# Some Observations on Macro-invertebrate Benthos of Lake Volta at Yeji Area (Stratum VII) Thirty Years after Impoundment

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**Abstract**

Quantitative samples taken from the bottom of Lake Volta at various depths of water were studied to monitor the seasonal as well as depth distribution of macro-invertebrates in the sediments. Macro-invertebrates occurred in sediments collected from all depths. The densities were highest between the shore and depths of 8-10 m. Macro-invertebrates were most abundant in July and least in May. The diversity of macrobenthos had reduced considerably. Generally, Chironominae were abundant while Orthocladiinae and Ephemeroptera were scarce in the sediments compared to what was found during the formative years of the lake. The observed change in the composition of benthos was attributed mainly to increasing anthropogenic influences exerted on the lake as evidenced by the changing chemistry of the lake water at Yeji.

## Introduction

Lake Volta in Ghana was formed in 1964 as a result of the construction of a hydroelectric dam on River Volta at Akosombo. Between 1960 and 1970 construction of large dams became commonplace in Africa, and man-made lakes such as Koussou in Côte d'Ivoire, Kariba in Zimbabwe and Kainji in Nigeria were all formed during this period.

Earlier studies conducted on Lake Volta covered limnology and hydrobiology (Viner 1970a, 1970b; Lawson *et al.*, 1969), phytoplankton populations (Biswas, 1969, 1972), fisheries (Vanderpuye, 1972; Petr, 1967, 1969a, 1974a) and benthic fauna (Petr 1969b, 1972, 1974b). Ecological studies on Lake Volta, however, could not be sustained at the same pace and by 1984 scientific studies had virtually come to a standstill (Petr 1986). Scientific study of the lake has been reviewed recently, following two severe droughts in the sub-region during 1972/73 and 1983/84, which drastically reduced the water level of the lake. The lake is being used increasingly as a transportation route from the south to the north of Ghana. In addition, it is an important source of fish for both domestic consumption and export. Thus, there is an urgent need for studying the ecology of the lake to ensure sustainable exploitation of the lake's resources.

A recent study focussed on the limnology and fishery of the lake (Ofori-Danson & Antwi, 1994). This study examined the occurrence, composition, densities and distribution of macro-invertebrates in the sediments of the lake 30 years after its formation. The present study forms part of an on-going project that seeks to relate the densities of macro-invertebrates to oxygen concentration levels and depths at which macro-invertebrates occur in the Volta Lake.

## Materials and methods

Lake Volta stretches from latitude 6° 15' N to latitude 9° 10' N and lies between longitude 0° 30' E and longitude 1° 30' W. It covers an area of approximately 8200 km$^2$ with a mean depth of 30 m. The lake is highly dendritic and heterogeneous. It also traverses most of the major ecological zones of the country. To facilitate the study of the lake, therefore, Evans & Vanderpuye (1973) divided the lake into eight strata or sections. All locations within each stratum were considered similar but differed from all other locations outside a particular stratum with respect to prevailing meteorological, physico-chemical and hydrological conditions. The study was conducted in the Yeji area of the lake (Fig. 1), i.e. stratum VII according to Evans & Vanderpuye (1973). This area lies within the river-lake transition zone (Petr, 1974b). The maximum depth of water in this stratum varied between 14 and 19 m. The stratum is influenced throughout the year by inflows of water from the White Volta and Black Volta rivers especially during the rainy season (Petr, 1969a).

