A N   I N V E S T I G A T I O N   I N T O   T H E   P H Y T O P L A N K T O N   O F   S E L E C T E D   A R E A S   O F   L A K E   K A R I B A

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I hereby declare that the information presented in this dissertation has not been presented to any University for the purpose of obtaining a degree.

RONALD DAVID KING

CONTENTS PAGE

PAGE

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SUMMARY

Some of the important features of Lake Kariba have been summarized, together with a description of the areas studied, the geology of the southern shore, the climate of the middle Zambezi Valley, and lake level fluctuations.

Standard methods were employed to collect the samples and the following parameters were measured: temperature, dissolved oxygen, water transparency, water depth, electrical conductivity, total alkalinity, calcium, magnesium, ortho-phosphate, nitrite, suspended solids, photosynthetic pigments, and algal counts. Replicate counts were made on a selected algal sample to test the accuracy of the method. A field vacuum pump is described.

The thermal properties of the selected areas are described, with comparisons, as well as the light penetration into the water. The dissolved oxygen cycles are also discussed and compared with the temperature patterns. The water quality in space and time is discussed; it showed almost no annual pattern at low concentrations.

The lake is oligotrophic as hydrogen sulphide is hardly ever recorded in the deep waters at Kariba, and was absent in the hypolimnion of the Mwenda Basin.

The standing crop of algae was very low in all lake samples, although two blooms were recorded in the Mwenda River. The Mwenda Basin maintains an almost homogeneous standing crop from the surface to the thermocline. The algal densities of the lake samples were all low, but the generic diversity was high, which is indicative of an oligotrophic, mature tropical ecosystem. Selected samples were submitted for detailed diatom analysis, and a preliminary species

list compiled. The generic frequency of all recorded organisms was calculated and the ecoligically and taxonomically important genera presented. The post turnover algal bloom is discussed, together with the composition of this population. Finally, the effect the Mwenda River flood has on the lake ecosystem is examined.

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RONALD DAVID KING

LIST OF FIGURES

Figure 24: Seasonal flux of photosynthetic pigments from the Mujery offshore area. [redacted] The hatched column ([▨]) is the seasor-l station mean.

Figure 25: The seasonal distribution of photosynthetic pigments along the cleared and uncleared transects at Mujery. The correlation coefficients (r) comparing the photosynthetic pigmenta of the two transects are included.

Figure 26: Photosynthetic pigment (μg Pt/l) depth profiles for the Mwenda Basin deep water station, from August 1971 to June 1972. The dotted line (_ I _) represents the Secchi disc transparency of the water. [redacted]

Figure 27: Mean seasonal algal density (total cell count) for the Mwenda River mouth. Vertical lines are the standard deviation. Mwenda Basin station 1 (B) is included.

Figure 28: Seasonal phytoplankton diversity of the Mwenda River mouth routine sampling stations. The vertical columns indicate the algal pop= ulation breakdown: Chlorophyta[ ], Pyrrhophyta[\\], Chrysophyta (minus diatoms)[//], Bacillariophyceae[ ] Cyanophyta[::]. The generic diversity index (d) for each station is indicated, together with the photosynthetic pigment values (Pt) and total cell counts (Tc) for comparison.

Figure 29: Mean generic diversity indices for the Mwenda River mouth, and the Mwenda Basin surface (B). Vertical lines are the standard deviations of the mean.

Figure 30: Seasonal phytoplankton diversity of the Sengwa River mouth. The vertical columns indicate the algal population breakdown: Chlorophyta[ ], Pyrrhophyta[\\], Chrysophyta(minus diatoms) [//], Bacillariophyceae[ ], Cyanophyta[::]. The generic diversity index(d) for each station is indicated, together with the photosynthetic pigment values (Pt) and total cell counts (Tc) for comparison. The horizontal black line indicates the extent of the "sudd" mat. Figures below the columns are the sampling stations.

Figure 31: The mean generic diversity index for the Sengwa River mouth. The vertical lines are the standard deviation of the mean- stations 1 and 2 were only sampled once.

Figure 32: Seasonal phytoplankton diversity of the Mujery offshore transects. The vertical columns indicate the algal population breakdown: Chlorophyta[ ], Pyrrhophyta[\\], Chrysophyta(minus diatoms)[//], Bacillariophyceac[ ], Cyanophyta[::]. Generic diversity (d), photosynthetic pigments (Pt) and total cell counts(Tc) are included for comparison.

Figure 33: Mean seasonal generic diversity index values for the two Mujery transects. The vertical lines are the standard deviations.

LIST OF TABLES

1 INTRODUCTION

Lake Kariba was formed when a dam wall was built across Kariba Gorge, creating one of the largest man-made lakes in the world. Inundation of the middle Zambezi Valley began in 1958 and was completed in 1963. The lake is geographically located between latitude 16° 30' S and 18° S, and longitude 27° E and 29° E. The long axis is approximately north east to south west, forming part of the natural boundary between Rhodesia and Zambia (Figure 1).

Lake Kariba has a dendritic shoreline and is characteristically divided into five main basins, separated by narrows or chains of islands (Coche 1968):

- B1 The Sebungwe-Mlibizi Basin, between the Sebungwe Narrows and the Devil's Gorge,
- B2 The Binga Basin, between the Chete Gorge and the Sebungwe Narrows,
- B3 The Central Basin, between the Sibilobilo Narrows and the Chete Gorge,
- B4 The Kariba Basin, between Kariba township and the Sibilobilo Narrows, and
- B5 The Sanyati Basin.

Some important characteristics of Lake Kariba are:

Area	4450 km^2
Length	280,3 km
Maximum width	64,0 km
Mean width	20,0 km
Maximum depth	128,0 m
Mean depth	29,0 m
Storage capacity	160,0 km^3
Water retention time	3,8 years

Mean operating level	484,63 m.a.m.s.l.
Mean flow of the Zambezi River	37,6 km^3 p.a.
Area of drainage basin	832 200 km^2
Thickness of dam wall	24 m
Maximum hydroelectric output	1 500 M.W.

During the early stages of impoundment the lake exhibited typical eutrophic characteristics, caused by flooding of terrestrial soils and decay of plants and animals drowned by rising lake waters. About twenty per cent of the total lake area was cleared of vegetation for fishing grounds prior to flooding. This material was burned, adding considerably to the trophic status of the water. By 1968 the eutrophic characteristics were far less evident, and by 1972 the lake was oligotrophic. This reverse in trophic status was because the initial nutrients were incorporated into cell mass (phytoplankton) and, following the death of the biomass, sedimented into the bottom muds. Also, the Zambezi River, which supplies by far the greatest quantity of water to the lake, is very poor in nutrients and low in silt load (Mitchell 1969). Large quantities of the early nutrient-rich water was lost to the dam through the sluice-gates and turbines at the dam wall. Along the shoreline the rise and fall in lake level causes nutrients to be released from grass and dung there (McLachlan 1971) and near river mouths flash floods deposit nutrients and silt into the lake, maintaining possibly meso-oligotrophy in these localized areas. The trophic status of the lake waters will remain in flux until equilibrium is reached.

The aims of this study were to investigate the physical and chemical properties of selected areas of Lake Kariba, and to determine the nature of the algal population composition in time and space. It was also intended to investigate the diatom flora of selected samples and to

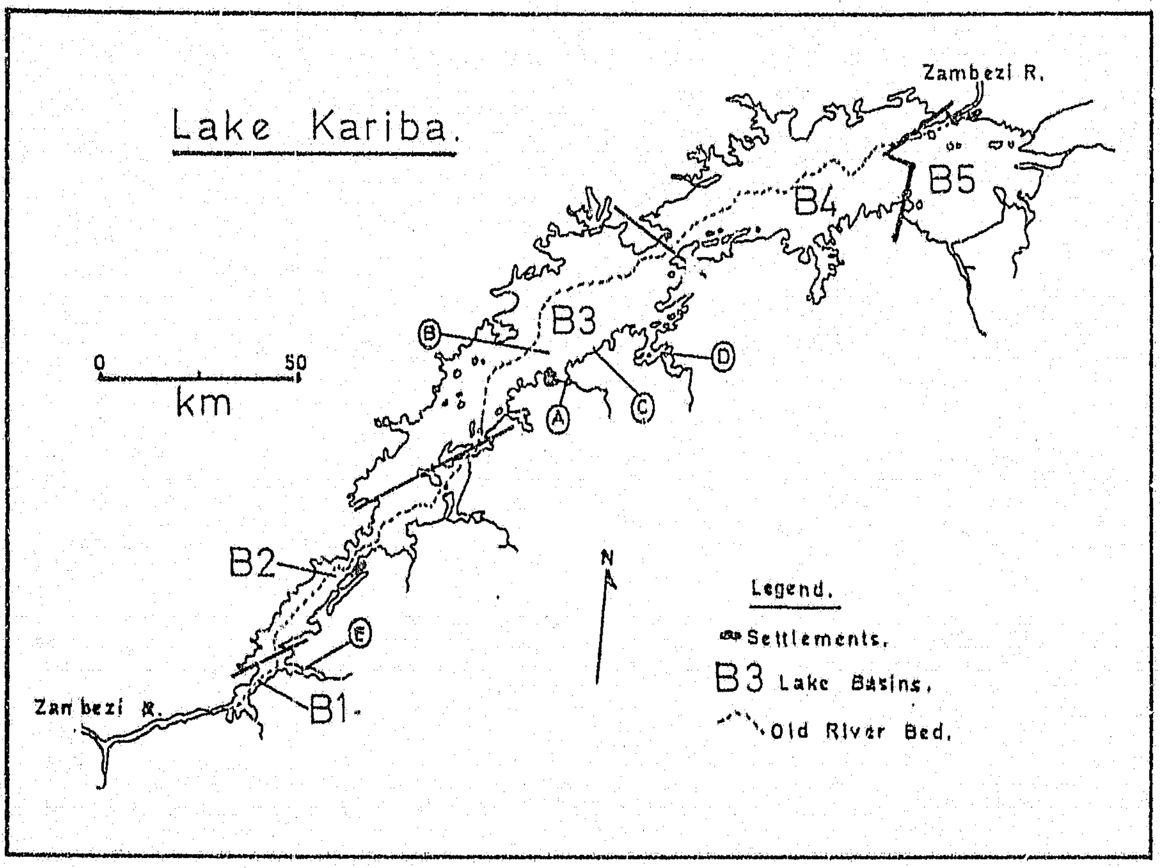


Figure 1: Map of Lake Kariba showing the location of the sampling areas (A = Mwenda River and Mwenda River mouth, B = Mwenda Basin, C = Mujery, D = Sengwa River mouth, E = Mlibizi River mouth).

compile a preliminary species list. The influence of river flooding (Mwenda River only) on the lake habitat was to be studied for at least one of the many floods which occur during the rainy season.

1.1 DESCRIPTION OF THE SAMPLING AREAS

1.1.1 The Mwenda River System

The Mwenda River system has three separate habitat types:

1.1.1.1 Mwenda River

The Mwenda River (Figure 2) meanders through Karroo Sandstones and Grits. The banks of the river are steeply shelving with many cliff features; wide sand banks occur on the river bends and in many places the river has

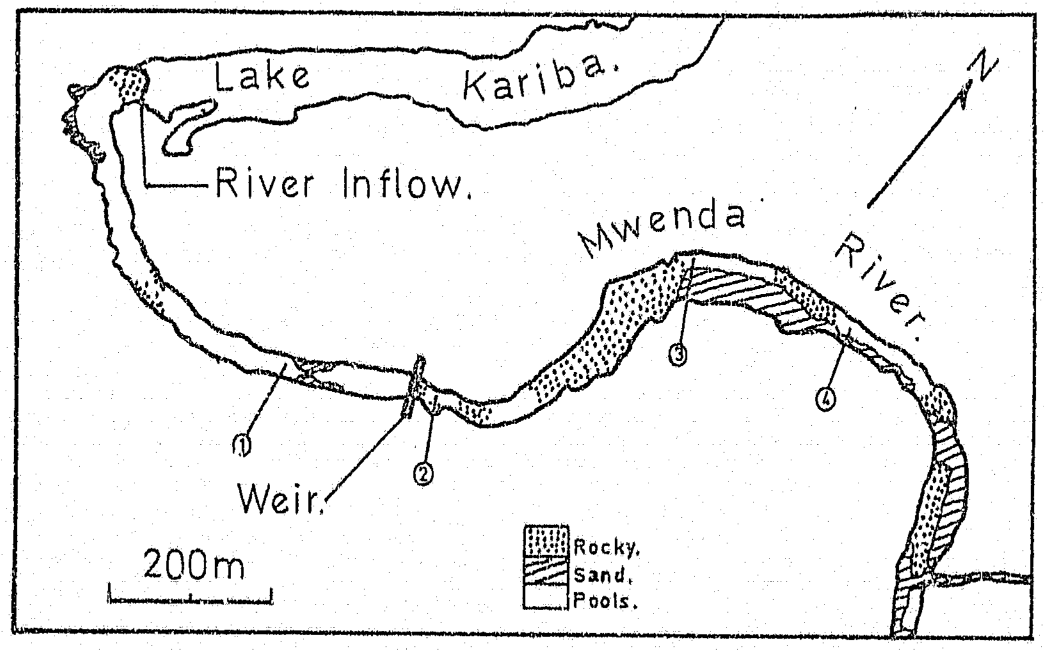


Figure 2: Section of the Mwenda River showing the routine sampling stations, the weir site and the point of river inflow into the sheltered region of the Mwenda River mouth.

eroded fairly deeply into the geology. The river bed is generally sandy with rapids occurring frequently.

The terrestrial vegetation of the Mwenda River catchment is mixed dry woodland (Henning 1971, Pers. obs. 1971, 1972), although Wild and Fernandes (1968) have described this area as Colophospermum mopane Leon - dominated woodland. No typical gallery vegetation occurs except in a few isolated areas. The aquatic vegetation is virtually non-existent except for some Phragmites Adans. stands in sheltered areas away from the main river flow.

During the rainy season (Novem' - to April) the river carries into the lake fairly high silt and nutrient loads. River flow does, however, depend on localized thunder storms causing rapid fluctuations in river level (see River Flooding section below). During the dry season (May to October) the river is reduced to a series of pools, most of which contain water throughout this dry period.

Sampling station 1 has steep banks with many shade trees, and a complete Salvinia molesta D.S. Mitchell mat when the river is not in flood. Stations 2, 3 and 4 have fairly steep banks with associated sand banks and rocky patches, and are well exposed. No aquatic macrophytes are present.

1.1.1.2 Mwenda River Mouth

The Mwenda River mouth (Figure 3) generally has a rocky coastline of large blocks of Karroo Sandstones and Grits (armoured coastline, McLachlan 1968). Beaches and shallow shorelines occur in many places generally associated with an abundance of dead trees, the species of which have been reported by McLachlan (1968) and MacDonald (1971).

The floating aquatic vegetation is dominated by Salvinia Seguier which occurs in sheltered bays and between the dead trees. The presence of "sudd" is very limited, but isolated mats occur in sheltered bays where Cyperaceous elements have colonized the Salvinia mats. When the Mwenda River floods, most of this vegetation is swept out into the open bay water,

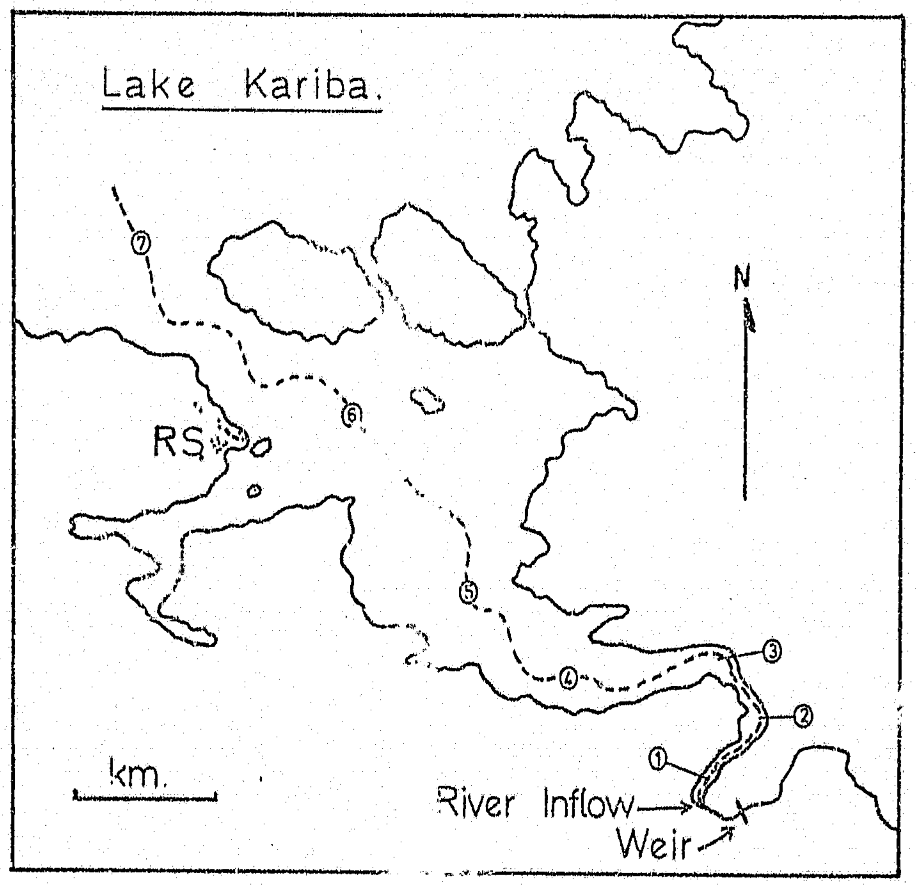


Figure 3: Map of the Mwenda River mouth showing sampling stations along the drowned river bed (1 - 7). The gauging weir, point of river inflow, and the Nuffield Lake Kariba Research Station (RS) are also shown.

where it is destroyed by wave action, contributing large amounts of detritus to the water.

The submerged aquatic vegetation appears to be on the increase (Bowmaker 1970) as large stands of Ceratophyllum L. and Lagerosiphon Harv. are exposed when the lake level recedes. The ecology of these genera in Lake Kariba has yet to be properly investigated.

Sampling stations 1, 2 and 3 are in the narrow upper reaches

[illegible]

1.1.1.? [illegible]

This station [illegible]

Lake Kariba Research Station [illegible]

typical [illegible]

depth of more than 40 m.

1.1.? The [illegible] River [illegible]

[illegible]

of the river mouth. These areas are sheltered from the north and east by a steep rocky ridge, and not exposed to the prevailing north easterly wind. The daily period of sunshine on the water is also less here than for the other four stations.

Stations 4 and 5 are in the transition zone between the sheltered stations and the open bay region (station 6). Features of these two stations are the large number of dead trees lining the shore, and exposure to the prevailing elements.

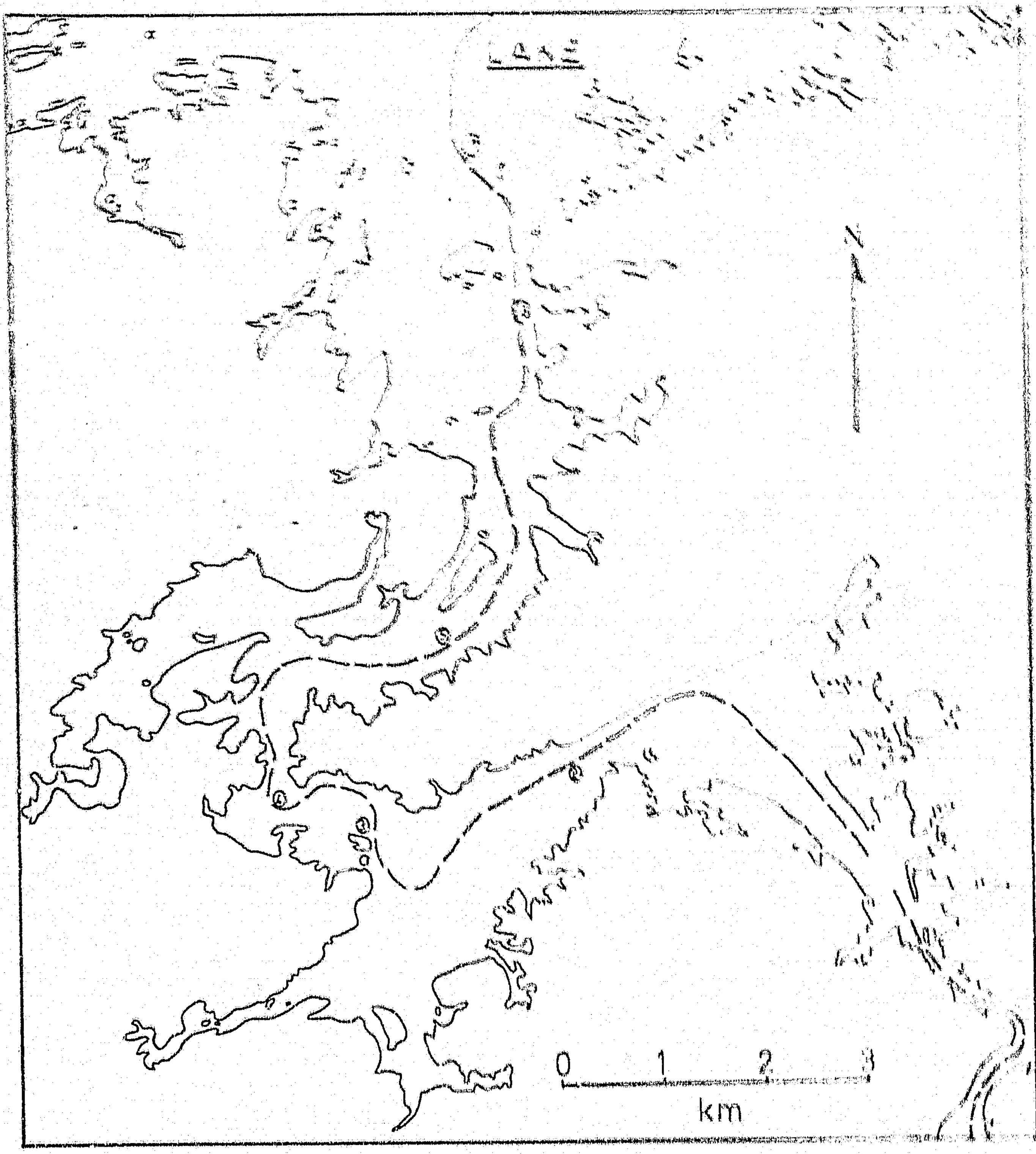
Station 6 is in the open Mwenda Bay area, sheltered to some degree by the two lakeward islands (Christmas and Elephant Islands). Station 7 lies just beyond the tree line off this island chain and is exposed to all the prevailing elements of the lake.

1.1.1.3 The Mwenda Basin

This station is situated 6 km north west off the Nuffield Lake Kariba Research Station (Figure 1). It is subject to typical exposed open water conditions, and the water has a depth of more than 40 m.

