.29	4.5	2.76	110.6	42
Aug-98	1.00	1.00	1.00	1.00	1.00	13.01	26.6	7.11	12.5	62.5	9	4.5	27.5	15.6	6.3	3.3	18.08	66	0.53	0.04	0.58	18.73	0.05	11.21	4.32	2.65	118.3	42
Sep-98	24.50	46.75	3.00	1.00	236.25	13.09	27.33	7.22	11.25	53.25	6.95	5.56	29.85	14.8	5.95	2.95	25.82	77.2	0.27	0.02	0.27	17.99	0.14	10.13	5.63	3.38	107.5	42
Oct-98	189.75	24.25	8.25	1.00	163.25	13.14	28.33	8.37	10	50.83	7.1	4.39	28.15	10	6.2	3.4	20.56	79.5	0.09	0.04	0.16	11.13	0.08	12.5	4.05	2.43	92.7	42
Nov-98	628.50	69.75	2.75	28.50	194.50	13.01	27.2	7.48	13.75	54.45	8.73	3.91	24.83	10.6	6.5	2.3	20.3	65	0.14	0.05	0.25	10.4	0.08	12.63	4.97	2.98	98.96	44
Dec-98	58.75	43.00	3.75	1.25	33.25	12.78	27.1	6.9	11.25	50.85	7.4	4.08	24.05	10.7	6.55	3.15	24.8	86	0.09	0.05	0.21	9.97	0.06	9.96	4.64	2.78	79.86	45
Jan-99	1.00	1.00	1.00	1.00	1.00	12.52	26.2	7.09	10	58	4.4	6.46	31	7.5	6.7	4.3	23.22	79	0.19	0.01	0.25	7.9	0.06	6.28	4.67	2.8	119.3	42
Feb-99	5.25	3.25	1.75	1.00	279.00	12.12	28.3	6.75	12.5	55.45	5.9	4.17	23.08	8.2	6.78	3.45	16.22	67.25	0.09	0.01	0.18	8.29	0.08	9.34	4.75	2.85	135.3	48.67
Mar-99	149.25	26.50	2.00	5.50	61.75	11.84	28.1	7.02	11.5	40.02	5.7	4.06	22.4	10.7	6.48	4.08	18.75	81	0.19	0.01	0.58	4	0.11	7.4	9.31	3.06	135.3	48.4
Apr-99	5.25	4.25	14.25	1.00	1.00	11.97	28.6	8.9	11.63	48.67	5.6	4.53	24.33	11.9	6.4	4.2	23.14	76.75	0.35	0.01	0.31	5.31	0.15	7.57	9.21	3.03	136.5	47.25
May-99	30.25	15.50	17.50	1.75	1.00	12.72	28.28	7.17	11.75	47.7	10.35	4.24	27.8	8.3	5.55	4.13	21.58	73.75	0.2	0.01	0.3	4.85	0.01	5.91	9.57	3.15	130.4	44.5
Jun-99	11.00	20.50	39.25	1.00	32.75	12.97	26.43	7.3	12.4	43.38	9.24	4.89	29.36	8.66	5.98	4	18.82	76.8	0.18	0.01	0.11	4.3	0.01	10.99	11.8	3.88	119.1	44.4
Jul-99	27.50	28.75	40.75	1.00	5.75	13.2	26.55	7.02	10.67	37.6	7.73	5.53	30.47	10.6	6.23	4.33	18	80	0.35	0.01	0.59	3.9	0.36	14.93	9	7.07	115	46
Aug-99	7.50	1.00	8.25	2.00	1.00	13	27.91	8.9	15	34.57	10.93	4.34	28.8	11	6.3	5.17	18	91	0.63	0.01	0.1	14.24	0.02	14.04	7.68	5.03	123	42

b. Barekese Double Square Root Transformed Variables for Multiple Regression Analysis

Time	N.fr	K.c	D.s	N. brv.	N. brp.	R.Level	Temp.	pH	Acidity	Alkalinity	Ca	Mg	Hdness	Cl	DO	BOD	ChlA	Secchi	NH3	NO2	NO3	SO4	PO4	SiO2	SS	Turbid.	Conduct.	TDS
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.8294	2.3596	1.6059	1.7783	2.6591	1.7783	1.3822	2.2361	2.0453	1.6818	1.4708	2.2361	2.8925	0.6769	0.5144	0.3761	1.7219	0.3162	1.7349	1.8170	1.8612	3.2875	2.5457
2	2.8257	1.0000	1.0000	1.0000	3.7999	1.8335	2.3315	1.6089	1.7783	2.7947	1.7602	1.4771	2.3246	2.0878	1.6148	1.4316	2.0598	2.8925	0.8838	0.3761	0.7746	1.3301	0.4472	1.7698	1.8803	1.9419	3.2011	2.5457
3	2.6558	2.1657	2.3105	1.4565	1.4565	1.8573	2.3085	1.6443	1.8314	2.7537	1.6266	1.3934	2.1779	2.0276	1.6207	1.4273	1.8712	2.8925	0.6325	0.5759	0.9516	1.3648	0.4949	1.2783	1.5651	1.6016	3.1593	3.7369
4	1.1892	1.0000	1.1502	1.0000	2.2416	1.8996	2.2812	1.6312	1.8483	2.6591	1.6454	1.4458	2.2434	2.0453	1.6034	1.3027	1.9858	2.8925	0.7692	0.4162	0.8324	1.7387	0.4472	1.8031	1.6454	1.4483	3.2140	3.6955
5	3.6552	1.3427	1.7321	2.4990	1.5314	1.8996	2.2603	1.6237	1.8612	2.7947	1.7416	1.5411	2.3858	2.0000	1.6004	1.3204	2.0130	2.8631	0.9306	0.5623	0.8235	2.4197	0.5318	1.8724	1.4565	1.2889	3.2429	2.5457
6	1.0000	1.0000	1.0000	1.0000	1.0000	1.8992	2.2710	1.6329	1.8803	2.8117	1.7321	1.4565	2.2900	1.9874	1.5843	1.3478	2.0621	2.8503	0.8532	0.4472	0.8727	2.0803	0.4729	1.8298	1.4417	1.2759	3.2839	2.5457
7	2.2248	2.6148	1.3161	1.0000	3.9205	1.9021	2.2864	1.6392	1.8314	2.7013	1.6237	1.5356	2.3374	1.9614	1.5618	1.3106	2.2542	2.9642	0.7208	0.3761	0.7208	2.0595	0.6117	1.7840	1.5404	1.3559	3.2200	2.5457
8	3.7115	2.2191	1.6948	1.0000	3.5745	1.9039	2.3071	1.7009	1.7783	2.6701	1.6324	1.4475	2.3034	1.7783	1.5780	1.3579	2.1294	2.9860	0.5477	0.4472	0.6325	1.8265	0.5318	1.8803	1.4186	1.2485	3.1029	2.5457
9	5.0070	2.8899	1.2878	2.3105	3.7345	1.8992	2.2837	1.6538	1.9256	2.7164	1.7189	1.4062	2.2323	1.8044	1.5967	1.2315	2.1226	2.8394	0.6117	0.4729	0.7071	1.7958	0.5318	1.8852	1.4931	1.3139	3.1542	2.5755
10	2.7685	2.5607	1.3916	1.0574	2.4013	1.8907	2.2816	1.6207	1.8314	2.6704	1.6493	1.4212	2.2145	1.8086	1.5998	1.3322	2.2316	3.0453	0.5477	0.4729	0.6769	1.7769	0.4949	1.7765	1.4677	1.2913	2.9896	2.5900
11	1.0000	1.0000	1.0000	1.0000	1.0000	1.8811	2.2624	1.6318	1.7783	2.7597	1.4483	1.5943	2.3596	1.6549	1.6089	1.4400	2.1952	2.9813	0.6602	0.3162	0.7071	1.6765	0.4949	1.5830	1.4700	1.2936	3.3063	2.5457
12	1.5137	1.3427	1.1502	1.0000	4.0870	1.8658	2.3065	1.6119	1.8803	2.7288	1.5585	1.4290	2.1918	1.6922	1.6136	1.3629	2.0068	2.8637	0.5477	0.3162	0.6514	1.6968	0.5318	1.7482	1.4763	1.2993	3.4106	2.6413
13	3.4953	2.2689	1.1892	1.5314	2.8032	1.8550	2.3024	1.6277	1.8415	2.5152	1.5451	1.4195	2.1755	1.8086	1.5955	1.4212	2.0809	3.0000	0.6602	0.3162	0.8727	1.4142	0.5759	1.6493	1.7468	1.3226	3.4106	2.6376
14	1.5137	1.4358	1.9429	1.0000	1.0000	1.8600	2.3126	1.7272	1.8467	2.6413	1.5383	1.4589	2.2209	1.8573	1.5905	1.4316	2.1933	2.9598	0.7692	0.3162	0.7462	1.5180	0.6223	1.6587	1.7421	1.3194	3.4181	2.6218
15	2.3452	1.9842	2.0453	1.1502	1.0000	1.8885	2.3061	1.6364	1.8514	2.6280	1.7936	1.4350	2.2962	1.6973	1.5349	1.4256	2.1553	2.9305	0.6687	0.3162	0.7401	1.4840	0.3162	1.5592	1.7588	1.3322	3.3792	2.5828
16	1.8212	2.1278	2.5030	1.0000	2.3922	1.8977	2.2674	1.6437	1.8765	2.5664	1.7435	1.4871	2.3278	1.7155	1.5638	1.4142	2.0828	2.9603	0.6514	0.3162	0.5759	1.4400	0.3162	1.8207	1.8534	1.4035	3.3035	2.5813
17	2.2900	2.3156	2.5266	1.0000	1.5485	1.9061	2.2699	1.6277	1.8073	2.4763	1.6674	1.5335	2.3495	1.8044	1.5799	1.4425	2.0598	2.9907	0.7692	0.3162	0.8764	1.4053	0.7746	1.9657	1.7321	1.6306	3.2747	2.6043
18	1.6549	1.0000	1.6948	1.1892	1.0000	1.8988	2.2985	1.7272	1.9680	2.4248	1.8183	1.4434	2.3166	1.8212	1.5843	1.5079	2.0598	3.0886	0.8909	0.3162	0.5623	1.9426	0.3761	1.9357	1.6647	1.4976	3.3302	2.5457

Table 4.2

a: Owabi Variables for Multiple Regression Analysis

Time	N.fr	K.c	D.s	N. brv.	N. brp.	R.Level	Temp.	pH	Acidity	Alkalinity	Ca	Mg	Hdness	Cl	DO	BOD	ChlA	Secchi	NH3	NO2	NO3	SO4	PO4	SiO2	SS	Turbid.	Conduct.	TDS
Mar-98	1.00	1.00	1.00	1.00	1.00	6.00	30.20	6.62	10.00	120.00	24.00	5.75	60.00	32.50	8.80	5.80	15.34	57.00	0.08	0.03	0.12	8.46	0.04	2.34	8.00	2.50	259.00	218.00
Apr-98	7.75	2.25	16.25	15.50	101.50	6.29	30.56	7.30	11.00	116.00	22.40	10.59	66.00	34.60	6.72	5.76	15.34	57.00	0.60	0.08	0.30	3.07	0.05	16.67	22.00	5.30	2.43	220.00
May-98	90.4	10.50	5.00	1.00	197.50	6.69	29.75	7.53	11.25	105.00	19	9.36	57.5	29.4	7.2	3.95	17.07	57	0.18	0.1	0.56	5.8	0.03	6.58	7.5	7.9	226	165
Jun-98	97	61.00	26.25	1.00	188.00	5.54	28.37	7.35	11.67	96.67	20	10.53	63.33	18.3	7.73	2.53	15.23	57	0.46	0.016	0.36	16.22	0.03	6.68	12.7	3.23	265.7	156
Jul-98	116.8	81.75	18.00	13.75	218.50	6.66	27.06	7.12	13.00	102.00	21.6	9.82	62	28.9	6.4	2.67	17.67	77.8	0.93	0.02	0.46	17.39	0.08	12.79	5.3	5.58	206.3	77.3
Aug-98	40	29.00	5.50	1.00	58.25	6.70	26.43	7.25	13.33	106.70	22	9.56	61.33	28.5	6.93	3.6	22.1	115	0.54	0.04	0.61	23.25	0.12	8.92	3.86	4.07	212.4	77.3
Sep-98	2.5	1.00	1.00	1.00	1.00	6.71	27.1	6.97	11.67	102.70	17.67	11.18	63.77	33.6	7.36	3.6	21.91	114.7	0.16	0.01	0.2	19.81	0.05	11.21	22	5.3	207.3	77.3
Oct-98	1.25	1.00	1.75	1.00	2.00	6.65	27.8	7.73	13.00	96.48	15.86	9.78	56.12	19.5	6.72	3.72	25.5	95.7	0.11	0.034	0.22	18.92	0.07	13.36	4.06	1.44	199	77.3
Nov-98	17	1.00	12.25	1.00	3.25	6.69	28.28	7.24	11.25	96.45	16.4	9.34	54.85	22.1	6.8	3	19.87	113.8	0.1	0.05	0.23	16.88	0.09	16.65	12	3.23	151.4	86.25
Dec-98	1.25	1.00	2.50	1.00	2.00	6.66	26.98	7.17	11.25	95.55	15	9.48	54	23.2	6.53	3.7	25.52	88	0.09	0.032	0.24	13.42	0.08	14.3	4.61	4.33	195.9	77.3
Jan-99	1	1.00	1.00	1.00	1.00	6.44	26.65	7.11	12.50	86.00	12.45	11.19	58.5	20.3	6	3.95	22.6	117.5	0.06	0.01	0.23	9.7	0.06	9.81	11	3.5	191.3	124.5
Feb-99	1	1.00	1.00	1.00	1.00	6.58	27.03	7.3	12.25	91.90	11.95	9.54	51.2	19.3	6.58	3.83	15.43	121.3	0.14	0.01	0.17	11.3	0.11	10.84	12	4.03	241.9	124.5
Mar-99	1	1.00	1.00	1.00	1.00	6.52	28.73	7.3	11.25	91.83	11.8	9.18	49.55	20.5	6.4	3.45	20.5	131.8	0.23	0.01	0.41	14.51	0.14	11.01	11.8	3.85	241.2	91.5
Apr-99	3.5	1.00	4.25	1.00	1.00	6.64	28.06	7.23	13.75	88.75	14.6	9.62	52.1	23.3	6.9	4.3	23.87	102.2	0.55	0.01	0.33	13.3	0.12	12.66	20	8	236.6	94.8
May-99	3.25	1.25	3.50	2.25	1.00	6.69	31.05	7.25	11.75	50.20	15.45	7.41	45.95	12.8	6.7	4.85	22.88	87.5	0.46	0.01	0.18	11.79	0.01	8.48	11.5	4.18	218.7	83
Jun-99	11.75	1.50	4.75	1.00	2.75	6.61	27.4	7.6	11.75	79.58	18.85	16.48	52.1	10.2	6.35	4.85	16.9	68	0.29	0.01	0.15	5	0.01	12.17	4.9	6.18	196.8	77.25
Jul-99	59.5	8.25	5.25	1.00	5.50	6.66	26.2	7.01	14.00	61.60	14.24	9.22	52.2	18.3	6.22	4.34	15.34	57	0.73	0.01	0.26	18.11	0.02	14.28	16.5	20.7	186.6	99.7
Aug-99	5.25	1.00	1.25	1.00	1.00	6.70	25.67	7.20	15.00	52.00	11.75	9.38	50.37	13.2	7.03	5.5	15.34	116.7	0.23	0.01	0.1	19.57	0.01	10.06	6.07	5.7	235	77.3

b: Owabi Double Square Root Transformed Variables for Multiple Regression Analysis

