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OF THE FISHERIES
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LIMNOLOGICAL SAMPLING DURING AN ANNUAL CYCLE AT THREE STATIONS ON LAKE TANGANYIKA (1993-1994)

by

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PREFACE

The Research for the Management of the Fisheries on Lake Tanganyika Project (Lake Tanganyika Research) became fully operational in January 1992. It is executed by the Food and Agriculture organization of the United Nations (FAO) and funded by the Finnish International Developmental Agency (FINNIDA) and the Arab Gulf Programme for United Nations Development Organizations (AGFUND).

This project aims at the determination of the biological basis for fish production on Lake Tanganyika, in order to permit the formulation of a coherent lake–wide fisheries management policy for the four riparian States (Burundi, Tanzania, Zaïre and Zambia).

Particular attention will be also given to the reinforcement of the skills and physical facilities of the fisheries research units in all four beneficiary countries as well as to the build-up of effective coordination mechanisms to ensure full collaboration between the Governments concerned.

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SUMMARY

This report presents the results of the first year of limnological sampling by LTR. Layers identified in the water column of Lake Tanganyika, parameter profiles and rhythmic patterns regulating the distribution of the nutrients are described.

Upwelling was observed in the south of the lake during the dry, windy season. Stratification was variable in strength but always present in the north. The lake showed a marked tilting of the epilimnion during the dry season from June to September. This period was followed by oscillations of water masses towards an equilibrium when the strong winds from the south east stopped. Conductivity and pH fluctuations indicated dampened oscillations, particularly at both ends of the lake. Movements of the epilimnion toward an equilibrium position generated and/or re-inforced internal waves. These waves were inferred from fluctuations of chemical or physical characteristics of the lake.

Ten parameters were measured frequently near Bujumbura, Kigoma and Mpulungu over one year. Variation in the concentration of several parameters was commonly by a factor of 3 or more. The time of long-period internal waves was estimated to be approximately 28 to 33 days. Pulse production caused by internal waves is suggested. It could be linked to "non-random patchiness" in nutrients and organisms.

Turbulence may have explained the presence of dissolved oxygen in deep water, sometimes detectable at 300 m, or ammonia in the epilimnion. Turbulence resulting from highly dynamic physical events might induce "random-patchiness" in water composition.

The results of the first year of sampling showed that the productivity of Lake Tanganyika, like that of the oceans, seemed to depend largely on regeneration processes.

1. INTRODUCTION

The Lake Tanganyika Research Project (LTR) completed one year of regular limnological sampling on Lake Tanganyika in July 1994. This is the first known simultaneous sampling and measuring of various limnological parameters, using the same techniques at different locations on the lake, over this time period. Results of this study are presented in this report as well as some initial conclusions. A second year of sampling was carried out to July 1995 and will be reported elsewhere. The interpretation of the present results should be considered as preliminary until the second year of data have been analysed.

2. OBJECTIVES OF THE LIMNOLOGICAL COMPONENT

The objectives of the limnological component were to obtain information on changes in time and space of some of the main physical and chemical parameters of the lake that would help to improve understanding of the abundance of organisms especially zooplankton and fish. The physical and chemical environment studied in the limnogical component is the basis of biological production on which fish production ultimately depends. The study of fluctuations in this environment at each station should enhance the understanding of food webs from nutrients to fish. The variations of limnological parameters in the water column on several time scales provide information which can be correlated with the hydrodynamics of the lake.

3. MATERIAL AND METHODS

3.1. General remarks

The following parameters have been measured during regular sampling (type A) and intensive sampling (type B), transparency (Secchi), temperature, dissolved oxygen, pH, conductivity, total phosphorus (TP), phosphate (total reactive phosphorus, TRP, as PO_4^{3-}), ammonia (NH_{4}-N), nitrite (NO_2-N), nitrate (NO_3-N) and turbidity (NTU). The parameters were generally measured by the HACH DREL 2OOO methods. Most of these methods proved to be sufficiently accurate for the study. They were suitable for use in remote stations and onboard medium sized boats where there were no laboratory facilities. Regular accuracy checks were carried out and confidence was gained by comparing ranges of concentrations with other studies (Van Meel ,1987; Degens *et al*., 1971; Hecky *et al.*, 1978; Beauchamp, 1939).

3.2. Sampling design and procedure

During the first year LTR only investigated the pelagic zone. Three different types of sampling were established: (1) regular sampling (type A) (2 to 4 per month), (2) intensive sampling (type B) (24 h cycle, every 6 weeks) and (3) seasonal sampling (type C) (every 3 months). Results of type A are reported here.

Results of type B and C sampling are presented in two separate documents (Plisnier, *in prep.*). The position of each sampling site (Table 1, Fig. 1) was recorded with a GPS (global positioning system), Raystar 390 of Raytheon, with an estimated accuracy of 15 to 100 m depending of the position of the satellite. The GPS was used during each experiment to position the boat. Full details of the sampling procedure are given in Plisnier (1993) and only a brief description is presented here.

Regular sampling at site A was performed normally every Tuesday morning at 0900 h (GMT + 2 h) except during the intensive sampling period (type B). Site A of each station was located >4 km from the shore where the depth of the lake was >120 m (Fig. 1). The exact coordinates recorded by GPS are given in Table 1. As the boat drifted, the position at the end of sampling may have been slightly different from that at the start. Samples were taken every 10 m from the surface to 100 m. The following parameters were measured (a) directly from the boat: transparency, water temperature, dissolved oxygen, pH and conductivity, and (b) from water samples taken to the laboratory: P (total), PO_4^{3-}, NH_3-N, NO_{2-}-N, NO_3-N and turbidity. Temperature, pH, conductivity and turbidity were measured every 10 m and the other parameters every 20 m ,from the surface to 100 m. Dissolved oxygen measurements were first made in November 1993 at Bujumbura and in April 1994 at Kigoma and Mpulungu. Regular sampling was carried on 28 occasions at Bujumbura/Uvira (referred to in tables and figures as Buj.-Uvi.), 29 occasions at Kigoma and 33 occasions at Mpulungu (Table C.1).

3.3 Instrumentation and analytical methods

Transparency measurements, taken at the start of the sampling period, were made with a 20 cm diameter Secchi disk. The mean value of measurements made by three separate observers was recorded. Water samples were collected using Van Dorn bottles (made by Limnos) of 7.4 and 2.0 l capacity. The weight of the bottles was increased when necessary. Bottles were lowered and raised with a hand winch. Water temperature, with an accuracy of $\pm$0.1°C, was first measured with a thermometer placed inside the water bottle. The thermometer was read as soon as the bottle reached the deck. This method was replaced with *in situ* measurements taken down to 80 m with a digital thermometer, coupled to an oxygen meter (made by Yellow Springs Instrument Co.), with the same accuracy as before. For lower depths the probe was placed in the sampling bottle and read when the bottle reached the surface. Other water temperature measurements were collected with a CTD-12 (with a precision of $\pm$0.01°C and with automatic Anderaa thermistor strings (with a similar precision but with an accuracy of $\pm$0.1°C (Huttula, pers. comm.)). Dissolved oxygen (DO) was measured with a dissolved oxygen meter, model 50B of Yellow Springs Instrument Co., equipped with a YSI 5739 probe and a YSI 5795A submersible stirrer. The cable allowed *in situ* measurements down to 80 m. At lower depths the probe was carefully introduced into a 7.4 sampling bottle after each vertical haul. Calibrations were made in the air and corrected for altitude before each sampling period. Precision was ±0.01 mg/l DO. pH readings were taken with a portable Hach pH meter, model 43800-00. Precision was ±0.01. For conductivity (µS/cm), a Hach conductivity meter, model 44600 was used. The instrument automatically compensates for temperature deviation from 25 °C. Turbidity measurements (NTU) were made with a Hach turbidimeter model 2100A. Precision was ±0.01 NTU. All the above instruments were regularly calibrated at each station.

The following parameters were measured by spectrophotometry using a Hach DR/2000 machine: ammonia, nitrates, nitrites, total phosphorus and phosphates. The methods are summarised in Table 2. Total phosphorus readings were not always reliable as values were sometimes less than phosphates. Obvious, inconsistent results were discarded. Analysis was later improved by using a COD reactor (made by Hach Co.). However results for phosphorus were considered preliminary, needing confirmation with improved methods. Orthophosphates (PO_4^{3-}) were measured during the first year on non-filtered water due to the lack of filtering equipment. They corresponded to total reactive phosphorus (TRP). Soluble reactive phosphorus (SRP) and total dissolved phosphorus (TDP) were measured during the second year and are presented elsewhere.

Location	Sampling sites	Latitude	Longitude
Bujumbura/ Uvira	A B/C	3°28.00’S 3°45.00’S	29°17.00’E 29°15.00’E
Kigoma	A B/C	4°51.26’S 4°50.69’S	29°35.54’E 29°34.65’E
Mpulungu	A B/C	8°43.98’S 8°34.45’S	31°02.43’E 30°50.10’E

Table 1 Coordinates of sampling sites recorded by GPS.

Parameters	Methods	Precision and units
Ammonia	Nessler (*)	± 0.01 mg/l (NH3-N)
Nitrates	Cadmium reduction	± 0.01 mg/l (N03-N)
Nitrites	Diazotization (*)	± 0.001 mg/l (N02-N)
Total phosphorus	Acid persuiphate (*)	± 0.01 mg/l (P04---)
Orthophosphates	Ascorbic Acid (*)	± 0.01 mg/l (P04---)

Table 2 Parameters measured by spectrophotometry methods (Hach Drei 2000) with corresponding precision and units.
(*) USEPA approved (United States Environmental Protection Agency).

4. RESULTS

4.1 The yearly limnological cycle

The best place to start to describe the limnological cycle of Lake Tanganyika is with the wind. The wind regulates the energy input into the lake through physical processes and causes mixing. The steps, which are developed below are summarised in Figure 2.

In May-June, south east winds drive warm epilimnion water towards the north of the lake. This results in a tilting of the epilimnion (Fig. 3.). The volume of warm water accumulated in the north depends on the strength of the wind. Thermocline depth is a good indicator of the volume of warm water amassed at the north of the lake. Thermocline depth at Bujumbura was 70 to 75 m in July 1993. In the south, near Mpulungu, the epilimnion was virtually absent at this time.

The warm water accumulation in the north is mainly a surface process. Water flows south as deep currents and causes upwelling along the southern coast. Upwelling was inferred from the measurement of colder and nutrient rich water that averaged 24.4 (C at the surface during the dry season (compared to 27.2 (C during the wet season) at Mpulungu. Surface water was also cooled by wind and lower air temperature in the dry season (Fig.A.1.1). Both processes (cooling from the deep, return currents and from lake-atmosphere interactions) resulted in very weak stratification. The stratification index (as defined in appendix A.5.) highlighted the differences between north and south in the dry season (Fig. 4). During upwelling, mixing of water near Mpulungu increased and higher concentrations of N and P (normally abundant below the thermocline) were measured in the epilimnion (Appendices A.14. and A.15.). Average water transparency decreased to between 8 and 10 m (compared to 12 to 18 m during the wet season). Higher phytoplankton biomass resulting from upwelling in the south was observed by Beauchamp (1939) and Coulter (1968). In 1993-94, mixing during upwelling was observed to be particularly conspicuous when deep internal waves (see below) showed an 'apex'. Figure 5 shows that two deep internal waves (detected at 250-300 m) are in phase with the lifting of the 23.75 to 24.00 (C isopleth that reached an 'apex' on 30/07/93 and 26/08/93. On a daily cycle, mixing increased particularly in the early morning when high winds and low air temperature coincided (Appendix A.6).

During the dry season, turbulence was extensive and vortices and exchange of water from both sides of the thermocline were detected to at least 200 m (Plisnier, *in prep.*). Coulter (1968) suggested that the amplitude of internal waves in the upper 150 m implied that turbulent mixing, due to internal waves, extended well below 150 m.

The south-east winds ceased at the end of the dry season, and the metalimnion "fell back" towards a horizontal plane but continued to oscillate over several months. This period was characterised by agitated water movements. The oscillations of the metalimnion and thermocline depth are illustrated in figure A.7.3. The changes in pH and conductivity provided an excellent way to examine the movements of the metalimnion (Fig. 6). Yearly variations in the pH at 40 m ranged between 8.47 and 9.40 at Bujumbura/Uvira and 8.66 to 9.12 at Mpulungu. Deep water characterised by lower pH (relative to the surface) affected the pH in surface waters at the end of the dry season. The nutrient rich deep water probably strongly influenced primary production when it was brought near the surface. Consumption of $HCO3^-$ during photosynthesis results in higher pH values. This could explain the fluctuations of pH measured in the lake. During the wet season, pH changes were reduced to reach more stable values in February at each station (Appendix A.12). Ammonia and nitrite also fluctuated less at Bujumbura/Uvira.

Secondary upwelling at the north of the lake was noted in October 1993 and was also probably linked with oscillations of the metalimnion. For example, deep conductivity isopleths rose towards the surface (Figure A.11.1.). Transparency near Bujumbura/Uvira was particularly low in October (8.4 m) and November 1993 (7.1 m). It is suggested that this event may be proportional to the intensity of the main upwelling in the south since both phenomena are related to wind intensity. However the secondary upwelling was weaker when compared to the southern upwelling as thermal stratification remained in the north. Phytoplankton blooms had previously been detected at this time of the year in the north (Symoens, 1955a,1955b; Dubois, 1958) which suggests the yearly occurrence of the secondary upwelling.

Strong waves were observed near the shores of Mpulungu and could have corresponded to a surge at the beginning of the metalimnion oscillations in September-October. These waves are observed every year at the end of the dry season. They are locally called "Chimbanfula". This means "digging for the rains" locally because they occur at the beginning of the wet season. Some fishermen report that "Chimbanfula" waves can be associated with fish kills and plankton blooms. In September 1993, a fish kill of *Boulengerochromis microlepis* was observed. Corpses were seen floating in many areas near Mpulungu. "Chimbanfula" waves may be related to travelling waves and oscillations of the metalimnion. This supports Coulter's (1991) suggestion that oscillations are accompanied by water movements that take the form of a large amplitude, progressive wave which gradually transforms into a standing wave. He suggested that such a surge could cause a "local severe mixing".

Internal waves during the whole year, at all the stations of LTR, were inferred from fluctuations of temperature (Fig. 5), pH, conductivity, turbidity, total phosphorus, phosphates, ammonia, nitrates and nitrites. Previously, internal waves had been noted from temperature and oxygen isopleths (Dubois, 1958; Coulter, 1968). In the present study, an average of 11 waves for all the parameters at each station were identified. They corresponded to a period of 33 days. Some parameters such as nitrates in the north and phosphates in the south had up to 13 peaks during the year (average period was 28 days). It is possible that some peaks were missed because of the relatively low frequency of sampling (2 to 3 samples of type A per month). There seemed to be no period when waves were absent for any of the parameters at any station. Even during the upwelling in the south, internal waves were detected in deep water (cf. temperature at 200 and 300 m) which supports the theories of Coulter (1991).

Pulses generated by internal waves were reflected in nutrient waves in the water column. The long period waves showed a vertical displacement of nutrient concentrations of *c.* 20 m in the water column. Regular pulses of phytoplankton production probably followed the rhythmic movements of internal waves because deep eutrophic water was able to reach the biotic and photic zones which usually showed oligotrophic characteristics. The "nutrient waves" should also have influenced organisms that were adapted to take advantage of favourable but episodic conditions.

As the lake became more stable, particularly, from February to May, turbidity increased near the thermocline at Bujumbura/Uvira. A deep-living community of organisms linked to nutrients and reduced matter brought up by the internal waves may have developed particularly when the lake was calm near the thermocline. In Lake Kivu, the stable chemocline at 60 m allowed a layer of chemosynthetic bacteria to form there (Haberyan and Hecky, 1988). This bacterial 'plate' was nourished by the abundant methane and other organic compounds moving up from deep waters. A bacterial 'plate' may also exist in Lake Tanganyika, particularly when the lake is calm.

4.2 Limnological parameters

4.2.1 Temperature and stratification

Thermal stratification was observed at each station during the whole year except in the south in the dry season (upwelling). The epilimnion generally extended from the surface to depths between 20 and 105 m. The upper metalimnion including the thermocline extended generally from 50 to 120 m. The thermocline was occasionally detected in the upper 20 m. The lower metalimnion reached at least a depth of 300 m. Hypolimnion water (<23.5(C) was measured at *c.* 300 m except during upwelling in the south. Internal waves, indicated by temperature fluctuations were noted at all depths including below the thermocline down to 300 m all the year. They were not clear from 0 to 30 m due to mixing of the epilimnion.

4.2.2 Transparency

Transparency fluctuated between 5.0 and 23.5 m at site A. The northern station at Bujumbura/Uvira had the lowest transparency (mean = 9.1 m). Higher mean values were recorded at

Kigoma (13.8 m) and Mpulungu (12.4 m.) (Table A.2.1). Transparency varied considerably on a daily basis. Variations in transparency (up to 5 m) were noted in a few hours in the south on 17/9/94, 18/11/94 and 16/12/94. Turbulent mixing may have been responsible for a high level of heterogeneity in nutrients, plankton and transparency. Water temperature and transparency showed a positive correlation particularly in Kigoma (r^2 = 0.56) and Mpulungu (r^2 = 0.53).

4.2.3 Turbidity

Average turbidity at Bujumbura/Uvira was highest (0.40 NTU) compared to Mpulungu (0.35 NTU) and Kigoma (0.25 NTU). Turbidity decreased with depth at each station. The lake was usually more transparent in deep waters than on the surface. This was probably due to a higher abundance of living organisms in the epilimnion. However, in some months turbidity increased in deeper water suggesting deeper pulses of production (Plisnier *et al.*, *in prep.*).

During the dry season, turbidity was significantly higher at the north and the south ends of the lake compared to Kigoma. During the wet season, a turbidity layer developed near the thermocline at Bujumbura/Uvira and was probably caused by communities of deep-living organisms (Figure A.9.3).

4.2.4 Dissolved oxygen

Surface waters were often saturated or supersaturated in dissolved oxygen. Dissolved oxygen was present down to *c.* 80 m at Bujumbura/Uvira and *c.* 200 m at Mpulungu. Results were limited for the first year (Appendix A.10). Some measurements of dissolved oxygen concentrations down to 300 m were made at each station and appeared to be related to turbulent processes.