1.1.2 The Sengwa River Mouth

The drowned river mouth of the Sengwa River is approximately 16 km from the point of river inflow at station 1 to the open bay water at station 7. This system overlays fine sandstones, which has resulted in hilly topography with many islands and a dendritic coastline (Figure 4).



<u>Figure 4</u>: The Sengwa River mouth, showing routine sampling stations along the drowned river bed. Note the dendritic nature of the shoreline. *Salvinia molesta* "sudd" mats occur in profusion between stations 1 and 4; from station 4 to the open water the shoreline and many of the sheltered bays are colonized. The broken line in the drowned river bed.

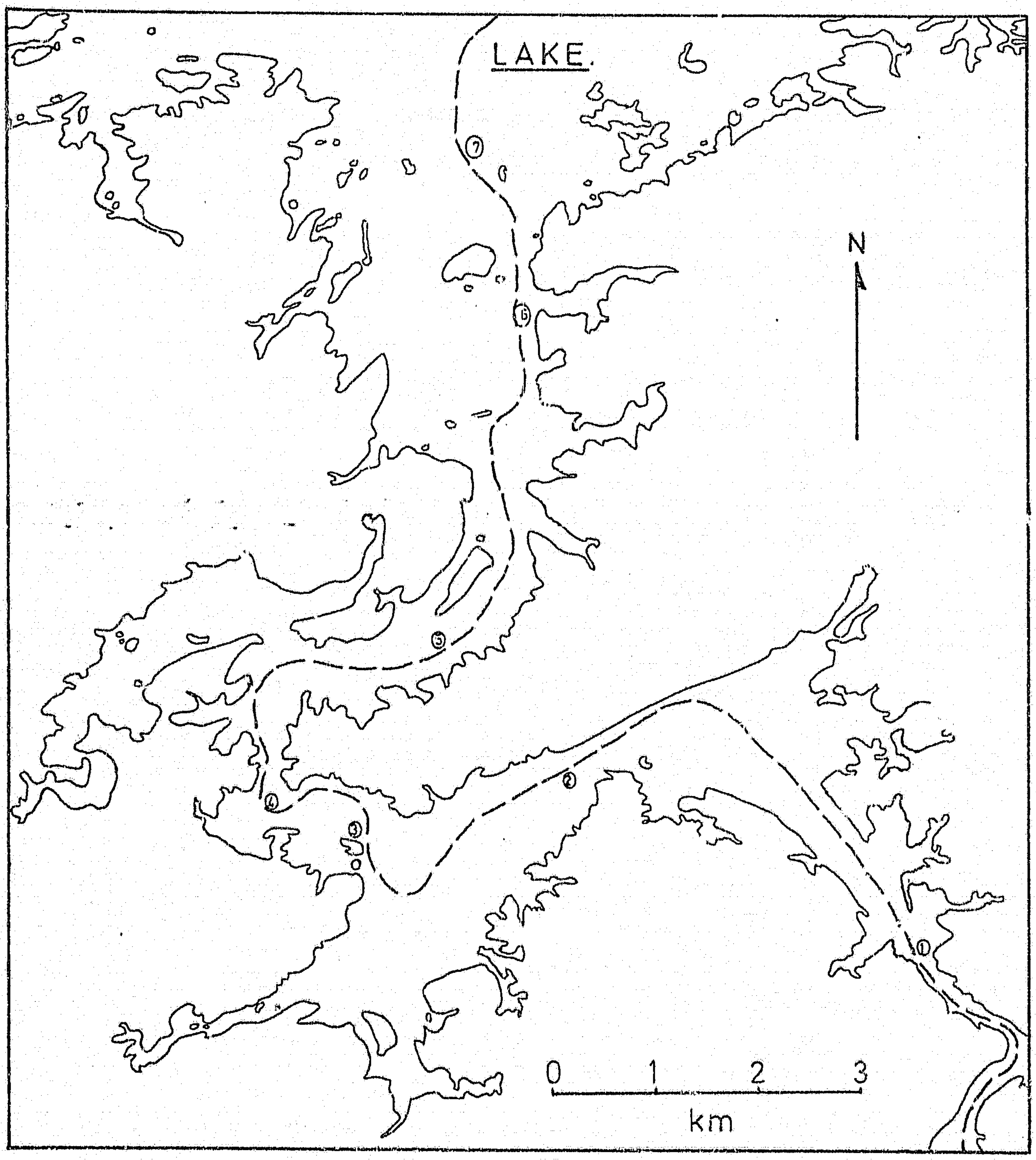


Figure 4: The Sengwa River mouth, showing routine sampling stations along the drowned river bed. Note the dendritic nature of the shoreline. Salvinia molesta "sudd" mats occur in profusion between stations 1 and 4; from station 4 to the open water the shoreline and many of the sheltered bays are colonized. The broken line is the drowned river bed.

Due to the meandering nature of the old river bed, many shallow shelving areas occur on which the stumps of dead trees remain. These act as anchors for the floating aquatic macrophytes. Most of the sheltered bays are covered by Salvinia molesta, and from stations 1 to 4 the drowned river mouth is almost completely colonized.

These stable Salvinia mats are a suitable substratum for the growth of other vascular plants, forming "sudd" mats (Mitchell 1969a). The stoloniferous reproductive nature of these "sudd" plants aids in binding the Salvinia into islands of varying size and stability. Wind action causes partial break-up of these mats, and the drowning of many plants by wave action. This detrital material sediments to the bottom muds. Details of the species constituting these floating macrophytes and their ecology are presented by Mitchell (1960, 1969) and McLachlan (1968).

1.1.3 Mujery Area

The Mujery area (Figure 5) has a very shallow sloping topography from the coastal plains towards the old Zambezi River course. The coast= line varies, due to the fluctuations in the lake level. Prior to inundation, much of this area was cleared of woody vegetation to provide a fishing ground when the lake formed. This area was invest= igated to assess the differences between the swampy inshore areas where no trees had been cleared (transect 1, station 1-3, station 4 is included for comparison with the open water), and an area cleared of trees (transect 2, station 5-7, with station 8 included for comparison with the open water).

Both stations 1 and 5 are in sheltered bays where wave action is reduced by the rooted macrophytic vegetation. At station 5 a small stream

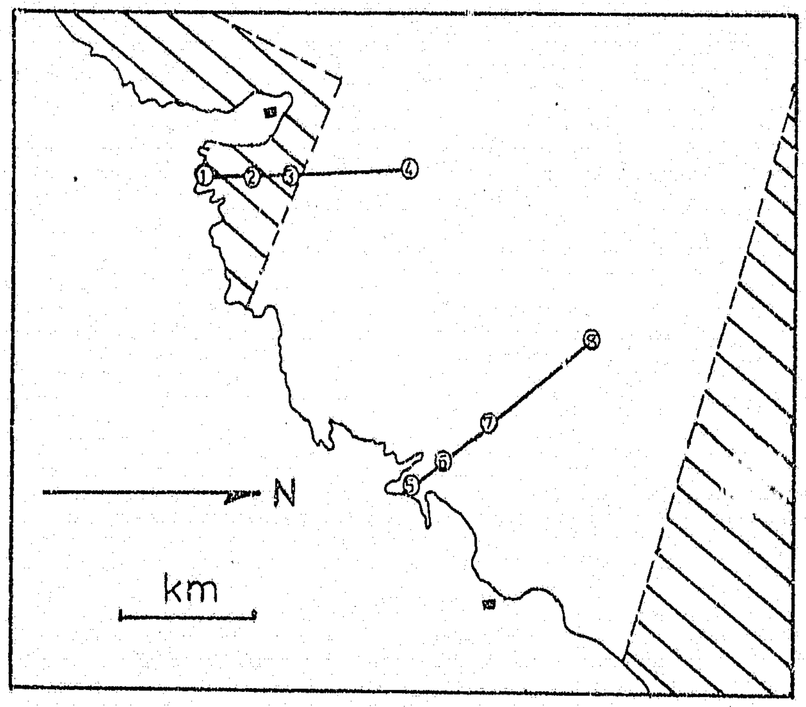


Figure 5: Map of the Mujery coastline showing the offshore transects, with the routine sampling stations. The shaded area was not cleared of the original bush for fishing grounds. ▣ Fishing camps.

enters the lake. As the distance increases from the shoreline along each transect line (stations 1-4 and 5-8) the degree of exposure and wave action increases

1.2 GEOLOGY OF THE SOUTHERN SHORE

Lake Kariba is orientated roughly north-east to south-west. The lake lies in an asymetrically folded syncline running parallel to its long axis. The south shore is characterised by scarp slopes of Upper Karroo Sandstone and Grits.

The lake is subdivided into four connecting basins by narrows between promontories or by chains of islands between promontories. There is a progressive decrease in the size of the basins from the Senyati in the north-east to the Sebungwe-Mlibizi basin in the south-west (Bond 1965). Bond (1965) roughly estimated the composition of the shoreline in terms of rock types as follows:

Molteno Series	41%
Forest Sandstone	17%
Basalt and Interbedded Sandstones	15%
Basement Gneiss	14%
Lower Karroo Sandstones	8%
Pebbly Arkose	2%
Fine Red Marly Sandstone	2%
Sandstone (? Kalahari)	1%

The Molteno Grits of the Upper Karroo Series comprise the largest proportion of the lake shore from Mlibizi to the Sengwa River mouth. From the Sengwa River mouth to the Sanyati basin area the important geological features are the Forest Sandstones in the Bumi area and the Basalts and Interbedded Sandstones of the Sibilobilo area, forming the main shoreline and the islands. The shoreline of the Sanyati Gorge is Gneisses of the Lower Karroo Series which also occur in the Noadza River and in the Kariba area. The remaining rock types constitute less than 10% of the shoreline (Bond 1965).

1.3 CLIMATE OF THE STUDY AREA

The seasonal climatic pattern for the central Lake Kariba area is as follows:

a) A cool, dry period from May to August, with a generally stable synoptic situation of no rainfall, low cloud incidence and light variable winds.

b) A hot, dry period from August to November, with a low incidence of cloud and rainfall and prevailing north-easterly winds and occasional south-westerly blows (Scudder 1962).

c) The rainy season from November to April, with unstable synoptic conditions producing typical African convection thunderstorms with associated high velocity winds (30 to 40 knots and occasionally up to 60 knots) causing surface waves on the lake with an amplitude of approximately two metres (Law 1965).

Figure 6 illustrates the climate of the study area (see Appendix 1). Long-term mean values have not been presented due to the variability in climatology of this section of the Zambezi Valley. During the 1971-1972 season the main rains began in November, reaching a maximum in January and decreasing to August. The rainfall for this period amounted to 778 mm. Previous rainfall records indicate a variation from 500 mm to 813 mm over the same area.

Air temperatures were generally high with maximum variation during the cool, dry period. Minimum temperatures were in August and maximum temperatures in October with a mean increase of 3° C per month. From October there was a steady decrease in air temperatures to July, initially as a result of the onset of the rains (Nuffield Lake Kariba Research Station records, 1971-1972).

1.4 LAKE LEVEL

The lake level values were obtained from the Central African Power Corporation (1972) at Kariba township. The dam was completed in December 1958,

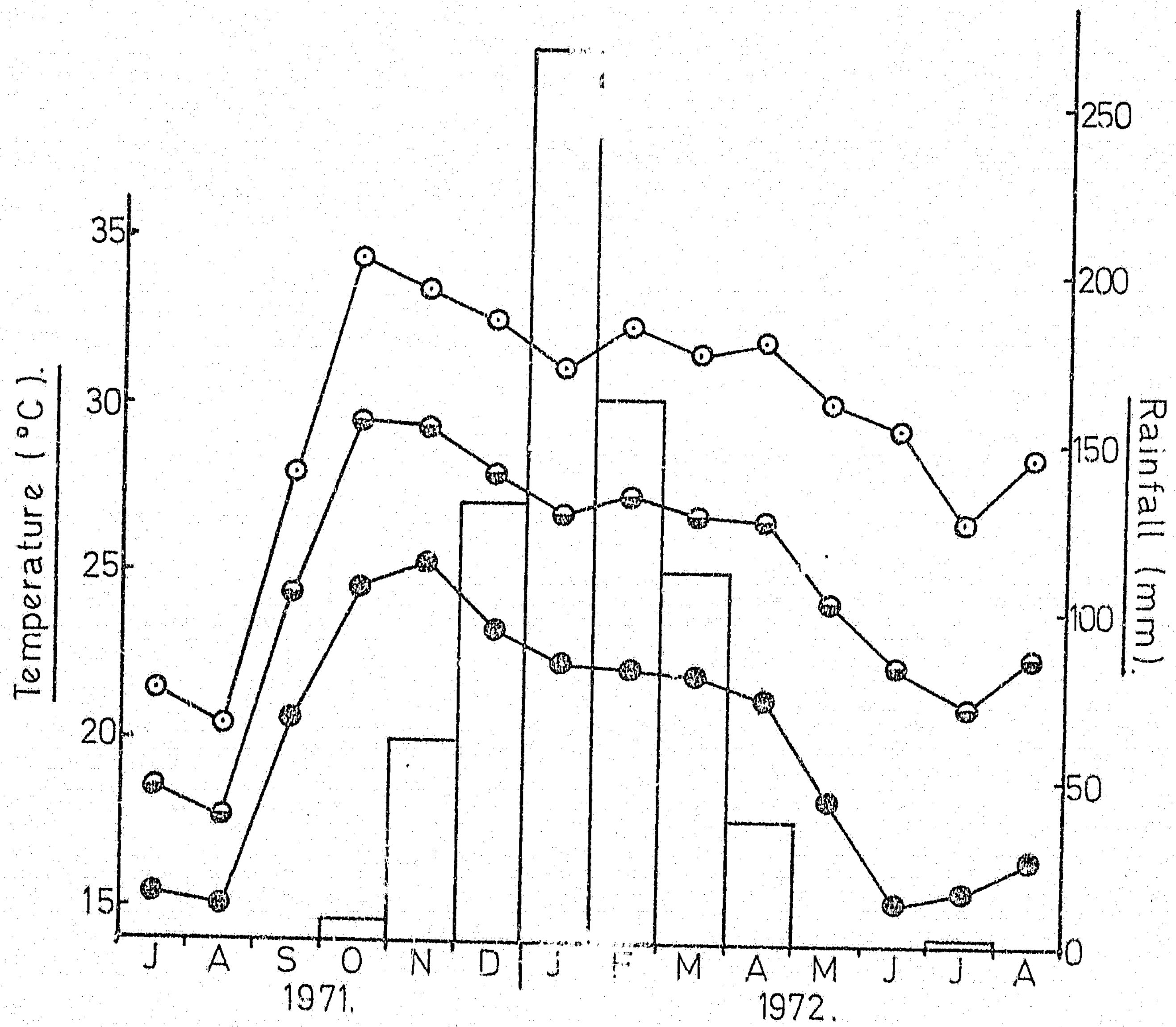


Figure 6: The seasonal mean, maximum and minimum air temperatures and rain- fall pattern recorded at the Nuffield Lake Kariba Research Station for 1971 - 1972.

with a first year rise in water level of approximately 60 m and from 9 to 12 m in each of the subsequent years, until the mean operating level of 484 m a.m.s.l. was reached in April 1963. The lowest draw-down level is 475 m a.m.s.l. and the maximum flood storage level is 489 m a.m.s.l.

The annual cycle of water level fluctuations begins in July when the flood gates are opened (Figure 7). This reduces the storage water for the next seasonal inflow of the Zambezi River, the major contributor to the lake.

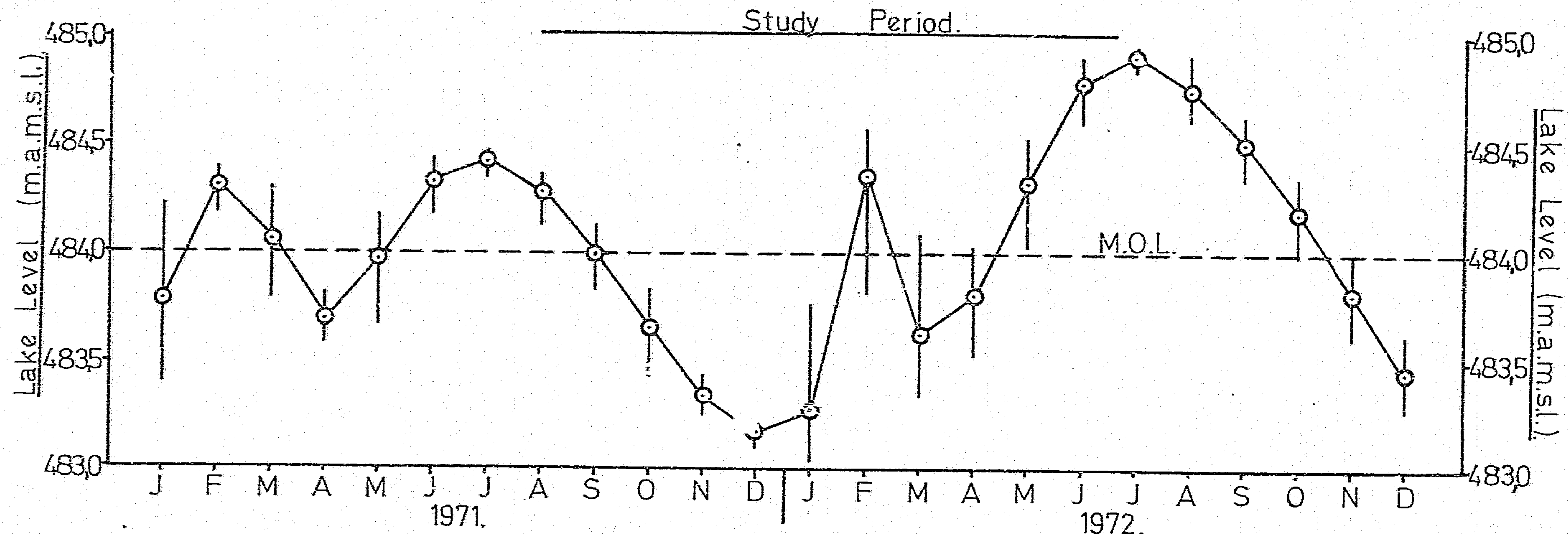


Figure 7: Mean maximum and minimum monthly lake level for 1971 and 1972. The broken line is the mean operating level (M.O.L.) of 484 metres above mean sea level. Values recorded at Kariba Dam wall. (From Central African Power Corporation 1971-1972).

The level increases markedly from December to February but then decreases until March-April as a result of the flood gate draw-down. This period (December to April) shows large fluctuations in the mean monthly water level values. Thereafter the level gradually rises to the maximum value for that particular season. Each season sufficient water is released from the dam to allow for the maximum possible inflow.

2 MATERIALS AND METHODS

There were six sampling periods on Lake Kariba during a limnological cycle - August, October and December 1971 and February, April and June/July 1972 (Table 1). The areas investigated were chosen because of their accessibility from the Nuffield Lake Kariba Research Station, and that they would support algal populations indicative of most of Lake Kariba.

The routine sampling areas were (Figure 1):

a) Mwenda River system

i) Mwenda River

ii) Mwenda River mouth

iii) Mwenda basin - deep water station

b) Sengwa River mouth

c) Mujery offshore area.

The intensive sampling of the Mwenda River flash flood on 16th February 1972 is in Table 2.

Table 1: Sampling dates for the five routine areas on Lake Kariba during 1971/1972. Figures in brackets are the sampling station codes and numbers e.g. M1 to M7 indicates seven stations in the Mwenda River mouth. Data from stations 1, 2 and 3 in the Sengwa River mouth are incomplete due to excessive mats of floating aquatic macrophytic vegetation which prevented access to the stations.

Sampling Areas	Sampling Periods					
	1971			1972		
	August	October	December	February	April	June-July
Mwenda River (MP1 to MP7)	4. 8.71	14.10.71	12.12.71	7. 2.72	13. 4.72	15. 6.72
Mwenda River mouth (M1 to M7)	3. 8.71	15.10.71	3.12.71	7. 2.72	18. 4.72	26. 6.72
Mwenda Basin (C1 to C8)	23. 8.71	17.10.71	6.12.71	19. 2.72	25. 4.72	30. 6.72
Mujery offshore transects (J1 to J4) (J5 to J8)	9. 8.71	20.10.71	13.12.71	16. 2.72	21. 4.72	8. 7.72
Sengwa River mouth (S1 to S7)	18. 8.71	23.10.71	15.12.71	24. 2.72	28. 4.72	5. 7.72

Table 2: Dates that the Mwenda River flash flood was monitored. Intensive sampling was carried out at the Mwenda River mouth stations 1, 3 and 6. All seven routine sampling stations were analysed spectro=photometrically for suspended solid material (silt load) on the 21st February 1972. The flood spate entered the lake water on 16th February 1972.

Sampling stations	Sampling Periods					
	1	2	3	4	5	6
1, 3 and 6	7.2.72	14.2.72	17.2.72	21.2.72	23.2.72	26.2.72

Whenever possible chemical analysis of the water samples was carried out within 48 hours of collection. The routine stations were sampled for temp=erature and dissolved oxygen at 1 m intervals, except for 5 m depth intervals at the Mwenda Basin station. Physico-chemical, photosynthetic pigment and phytoplankton samples were taken from the surface (0 m); for the Mwenda Basin routine station, 5 m depth interval samples were performed, except during thermal stratification when additional readings for temperature and dissolved oxygen were made near the thermo-oxycline.

The four Mwenda River stations were sampled at the surface (0 m) only during the six sampling periods, as this river is a series of pools during the long dry season.

During the Mwenda River flash flood (February 1972) temperature and dissolved oxygen were recorded from stations 1, 3 and 6 in the Mwenda River mouth at 1 m depth intervals from the surface to the bottom sediments. Photosynthetic pigment data were obtained from samples collected at 1 m intervals from surface down to 5 m depth (at station 6). The turbidity (and the effect of suspended solid material on the penetration of different wavelengths of visible light [340 - 900 mµ]) and electrical conductivity measurements were made on surface water samples.

The measurment of water temperature and dissolved oxygen profiles, secchi transparency and water depth were aimed at obtaining basic limnological data, while conductivity, calcium, magnesium, nitrite and ortho-phosphate indicated the levels of some plant nutrients, with alkalinity being a measurment of the carbonate and bicarbonate levels. Unfortunately a more comprehensive analysis could not be carri' ' out as the facilities at the research station were fairly limited. The phytoplankton . opulation was measured by extracting photosynthetic pigments and making a count of a.gal cells, and submitting certain samples for detailed diatom analysis. The inorganic load carried by the river flood waters was determined by measuring the suspended solids of these samples.

2.1 SAMPLE COLLECTION

2.1.1 Water samples: surface samples were collected directly, and depth samples with a 2,0 l Friedlinger bottle. These samples were then placed into 1,0 l polyethylene bottles after filtration through 0,47 µ Millipore filters (algae on discs kept as phytoplankton samples), and preserved with 1,0 ml chloroform which stabilized the ortho-phosphates (Hellwig 1964). Samples were transported to the laboratory and placed in a refrigerator at $\pm$ 2° C. The samples were used for chemical analysis (electrical conductivity, total alkalinity, calcium, magnesium, ortho-phosphate and nitrite).