Time	N.fr	K.c	D.s	N. brv.	N. brp.	R.Level	Temp.	pH	Acidity	Alkalinity	Ca	Mg	Hdness	Cl	DO	BOD	ChlA	Secchi	NH3	NO2	NO3	SO4	PO4	SiO2	SS	Turbid.	Conduct.	TDS
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.5651	2.3442	1.6040	1.7783	3.3098	2.2134	1.7199	2.7832	2.3877	1.7223	1.5519	1.9790	2.7477	0.5367	0.4162	0.5886	1.7065	0.4472	1.2368	1.6818	1.2574	4.0117	3.8425
2	1.6685	1.2247	2.0078	1.9842	3.1741	1.5837	2.3512	1.6437	1.8212	3.2818	2.1755	1.8039	2.8503	2.4253	1.6101	1.5492	1.9790	2.7477	0.8801	0.5335	0.7401	1.3237	0.4729	2.0206	2.1657	1.5173	1.2485	3.8513
3	3.0835	1.8001	1.4953	1.0000	3.7488	1.6083	2.3355	1.6565	1.8314	3.2011	2.0878	1.7491	2.7537	2.3286	1.6381	1.4098	2.0326	2.7477	0.6514	0.5623	0.8651	1.5519	0.4162	1.6016	1.6549	1.6765	3.8773	3.5840
4	3.1383	2.7947	2.2635	1.0000	3.7029	1.5342	2.3079	1.6465	1.8483	3.1356	2.1147	1.8014	2.8210	2.0683	1.6674	1.2612	1.9755	2.7477	0.8235	0.3557	0.7746	2.0068	0.4162	1.6077	1.8878	1.3406	4.0374	3.5341
5	3.2875	3.0069	2.0598	1.9256	3.8447	1.6065	2.2808	1.6335	1.8988	3.1780	2.1558	1.7702	2.8061	2.3186	1.5905	1.2783	2.0503	2.9699	0.9820	0.3761	0.8235	2.0421	0.5318	1.8911	1.5173	1.5369	3.7899	2.9651
6	2.5149	2.3206	1.5314	1.0000	2.7626	1.6089	2.2674	1.6409	1.9108	3.2140	2.1657	1.7584	2.7985	2.3105	1.6225	1.3774	2.1682	3.2747	0.8572	0.4472	0.8838	2.1959	0.5886	1.7282	1.4017	1.4204	3.8176	2.9651
7	1.2574	1.0000	1.0000	1.0000	1.0000	1.6095	2.2816	1.6248	1.8483	3.1834	2.0503	1.8286	2.8259	2.4076	1.6471	1.3774	2.1635	3.2726	0.6325	0.3162	0.6687	2.1097	0.4729	1.8298	2.1657	1.5173	3.7945	2.9651
8	1.0574	1.0000	1.1502	1.0000	1.1892	1.6059	2.2962	1.6674	1.8988	3.1341	1.9956	1.7684	2.7370	2.1014	1.6101	1.3888	2.2472	3.1277	0.5759	0.4294	0.6849	2.0856	0.5144	1.9118	1.4195	1.0954	3.7559	2.9651
9	2.0305	1.0000	1.8708	1.0000	1.3427	1.6083	2.3061	1.6403	1.8314	3.1338	2.0124	1.7482	2.7214	2.1682	1.6148	1.3161	2.1113	3.2661	0.5623	0.4729	0.6925	2.0270	0.5477	2.0200	1.8612	1.3406	3.5078	3.0475
10	1.0574	1.0000	1.2574	1.0000	1.1892	1.6065	2.2791	1.6364	1.8314	3.1265	1.9680	1.7547	2.7108	2.1947	1.5986	1.3869	2.2476	3.0628	0.5477	0.4229	0.6999	1.9140	0.5318	1.9446	1.4653	1.4425	3.7412	2.9651
11	1.0000	1.0000	1.0000	1.0000	1.0000	1.5930	2.2721	1.6329	1.8803	3.0453	1.8784	1.8290	2.7656	2.1226	1.5651	1.4098	2.1804	3.2924	0.4949	0.3162	0.6925	1.7648	0.4949	1.7698	1.8212	1.3678	3.7190	3.3404
12	1.0000	1.0000	1.0000	1.0000	1.0000	1.6016	2.2801	1.6437	1.8708	3.0962	1.8593	1.7575	2.6750	2.0960	1.6016	1.3989	1.9819	3.3187	0.6117	0.3162	0.6421	1.8335	0.5759	1.8145	1.8612	1.4169	3.9437	3.3404
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.5979	2.3152	1.6437	1.8314	3.0956	1.8534	1.7406	2.6531	2.1278	1.5905	1.3629	2.1278	3.3883	0.6925	0.3162	0.8002	1.9517	0.6117	1.8216	1.8534	1.4008	3.9409	3.0928
14	1.3678	1.0000	1.4358	1.0000	1.0000	1.6052	2.3016	1.6398	1.9256	3.0693	1.9547	1.7611	2.6866	2.1970	1.6207	1.4400	2.2104	3.1795	0.8612	0.3162	0.7579	1.9097	0.5886	1.8863	2.1147	1.6818	3.9220	3.1203
15	1.3427	1.0574	1.3678	1.2247	1.0000	1.6083	2.3606	1.6409	1.8514	2.6618	1.9826	1.6499	2.6036	1.8915	1.6089	1.4840	2.1871	3.0585	0.8235	0.3162	0.6514	1.8530	0.3162	1.7065	1.8415	1.4299	3.8456	3.0183
16	1.8514	1.1067	1.4763	1.0000	1.2878	1.6034	2.2879	1.6604	1.8514	2.9868	2.0837	2.0148	2.6866	1.7871	1.5874	1.4840	2.0276	2.8716	0.7338	0.3162	0.6223	1.4953	0.3162	1.8678	1.4878	1.5767	3.7455	2.9647
17	2.7773	1.6948	1.5137	1.0000	1.5314	1.6065	2.2624	1.6272	1.9343	2.8015	1.9426	1.7425	2.6879	2.0683	1.5792	1.4434	1.9790	2.7477	0.9243	0.3162	0.7141	2.0629	0.3761	1.9439	2.0154	2.1330	3.6960	3.1599
18	1.5137	1.0000	1.0574	1.0000	1.0000	1.6089	2.2509	1.6381	1.9680	2.6853	1.8514	1.7501	2.6641	1.9061	1.6283	1.5314	1.9790	3.2868	0.6925	0.3162	0.5623	2.1033	0.3162	1.7809	1.5696	1.5451	3.9153	2.9651

4.3 Results and Discussion

The correlation matrices for all variables from Barekese and Owabi reservoirs and the computer output of the multiple regression analysis of the variables on the commonly occurring Chironomidae from these reservoirs are given in appendices C, D, E and F.

A summary of the results of the multiple regression analysis performed on the data from Barekese and Owabi reservoirs is presented in Table 4.3.1 and Table 4.3.2 respectively.

Four models uniquely predicted the abundance of the chironomid species found in Barekese Reservoir. They are:

a. N.f. = 13.5903 – 8.1639*BOD Model 1

b. K.c. = 17.0061 – 8.7305*DO – 3.171NH_3-N + 1.8463*PO_4 Model 2

c. D.s. = No significant model at $p<0.05$ or $p<0.1$

d. N.brv. = -6.9937 + 2.7233*NO_2-N + 3.8711*Acidity Model 3

e. N.brp. = 15.3052 – 8.0855*BOD – 2.6608*NH_3-N Model 4

The corresponding models for Owabi Reservoir are:

f. N.f. = -2.2294 – 5.0398*BOD + 2.3409*Turbid. + 3.7969*Ca^{2+} Model 5

g. K.c. = 1.3177 – 4.0759*BOD + 1.3177*NH_3-N + 2.0980*Ca^{2+} Model 6

h. D.s. = -5.7176 + 1.6058*NH_3-N + 2.1880*TH Model 7

i. N.brv. = 0.8038 + 0.8733*NH_3-N + 0.3065*Cl^- - 0.2640*Cond. Model 8

j. N.brp. = -23.8551+3.3532*NH_3-N+2.1587*NO_3-N+7.8146*TH+0.0997*Chl A Model 9

N.f. = Nilodorum fractilobus, K.c. = Kiefferulus chloronotus, D.s. = Dicrotendipes schoutedeni, N.brv. = Nilodorum brevibucca, N.brp. = Nilodorum brevipalpe, Cond. = Conductivity, Chl A = Chlorophyll a, TH = Total Hardness

Table 4.3.1: Summary of Multiple Regression Analysis of Various Factors on Abundance of Commonly Occurring Chironomidae in Barekese Reservoir During The Period of Study (March 1998 – August 1999)

Independent Variable	*Nilodorum fractilobus*			*Kiefferulus chloronotus*			*Dicrotendipes schoutedeni*			*Nilodorum brevibucca*			*Nilodorum brevipalpe*		
	Model 1			Model 2						Model 3			Model 4		
	b	S.E.	beta	b	S.E.	beta	b	S.E.	beta	b	S.E.	beta	b	S.E.	beta
BOD	-	3.5364	-0.50										-.8.0855*	3.5589	-0.48
DO	.8.1639*			-8.7305*	3.7864	-0.40									
NH_3-N				-3.1717**	0.9447	-0.57							-2.6608$^{n.s.}$	2.0694	-0.27
NO_2-N							No significant			2.7233*	0.9732	0.12			
PO_4				1.8463$^{n.s.}$	0.9781	0.32	Model at $p<0.05$								
Acidity										3.8711*	1.7313	0.44			
Constant (a)	13.5903			17.0061						-6.9937			15.3052		
R^2	0.2499			0.5964						0.4340			0.3565		
F	5.329			6.897						5.752			4.154		
P	0.0347			0.0044						0.0140			0.0367		
D-W (d)	2.3825			2.2074						2.9477			2.2147		
Test for auto-correlation	N.A			No +ve/-ve serial auto-correlation						Inconclusive			Inconclusive		

NB.: N.A=Not Applicable *=$p<0.05$ **=$p<0.01$ ***=$p<0.001$ D-W (d)=Durbin-Watson statistic n.s.=Not significant at $p<0.05$

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Table 4.3.2: Summary of Multiple Regression Analysis of Various Factors on Abundance of Commonly Occurring Chironomidae in Owabi Reservoir During The Period of Study (March 1998 – August 1999)

Independent Variable	*Nilodorum fractilobus*			*Kiefferulus chloronotus*			*Dicrotendipes schoutedeni*			*Nilodorum brevibucca*			*Nilodorum brevipalpe*		
	Model 5			Model 6			Model 7			Model 8			Model 9		
	b	S.E.	beta	b	S.E.	beta	b	S.E.	Beta	b	S.E.	beta	b	S.E.	beta
BOD	-5.0398*	1.3260	0.52	-	0.9176	-0.52									
NH_3-N				4.0759****	0.5380	0.30	1.6058**	0.4840	0.59	0.8733*	0.3297	0.42	3.3532**	1.0241	0.45
NO_3-N				1.3177****									2.1587$^{n.s.}$	2.3301	0.18
Conductivity										-	0.0845	-0.53			
T. Hardness										0.2640**			7.8146**	2.3207	0.49
Turbidity	2.3409****	0.5296	0.61				2.1880$^{n.s.}$	1.0441	0.37						
Ca^{2+}	3.7969****	0.9116	0.57		0.6519	0.39									
Cl^-				2.0980**							0.2797	0.18			
Chl A										0.3065$^{n.s.}$			0.0997	0.0347	0.39
Constant (a)	-2.2249			1.3177			-5.7176			0.8038			-23.8551		
R^2	0.7470			0.8056			0.5279			0.6659			0.8297		
F	13.780			19.333			8.386			9.30			15.830		
P	0.00018			0.00003			0.00359			0.0013			0.000006		
D-W (d)	1.7195			1.3915			1.4108			2.7037			1.7920		
Test for auto-correlation	Inconclusive			Inconclusive			Inconclusive			Inconclusive			Inconclusive		

NB. N.A=Not Applicable *=$p<0.05$ **=$p<0.01$ ***=$p<0.001$ D-W (d)=Durbin-Watson statistic n.s.=Not significant at $p<0.05$

Eight multiple linear regression models viz., models 2,3,4,5,6,7,8 and 9 were significant at $p \leq 0.05$. Model 1 was a simple linear regression fit whereas no significant model was found that could predict abundance of *Dicrotendipes schoutedeni* at $p < 0.05$.

For the Chironomidae of Barekese, the single variable BOD (Model 1) explained twenty-five percent of variability in abundance of *Nilodorum fractilobus*. The effect of BOD on *Nilodorum fractilobus* was negative (Fig. 4.2.1); it accounted for fifty percent of the total impact of independent environmental variables on the species. The multiple regression as fitted in Model 2 explained sixty percent of variability in *Kiefferulus chloronotus*. NH_3-N and DO had a negative influence on abundance of *K. chloronotus* whereas PO_4 had a positive influence on the abundance of the species.

Model 3, as fitted, explained forty-three percent of variability in abundance of *Nilodorum brevibucca*. Two independent variables, NO_2-N and acidity regulated the species (Table 4.3.1). In Model 4, BOD and NO_2-N predicted the abundance of *Nilodorum brevipalpe* in Barekese Reservoir. The model as fitted accounted for thirty-six percent of variability in *N. brevipalpe*; BOD and NO_2-N both had a negative impact on *N. brevipalpe*. However, the impact of BOD (48%) was greater than that of NO_2-N (27%).

Abundance of *Nilodorum fractilobus* in Owabi Reservoir was predicted by three independent variables, *viz.*, BOD, Turbidity and Ca^{2+} (Model 5). The model as fitted explained seventy-five percent of the variability observed in *N. fractilobus* (Table 4.3.2). Turbidity of the water and Ca^{2+} influenced the abundance of *N. fractilobus* positively but BOD had a negative influence. The relative importance of the three variables on the abundance of *N. fractilobus* was of the order Turbidity>Ca^{2+}>BOD (Fig. 4.2.2).

Model 6, as fitted, explained eighty-one percent of the variability in abundance of *Kiefferulus chloronotus*; BOD, NH_3-N and Ca^{2+} were the significant factors that affected the abundance of the species. BOD had the greatest influence on the species and accounted for fifty-two percent of the total influence of the physico-chemical parameters that affected the species (Fig. 4.2.2). BOD had a negative influence.