4.2.5 Conductivity

Conductivity was generally between 660 (S/cm near the surface and 700 (S/cm at 300 m (Figure A.3.1. and appendix A.11.). Conductivity at Kigoma was often slightly lower than at both ends of the lake. Greatest variability of conductivity was measured at Bujumbura/Uvira in the upper layer (values between 520 and 728 (S/cm have been recorded). The changes of conductivity were relevant as they could be used as indicators of metalimnion movements (cf. 4.1.).

4.2.6 pH

pH often ranged between 9.0 at the surface and 8.7 at 300 m (Figure A.3.1. and appendix A.12.). Variations of pH during the year were highest at Bujumbura/Uvira. At both ends of the lake, pH oscillations lessened over the year. Both pH and conductivity seemed to be excellent "tracers" of vertical water movements. pH did not change as rapidly as other parameters probably due to the high buffering capacity of Lake Tanganyika.

4.2.7 Phosphorus

Concentrations of phosphorus in surface waters were *c.* 0.05 mg/ l (TRP in mg/l $PO4^{3-}$). A clear increase with depth was observed with concentrations of x5 to x10 at 100 m depth (Table A.14.1) compared to the surface. During the upwelling period in the south, the concentrations of total phosphorus doubled in the epilimnion (mean of 0.32 mg/l as $PO4^{3-}$ in the upper 0-100 water column compared to 0.12 mg/l during the wet season). Pulses of high phosphate concentrations caused by internal waves raising the rich deeper layers, were observed especially at Bujumbura/Uvira and Kigoma.

4.2.8 Nitrogen

Nitrates had a maximum in concentration of *c.* 0.10 mg/l NO3-N at 60-80 m in the north and 100-140 m in the south (Appendix A.15). The nitrate rich layer was related to the thermocline and oxycline depths at each station. The layer was particularly well defined when the lake became calm after January-February 1994. Below the nitrate layer a nitrite layer was sometimes detected such as at 80 m at Bujumbura/Uvira (0.005 mg/l NO2-N). At this station, higher values of nitrites were also observed in the upper 100 m during the mixing period in October and November. This was probably linked with the well defined thermocline near Bujumbura/Uvira and a strong vertical gradient of dissolved oxygen affecting nitrification and denitrification processes. Below the oxycline, high concentrations of ammonia were measured. At Bujumbura/Uvira mean concentrations of ammonia were 0.05 mg/l NH4-N at the surface water and >0.40 mg/l NH4-N at 300 m. Mixing may have brought significant concentrations to the surface (>0.20 mg/l NH4-N). High ammonia concentrations were recorded more often at Bujumbura/Uvira, probably because of the shallow thermocline depth there. Ammonia was often low or not detected in Mpulungu probably because of deeper oxygenation processes in the south.

5. DISCUSSION

Mixing of nutrients

Lake Tanganyika is not oligotrophic as deep waters contain extremely large quantities of nutrients (P, N, Si). However, it may not be called eutrophic either as surface water are often poor in nutrients. Van Meel (1987) suggested that the lake was pseudoeutrophic as it possessed both oligotrophic and eutrophic characteristics. The uneven distribution of nutrients is largely the consequence of the existence of thermal stratification in the lake. The thermocline is the main barrier between very different water layers. Fluctuations in the extent stratification determine the degree of nutrient influx into the photic zone. Two main features of stratification are the depth of the thermocline and its strength. The former is highly dependent on the heat budget and on the winds:

(1) An increased input of heat results in a deepening of the thermocline and keeps the nutrient rich layers in deeper waters.

(2) The wind from the south-east causes the accumulation of warmer epilimnion water and thereby deepens the thermocline in the north, while in the south deep, rich waters upwell. When the force of the wind weakens or ceases after the dry season, oscillations of the metalimnion form internal waves. The waves, mainly detected below the thermocline, may themselves influence thermocline depth. The rhythmic movements of internal waves induce a regular pulse of production when deep eutrophic water is able to reach the biotic and photic zones where photosynthesis can increase. The "nutrient waves" should influence organisms adapted to capitalize on these favourable but episodic events.

Thermocline strength (= stratification level) relies on water density changes which are mainly dependant on temperature and the salinity gradients in the water column. The level of stratification determines the extent of turbulent mixing, for example a weakly stratified thermocline would allow more "permeability" between different layers.

It would appear that the productivity of the lake is highly dependant on the hydrodynamic state of the lake and on climatic conditions, particularly the wind and the heat budget. Computation of the dynamics of the thermal regime of such a large lake depends on accurate estimations of wind induced shear stresses over the lake and on correct identification of vertical turbulent diffusion which control the processes of vertical mixing (Huttula and Podsetchine, 1994).

Upwelling and secondary upwelling

When the winds are strong, the tilting of the epilimnion and the upwelling in the south will be important. After the cessation of the wind, upward movement in the north should be similar and as important to the upwelling in the south during the dry season. Indeed, significant fluctuations of some parameters (e.g. conductivity) suggest the existence of a secondary upwelling in October-November in the north of the lake. Historical data have shown that phytoplankton blooms occurred in the north at this time of year (Symoens, 1955a,1955b; Dubois, 1958; Hecky and Kling, 1981). This northern bloom often coincided with the onset of the rain that was held mainly responsible for a higher nutrient input. However, while the rains probably play some role in phytoplankton blooms, it has been suggested above that the secondary upwelling with upward movement of deep waters in the north at that time should be held mainly responsible for bringing nutrients towards the surface. This would explain the typical delay between high algae production in the south followed a few months later by increased productivity in the north. It is suggested that the upwelling detected in the north of Lake Malawi in October 1993, from satellite images of the lake surface temperature (Wooster *et al.*, 1993) may be similar to secondary upwelling in Lake Tanganyika.

Pulses and patchiness in water composition

The lake is certainly not homogeneous and stable during an annual cycle. Patchiness has been observed in several studies on autotrophic (algae blooms) as well as heterotrophic organisms (zooplankton) (Vuorinen and Kurki, 1994; Bosma, pers. com.). The patchy distribution of *Stolothrissa tanganicae* has been reported by Collart (de Bont, 1972).

Patchiness could possibly be divided into:

(1) "non random patchiness". Changes in limnological parameters measured by LTR in 1993-94 showed some rhythmic changes induced by internal waves with a defined period (apparently 28 to 33 days). A pulse production might result from this. Hecky and Fee (1981) found that Lake Tanganyika phytoplankton had the highest growth rate of those examined in tropical lakes. It is possible that fast growing algal populations, adapted to fluctuating environmental conditions, are able to capitalize upon these "nutrient waves".

(2) "random patchiness" due to turbulence and currents. An extensive patchiness in the chemical characteristics of Lake Tanganyika was observed, particularly during short term experiments such as 24 h cycles (Plisnier, *in prep.*). Very variable transparency on a short time scale (hours) might result from patchiness in nutrients. It could also be affected by solar radiation and photo-inhibition or movements of water.

De Bont (1972) had suggested that patchiness in fish distribution could be the result of patchiness in the environment of the lake. He suggested that the main factor responsible for fish patchiness was the internal waves (that are here classified as "non-random patchiness"). However, "random patchiness" is certainly also involved in the distribution of fish. Investigations in patchiness in physical limnology (temperature, mixing index, etc.) and in nutrients might quantify links with zooplankton and fish distribution. Important information includes the size of patches and temporal changes. Only a multi-disciplinary lake wide investigation using *R.V. Tanganyika Explorer* could do this. It should be realised that relationships between different levels of the food web will only be possible with <u>simultaneous</u> sampling because of the dynamic nature of Lake Tanganyika. It is highly advisable to measure some main limnological parameters during fish cruises.

6. CONCLUSIONS

This first year of data shows that productivity of Lake Tanganyika like the sea and probably like other large deep tropical lakes, depends to a large extent on the regeneration of nutrients from the water column .

Nutrient rich waters were observed below the thermocline. Their access to the upper photic layers is highly dependant of hydrodynamic events driven by climatic conditions.`

A limnological cycle could be summarised in the following sequence of events:

- SE winds drive surface water northwards
- This tilts the metalimnion
- Upwelling occurs during the windy dry season in the south
- SE winds stop and metalimnion oscillates
- Surge flows back and forth along the lake
- Secondary upwelling raises deep waters in the north
- Internal waves are re-activated by the surge
- Metalimnion oscillations dampen

Internal waves have been observed for all the parameters studied at all three stations around the lake throughout the year from August 1993 to July 1994. They are a very important aspect of the lake's limnology and could play a considerable role in the "non-random patchiness" and the production pattern of the ecosystem. A regular pulse of production is likely to follow the rhythmic movements of internal waves bringing deep eutrophic water toward the photic zone. These "nutrient waves" could also have acted as a major environmental factor in the selection of organisms (in the pelagic particularly) by favouring the occurrence of fast growing organisms adapted to highly variable fluctuating conditions.

"Non-random patchiness" could be linked on a large scale with internal waves, upwelling and main currents while on a shorter time and geographical scale, "random patchiness" probably resulted from turbulence. Vortices have been often observed in the water column at each station.

Elucidation of patchiness in limnological parameters is vital to the understanding of patchiness in higher trophic levels such as zooplankton and fish. Simultaneous sampling through multi-disciplinary lake wide cruises is a pre-requisite. Parts of "non-random" patchiness (internal waves) may however be best studied through very frequent sampling at a few fixed stations.

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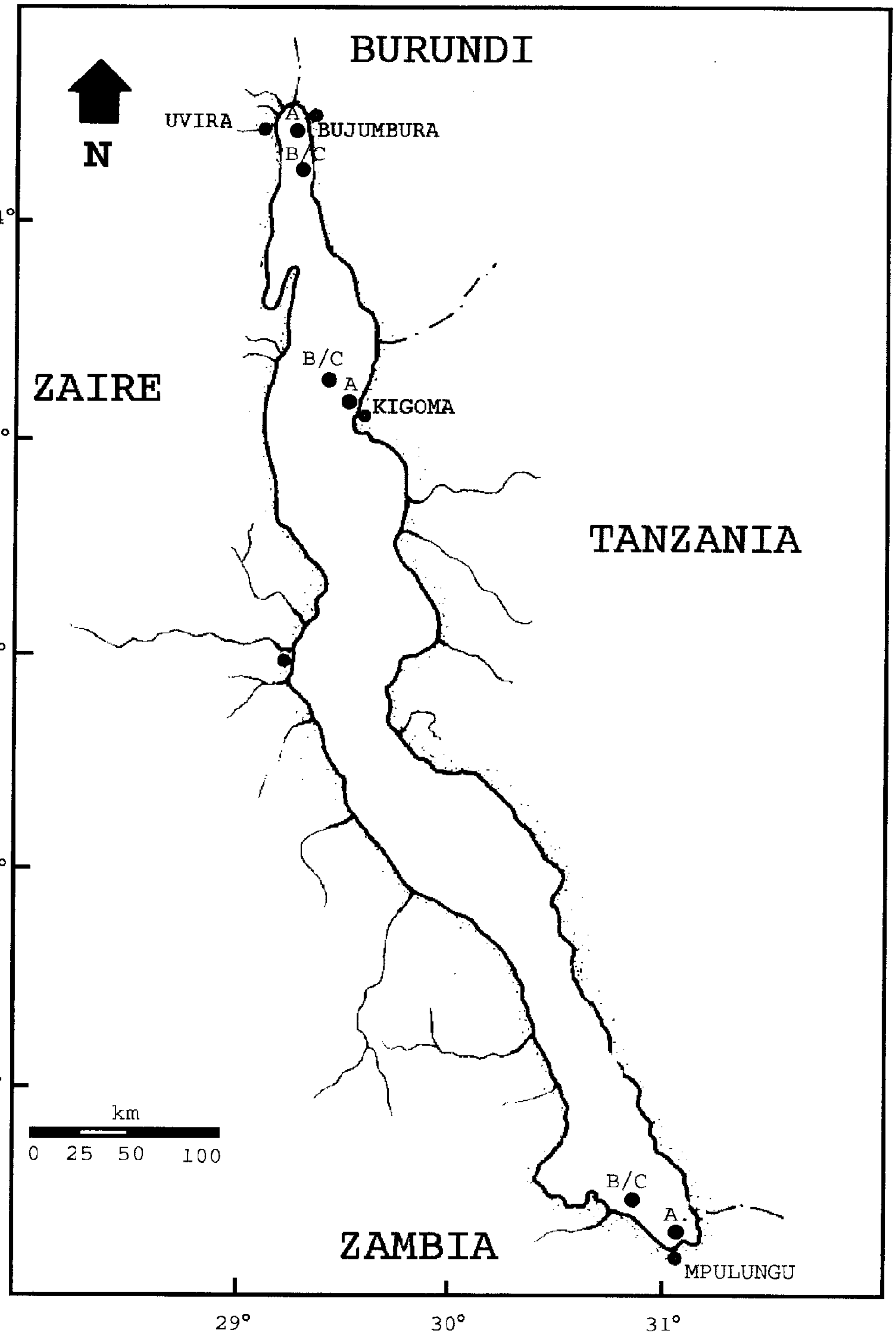


Figure 1 : Location of sites A, B and C for limnological sampling near each station (A = regular sampling down to 100 m, B = intensive sampling every 6 weeks (24 h cycle), C = seasonal sampling (every 3 month) at the same sites as B.

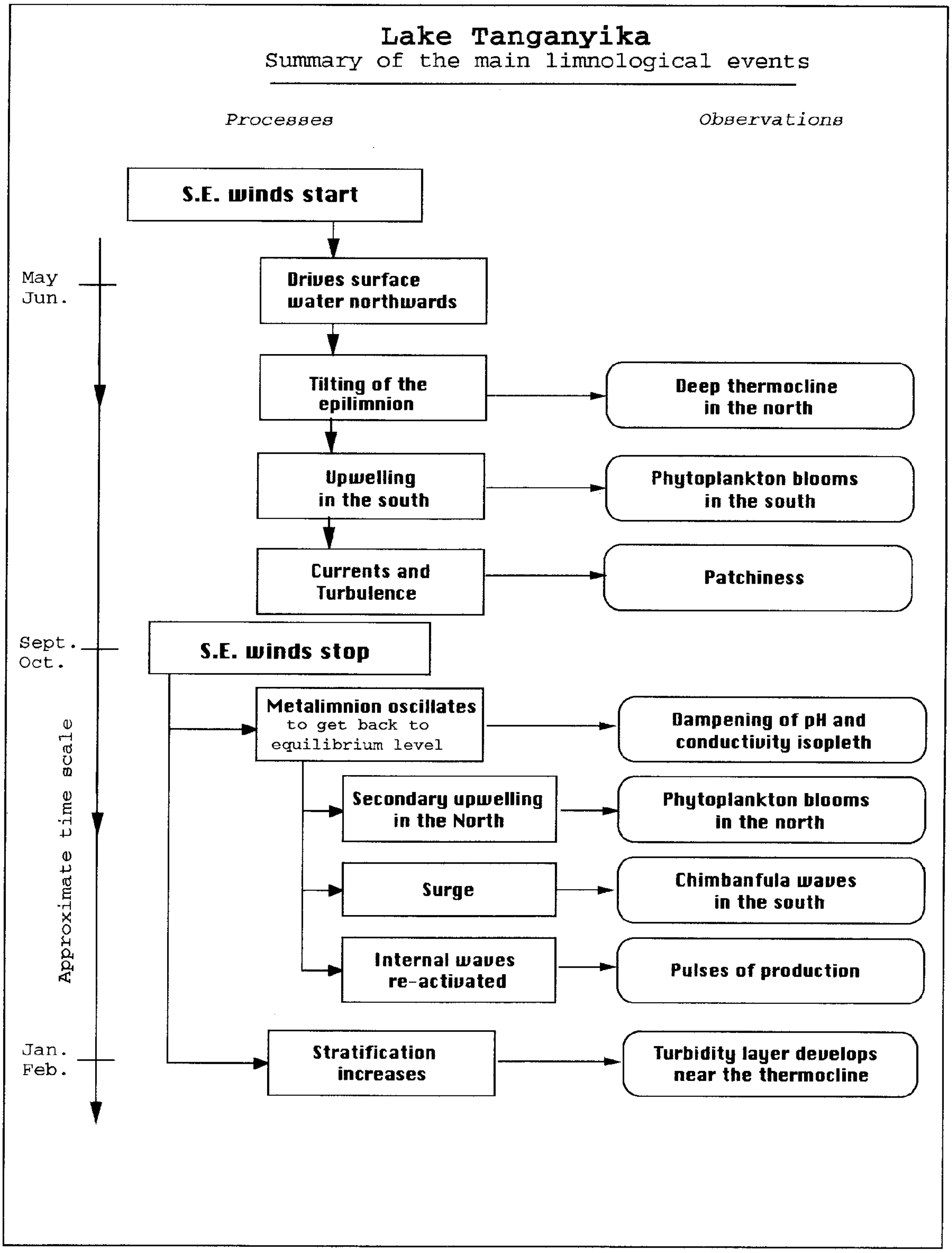


Figure 2 : Important events in the limnology of Lake Tanganyika during a yearly cycle.