2.1.2 Phytoplankton samples: the Millipore filters were placed in ;0 ml Poly Top vials and the algae ramoved by squirting a light jet of deionized water on to the discs, and then lightly brushing with a soft camel hair brush. The discs were rai..ed from the water and washed with deionized water, the sample being made up to volume after 0,1 ml Lugol's iodine (Vollenweider 1969) had been added as a preservative. This fixed the algae, and improved their sedimen ation (Rodhe et al 1959). The iodine also acted as a dye which helped particul..ly in identifying the Chlorophyceae. A few drops of 60% glycerine were also added which prevented the organisms from sticking together. These samples were stored in a refrigerator until they were microscopically examined.

Additional phytoplankton samples were collected by slowly hauling a 60 μ net with the samples concentrated by the addition of Lugol's iodine solution. The phytoplankton were then placed into vials and stored in a refrigerator. These samples were used in the identification of the more abundant organisms (diatoms), river flood and annual bloom algae.

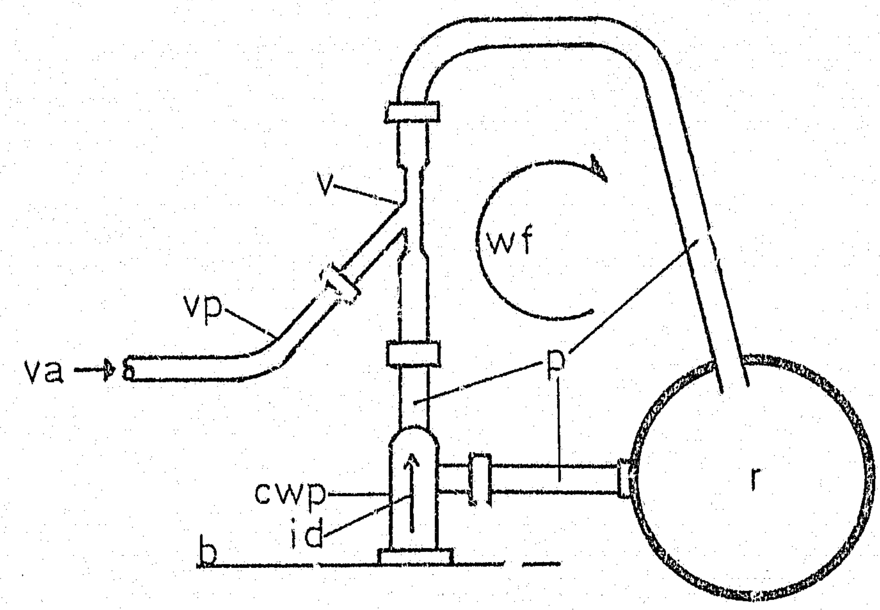
2.1.3 <u>Suspended solid samples</u>: these were collected directly in 1,0 l polyethylene bottles, 0,5 ml chloroform added as a preservative. These samples were stored in a refrigorator at ± 2° C.

2.2 THE FILTERING APPARATUS

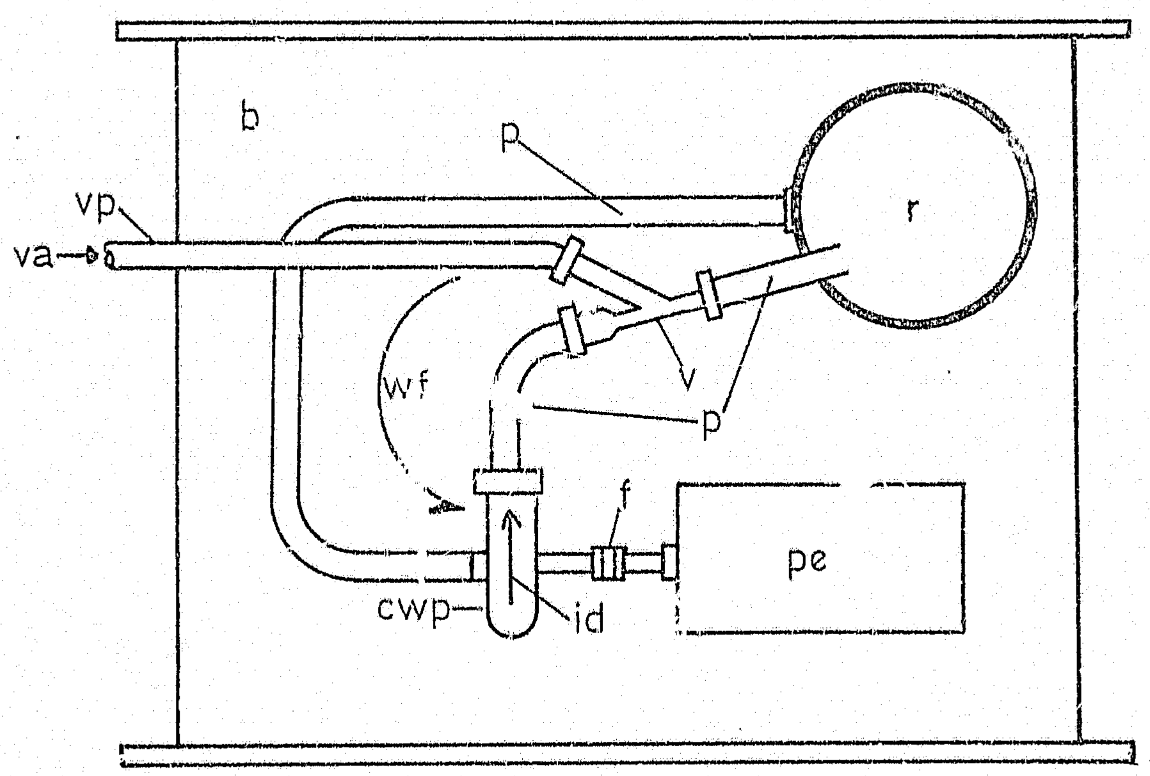
The field vacuum pump was designed to be light and portable for use in a small boat. The construction was kept as simple as possible, yet sufficiently strong to withstand extensive field operation.

The pump consisted of a wooden base 120 x 70 x 2,5 cm, with sides and carrying handles fixed in a convenient position (Figure 8). A 50 mm thick foam plastic sheet was glued to the under surface of the base to reduce vibration noise of the engine. The power source, a Suffolk lawnmower petrol engine model No. 13A, was securely fastened to the base with four bolts. The centrifugal water pump, Labawco Bellemeade Type XB, was placed in position on wooden blocks so the impeller shaft alligned onto the crankshaft of the engine. These two shafts were coupled with a suitable flexible connector and the allen screws secured. The water pump was securely bolted to the base.

FIELD VACUUM PUMP.



Schematic Diagram.



Plan View.

Figure 8: Field vacuum apparatus - diagram not to scale. wf = water flow direction, r = reservoir, v = venturi, cwp = centrifugal water pump, vp = rubber vacuum pipe, id = impeller direction, b = base, p = P.V.C. pipe, va = vacuum, f = flexible connection, pe = petrol engine.

A 20 l metal drum was used as a reservoir by removing one end to facilitate filling. A 30 mm hole was cut into the side of the drum 100 mm from the closed end and a 30 mm pipe nipple braized into position. A 25 mm foam rubber disc was glued to the outside of the closed end to reduce vibration noise. The reservoir was placed into position on the base.

A 30 mm plastic pipe was connected from the reservoir nipple to the water pump intake and secured with screw clamps. The bends in this plastic pipe were 30 mm standard water pipe elbows, secured with screw clamps.

A standard laboratory water tap vacuum venturi was connected to the outflow of the water pump by a short length of 30 mm plastic pipe. The outflow water from the venturi was passed to the reservoir through a length of 8 mm I.D. laboratory plastic tubing.

The air intake connector (vacuum) of the venturi was connected to the glass Millipore filtering apparatus with rubber vacuum tubing. A copper T-piece was inserted into this tubing so filtering could be carried out in duplicate. The vacuum was effectively controlled by adjusting the speed of the petrol engine. The Millipore apparatus was secured by laboratory retort clamps and a stand to avoid damage while filtering in the boat. The direction of water flow can be seen in Figure 8.

This vacuum apparatus possesses distinct advantages, namely:
1) it is very cheap and simple to construct; 2) running and maintenance costs are very low; 3) it gives trouble-free service; 4) all faults are simple to diagnose; 5) it is light to transport and simple to use; 6) it provides a suitable vacuum for fairly rapid filtration, but not

enough to rupture phytoplankton cells.

2.3 FIELD ANALYSIS

2.3.1 Water temperature

Depth profiles were determined using an E.I.L. Dissolved Oxygen Thermometer. Readings were generally taken at 1 m depth intervals. Surface water temperatures for the Mwenda River stations were read from a -5 to 100° C mercury thermometer. The E.I.L. Dissolved Oxygen Thermometer was callibrated against standard mercury thermo=meters.

2.3.2 Dissolved oxygen

Depth profiles were recorded by means of the E.I.L. Dissolved Oxygen Thermometer and expressed as percentage oxygen saturation. This instrument was callibrated as often as possible prior to use. Where there is no data for a particular sampling period the instrument was out of order and beyond immediate repair on the research station.

2.3.3 Water transparency

This was determined with a 30 cm diameter Secchi disc, and expressed in metres below the surface.

2.3.4 Water depth

This was recorded by sounding with a weighted cable from a winch with a depth gauge. These data are in metres below the surface.

2.3.5 River flooding

The flood data was recorded from the gauging weir on the Mwenda River (Figure 2). The river rose from 175 mm at 23h00 on the 16th February 1972 to 1300 mm by 12h00 on the 17th February, with a flow rate of 640 cumecs. The flood waters contained approximately 50 mg/l of suspended silt material, which was measured gravimetrically. The level then subsided to 160 mm by the 23rd February and remained at this level thereafter.(Ministry of Water Development 1972). Sampling was carried out between 10h30 and 15h00 at stations 1, 3 and 6 on the 7th, 14th, 17th, 21st, 23rd and 26th of February respectively.

2.4 LABORATORY ANALYSIS

Water samples filtered and stabilized with chloroform were used for chemical analysis which was carried out in the students' laboratory (prefabricated) at the Nuffield Lake Kariba Research Station. Colorimetric analyses were read on a battery-operated Pye-Unicam SP600 Spectrophotometer. This instrument functioned very well, except during the hot wet season when the high humidity affected the electronic circuits. This was overcome by placing silica gel bags adjacent to these circuits (Philips SA 1971).

Water samples stored at $\pm 2^{0}$ C were allowed to reach room temperature prior to analysis. A fresh set of reagents and standards was made up for each of the six sampling periods. Samples were analysed in duplicate.

Reagents were made in lake water that had been passed through two 40,0 x 2,5 cm columns packed with an anion-cation exchange resin. Resins were replaced once the electrical conductivity of the water rose above 0,4 mS/cm at 25° C. This water was used generally in the laboratory.

Glassware was washed in a 4% Teepol solution for at least 24 hours. No detectable contamination resulted from this analysis preparation.

The methods of analysis used are listed below and are set out in Golterman (1969) and Swingle (1961).

2.4.1 Filtered Samples

2.4.1.1 Electrical conductivity in mS/cm at 25° C was measured using a Dionic water tester corrected for ambient temperature.

2.4.1.2 Total alkalinity as meq $CaCO_3$/l was determined by titrating 0,1 M H_2SO_4 with a mixed indicator (methyl red plus bromocresol green) to an end-point pH 4,2 to 5,4. The exact end-point depends on the amount of CO_2 in solution and gives a measure of the OH^- + $CO_3^{=}$ + HCO_3^-.

2.4.1.3 Calcium was determined as mg Ca/l by the formation of a red colour complex with glyoxalbis - (2 - hydroxanil) = di - (o - hydroxyphenylimino) ethane which was read at 520 mμ (Kerr 1960).

2.4.1.4 Magnesium was recorded as mg Mg/l by the formation of a coloured complex with the dye Brilliant Yellow (Tarras 1948) which was read at 540 mμ.

2.4.1.5 Ortho-phosphate was determined as mg PO_4/l at 882 mμ by the formation of a colour complex in acid solution, and the subsequent formation of a blue colour after reduction with ascorbic acid (Murphy and Riley 1962).

2.4.1.6 Nitrite was recorded as mg NO_2/l at 530 mμ by the formation of a red colour complex with alpha-naphthylamine in acid solution (Swingle 1961).

2.4.2 Unfiltered Samples

2.4.2.1 Suspended solid material (silt load) carried by the Mwenda River flood waters was determined by placing a 200 ml aliquot ($\pm$ 1% error) in a centrifuge tube, which had previously been equilibrated in a draft oven at 80° C for 4 hours. After centrifugation for 30 minutes at 3000 rpm, the supernatant was discarded and the tubes replaced into the oven at 100° C for 10 hours. The tubes were then allowed to cool in a desiccator and weighed once they had reached room temperature. Each tube was weighed 4 times and the mean calculated. The results are expressed in g suspended solid material/l.

2.4.2.2 Light penetration: the effect of suspended solid material (mainly inorganic flood silt load) on the penetration of the different wave lengths of visible light into the lake water was determined spectrophotometrically. Unfiltered water samples (stabilized with chloroform) were scanned from 340 to 900 mμ. The horizontal distribution of suspended solid material in the Mwenda River mouth was determined by measuring the scattering properties of the silt laden water spectrophotometrically at 530 mμ.

2.4.3 Photosynthetic Pigments

Samples were filtered through Millipore prefilter discs which retained the smallest phytoplankton. The discs were then placed in 10,0 ml methanol in scintillation vials, deposited in a cold box and transported to the laboratory where they were left in the refrigerator for 24 hours. This cold extraction method of the photosynthetic pigments proved more practical than the rapid hot extraction. After 24 hours the discs were removed and the super= natant liquid centrifuged at 2500 rpm for 1 minute with a Christ hand centrifuge. The supernatant was exa... ned at 663 mμ and 760 mμ with a 2,0 cm light path on a Pye-Unicam SP600 spectro= photometer. The total photosynthetic pigment was calculated from the formula presented by Golterman (1969),

$$Pt = u_{E_{663}}^{1cm} \times \frac{1000}{K} \times \frac{\text{Vol. extract (ml)}}{\text{Vol. filtrate (l)}} = \mu g\ Pt/l$$

$$u_{E_{663}}^{1cm} = \frac{u_{E_{663}} - u_{E_{760}}}{\text{light path (cm)}}$$

Pt - total photosynthetic pigment (chlorophyll a and phaeophytin) as μg Pt/l

u - unacidified sample

E_{663}, E_{760} - extinction at 663 mμ and 760 mμ

K - extinction coefficient.

2.4.4 Phytoplankton Counting

The phytoplankton samples collected were made up to a volume (between 20 and 90 ml) according to the concentration of par= ticulate material in the sample. Each sample was well shaken and an aliquot (2,35 ml) placed in a Wild shallow counting chamber and allowed to sediment for a few hours. The chamber was then placed onto the stage of an Olympus inverted microscope, and the area of the coverslip (25,0 mm diameter) scanned to compile a list of genera present (Figure 9). All whole algal cells were noted. A quantitative estimation of the population was made by counting all cells (and organisms) along a transect 0,21 mm wide at 400x magnification from the centre right of the chamber as shown in Figure 9. The length of each transect depended upon the sample population (it varied between 2,0 mm and 50,0 mm). Approximately 200 organisms were counted, which is considered by Lund et al (1958) to be sufficient.

The density of the phytoplankton was then expressed as the total number of cells/l or as the total number of algal occurrences/l. From the count sheets the percentage of each genus or group of genera was calculated. These calculations, based either on the total cell count or total occurrence, produced almost identical results, so it is acceptable, in the case of this report, to present either set of results.

The phytoplankton populations of the areas studied were in many cases very diverse, with only a few individuals of a species present (e.g. desmids).

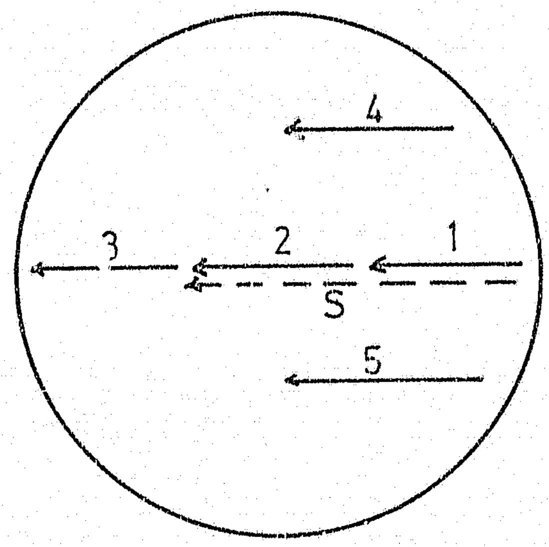


Figure 9: The counting positions on the field of view for the various counts. The solid arrows, numbered 1 to 5, are the replicate count positions for sample M17, and the broken arrow (S) is the transect position for the lake sample counts -- the transect length depends on the algal density.

The algae were arranged according to Prescott's (1962) classification (Appendix 18). In the case of the Bacillariophyceae the only subdivision was for the centric and pennate diatoms, which are considered separately from the rest of the Chrysophyta. The percentage of each genus in the population was summed into their respective major groupings and then represented as a percentage of each group in the population.

A sample from the Mwenda River mouth (August, station 7, number M17) was selected for a detailed count and statistical analysis to test the accuracy of the method, the randomness of the samples, and the variation between counting chambers. An aliquot (2,35 ml) of the sample was placed into each of the six counting chambers used, and five counts per chamber made (see Figure 9).

2.4.5 Statistical Methods

The phytoplankton counts and the chemical analysis data were statistically analysed, using an Olivetti Programma 101 computer. The methods employed are as follows:

2.4.5.1 Standard deviation:

$$\sigma = \sqrt{\frac{N\ \ x^2 - (\ \ x)^2}{N(N-1)}}$$

where x = variate value

N = number of samples

2.4.5.2 The standard error of the mean:

$$S.E. = \frac{\sigma}{\sqrt{n}}$$

where n = number of values

2.4.5.3 Counting accuracy:

$$\text{accuracy} = \frac{\sigma}{\bar{x}}$$

2.4.5.4 Chi-squared:

$$\chi^2 = \frac{\sum (a - \bar{x})^2}{\bar{x}}$$

where a = count values

$\bar{x}$ = population mean

Degrees of freedom = $n - 1$

= (counts - 1) x (chambers - 1)

2.4.5.5 The Bravais-Pearson coefficient of linear correlation:

$$= \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

where x, y = variables

N = number of observations

2.4.5.6 The generic diversity index (d):

$$d = \frac{S - 1}{\log N}$$

where S = number of genera

N = number of individuals

Statistical tests 2.4.5.1 and 2.4.5.5 were taken from the Olivetti Programma 101 Manual (1966), methods 2.4.5.2, 2.4.5.3 and 2.4.5.4 from Gregory (1964), and the generic index (2.4.5.6) from Margalef (1958). The frequency of all genera recorded from the lake samples was computed and a Raunkiaer "J" shaped frequency histogram plotted (see Raunkiaer 1934 in Kershaw 1964), from which the ecologically important genera were extracted, i.e. genera which were recorded from more than 61,0% of all samples investigated.

3 PHYSICAL LIMNOLOGY

Physical properties of the water of selected areas were assessed by recording temperature depth profiles and light transparency into the water, at the routine sampling sites.

3.1 THERMAL PROPERTIES OF THE WATER

Fluctuations in thermal properties of the water body influence seasonal changes in other physical, chemical and biological parameters under investigation. Changes in water temperature are brought about by the local climatic pattern. The heavy convection thunderstorms, characteristic of the middle Zambezi Valley, cause the river systems to be flushed by cool, silt laden waters, the effects of which can be seen when the Mwenda River floods. These conditions also affect the open lake waters to a lesser extent than the drowned river mouths.

The annual cycle of thermal stratification in the open lake (Mwenda Basin) was controlled by ambient air temperatures and rainfall pattern (cf. Figures 6 and 11). The rapid increase in mean air temperature from August to October results in a corresponding increase in water temperature, producing a well developed thermocline by April. The fairly rapid cooling of the air temperature and subsequent water cooling result in isothermal conditions from about April - May (turnover) through to July. Similar conditions prevail for the other basins of Lake Kariba (Coche 1968), though isothermal conditions are first recorded in basin 1 and last in basins 4 and 5. This is mainly due to the water depth, depth and intensity of the thermocline, and the temperature of the inflowing Zambezi waters.

3.1.1 The Mwenda River System

3.1.1.1 The Mwenda River

The four sampling stations showed a common annual cycle related to the local climatic pattern for the area, the degree of sheltering by adjacent vegetation and presence of Salvinia at station 1. Salvinia did not occur beyond station 1 on the Mwenda River, causing the low temperature at this station in August, October and December (Table 3). In August the temperature at station 1 was 1,3° C lower than the mean value for stations 2, 3 and 4; in October, 6,8° and in December, 3,5° C lower.

Table 3: Surface water temperatures recorded from the Mwenda River.

		Sampling Period						
		4.8.71	14.10.71	2.12.71	7.2.72	13.4.72	15.6.72	Mean, S.E.
Sampling Station	1	17,5	23,5	24,5	30,5	27,5	17,5	23,5 ± 5,2
	2	19,0	28,4	28,0	29,9	29,4	21,7	26,1 ± 4,7
	3	19,1	30,0	28,1	29,8	28,0	18,6	25,6 ± 5,3
	4	18,2	29,5	28,0	29,0	26,5	17,8	24,8 ± 5,4
Mean		18,4 ±0,75	27,8 ±2,9	27,1 ±1,7	29,8 ±0,6	27,8 ±1,2	18,9 ±1,9	

The increase in water temperatures from August to October was the result of a mean monthly air temperature increase from 17,7° C to 29,4° C. Fairly static temperatures were recorded for February (mean 29,8° C) for all four stations when the Mwenda River was in flood. The high temperature for station 1 was due to the Salvinia mat being completely flushed out. The temperature at station

1 was 27,5° C in April and 17,5° C in June, indicating that the Salvinia mat had re-colonized the area.

Stations 2 and 3 exhibited a similar annual temperature cycle, except in June, when station 2 was 3,1° C warmer than station 3, due to the exposure of the "pool" at this period. Station 4 was cooler than either stations 2 or 3 in August, April and June, due largely to the overhanging fringing woody vegetation and the steep-sided banks.

3.1.1.2 The Mwenda River Mouth

The temperature profiles of the Mwenda Basin are included in Figure 10. The seasonal temperature cycle in the Mwenda River mouth can be compared with that in the open lake waters, particularly the development of the lake thermocline (± 30 m) and its influence on the drowned river mouth.