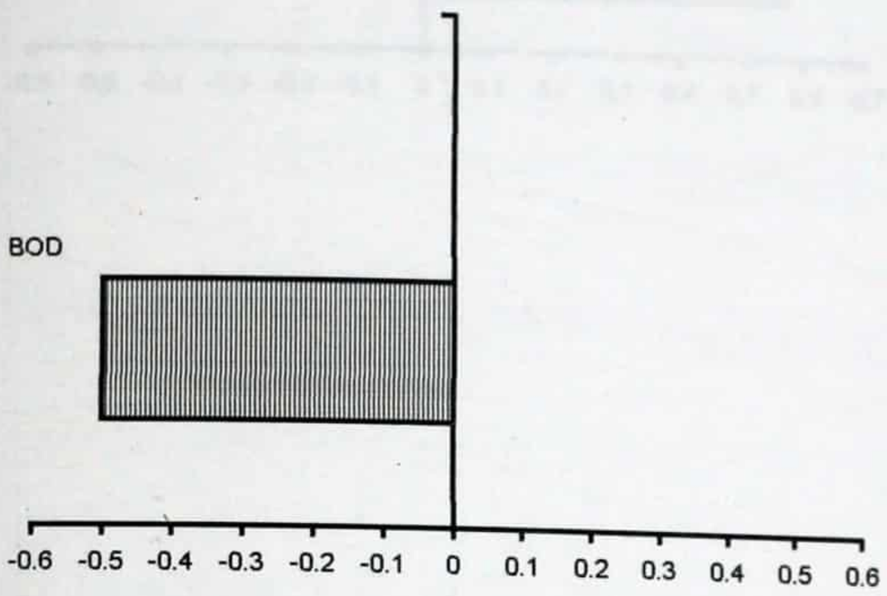
Model 7 explained fifty-three percent of the variability observed in abundance of *Dicrotendipes schoutedeni* (Table 4.3.2). BOD accounted for 52% of the impact of the physico-chemical influences on the species. BOD had a negative influence on the abundance of the species whereas the effect of Total Hardness (TH) was not significant (Fig. 4.2.2).

In the case of *Nilodorum brevibucca*, Model 8 as fitted explained sixty-seven percent of the variability in the species. Variables that influenced abundance of *N. brevibucca* were NH_3-N, Conductivity and Cl^-. Conductivity had the greatest influence (53%) on the species whereas the contribution of Cl^- was marginal (18%) (Fig. 4.2.2).

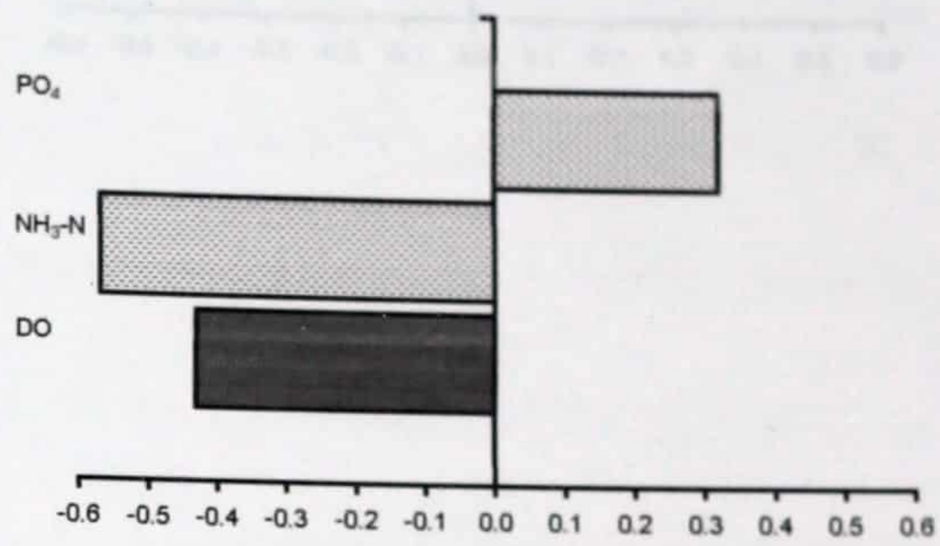
Eighty-three percent of variability in abundance of *Nilodorum brevipalpe* was explained in Model 9. Four variables, NH_3-N, TH, Chl A and NH_3-N had significant influence on abundance of *N. brevipalpe*. Of these, Total Hardness had the greatest effect on the abundance of *N. brevipalpe* (50%) whereas NO_3-N had the least influence (20%)(Fig. 4.2.2).

The food habits of the larvae of the Chironomidae were not investigated in this study. However, it is known that the larvae of many species feed on detritus and phytoplankton. Generally, NH_3-N is preferred by phytoplankton and aquatic macrophytes to other forms of nitrogen for their growth (Straškraba and Tundisi, 1999).

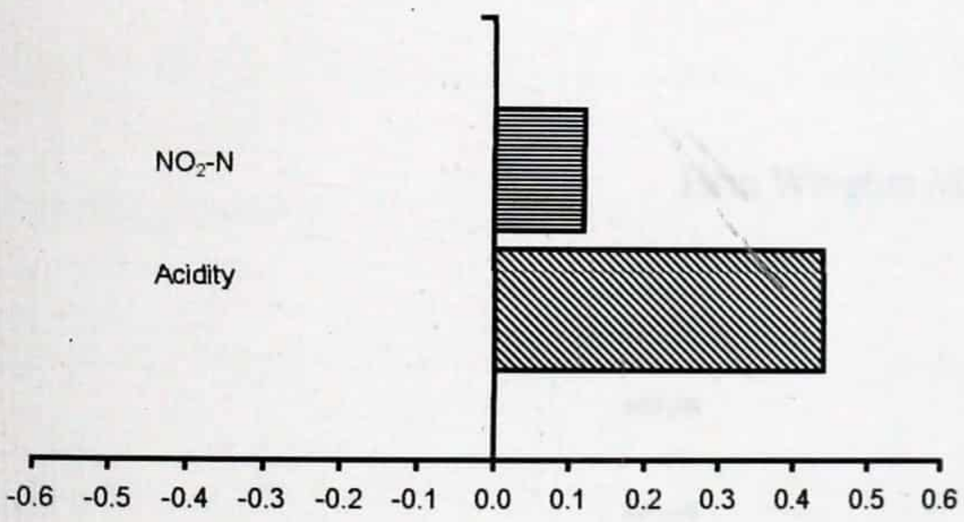
Beta Weights *Nilodorum fractiolobus*



Beta Weights *Kiefferulus chloronotus*



Beta Weights *Nilodorum brevibucca*



Beta Weights *Nilodorum brevipalpe*

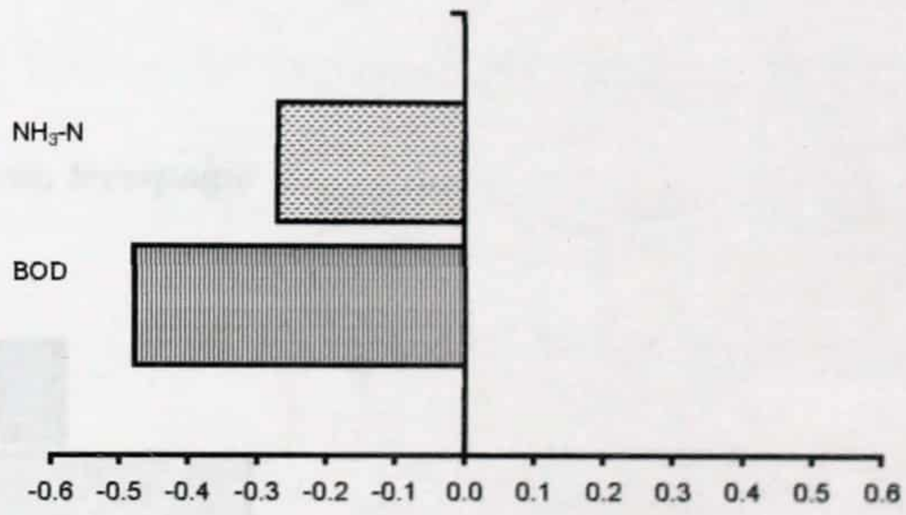
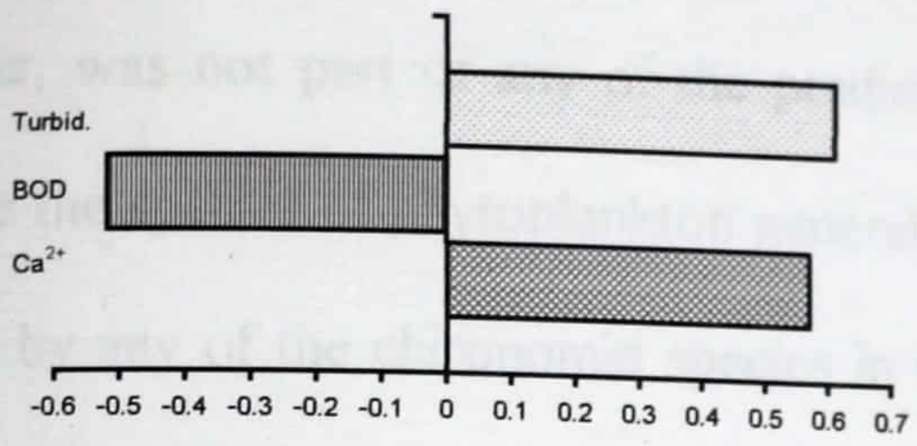
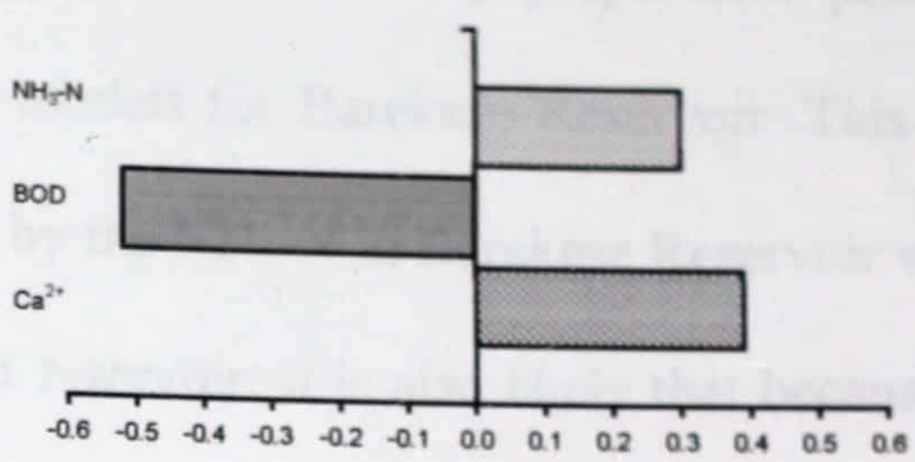
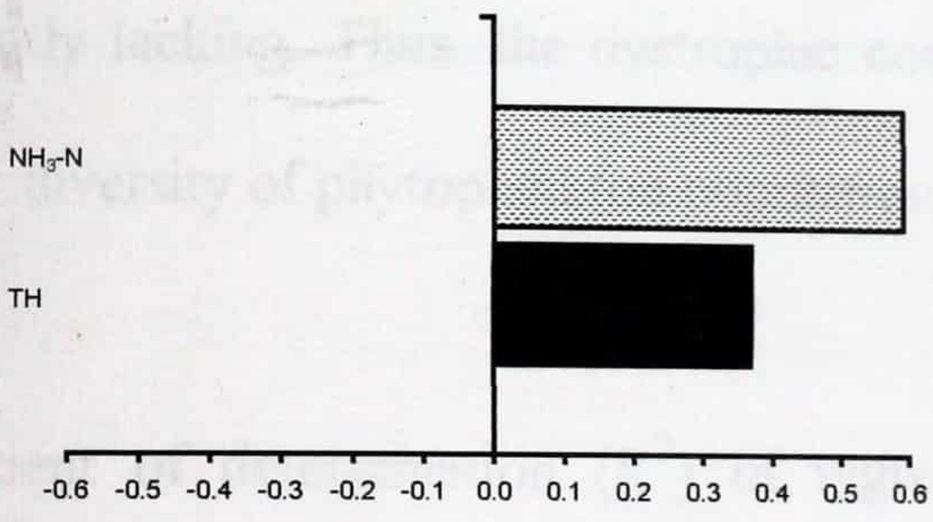
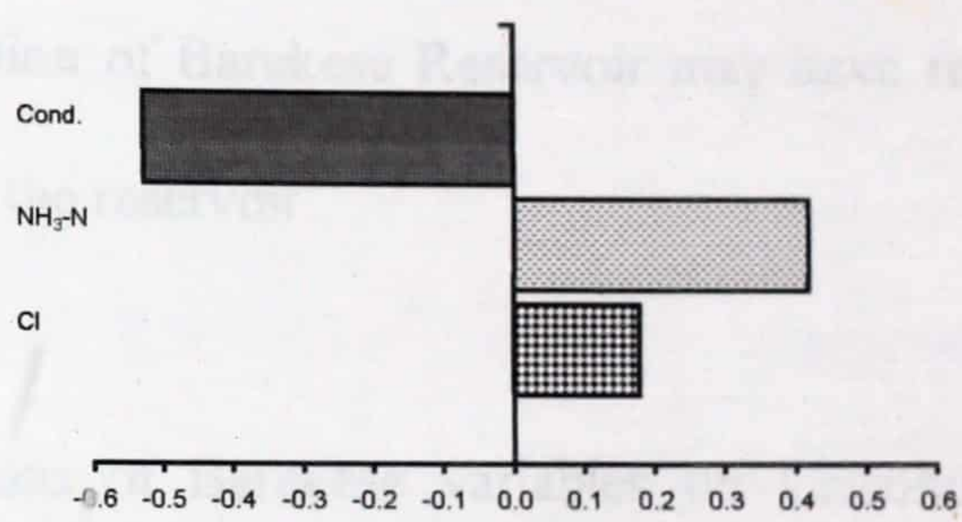


Fig.4.2.1 Relative Importance of Physico-Chemical Factors Influencing Abundance of Commonly Occurring Chironomidae in Barekese Reservoir During the Period of the Study (March 1998 – August 1999)