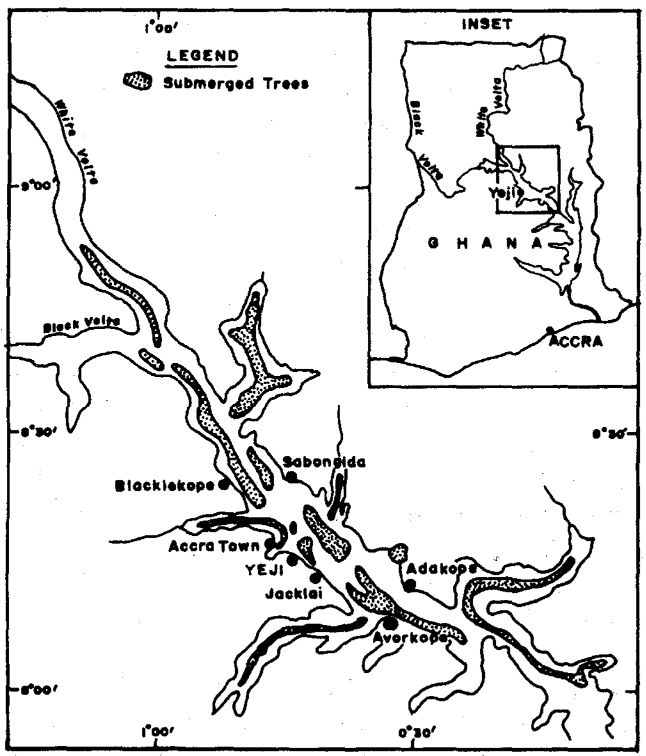

Fig. 1. Map of Lake Volta showing study area and locations of sampling sites

Bottom sediments were collected from six sites (Blackiekope, Sabongida, Accra Town, Jacklai, Adakope and Avorkope), all in the Yeji area of the Lake Volta, every other month from March 1995 until January 1996. Blackiekope and Sabongida represented the northern segment of the stratum VII, Jacklai and Accra Town the middle segment and Adakope and Avorkope the southern segment of the Stratum. An Ekman grab with an effective sampling area of 0.0225 m$^2$ and operated from a boat was used for the collection of the bottom sediments. Two to five Ekman grab samples of the bottom sediments were collected from the bottom lying at various depths at the six sites. It was not possible to visit all the six sites on each visit for logistic reasons. However, it was ensured that at least one site from each sector of the stratum was sampled on each visit.

Each sample was washed through 210-µm mesh, nitex net to remove mud and other fine particulate matter. The benthos retained by the net was preserved in 70% ethanol and examined in the laboratory under a dissecting microscope. The macro-invertebrates were sorted out into their major taxonomic groups, identified and counted. Generally, the macro-invertebrates were identified to the family level. In a few cases, however, identification was possible to the genus level. Mean densities of the macro-invertebrates at the various depths sampled were estimated. The data from all stations were considered as coming from the same habitat, and proportions of the commonly occurring macro-invertebrate groups at the various depths calculated.

In addition, water samples (vertical profile) were taken for analysis to assess the temperature, *p*H, oxygen saturation, Biochemical Oxygen Demand (BOD), alkalinity, total hardness, total dissolved solids and conductivity. Sodium, potassium, calcium, magnesium, chloride, phosphate, nitrate, nitrite, ammonia, silicate and sulphate concentrations were also estimated. A one litre Bio-Hydro water sampler was used for the collection of water samples. Temperature, *p*H, total dissolved solids and conductivity of the water were measured in the field with the aid of portable meters (Hach Kits). Transparency of the water was measured with a Secchi disc. The transparency was estimated as the depth at which the disc just disappeared.

Dissolved oxygen was measured in the field with a Dissolved Oxygen (DO) meter (YSI Model 51B Oxygen meter). $BOD_5$ was estimated by using the azide modification of the Winkler method. Dissolved oxygen in the water was measured on the first day. The sample was then diluted and incubated at 20 °C in the dark for 5 days after which residual oxygen in the incubated bottle was again measured. The remaining water was stored in wide-mouthed plastic bottles, kept in a refrigerator at Yeji, transported to the laboratory in Accra in a cold box and kept refrigerated until analysed. Methods of analyses followed those outlined in the Standard Methods for the Examination of Water and Waste Water (American Public Health Association, American Water Works Association & Water Pollution Control Association, 1996).

Total Hardness (TH) was estimated by titration with EDTA against Murexide indicator. Alkalinity was measured by double titration with acid against phenolphthalein and methyl orange indicators at *p*H of 4.5. Acidity was estimated by titration with a strong alkali against phenolphthalein indicator. Nitrate was estimated by the hydrazine reduction method. Nitrate in the sample was reduced to nitrite with hydrazine phosphate followed by diazotisation and coupling with N-(1-naphthyl-)-ethylenediamine dihydrochloride to form an intensely coloured azo dye which was measured on a spectrophotometer at 520 nm.

Estimation of nitrite concentration followed the direct diazotisation method. Nitrite was made to form a diazo compound in a strongly acidic medium. The diazo compound formed was then passed through the same procedure as for nitrates to form a red-coloured azo compound; and the intensity of the colour measured on a spectrophotometer at 540 nm. Ammonia was estimated through direct nesslerisation of the sample followed by measurement of intensity of the colour formed at 410 nm.