During August, the highest temperature of 24,5° C was in sheltered waters where the river enters into the lake (station 1). Here the temperature dropped from 24,5° C at the surface to 22,8° C at 3 m. Continuing along the drowned river transect (stations 2, 3 and 4) the surface and bottom temperatures differed by no more than 1° C. At stations 5, 6 and 7, and the Mwenda Basin station, a drop of less than 1° C in temperature from surface to bottom was recorded.

The October sample showed temperatures of the Mwenda lake system had increased by approximately 4° C (an increase of approximately 2° C per month). The warmest temperatures were again recorded in the sheltered part of the drowned river mouth (28,0° C at station 2). The rest of the Mwenda River mouth remained below 27,0° C; temperatures below 26,0° C were at stations 6 and 7. The lake thermocline began to develop as the surface waters of the open lake became warmer (26,3° C at Om and 23,8° C at 35 m).

By December the temperatures of the sheltered regions had increased by 2,0° C, with stations 1 and 2 having surface temperatures higher than 30,0° C. Stations 3, 4 and 5 all showed a temperature decrease of ± 1,8° C from sur= face to bottom. At stations 6 and 7 a decrease in temperature of 0,9° C was recorded between the surface and bottom waters. The surface waters of the open lake continued to increase in temperature (29,4° C at 0 m), while the deep waters lost heat to the upper waters (bottom waters were 23,2° C at 40 m). A weak thermocline was apparent between 20 m and 32 m.

In February the sheltered stations showed a marked in= crease in water temperature. The surface and bottom waters for stations 1 and 2 were 33,4° C and 28,6° C, and 34,5° C and 28,1° C respectively. This localized yet temperature gradient was between 1m and 3m at station 1, and between 1 m and 3 m at station 2, but did not reach station 3. These conditions resulted from the inflow of water from the Mwenda River undercutting the warm turbid lake waters (turbid river water first enters the lake in early December) for a short distance only, and then flowing out along a favourable density level.

Apart from the warming of surface waters, stations 3, 4 and 5 showed similar characteristics to the December sample. The surface waters of station 6 increased by 1,3° C to 29,7° C, with the bottom waters cooling slightly to 27,1° C. The surface temperature recorded at station 7 was 29,4° C, with the water column remaining isothermal up to 20 m; thereafter the temperature decreased from 27,7° C at 20 m to 24,6° C at 30 m.

The April sample coincided with the beginning of the cool dry period. The Mwenda River mouth was isothermal, with a mean water temperature of 27,4° C and a maximum fluctuation at all stations between 27,1° C and 27,9° C. The surface waters of the open lake cooled to 27,2° C, causing the thermocline to intensify to 27,0° C at 30 m and 23,9° C at 32 m. This further lowering of the lake thermocline caused the cold, dense bottom water to flow out of the Mwenda River mouth.

3.1.1.3 The Mwenda Basin

Annual thermal conditions prevailing in the mid-Lake Kariba region were determined by sampling the Mwenda

Basin. This station is considered typical of the open lake water. The pattern of thermal stratification showed two distinct phases: a) isothermal conditions prevailing from May–June to October, when the difference in surface and bottom water temperatures was less than 1° C, and b) the development of the thermocline beginning in late October by the warming of surface water from 25,0 to 29,4° C, and intensifying to March, when it was very pronounced. Turnover began in May with a decrease in surface water temperature from 27,2 to 25,0° C and lasted for about ten days before isothermal conditions again prevailed (Mitchell, pers. comm.). The isotherm pattern for the Mwenda Basin is shown in Figure 11.

During the cool dry period the lake remains isothermal with vertical water movements mixing the entire water profile. When the thermocline starts developing and intensifying, complete profile mixing does not occur once the thermocline is fully developed. At this stage the hypolimnetic waters are completely isolated from the epilimnetic waters, which are mostly confined to the old Zambezi Valley. The thermocline acts as a barrier between the epilimnion and hypolimnion, and destratification only takes place once the epilimnetic waters cool under the influence of the local climate. The relationship between the climatic pattern and stratification development and breakdown can be seen by comparing Figures 6 and 11.

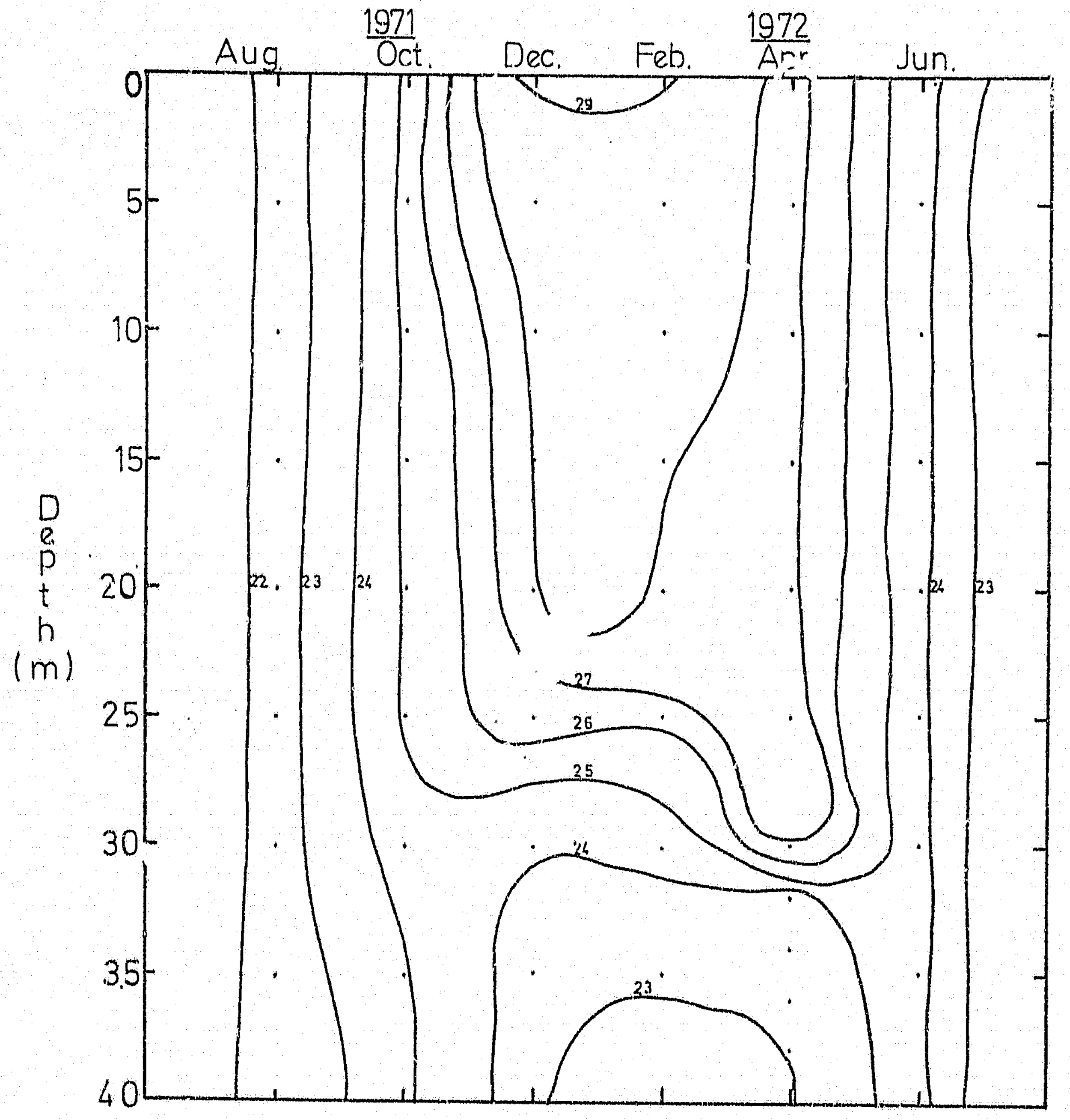


Figure 11: Temperature depth profile isopleth diagram for the Mwenda Basin deep water station.

The development of the lake thermocline can be seen in F gure 12 (the oxygen curves will be discussed below). By plotting the surface water (0 m) and deep water (35 m) temperatures for 1971 - 1972, the period of maximum stratification and the rate of formation and destruction of the thermocline can be seen. The epilimnetic water shows a typical relationship with the ambient air temp= erature. The hypolimnetic water, however, shows little temperature change throughout the year; therefore the breakdown of the lake stratification is controlled by the temperature (and thus density) of the epilimnetic waters.

3.1.2 The Sengwa River

The seasonal temperature depth profile pattern is presented in Figure 13. The data are incomplete for August, October, February and April as a result of dense infestations of Salvinia and "sudd" restricting access to the relevant sampling stations.

During August the "sudd" mat covered stations 1 and 2, and there was much loosely packed vegeta' ɔn at station 3. From station 3 to station 7 the river showed a fairly uniform temperature pattern, ranging from 23,5^{o} C to 21,8^{o} C, with a maximum temperature differ= ence between surface (23,3^{o} C) and bottom (21,9^{o} C) of 1,4^{o} C.

By October the "sudd" mat had moved further down the river mouth so that access to station 3 was prevented. The water temperature by this time had shown an approximate increase of 2^{o} C per month (a

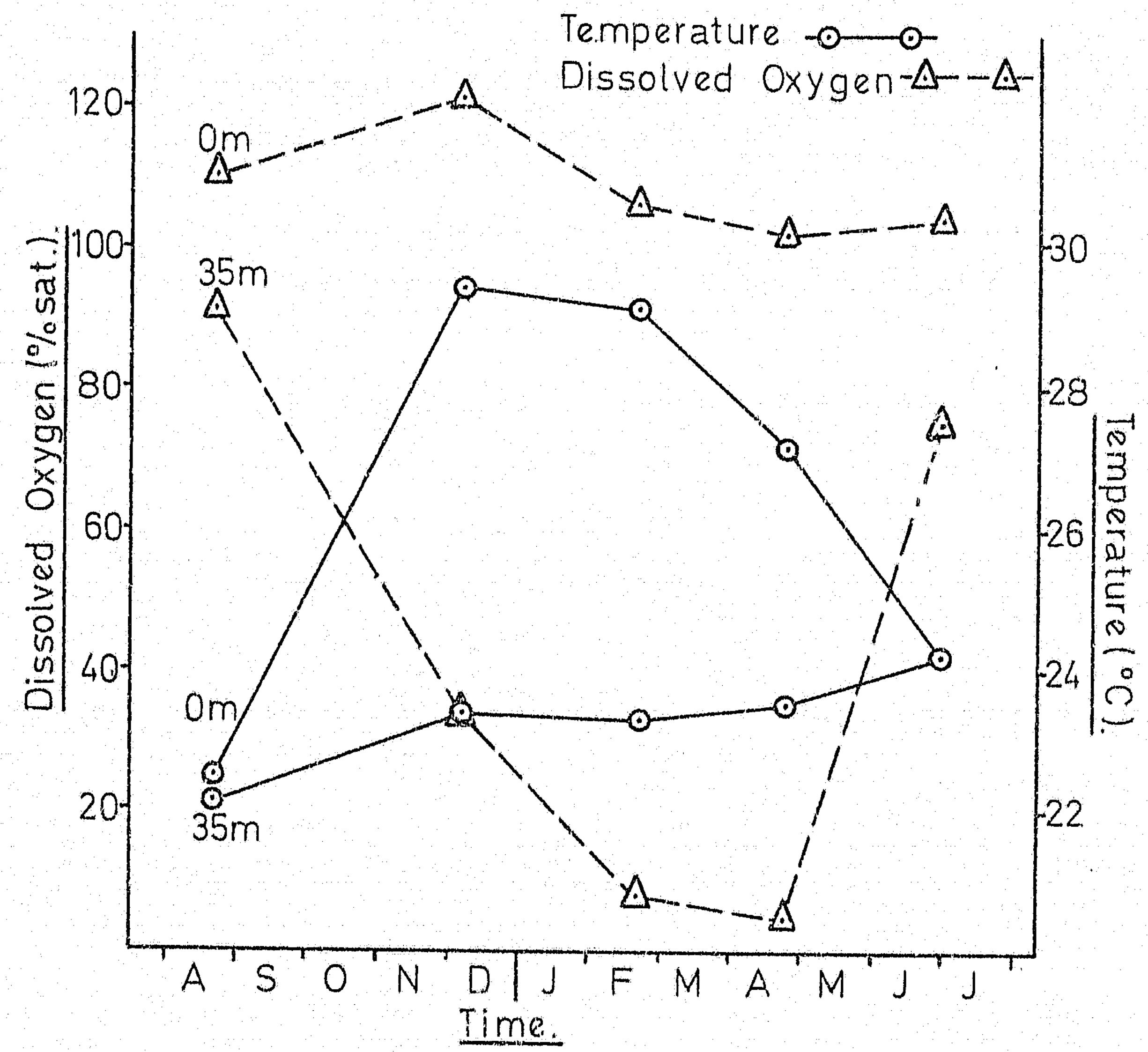


Figure 12: Relationship between surface water and water below the thermocline (35 m) for temperature and dissolved oxygen, recorded at the Mwenda Basin deep water station.

similar increase in temperature for the same period was recorded in the Mwenda River mouth). The surface temperature at station 4 was 26,7° C and the bottom 25,9° C. Stations 5 and 6 exhibited similar temperature profiles with a mean surface temperature of 27,7° C and that at the bottom 25,7° C. The highest temperature (28,3° C) was recorded from the surface waters at station 7, which also showed a temperature decrease from surface (28,3° C) to bottom (25,2° C) of 3,1° C (depth 29 m). This high temperature was probably due to warming of the lake waters overlying shallow submerged soils along the Mujery coastline.

By December, the "sudd" mat partially moved out beyond station 4 by wind action, leaving a large number of small mats of "sudd" and free-floating <u>Salvinia</u> (<u>Salvinia</u> not in association with the "sudd"). Thus stations 1 and 2 were visited for the only time during this study. Station 1 showed a temperature decrease of 1,[illegible]° C from surface (30,4° C) to 5 m (28,8° C). Stations 2 and 3 showed a mean profile temperature of 29,1° C. The surface water temperature at stations 4 and 5 increased to 30,2° C, and the largest decrease in temperature from surface (30,2° C) to bottom (27,4° C) at station 5 was 2,8° C. No data are available for stations 6 and 7 due to strong wind making their recording unsafe.

By February the "sudd" mat had re-established itself, preventing access to stations 1 and 2. The temperature profile data shows no change from December except that the bottom water temperature at station 5 decreased to 27,3° C. Stations 6 and 7 exhibited very similar temperature profiles, with temperature decreases from surface to bottom of 3,7° C and 4,4° C respectively (a temperature decrease with depth of $< 0,1^{\circ}$ C/m).

By April the "sudd" mat extended beyond station 3. The temperatures had started dropping, with the maximum surface value recorded at station 5 (28,2° C). The bottom waters had cooled to a mean temperature of 26,6° C. The surface waters cooled rapidly (Figure 13) and the bottom waters lost heat less slowly.

Seasonal temperatures of the Sengwa River mouth showed a similar pattern to those of the Mwenda River mouth (cf. Figures 10 and 13). There was a general warming of the water profile from July-August through to December-January, after which the temperatures dropped to the minimum in June-July. During the hot period (December to February) no temperature stratification was recorded. From these figures it is also clear that the rate of cooling of the water was more rapid than the warming. This pattern is dependent firstly on the annual ambient air temperature cycle, and secondly on the rainfall pattern and nature of river flooding into the river mouth.

3.1.3 The Mujery Offshore Area

The mean water temperatures for the two offshore depth profile transects are shown in figure 14. Both transects showed s typical "bell-shaped" seasonal temperature patterns.

During August transects 1 and 2 showed mean profile temperatures of 23,3° C and 24,1° C respectively, and by

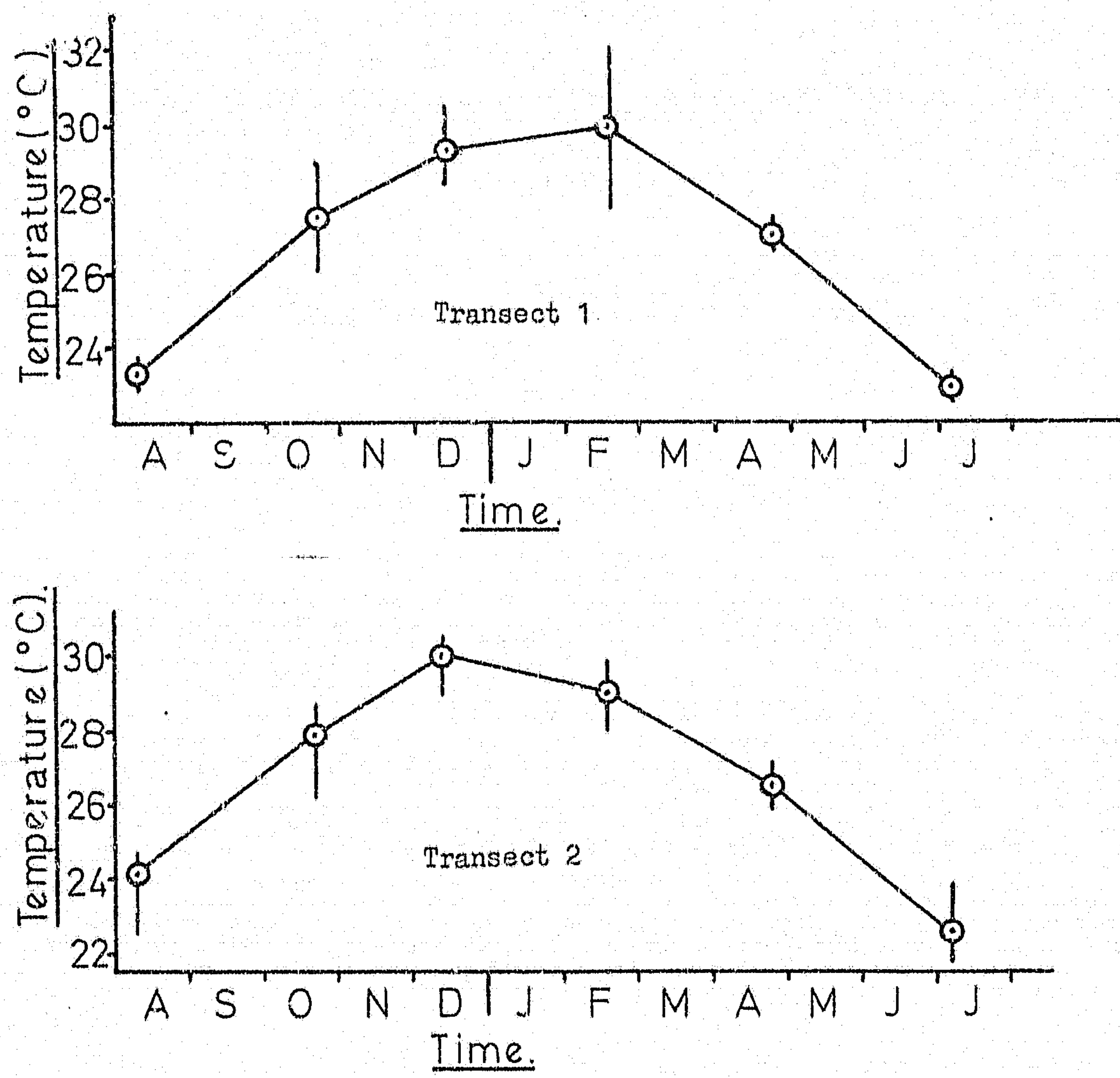


Figure 14: The mean maximum and minimum recorded seasonal water temperatures for the [redacted] offshore transects at Mujery.

October 27,5° C and 27,9° C respectively.

By December the temperature of transect 1 had increased by 1,8°C to 29,3°C, and transect 2 by 2,1°C to 30,0°C. The temperature of transect 1 increased further to 29,9°C in February, the highest temperature of 32,0°C being recorded adjacent to the lake shore at 0 m. Transect 2 showed a decrease in mean water temperature of 1° C to 29,0° C.

By July the mean water temperature of transect 1 had decreased by 6,9°C from 29,9°C and transect 2 temperature by 6,0° C from 29,0° C to 23,8° C, completing the annual cycle.

At no period did either transect 1 or 2 show thermal stratification. This is mainly due to the shallow water depth (less than 10 m deep), and complete vertical mixing throughout the year.

3.2 WATER TRANSPARENCY

The Secchi disc method to determine the transparency of water has been extensively used. The light intensity at the limit of visibility of the disc is about 15% of the subsurface intensity, but varies considerably due to local conditions.

3.2.1 Mwenda River System

The light transparency data for the Mwenda River mouth and the Mwenda Basin are presented in Table 4. No data are presented for the Mwenda River, as the Secchi disc readings were always < 0,1 m; this is due to the heavy suspended silt load kept in suspension throughout the year.

Table 4: Water transparency of the Mwenda River system as determined by the Secchi disc method (M).

Sampling date	Mwenda River Mouth						
	3. 8.71	15.10.71	3.12.71	7. 2.72	18. 4.72	26. 6.72	Mean, S.E.
Sampling Stations 1	1,2	1,3	1,2	0,3	0,9	1,3	1,0 ± 0,4
2	1,9	2,0	1,5	0,3	1,0	1,7	1,4 ± 0,6
3	2,1	3,5	2,2	1,1	1,4	2,0	2,0 ± 0,8
4	3,0	4,5	2,8	2,1	1,8	2,7	2,8 ± 0,9
5	4,0	4,5	4,4	2,8	3,4	3,5	3,8 ± 0,6
6	4,9	4,5	4,0	4,9	4,6	3,5	4,4 ± 0,5
7	4,5	4,5	4,5	5,8	5,8	3,8	4,8 ± 0,8

Mwenda Basin						
23. 8.71		6.12.71	19. 2.72	24. 4.72	30. 6.72	Mean, S.E.
5,2	-	6,2	7,7	6,2	3,5	5,8 ± 1,5

The water transparency of the Mwenda River mouth showed a mean increase of 3,7 m from station 1 to station 7 through the year (Figure 15). Characteristically the lowest water transparency values were recorded at stations 1 and 2 (0,3 m in February 1972) and the highest values at station 7 (5,8 m in February and April 1972). The greatest difference between the transparency of station 1 and station 7 occurred in February (5,5 m). This was due to the light-scattering properties of the silt-laden Mwenda River flood waters entering the lake at station 1. Phytoplanktonic populations also influence light penetration into the water.