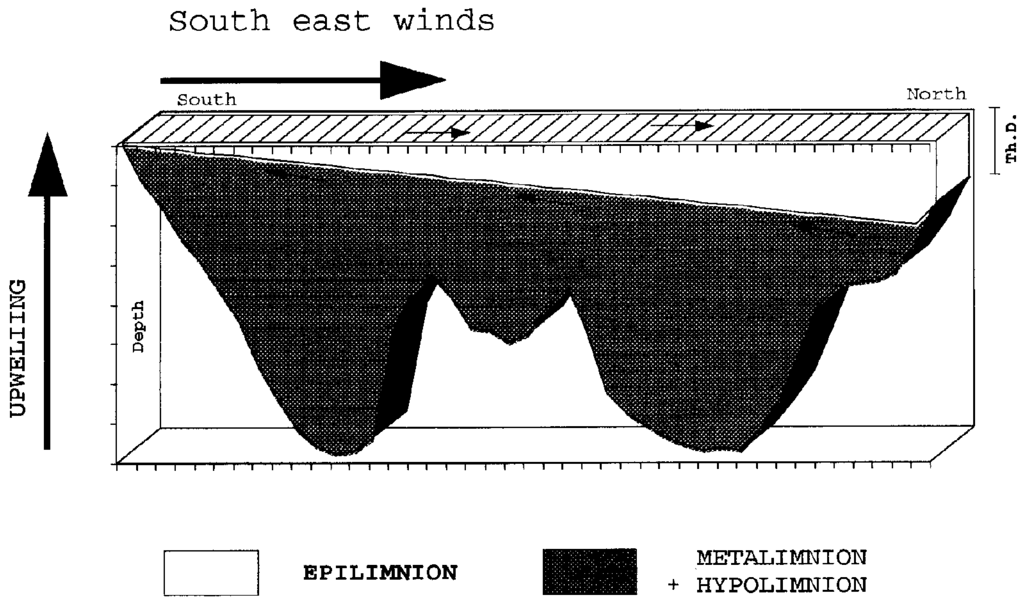


Figure 3 : Schematic representation of a profile of Lake Tanganyika showing the tilting of the epilimnion caused by the south east winds during the dry season (May to September) and a resulting upwelling in the south. Th.D. indicates thermocline depth. Drawing is not to scale.

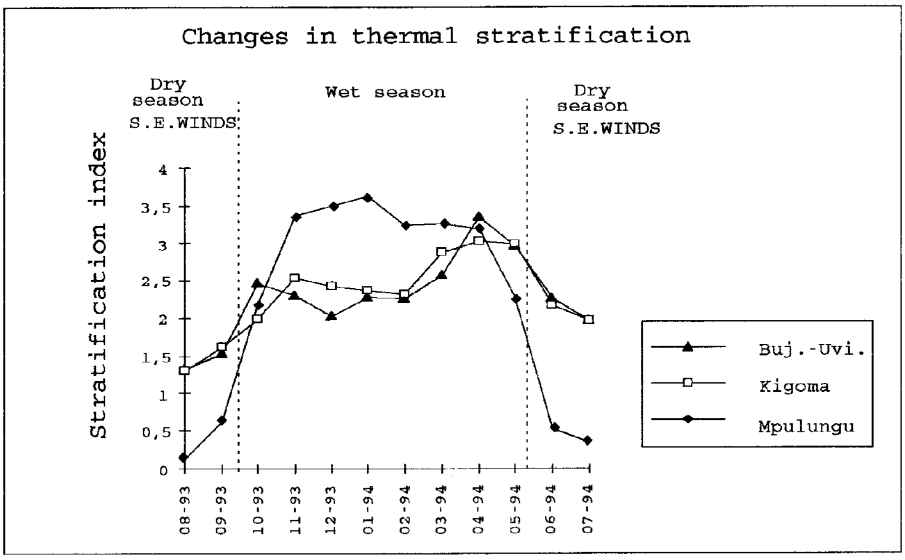


Figure 4 : Changes in the stratification index at site A at Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

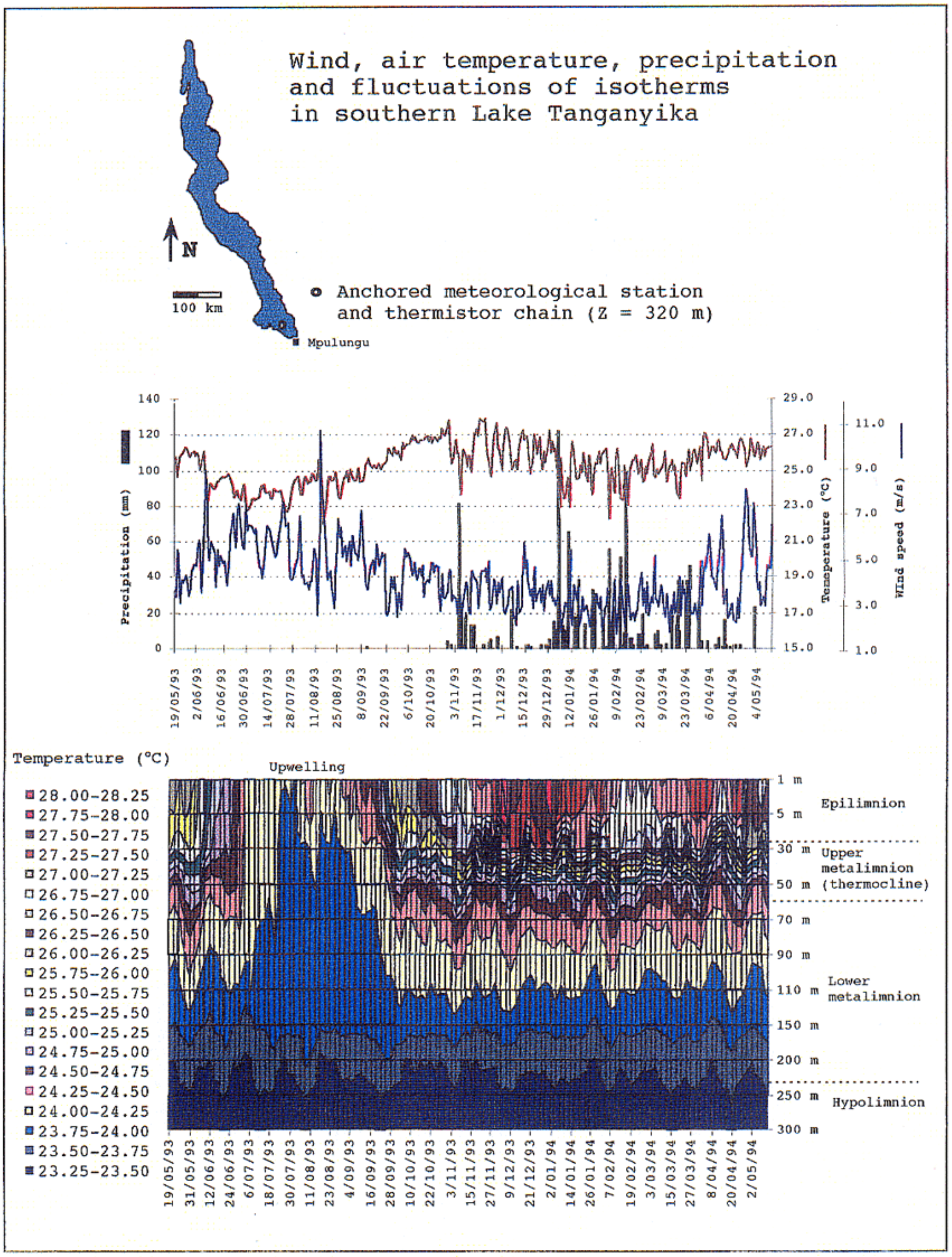


Figure 5 : Fluctuations in daily average air temperature (°C) and wind speed (m/s). Isopleths of water temperature (°C) are averaged on 24 h and shown for every 3 days from 19/5/1993 to 12/5/1994. Temperature and wind speed were measured at the LTR meteorological station and thermistor chain anchored in the south of Lake Tanganyika. Precipitation (mm) was recorded at the Mpulungu station. Upwelling period and layers identified are indicated.

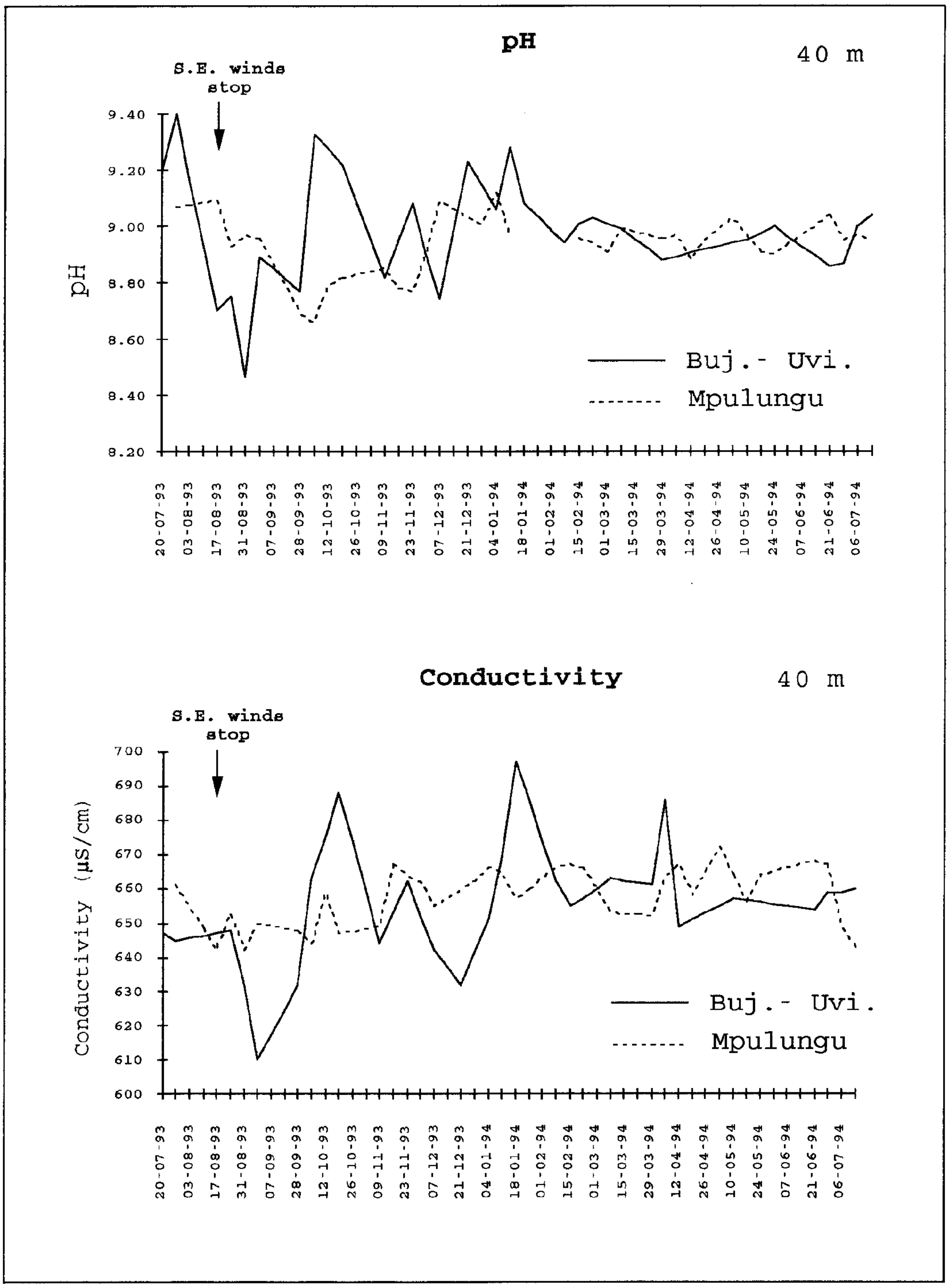


Figure 6. Changes in pH and conductivity (µS/cm) at 40 m in Bujumbura/Uvira and Mpulungu from August 1993 to July 1994 (an indicator for metalimnion oscillations and dampening). Approximate cessation of the south-east winds in 1993 is indicated. Values for weeks not sampled are interpolated.

APPENDIX A

A.1 Meteorology

Weather is a major factor influencing changes in lake ecosystems. Data for precipitation, temperature and wind speed from each station are presented here for the period studied.

A.1.1 Precipitation

Precipitation was extremely low at Bujumbura between August 1993 and July 1994 (Fig. A.1.1) compared to previous years. Only 427 mm were recorded at the LTR automatic station while the yearly 'mean' total precipitation for 30 years was 855 mm at Bujumbura Airport. Uvira, *c.* 25 km from Bujumbura, recorded 697 mm of precipitation in 1993-1994 (CRSN, personal communication) a value lower but still comparable to the yearly mean recorded there (810 mm) for a period of 10 years. For the same period, precipitation at Kigoma was below the 10 yr mean, 821 compared to 961 mm. At Mpulungu the precipitation, 1176 mm, was also below the mean (20 yr data) of 1248 mm.

Mean monthly values for precipitation from 17 stations around the lake are presented in Figure A.1.2. Latitude and altitude were two important factors influencing precipitation. At low latitude (towards Mpulungu) there was generally one main wet season with a high level of precipitation during a few well defined months, particularly December to March. At latitudes closer to the equator (towards Bujumbura) precipitation was 'spread out' during two seasons whose peaks were generally in March to April and November to December. This rhythm was linked with the passage of the ITCZ (inter tropical convergence zone) and general atmospheric circulation.

There was considerable precipitation during a short period at Mpulungu. Total precipitation of 300 mm per month was common compared to the mean monthly maximum for Bujumbura of 120 mm. The heavy precipitation may have washed nutrients into the lake at Mpulungu at a greater rate than in the north.

Altitude also directly influenced the amount of precipitation probably as a result of convection flow and condensation of clouds near the escarpments. Stations at 'lower altitudes' experienced less precipitation.

A.1.2. Air temperature

Air temperature data presented in Figure A.1.1 showed variation but absolute values should not be strictly compared between stations. The main reason is that the data originate from sites situated at different distances from the lake at each station. At Bujumbura, the site was on the shore, at Kigoma the site was 5 km inshore and at Mpulungu the site was an anchored buoy (*c.* 30 km) with an automatic recording station in the pelagic zone. The location of the recording sites is likely to cause bias when comparing air temperatures. An automatic station was installed in June 1995 on the shore at Mpulungu and thus better comparisons will soon be possible between the two ends of the lake. Two peaks of air temperature were observed during the year (Fig. A.1.1), one in October and the other in April-May. At Mpulungu the first peak was longer and lasted until November-December. The minimum values were observed in June-July at each station. There was also a well defined low value in December at Bujumbura and Kigoma while this second low was observed later, in February, at Mpulungu. The variation in air temperature thus showed a similar pattern at each station, two peaks and two minima with, however, longer lasting or delayed peaks in Mpulungu.

The daily cycles of air temperature (recorded every hour at the anchored automatic station 30 km north of Mpulungu) were averaged for each month (Fig. A.1.3) It can be observed that air temperature reached a maximum between 1400 and 1600 h depending on the month. In September and October 1993, a second peak was recorded during the night (2300 to 0100 h) which appeared to be linked with a warm wind. The minimum temperature was reached between 0400 and 0700 h depending on the month.

At Mpulungu the highest mean, hourly air temperature, 27.5 $^{(}$C, was recorded in October 1993 at 1200 h while the lowest hourly mean of air temperature, 22.4 $^{(C}$, was recorded at 0700 h in June 1994. In June 1994 at 0500 h, two hours before the low temperature was recorded, the highest hourly mean wind speed (8.5 m/s) was recorded. The morning hours of June were thus characterised by two favourable conditions for mixing of the water column by convection, high wind speed and low air temperature (with probably a low heat budget).

A.1.3. Wind speed

Only three types of wind are considered here, the on- and off-shore winds, the south-east trade wind during the dry season and the stormy winds of the wet season. The on- and off-shore winds are thermal in origin, caused by the temperature differences between the land and water. Beauchamp (1939) showed a clear relationship between the speed of the off-shore winds and the maximum and minimum temperatures of the preceding day and night. This type of wind was noted all year round (example for Mpulungu is shown in Fig. A.1.3) and was particularly important during the dry season. Radiation differences between day and night were then important and thermal difference between lake and land were much higher. The south east trade wind was observed during the dry season. Near Mpulungu, during the night, its effect was cumulative with the off-shore winds. This 'combined' wind is locally named "Kapata". It can start very suddenly in the evening or during the night but is sometimes interrupted. There can be pulses of several days of wind separated by quieter periods. It can reach an hourly mean speed of 8 m/s as recorded in July 1994 (Fig. A.1.3). Figure A.1.3 shows that the wind speed reached a maximum in the early morning (0400 to 0800 h) at Mpulungu during the dry season. The on-shore wind, mainly from the north, was observed during almost the whole year, particularly in September and October, between 1400 and 1600 h. This wind seemed much less important than the Kapata wind as it occurred when the water showed a daily stratification of the upper layers (Figures B.1 to B.11). The stirring effect of the on-shore wind on the water is probably less important. It was reported by fishermen to have little influence on fishing. June 1994 was the only month with virtually no on-shore wind. This followed strong night time winds from the south (Kapata). Storm winds during the dry season were generally from the north.

The wind speeds were difficult to compare between stations because recordings were made at different distances from the lake. In Figure A.1.1, the wind speed values are given for Bujumbura and at two sites off Mpulungu, an automatic station on a buoy *c.* 30 km north of Mpulungu and on the shore, in front of the Department of Fisheries, Mpulungu. At Mpulungu the wind was stronger on the lake compared to the shore as the latter was sheltered from the north and south by hills. The winds from both sites were stronger than at Bujumbura. The correlation between the shore wind station and the pelagic wind station of Mpulungu was highly significant ($P<0.001$). The increased wind speed recorded in the pelagic area was between 0.36 and 1.45 m/s higher than the wind recorded on shore (data obtained over 10 months). The wind speed on the shore and in the pelagic area of Mpulungu was respectively 36 % and 70 % higher than the wind speed recorded at Bujumbura port. The highest wind speeds were noted particularly during the dry season (April to September) when there were 'Kapata' winds. The months with the lowest mean wind speeds were December in Bujumbura and January in Mpulungu. Data for Kigoma are not presented here but Huttula and Kotilainen (1994) noted that the wind was less variable than at the other stations, 3.9 m/s in August 1993 and 3.4 m/s in March 1994.