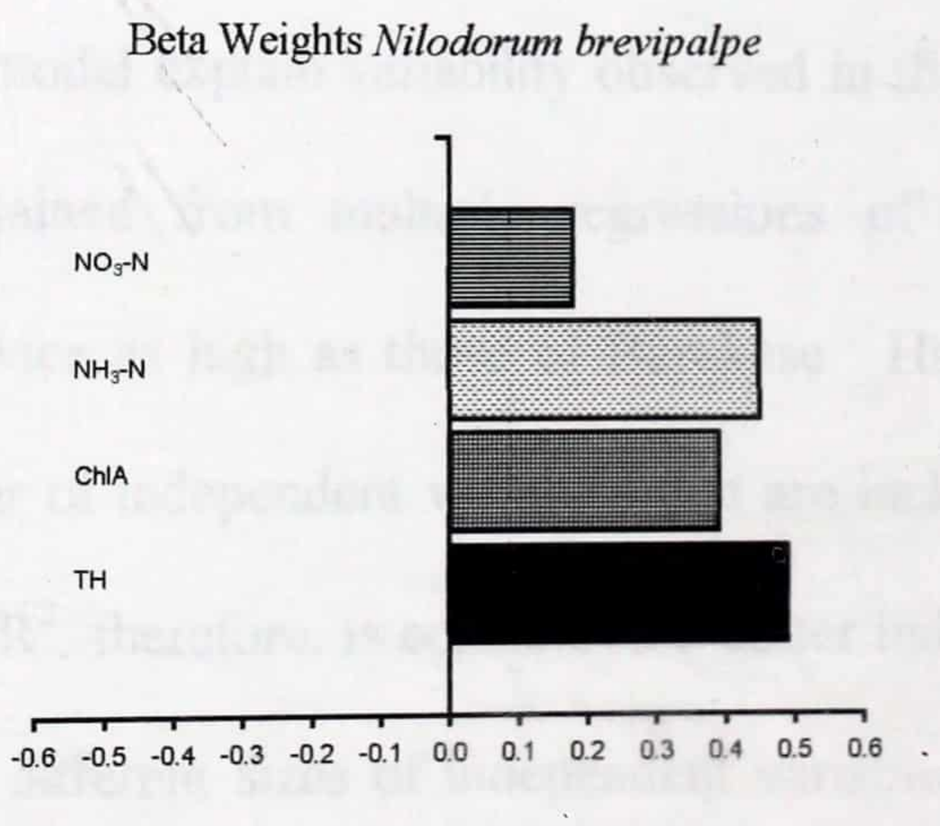


Fig.4.2.2 Relative Importance of Physico-Chemical Factors Influencing Abundance of Commonly Occurring Chironomidae in Owabi Reservoir During the Period of the Study (March 1998 – August 1999)

Thus, it was expected that the high NH_3-N, in both reservoirs, would stimulate phytoplankton and algal blooms as well as growth of macrophytes. NH_3-N is always in a balance with DO and the two are generally correlated. Chlorophyll *a*, an index of phytoplankton production, however, was not part of any of the predictor models for Barekese Reservoir. This may be because the species of phytoplankton generated by the NH_3-N in Barekese Reservoir were not utilised by any of the chironomid species in that reservoir. It is also likely that because of the dystrophic nature of the waters of Barekese, the food needs of Chironomidae were not met in sufficient quantities in spite of the high concentrations of NH_3-N and PO_4 that occurred in the surface waters. Aldridge *et al.*, (1998) explained that in dystrophic waters, as was observed in the Barekese Reservoir, there is rapid attenuation of light by the deep brown colour of the water. The prerequisite wavelengths needed for growth of specific phytoplankton were apparently lacking. Thus, the dystrophic condition of Barekese Reservoir may have resulted in poor diversity of phytoplankton population in the reservoir.

Coefficient of determination (R^2) of regressions of Barekese variables on Chironomidae ranged from 0.25 (in Model 1) to 0.60 (in Model 2) (Table 4.3.1). In the case of Owabi, R^2 ranged from 0.53 (Model 7) to 0.83 (Model 9). The coefficient of determination is a measure of how well predictors in a model explain variability observed in the dependent variable (Zar, 1984). Values of R^2 obtained from multiple regressions of Owabi variables on the Chironomidae were about twice as high as those of Barekese. However, adjusted R^2 takes into consideration the number of independent variables that are included in regression models under comparison. Adjusted R^2, therefore, is considered a better index for comparing multiple regression models that have different sizes of independent variables. Table 4.3.3 shows the ranking of adjusted R^{2s} for the 9 models (see Appendices E and F). Based on the ranking of adjusted R^2, it was observed that the best model was Model 9 whereas the poorest fitted

model was Model 4.

Infestation of reservoirs by Chironomidae is becoming an important management problem because of increasing nutrient inputs to reservoirs and the widespread degradation of the environment (Ali, 1991). Also, Koskenniemi and Sevola (1992) found that the coarse substratum of reservoirs as well as the dystrophic waters influenced productivity of Chironomidae in Finland. Ponce-Palafax and Arredondo-Figueroa (1995) observed that alkalinity, nitrite, ammonia and PO_4 as well as dissolved substances, organic matter content influenced the metabolism of the ponds in Mexico. Sankarperumal and Pandian (1992) concluded in a study of Chironomidae in sewage canal and pond systems in India that the quality and quantity of organic matter content of the substratum were important variables in the growth and abundance of *Chironomus circumdatus*.

McLachlan and McLachlan (1971) also showed that in addition to the changing water chemistry, increase of organic debris influenced the abundance of Chironomidae in Lake Kariba. McLachlan further observed that larvae of *Nilodorum brevibucca* required a particular size of bottom particles to allow for the proper growth and development of the larva (McLachlan, 1969a; 1970). Marshall (1995) also observed that low water levels in Lake Chivero, in Zimbabwe was responsible for the reduction in abundance of Chironomidae in the lake.

In this study, thirteen physico-chemical parameters, namely DO, BOD, NH_3-N, NO_2-N, NO_3-N, PO_4, Chl. A. , Ca^{2+}, TH, Acidity, Turbidity, Cl^- and Conductivity were major factors that predicted abundance of the commonly occurring Chironomidae in Barekese and Owabi reservoirs. The physico-chemical variables may be put into three broad categories:

1. **Variables related to the organic pollution of the reservoir:**

   DO

   BOD

   Cl^-

   Acidity

2. Variables related to the nutrient status of the reservoir:

   NH_3-N

   NO_2-N

   NO_3-N

   PO_4

   Chl. A

   Ca^{2+}

3. Variables related to the geology of the basin:

   Turbidity

   Conductivity

   Total Hardness

These variables are, in general, in agreement with those found in other studies cited above. Whereas the variables related to geology of the basin were occasionally, important factors of the prediction models (Models 3, 7 and 8), those related to eutrophication and organic pollution of the reservoirs featured more frequently in the models (Models 1,2,4,5,6 and 9). This confirms the observation made by Ali (1980, 1991) that increasing anthropogenic

impacts are likely to increase abundance of Chironomidae in reservoirs.

The regression constants ***a*** i. e. intercepts of models 3,5,7 and 9 are negative. This observation indicates that there is a threshold level of variables for the species of Chironomidae on which they impact (Glenn *et al*., 1999).

Table 4.3.3: Summary of Adjusted R^2 for Multiple Regression Analysis of Variables on Commonly Occurring Chironomidae in Barekese and Owabi Reservoirs

Reservoir	Model No.	Adjusted R^2	Rank
Barekese	1	Not Applicable	-
Barekese	2	0.5100	5
Barekese	3	0.3586	7
Barekese	4	0.2706	8
Owabi	5	0.6928	3
Owabi	6	0.7639	2
Owabi	7	0.4649	6
Owabi	8	0.5943	4
Owabi	9	0.7772	1

CHAPTER FIVE

GENERAL DISCUSSION, STRATEGY FOR THE CONTROL OF NUISANCE CHIRONOMID SPECIESAND CONCLUSIONS.

"... ecosystem theory offers a number of pointers for the proper management of reservoirs and their watersheds. In particular, ecological theory helps to solve water quality problems with natural biological controls rather than using more environmentally damaging chemical control" Straškraba and Tundisi (1999).

5.1 General Discussion

5.1.1 Species Composition and Richness

Seventeen chironomid species were recorded from the two reservoirs, in the current study whilst fourteen species were reported from Barekese Reservoir by Whyte (1980). An examination of the species composition shows a change in the chironomid fauna. *Nilodorum brevipalpe*, which was previously absent in the Barekese Reservoir, was now present. The number of *Dicrotendipes* species had also increased from two to at least four.

Empirically, fifty-nine and forty chironomid species were present in Barekese and Owabi reservoirs respectively. However, only seventeen species were actually caught, in traps, at the two reservoir sites. The numbers represent 29% and 43% respectively of the theoretical number of chironomids that was available at Barekese and Owabi.

Generally, oligotrophic waters have a more diverse chironomid fauna than eutrophic or organically polluted waters (Sæther, 1975; 1979). This is because as the water becomes eutrophic or organically enriched ~~the non-~~tolerant species are eliminated and are replaced by a

few tolerant species that explode in numbers. The seventeen species of Chironomidae recorded from the reservoirs, therefore, is a good estimate of chironomid species diversity in the two reservoirs. This is confirmed by the high coefficient of determination ($R^2 = 0.82$ and 0.97 respectively) for the optimised distribution models of Chironomids from Barekese and Owabi reservoirs (Fig. 3.3.3b and Fig. 3.3.4b).

Sæther (1975) observed that the use of chironomid communities as indicators of the trophic and, by extension, pollution status of lakes has a worldwide application. *Nilodorum* and *Dicrotendipes* dominated Barekese and Owabi reservoirs. In addition, *Kiefferulus*, an indicator of dystrophic lakes (Cranston *et al.*, 1989) was present in Barekese Reservoir in larger numbers than in Owabi. The two reservoirs may be described as *Nilodorum-Dicrotendipes - Kiefferulus* reservoirs to reflect the prevailing chironomid assemblages.

The present study has shown that increasing eutrophication and pollution of the waters of the reservoirs were, apparently, responsible for the large numbers of individual chironomids trapped from both reservoirs (See Appendices A and B). *Nilodorum fractilobus, N. brevipalpe, N. brevibucca, Dicrotendipes schoutedeni and Kiefferulus chloronotus* were the important species (and therefore, potential nuisance species) in the two reservoirs when one considered their abundance and their contributions to productivity of the two reservoirs. In this regard, *Nilodorum fractilobus* and N. *brevipalpe* were considered the species that needed to be controlled immediately.

5.1.2 Seasonal Abundance and Production of Chironomidae

The current study on the production of Chironomidae, based entirely on emergence trap collection, is apparently the first of its kind in Ghana. In the other methods that are available

for estimating production, the duration of the aquatic stage (CPI) needs to be established.

Whyte (1971) suggested a new method for assessing production of Chironomidae in the Danfa Reservoir because of the apparent lack of a suitable model for the estimation of chironomid production in tropical waters where several cohorts may co-exist. He collected eggs from ovipositing females and reared the eggs to adults in the laboratory. He developed a model for estimating the number of individuals that progressed from the egg stage through the various instars to adults. Whyte observed that there was as much as 88.5% mortality of larvae of the second instar of *Tanytarsus zariae*, one of the species that he cultured in the laboratory.

The culture of Chironomidae, in tropical environments, is beset with problems. Fungi, belonging to the genus *Coelomomyces*, often attack the eggs and larvae of many aquatic Diptera, such as the Chironomidae, in the wild and laboratory cultures (Amakye pers. observations; Weiser and Chapman, 1982). It is apparent that such attacks could be responsible for the deaths that occurred at the second larval instar stage in Whyte's experiment.

Whyte also conceded that his field collection methods failed to sample the first and second instars of the Chironomidae from the Danfa Reservoir. His estimates of the standing stocks of these instars, therefore, were assumptions. Based on simulated data, however, Whyte estimated dry season production of *Tanytarsus zariae*, the dominant species in Danfa Reservoir, as 11.2 g m^{-2}. His method, apparently, has not been repeated in Ghana but it is worth noting that the production of *Tanytarsus zariae* in Danfa is of the same order of magnitude as the chironomid species in the present study.

The use of emergence-trap collections in chironomid production studies, therefore, may be

preferable to methods that rely on immature chironomids when the former is viewed against the backdrop of the large-scale mortalities and inadequate means of identification associated with the latter methods. The present method is simple, enables the different contributors to total production to be identified and the relative importance of the contributors to be assessed. In general, chironomid production in Barekese was about 4 times as high as in Owabi Reservoir. The differences in the production of chironomids in the two reservoirs can be attributed to anthropogenic factors and rainfall pattern within the catchments of the reservoirs. The two factors influenced the physico-chemical characteristics, as well as quality and quantity of food in the reservoirs. Except during spates, Owabi Reservoir had clear water, whereas the water of Barekese Reservoir had a deep brown colour and contained more detritus than water from Owabi (see Table 2.1 regarding transparency). Detritus is an important food item for chironomids (Hauer and Benke, 1991) ; and it influences production in the family (McLachlan, 1969a; Benke, 1993).The higher amount of food available to the Chironomidae in Barekese Reservoir, all year round, therefore, could be responsible for the high chironomid production that was observed .

Potter and Learner (1974) estimated production of Chironomidae, based on submerged emergence trap collections, in a Welsh lake, to be 1.4 g m^{-2} $yr.^{-1}$. However, Kimerle and Andersen (1971) cited by Benke (1984) estimated production of *Glyptotendipes barbipes*, a chironomid inhabiting a sewage stabilisation pond in the USA, to be 162 g m^{-2} yr^{-1}. Estimates of chironomid production from African reservoirs or lakes, based on emergence trap collections, are scarce (Talling and Lemoalle, 1998). Nevertheless, McLachlan and McLachlan (1971) estimated production of emerging chironomids from the newly formed Lake Kariba to be 2.45 g m^{-2} yr^{-1}. In addition, Vareschi and Jacobs (1984) cited by Talling and Lemoalle (1998) estimated production of the single chironomid, *Leptochironomus*

deribae, in Lake Nakuru, in Kenya, to be 31.6 g m^{-2} $yr.^{-1}$.

It is apparent that chironomid production in freshwater habitats varies greatly across and within climatic zones. Among the reasons given by Benke (1984) for such wide variations is the method used in assessment of production. For example, Benke (1984) observed that production estimates based on emergence trap collections were usually higher than the Size Frequency (SF) method. In addition, floating emergence traps like 'WEEK' that was used in this study caught five times more adult chironomids than submerged traps (Morgan *et al.*, 1963; Potter and Learner, 1974;). It is, therefore, reasonable to assume that if floating traps had been used then production in the Welsh lake would have been higher (~7.0 g m^{-2} $yr.^{-1}$). In that instance, chironomid production in Barekese (170.7 g m^{-2} $yr.^{-1}$) and Owabi (41.0 g m^{-2} $yr.^{-1}$) would be about 24 and 6 times respectively, the production of chironomids in the eutrophic Welsh lake. Benke (1984) considers chironomid production $\geq$ 50.0 g m^{-2} $yr.^{-1}$ to be high. The high values of production obtained in the present study, therefore, are normal. It is worth noting, however, that the estimated production of 31.6 g m^{-2} yr^{-1} for *Leptochironomus deribae*, the dominant species in Lake Nakuru, in Kenya, is close to the estimate for *Nilodorum fractilobus* (25.7 g m^{-2} $yr.^{-1}$) in Barekese Reservoir. In addition, the total chironomid production in Barekese (170.7 g m^{-2} $yr.^{-1}$) was about the same magnitude as that for the single species, *Glyptotendipes barbipes*, in the sewage stabilisation ponds in the USA. Generally, it may be said that the method used in this study provided production estimates of the same order of magnitude as the other methods.

Since temperatures are high throughout the year, in the tropics, the duration of the aquatic stage of Chironomidae is shorter (Benke, 1984; Benke *et al.*, 1984; Hauer and Benke, 1991; Benke, 1993). Chironomidae, therefore, produce several generations, a year, in the tropics, in contrast to the single or two generations per year that occur in temperate climates. Thus, turn

over rates are high in tropical, aquatic environments (Benke, 1984). The high production of Chironomidae that was observed in Barekese and Owabi reservoirs, therefore, may be due to the high turn-over rates apparently occurring in the two reservoirs.

One gram of Chironomid biomass (DM) is equivalent to 4.85 cal of energy (Illies, 1971). Thus, the energy flow from Chironomidae into the biocoenosis of Barekese and Owabi reservoirs was equivalent to 827.7 and 198.9 cal m^{-2} $yr.^{-1}$ respectively.