The ascorbic acid method was used for estimation of total phosphate concentration in the sample. Ammonium molybdate was added to the sample to form molybdophosphoric acid followed by addition of ascorbic acid, which reduced the molybdophosphoric acid into an intense blue colour. Intensity of the colour was measured at 880 nm. The argentometric method was followed in estimation of chloride concentration. Silver nitrate was titrated against a potassium chloride indicator.

For sulphate concentration, the absorbance of $BaSO_4$ was measured at 420 nm after precipitation by addition of barium chloride to the sample and determination of concentration by reading the corresponding value from a standard curve. In the case of silicates, ammonium molybdate was added to the sample to produce heteropoly acids with the phosphates and silicates present. Oxalic acid was added to the sample to remove the molybdophosphoric acid and the intensity of the yellow colour developed measured at 410 nm.

Potassium and sodium were measured on a flame photometer. Calcium concentration was estimated by titration with EDTA against Murexide indicator and magnesium, by principle, the difference between TH and calcium hardness multiplied by a correction factor (0.243). All spectrophotometric measurements were performed on UN/VIS Ultraspec II (model 80-2091-73) spectrophotometer located at WRI; and all chemical analyses were completed within 14 days of sample collection.

## Results and discussion

*Physico-chemical parameters*

Dissolved oxygen (DO) levels were high at all depths sampled. Oxygen concentrations, tended to decrease with depth (Fig. 2a–

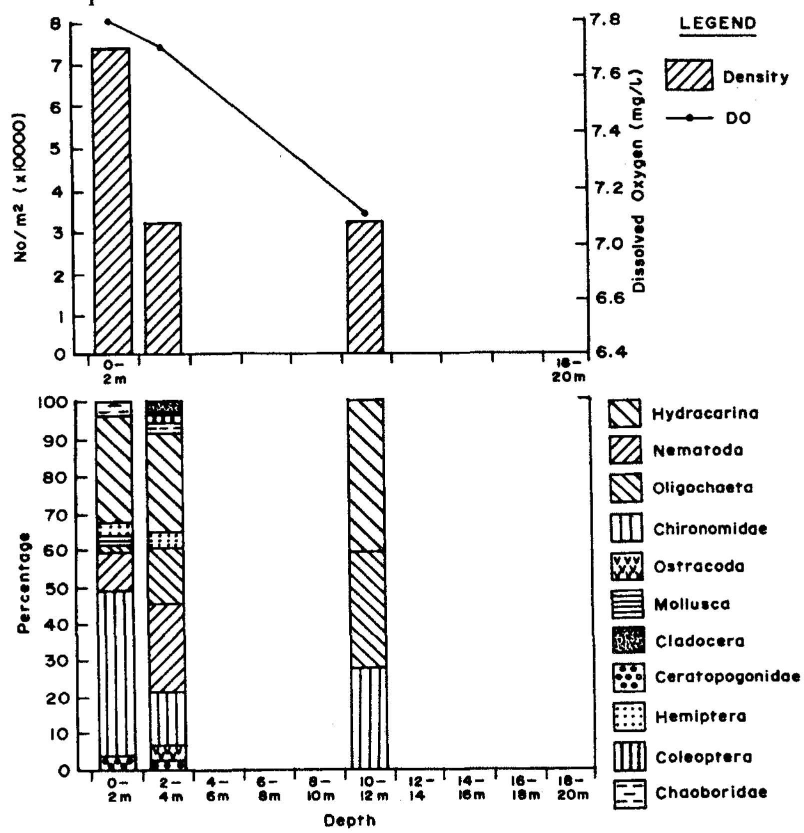


Fig. 2a. Density of macro-invertebrates collected from various depths of Lake Volta and the percentages of the dominant groups present in the sediments, March 1995