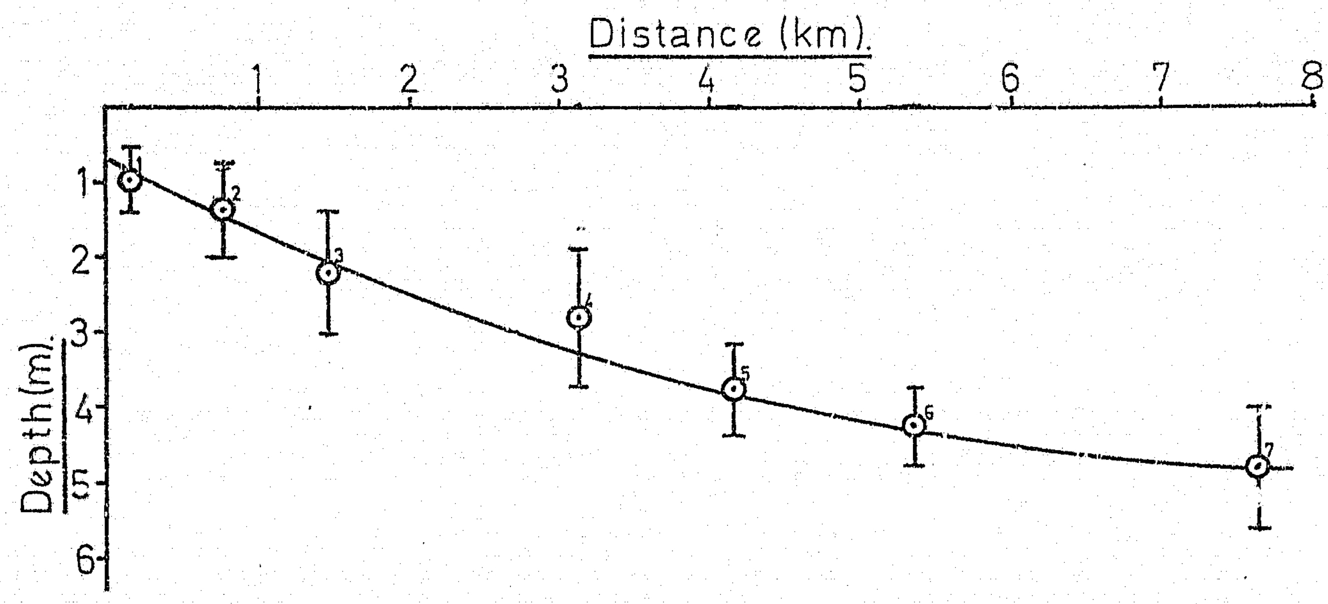


Figure 15: Mean light transparency values for the Mwenda River mouth. Vertical lines are the standard deviation, and the figures adjacent to the mean are the sampling stations.

The water transparcney data of the Mwenda Basin showed a mean annual value of 5,8 m. The increase in transparency from August to February (5,2 m to 7,7 m) was due to a decrease in surface algal populations. By April the transparency decreased to 6,2 m and by June-July the Secchi disc value was 3,5 m. This relatively poor water transparency was due to the increase of phytoplankton in the upper layers of the water body, caused by the release of plant nutrients from the hypolimnion during turnover (see Figure 11).

3.2.2 Sengwa River Mouth

The results are presented in Table 5. The Sengwa River mouth exhibits a similar pattern to the Mwende River mouth, with the lowest water trancparency values (1,2 m) being recorded at the station closest to the point of river inflow, and the highest values at the station under the influences of the open lake (Figure 16). This pattern was, however, not always evident in the Sengwa River mouth, due to the effect of the floating macrophytic vegetation. In October the light transparency at stations 5 and 6 was lower than that at both stations 4 and 7 and in December that at station 6 was lower than that at station 5. This was the result of wind destruction of the floating macrophyte mats, with the subsequent increase in suspended detrital material. The poor phytomass was unlikely to have any effect on light penetration in the Sengwa River mouth.

Table 5: Water transparency values recorded for the Sengwa River mouth.

Sampling Stations	Sampling Dates						
	18. 8.71	23.10.71	15.12.71	24. 2.72	28. 4.72	5. 7.72	Mean, S.E.
1	-	-	1,2	-	-	2,1	1,6 ± 0,6
2	-	-	3,2	-	-	2,5	2,8 ± 0,5
3	4,5	-	4,5	2,5	-	2,8	3,6 ± 1,1
4	4,5	5,3	5,0	2,7	2,7	2,8	3,8 ± 1,2
5	5,0	4,8	5,6	3,5	2,7	4,2	4,3 ± 1,0
6	5,0	4,3	5,2	4,2	4,0	4,5	4,5 ± 0,5
7	6,5	5,6	5,9	4,7	5,3	5,7	5,6 ± 0,6
Mean, S.E.	5,1 ± 0,8	5,0 ± 0,6	4,4 ± 1,6	3,5 ± 0,9	3,7 ± 1,2	3,5 ± 1,3	

3.2.3 Mujery Offshore Area

Lowest transparency values at both transect 1 and 2 transects were at the stations closest to the shore (stations 1 and 5), and the highest values at the lakeward stations (4 and 8).

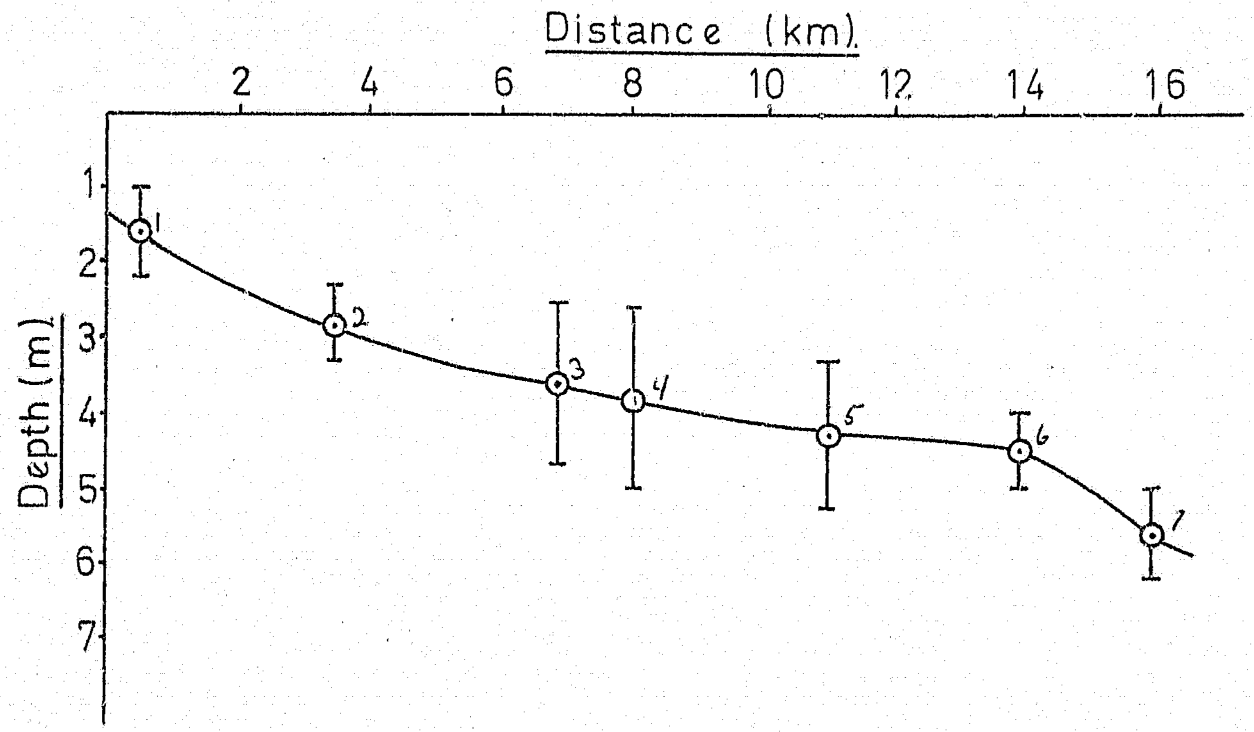


Figure 16: Mean light transparency for the Sengwa River mouth. Vertical lines are the standard deviations, and the figures adjacent to the mean values are the sampling stations.

The mean water transparency values of transect 1 stations were higher than those of transect 2 stations (Table 6), this difference being masked by the fact that Secchi disc transparency was recorded down to the sediments more often in transect 2 than transect 1. The water in the transect 1 area contained more suspended material originating from destruction of periphytic communities on the dead trees and rooted macrophytes for stations 1-3 than did that in the transect 2 area. This is not apparent from the phytomass data (photosynthetic pigments) as the suspended material was detrital in nature. This large amount of detrital material was recorded from algal count samples.

Table 6: Water transparency data for the [redacted] offshore tran= sects in the Mujery area. The figures underlined indicate transparency to the bottom sediments.

Sampling Stations		Sampling Dates 9. 8.71	20.10.71	13.12.71	16. 2.72	21. 4.72	8. 7.72	Mean, S.E.
Transect 1	1	1,8	0,8	1,7	1,5	1,5	2,5	1,6 ± 0,5
	2	2,3	1,5	2,1	4,3	3,2	3,0	2,7 ± 1,0
	3	3,8	4,0	4,7	4,6	4,4	4,3	4,3 ± 0,3
	4	4,5	4,7	4,8	4,8	4,6	4,4	4,6 ± 0,1
Mean S.E.		3,1 ± 1,2	2,7 ± 1,9	3,3 ± 1,6	3,8 ± 1,5	3,4 ± 1,4	3,5 ± 0,9	
Transect 2	5	1,3	1,1	1,0	0,6	0,8	1,8	1,1 ± 0,4
	6	2,9	2,5	2,0	2,7	1,6	2,2	2,3 ± 0,5
	7	4,1	4,4	2,2	2,9	2,9	2,9	3,2 ± 0,8
	8	4,6	5,0	5,0	4,3	4,9	4,7	4,8 ± 0,3
Mean S.E.		2,1 ± 1,4	3,2 ± 1,8	2,5 ± 1,7	2,6 ± 1,5	2,5 ± 1,8	2,9 ± 1,3	

4 CHEMICAL LIMNOLOGY

4.1 DISSOLVED OXYGEN

The dissolved oxygen content of fresh water is considered to be an indicator of algal photosynthetic production. The upper layers of eutrophic waters are usually supersaturated with oxygen (e.g. Hartbeespoort Dam). Scott (1974) has pointed out that the oxygen maxima for Hartbeespoort Dam show a significant correlation with maximum phytomass (total cell counts). The vertical and horizontal oxygen supersaturation depends on the biology of the specific planktonic organism. In oligotrophic Lake Kariba, the oxygen content is affected by gaseous diffusion across the air-water interface, algal production, and decomposition of the detritus.

4.1.1 The Mwenda River System

No dissolved oxygen values for the Mwenda River sampling stations were taken due to the difficulties encountered in recording *in situ* measurements.

4.1.1.1 The Mwenda River Mouth

The dissolved oxygen isopleth diagrams are presented in Figure 17. The dissolved oxygen profiles for the Mwenda Basin have been included so that the relationship between the drowned river mouth and deep water oxycline development and breakdown can be seen.

In August the dissolved oxygen values were near saturation for the entire system, though the sheltered stations (stations 1 to 4) were below 100% saturation, and the "bay" stations showed oxygen $>$ 90% saturation practically to the bottom sediments.

By October the river mouth oxycline started to form. The upper waters of all stations were saturated to slightly supersaturated (except stations 1 and 2). The bottom waters started decreasing in oxygen saturation. The oxygen distribution with depth in the open water was similar to that of the river mouth water.

The December dissolved oxygen isopleths showed an increased intensity of the oxycline as a result of a high oxygen demand in the bottom waters.

The sheltered stations (1, 2 and 3) also showed lower surface values. The oxycline was somewhat diffuse at these stations. From station 4 toward the open lake, the oxycline followed the profile of the old Mwenda River bed, i.e. establishing at 15 m to 25 m depth with the bottom waters being less than 30% saturated. The depth of the open lake oxycline was approximately the same.

By February the Mwenda River mouth was below saturation, except for the surface waters at stations 6 and 7, and the open lake. The bottom waters were below 30% saturation, except at station 2 ($>$ 40%). Station 1 showed an intense decrease in dissolved oxygen with depth (82% at 0 m and 25% at 3 m), with station 2 showing a similar pattern with the oxycline at 0 m to 2 m. Station 3 showed the presence of a double oxycline* (the first at 3 m to 4 m and the second at 9 m to 11 m depth). The oxycline then followed the river mouth bottom profile with a slight divergence at station 6 (19 m to 25 m). The oxycline was most intensive up to 5 m above the bottom sediments at station 7. The oxygen isopleths in the open lake corresponded closely to those of the Mwenda River mouth. The oxygen-deficient bottom waters (< 10% saturation below 33 m) in the Mwenda Basin extended into the Mwenda River mouth to a point between station 6 and station 7.

The final stage in the oxycline development can be seen in the April isopleth diagram. Generally there was an increase in the dissolved oxygen profile from station 1 to stations 6 and 7 (these last two stations had 90% saturation practically down to the bottom sediments). The bottom waters of station 3 showed increased oxygen deficiency (< 40% below 11 m). This was possibly due to high respiration of organic matter in the bottom water. The established lake oxycline was situated at 30 m to 35 m depth, and did not enter the Mwenda River mouth.

From the data presented above it is apparent that the oxygen cycle in the Mwenda River mouth is controlled predominantly by respiratory processes rather than by photosynthetic activity due to the deficient algal flora. The oxygen in solution is consumed by the organisms de- composing the organic material that slowly sediments through

* The upper oxycline resulted from an oxygen demand created by the influent river water flowing along a density gradient, and the lower one by an oxygen demand from thebbottom sediments (this lower oxycline was present along the entire length of the river mouth profile in February).

the water profile and finally comes to rest on the bottom sediments where, at the sediment-water interface, maximum oxygen consumption takes place. The fairly high oxygen values which exist in the Mwenda River mouth throughout the year indicate that a fairly deep photic zone is present.

Once the surface waters of the river mouth have cooled sufficiently and become slightly more dense than the bottom waters, oxygen is again replenished to the lower layers. This is a process of eddy diffusivity rather than turnover, for the waters of the river mouth did not stratify during the 1971 - 1972 period and therefore theoretical profile rejuvenation did not occur.

4.1.1.2 The Mwenda Basin

The dissolved oxygen depth isopleth is presented in Figure 18 (see also Figure 17). The surface waters remained saturated throughout the year, with supersat= uration occurring down to 5 m from August to mid-January (121% saturation on 6.12.71). This was the result of strong northerly winds blowing down the long axis of the lake for long periods, producing $\pm$ 2 m waves.

The August sample showed 90% dissolved oxygen down to $\pm$ 37 m (lake isothermal). Oxygen stratification began in October, with the bottom waters becoming increasingly deficient on oxygen until February ($<$ 5% saturation at

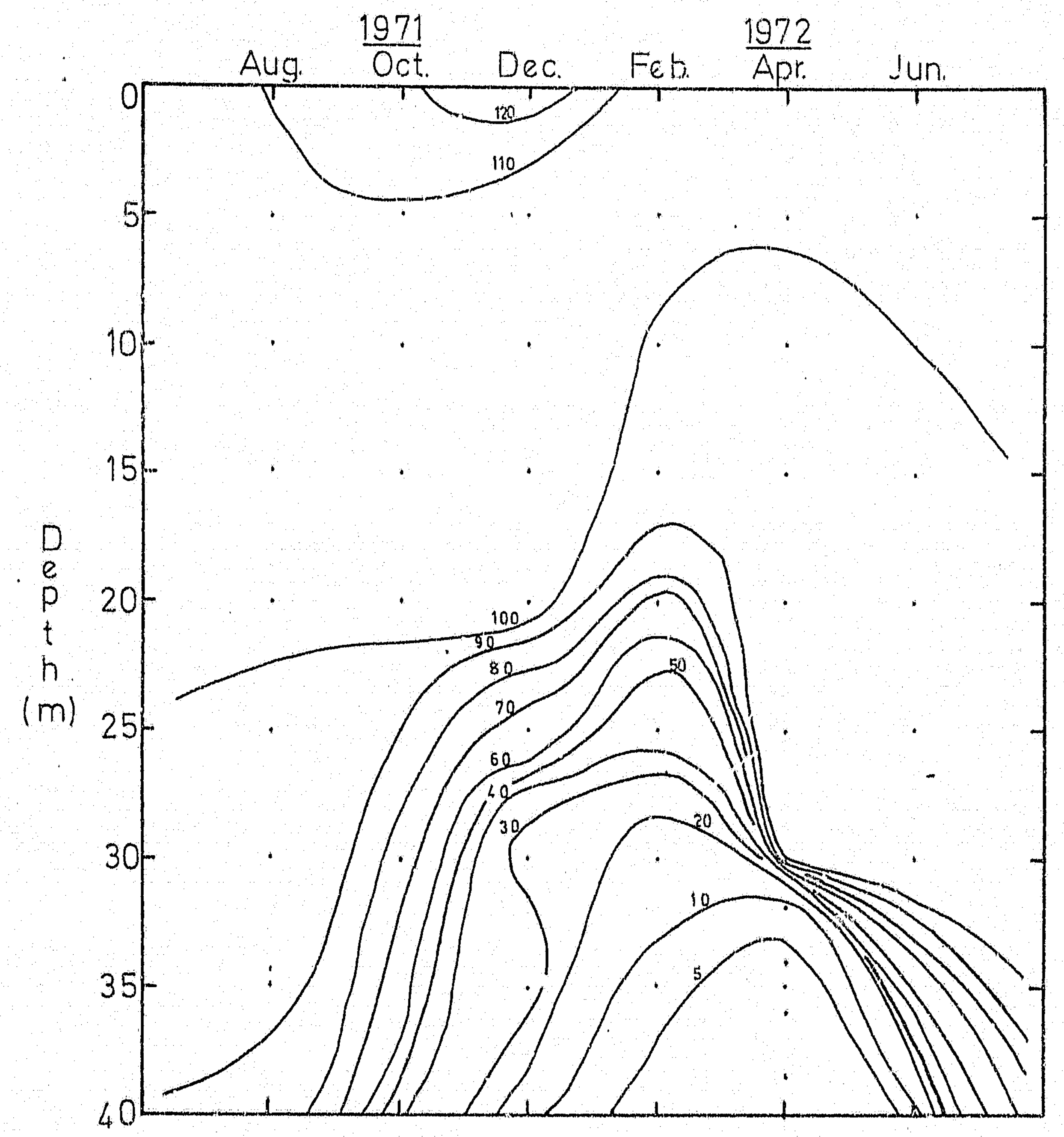


Figure 18: Dissolved oxygen isopleth diagram for the Mwenda Basin deep water station.

± 37 m). From February to April the oxycline became established between 30 m and 31 m (94% at 30 m and 6% at 32 m).

Once thermal stratification started to break down, oxygen-rich water again circulated to the bottom waters with most of the profile (32 m depth) only slightly under-saturated by July. It therefore appears that dissolved oxygen distribution in the open lake water is mainly due to wind-induced wave action, and the oxygen regime within the water was due to the particular temperature pattern which occurred. The increase in depth of oxygen-saturated surface water could be enhanced by the post turnover plankton bloom (> 1,5 μg Pt/1 in surface water in June). At present this is pure speculation, for little is known about the biological effects of and responses to thermal and oxy-destratification in Lake Kariba.

4.3.2 The Sengwa River Mouth

The recording of dissolved oxygen at stations 1 to 3 was affected by floating aquatic macrophytes ("sudd") which prevented access to these sampling stations.

Occasionally small mats of the floating plants were seen in the main river passage. The large amount of organic material present in the water because of these aquatic plants (probably the main contributor to the particulate organic matter) has a great influence on the oxygen regime of the Sengwa River. Large quantities of organic matter were noted from the plankton samples and bottom sediments. The continuous raining down of this organic material onto the sediments creates a high oxygen demand as a result of intensive bacterial decomposition which causes oxygen stratification all year round, strongest during the hottest months.

The dissolved oxygen isopleths for the Sengwa River mouth are presented in Figure 19. In August a weak oxycline was present in the last 9 m of the water profile, being most intense at stations 3 and 4 (90%saturation at 6 m and about 55% at the bottom). From station 5 to station 7 the oxycline was somewhat diffuse, although the isopleths still followed the river bed. The surface water from just beyond station 5 to station 7 (open bay) was at saturation point except for a small area slightly undersaturated at station 6 (90% saturation at 2 m).

In October the oxygen isopleths sloped slightly down to the deeper water. The rest of the profile was similar to the August sample except that the bottom waters had lost considerable amounts of oxygen, intensifying the oxycline which had also become shallower. The bottom waters of station 6 and station 7 contained < 20% dissolved oxygen.

The bottom waters at station 1 and station 2 showed a very strong oxycline in the bottom 4 m, with oxygen-deficient conditions occurring in the surface waters at the point of river inflow into the lake. The latter values (< 40% saturation) were the result of reduced light penetration due to a heavy silt load and also large amounts of organic material. At stations 3 and 4 the oxycline became slightly diffuse but was re-established between 5 m and 13 m (respective dissolved oxygen values were 80% and 20%). The bottom waters of all stations except station 1 contained < 10% dissolved oxygen (< 2% saturation at 25 m for station 6). The surface water from station 5 to the open water contained 100% dissolved oxygen.

The February values showed the main oxycline sloping down towards the open water (between 4 m and 6 m at station 3, and between 11 m and 14 m at station 7), with a gradient ranging from 40% saturation to < 10% in the bottom waters. All surface waters remained below 96% saturation.

By April the profile had become re-oxygenated. From the temperature data there is no indication of a thermocline formation, thus no turnover, so oxygen replenishment to the bottom waters was probably due to weak vertical eddy currents caused by slight density differences in the water. A weak oxycline was still present (about 5 m thick) extending horizontally from station 4 to station 5 (from 5 m to 13 m, 80% to 50% saturation); it then sloped steeply down towards station 7 (between 21 m and 26 m). The only supersaturated water occurred in the open bay at station 7 (113% saturation). This was due to the greater wind action on the water surface there than in the sheltered river mouth.