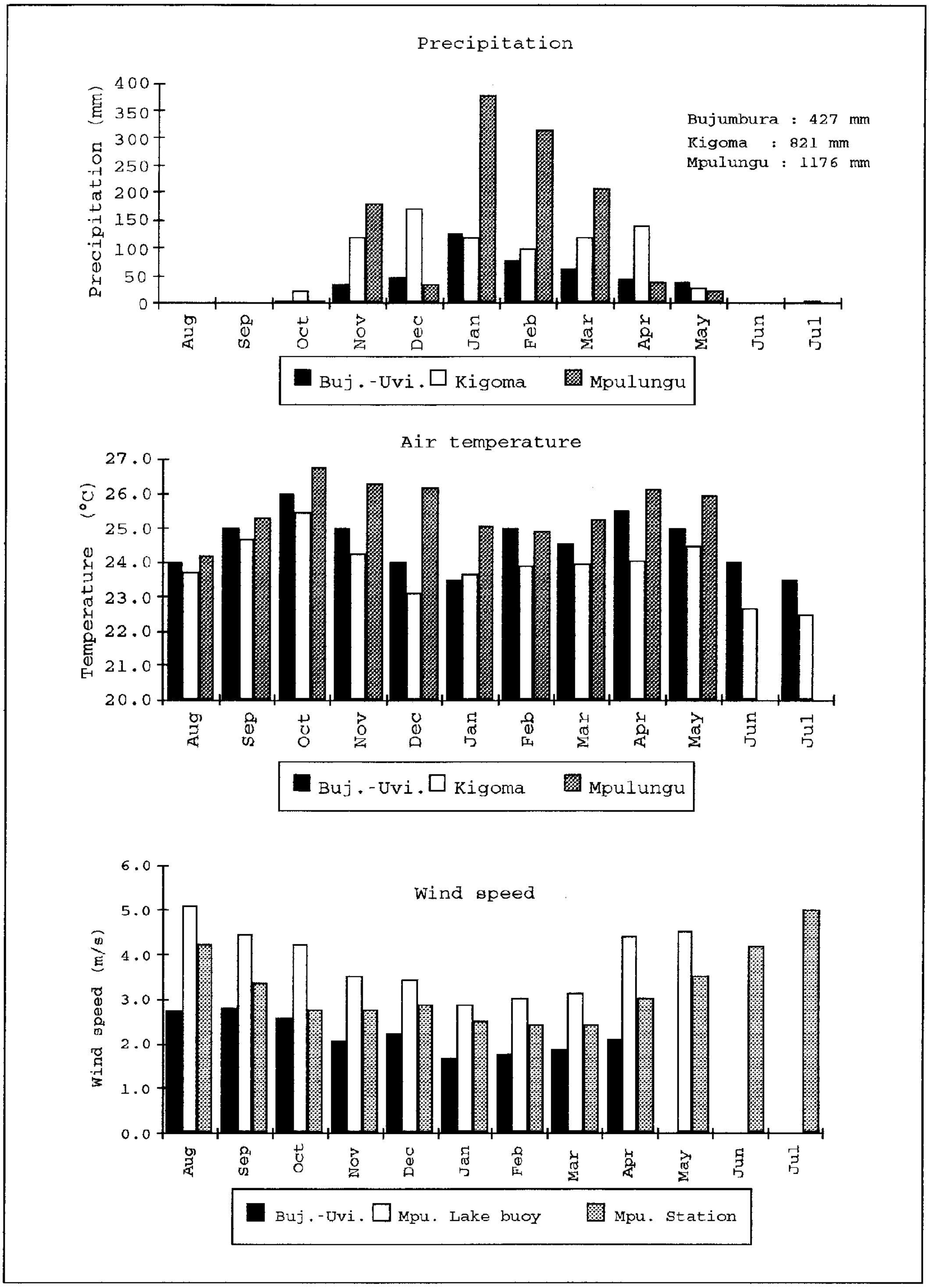


Fig. A.1.1. Monthly total precipitation (mm), mean air temperature (°C) and mean wind speed (m/s) at Bujumbura, Kigoma and Mpulungu (Bujumbura: LTR automatic station, Kigoma: Meteorological Station, Mpulungu: LTR automatic station on lake and shore station for wind speed) from August 1993 to July 1994.

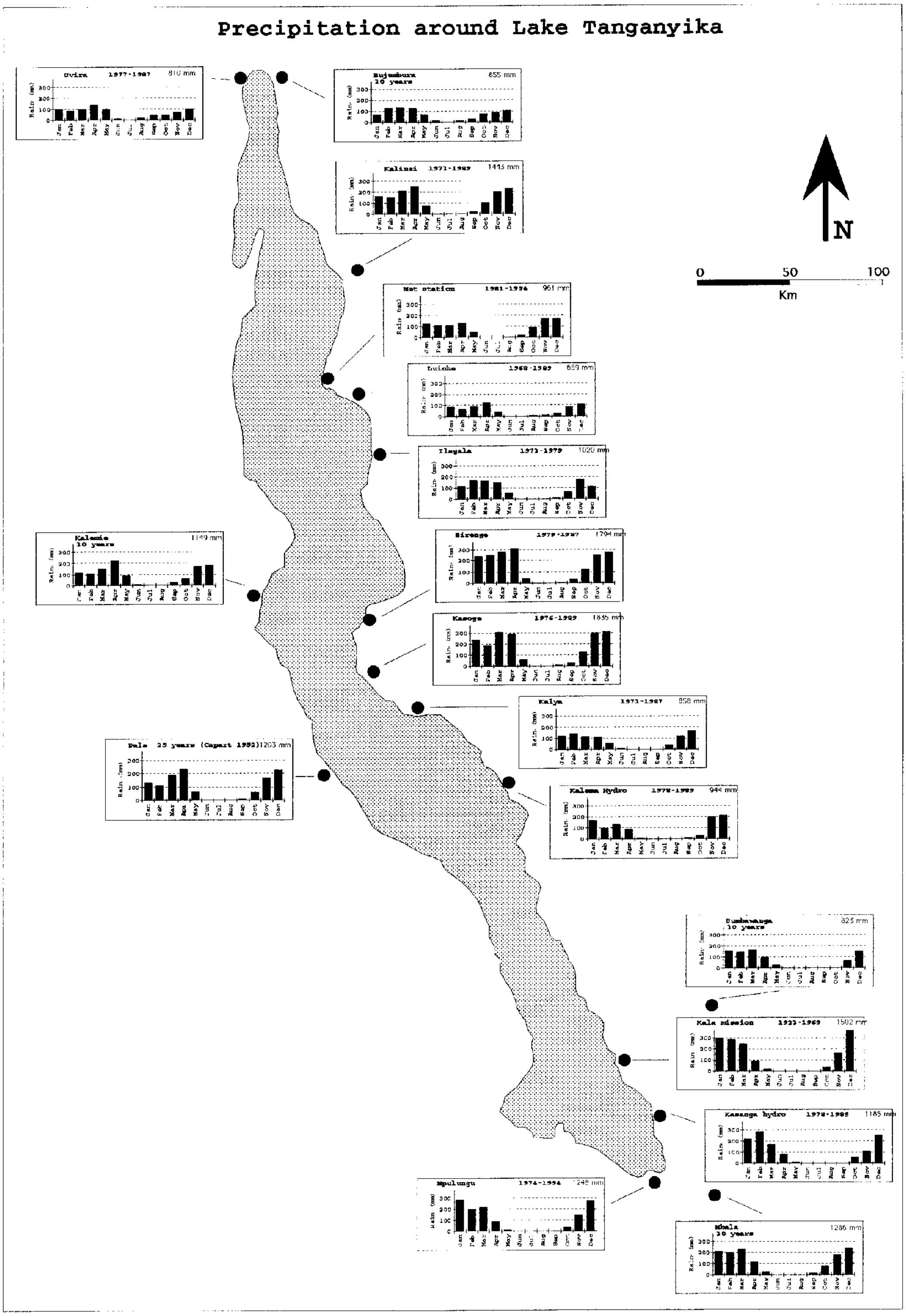


Fig. A.1.2. Monthly mean precipitation at 17 stations around Lake Tanganyika. (Data from CRSN, Uvira; Bujumbura Airport, Meteorological Station; Departement of Meteorology, Kigoma; DOF; Mpulungu; Mbala Airport, Departement of Meteorology and Capart, 1952).

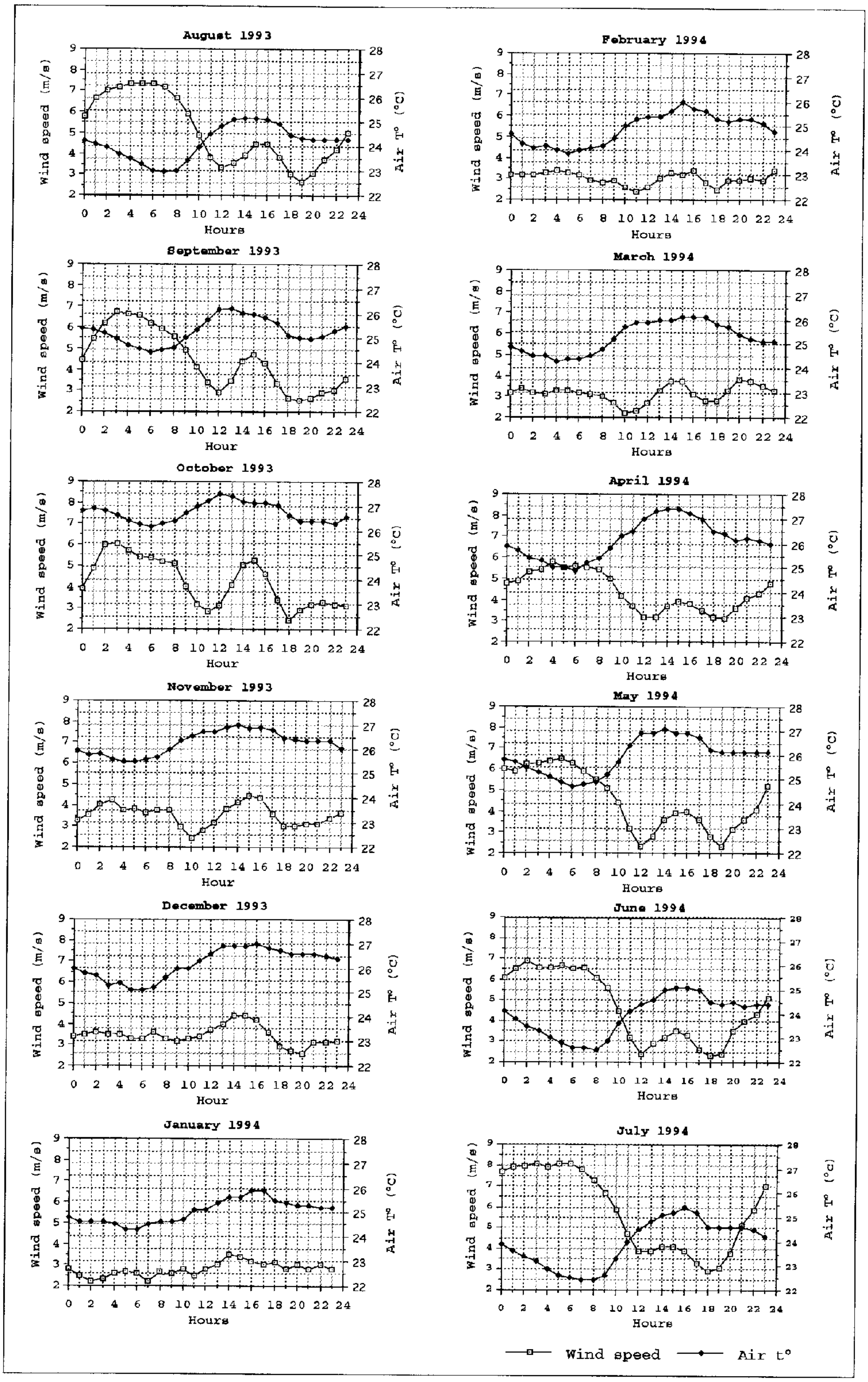


Figure A.1.3. Daily wind speed (m/s) and air temperature (°C) from August 1993 to July 1994 at the meteorological buoy installed in the south (Mpulungu) (NB:data for May and June 1994 is not complete).

A.2 Means, medians, maximum and minimum values of parameters.

The values of each parameter measured at site A of each station are presented in Table A.2.1. In this table means were calculated for the 0 to 100 m water column. More specific data are given in the following sections.

Yearly median values were as follows. For **temperature** at Bujumbura/Uvira, 25.8 (C, was close to that at Kigoma, 25.7 (C, but higher than at Mpulungu, 24.5 (C. However variation was higher in Mpulungu. **Transparency** was lower at Bujumbura/Uvira, 8.7 m, than at Kigoma or Mpulungu, 12.8 and 11.9 m respectively). **pH** was generally similar at each station, approximately 8.9. Higher variation was noted at Bujumbura/Uvira than at the other stations. **Conductivity** was 659 at Bujumbura/Uvira, 654 at Kigoma and 662 (S/cm at Mpulungu. Conductivity was more variable at Bujumbura/Uvira than in the other stations. **Turbidity** was very similar at Bujumbura/Uvira and Mpulungu, 0.32 and 0.33 NTU respectively, but lower at Kigoma, 0.25 NTU. **Total phosphorus** was 0.03 at Buj-Uvi, 0.39 at Kigoma and 0.08 (m/l at Mpulungu. **Phosphates** values measured from unfiltered water were 0.6 at Bujumbura/Uvira, 0.9 at Kigoma and 0.4 (m/l at Mpulungu. **Ammonia** had a median value of 0 at each station but could occasionally reach 26 at Bujumbura/Uvira, 24 at Kigoma and 39 (m/l at Mpulungu. **Nitrates** were 3.6 at Bujumbura/Uvira, 5.4 at Kigoma and 5.0 (m/l at Mpulungu. At Bujumbura/Uvira and Mpulungu, median values of **nitrite** were 0.1 and at Kigoma 0.2 (m/l.

Median values are graphically compared in Figure A.2.1 using the "box and whiskers" representation (Tuckey, 1977).

Buj.-Uvi										
	SD	T°	pH	C.	Turb.	Tot P	PO4---	NH4-N	NO3-N	NO2-N
Median	8,7	25,8	8,91	659	0,32	0,03	0,06	0,00	0,05	0,002
Max	15,4	27,3	9,48	728	2,10	2,15	0,83	0,37	0,16	0,019
Min	5,0	24,0	8,14	520	0,12	0,00	0,00	0,00	0,03	0,000
Average	9,1	25,5	8,90	659	0,40	0,13	0,15	0,04	0,06	0,003
Stdev	2,4	0,9	0,25	22	0,29	0,29	0,18	0,07	0,03	0,003
N	29	295	297	297	294	100	215	177	180	180

Kigoma										
	SD	T°	pH	C.	Turb.	Tot P	PO4---	NH4-N	NO3-N	NO2-N
Median	12,8	25,7	8,96	654	0,25	0,39	0,09	0,00	0,08	0,004
Max	23,5	27,4	9,36	702	0,85	1,60	0,80	0,34	0,21	0,010
Min	8,1	23,7	8,63	553	0,09	0,04	0,00	0,00	0,00	0,000
Average	13,8	25,6	8,95	652	0,25	0,47	0,15	0,02	0,08	0,003
Stdev	3,7	1,0	0,16	16	0,09	0,29	0,17	0,05	0,04	0,002
N	31	333	322	325	323	209	240	190	184	184

Mpulungu										
	SD	T°	pH	C.	Turb.	Tot P	PO4---	NH4-N	NO3-N	NO2-N
Median	11,9	24,5	8,94	662	0,33	0,08	0,04	0,00	0,07	0,002
Max	20,5	28,2	9,35	704	0,70	1,58	0,33	0,54	0,15	0,010
Min	7,0	23,3	8,56	607	0,14	0,01	0,00	0,00	0,02	0,000
Average	12,4	25,1	8,93	658	0,34	0,15	0,05	0,02	0,08	0,003
Stdev	3,2	1,2	0,13	12	0,10	0,22	0,05	0,06	0,03	0,001
N	32	373	351	375	375	183	237	193	205	205

Table A.2.1. Median, maximum, minimum, average, standard deviations and number of measurements for the measured parameters at each station, site A, 0 to 100 m, from August 1993 to July 1994.
(Secchi disk (SD) in m, temperature in °C, conductivity in µS/cm at 25 °C, turbidity in NTU, total phosphorus in mg/l amonia in mg/l NH4-N, nitrate in mg/l NO3-N , and nitrite in mg/l NO2-N.

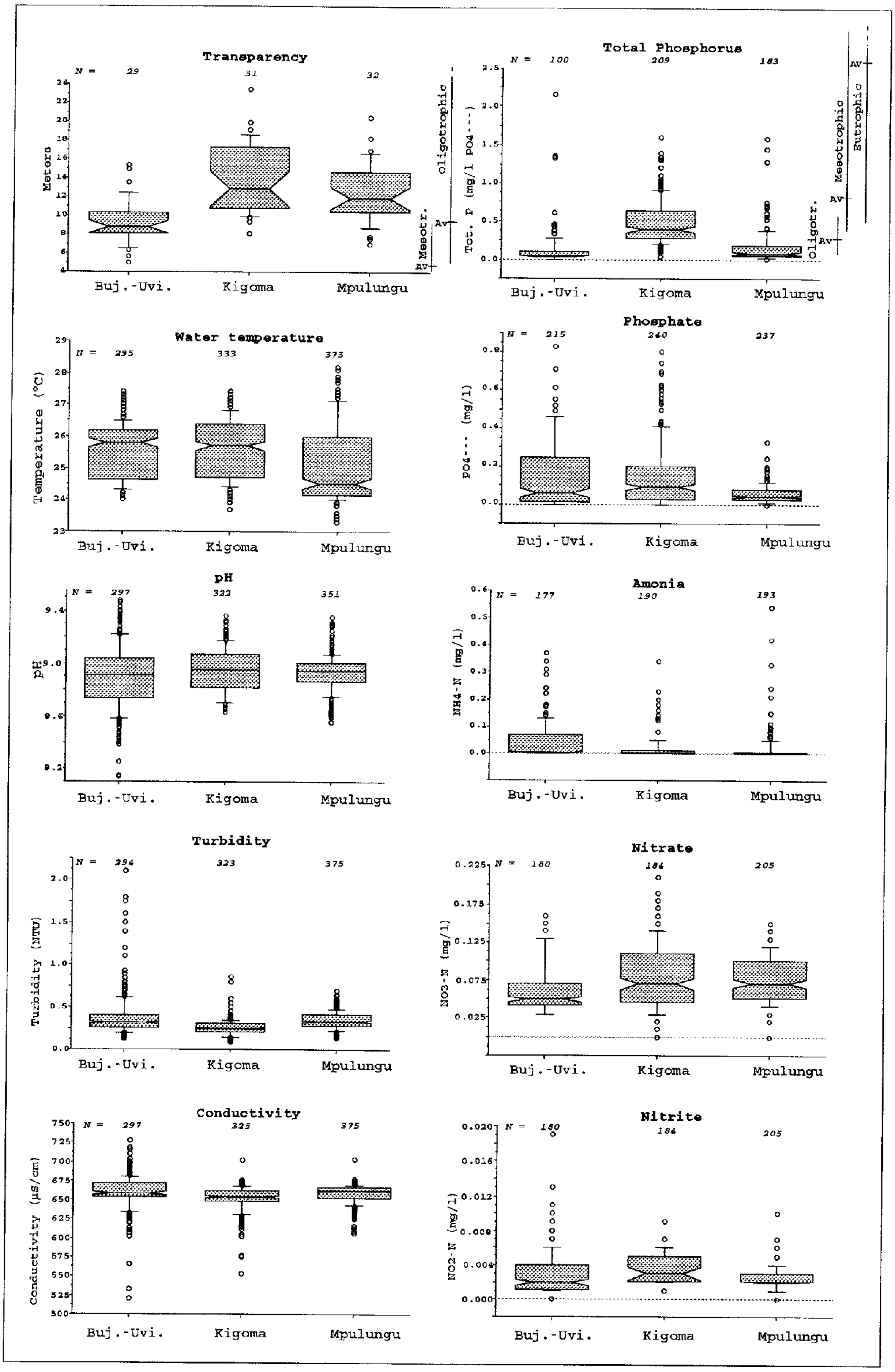
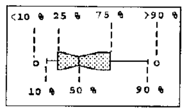


Fig. A.2.1 Median and percentage values for each parameter measured at site A (0 to 100 m) at Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Number of measurements (N) is indicated. Trophic ranges and means (AV), follow the classification of OECD (1982) in Rast *et al.* (1989), is given for transparency and total phosphorus.