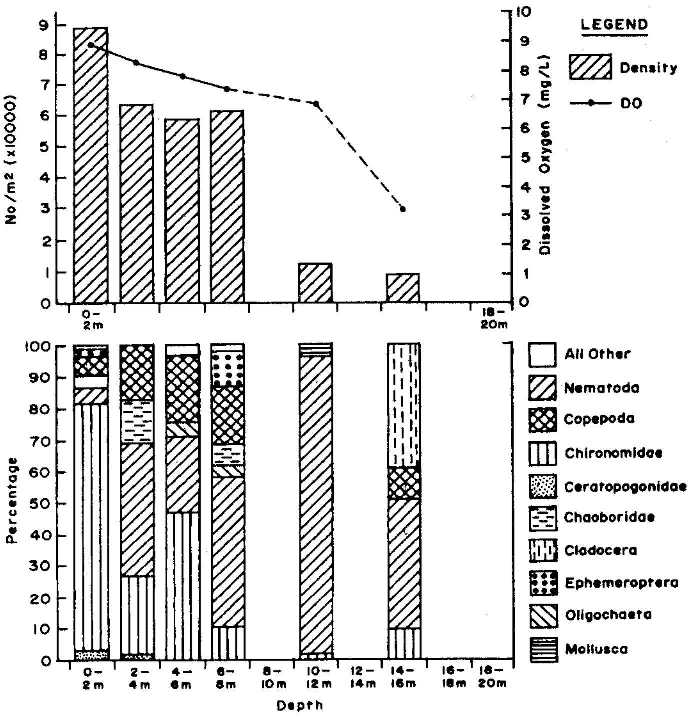


Fig. 2b. Density of macro-invertebrates collected from various depths of Lake Volta and the percentages of the dominant groups present in the sediments, May 1995

2e). With the exception of dissolved oxygen, very little variation was observed in the other physico-chemical parameters (Table 1). The lowest DO occurred in May (41.1%, 3.0 mg$L^{-1}$) at about 16 m (Fig. 2b) whereas the highest DO (123%, 9.3 mg L-$^{1}$) occurred in the inshore areas of the lake in May and July 1995 (Fig. 2b, 2c). The levels of macro-nutrients ($NO_3$, $NO_2$, $NH_3$-N and Phosphate) also were high (Table 1 &2).

*Abundance of macro-invertebrates*

Macro-invertebrates occurred in all the bottom samples that were examined. Most invertebrate groups were not found in sediments collected from below 18 m. Only the Chironomidae were found at water depths lower than 18 m. Macro-invertebrate abundance followed a seasonal trend. Densities were higher during the rainy season (May to September/ October) than in the dry season (February/March or April) (Fig. 3). The highest benthos standing stock was estimated to be 108,824 individuals $m^{-2}$ in July 1995 whereas the lowest recorded was 41,863 individuals $m^{-2}$ in May 1995.

Macro-invertebrates that were common in the sediments included the Chironomidae (Chironominae), Micro-crustacea (Cladocera and Ostracoda), Gastropoda, Ephemeroptera, Trichoptera, Hydracarina, Annelida and Nematoda. It was observed, in general, that higher standing stocks of macro-invertebrates occurred between the shoreline and 8 m depth isoline than in deeper waters of the lake (Fig. 2a – 2e).

*Composition and distribution of macro-invertebrates*

The composition of macro-invertebrates found in the sediments of Lake Volta varied in time and space. The inshore sediments in March 1995 were dominated by Chironomidae (0-2 m) and Hydracarina (2 – 4 m) whereas the offshore sediments (10 – 12 m) were dominated by Hydracarina (Fig. 2a). In May 1995, the inshore sediments were dominated by Chironomidae (0–2 m; 4 – 6 m) and Nematoda (2–4 m; 6–8 m) while the offshore sediments were dominated by Chironomidae (10–12 m) and Cladocera and Nematoda (14–16 m) (Fig. 2b). Generally the Ephemeroptera were

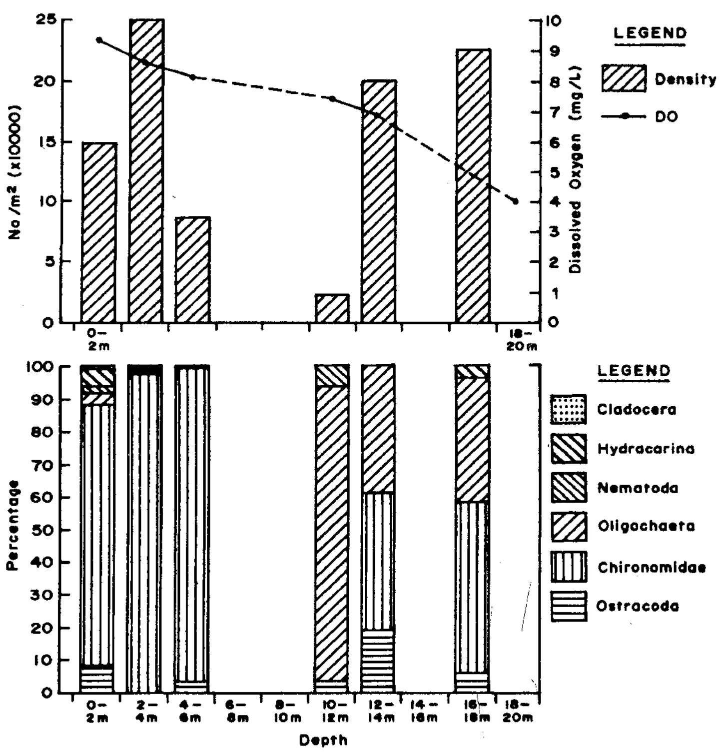


Fig. 2c. Density of macro-invertebrates collected from various depths of Lake Volta and the percentages of the dominant groups present in the sediments, July 1995