The oxygen cycle of the Sengwa River mouth showed a very similar pattern to that in the Mwenda River mouth, but with three main differences:

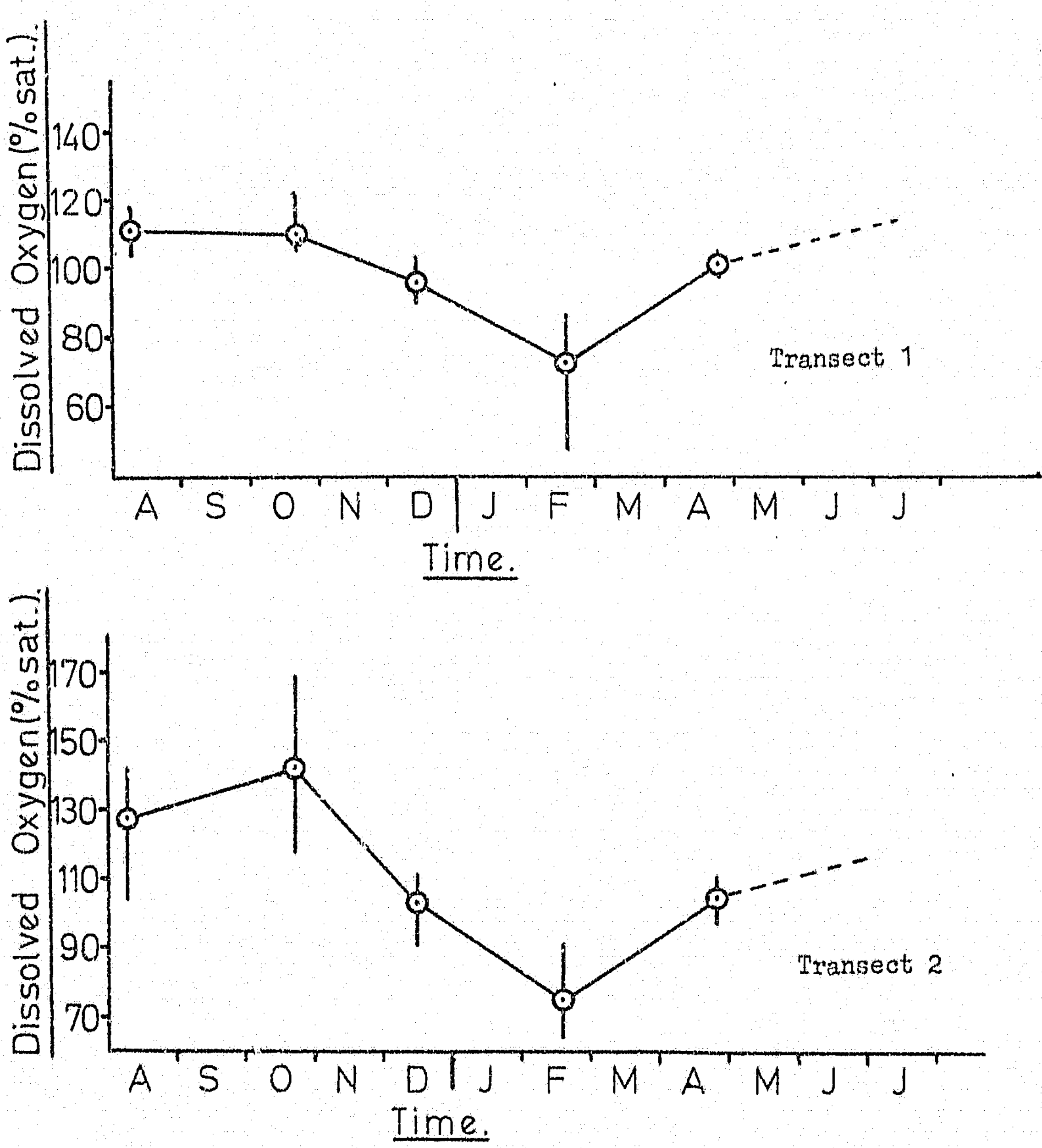
1) the surface waters in the Mwenda River mouth were generally more oxygen-saturated than in the Sengwa River mouth
2) the oxycline in the Mwenda River mouth was not as intensive as in the Sengwa River mouth
3) the bottom waters were not as oxygen-deficient in the Mwenda River mouth as in the Sengwa River mouth.

4.1.3 Mujery Offshore Area

The dissolved oxygen data for the Mujery offshore area are presented in Figure 20 (Appendix 4). The variation in dissolved oxygen between stations in each transect is shown by plotting the mean maximum and minimum recorded values for the particular sampling period.

The water profile of transect 1 was saturated with oxygen from August to late November. By December the water was slightly below saturation, by February just above saturation, and by April the water profile had again become saturated.

Transect 2 showed a similar pattern. The dissolved oxygen values for August to October were higher than those in the transect 1; this was probably the result of wind-induced wave action causing complete vertical mixing in these shallow parts of Lake Kariba. The lowest dissolved oxygen values were recorded



<u>Figure 20</u>: The mean maximum and minimum seasonal dissolved oxygen values recorded from the Mujery offshore area. [redacted] Each point on these graphs represents the mean value of the depth profile at all four sampling stations for a particular month. The broken line (- - -) indicates the possible flux in dissolved oxygen in June - July.

for February (mean dissolved oxygen $< 80\%$ saturation); thereafter they increased to saturation by April.

There was an inverse relationship between dissolved oxygen and the temperature pattern in the shallow waters at Mujery. When the ambient air temperatures started increasing in August, the water temperatures followed a similar pattern (see Figures 6 and 14) but not so for the dissolved oxygen. The saturated or super=saturated dissolved oxygen values could be partly due to photo=synthesis, which increases with increasing temperature (the highest photosynthetic pigment values were recorded in October). The subsequent decrease in dissolved oxygen by February could be the result of extremely high light penetration (Table 6) and deficient photosynthetic raw materials limiting the primary production. The increase in dissolved oxygen by April was again the result of oxygen diffusing directly into the water.

4.2 LAKE WATER QUALITY - EXCLUDING DISSOLVED OXYGEN

Chemical values in this section were obtained from chloroform-stabilized water samples analysed at the Nuffield Lake Kariba Research Station.

4.2.1 The Mwenda River System

The water quality of the Mwenda River system will be described as a whole. The water chemistry of the four stations on the Mwenda River is presented in Table 7, that of the seven stations in the Mwenda River mouth in Table 8, and the maximum and minimum values of the Mwenda Basin in Table 9.

Table 7: Water quality of the Mwenda River. Where no data are presented, high suspended matter loads were noted. This matter could not be removed by filtration, and thus masked the recording of the low colour development of the chemical analyses.

Chemical Parameter		Aug	Oct	Dec	Feb	Apr	June	Mean S.E.
Electrical conductivity (mS/cm at $25^{\circ}C$)	1	4,1	4,4	5,5	4,3	7,0	6,2	
	2	8,3	12,0	20,3	4,1	7,0	8,9	10,2
	3	12,0	16,8	22,7	4,5	6,9	8,2	± 0,7
	4	9,7	23,9	28,7	4,5	7,2	9,1	
Total alkalinity (meq/l)	1	0,04	0,50	,73	0,80	0,75	0,73	
	2	0,90	1,09	1,43	0,61	0,70	0,76	0,99
	3	1,30	1,76	2,12	0,59	0,70	0,87	± 0,6
	4	1,00	1,54	2,89	0,39	0,73	0,97	
Calcium (mg Ca/l)	1	5,18	8,25	21,36	12,56	7,01	7,20	
	2	7,37	11,51	20,56	11,00	6,76	7,56	8,97
	3	3,34	6,21	10,28	12,08	6,68	6,44	± 4,4
	4	0,61	1,25	0,45	0,39	0,29	0,23	
Magnesium (mg Mg/l)	1	0,13	0,15	0,31	0,35	0,14	0,11	
	2	0,22	0,51	0,61	0,36	0,17	0,14	0,38
	3	0,25	1,07	0,79	0,38	0,16	0,07	± 0,3
	4	0,61	1,25	0,45	0,39	0,29	0,32	
Calcium : magnesium ratio	1	39,9	55,0	68,8	35,9	50,1	65,4	
	2	33,5	22,6	33,7	32,8	39,8	54,0	35,3
	3	13,4	5,8	13,0	31,8	41,8	92,0	± 21,5
	4	7,6	4,5	14,6	31,6	23,3	36,2	
Ortho - phosphate (μg PO_4/l)	1	10,0	10,0	14,6	10,0	10,0	10,0	
	2	10,0	10,0	37,2	10,0	10,0	10,0	13,0
	3	10,0	25,2	27,9	10,0	10,0	10,0	± 7,1
	4	10,0	10,0	17,0	10,0	10,0	10,0	
Nitrite (μg NO_2/l)	1	-	10	10	10	10	31	
	2	-	10	10	10	10	44	19
	3	-	30	13	10	10	70	± 16,0
	4	-	10	19	10	10	44	

4.2.1.1 The Mwenda River

During the period under investigation the Mwenda River stations showed a cycle of nutrient concentrations in the pools once the river stopped flowing (March) and then after dilution by the river flood waters (January - February). Flood waters contain suspended sediment loads in excess of 50 mg/l, so a large proportion of the plant nutrients are adsorbed onto the clay colloids, and are not available for algal growth (Twinch 1974). They may only be released once the sediment has dropped out. Then, when the pools are again isolated, and oxygen tension and pH have decreased, an increase in nutrient concen= tration occurs. This, and the lowering of the pool water level, is the result of extremely high surface evaporation during the dry season. Only an insignificant amount of water was lost from the pools by seepage through the river bed sands to the water table. The lake has raised the local water table sufficiently for saturated sands to be loacted within 50 cm of the surface of the dry river bed, above station 4.

Electrical conductivity (estimate of total ionic concen= tration) of the four river stations increased from August to December (9,7 to 28,7 mS/cm at 25° C at station 4). During the annual flood the pool water was swept into the lake, and conductivity dropped to 4,1 - 4,5 mS/cm at 25° C. Once the river stopped flowing, the conductivity again increased. Station 1 showed very low values throughout the year. In August station 4 showed a conductivity value of 12,0 mS/cm at 25° C which was partly the result of the river bed muds being disturbed by workmen building the Hughes' Weir, and also the addition of washing powder to the water.

The total alkalinity showed a similar pattern to the electrical conductivity, by increasing from August to December. Dilution took place with the onset of the flood, reducing the alkalinity from 2,89 meq $CaCO_3$/l in December to 0,39 meq $CaCO_3$/l in February at station 4. This reduction was not the result of primary production, as the flood waters contained no detectable photosynthetic pigments or identifiable plankton. The highest value recorded at station 1 was 0,80 meq $CaCO_3$/l in February, which is similar to that of the lake water. The level of soluble carbon at this station appears to be controlled by the Salvinia mat, rather than by river flood water. The maximum colonization (objective estimate) of the Salvinia coincided with the low alkalinity value of 0,40 meq $CaCO_3$/l in August. By October ageing Salvinia plants were present, which could release soluble carbonaceous material back into the water, resulting in an increase in alkalinity.

The result of the decrease in pool volume due to surface evaporation was also evident in the calcium and magnesium values. Certain deviations from the aforementioned pattern appear in these results, which cannot be satisfactorily explained, except that the interaction between the soluble cations and the suspended clay particles could be significant. The primary producers utilize these ions by incorporating them into biomass, thus altering the equilibria; this causes adsorption/desorption reactions to take place, and alters the concentration of available ions in solution.

The maximum annual fluctuation of calcium was recorded at station 1, where in August 5,[illegible] mg Ca/l, and in December 21,36 mg Ca/l were recorded. Generally, the lowest values were recorded in August and the highest in December for all the river stations.

The magnesium values also showed an increase from August to October, when the highest values were recorded (1,25 mg Mg/l at station 4). There was a marked decrease in soluble magnesium towards the end of December for stations 3 and 4, and a corresponding increase at stations 1 and 2. Thereafter there was a decrease in February due to the effects of river flooding, except at station 1 where an increase from 0,31 to 0,35 mg Mg/l was noted. This was because the river waters contained more magnesium than this pool water. From February to June all stations showed a decrease in magnesium ions.

The consistently low magnesium and high calcium values for the river stations showed that soluble carbon (CO_3^{2-}

and HCO_3^-) was derived predominantly from calcium rather than magnesium salts. At station 1 the calcium : magnesium ratio was lowest during the period of river flow (Ca : Mg = 35,9) and highest when the river pools were at their lowest (Ca : Mg = 68,8). At this site the magnesium was possibly utilized by the rapidly increasing Salvinia mat to a greater extent than calcium. It is unlikely that adsorption onto suspended clay particles took place in this pool, as the suspended sediment load dropped out soon after the river had stopped flowing (Pers. obs).

From August to December there was a general decrease in the Ca : Mg ratio from stations 1 to 4. Stations 2, 3 and 4 showed a decrease in the Ca : Mg ratio from August to October, indicating a nett decrease of calcium with respect to magnesium. This could be due to increased adsorption of calcium onto the clay colloids as the concentration of suspended and soluble solids increased.

The flood waters in February showed a mean Ca : Mg ratio of 33,0. From February to June all stations showed an increase in the cation ratio, which coincided with an increase in total photosynthetic pigment values from February to April, and then an increase or a maintenance of the algal population.

The ortho-phosphate concentration at the four stations for the six sampling periods generally remained below 10 µg PO_4/l though a maximum value of 37 µg PO_4/l was recorded in December at station 2. This was, however, the result of building operations on the Hughes' Weir. A detectable amount of phosphorus occurred in the pools in December, but was not evident once the phosphorus-deficient flood waters had replaced the pool waters (Bowmaker 1973).

Nitrite nitrogen (the only species which could be accurately determined at the research station) generally remained below 70 µg NO_2/l. Very low levels of nitrite were recorded during the dry season, but were no longer accurately detectable once river flooding occurred. By June, values between 31 and 70 µg NO_2/l were recorded. This was probably due to the breakdown of organic material after the initial algal growth following river flooding.

4.2.1.2 The Mwenda River Mouth

The water chemistry of the Mwenda River mouth showed only slight changes from station 1 through to station 7 for any particular sampling period (the complete data table is presented in Appendix 5).

At no stage during this investigation were the upper reaches of the river mouth covered by *Salvinia*. This was the case during Bowmaker's studies (1973) when stations 1 and 2 (Bowmaker stations 4 and 5) were covered by Salvinia. Salvinia was however always present, to a greater or lesser extent, as narrow fringing mats stabilized by rooted aquatic macrophytes and dead trees. Salvinia did, therefore, play a less important role than it did at Mwenda River station 1 or during Bowmaker's studies.

The Mwenda River mouth can be classified as oligotrophic, as low nitrogen and phosphorus values were recorded throughout. Bowmaker (1973) indicates nitrate values between 0,0 and 0,56 mg/1, nitrite between 0,0 and 0,17 mg/1, ammonia nitrogen between 0,01 and 0,17 mg/1, and phosphate phosphorus values between 0,006 abd 0,617 mg/1, the maximum values noted from the river pools in the dry season. The data presented in Table 7 as well as that presented by Bowmaker (1973) show plant nutrient levels typifying an oligotrophic state, with mostly insignificant variations from river pools to open lake, and through water depth profiles.

The electrical conductivity showed a maximum fluctuation between 6,1 and 7,5 mS/cm at 25° C, for all samples. The total alkalinity showed a very slight seasonal fluctuation, the highest values being recorded just prior to the rains (mean of 8,0 meq/1) and the lowest after the first heavy thunderstorm (mean 1,7 meq/1).

Table 8: Mean water chemistry values for the Mwenda River mouth for the routine sampling periods.

Chemical Parameter	Sampling Date 3. 8.71	15.10.71	3.12.71	7. 2.72	18. 4.72	26. 6.72	Mean S.E.
Conductivity (mS/cm at 25°C)	6,9	7,0	7,0	6,6	7,0	7,3	6,9 ± 0,03
Total alkalinity (meq/l)	0,76	0,80	0,71	0,71	0,78	0,80	0,76 ± 0,00
Calcium (mg Ca/l)	3,18	8,11	14,90	10,02	8,04	8,35	8,76 ± 3,80
Magnesium (mg Mg/l)	0,47	0,33	0,15	0,13	0,20	0,16	0,24 ± 0,10
Orthophosphate (μg PO_4/l)	< 10	< 10	< 10	< 10	< 10	< 10	-
Nitrite (μg NO_2/l)	< 10	< 10	30	< 10	50	30	-

The waters of the Mwenda River mouth are relatively low in mineralization, major cations present being Ca > Mg > Na > K (Bowmaker 1973). The low cation values recorded are mainly due to the suspended silt load acting as a very efficient ion exchanger. This also plays an import= ant role with respect to the anions, which become ad= sorbed onto the surface of the clay particles, and are thus unavailable for algal growth. Twinch (1974) has indicated that considerable amounts of nitrogen and phosphorus became available after digestion of unfiltered samples from turbid, ol trophic Midmar Dam.

Low ortho-phosphate values were recorded for all the samples analysed (< 10 µg PO_4/l). Similarly, nitrite values were low, the maximum value of 50 µg NO_2/l being recorded in April.

Considerable chemical variation exists between samples from shoreline stations, which may or may not be covered by <u>Salvinia</u>, and the open water (stations over the drowned river bed). Bowmaker (1973) has indicated that the only region of the Mwenda River mouth which maintains a rich fauna is under the <u>Salvinia</u> mat along the shoreline. Lake level fluctuations play an important role in plant nutrient supply to the lake water, for McLachlan (1971) demonstrated that animal dung and vegetated shorelines release considerable amounts of nutrient material into the water when inundated. As most of the shoreline in the Mwenda River mouth is "armoured" and steeply sloped, the littoral zone is greatly reduced; therefore it is expected that an insignificant amount of plant nutrients is released into the lake water. Thus, as most of the nutrient material was either adsorbed onto suspended clay particles or bound up into cell mass which finally sediments onto the bottom, and only a small amount of nutrient material is released into the water or enters via the river, the water quality of the Mwenda River improves and primary production decreases. This aspect was partly manifest by the reduction of <u>Salvinia</u> colonization and the poor flora; these nutrient reductions will in time be detrimental to the entire food chain.

4.2.1.3 The Mwenda Basin

The chemistry of the Mwenda Basin station showed very little variation throughout the period under investigation (Table 9). The concentrations of chemical ions were not very different from those of the bay and open water stations of the Mwenda River mouth. No chemical stratification with depth was recorded, though Mitchell (1970) recorded some chemocline formation early in the lake's existence. The variation in the concentration of the chemical species recorded between the sampling periods was also very small.

The June sample was collected shortly after the lake destratified when the biomass increased rapidly (post turnover algal bloom), and still no flux in water chemistry could be detected (Appendix 6). This suggests that Lake Kariba is tending more and more toward a typical tropical type mature ecosystem where plant nutrients are barely detectable throughout the year, i.e. most available nutrient material was bound up in the biomass and not readily available for plant growth.

The data recorded during 1971 and 1972 fall within the range presented by Coche (1968), but the biomass was presumably less than during Coche's investigations - unfortunately no early phytoplankton information is available to verify this suggestion.

Table 9: Maximum and minimum values for the recorded chemical parameters at the Mwenda Basin routine sampling station. These ranges are taken from data (Appendix 6) for the five sampling periods from the depth profiles (0 - 35 m).

Chemical Parameter	Chemical Ranges
Electrical conductivity (mS/cm at 25°C)	6,7 - 7,4
Total alkalinity (meq/l)	0,70 - 0,80
Calcium (mg Ca/l)	7,50 - 11,92
Magnesium (mg Mg/l)	0,07 - 0,26
Ortho-phosphate (µg PO_4/l)	< 10 - 25
Nitrite (µg NO_2/l)	< 10 - 70

4.2.2 Sengwa River Mouth

The mean water chemistry data is presented in Table 10, and the complete data for all sampling stations in Appendix 7.

The occurrence of Salvinia and the established "sudd" mat have a marked influence on the energy flow through the food chain (Bowmaker 1973). Almost the entire margin of the Sengwa River mouth is fringed by Salvinia or "sudd" mats. The area from station 1 to approximately station 4 (see Figure 5) is almost completely covered. The nutrient material bound up in these macrophytes generally remains in the river mouth, only a negligible amount being lost by water movement and wind blowing the plants out into the Sengwa Bay. There does not appear to be an annual flood which flushes the system out into the open lake, as is the case in the Mwenda River mouth. The Sengwa River mouth

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The electrical conductivity increased from 6,9 mS/cm to 8,6 mS/cm at 25° C in April, and then decreased to 8,3 mS/cm at 25° C in June. Stations 1 and 2 were only visited in December (mid-summer) and June (mid-winter), when conductivity gradients were recorded (Appendix 7). These two stations appear to be more mineralized with respect to calcium and magnesium than the rest of the river mouth. There was very little variation in the cationic levels throughout the year, except for 17,65 mg Ca/l in December, and 0,48 mg Mg/l in August.

Total alkalinity showed a very similar pattern to the electrical conductivity, with stations 1 and 2 having more available soluble carbon than the other stations. There appears to be a weak annual cycle, for 0,80 meq/l of total alkalinity was recorded in August; this decreased to 0,75 meq/l in December, then increased to 0,93 meq/l in April, and decreased slightly in June.

Ortho-phosphate and nitrite became available in the cool dry period and the hot dry period, but once the rains come in early December, those chemical species become limiting due to the rapid growth of the macrophyte plants and dilution by precipitation. Phyto=plankton are unlikely to have a marked effect on nutrient concen=tration in the Sengwa River mouth as light penetration into the water is limited by the floating aquatics. The periphytic algae growing on the Salvinia submerged leaves are sparse in number and species diversity if compared to samples from other parts of the lake. At stations 5, 6 and 7 the Salvinia mat was restricted to the margin of the lake; there the phytoplankton were likely to be the major controlling factor in the levels of available plant nutrients.

Table 10: Mean water chemistry data for the Sengwa River mouth (see Appendix 7).

Chemical Parameter	Sampling Period						Mean ,S,E ,
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.	
Conductivity (mS/cm at 25°C)	6,9	7,2	7,4	7,2	8,6	8,3	7,6 ± 0,07
Total alkalinity (meq/1)	0,80	0,78	0,75	0,78	0,93	0,91	0,82 ± 0,09
Calcium (mg Ca/1)	7,78	-	17,65	9,14	10,39	10,19	1,15 ± 3,9
Magnesium (mg Mg/1)	0,48	-	0,14	0,15	0,27	0,18	0,23 ± 0,14
Calcium : magnesium ratio	16,2	-	126,2	60,8	38,2	56,6	47,6
Ortho-phosphate ($\mu g\ PO_4/1$)	77,1	82,7	< 10	< 10	< 10	16,4	< 10 to 87,3
Nitrite ($mg\ NO_2/1$)	-	0,04	< 0,01	< 0,01	< 0,01	0,01	< 0,01 to 0,04

4.2.3 Mujery Offshore Area

The chemical analysis data presented in Table 11 shows that the concentrations of chemical species were very low, and not unlike those for the Mwenda River mouth and Mwenda Basin stations. Only slight variations were noted between the four sampling stations along each of the two offshore transects, as well as for the different sampling periods.

Table 11: Mean water quality of the Mujery [redacted] transects. Figures in brackets are the ranges of the mean.

Chemical Parameter	Sampling Stations: Uncleared area 1 - 4	Sampling Stations: Cleared area 5 - 8
Electrical conductivity (mS/cm)	7,0 (6,4 - 7,6)	7,1 (6,4 - 8,0)
Total alkalinity (meq/l)	0,81 (0,75-0,90)	0,80 (0,72-0,89)
Calcium (mg Ca/l)	9,71 (7,56-14,64)	10,41 (7,40-17,52)
Magnesium (mg Mg/l)	0,20 (0,04-0,47)	0,21 (0,00-0,54)
Ortho-phosphate (µg PO_4/l)	(< 10,0-14,0)	(< 10,0-25,8)
Nitrite (mg NO_2/l)	0,045 (0,010-0,450)	0,021 (0,003-0,035)

4.3 HYDROGEN SULPHIDE

In the early part of the development of Lake Kariba, hydrogen sulphide was recorded (by smell) from hypolimnetic waters. Soon after impoundment there was a rapid increase in the biomass as a result of nutrients released from the old terrestrial soils, and from the burning of the vegetation from the cleared areas (e.g. Mujery). The biological decomposition of this biomass after stratification was established produced vast amounts of hydrogen sulphide (Harding 1966 and Coche 1968) below the thermocline at a station at 10 m depth (in 1959) near the dam wall. As the lake aged the thermocline at this station deepened and the amount of hydrogen sulphide decreased in the hypolimnion. By 1971 only a few isolated samples of bottom water (± 45 m depth) produced a faint sulphide smell (Begg 1971) from the dam wall station. In this survey samples collected from below the thermocline in the Mwenda Basin (40 m) in February revealed very low oxygen saturations (< 5% saturation) and no hydrogen sulphide. Oxygen-deficient conditions above the bottom sediments were also recorded when the Mwenda River was in flood in February. These oxygen-deficient conditions persisted for a short period only, and no hydrogen sulphide was produced.