A.3 Vertical profiles and identification of layers

The classical definition of the water layers that applies to temperate lakes does not seem to be appropriate for Lake Tanganyika. Besides the epilimnion and hypolimnion, the metalimnion should probably be split into two layers. Craig *et al.* (1974) identified an "intermediate" layer between the metalimnion and the hypolimnion while other researchers have described an "upper hypolimnion". In the present study, the lake was divided into four layers based on limnological parameters. Depths of the four layers varied during the year. The epilimnion generally reached a depth of 20 to 105 m depending on the station. The mean thermocline depth for the three stations at site A was 53 m in 1993-1994 and fluctuated between 15 and 90 m. The upper metalimnion, including the thermocline was generally observed between 50 and 120 m. Temperature decreased rapidly in the upper metalimnion. The lower metalimnion generally started between 50 and 120 m and spread to at least 300 m. Temperature decreased slowly in this layer. The upper depth of the hypolimnion was variable. It seemed adequate to define it as the depth where temperature was <23.5 °C since temperature variation below this level was slight.

As is seen in Figures A.3.1, A.3.2 and A.3.3, the lake water generally showed oligotrophic characteristics near the surface but had high concentrations of nutrients in deep water.

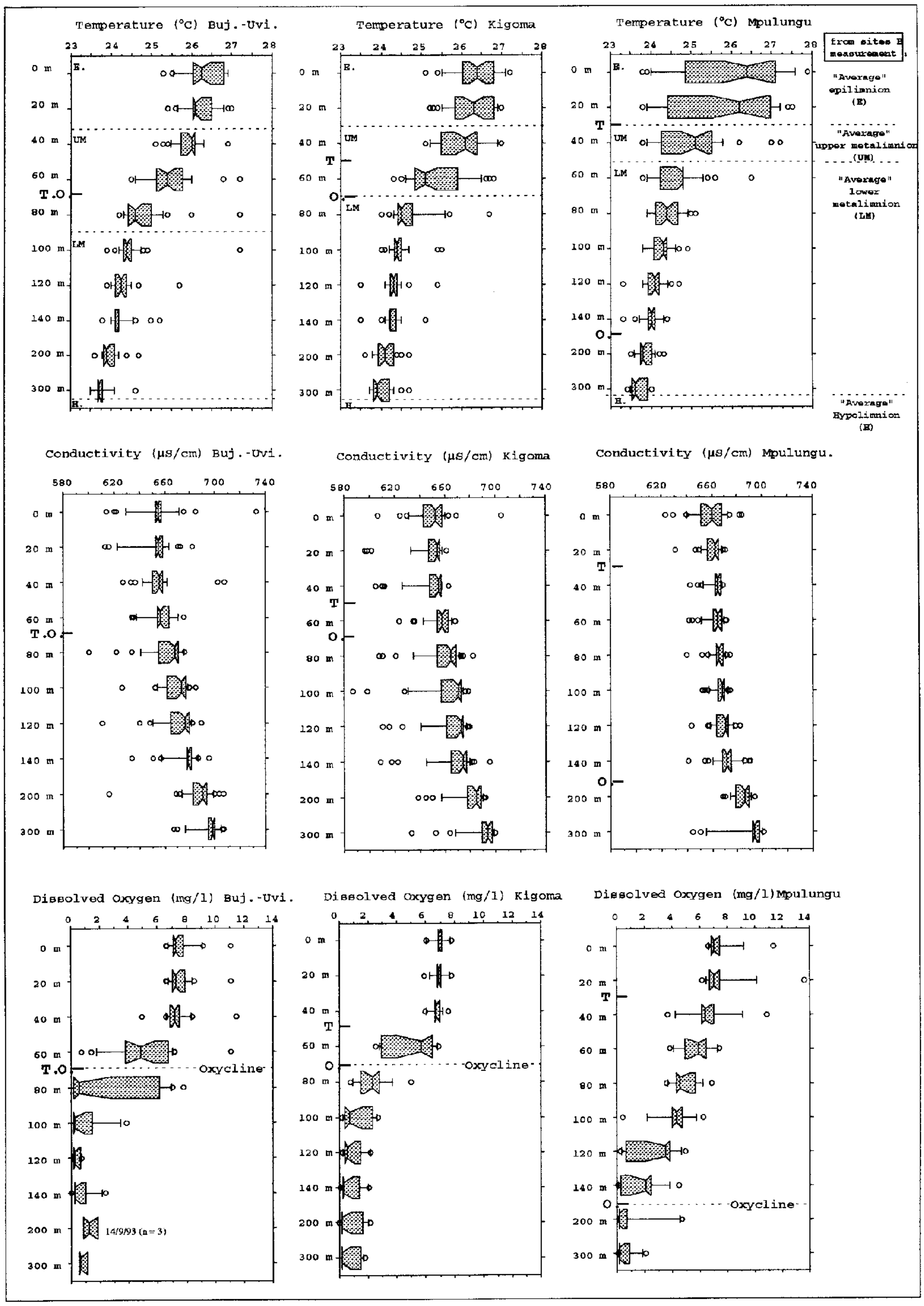
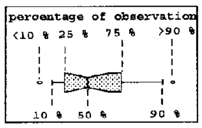


Fig. A.3.1 Median and percentile values of temperature (°C), conductivity (µS/cm) and dissolved oxygen (DO, mg/l). Sampling was carried out at site B, 0 to 300 m, Bujumbura/Uvira, Kigoma and Mpulungu over 24 h every 6 weeks from August 1993 to July 1994 for temperature and conductivity. Only a few measurements of DO were taken >100 m. The depths of the thermocline (T) and oxycline (O) are indicated.



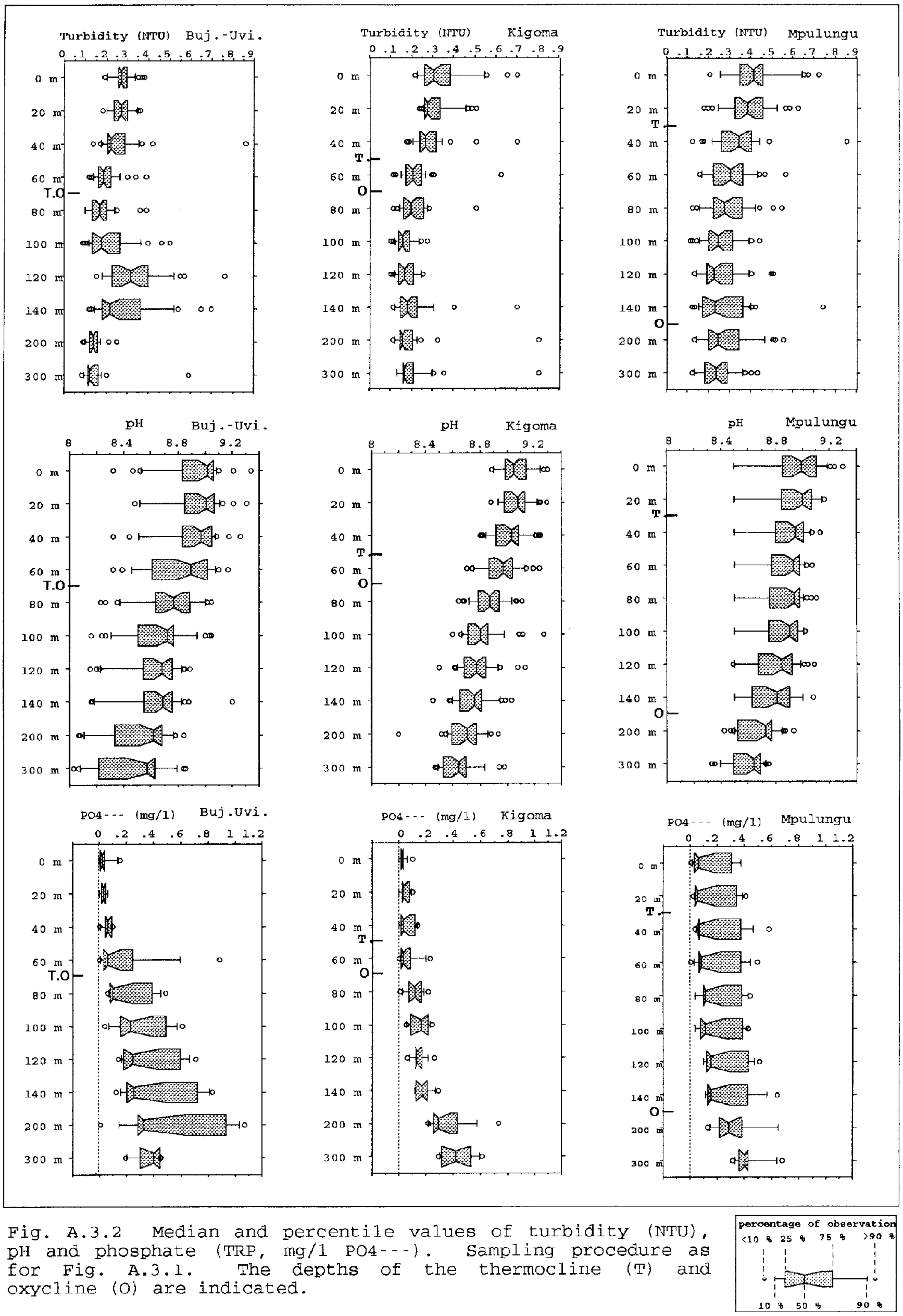


Fig. A.3.2 Median and percentile values of turbidity (NTU), pH and phosphate (TRP, mg/l PO4---). Sampling procedure as for Fig. A.3.1. The depths of the thermocline (T) and oxycline (O) are indicated.

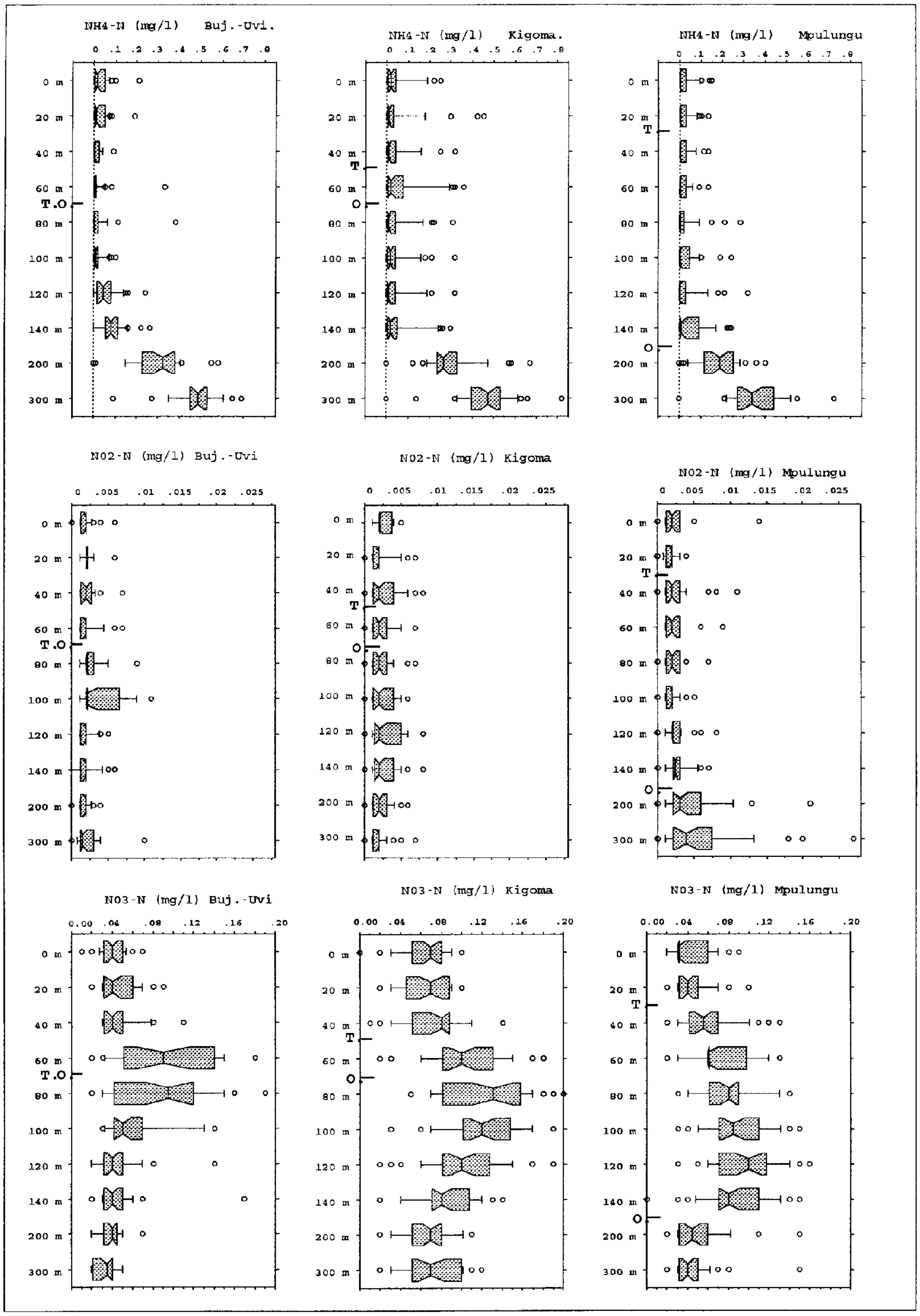
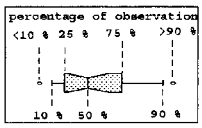


Fig. A.3.3. Median and percentile values of ammonia (mg/l NH4-N), nitrite (mg/l NO2-N) and nitrate (mg/l NO3-N). Sampling procedure as for Fig. A.3.1. The depths of the thermocline (T) and oxycline (O) are indicated.



Lake layers and sampling types

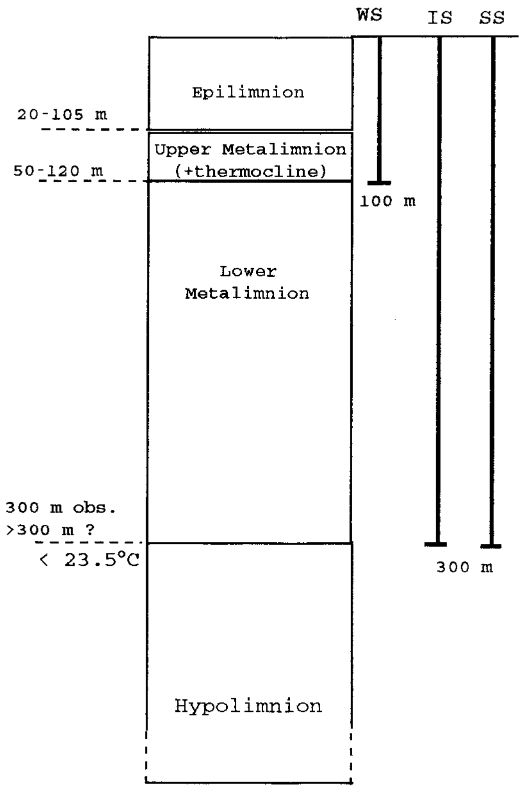


Figure A.3.4. Layers based on temperature stratification and known mixing. Sampling depth are shown (W.S=weekly sampling (A) I.S.= intensive sampling (B) and S.S.= seasonal sampling (C)

A.4 Temperature

At Bujumbura/Uvira site A the mean surface temperature was 26.13 °C during the dry season and 26.45 °C during the wet season (Table A.4.1). At Kigoma, similar but slightly higher temperatures were recorded, 26.18 °C during the dry season and 26.77 °C during the wet season. At Mpulungu the surface temperature at site A was 24.39 °C and 27.17 °C respectively. The low dry season temperature in Mpulungu corresponded to the upwelling period. During the wet season, the mean temperature was higher than at the northern stations. It can be observed that the mean surface temperature differed between season at each station (0.39 °C at Bujumbura/Uvira, 0.59 °C at Kigoma and 2.78 °C at Mpulungu). ANOVA indicated a highly significant ($P < 0.001$) difference in temperature for station, season and depth as well as for each interaction (Table A.4.2).

Median temperature values of the water column from 0 to 100 m are compared between each station in Figure A.2.1 and Table A.4.3. There were significant differences in temperature between Mpulungu (with more extreme values) and the two northern stations. The results of comparisons between temperature means using the least significant difference method (LSD) (Sokal and Rohlf, 1995) are shown in Table A.4.4. Between Bujumbura/Uvira and Kigoma there were no significant differences in temperature during the year but between these two stations and Mpulungu there was a significant difference ($p<0.001$) during the dry season due to upwelling of cold water at the latter.