When abundance of the chironomids is considered, a trend towards seasonality, in Owabi Reservoir is observed. Higher chironomid biomass occurred between March/April and August, during the rainy season, when the reservoir was filling than between September and March at the draw down period (Fig. 3.4.2). A similar phenomenon was observed in Lake Kariba and Lake Volta (McLachlan, 1970; Amakye, 2001). In both lakes, the rising reservoir water, during the rainy season, led to an increase in the density of Chironomid larvae. The in-coming floods or spates, observed in Owabi, brought large amounts of allocthonous matter into the reservoir. A major component of the allocthonous matter comprises detritus, an important food resource for Chironomidae. Subsequently, the production of chironomids in Owabi Reservoir increased with the arrival of the floods. However, no trend towards seasonality was obvious in the case of chironomid production in Barekese Reservoir (Fig. 3.4.1). Instead, peaks of the different species tended to occur at regular intervals, during the study period. This indicated that the factor that limited production in Barekese was not directly related to the floods and the incoming food, in the form of detritus, as was observed in Owabi Reservoir. Thus, food may not be a limiting factor to chironomid production in Barekese Reservoir.

It was also observed that the peaks of the different species emerging from the reservoirs were

scarcely concurrent. This is a strategy adopted by congeneric chironomids and other aquatic macroinvertebrates to achieve reproductive isolation and thereby avoid competition for resource and suitable swarming spaces (Boerger, 1981; Grant and Mackay, 1969).

5.1.3. Effects of Physico-Chemical Variables on Chironomidae

Although variations in physico-chemical parameters are known to affect the abundance of macroinvertebrate benthos in reservoirs and lakes (Stralkraba and Tundisi, 1999, Petr, 1974, Green and Vascotto, 1978 quoted by Chessman, 1999), their use as predictors of abundance of chironomids has not been investigated, previously, in Ghana. This is apparently the first study that evaluates the potential of physico-chemical variables as predictors of chironomid abundance in Ghana.

Nine multiple linear regressions could predict the abundance of the five nuisance Chironomidae in Barekese and Owabi reservoirs by relating physico-chemical variables of the reservoirs to the abundance of the species. Of the twenty-eight variables that were utilised in setting up prediction models, thirteen variables (57%) showed potential as predictors of chironomid abundance. Variables that were significant predictors ($p < 0.05$) included BOD, DO, Chloride, Acidity, $NH_3 - N$, $NO_2 - N$, $NO_3 - N$, PO_4, Chlorophyll A, Ca^{2+}, Turbidity, Conductivity and Total Hardness of the reservoir water. Out of the thirteen significant predictors, nine (69%) were positive predictors, three (23 %) were negative and one (8%) was ambivalent (Fig. 4,2,1 and Fig. 4.2.2). The positive predictors of chironomid abundance were Turbidity, $NO_2 - N$, $NO_3 - N$, Chlorophyll A, Total Hardness, PO_4, Acidity, Ca^{2+} and Cl^-. The negative predictors were BOD, Dissolved Oxygen and Conductivity. NH_3-N was negative or positive depending on the chironomid species involved.

A reservoir's water temperature affects the abundance of macro-invertebrates by controlling the rate at which larvae develop. For example, in the low-lying areas of the Onchocerciasis Control Programme (OCP) in West Africa, the mean annual temperature of water is around 25° C. At this temperature, it takes between five and seven days for *Simulium* eggs to develop into pupae (Davis *et al.*, 1978). However, at altitudes higher than 1000 m mean temperatures can be as low as 20 °C. At such temperatures, *Simulium* larvae cannot establish themselves (APOC, 1998). Mean water temperature at Barekese and Owabi was 28°C (Table 2.1). During the present study, mean water temperature at Barekese and Owabi, also never fell below 20 ° C. Water temperature, therefore, did not have a definite effect on the abundance of Chironomidae of the two reservoirs.

Unlike the observations made by others (McLachlan and McLachlan, 1971; Petr, 1974; Dinsmore *et al.*, 1999), the fluctuating water level in Barekese and Owabi reservoirs was not a significant predictor in any of the models that was erected in the present study. However, it was observed that the location of individual traps affected their performance. Traps at the shallower, in-shore areas or placed over weeds caught more chironomids than traps located offshore, in deeper waters. The observation made conforms to that made by McLachlan and McLachlan (1971), Petr (1972, 1974) and Dinsmore *et al.*, (1999). The present study, however, was not concerned with distribution patterns of the species with respect to depth but the over-all production of Chironomidae in the reservoirs. In this regard, the overall abundance of Chironomidae from all parts of the reservoir was paramount.

In deep meso-eutrophic reservoirs in temperate climates and very deep reservoirs and lakes in the tropics, temperature related stratification of the water column results in the establishment of a dissolved oxygen gradient from the surface to the bottom of the reservoir that may last for

months (Petr, 1986; Heinis and Crommentuijn, 1992; Marshall, 1995). Under such conditions, dissolved oxygen levels are high near the surface and in shallow littoral areas whereas the offshore, profundal areas have minimal or no oxygen at all (Heinis and Crommentuijn, 1992)

However, the species of Chironomidae that were found in Barekese and Owabi reservoirs, during the present study, belonged to the tribe Chironomini. Many species of the Chironomini are adapted, physiologically, to living in hypoxia or anoxia for extended periods because they possess haemoglobin (Walshe, 1950; Weber, 1980) or can metabolise glycogen under anaerobic conditions (Hamburger *et al.*, 1995).

Also, in most shallow, wind-swept, tropical reservoirs such as Barekese and Owabi, stratification and mixis are regular diel occurrences that allow oxygen to reach the bottoms (Talling and Lemoalle, 1998). Thus, the bottoms of the two reservoirs were never devoid of oxygen for long periods on any particular day. For these reasons, therefore, DO would not be a significant predictor of abundance of the five-chironomid species that were studied. Also, because of the frequency (i. e. weekly intervals) of sample collection the effect of diurnal DO concentrations on abundance of the Chironomidae would not be captured.

The relationship between *Kiefferulus chloronotus* and dissolved oxygen is an interesting one that needs further investigation. *Kiefferulus chloronotus* is found mainly in dystrophic waters (Cranston *et al.*, 1989). Such waters contain high organic matter that reduces oxygen levels in the water. It is apparent that *Kiefferulus* is adapted to living in hypoxic conditions and that improved dissolved oxygen was detrimental to the species.

Nilodorum brevibucca, *N. brevipalpe* and *N. fractilobus* are all indicators of organic pollution and eutrophication (Petr, 1969). Although all three species were present in both reservoirs, *N. brevibucca*, in Owabi Reservoir, was the only species on which conductivity acted as a negative predictor of abundance. Conductivity of a water body is an indicator of the dissolved minerals in it. It is also a measure of the level of organic pollution and eutrophication that has occurred in the water (Straškraba and Tundisi, 1999). Thus, more eutrophic or organically polluted waters would have higher electrical conductivity than oligotrophic or slightly polluted waters. The conductivity of reservoir water from Owabi was about 1.3 times as high as that of Barekese (Table 2.1). Also, the main contributor to the high conductivity of the reservoir water was the chloride ions. Chloride in Owabi was nearly twice as high as the level observed in Barekese Reservoir and in other pristine waters (Straskraba and Tundisi, 1999). Straškraba and Tundisi (1999) indicated that when chloride values are higher than the recommended levels for pristine waters then sewage or industrial pollution should be suspected. It is apparent that *N. brevibucca* prefers waters with lower conductivity (i. e. less organically polluted waters) than the other two *Nilodorum* species. The different responses of the various *Nilodorum* species, to a single parameter such as conductivity is proof that the Chironomidae are good indicators of a wide range of prevailing environmental factors in our water bodies.

The other nine parameters, which were positive indicators of the abundance of Chironomidae, were all related to the eutrophication or nutrient loads of the reservoirs. This observation confirms the findings made by Dinsmore *et al.*, (1999) that multiple linear regression models work best in meso-eutrophic to dystrophic waters. It would be interesting to investigate what the situation is like in an oligotrophic reservoir in Ghana.

The greater proportion of the factors that affected abundance of the Chironomidae was environmental or anthropogenic in nature. These factors were greatly influenced by rainfall or their impact was greatly felt when the initial floods entered the reservoirs. Thus, for the control of the abundance of the nuisance chironomid species, one needs to pay attention to the control of these environmental factors.

5.2 Control Strategy

The present study confirmed that Chironomidae occurred in large numbers in Barekese and Owabi reservoirs alongside other Diptera like Chaoboridae. Infestation of reservoir water by chironomids is usually controlled by application of chemical pesticides (Williams, 1974; Houston *et al.*, 1989). Synthetic pyrethroids, which do not persist in the environment, have been used frequently to control nuisance chironomid species in some countries (Mitcham and Shelly, 1980; Bay, 1993;). However, when nuisance flies in water supply reservoir need to be controlled then the use of chemical pesticides is not advisable because of the health implications (Berg. 1995). Methods of control that are alternative to pesticide application, then, are needed for the sustainable control of the nuisance species.

An integrated approach to the control of the nuisance flies is outlined here. The strategy is based on information gathered from the physico-chemical and ecological investigations carried out in the present study.

5.2.1 Strategies

The successful control of the nuisance chironomid species is hinged on three strategies:

(i) Ensuring the integrity of the potable water reservoir, transmission and distribution lines.

(ii) Actual control of the nuisance species in the raw water reservoir.

(iii) Watershed management.

i. **Ensuring Integrity of the Potable Water Reservoir, Transmission and Distribution Lines**

After production, potable water is stored in reservoirs and pumped through a network of pipes to consumers on demand (GWCL, pers. com.). The potable water reservoirs have vents that allow entry of air; and the vents are screened to prevent ovipositing Chironomidae from entering the reservoir. As a first step and in line with the principle of solving problems that are easiest first, it is suggested that a maintenance audit of the water works should be taken. The general maintenance culture at the plants should be improved upon and routines kept. All leakage on the transmission and distribution lines should be eliminated. The screens on the potable water reservoirs should also be replaced immediately they are damaged.

ii. **Control of Nuisance Flies in the Raw Water Reservoir**.

Strategy for the control would comprise:

a). *Measures Aimed at Cutting Down Inputs of Nutrients and Organic Pollutants to The Reservoirs:*

The levels of nutrients that were observed in both reservoirs were high and ranged between one and two orders of magnitude above the limits found in pristine waters. The major contributors to these inputs were households and poultry farms that were located within the catchments of the two reservoirs. Most of the houses have cesspool tanks that have their overflows directed into the valleys of the reservoirs. Poultry farms, especially the large, commercial ones also dispose of large quantities of poultry litter in the dry valleys of the reservoirs, as there is no regulation governing the disposal of litter from such

farms. Large nutrient inputs and suspended solids, therefore, enter the reservoirs when the rainy season starts.

The commercial poultry farmers, for example, should be helped to add biogas plants to their farms to generate methane that could be used to keep day-old chicken warm in the brooder house. Excess methane could be used as fuel to generate electricity by adapting power generators to run on methane. The effluents and sludge from the biogas digesters could then be used in fertilising farmlands in the district. In this regard new agronomic practices would need to be introduced to farmers to prevent spill over from the farmlands from entering the reservoirs.

Households also could be encouraged to install rudimentary filter beds ('soak away') to treat effluents from the houses or the overflows from the cesspool tanks, partially, before they enter the basins. These measures will cut down the inflows of nutrients, from such point sources, to the reservoirs.

b). *Biomanipulation of the Species.*

Frempong and Nijjhar (1973) provided a list of fish present in Barekese Reservoir area during the formative years of the reservoir. Some bottom feeding species from the families Mormyridae and Cyprinidae were present although they were scarce in the reservoir proper. Frempong and Nijjhar (1973) however, reported no ***zooplanktivores*** from the Barekese Reservoir proper. *Tilapia busumana* was predominant whiles *Labeo senegalensis*, a bottom feeder, was scarce even in the catches downstream of the dam. In general, Frempong and Nijjhar (1973) suggested that the change from a riverine to a lacustrine condition would affect

the fish population of Barekese Reservoir. Observation made by the author and from interviews with fishermen, permitted by GWCL to fish from the two reservoirs, revealed that fish caught from Barekese Reservoir was mainly *Heterotis niloticus* whereas *Hemichromis spp.* and *Tilapia spp* were landed at Owabi. *Heterotis* is a pelagic, microphagous fish that feeds mainly on algae and other small plants. *Tilapia* and *Hemichromis* are phytophagous or planktivores although some species of *Hemichromis* are piscivorous (Dankwa *et al.*, 1999). Both reservoirs, therefore, lacked bottom feeders and ***zooplanktivores,*** especially the important family Clupeidae.

Chironomid larvae are benthic in habit. However, the first instar larvae of most species are planktonic (Bryce and Hobart, 1972). Therefore, there was inadequate representation or absence of plankton-eating fish and those that were bottom feeders that could exploit the chironomid (and chaoborid) larval populations in the two reservoirs. This accounted for the explosion in population of Chironomidae in the two reservoirs; and the introduction of such fish species appears to be an attractive option.

The selection of the fish types is based on a study of the food habits of fish in the Yeji area of Lake Volta (Reynolds, 1970; Amakye, 1996) and information provided by Dankwa *et al.*, (1999). All the species are also lacustrine or can adapt to lacustrine conditions.

The bottom feeders may be selected from:

Clarias spp

Auchinoglanis occidentalis

Mormyrus spp

The zooplanktivores may be selected from:

Synodontis (Hemisynodontis) membranaceus

Synodontis schall

Sierrathrissa leonensis

Pelomula leonensis

These species will exploit the large energy that is locked up in the nuisance chironomid species but which is at the moment not utilised by any of the fish species present in both reservoirs.

c). Non-Chemical Pesticide Control Approach

Although expensive, non-chemical pesticides such as *Bacillus thuringensis* (*B.t.i.*) can be used effectively to control nuisance flies (Houston et al., 1989). *B t. i.* is available as the commercial product 'Teknar' or 'VectoBac'. *B t. i.* is safe to humans and other non-dipteran macro-invertebrates as the effect of the product is limited to the Diptera (Gaugler and Finney, 1982). It does not persist in the environment and it is not bio-magnified in the food chain (Silapanuntakul *et al.*, 1983). However, because of the large volumes that are required to achieve effective control as well as the cost B. t. i. can be used only on a limited scale. It is therefore recommended that *B. t. i.* be used to eliminate residual populations in the potable water reservoirs.

5.2.2 Validity of Control Plan:

Cost Effectiveness of Chemical Control

Estimated cost of a single application of a synthetic pyrethroid is provided below:

(a). Pyrethroid Application:

Capacity of Barekese reservoir 208,000,000 m^3

Assuming a 4% concentration as an effective dose against the chironomids, the volume of pyrethroid (Permethrin 20EC) needed will be:

4/100 x 20 x 208,000,000 x 1000 l = 166,400,000 l.

A litre of Permethrin 20EC costs ¢100,000 :00

Therefore, a single pesticide application will cost ¢1, 664,000,000,000,000:00

The cost of insecticide alone does not make this option a feasible one presently.