found at between 0.5 and 1.0 m depth. The micro- crustacea occurred at most depths but tended to be abundant at the inshore areas (0-2 m). Hydracarina and Hemiptera were found in the coves and bays along the shoreline. Trends in occurrence of the other groups were not clear-cut. However, the situation could be due to other biotic and abiotic factors such as the position of the thermocline and oxygen content of the water (Petr, 1974b).

The Chironomidae were the dominant group in the inshore sediments (0–2, 2–4 and 4–6 m) in July 1995. The offshore sediments, on the other hand, were dominated by Nematoda (10–12 m), Chironomidae and Nematoda (12–14 m; 16–18 m) (Fig. 2c). In September 1995, however, when the rainy season was coming to an end, the Chironomidae dominated both the inshore and offshore sediments (Fig. 2d). This condition persisted into January 1996 when, with the exception of sediments from 12–14 m where Ostracoda were dominant, all the inshore and offshore samples were dominated by Chironomidae (Fig. 2e).

The Chironomidae (mainly Chironominae) constituted about 90% of the total macro-invertebrate benthos that was collected. In addition, they were the only group that was found beyond 20 m depth. Thus, they constituted the most abundant macro-invertebrate food resource available for use by fish in the lake.

The density of macro-invertebrates recorded in the sediments of Lake Volta at Yeji during the formative years ranged between 780 and 1850 individuals $m^{-2}$ (Petr, 1974b). The density of macro-invertebrates observed in sediments of Lake Volta at Yeji, in this study, ranged from 41,803 to 108,824 individuals $m^{-2}$. This shows a 58-fold increase in the number of macro-invertebrates at the bottom of the lake.

The density of benthos of Lake Volta is about five times that of the benthos of Lake Winnipeg (8,919 $m^{-2}$), a temperate lake

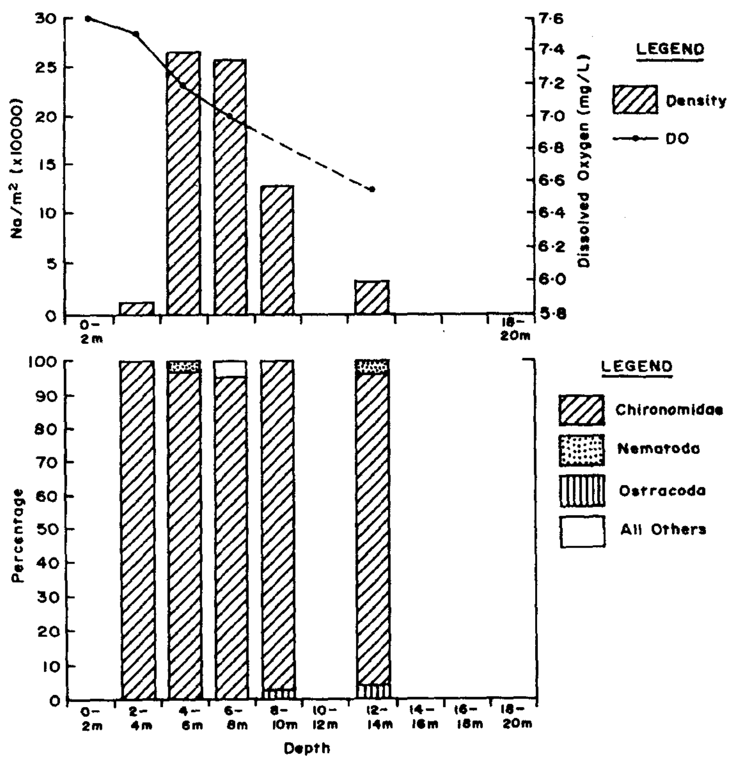


Fig. 2d. Density of macro-invertebrates collected from various depths of Lake Volta and the percentages of the dominant groups present in the sediments, September 1995

(Hamilton *et al.*, 1970). It compares also with a density of 1994 individuals $m^{-2}$ observed in Lake Chivero in Zimbabwe (Marshall, 1995). Thus, the density of macro-invertebrates of Lake Volta is between 40 and 100 times the density of benthos of Lake Chivero (a tropical lake of the same age). However, the dominant macro-invertebrate groups of the two lakes are different. Whereas Lake Chivero, an eutrophic reservoir, was dominated by *Molluscs* (especially *Melanoides tuberculata*), the benthos of Lake Volta at Yeji was dominated by Chironomidae.