The production of hydrogen sulphide has decreased markedly since the early days of the reservoir (Coche 1968), and at present, with the trophic status of the lake waters on the decline, the production of hydrogen sulphide has almost ceased (Begg 1972).

5 PHYTOPLANKTON

The phytoplankton standing crop of Lake Kariba is almost unknown except for reports on the net plankton by Thomasson (1965) and Begg (1967). It was therefore decided to investigate the biomass, algal population structure and seasonal variation of the selected areas of Lake Kariba.

The identification of the algae was restricted to the generic level (except for selected samples submitted for complete diatom analysis), due to the extreme diversity of the samples. A complete taxonomic classification of the plankton samples was considered out of the scope of this project; however, notes on the algal taxa and their ecology in Lake Kariba are presented in Appendix 18.

5.1 PHOTOSYNTHETIC PIGMENTS

5.1.1 Horizontal Variation

The horizontal variation of surface photosynthetic pigments for each sampling period along the respective transects, and for each sampling station throughout the annual cycle, is presented for all the sampling areas.

5.1.1.1 Mwenda River

The photosynthetic pigment data for the Mwenda River can be seen in Figure 21. The lowest photosynthetic pigment values for the year were recorded at station 1 (maximum Pt 2,25 µg Pt/1), which can be directly related to the *Salvinia* mat which covered this area for most of the year. This effectively prevented light penetration into the

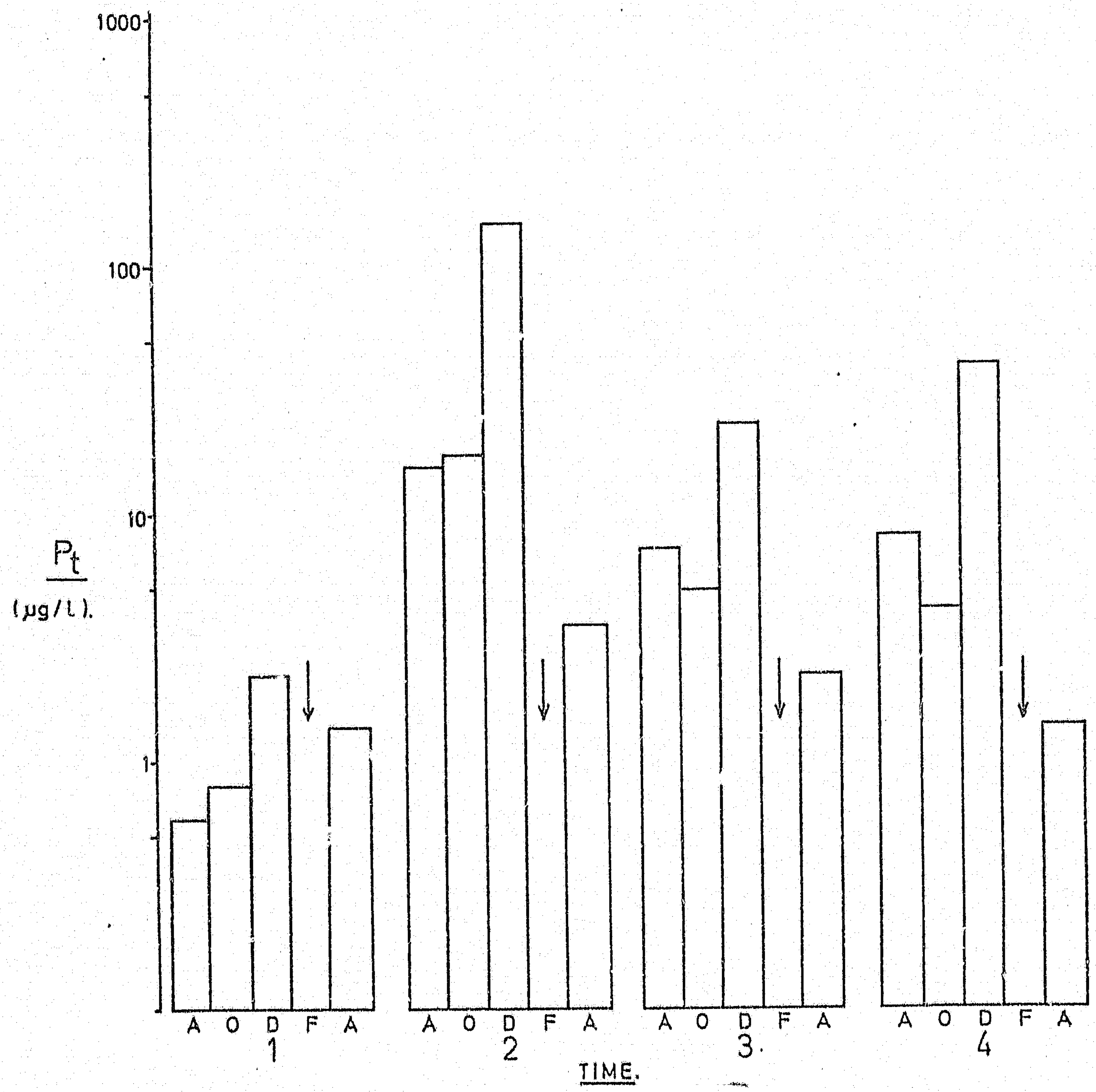

Figure 21: Total photosynthetic pigment data for the four Mwenda River routine sampling stations, for the five sampling periods. The arrows (↓) indicate when the river was in flood.

water, preventing this water body from warming up during the summer as did stations 2, 3 and 4 (see Table 3). The highest phytoplankton densities (152,8 μg Pt/l, dominant organisms Pediastrum clathratum, P. boryanum, P. simplex and Melosira granulata) were recorded for station 2, which was the result of building operations on the Hughes' Weir, and the addition of phosphate deter= gents to this pool by the workmen. Stations 2 and 3 showed intermediate phytoplankton densities, and are probably representative of the many pools of the Mwenda River.

The seasonal photosynthetic pigment fluctuations for all stations correlated with changes in their thermal pattern. From August to December the volume of water in each pool was reduced by evaporation, and consequently the available nutrient material was concentrated, resulting in an in= creased phytomass. The August values for stations 3 and 4 cannot be explained. With the onset of the rainy season the flood waters scoured the river bed, removing all the pool algae, and replacing the latter with algae-free water. Once the river stopped flowing and the pools again became discrete, the algae recolonized the habitat.

5.1.1.2 Mwenda River Mouth

The photosynthetic pigments of the riverine stations 1, 2, 3, and 4 of the Mwenda River mouth transect generally showed higher phytomass values than the bay stations (stations

5 and 6) or the open lake station (station 7 and Mwenda deep station B). From the data presented in Figures 22 and 23 the total phytoplankton density does not appear to be influenced to any great extent by the physical environ= ment, as no clear seasonal pattern for any one station emerged. There was, however, a gradual increase of plant pigment concentration from station 1 to station 7 and the open lake station. From August to October there was a sharp decline in pigment concentration from station 1 to station 2; thereafter little fluctuation.

In December the pigment concentration decreased gradually from the riverine to the open lake stations. In February the riverine stations still maintained their relatively high algal densities (Scenedesmus sp., Peridinium sp. and Anabaena sp.), but a decrease to station 5 was apparent, with stations 6 and 7 also showing lower values. This was the result of the heavy thunderstorms characteristic of this period. The riverine stations were affected less by rainwater because of the lake width at the sampling stations; the river flood water brought nutrients from upstream to maintain these populations. The bay stations were affected by rainwater dilution, particularly at the surface, and increased wind-induced vertical mixing. By April the algal density had been markedly reduced at stations 1 and 2 to 1,12 µg Pt/l. This can be attributed to the poor light penetration into the water as a result of the suspended silt load, lack of available nutrient material,

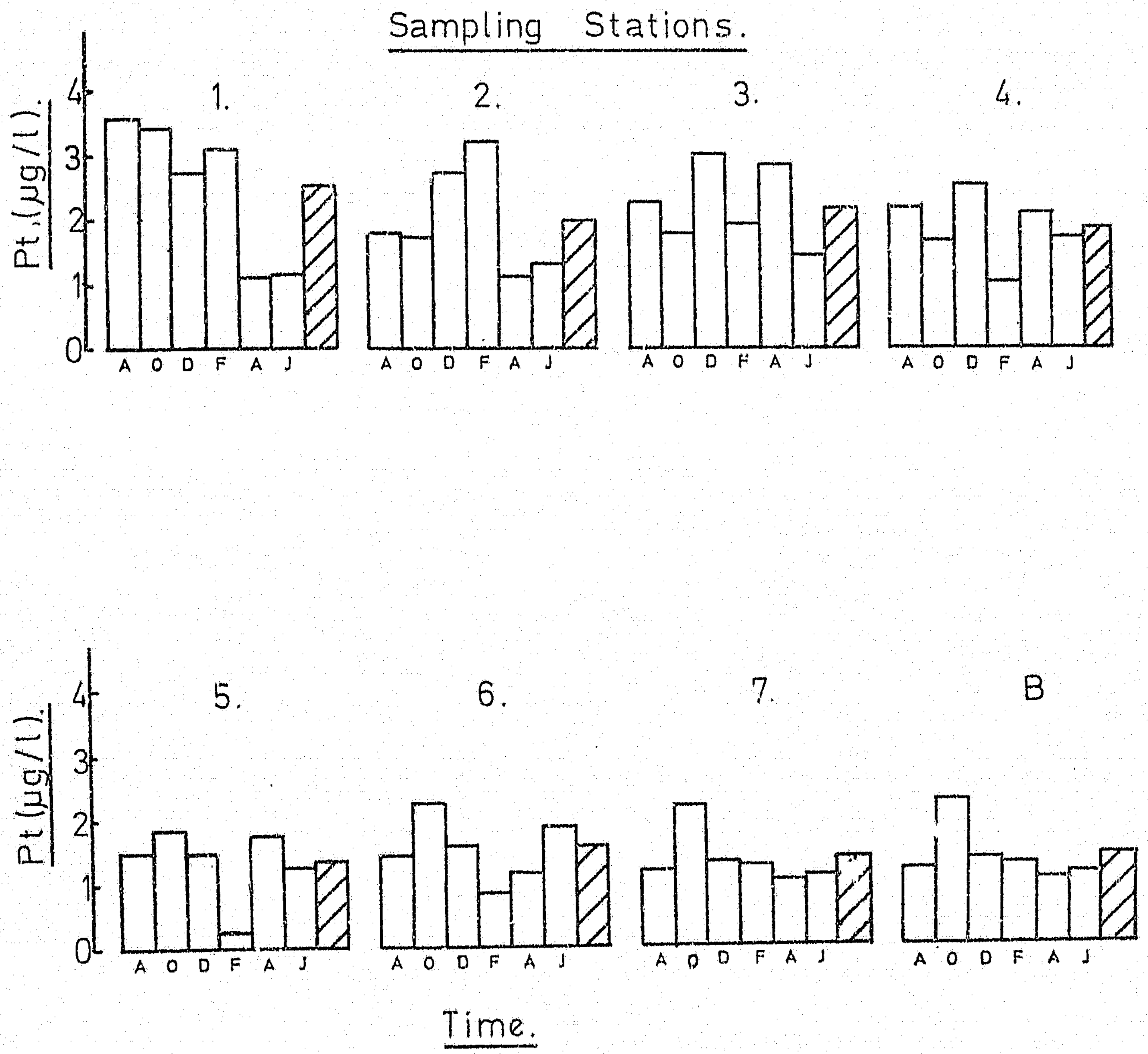

Figure 22: Surface photosynthetic pigment data for the seven routine sampling stations (station B is the surface sample of the Mwenda Basin deep station) on the Mwenda River mouth. The hatched column (▨) is the station mean for the six sampling periods.

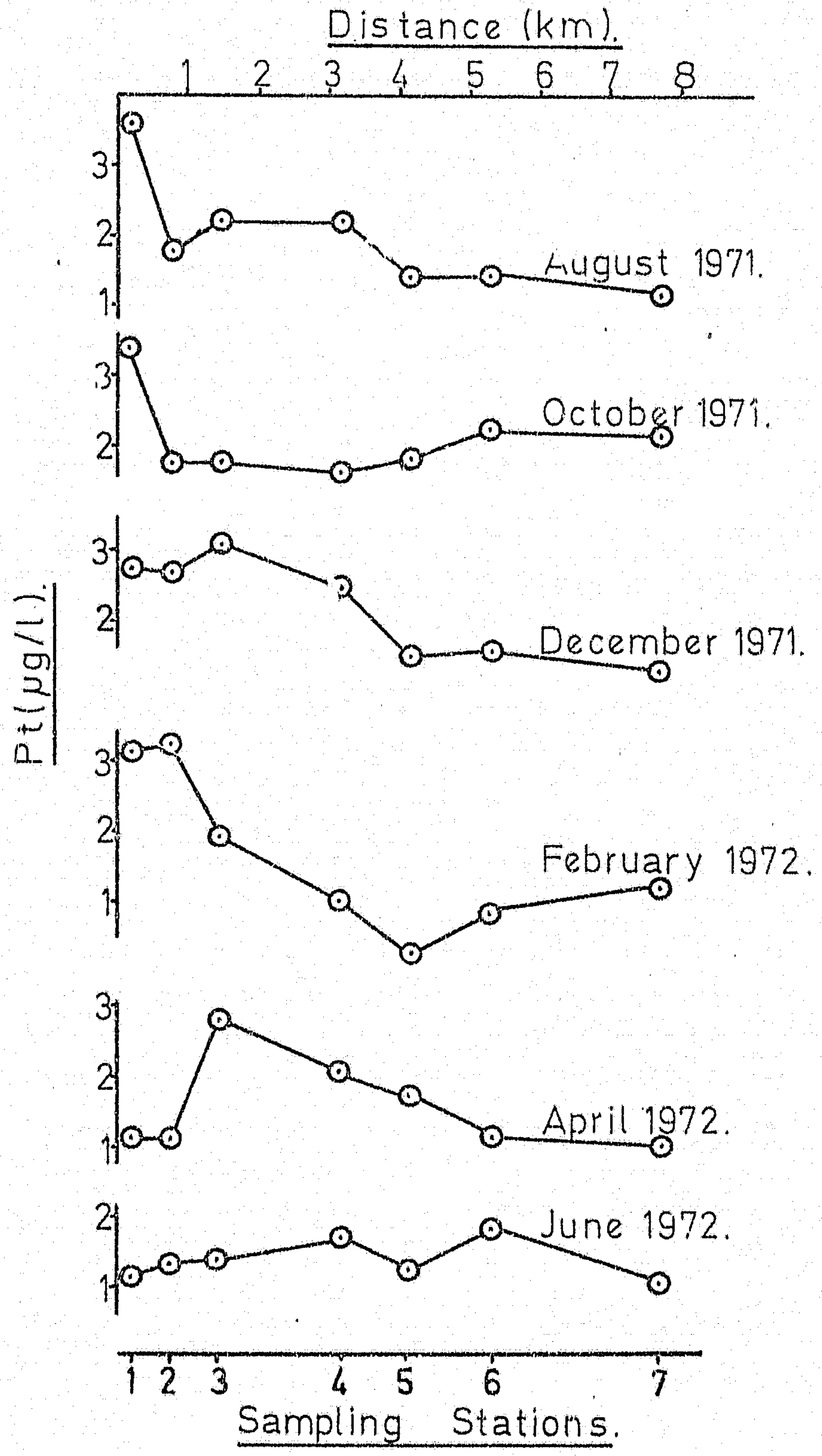

Figure 23: Photosynthetic pigment data for the Mwenda River mouth through an annual cycle.

and lower water temperatures. The plant pigments at station 3 had increased slightly since February (high diatom populations) with a gradual decrease to station 7. The winter sample (June) revealed that the river mouth contained a very poor phytoplankton standing crop. This is probably the result of low water temperatures.

From the data presented for the Mwenda River mouth it is clear that there were a large number of factors which controlled and affected the primary production in this area. These factors are not the same from year to year, as the Salvinia mat does not completely cover the riverine areas, and the rains do not occur at the same time each year nor with the same intensity; the effect of river flooding will therefore not always be identical. Generally, it can be said that the riverine stations showed a higher primary production with regard to photosynthetic pigment, than did the bay or open water stations.

5.1.1.3 Sengwa River Mouth

Photosynthetic pigment data for the Sengwa River mouth for August and December 1971, and February and April 1972 are presented in Table 12.

The total phytoplankton density data for this area are scanty, as the area was only sampled for algae on four occasions, and then not all the stations could be reached.

There was an increase in phytomass from August to December, which was probably the result of the rains and nutrient release from decaying macrophytic vegetation. By February the photosynthetic pigments had again decreased to < 1 µg Pt/l. This could be the result of reduced available plant nutrient material. As the water temperstures cooled, the plant pigment level increased to between 1 and 2 µg Pt/l by April. The interpretation of such low concentrations is extremely difficult, as the values of photosynthetic pigments recorded are close to the limits of the method used.

Table 12: Total photosynthetic pigment data for the Sengwa River mouth (µg Pt/l).

Sampling Station	Sampling Period			
	August	December	February	April
1	-	2,13	-	-
2	-	1,74	-	-
3	0,59	2,08	0,90	-
4	0,48	1,08	0,39	1,80
5	0,22	2,30	0,28	1,01
6	0,22	2,02	0,67	1,52
7	0,11	1,91	0,67	1,12

5.1.1.4 Mujery Offshore Area

The seasonal flux of photosynthetic pigments for the Mujery offshore area is in Figures 24 and 25. The August values were below 1 µg Pt/l, probably the result of the cool winter water temperature. By October the mean water temperature had increased by 4^{o} C, resulting in an

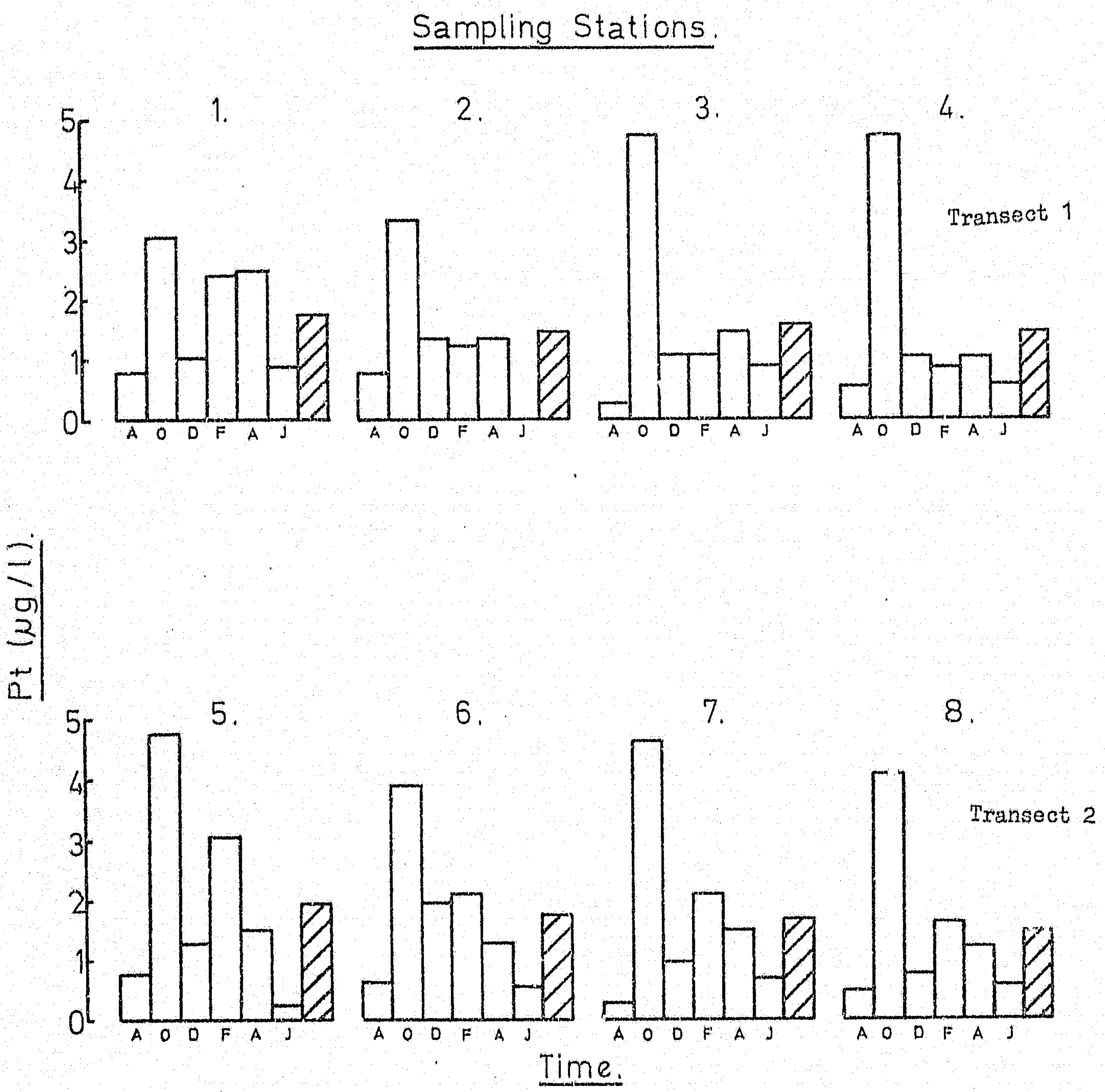

Figure 24: Seasonal flux of photosynthetic pigments from the Mujery offshore area. [redacted] The hatched column (▨) is the seasonal station mean.