(b). Biomanipulation

Alternatively, the cost of introducing the fish species into Barekese reservoir as recommended in this strategy will cost ¢225,000,000:00 made up of

500,000 fingerlings of *Clarias* at ¢350 ¢175,000,000 :00

500,000 *Sierrathrissa leonensis* at ¢100 ¢50, 000,000:00

In addition to being more cost effective, the introduction of the fish species will improve the fishery of the reservoirs as a wider variety of fish will be caught when the introduced species become established in the reservoirs. The introduction will also improve on the protein intake of the riparian communities.

iii). **Watershed Management**

It is recommended that the unfettered encroachment of the two reservoirs should be reduced. This will be most difficult to achieve. However, to facilitate the implementation of this control measure it is recommended that GWCL, the riparian District Assemblies and residents should collaborate to fashion out guidelines pertaining to physical development and disposal of solid and liquid waste within the watershed areas of the two reservoirs. The policy must

include clearly spelt-out sanctions for offenders. Lastly, re-forestation of the watershed should be increased to cover a wider area than the immediate banks of the reservoirs.

5.3 Conclusions

Multiple linear regression models are not always cause and effect models. They are only pointers to possible factors that are responsible for the changes observed when many environmental factors are operating on a biocoenosis (Frantzen, 1992). The multiple regression approach thus becomes a useful approach for investigating environmental problems when there is no previous knowledge of the species-specific sensitivities or tolerances of species to different environmental variables or stress (Johnson, 1995) as this study has demonstrated. Thus, outputs from regression models are exploratory and can suggest preliminary hypotheses (Rossaro, 1992). The regression constant ***a***, i.e. the intercepts of Models 3, 5, 7 and 9, are for example negative. This observation indicates that threshold level of variables existed for the species of Chironomidae on which they impact (Glenn *et al*., 1999). There is need, therefore, for further investigations, in future, to establish threshold levels for those predictors, in the present study, that affected the abundance of the various chironomid species.

The present method dwelt heavily on the males of the species because keys for identification of females were not available. Thus, estimates of production of the individual chironomid species did not take into account the contributions of the females when the importance of the individual species to over-all chironomid production was under consideration. However, this did not detract the author from following the relative importance of the various species of Chironomidae to chironomid production in the two reservoirs. Not so much is known, however, about the females of many of the Chironomidae of Ghana. A concerted effort at

identification of the females would further enhance the precision of production estimates obtained by the method adopted by the author in the present study.

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APPENDICES

Appendix A

Parameters Used For Estimation of Production of Chironomidae of Barekese Reservoir

	Mar-98				Apr-98			
			Individual				Indivisual	
Species	DM/Trap (g)	Mean No /Trap	Weight (g) DM	Biomass ($g\ m^{-2}$)	DM/Trap (g)	Mean No /Trap	Weight (g) DM	Biomass ($g\ m^{-2}$)
Nilodorum fractilobus	0.0000	0.0000	0.0000	0.0000	0.1376	63.7500	0.0024	1.1233
Microchironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.2360	3.0000	0.0787	1.9265
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicrotendipes schoutedeni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.3496	208.5000	0.0017	2.8539
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0000	0.0000	0.0000	0.0000	0.1420	257.5000	0.0006	1.1592
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0024	63.7500	0.0030	0.0196
Chironomus sp. 1 (nr. transvalensis?)	0.0000	0.0000	0.0000	0.0000	0.0210	28.5000	0.0007	0.1718
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0200	63.7500	0.0003	1.6327
Total	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.9086**	**688.7500**	**0.0874**	**8.8870**

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Appendix A: (Continued).

Species	May-98				Jun-98			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.2328	65.0000	0.0036	1.9004	0.0055	2.0000	0.0027	0.0445
Microchironomus/ Harnischia spp?	0.0027	31.6670	0.0001	0.0222	0.0062	79.0000	0.0001	0.0506
Kiefferulus chloronotus	0.0019	34.6667	0.0001	0.0155	0.0005	2.2500	0.0002	0.0001
Dicrotendipes schoutedeni	0.0057	4.6670	0.0012	0.0465	0.0037	1.5000	0.0024	0.0298
Nilodorum brevibucca	0.0004	1.3333	0.0003	0.0029	0.0004	21.0000	0.0002	0.0033
Nilodorum brevipalpe	0.0301	65.0000	0.0005	0.2457	0.0137	48.5000	0.0030	0.1118
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	25.8600	63.3333	0.0041	2.1112	0.5064	132.0000	0.0038	4.1336
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0633	368.6700	0.0002	0.5167	0.0000	0.0000	0.0000	0.0000
C. sp. 2								
C. sp. 3								
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica								
Clinotanypus claripennis								
Total	**21.1969**	**634.3373**	**0.0101**	**4.8611**	**0.5364**	**286.2500**	**0.0124**	**4.3737**

Appendix A: (Continued).

Species	Jul-98				Aug-98			
	DM/Trap (g)	Mean No /Trap	Individ. Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individ. Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.0598	177.5000	0.0003	0.4844	0.0000	0.0000	0.0000	0.0000
Michrochironomus/ Harnischia spp?	0.0028	45.7500	0.0001	0.0226	0.0000	0.0000	0.0000	0.0000
Kiefferulus chloronotus	0.0005	2.2500	0.0002	0.0041	0.0000	0.0000	0.0000	0.0000
Dicrotendipes schoutedeni	0.0030	8.0000	0.0004	0.0242	0.0000	0.0000	0.0000	0.0000
Nilodorum brevibucca	0.0005	38.0000	0.0001	0.0039	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0104	22.5000	0.0005	0.0849	0.0000	0.0000	0.0000	0.0000
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0001	0.2500	0.0002	0.0005	0.0000	0.0000	0.0000	0.0000
All Female	0.4920	337.0000	0.0015	4.0161	0.0072	22.0000	0.0003	0.0588
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0087	2.2300	0.0039	0.0710	0.0000	0.0000	0.0000	0.0000
C. sp. 2	0.0040	17.5000	0.0002	0.0329	0.0000	0.0000	0.0000	0.0000
C. sp. 3								
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica								
Clinotanypus claripennis								
Total	**0.5818**	**650.9800**	**0.0074**	**4.7446**	**0.0072**	**22.0000**	**0.0003**	**0.0588**

Appendix A : (Continued).

Species	Sep-98				Oct-98			
	DM/Trap (g)	Mean No /Trap	Individ. Weight (g) DM	Biomass ($g\ m^{-2}$)	DM/Trap (g)	Mean No /Trap	Individ. Weight (g) DM	Biomass ($g\ m^{-2}$)
Nilodorum fractilobus	0.0191	23.5000	0.0008	0.1561	0.1136	251.6700	0.0005	0.9276
Microchironomus/ Harnischia spp?	0.0044	21.5000	0.0020	0.0357	0.0012	34.3300	0.0001	0.0096
Kiefferulus chloronotus	0.0012	47.5000	0.0002	0.0943	0.0173	31.0000	0.0006	0.1412
Dicrotendipes schoutedeni	0.0017	2.0000	0.0009	0.0139	0.0019	9.6667	0.0002	0.0155
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0910	235.2500	0.0004	0.7426	0.0408	216.3300	0.0002	0.3331
Dicrotendipes pilosimanus/fusconotatus	0.0001	0.2500	0.0002	0.0006	0.0156	0.3333	0.0473	0.1273
Polypedilum (Uresipedilum) sp	0.0001	0.2500	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000
All Female	0.2778	366.2500	0.0008	2.2678	0.1448	115.6667	0.0013	1.1820
Chironomus imicola	0.0625	3.5000	0.0178	0.5106	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0010	3.2500	0.0003	0.0084	0.0022	1.3300	0.0017	0.0180
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0002	9.3330	0.0000	0.0014
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0750	0.2500	0.3004	0.6130	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0001	0.2500	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000
Total	**0.5340**	**703.7500**	**0.3240**	**4.4434**	**0.3376**	**669.6597**	**0.0519**	**2.7557**

Appendix A: (Continued).

Species	Nov-98 DM/Trap (g)	Nov-98 Mean No/Trap	Nov-98 Individ. Weight (g) DM	Nov-98 Biomass (g m^{-2})	Dec-98 DM/Trap (g)	Dec-98 Mean No /Trap	Dec-98 Individ. Weight (g) DM	Dec-98 Biomass (g m^{-2})
Nilodorum fractilobus	0.3221	837.3000	0.0004	2.6298	0.0207	57.7500	0.0004	0.1688
Microchironomus/ Harnischia spp?	0.0004	1.0000	0.0004	0.0033	0.0002	0.5000	0.0003	0.0014
Kiefferulus chloronotus	0.0181	91.6670	0.0002	0.1478	0.0891	42.0000	0.0021	0.0727
Dicrotendipes schoutedeni	0.0014	2.3330	0.0006	0.0114	0.0002	2.7500	0.0001	0.0020
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0002	0.2500	0.0006	0.0012
Nilodorum brevipalpe	0.0918	295.0000	0.0003	0.7427	0.0010	32.2500	0.0000	0.0088
Dicrotendipes pilosimanus/fusconotatus	0.0005	0.3333	0.0150	0.0041	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0002	0.2500	0.0007	0.0014
All Female	0.2669	957.3333	0.0003	2.1783	0.0440	146.7500	0.0003	0.3592
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0045	0.6667	0.0068	0.0370	0.0007	2.7500	0.0003	0.0061
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0020	0.3333	0.0061	0.0163	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0039	16.0000	0.0002	0.0318
Total	**0.7077**	**2185.9666**	**0.0301**	**5.7707**	**0.1602**	**301.2500**	**0.0050**	**0.6534**

Appendix A: (Continued).

Species	Jan-99				Feb-99			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass ($g\ m^{-2}$)	DM/Trap (g)	Mean No /Trap	Individ. Weight (g) DM	Biomass ($g\ m^{-2}$)
Nilodorum fractilobus	0.0000	0.0000	0.0000	0.0000	0.0019	5.6667	0.0003	0.0158
Michrochironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0013	21.6670	0.0001	0.0109
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0005	3.0000	0.0002	0.0044
Dicrotendipes schoutedeni	0.0000	0.0000	0.0000	0.0000	0.0003	1.0000	0.0003	0.0024
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.1667	37.3300	0.0005	1.3611
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0013	1.0000	0.0013	0.0109
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0002	1.0000	0.0002	0.0182
All Female	0.0000	0.0000	0.0000	0.0000	0.0795	102.3300	0.0008	0.6486
Chironomus imicola								
Chironomus sp. 1 (nr. transvalensis?)								
C. sp. 2								
C. sp. 3								
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica								
Clinotanypus claripennis								
Total	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.2515**	**171.9937**	**0.0035**	**2.0723**

Appendix A: (Continued)..

Species	Mar-99 DM/Trap (g)	Mar-99 Mean No /Trap	Mar-99 Individual Weight (g) DM	Mar-99 Biomass (g m^{-2})	Apr-99 DM/Trap (g)	Apr-99 Mean No /Trap	Apr-99 Individual Weight (g) DM	Apr-99 Biomass (g m^{-2})
Nilodorum fractilobus	0.1448	422.7500	0.0008	1.1820	0.0052	8.5000	0.0060	0.0424
Michrochironomus/ Harnischia spp?	0.0110	105.0000	0.0001	0.0109	0.0027	15.5000	0.0002	0.0220
Kiefferulus chloronotus	0.0168	71.2500	0.0002	0.1371	0.0360	8.0000	0.0045	0.2939
Dicrotendipes schoutedeni	0.0080	4.0000	0.0020	0.0653	0.0082	26.5000	0.0003	0.0669
Nilodorum brevibucca	0.0507	12.7500	0.0040	0.4136	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.1249	146.2500	0.0009	1.0196	0.0000	0.0000	0.0000	0.0000
Dicrotendipes pilosimanus/fusconotatus	0.0005	3.5000	0.0001	0.0041	0.0000	0.0000	0.0000	0.0000
Polypedilum (uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.8479	595.7500	0.0014	6.9219	0.0000	0.0000	0.0000	0.0000
Chironomus imicola	0.0013	3.0000	0.0004	0.0109	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0253	21.0000	0.0012	0.2065	0.0050	20.5000	0.0002	0.0408
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0013	1.2500	0.0011	0.0109	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**1.2325**	**1386.5000**	**0.0122**	**9.9828**	**0.0571**	**79.0000**	**0.0112**	**0.4660**

Appendix A: (Continued).

Species	May-99				Jun-99			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individua l Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.0060	29.2500	0.0001	0.0045	0.0063	12.3300	0.0005	0.0518
Michrochironomus/ Harnischia spp?	0.0275	1.2500	0.0220	0.2245	0.0060	1.0000	0.0060	0.0490
Kiefferulus chloronotus	0.0022	14.5000	0.0002	0.0180	0.0011	26.0000	0.0000	0.0090
Dicrotendipes schoutedeni	0.0183	16.5000	0.0001	0.0149	0.0072	51.0000	0.0001	0.0589
Nilodorum brevibucca	0.0001	0.7500	0.0001	0.0004	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.0044	42.3300	0.0001	0.0357
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0080	1.7500	0.0065	0.0659	0.0398	19.3300	0.0021	0.3249
Chironomus imicola	0.0012	7.0000	0.0002	0.0102	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0021	29.0000	0.0001	0.0173	0.0090	1.3333	0.0068	0.0733
C. sp. 2	0.0018	2.5000	0.0070	0.0147	0.0033	39.0000	0.0001	0.0267
C. sp. 3	0.0050	0.7500	0.0007	0.0041	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0677**	**103.2500**	**0.0370**	**0.3745**	**0.0771**	**193.3233**	**0.1570**	**0.6293**

Appendix A: (Continued).

Species	Jul-99 DM/Trap (g)	Jul-99 Mean No /Trap	Jul-99 Individual Weight (g) DM	Jul-99 Biomass (g m^{-2})	Aug-99 DM/Trap (g)	Aug-99 Mean No /Trap	Aug-99 Individual Weight (g) DM	Aug-99 Biomass (g m^{-2})
Nilodorum fractilobus	0.0073	26.5000	0.0003	0.0600	0.0040	8.6670	0.0005	0.0337
Michrochironomus/ Harnischia spp?	0.0006	32.5000	0.0001	0.0198	0.0004	0.3333	0.0012	0.0033
Kiefferulus chloronotus	0.0001	27.7500	0.0000	0.0004	0.0012	4.0000	0.0003	0.0101
Dicrotendipes schoutedeni	0.0072	39.7500	0.0002	0.0588	0.0003	0.3333	0.0009	0.0024
Nilodorum brevibucca								
Nilodorum brevipalpe	0.0044	4.7500	0.0009	0.0357	0.0014	2.6667	0.0005	0.0114
Dicrotendipes pilosimanus/fusconotatus								
Polypedilum (Uresipedilum) sp								
All Female	0.0398	0.5000	0.0796	0.3249	0.0225	46.3300	0.0005	0.1834
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0090	44.2500	0.0002	0.0737	0.0009	1.6667	0.0005	0.0073
C. sp. 2								
C. sp. 3								
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica								
Clinotanypus claripennis								
Total	**0.0684**	**176.0000**	**0.0813**	**0.6090**	**0.0317**	**64.9964**	**0.0054**	**0.2598**

Appendix B:

Parameters Used For The Estimation of Production of Chironomidae in Owabi Reservoir

	Mar-98				Apr-98			
Species	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.0000	0.0000	0.0000	0.0000	0.0032	13.5000	0.0023	0.0253
Microchironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0053	61.3300	0.0001	0.0043
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0005	1.6667	0.0003	0.0041
Dicrotendipes schoutedeni	0.0000	0.0000	0.0000	0.0000	0.0028	20.3300	0.0001	0.2323
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0005	19.3333	0.0000	0.0005
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.0528	134.0000	0.0004	0.4266
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0014	0.6667	0.0021	0.0112
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0000	0.0000	0.0000	0.0000	0.8699	195.0000	0.0045	7.0830
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0000	0.0000	0.0000	0.0000	0.0006	6.3333	0.0000	0.0047
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.9370**	**452.1600**	**0.0097**	**7.7919**

Appendix B: (Continued).