Seasonal differences were noted with depth between stations. For example the mean temperatures at 60 and 80 m were higher at Bujumbura/Uvira during the dry season, 25.8 and 25.2 °C respectively, compared to the wet season, 24.9 and 24.4 °C ($p <0.001$). This was probably due to the deeper thermocline or may also have resulted from downwelling. At Mpulungu, the opposite to Bujumbura/Uvira was observed as the temperature was lower from 0 to 100 m during the dry season than during the wet season (Table A.4.1). This was statistically significant ($p<0.001$) from 0 to 40 m (Table C.2). The lower temperature probably resulted from upwelling and an increase in mixing during the coolest and windiest period of the year (June to September).

Monthly, median values of temperature, taken at each depth at each station illustrate the development of temperature isopleths (Fig. A.4.1.). The different profiles, probably caused by regional differences in climate, between Mpulungu and the northern stations are evident (Fig. A.4.2) and confirmed by the median test (Dagnelie, 1975): c^2obs = 46.2 ($p<0.001$) between Kigoma and Mpulungu and c^2obs = 31.4 ($p<0.001$) between Bujumbura/Uvira and Mpulungu. The profiles between Bujumbura/Uvira and Kigoma were not statistically different (c^2obs = 0.21).

Depth		Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	26.15	26.15	24.25	26.30	26.70	27.20	26.30	26.60	26.90
	Av.	26.13	26.18	24.39	26.45	26.77	27.17	26.33	26.58	26.35
	St.d.	0.37	0.49	0.54	0.38	0.42	0.54	0.4	0.52	1.39
	N	10	10	10	17	21	24	27	31	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	25.80	25.95	24.15	26.20	26.50	26.85	26.20	26.50	26.60
	Av.	25.88	26.06	24.35	26.37	26.62	26.78	26.18	26.44	26.07
	St.d.	0.40	0.46	0.47	0.38	0.44	0.51	0.45	0.52	1.23
	N	11	10	10	18	21	24	29	31	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	25.90	25.93	24.10	26.10	26.30	25.65	26.10	26.30	25.35
	Av.	25.95	26.03	24.29	26.06	26.10	25.69	26.02	26.08	25.28
	St.d.	0.38	0.52	0.44	0.64	0.65	0.63	0.55	0.6	0.86
	N	11	10	10	18	21	24	29	31	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	26.10	25.90	24.20	24.70	25.00	24.75	25.00	25.30	24.65
	Av.	25.81	25.89	24.30	24.93	25.17	24.86	25.27	25.40	24.69
	St.d.	0.60	0.59	0.39	0.67	0.60	0.74	0.76	0.68	0.70
	N	11	10	10	18	21	24	29	31	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	24.80	25.30	24.00	24.40	24.60	24.30	24.55	24.60	24.30
	Av.	25.18	25.29	24.09	24.45	24.63	24.34	24.72	24.84	24.27
	St.d.	0.75	0.62	0.31	0.19	0.31	0.35	0.59	0.53	0.36
	N	11	10	10	19	21	24	30	31	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	24.55	24.55	24.00	24.20	24.35	24.25	24.20	24.40	24.10
	Av.	24.57	24.68	23.99	24.22	24.35	24.22	24.34	24.46	24.15
	St.d.	0.42	0.62	0.19	0.16	0.15	0.34	0.32	0.40	0.31
	N	10	10	10	19	20	22	29	30	32

Table A.4.1. Water temperature (°C) recorded at site A (0900-1000 h). Bujumbura/Uvira, Kigoma and Mpulungu, from August 1993 to July 1994.

Source :	DF	F test	p > F	
Station (A)	2	202.6	0.0001	***
Season (B)	1	96.9	0.0001	***
Depth (C)	10	144.5	0.0001	***
AB	2	172.4	0.0001	***
AC	20	2.4	0.0004	***
BC	10	35.8	0.0001	***
ABC	20	3.6	0.0001	***
Error	918			

Table A.4.2. ANOVA for temperature measured every 10 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A). season (B) and depth (C).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001).

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	25.85	25.70	24.10	25.50	25.70	25.10	25.80	25.70	24.50
Av.	25.64	25.59	24.22	25.43	25.62	25.50	25.50	25.61	25.11
St.d.	0.71	0.83	0.40	1,00	1.02	1.23	0.92	0.97	1.20
N	98	95	114	197	230	259	295	325	373

Table A.4.3. Temperature (°C) (recorded at site A (0900-1000 h) of Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994 for each season and for the whole year. Medians, means, standard deviations and number of observations for water column from 0 to 100 m.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	NS	***	***

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	***	***				
Rain season	Buj.	NS	NS	***			
	Kig.	NS	NS	***	NS		
	Mpu.	NS	NS	***	NS	NS	

Table A.4.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for temperature (°C), 0 to 100 m water column at site A, from August 1993 to July 1994.
A = between stations and B = between seasons at each station.
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

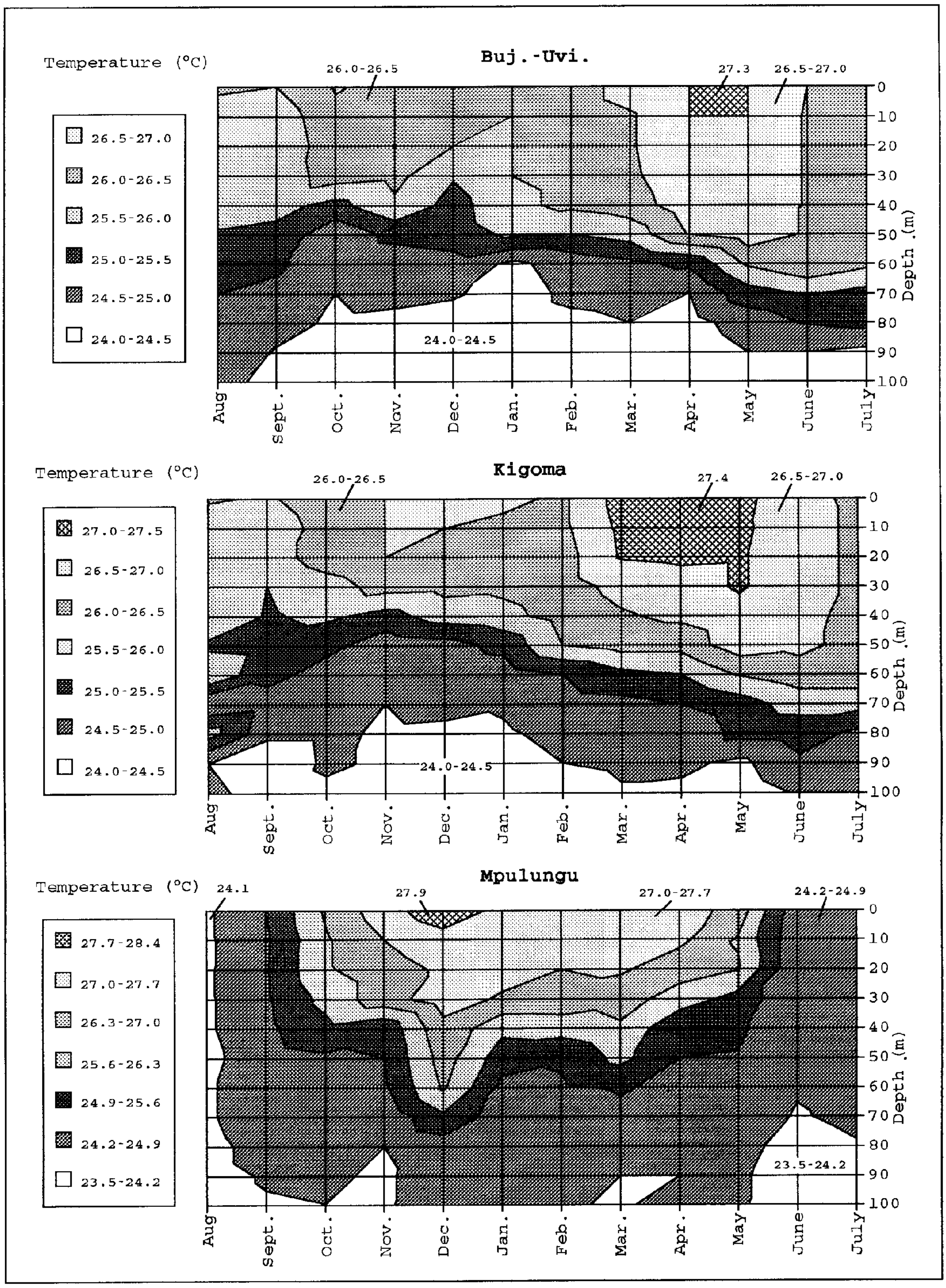


Fig. A.4.1. Isopleths of monthly median temperature (°C) measured at site A (0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993-July 1994.

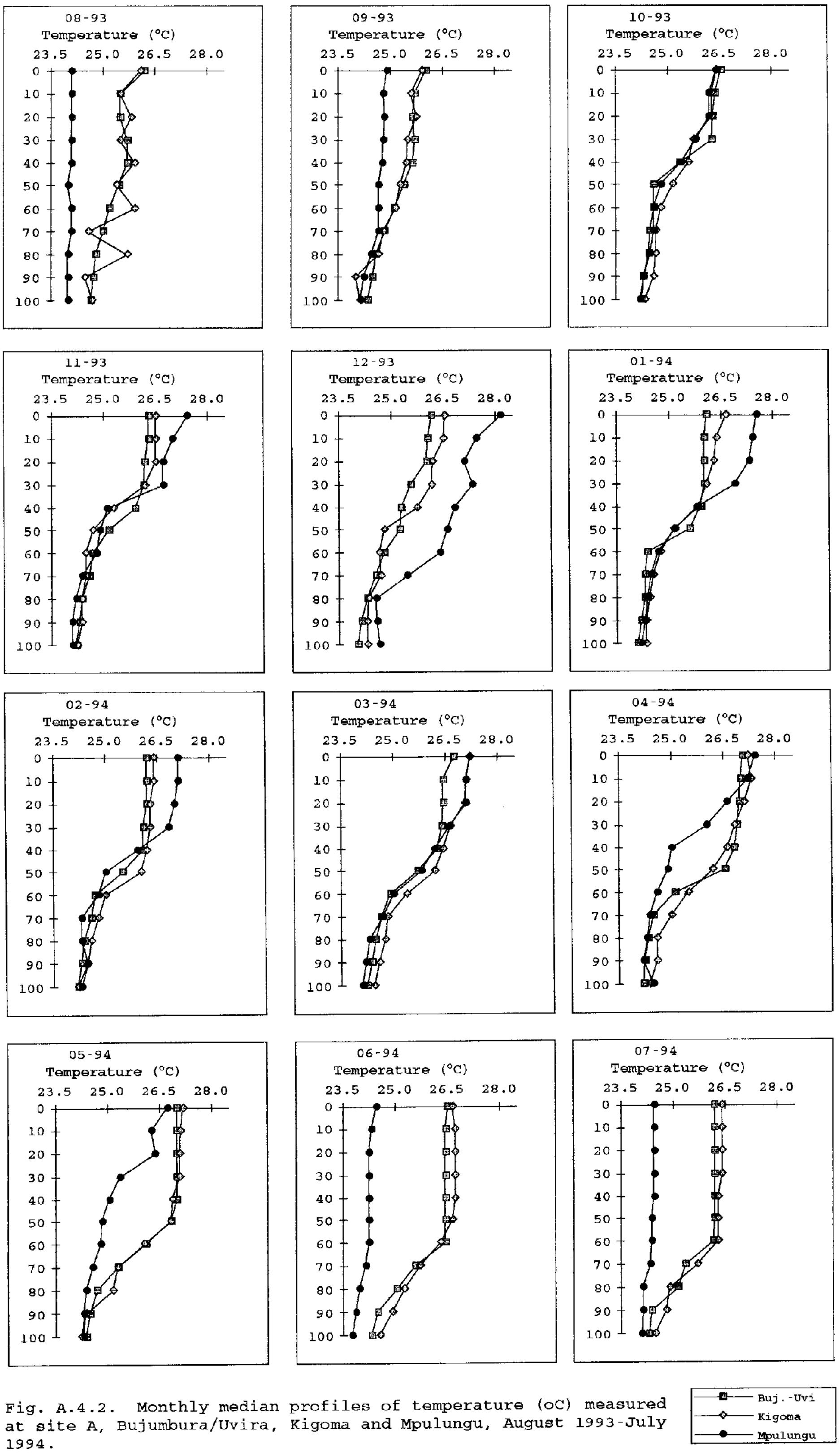


Fig. A.4.2. Monthly median profiles of temperature (oC) measured at site A, Bujumbura/Uvira, Kigoma and Mpulungu, August 1993-July 1994.

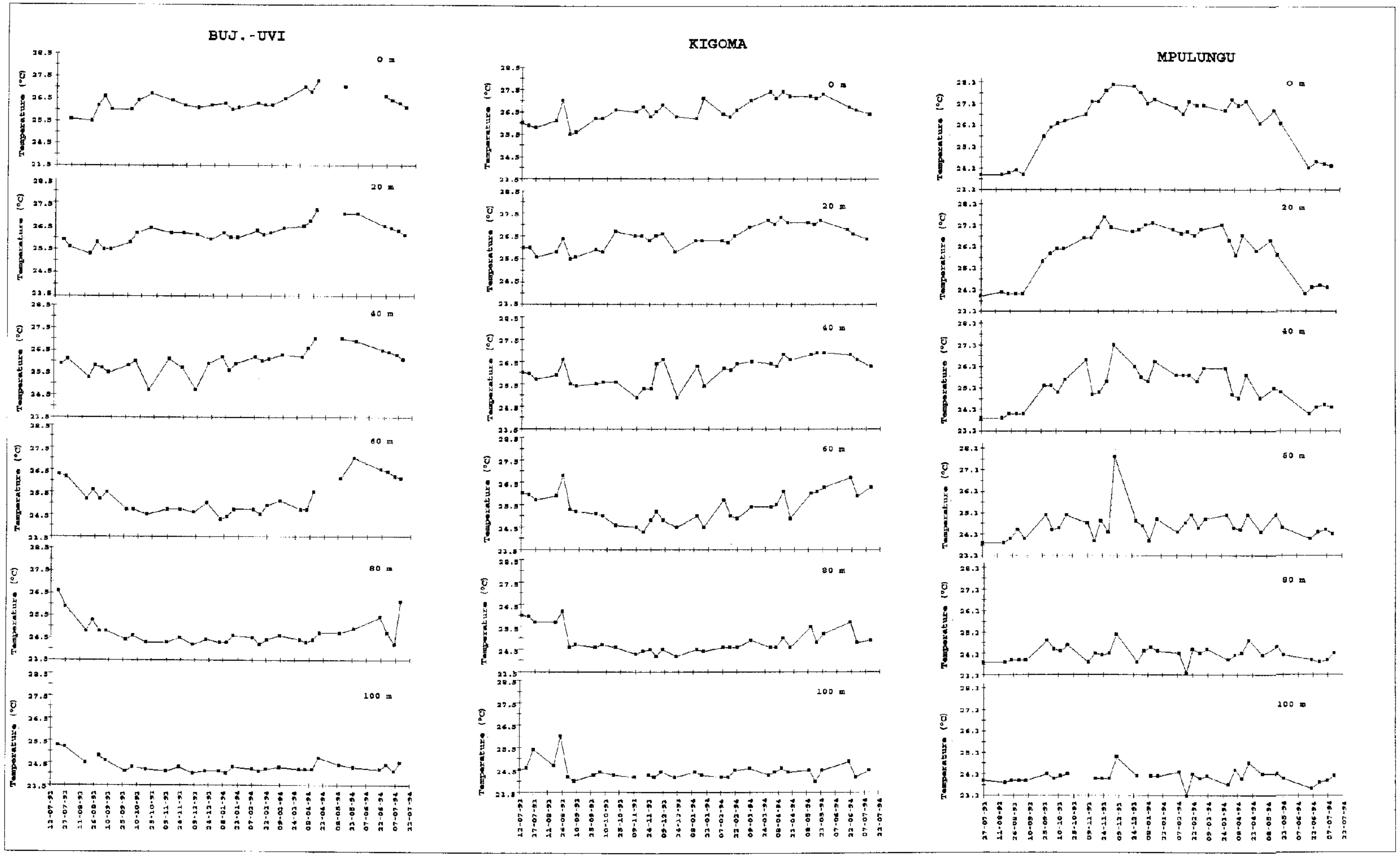


Fig. A.4.3. Changes in temperature (°C) at 0, 20, 40, 60, 80 and 100 m at site A, Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 199

A.5. Stratification

Lake stratification was quantified by a stratification index (SI):

$$SI = sDi * 10000$$

where:
sDi is the standard deviation of the matrix of water density D at each depth i.

For computation, water density at depth i (Di) was derived from the following polynomial regression (r=1), calculated for the temperature range 20.0 to 30.0 °C, using Hutchinson's (1957) tables:

$$Di = A + 3.977e^{-5} * Ti - 7.052e^{-6} * Ti^2 + 3.008e^{-8} * Ti^3$$

where:

Ti is the temperature (°C) at depth i
A is a constant equal to 1.000017195

The effect of atmospheric and water column pressure on water density was not accounted for as it was assumed that it would be equal at all stations (Beadle, 1974; Beauchamp, 1964).

When the temperature was quite homogenous in the water column, the stratification index SI was small or = 0. This was the condition most favourable for vertical mixing. It was observed during upwelling periods. If the stratification was well established there was a greater difference between the temperature at the surface and at the bottom of the measured depth causing density differences and increased SI values. Figure 4 and Table A.5.1 show that during the dry season the stratification was very low at Mpulungu (SI = 0.12 in August 1993) while it rapidly increased in October and November 1993 and reached a maximum (3.6) in January 1994.

Bujumbura/Uvira, Kigoma and Mpulungu showed more established stratification only during the dry season (e.g. SI ranges between 1.3 and 1.6 in August-September 1993). Peak values of SI at these stations coincided with air temperature peaks in October-November and April-May. Overall, differences in stratification were more extreme in the south than in the north of Lake Tanganyika.