Petr (1969b, 1974b) observed during the formative years of Lake Volta that the highest biomass of benthos in the Yeji area of Lake Volta occurred during the period of stratification (in the hot season in April). He also observed that at this time of the year, the depth limit to which benthos could be found was 5 m. This depth coincided with the position of the thermocline (Petr, 1969b, 1974b). In the wet season, however, the distribution of the benthos was uniform and species tended to spread into deeper waters. In the present study, however, the highest population density was observed in July (wet season) when the lake water was rising, whereas the lowest density was observed in May (at the close of the hot season) (Fig. 3). This seasonal pattern of distribution may be due to availability of fresh food resource and to the generally improved oxygen levels in the lake during the rainy season as compared to the dry season.

McLachlan (1970) noted in Lake Kariba that as the lake water rises fresh vegetation becomes inundated. These decompose and increase nutrient and detritus inputs to the lake. Under such conditions, an increase in the abundance of Chironomidae was observed at the bottom of Lake Kariba. Similarly, as the Lake Volta water rises in the Yeji area, vegetation on the flood plains becomes inundated. Thus, fresh detritus becomes available for use by detritivores

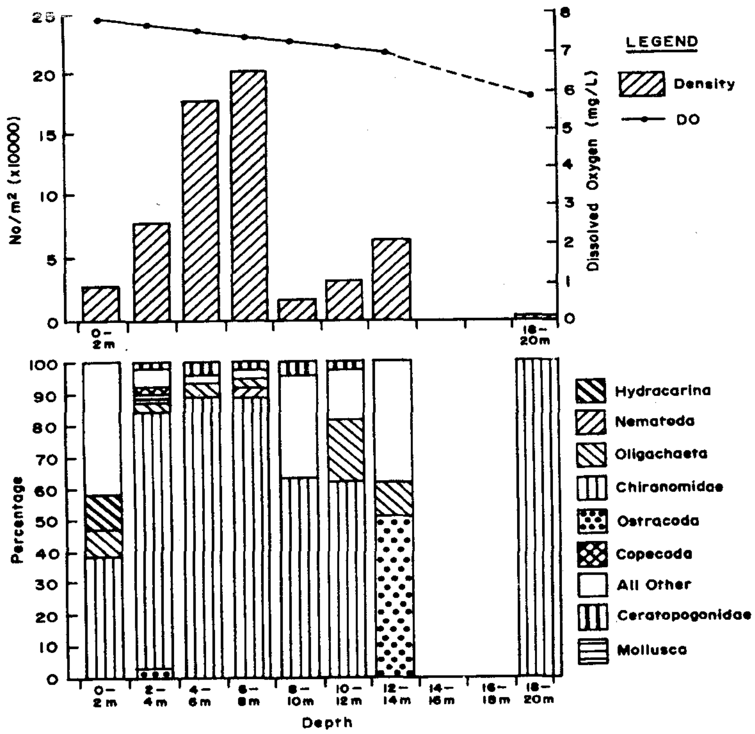


Fig. 2e. Density of macro-invertebrates collected from various depths of Lake Volta and percentages of the dominant groups present in the sediments, January 1996.

especially Chironomidae leading to their enhanced growth and proliferation in Lake Volta.

One of the more important factors that determines the depth at which macro-invertebrates may be found in lakes and reservoirs is the dissolved oxygen content of the water (Hynes, 1969; Jónasson, 1978). Petr (1969b) observed that the critical oxygen level for the distribution of benthos in the Yeji Area was 30% saturation. This concentration coincided with the 5-m depth isoline. Marshall (1978) observed a similar situation in Lake McIlwaine (Zimbabwe) where most of the benthos was restricted to 8 m (below which no animals were found).