Species	May-98 DM/Trap (g)	May-98 Mean No /Trap	May-98 Individual Weight (g) DM	May-98 Biomass (g m^{-2})	Jun-98 DM/Trap (g)	Jun-98 Mean No /Trap	Jun-98 Individual Weight (g) DM	Jun-98 Biomass (g m^{-2})
Nilodorum fractilobus	0.0185	214.0000	0.0001	0.1502	0.1411	128.3330	0.0011	1.1524
Microchironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Kiefferulus chloronotus	0.0059	10.0000	0.0006	0.0048	0.0639	80.0000	0.0001	0.0522
Dicrotendipes schoutedeni	0.0058	27.0000	0.0002	0.0441	0.0239	33.6667	0.0007	0.1924
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0083	393.0000	0.0000	0.0527	0.1052	249.3333	0.0004	0.8141
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0001	1.5000	0.0001	0.0012	0.0000	0.0000	0.0000	0.0000
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0386**	**645.5000**	**0.0010**	**0.2530**	**0.3341**	**491.3330**	**0.0023**	**2.2110**

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Appendix B: (Continued).

Species	Jul-98 DM/Trap (g)	Jul-98 Mean No /Trap	Jul-98 Individ. Weight (g) DM	Jul-98 Biomass (g m^{-2})	Aug-98 DM/Trap (g)	Aug-98 Mean No /Trap	Aug-98 Individ Weight (g) DM	Aug-98 Biomass (g m^{-2})
Nilodorum fractilobus	0.0105	145.0000	0.0007	0.0852	0.0097	39.0000	0.0003	0.0796
Microchironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0004	4.5000	0.0001	0.0037
Kiefferulus chloronotus	0.0540	80.7500	0.0007	0.4410	0.0027	28.0000	0.0001	0.0220
Dicrotendipes schoutedeni	0.0289	17.0000	0.0017	0.2361	0.0013	4.5000	0.0003	0.0110
Nilodorum brevibucca	0.0055	12.7500	0.0004	0.0448	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0593	218.0000	0.0003	0.4841	0.0138	58.5000	0.0000	0.1122
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0000	0.0000	0.0000	0.0000	0.0287	136.2500	0.0002	0.2336
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0001	1.0000	0.0010	0.0082	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis								
Total	**0.1583**	**474.5000**	**0.0049**	**1.2994**	**0.0566**	**270.7500**	**0.0012**	**0.4621**

Appendix B: (Continued).

Species	Sep-98				Oct-98			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.0005	3.0000	0.0002	0.0048	0.0000	0.0000	0.0000	0.0000
Michrochironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0002	0.2500	0.0010	0.0002
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0002	1.5000	0.0001	0.0016
Dicrotendipes schoutedeni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.0001	1.0000	0.0001	0.0004
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0011	5.5000	0.0002	0.0089	0.0000	0.0000	0.0000	0.0000
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0016**	**8.5000**	**0.0004**	**0.0137**	**0.0005**	**2.7500**	**0.0011**	**0.0022**

Appendix B: (Continued)

Species	Nov-98				Dec-98			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.0051	21.3300	0.0002	0.0418	0.0003	0.2500	0.0011	0.0022
Microchironomus/ Harnischia spp?	0.0000	38.6700	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicrotendipes schoutedeni	0.0012	15.0000	0.0001	0.0098	0.0024	1.5000	0.0016	0.0193
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0030
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.2500	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.2500	0.0000	0.0000
All Female	0.0004	50.3300	0.0001	0.0298	0.0010	18.2500	0.0001	0.0016
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0016	4.3300	0.0000	0.0127	0.0007	1.0000	0.0007	0.0057
C. sp. 2								
C. sp. 3								
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica	0.0004	3.3337	0.0001	0.0003	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis								
Total	**0.0120**	**133.3267**	**0.0005**	**0.0946**	**0.0044**	**22.5000**	**0.0035**	**0.0320**

Appendix B: (Continued).

Species	Jan-99 DM/Trap (g)	Jan-99 Mean No /Trap	Jan-99 Individual Weight (g) DM	Jan-99 Biomass (g m^{-2})	Feb-99 DM/Trap (g)	Feb-99 Mean No /Trap	Feb-99 Individual Weight (g) DM	Feb-99 Biomass (g m^{-2})
Nilodorum fractilobus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Microchironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicrotendipes schoutedeni	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

Appendix B: (Continued).

Species	Mar-99				Apr-99			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.0000	0.0000	0.0000	0.0000	0.0022	3.2500	0.0007	0.0186
Microchironomus/ Harnischia spp?	0.0000	0.0000	0.0000	0.0000	0.0004	1.0000	0.0004	0.0003
Kiefferulus chloronotus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicrotendipes schoutedeni	0.0000	0.0000	0.0000	0.0000	0.0014	3.2500	0.0004	0.0117
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0000	0.0000	0.0000	0.0000	0.0000	1.5000	0.0007	0.0082
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0002	0.2500	0.0008	0.0016
Polypedilum (Uresipedilum) sp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All Female	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0000	0.0000	0.0000	0.0000	0.0047	1.4500	0.0010	0.0141
C. sp. 2	0.0036	2.5000	0.0014	0.0294	0.0001	1.0000	0.0001	0.0008
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0016	0.2500	0.0006	0.0131
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0016	0.2500	0.0006	0.0131
Clinotanypus claripennis								
Total	**0.0036**	**2.5000**	**0.0014**	**0.0294**	**0.0116**	**12.2500**	**0.0047**	**0.0684**

Appendix B: (Continued).

Species	May-99 DM/Trap (g)	May-99 Mean No /Trap	May-99 Individual Weight (g) DM	May-99 Biomass (g m^{-2})	Jun-99 DM/Trap (g)	Jun-99 Mean No /Trap	Jun-99 Individual Weight (g) DM	Jun-99 Biomass (g m^{-2})
Nilodorum fractilobus	0.0207	3.0000	0.0069	0.1687	0.0045	10.7500	0.0004	0.0369
Microchironomus/ Harnischia spp?	0.0029	1.0000	0.0029	0.0235	0.0029	0.7500	0.0039	0.0240
Kiefferulus chloronotus	0.0137	0.3333	0.0410	0.1116	0.0033	0.5000	0.0066	0.0269
Dicrotendipes schoutedeni	0.0051	3.3333	0.0015	0.0414	0.0051	3.7500	0.0014	0.0414
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0007	1.6667	0.0004	0.0061	0.0007	12.5000	0.0001	0.0061
Dicrotendipes pilosimanus/fusconotatus	0.0000	0.0000	0.0000	0.0000	0.0004	0.5000	0.0008	0.0031
Polypedilum (Uresipedilum) sp	0.0048	0.3333	0.0143	0.0390	0.0000	0.0000	0.0000	0.0000
All Female	0.0091	0.3333	0.0273	0.0739	0.0000	0.0000	0.0000	0.0000
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chironomus sp. 1 (nr. transvalensis?)	0.0010	2.3333	0.0004	0.0082	0.0024	5.7500	0.0004	0.0200
C. sp. 2	0.0029	5.0000	0.0006	0.0233	0.0000	0.0000	0.0000	0.0000
C. sp. 3								
C. sp. 4								
C. sp. 5								
Ablabesmyia nilotica	0.0004	0.6667	0.0006	0.0034	0.0001	0.0039	0.0000	0.0000
Clinotanypus claripennis								
Total	**0.0613**	**17.9999**	**0.0959**	**0.4991**	**0.0194**	**34.5039**	**0.0136**	**0.1584**

Appendix B: (Continued).

Species	Jul-99				Aug-99			
	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})	DM/Trap (g)	Mean No /Trap	Individual Weight (g) DM	Biomass (g m^{-2})
Nilodorum fractilobus	0.1750	58.5000	0.0003	0.1429	0.0061	8.5000	0.0007	0.0498
Microchironomus/ Harnischia spp?	0.0029	25.2500	0.0001	0.0235	0.0000	0.0000	0.0000	0.0000
Kiefferulus chloronotus	0.0033	7.2500	0.0005	0.0269	0.0000	0.0000	0.0000	0.0000
Dicrotendipes schoutedeni	0.0018	4.2500	0.0004	0.0143	0.0006	0.5000	0.0011	0.0046
Nilodorum brevibucca	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nilodorum brevipalpe	0.0007	4.5000	0.0002	0.0061	0.0000	0.0000	0.0000	0.0000
Dicrotendipes pilosimanus/fusconotatus	0.0002	0.5000	0.0004	0.0014	0.0000	0.0000	0.0000	0.0000
Polypedilum (Uresipedilum) sp	0.0048	2.0000	0.0024	0.0390	0.0000	0.0000	0.0000	0.0000
All Female	0.0948	141.5000	0.0007	0.7739	0.0153	27.5000	0.0006	0.1245
Chironomus imicola	0.0000	0.0000	0.0000	0.0000	0.0037	4.5000	0.0008	0.0298
Chironomus sp. 1 (nr. transvalensis?)	0.0010	0.5000	0.0020	0.0082	0.0037	4.5000	0.0008	0.0038
C. sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C. sp. 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ablabesmyia nilotica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clinotanypus claripennis								
Total	**0.1270**	**244.2500**	**0.0070**	**1.0362**	**0.0294**	**45.5000**	**0.0040**	**0.2125**

Appendix C:

Correlation Matrix for Barekese Reservoir Based on Double Square Root Transformed Variables

	N.f	K.c	D.s	N.brv	N. brp	R.level	Temp	pH
N.f	1.00000							
K.c	.60349	1.00000						
D.s	.02937	.39874	1.00000					
N.brv	.72418	.25742	.04141	1.00000				
N. brp	.51343	.42265	-.27389	.06745	1.00000			
R.level	.10491	.33456	.30656	.15510	.00993	1.00000		
Temp	-.02787	-.20385	-.22241	-.26079	.08044	-.79402	1.00000	
pH	.06500	.02430	.33050	-.04767	-.18919	.26633	.02112	1.00000
Alklnity	.14190	-.20380	-.44604	.20018	.18729	-.18444	-.01996	-.39639
Ca	.10926	-.09587	.16780	.17750	-.15168	.10366	.18788	-.02055
Mg	-.21908	-.13046	.08076	-.03688	-.08107	.38388	-.61890	-.06329
Hdness	-.11254	-.18430	.16195	.02484	-.14537	.46199	-.44918	.02015
Cl	-.01752	-.30368	-.24967	.11460	-.03635	-.32326	.31744	-.21447
DO	-.15093	-.41233	-.45641	.04590	-.07516	-.67841	.51503	-.33348
BOD	-.49986	-.40692	.26755	-.44809	-.53434	-.46180	.40784	.19857
ChlA	-.07111	.17760	-.26784	-.26662	-.00028	-.00334	.13772	.07514
Secchi	-.10002	.06249	.01413	-.22098	.06197	.09218	-.14289	.35310
NH_3	-.20205	-.55314	-.02947	.16632	-.36742	.04248	-.12804	.10357
NO_2	.36652	.07548	-.09190	.49538	-.04793	-.06601	.09317	-.21867
NO_3	.16542	.15690	.17194	.24364	-.03005	.15501	-.41361	-.13628
SO_4	.10994	-.15354	-.31420	.39565	-.02912	.49070	-.36336	.07653
PO_4	-.27401	-.27354	-.26131	-.12743	-.25164	-.00427	-.30895	-.08413
SiO_2	.06802	-.00825	-.08852	.07241	.24367	.50903	-.27787	.12905
SS	-.23748	-.14896	.25711	-.28865	-.15964	-.48690	.46066	-.05277
Turbid	-.21466	-.30983	-.01839	-.21718	-.06762	-.61474	.60378	-.28437
Cond	.05680	.22963	-.04507	.01048	.18642	-.18757	-.04289	-.53827
TDS	-.10258	-.05215	.14875	-.00521	-.09351	-.06669	.01503	-.06517

	Acidity	Alklnity	Ca	Mg	Hdness	Cl	DO	BOD
Acidity	1.00000							
Alklnity	-.29240	1.00000						
Ca	.34263	-.14144	1.00000					
Mg	-.23790	.10965	-.28145	1.00000				
Hdness	-.11589	.02850	.28001	.81529	1.00000			
Cl	-.18311	.36959	.32541	-.17307	-.04017	1.00000		
DO	-.31741	.27135	-.07903	-.31676	-.36001	.45848	1.00000	
BOD	-.18168	-.47385	.08027	.01200	.07768	-.10901	.16102	1.00000
ChlA	-.26739	-.07578	-.08978	.16289	.16085	-.25723	-.06620	-.00578
Secchi	-.01587	-.43564	-.30749	.19256	.03834	-.07319	.14134	.23120
NH_3	.20039	.01072	.42060	.36408	.52351	.53449	-.03739	.19919
NO_2	-.11901	.53270	.24548	-.30876	-.14894	.60823	.47211	-.38874
NO_3	-.02194	.21500	-.28473	.19024	-.06268	.22024	-.28668	-.23307
SO_4	.31235	.30226	.19035	.24508	.36864	.19698	-.02802	-.47607
PO_4	-.31868	.21368	-.54037	.58012	.31207	-.37838	.11270	.18553

Appendix C: (Continued).