The mean stratification index for 1993-1994 was 2.27 at Bujumbura/Uvira, 2.30 at Kigoma and 2.19 at Mpulungu (Table A.5.2). There was greater variation in the index values at Mpulungu as indicated by the standard deviations of 0.55, 0.53 and 1.39 respectively. ANOVA indicated that season ($p<0.001$) and station ($p<0.05$) were significant as well as the interaction season-station (Table A.5.3). Yearly means between stations compared by the LSD method were not significant (Table A.5.3). When SIs were compared between seasons the greatest variation was found at Mpulungu where it was 3.08 during the wet season and 0.40 during the dry season (Table A.5.2). The difference was highly significant ($p<0.001$) as confirmed by the LSD test (Table A.5.4).

	Buj-Uvi	Kigoma	Mpulungu
08-93	1.32	1.30	0.12
09-93	1.53	1.63	0.62
10-93	2.46	1.98	2.17
11-93	2.29	2.53	3.37
12-93	2.01	2.42	3.50
01-94	2.28	2.37	3.62
02-94	2.26	2.31	3.25
03-94	2.56	2.88	3.27
04-94	3.36	3.02	3.18
05-94	2.96	2.99	2.28
06-94	2.27	2.17	0.53
07-94	1.97	1.97	0.35

Table A.5.1. Stratification indices (SI), 0 - 100 m, site A, Bujumbura/Uvira, Kigoma and Mpulungu, 1993-1994.

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Av.	1.77	1.77	0.40	2.52	2.56	3.08	2.27	2.30	2.19
St.d.	0.43	0.39	0.22	0.44	0.37	0.55	0.55	0.53	1.39
N	4	4	4	8	8	8	12	12	12

Table A.5.2. Stratification indices during the dry season (June to September) and the wet season (October to May) at Bujumbura/Uvira, Kigoma and Mpulungu.

Source :	DF	F	P	Sign.
Station (A)	2	3.317	0.0499	*
Season (B)	1	86.438	0.0001	***
AB	2	17.557	0.0001	***
Error	30			

Table A.5.3. ANOVA of stratification index. Variables are season (A) (dry season = June to September and wet season = October to May) and station (B) (Bujumbura/Uvira, Kigoma and Mpulungu).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	NS	NS	NS

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	***	***				
Rain season	Buj.	**	**	***			
	Kig.	**	**	***	NS		
	Mpu.	***	***	***	*	*	

Table A.5.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for stratification indices (SI), 0 to 100 m water column at site A, from August 1993 to July 1994.
A = between stations and B = between seasons at each station.
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

A.6. Upwelling

The southern upwelling was characterised by temperature homogeneity in the water column (Fig. 5). The upwelling corresponded with high wind speeds (3 hourly mean between 4 and 7 m/s) and with the minimum air temperature for the year (3 hourly mean was *c.* 23°C), conditions found during the dry season. The data from the thermistor chain showed that suitable conditions for upwelling occurred mostly during the night and in the early morning (Monthly changes in temperature every 3 hours are given in Figures B.1-B.11). After the dry season, in September 1993, the 23.75 to 24.00 °C isotherm was not detected again in the upper 90 m (up to May 1994). The upwelling probably ended between 10 and 21 September 1993 when the 24.25 to 24.5 °C isotherm disappeared and a permanent thermocline was formed (Figure B.4).

In summary the upwelling took place during the dry season and usually the pulses were strongest at night when the wind speed was highest and the air temperature reached a minimum. In the period 24 July 1993 to 5 August 1994 upwelling corresponded with the ascending phase of a deep internal wave at 250 and 300 m (cf. isotherms of 23.25 to 23.50 °C in Appendix B.2).

The persisting waves of the preceding year 1992-1993 were detected between 200 and 300 m deep (Fig. 5) (isotherm below 23.75 °C). The 23.75 to 24.00 °C isotherm showed the most pronounced displacement towards the surface. This isotherm was usually between 110 and 150 m but reached the surface in July 1994. Internal waves were recorded during the whole wet season at each depth sampled from 300 m to the thermocline. Waves were not detected above the thermocline because of interference from turbulence. As mentioned above, deep internal waves were observed without interruption during the dry season at 250 m and 300 m (Fig. 5). Regular measurements of deeper layers are required to study the depths affected by internal waves. It is highly probable that these waves have a lower depth range than expected as indicated by parameters measured over 24 h. Coulter (1991) suggested that internal waves could persist much longer than one season. In the present study of one year no interruption of the internal waves in the deep layers was found.

A.7 Thermocline depth

Mean thermocline depth at site A was 49.7, 53.4 and 41.0 m at Bujumbura/Uvira, Kigoma and Mpulungu respectively during the wet season. The thermocline depth during the dry season was lower at Bujumbura/Uvira and Kigoma, 65.0 and 75.6 m but not present at Mpulungu due to upwelling and mixing by convection (Table A.7.1). The greatest variation in the mean thermocline depth was observed during the wet season at Mpulungu (Fig. A.7.1). ANOVA (Table A.7.2) indicated station and station-season interactions were the most important factors influencing thermocline depth ($p<0.001$). When the data were considered for the whole year, there was no statistical difference between Bujumbura/Uvira and Kigoma (Table A.7.3) confirming the homogeneity between the northern stations.

As well as differences in the depth of the thermocline between seasons, the thermocline deepened during most of the wet season at the northern stations. This was particularly obvious at Kigoma. A gradual transition from the shallow thermocline of the wet season to the deeper thermocline of the dry season was noted (Figs 10 and 14). The thermocline deepened from October to June at Bujumbura/Uvira and from November to June at Kigoma. The sinking of the thermocline in the north appeared to be caused partially by the accumulation of warmer water resulting from southerly winds.

These winds seemed to start before the main winds of the dry season. At Mpulungu, the thermocline was deepest between December 1993 and March 1994 and then became shallower to disappear finally during the upwelling (June 1994). The thermocline tilted towards the north particularly during the dry season. At the end of this season, when the main south east winds stopped, the thermocline (and metalimnion) "fell back" into an equilibrium position taking several oscillations, detected at each station before this position was reached. The range of variation was about 10 to 15 m at Bujumbura/Uvira and Kigoma and 20 to 25 m at Mpulungu. These fluctuations were associated with internal waves (Fig. A.4.3).

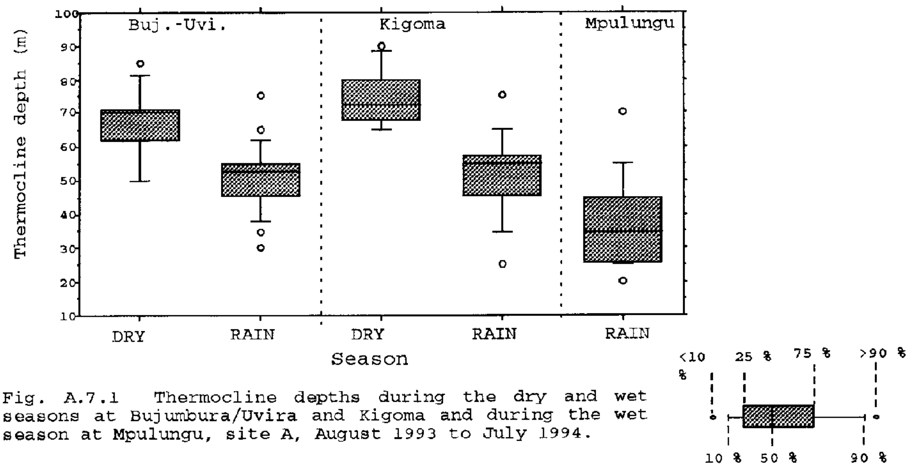


Fig. A.7.1 Thermocline depths during the dry and wet seasons at Bujumbura/Uvira and Kigoma and during the wet season at Mpulungu, site A, August 1993 to July 1994.

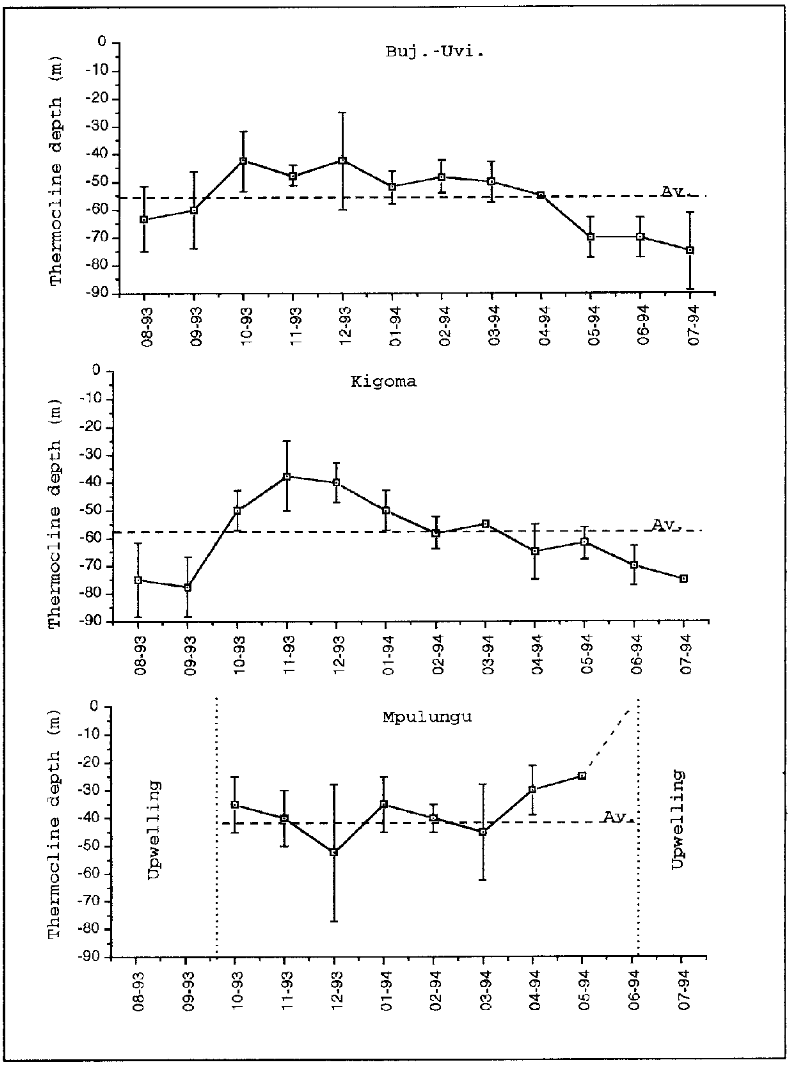


Fig. A.7.2 Monthly mean thermocline depths at Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Standard deviations and the year's mean (dashed line) are given.

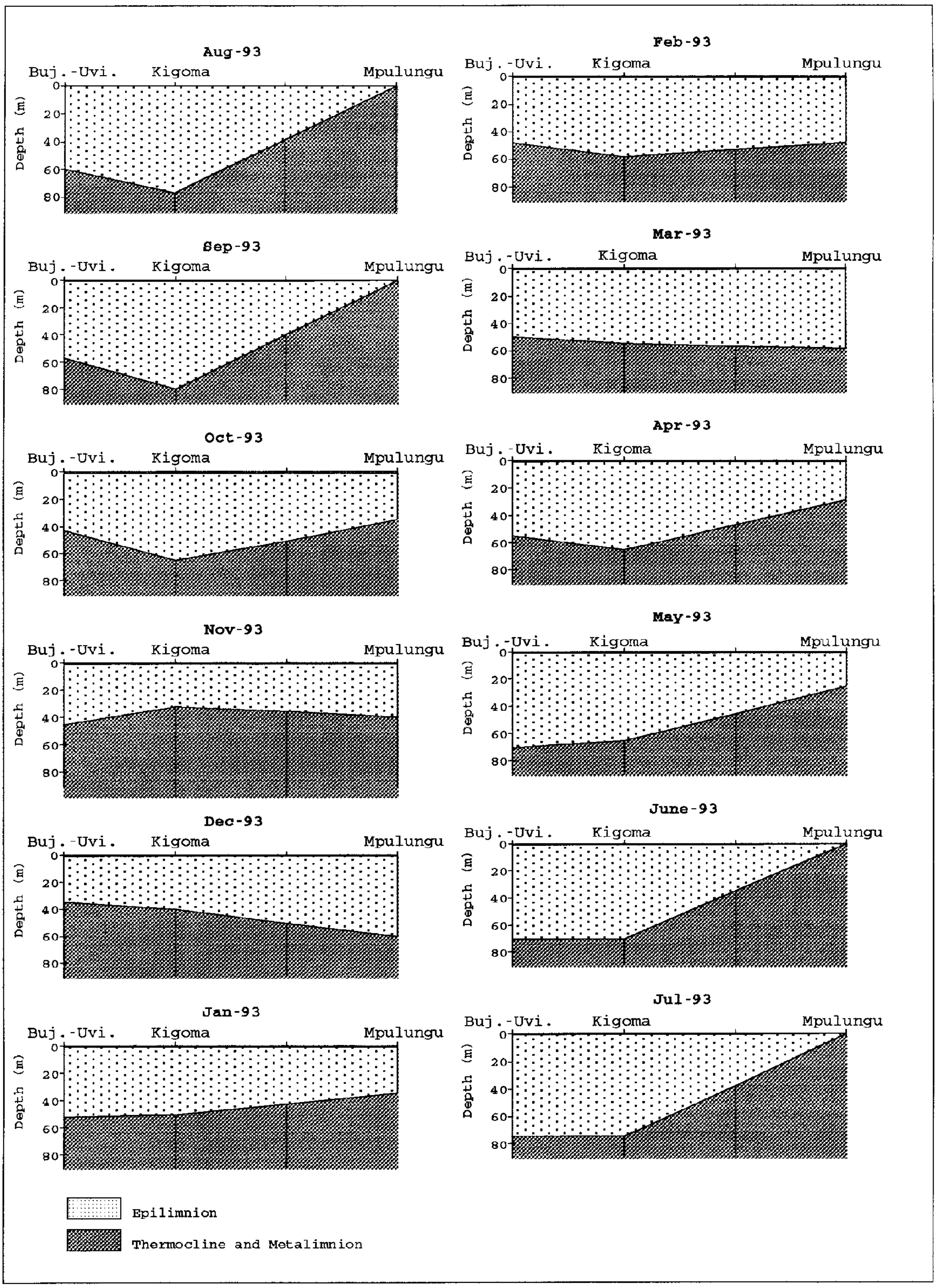


Fig. A.7.3 Changes in thermocline depth (monthly means) at site A, Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994.

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Av.	65.0	75.6	NA	49.7	53.4	41.04	54.8	59.3	41.04
St.d.	10.9	9.4	NA	10.9	13.9	15.11	13.0	16.2	15.11
N	9	8	NA	18	22	24	27	30	24

Table A.7.1. Thermocline depth (m) during the wet and dry season at Bujumbura/Uvira, Kigoma and Mpulungu (NA = not available during upwelling in Mpulungu).

Source :	DF	F	P	Sign.
Station (A)	2	91.45	0.0001	***
Season (B)	1	0.17	0.6837	NS
AB	2	49.45	0.0001	***
Error	84			

Table A.7.2. ANOVA thermocline depth.
Variables were season (A) (dry season = June to September and wet season = October to May) and station (B) (Bujumbura/Uvira, Kigoma and Mpulungu).
(NS: non significant, * = 0.05 $\geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$)

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	NS	***	***

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	NA	NA				
Rain season	Buj.	**	***	NA			
	Kig.	*	***	NA	NS		
	Mpu.	***	***	NA	*	**	

Table A.7.3. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for thermocline depth, 0 to 100 m water column at site A, from August 1993 to July 1994.
A = between stations and B = between seasons at each station.
(NS: non significant, * = 0.05 $\geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$)

A.8 Transparency

During the first year of sampling the main measurement taken to indicate plankton biomass was transparency. Equipment for chlorophyll a measurements is not available. Although transparency is an indirect measurement, it is known from previous studies of Lake Tanganyika, that variations in transparency probably reflect changes in phytoplankton biomass (Ferro and Coulter, 1974; Hecky *et al.*, 1981). Future measurement of chlorophyll a and transparency will determine the reliability of this relationship.

Mean transparency was 9.1 m at site A at Bujumbura/Uvira (range 5.0 - 15.4 m), 13.8 m at Kigoma (range 8.1 - 23.5 m) and 12.4 m at Mpulungu (range 7.0 - 20.5 m) (Table A.2.1). There were short term (hourly) and long term (seasonal) variations in transparency. Water temperature and transparency were positively related at all three study sites ($p<0.05$ for Bujumbura/Uvira and $p<0.001$ for Kigoma and Mpulungu).

On 31 May 1994, at each station, transparency was measured throughout the day (from 0600 to 1800 h) every hour, by 3 different observers. The turbidity of the mixolimnion water was measured at the same time. Transparency was variable (changes of 1.5 to 3 m) during the day at each station (Fig. A.8.1) in particular at Kigoma. In another study, daily variation was noted at Mpulungu where monthly observations were made along five coastal 'lines' in 1993-1994. A total of 1020 measurements were taken during this time. Transparency could change by up to 5 m in less than 2 h. It is possible that fluctuations in transparency were related to internal waves and turbulence which made nutrients available for rapid assimilation by algae. The lake water generally showed oligotrophic characteristics near the surface but richer, eutrophic characteristics in deeper water. The phytoplankton growth probably responded rapidly to the internal waves which brought nutrients to the upper layers either in rhythmic (waves) or non rhythmic (turbulence) ways.

General long-term trends in transparency in the north of the lake were linked with thermocline depth (Fig. A.8.3). As the thermocline became deeper towards the end of the wet season and the epilimnion warmer, transparency increased. The 'nutricline' then reached lower depths than at the beginning of the wet season which might explain the lower production and higher transparency at the surface layers. Ferro (1975) observed similar changes in transparency and thermocline depth. At Mpulungu, during the upwelling period (June to September), transparency was low (8 to 10 m). The water was clearest in December 1993 (*c*. 18 m) and again in March 1994 (*c*. 13 m). When the south east wind started the water generally became less transparent but pulses of clear water were always present even during the dry season. The results of transparency measurements taken at the five sites near Mpulungu (Fig. A.8.3) indicated that the general trends observed at Mpulungu could be extrapolated to the whole south of the lake.