The lowest oxygen saturation observed at Yeji during the present study was 41.1% (3.0 mg $l^{-1}$) at about 16 m. This is a considerable improve-ment in oxygen when compared to the observations made by Petr (1969b). This may be partly responsible for the occurrence of invertebrates at the greater depths observed in this study.

Petr (1969b) attributed the high standing crop of Chironomidae in Lake Volta to blooms of *Microcystis* and *Oscillatoria*, which he considered as food for the group. Blooms of the two algae were still observed in the lake; however, there was a decreased representation of Orthocladiinae with a corresponding increase in the numbers of Chironominae. BOD level recorded in this study (Table 1) is twice as high as that observed by Ofori-Danson & Antwi (1994) in the gorge area of Lake Volta at Akosombo (Stratum II).

Phosphate concentration is hundred times higher, nitrate fourteen times higher, nitrite twenty times higher, ammonia eighty times and sulphate thirty three times higher than concentrations occurring in the surface waters of Lake Volta at Akosombo (Table 2). The concentrations observed are also much higher than background levels in oligotrophic reservoirs (Table 2). Yeji is a large lakeside settlement with poor sanitation facilities. The bulk of both solid and liquid wastes, including faeces, end up in the lake.

TABLE 1

*Physico-chemical characteristics of the waters of the Lake Volta at Yeji (Stratum VII), March 1995-January 1996 (Mean ± 95% Confidence)*

| | *0m* | *2m* | *6m* | *10m* | *14m* |
|---|---|---|---|---|---|
| Temperature (°O) | 30.8 ± 1.0 | 29.8±0.85 | 29.6±1.0 | 29.5±0.96 | 29.0±1.19 |
| *p*H (*p*H Units) | 7.2 ± 0.23 | 7.1±0.22 | 7.0±0.23 | 6.9±0.25 | 6.7±0.25 |
| Oxygen saturation (%) | 123.1=19.40 | 118.0±18.12 | 111.2±21.83 | 104.9±27.27 | 89.0±32.57 |
| $BOD_5$ (mg $L^{-1}0_2$) | 3.9 ± 1.04 | | | | |
| Alkalinity (mg.$L^{-1}$ $CaCO_3$) | 52.5±15.30 | 52.6±15.76 | 50.8±15.71 | 49.99±16.70 | 49.0±17.84 |
| Total hardness (mg $L^{-1}$ $CaCO_3$) | 28.0 ± 4.94 | 28.5±4.28 | 27.7±5.02 | 27.5±5.21 | 27.5±5.36 |
| TDS (mg $L^{-1}$) | 69.4±44.72 | 67.7±42.69 | 67.4±46.37 | 64.5±41.90 | 65.8±39.70 |
| Conductivity (us $cm^{-1}$) | 142 ± 95.05 | 131.5±77.81 | 135.5±92.50 | 131.7±88.04 | 135.7±87.64 |
| Sodium (mg $L^{-1}$) | 12.3±5.83 | 10.6±3.69 | 11.8±4.61 | 12.0±5.66 | 12.8±5.48 |
| Potassium (mg $L^{-1}$) | 9.3±5.54 | 8.8±5.17 | 8.8±4.88 | 8.5±4.43 | 7.9±3.61 |
| Calcium (mg $L^{-1}$) | 9.3±1.42 | 9.6±1.82 | 9.9±2.33 | 9.4±1.24 | 10.2±2.77 |
| Magnesium (mg $L^{-1}$) | 1.9±1.00 | 2.12±1.04 | 2.0±1.22 | 1.8±1.05 | 1.9±0.98 |
| Chloride (mg $L^{-1}$) | 11.1±5.68 | 11.0±5.02 | 11.2±5.31 | 10.6±4.81 | 11.1±5.10 |
| Phosphate (mg $L^{-1}$) | 0.3±0.30 | 0.3±0.25 | 0.3±0.30 | 0.4±0.41 | 0.3±0.29 |
| Nitrate (mg. $L^{-1}$) | 0.7±0.31 | 0.8±0.34 | 0.9±0.44 | 1.1±0.46 | 1.1±0.35 |
| Nitrate (mg $L^{-1}$) | 0.1±0.16 | 0.1±0.17 | 0.1±0.12 | 0.1±0.13 | 0.1±0.21 |
| Ammonia- nitrogen (mg $L^{1}$) | 0.8±0.83 | 0.4±0.29 | 0.3±0.21 | 0.6±0.54 | 0.4±0.26 |
| Silicate (mg $L^{-1}$) | 12.5±4.58 | 12.7±4.69 | 12.0±4.47 | 12.9±5.08 | 13.5±4.14 |
| Sulphate (mg $L^{-1}$) | 6.6±4.94 | 6.6±4.87 | 7.2±6.13 | 11.6±13.23 | 6.3±4.76 |
| Transparency (cm) | 70.7±34.70 | | | | |