	Chl. A	Secchi	NH_3	NO_2	NO_3	SO_4	PO_4	SiO_2	NH_3
NH_3	-.22297	.00081	1.00000						
NO_2	-.22656	-.15617	.00146	1.00000					
NO_3	-.54730	-.16412	.24711	.09257	1.00000				
SO_4	.13222	.03393	.32260	.40303	-.12100	1.00000			
PO_4	.23734	.14698	-.10410	-.22662	-.03704	-.02444	1.00000		
SiO_2	.18254	.30022	.30388	-.14485	-.28919	.45431	-.25822	1.00000	
SS	.04246	-.06370	.24496	-.39458	-.18301	-.64733	-.23983	-.07148	
Turbid	-.14559	.00668	.30499	.12889	-.16356	-.42928	-.16425	-.06263	
Cond	.09982	-.44655	-.36056	.12993	.28973	-.21831	.07951	-.30721	
TDS	-.63699	-.10466	-.06815	.34940	.45055	-.23803	-.10514	-.49523	

	SS	Turbid	Cond	TDS
SS	1.00000			
Turbid	.65667	1.00000		
Cond	-.02982	-.13235	1.00000	
TDS	-.02132	.15338	.08049	1.00000

CRITICAL VALUE (1-TAIL, .05) = +/- 0.40096
CRITICAL VALUE (2-tail, .05) = +/- 0.46696

N = 18

Appendix D:

Correlation Matrix for Owabi Reservoir Based on Double Square Root Transformed Variables

	N.f	K.c	D,s	N.brv	N.brp.	R.Level	Temp	pH
N.f	1.00000							
K.c	.87730	1.00000						
D,s	.76776	.70595	1.00000					
N.brv	.27600	.36253	.54630	1.00000				
N.brp.	.83821	.85242	.78088	.54035	1.00000			
R.Level	-.14910	-.31965	-.35143	-.03540	-.32058	1.00000		
Temp	-.07656	-.12282	.19972	.29049	.17864	-.32501	1.00000	
pH	.14425	.04386	.20818	-.03071	.21753	.19284	.01942	1.00000
Acidity	.18308	.17027	-.04720	-.07939	-.07426	.40091	-.70347	.16004
Alknity	.06742	.20621	.19533	.21439	.39764	-.31567	.22741	-.08038
Ca	.47261	.51772	.52734	.43781	.63369	-.37067	.37852	-.13422
Mg	.05632	-.00235	.10173	-.01028	.04325	-.06801	-.29343	.32500
Hdness	.35101	.48137	.42592	.41060	.61324	-.43585	.04205	-.19333
Cl	.11077	.20346	.12457	.35969	.38808	-.10016	.22350	-.40869
DO	.02562	.07621	.00502	-.17248	.11972	-.55275	.39384	-.40426
BOD	-.41519	-.54695	-.37516	.05999	-.35678	.08351	.28256	-.19586
ChlA	.37268	.12861	.03767	-.09594	.42600	.13602	.29851	.29679
Secchi	-.51230	-.38272	-.51741	-.31536	-.53976	.47625	-.42894	.04552
NH_3	.61619	.62457	.62423	.54970	.52674	-.01528	.02109	.05588
NO_2	.30158	.16831	.38692	.30514	.55940	-.03268	.42521	.20501
NO_3	.60309	.65298	.47533	.23593	.70642	.01669	.06768	.25391
SO_4	.09817	.23517	-.10316	-.33254	-.16626	.19509	-.57972	-.15653
PO_4	-.19108	.01990	-.05866	.03232	-.00402	.10329	-.11469	-.03438
SiO_2	-.00470	-.12390	.23463	.29062	-.06336	.51532	-.34181	.40683
SS	.07717	-.14670	.27896	-.09579	-.09532	.13367	.05625	.00466
Turbid	.43105	.16049	.15385	.06296	.12441	.29745	-.24761	-.14179
Conduct	.01906	.09378	-.38269	-.69358	-.28101	.06531	-.34598	-.09101
TDS	.06059	.05054	.18042	.23135	.34622	-.66326	.57869	-.24467

	Acidity	Alknity	Ca	Mg	Hdness	Cl	DO	BOD
Acidity	1.00000							
Alknity	-.55036	1.00000						
Ca	-.45881	.56891	1.00000					
Mg	-.03163	.16741	.16069	1.00000				
Hdness	-.25538	.74726	.71386	.24711	1.00000			
Cl	-.35437	.79564	.49599	-.21866	.73589	1.00000		
DO	-.40168	.36510	.49724	-.22225	.36208	.37998	1.00000	
BOD	-.01514	-.27404	-.00442	.01157	-.22110	-.11546	.17182	1.00000
ChlA	-.19889	.16152	.12638	-.08907	.05060	.21796	.13744	-.00801
Secchi	.31383	-.15758	-.62486	-.12001	-.33120	-.13448	-.33018	-.22075
NH_3	.39273	-.18904	.24511	-.03904	.08909	-.00371	-.16962	-.04202
NO_2	-.40731	.58200	.57757	-.14000	.47798	.57100	.24813	.00747
NO_3	.02138	.42147	.26879	-.11953	.35707	.44759	-.15092	-.53849
SO_4	.53925	-.22808	-.26250	-.35241	-.09986	-.06846	-.00574	-.52164
PO_4	-.07707	.60762	-.12684	-.18526	.20317	.52418	-.12330	-.47845

Appendix D (Continued).

	ChlA	Secchi	NH_3	NO_2	NO_3	SO_4	PO_4	SiO_2
NH_3	-.12613	-.33700	1.00000					
NO_2	.54168	-.38560	-.08255	1.00000				
NO_3	.39474	-.08709	.44526	.42175	1.00000			
SO_4	-.35961	.51069	.06965	-.36252	.09094	1.00000		
PO_4	-.15458	.49912	-.12584	.15645	.47466	.25715	1.00000	
SiO_2	-.25426	.29015	.22482	-.02000	.10242	.10755	.22910	1.00000
SS	-.05432	.21436	-.25574	.28095	-.06156	.14869	.18822	.29803
Turbid	.21959	-.31649	.54049	-.16327	.15956	-.05983	-.29939	.25798
Conduct	.07933	.28791	-.23939	-.49350	-.06479	.55406	-.00603	-.42603
TDS	.30579	-.58633	-.07514	.44170	.03376	-.64596	-.06667	-.49326

	SS	Turbid	Conduct	TDS
SS	1.00000			
Turbid	-.16485	1.00000		
Conduct	-.07076	-.06583	1.00000	
TDS	-.12809	-.05795	-.42421	1.00000

CRITICAL VALUE (1-TAIL, .05) = +/- 0.40096
CRITICAL VALUE (2-tail, .05) = +/- 0.46696

N = 18

Appendix E:

Results of Multiple Regression Analysis of Barekese Variables on Commonly Occurring Chironomidae Using "Microstat" Software.

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:BARESQRT LABEL: Bare Square root Transformed Data
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 1. Regression of Double Square Root Transformed variables on *Nilodorum fractilobus* of Barekese Reservoir .

INDEX	NAME	MEAN	STD.DEV.
1	BOD	1.3877	.0703
DEP. VAR.:	N.f	2.2610	1.1485

DEPENDENT VARIABLE: N.f

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 16)	PROB.
BOD	-8.1639	3.5364	-2.309	.03466
CONSTANT	13.5903			

STD. ERROR OF EST. = 1.0253

r SQUARED = .2499
r = -.4999

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	5.6027	1	5.6027	5.329	.0347
RESIDUAL	16.8206	16	1.0513		
TOTAL	22.4233	17			

DURBIN-WATSON TEST = 2.3825

Appendix E (Continued).

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:BARESQRT LABEL: Bare Square root Transformed Data
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 2. Regression of Double Square Root Transformed variables on *Kiefferulus chloronotus* of Barekese Reservoir .

INDEX	NAME	MEAN	STD.DEV.
1	DO	1.5952	.0304
2	NH_3	.7106	.1209
3	PO_4	.4938	.1176
DEP. VAR.:	K.c	1.7371	.6724

DEPENDENT VARIABLE: K.c

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 14)	PROB.	PARTIAL r^2
DO	-8.7305	3.7864	-2.306	.03694	.2752
NH_3	-3.1717	.9447	-3.357	.00469	.4460
PO_4	1.8463	.9781	1.888	.07999	.2029
CONSTANT	17.0061				

STD. ERROR OF EST. = .4707

ADJUSTED R SQUARED = .5100
R SQUARED = .5964
MULTIPLE R = .7723

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	4.5846	3	1.5282	6.897	4.403E-03
RESIDUAL	3.1020	14	.2216		
TOTAL	7.6866	17			

DURBIN-WATSON TEST = 2.2074

Appendix E (Continued).

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:BARESQRT LABEL: Bare Square root Transformed Data
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 3. Regression of Double Square Root Transformed variables on ***Nilodorum brevibucca*** of Barekese Reservoir .

INDEX	NAME	MEAN	STD.DEV.
1	Acidity	1.8441	.0516
2	NO_2	.3995	.0917
DEP. VAR.:	N.brv	1.2330	.4563

DEPENDENT VARIABLE: N.brv

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 15)	PROB.	PARTIAL r^2
Acidity	3.8711	1.7313	2.236	.04097	.2500
NO_2	2.7233	.9732	2.798	.01351	.3430
CONSTANT	-6.9937				

STD. ERROR OF EST. = .3654

ADJUSTED R SQUARED = .3586
R SQUARED = .4340
MULTIPLE R = .6588

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	1.5363	2	.7682	5.752	.0140
RESIDUAL	2.0032	15	.1335		
TOTAL	3.5395	17			

DURBIN-WATSON TEST = 2.9477

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Appendix E (Continued).

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:BARESQRT LABEL: Bare Square root Transformed Data
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 4. Regression of Double Square Root Transformed variables on *Nilodorum brevipalpe* of Barekese Reservoir.

INDEX	NAME	MEAN	STD.DEV.
1	BOD	1.3877	.0703
2	NH_3	.7106	.1209
DEP. VAR.:	N. brp	2.1940	1.1840

DEPENDENT VARIABLE: N. brp

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 15)	PROB.	PARTIAL r^2
BOD	-8.0855	3.5589	-2.272	.03824	.2560
NH_3	-2.6608	2.0694	-1.286	.21801	.0993
CONSTANT	15.3052				

STD. ERROR OF EST. = 1.0112

ADJUSTED R SQUARED = .2706
R SQUARED = .3565
MULTIPLE R = .5970

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	8.4947	2	4.2473	4.154	.0367
RESIDUAL	15.3365	15	1.0224		
TOTAL	23.8312	17			

DURBIN-WATSON TEST = 2.2147

Appendix F:

Results of Multiple Regression Analysis of Owabi Variables on Commonly Occurring Chironomidae Using "Microstat' Statistical Package.

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:OWABSQRT LABEL: Owabi Sqrt Consolidated data for regress
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 5. Regression of Double Square Root Transformed Variables on *Nilodorum fractilobus* of Owabi Reservoir.

INDEX	NAME	MEAN	STD.DEV.
1	Turbid	1.4832	.2158
2	Ca	2.0136	.1235
3	BOD	1.4123	.0851
DEP. VAR.:	N.f	1.7749	.8266

DEPENDENT VARIABLE: N.f

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 14)	PROB.	PARTIAL r^2
Turbid	2.3409	.5296	4.420	.00058	.5825
Ca	3.7969	.9116	4.165	.00095	.5534
BOD	-5.0398	1.3260	-3.801	.00195	.5079
CONSTANT	-2.2249				

STD. ERROR OF EST. = .4581

ADJUSTED R SQUARED = .6928
R SQUARED = .7470
MULTIPLE R = .8643

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	8.6760	3	2.8920	13.780	1.838E-04
RESIDUAL	2.9382	14	.2099		
TOTAL	11.6142	17			

DURBIN-WATSON TEST = 1.7195

Appendix F (Continued).

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:OWABSQRT LABEL: Owabi Sqrt Consolidated data for regress
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 6.Regression of Double Square Root Transformed Variables on *Kiefferulus chloronotus* of Owabi Reservoir.

INDEX	NAME	MEAN	STD.DEV.
1	Ca	2.0136	.1235
2	BOD	1.4123	.0851
3	NH_3	.7158	.1498
DEP. VAR.:	K.c	1.3892	.6622

DEPENDENT VARIABLE: K.c

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 14)	PROB.	PARTIAL r^2
Ca	2.0980	.6519	3.218	.00619	.4252
BOD	-4.0759	.9176	-4.442	.00056	.5849
NH_3	2.2403	.5380	4.164	.00095	.5533
CONSTANT	1.3177				

STD. ERROR OF EST. = .3218

ADJUSTED R SQUARED = .7639
R SQUARED = .8056
MULTIPLE R = .8975

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	6.0045	3	2.0015	19.333	3.008E-05
RESIDUAL	1.4494	14	.1035		
TOTAL	7.4538	17			

DURBIN-WATSON TEST = 1.3915

Appendix F (continued)

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:OWABSQRT LABEL: Owabi Sqrt Consolidated data for regress.
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28
Model 7. Regression of Double Square Root Transformed
Variables on *Dicrotendipes schoutedeni* of Owabi Reservoir.

INDEX	NAME	MEAN	STD.DEV.
1	Hardness	2.7350	.0694
2	NH_3	.7158	.1498
DEP. VAR.:	D,s	1.4160	.4069

DEPENDENT VARIABLE: D.s.

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 15)	PROB.	PARTIAL r^2
Hardness	2.1880	1.0441	2.096	.05349	.2265
NH_3	1.6058	.4840	3.318	.00468	.4233
CONSTANT	-5.7176				

STD. ERROR OF EST. = .2977

ADJUSTED R SQUARED = .4649
R SQUARED = .5279
MULTIPLE R = .7266

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	1.4860	2	.7430	8.386	3.592E-03
RESIDUAL	1.3290	15	.0886		
TOTAL	2.8150	17			

DURBIN-WATSON TEST = 1.4108

Appendix F (Continued)

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:OWABSQRT LABEL: Owabi Sqrt Consolidated data for regress
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 8. Regression of Double Square Root Transformed
Variables on *Nilodorum brevibucca* of Owabi reservoir.

INDEX	NAME	MEAN	STD.DEV.
1	Cl	2.1615	.1823
2	NH3	.7158	.1498
3	Conduct	3.6839	.6210
DEP. VAR.:	N.brv	1.1186	.3090

DEPENDENT VARIABLE: N.brv

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 14)	PROB.	PARTIAL r^2
Cl	.3065	.2797	1.096	.29168	.0790
NH3	.8733	.3297	2.649	.01907	.3338
Conduct	-.2640	.0845	-3.123	.00748	.4107
CONSTANT	.8038				

STD. ERROR OF EST. = .1968

ADJUSTED R SQUARED = .5943
R SQUARED = .6659
MULTIPLE R = .8160

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	1.0805	3	.3602	9.300	1.229E-03
RESIDUAL	.5422	14	.0387		
TOTAL	1.6228	17			

DURBIN-WATSON TEST = 2.7037

Appendix F (Continued)

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: A:OWABSQRT LABEL: Owabi Sqrt Consolidated data for regress
NUMBER OF CASES: 18 NUMBER OF VARIABLES: 28

Model 9. Regression of Double Square Root Transformed
Variables on *Nilodorum brevipalpe* of Owabi Reservoir.

INDEX	NAME	MEAN	STD.DEV.
1	Hdness	2.7350	.0694
2	ChlA	3.0512	4.3178
3	NH3	.7158	.1498
4	NO3	.7147	.0900
DEP. VAR.:	N.brp.	1.7652	1.1062

DEPENDENT VARIABLE: N.brp.

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 13)	PROB.	PARTIAL r^2
Hdness	7.8146	1.9810	3.945	.00168	.5448
ChlA	.0997	.0347	2.874	.01304	.3885
NH3	3.3532	1.0241	3.274	.00604	.4520
NO3	2.1587	1.9696	1.096	.29296	.0846
CONSTANT	-23.8551				

STD. ERROR OF EST. = .5221

ADJUSTED R SQUARED = .7772
R SQUARED = .8297
MULTIPLE R = .9109

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	17.2589	4	4.3147	15.830	6.445E-05
RESIDUAL	3.5435	13	.2726		
TOTAL	20.8024	17			

DURBIN-WATSON TEST = 1.7920