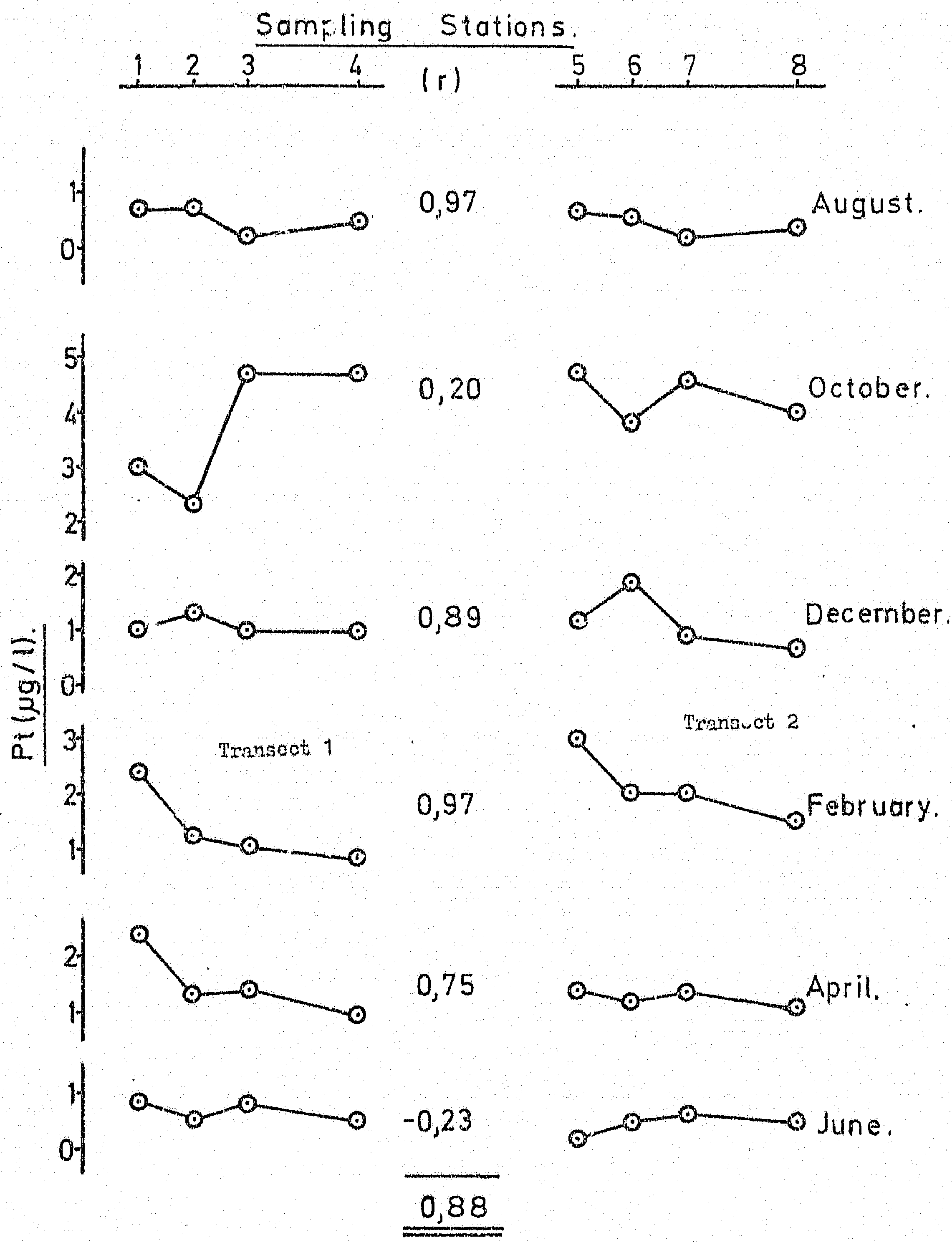

Figure 25: The seasonal distribution of photosynthetic pigments along the [redacted] transects at Mujery. The correlation coefficients (r) comparing the photosynthetic pigments of the two transects are included.

increase of algal biomass. From December to April all stations showed photosynthetic pigment values ranging between 1 and 3 µg Pt/l. The June samples contained a low phytomass value, similar to the August samples. The annual photosynthetic pigments fluctuate with the physical environment (temperature rather than light, as Secchi disc transparency depths were mostly very close to or recorded to the lake bottom), rather than the chemical environment, as no annual cycle in any of the plant nutrients recorded was noted.

The sampling stations closer to the shore generally showed slightly higher photosynthetic pigment values than the open water stations. The winter samples (August to June) contained a poor phytomass, with slight variation from the shore (stations 1 and 5) to the open water stations (4 and 8). By spring (October) the shore stations showed a decrease to stations 2 and 5, which then increased to the open water. During the hot dry period of the summer the photosynthetic pigment values along the transect lines revealed a slight increase at stations 2 and 6, with the rest of the water remaining at ± 1 µg Pt/l. Once the rains had come (February) and the lake level rose, the algal growth at the shore stations increased as a result of nutrient material being released into the water from animal dung and ash from bush fires on the flat flood plains (McLachlan 1971). There was a noticeable gradient from the shore to open water stations during this period.

A good correlation (Figure 25) existed between the photo= synthetically active phytomass from the uncleared and cleared transects (correlation coefficient between the two transects through the annual cycle is 0,8799). In spring a poor correlation was noted between the transects; this was the result of a fluxing algal population from shore to open water. From February to June the water temperatures dropped, as did the photosynthetic pigments; when comparing the two transects a poor correlation coefficient was recorded (negative correlation in June).

5.1.2 Vertical Distribution

The distribution of photosynthetic pigments with depth and time was recorded at the Mwenda Basin deep water station (Figure 26).

The August samples revealed a water column fairly uniform in photosynthetic pigment with increased depth (± 1,5 µg Pt/l). This situation resulted from complete vertical mixing after the lake destratified, so that the bottom waters contained up to 1,0 µg Pt/l. The only plankton maximum (± 45% of the population of all samples was *Scenedesmus bijuga*) was recorded in December when the lake waters warmed and the light climate favourable for algal growth improved. The maximum occurred between about 7 m and 23 m depth. By February the epilimnetic water had probably mixed down to the intensifying thermocline, which effectively dispersed the algae in the upper layers, and improved the light penetration into the deeper waters. A gradient of photosynthetic pigments had developed by April, when the thermal stratification was at its

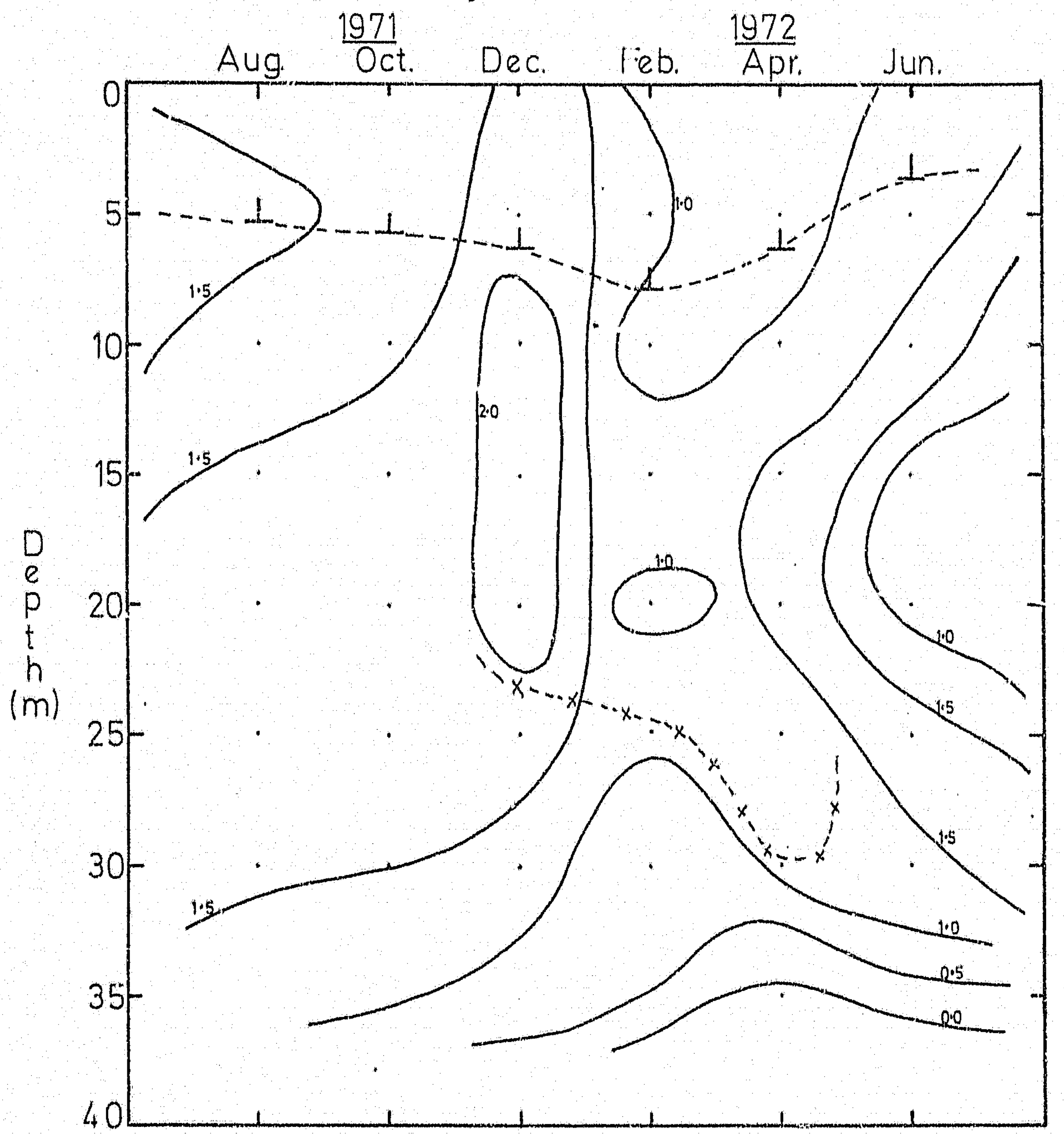

Figure 26: Photosynthetic pigment (µg Pt/l) depth profiles for the Mwenda Basin deep water station, from August 1971 to June 1972. The dotted line (_ ⊥ _) represents the Secchi disc transparency of the water. The broken line (-x--x-) indicates the position of the thermocline.

maximum. The surface water contained < 1,0 μg Pt/l of extractable plant pigments, which increased to just above 1,5 μg Pt/l between 14 m and 22 m depth; it then decreased to 1,0 μg Pt/l at the thermocline at 30 - 32 m depth. The plant pigments decreased further with depth and at 35 m no extractable photosynthetic pigments could be detected.

Once thermal stratification had broken and the surface waters began warming, the algal growth again concentrated in the upper layers of the euphotic zone, which effectively caused the Secchi disc transparency to decrease. The algal growth between 25 - 30 m depth was the result of plant nutrients being released from the bottom sediments at turnover. A very similar pattern of photosynthetic pigment flux was recorded by Talling (1966) for a routine offshore station in Lake Victoria. The post turnover algal bloom will be discussed in section 5.2.5 below. As the thermal stratification again began to develop, the mixing caused homogeneity with respect to photosynthetic pigments in the epilimnion.

5.2 ALGAL POPULATIONS AND DYNAMICS

5.2.1 Counting Precision

The algal diversity and the tremendous variation in algal densities of the lake samples made it impractical to determine the statistical accuracy of each sample count; sample M17 was therefore selected to determine the accuracy of the counting method. The mean percentage of each genus in this sample is seen in Table 13.

Normally the lake sample algal counts were terminated after about 200 organisms had been recorded (Lund et al 1958). The results of these algal counts are in Appendix 12 and the results of the statistical analysis of the counts in Table 14. The accuracy of the counts was about 94% for both total cell counts and total

Table 13: The mean percentage of each genus recorded in sample M17.

	MEAN, S.E.
Chlorophyta	
Pediastrum	1,1 ± 0,6
Coelastrum	2,3 ± 1,4
Oocystis	1,1 ± 0,7
Franceia	0,3 ± 0,2
Schroederia	6,6 ± 2,3
Scenedesmus	42,7 ± 4,0
Crucigina	1,3 ± 0,8
Staurastrum	0,6 ± 0,2
Pyrrhophyta	
Peridinium	0,5 ± 0,3
Chrysophyta	
Tet[illegible]ella	3,8 ± 1,3
Bacillariophyceae	
Centric diatoms	7,4 ± 2,0
Pennate diatoms	14,0 ± 1,8
Cyanophyta	
Merismopedia	2,2 ± 2,7
Anabaena	16,4 ± 4,0

Table 14: Results of the statistical analysis of algal counts of sample M17.

	Total cell count	Total occurrences
Standard error	0,015015	0,004819
Counting accuracy %	94,1	94,6
Chi-squared n = 20	0,09772	0,04718

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occurrence (number of organisms) counts. The Chi-squared analysis of the data showed that there was no significant difference between the six counting chambers or between the five counting positions of each counting chamber. The algae were therefore randomly distributed on the coverslip surface of the counting chambers. The standard error of counting was significantly low to justify the high counting accuracy.

5.2.2 Algal Density of the Sampling Stations

The algal density of all the sampling areas will be based on the total cell count data, rather than number of organisms, because of the significant correlation between these two parameters; the latter would give similar patterns (correlation coefficients for all the lake samples are presented in Appendix 13).

5.2.2.1 Horizontal Variation

5.2.2.1.1 Mwenda River

A quantitative assessment of the algae in the Mwenda River was generally not possible, because of the high suspended silt load and low algal densities. Algal growth was almost entirely inhibited due to insufficient light penetration into the water. At station 1 the *Salvinia* mat impeded light penetration, which retarded algal gr th.

Two algal blooms were recorded at station 2 however, which can be attributed to nutrient additions to the water by the workmen at the weir site. The first bloom was recorded in August, where a Schroederia sp. had an algal density of 89,85 x 10^6 cells/l. This was by far the highest plankton count recorded during this investigation. The second high count was recorded in December (17,64 x 10^6 Cells/l). The population was dominated by Pediastrum clathratum and P. simplex, and Melosira granulata with Microcystis sp. and Phormidium sp. as subdominants.

The flood waters contained no identifiable plankters or plant pigments. Due to the impoverishment of the Mwenda River samples, no seasonal flux in algal population could be detected. These samples do not entirely agree with the photosynthetic pigment data, because of the nature of the samples, e.g. high suspended terrogenic detritus loads, and the small volume of water which could be filtered through the 0,47 µ Millipore filters (between 60 ml and 300 ml).

5.2.2.1.2 Mwenda River Mouth

The standing crop of the Mwenda River mouth is presented in Table 15. Generally the phytomass remained below 1,00 x 10^6 cells/l for all samples. The highest algal densities were recorded from the bay and open water stations (stations 5, 6 and 7, in October and April), and the lowest values from the riverine stations (stations 1, 2, 3 and 4); this is probably due to the degree of shelter each station is afforded by the land and by the aquatic macro= phytes, and also the amount of light entering the water.

During August a gradual increase in algal cell numbers from station 1 to station 7 was noticed. The open water contained large numbers of Scenedesmus bijuga and diatoms - this contrib= uted to the marked increase from station 7 to the Mwenda deep station (0 m). By October the algal population of the riverine stations, including station 5, showed a decrease, but stations 6 and 7 showed marked increases, as a result of increased numbers of Anabaena. The December sample showed a decrease from station 1 to station 5 with a corresponding increase in the Pyrrhophyceae, which then decreased to the open water. The population from stations 1 to 5 also contained large numbers of diatoms, which were absent at stations 6 and 7. In February, once the flood waters had entered the lake, the riverine stations showed a gradient of a poor algal population at station 1, which increased to station 4 (increases in Scenedesmus sp. and Schroederia sp.). It then decreased to the open water at station 7, but increased to the deep water station, due to a high Anabaena sp.

Table 15: Seasonal phytoplankton standing crop of the Mwenda River mouth (cells x 10^6/l).

Station	Sampling Period					Mean, S.E.
	Aug.	Oct.	Dec.	Feb.	Apr.	
1	0,24	0,11	0,31	0,13	0,49	0,26 ± 0,15
2	0,20	0,06	0,14	0,26	0,52	0,24 ± 0,17
3	0,39	0,09	0,29	0,42	0,67	0,37 ± 0,21
4	0,39	0,05	0,36	0,88	0,72	0,48 ± 0,33
5	0,52	0,19	0,55	0,38	1,99	0,73 ± 0,72
6	0,56	1,66	0,11	0,20	0,66	0,64 ± 0,62
7	0,68	7,19	0,71	0,17	1,59	2,07 ± 2,91

population at that time. The low algal populations at stations 1 and 2 were due to the suspended silt load (and therefore reduced light penetration into the water); many of the algae were mechanically broken by this suspended material (see section 6 below). In April the algal densities of the samples showed a similar pattern to the February samples. These algal densities had, however, increased since February but the typical gradient still remained, with the algal maxima at station 5 (increase in the population of diatoms, Gonatozygon, Anabaena and Tetraedriella). The relative percentages of these plankters in the population remained the same at station 6, although the densities of the taxa decreased (a slight decrease in the percentage of diatoms in the population was noted). At station 7 the densities of the taxa increased, similar to station 6. The plankton population density at the Mwenda Basin deep station was similar to that of the open water river samples, but the plankton was dominated by the diatoms and Tetraedriella sp.

The mean seasonal algal densities for the seven Mwenda River mouth stations are presented in Figure 27. There was an overall increase in algal densities from station 1 to station 7 and the open water. The riverine algal populations (stations 1, 2, 3 and 4) were more stable than the bay stations (stations 5, 6 and 7) as indicated by their relatively small standard deviation values. The algal population at station 7 showed extreme instability throughout the year, but there was less variation in the algal densities at station B.

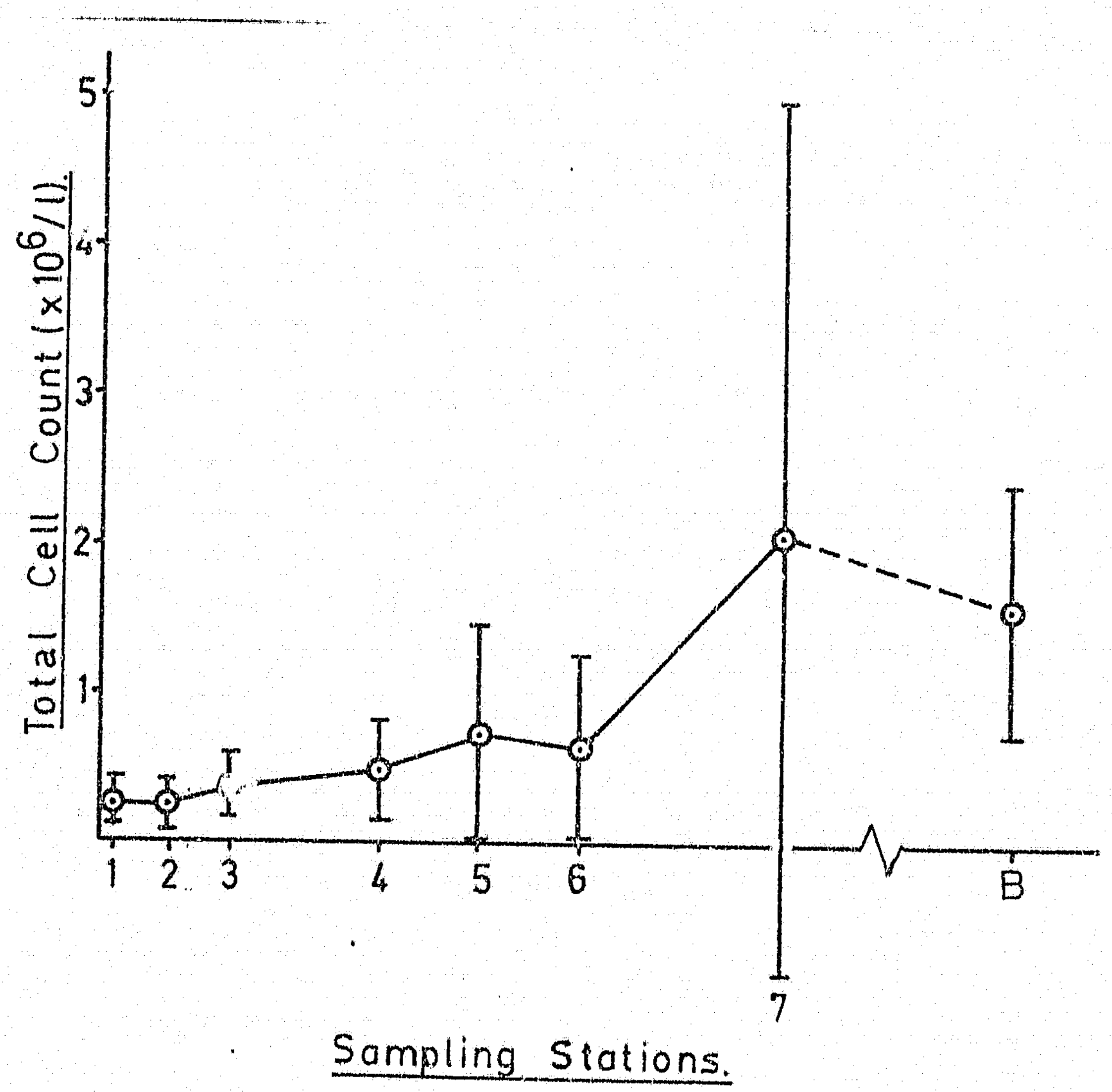

Figure 27: Mean seasonal algal density (total cell count) for the Mwenda River mouth. Vertical lines are the standard deviation. Mwenda Basin station 1 (B) is included.

The large fluctuation in algal density at station 7 can be attributed to the fact that this area is the zone of transition between the open lake water and water contained within the Mwenda River mouth system. A further factor which contributed to these algal maxima was the effect of wind-induced wave action (north east swell running down the length of the lake) eroding "Block Beach" on Christmas Island (see Bowmaker's map, 1969). The sand on these beaches is almost entirely covered by Panicum repens L. which is extensively grazed by game. Dead grass and dung together with sand grains are suspended by the pounding waves, and the swell moves this material across the opening of the Mwenda River mouth. Nutrient material is released into the water (McLachlan 1971), which is consumed by the algal population, and is therefore not easily detectable.

5.2.2.1.3 Sengwa River Mouth

The standing crop data for the Sengwa River mouth is presented in Table 16. The algal density of this area generally remained below 1,0 x 10^6 cells/l. In August the station samples showed density values ranging between 0,25 - 0,56 x 10^6 cells/l. The October sample showed similar density values, but the algal population dominance had shifted from a green - blue-green population to a green algae population. In December, when all sampling stations were visited, the algal density showed an increase from station 1 to station 3, remaining just less than 1,00 x 10^6 cells/l at stations 4 and 5, and decreasing to the open water station. These phytoplankton maxima at stations 3, 4 and 5 could be the result of the Sengwa River adding nutrients to the river mouth, nutrients released when the macrophyte "sudd" mat was broken up by wind action and decayed, and an improved light climate in the water. The algal population at station 1 was dominated by <u>Melosira</u> sp. and at stations 2 to 7 by <u>Anabaena</u> sp. The standing crop was low in February, showing a slight increase from station 3 to station 7 (0,23 to 0,55 x 10^6 cells/l). The three stations visited in April showed elevated algal densities from February. These algal maxima were due to <u>Melosira</u> sp. at stations 4 and 5, and <u>Scenedesmus</u> sp. at station 6.

The algal populations were generally fairly stable in the Sengwa area as the magnitude of the population fluctuations were small throughout the year. This can be seen from the