TABLE 2

*Comparison of physico-chemical characteristics of surface waters from Stratum II and Stratum VII of Lake Volta with particular reference to indicators of organic pollution*

| *Parameter* | *Background level (Oligotrophic waters) Straskraba & Tundisi (1999)* | *Ofori-Danso & Antwi (1994) Akosombo gorge area* | *Current study* |
|---|---|---|---|
| Conductivity (µS $cm^{-1}$) | - | 68.9 | 142 |
| Alkalinity (as mg$L^{-1}$ $CaCO_3$) | | 40.2 | 52.5 |
| $BOD_5$ (as mg $L^{-1}O_2$) | | 1.6 | 3.9 |
| Chloride (mg $L^{-1}$) | 2-10 | 7.4 | 11.1 |
| $PO_4$-P (mg $L^{-1}$) | <0.01 | 0.003 | 0.3 |
| $NO_3$-N (mg $L^{-1}$) | <0.1 | 0.05 | 0.7 |
| $NO_2$-N (mg $L^{-1}$) | <0.002 | 0.005 | 0.1 |
| $NH_3$-N (mg $L^{-1}$) | 0.1-0.2 | 0.01 | 0.8 |
| $SO_4$ (mg $L^{-1}$) | - | 0.2 | 6.6 |

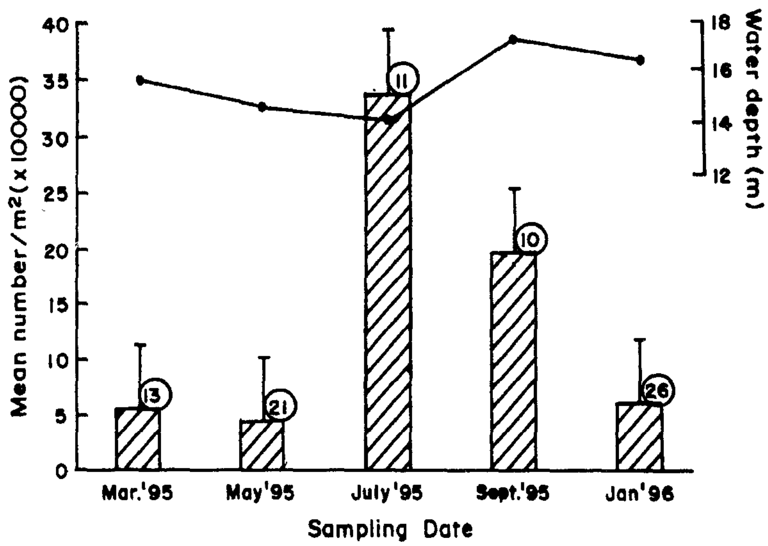


Fig. 3. Seasonal abundance of Benthic Macro-invertebrates in Lake Volta at Yeji, Ghana Blocks = Mean, Vertical bars = one Standard Error of Mean, Circled numbers = number of means.

Straškraba & Tundisi (1999) confirmed that high nutrient levels like those observed in the present study occur in waters that are receiving sewage effluent or under great anthropogenic influence.

Sæther (1979) also showed that increasing eutrophication of lake waters results in the replacement of chironomid species characteristic of oligotrophic lakes (such as the Orthocladiinae) by species characteristic of eutrophic lakes like Tanypodinae and Chironominae. Thus, although eutrophication of the lake water may have just begun, this has already been reflected in a change in the composition of the chironomid benthos.

Macro-invertebrates are important source of food for many fish species (Petr, 1967, 1974ab; Lauzanne, 1972; Ioffe, 1972). It is, therefore, reasonable to conclude that a reservoir with a large density of macro-invertebrates such as that found in Lake Volta would improve fish production. It is paradoxical, therefore, that even though macro-invertebrate density is high there has been a downward trend in fish production of the lake in recent times (Ofori-Danson & Antwi, 1994). It is possible that the situation is due to the change in the composition of the fish fauna resulting in dominance of groups that are unable to utilise this food resource directly. It is also possible that the decrease in fish populations, in general, will have contributed to the high densities of macro-invertebrates encountered.

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