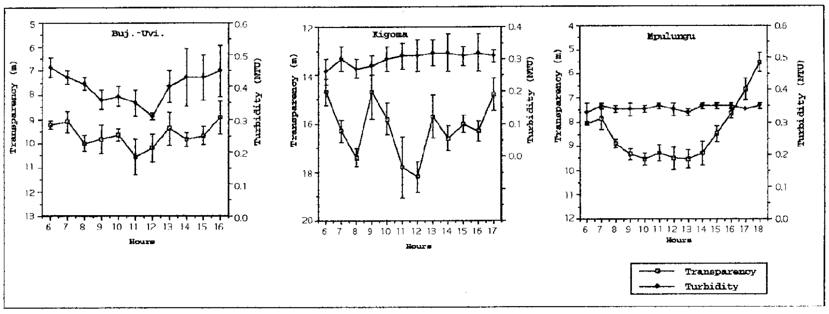


Fig. A.8.1 Daily changes of transparency (m) and turbidity (NTU) at site A of Buj.-Uvi, Kigoma and Mpulungu on 31/5/94.

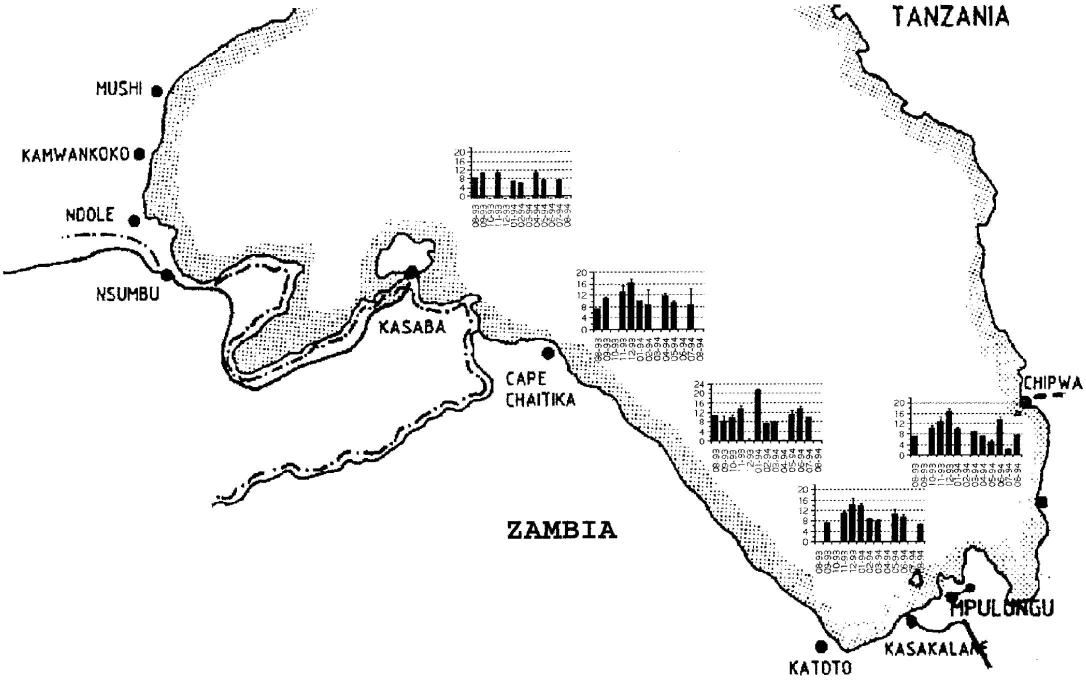


Fig. A.8.2. Seasonal changes of transparency (m) at 5 sites near Mpulungu from August 1993 to September 1994.

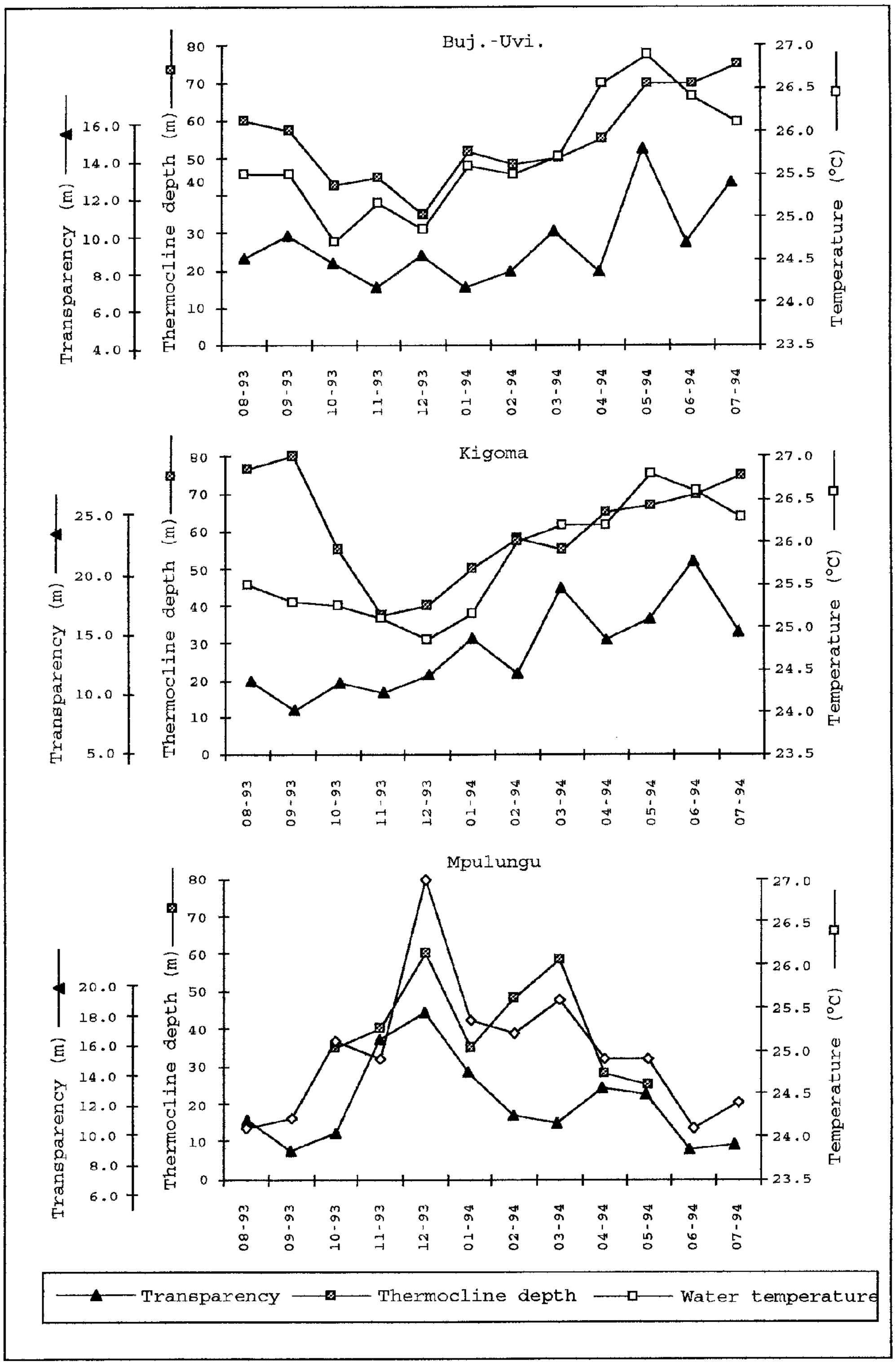


Fig. A.8.3 Changes in transparency (m), thermocline depth (m) and mean temperature (°C) of the surface to 100 m water column at Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 - July 1994.

A.9 Turbidity

Silt, clay, organic matter, algae and others micro-organisms may cause turbidity. Plankton and other micro-organisms probably cause the greatest variability in turbidity in the pelagic area. The pelagic area is not significantly influenced by river inflows in Lake Tanganyika. Generally, these waters are colder and sink rapidly below the thermocline. When yearly data were compared between stations (Table A.9.3), the highest mean turbidity of the water column from 0 to 100 m was recorded at Bujumbura/Uvira (0.40 NTU) followed by Mpulungu (0.34 NTU) and Kigoma (0.25 NTU). These differences were highly significant ($P < 0.001$) (Table A.9.4) and showed similar trends to transparency data (Table A.2.1 and Fig. A.2.1). Maximum values of turbidity were also recorded at Bujumbura/Uvira, 2.1 NTU, compared to Kigoma, 0.85 NTU, and Mpulungu, 0.70 NTU, while the minimum values were 0.12 NTU at Bujumbura/Uvira, 0.09 NTU at Kigoma and 0.14 NTU at Mpulungu (Table A.2.1). Turbidity decreased with depth (Fig. A.3.2) although at Bujumbura/Uvira, a marked increase was observed near the thermocline from March 1994 to May 1994.

The main factors influencing turbidity were station, depth, and the interaction between station and season (ANOVA, Tables A.9.2 and A.9.3). During the dry season, the turbidity at both ends of the lake (0.30 NTU at Bujumbura/Uvira and 0.35 NTU at Mpulungu) was significantly higher ($p<0.001$) than at Kigoma (0.25 NTU). There was a significant interaction between station and season. At Bujumbura/Uvira turbidity during the wet season, 0.43 NTU, was statistically different ($p<0.001$) from the dry season, 0.34 NTU, although no seasonal differences were detected at Kigoma and Mpulungu. Seasonal differences at Bujumbura/Uvira were mainly due to the increase of turbidity at 40 m (Fig. A.9.3 and Table C.3) which was most apparent in March and April 1994.

Changes in the shape of the isopleths of turbidity at site A of Bujumbura/Uvira indicated the increased turbidity during the wet season. At site B *c.* 30 km south of site A a turbidity layer also developed during the wet season but between 120 and 140 m. A layer of high turbidity during the wet season was not observed at site A of Kigoma (Fig. A.9.1) but was noted at site B, (>0.20 NTU) at 120 m in December 1993 and January 1994 (Fig. A.9.2). At Mpulungu, the turbidity at the surface was lower (0.30 to 0.36 NTU) in December (in this month the water was distinctly stratified and was very transparent, Secchi disk *c.* 18 m) but started to increase in January and February in the surface to 40 m layer. From April, (when the winds of the dry season started) to July the higher turbidity isopleth (>0.42 NTU) sank from 0-30 m to 60 m which indicated the increasing importance of mixing. At Mpulungu surface maximum turbidity was also observed in July (turbidity between 0.54 and 0.60 NTU) (Fig. A.9.2).

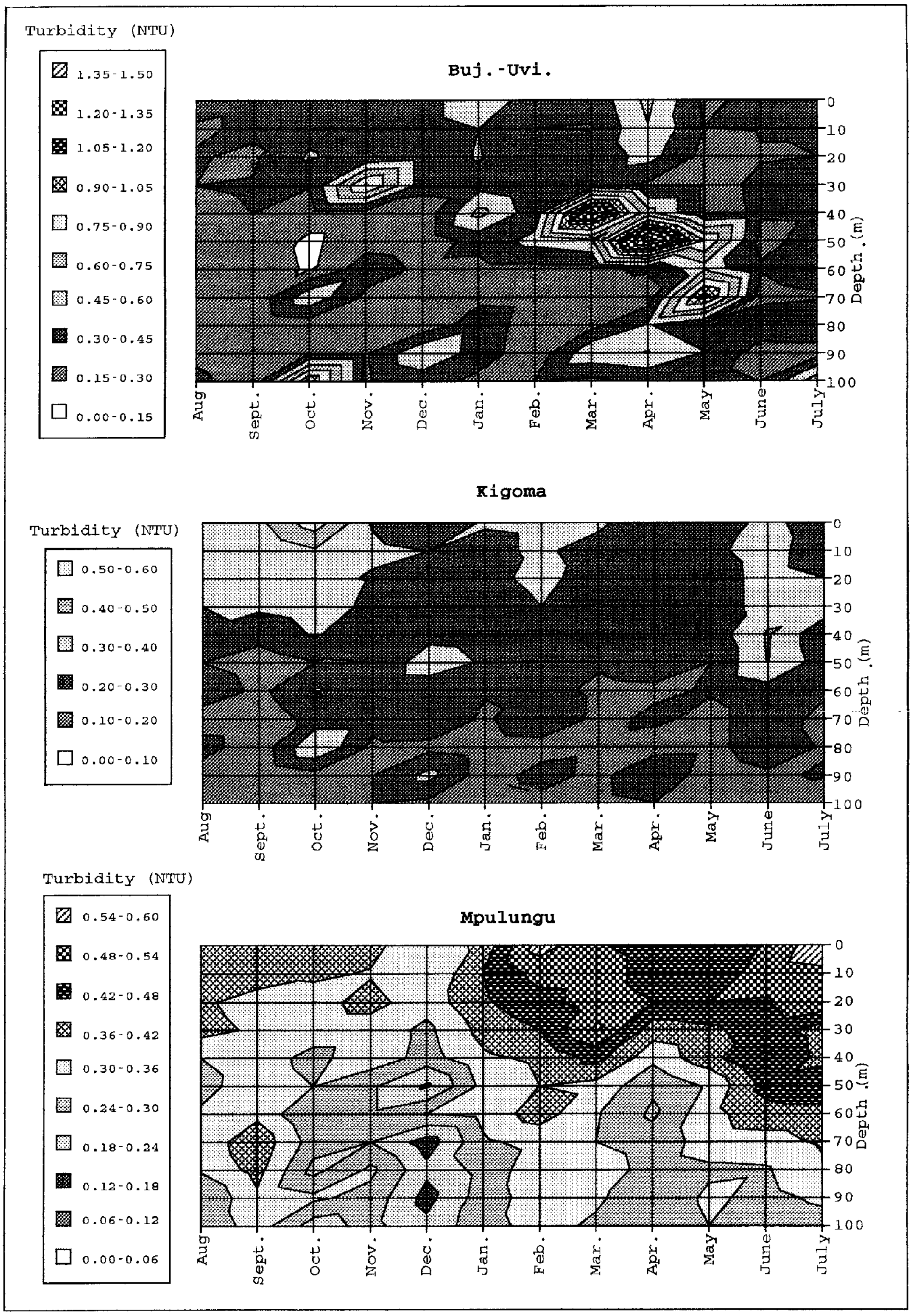


Fig. A.9.1. Median isopleths of turbidity (NTU) measured at site A (0 to 100 m) of Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

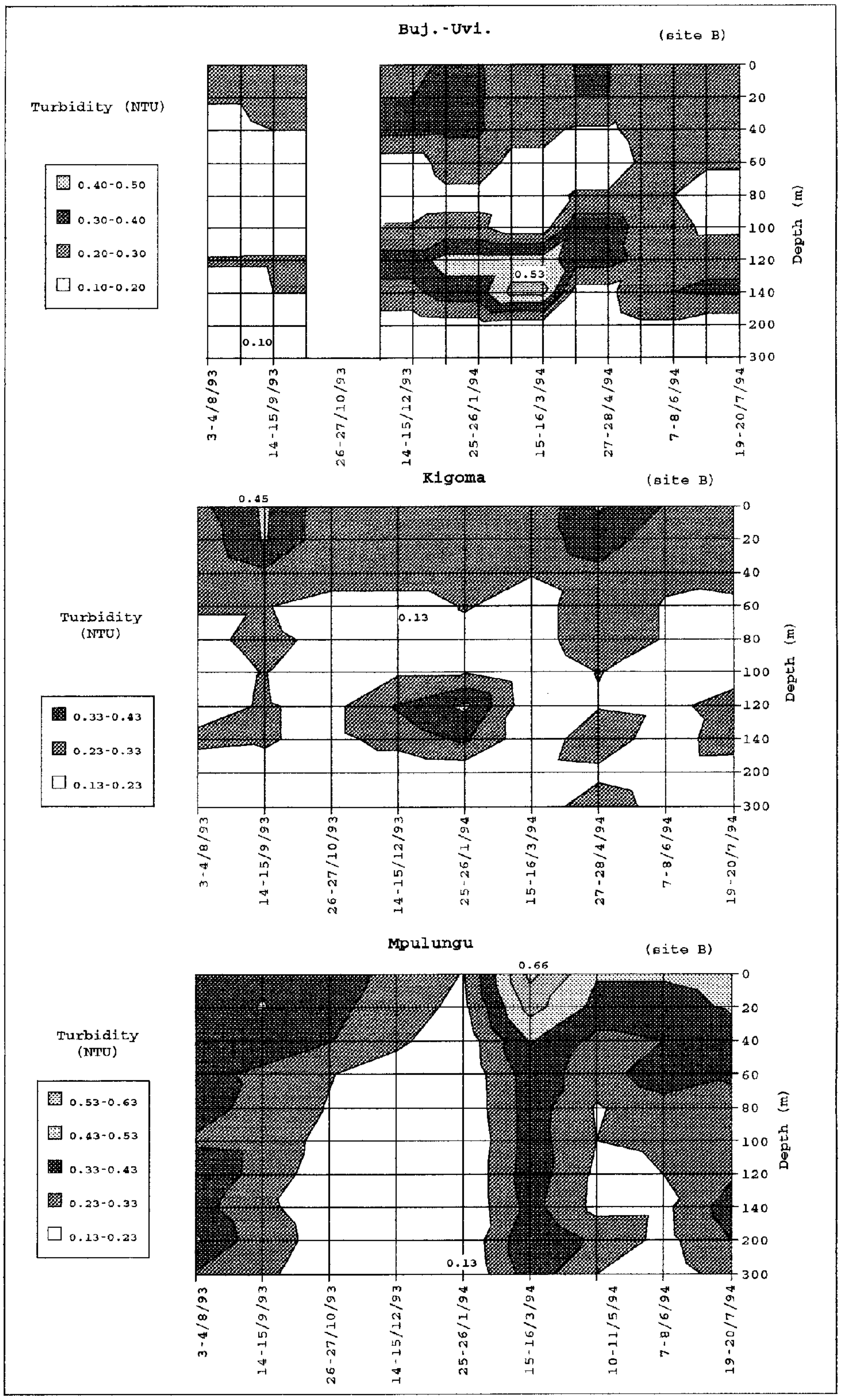


Fig. A.9.2. Median isopleths of turbidity NTU) measured at sites B (0 to 300 m) of Bujumbura/Uvira, Kigoma and Mpulungu during nine intensive sampling periods, 3 and 4 August 1993 to 19 and 20 July 1994.

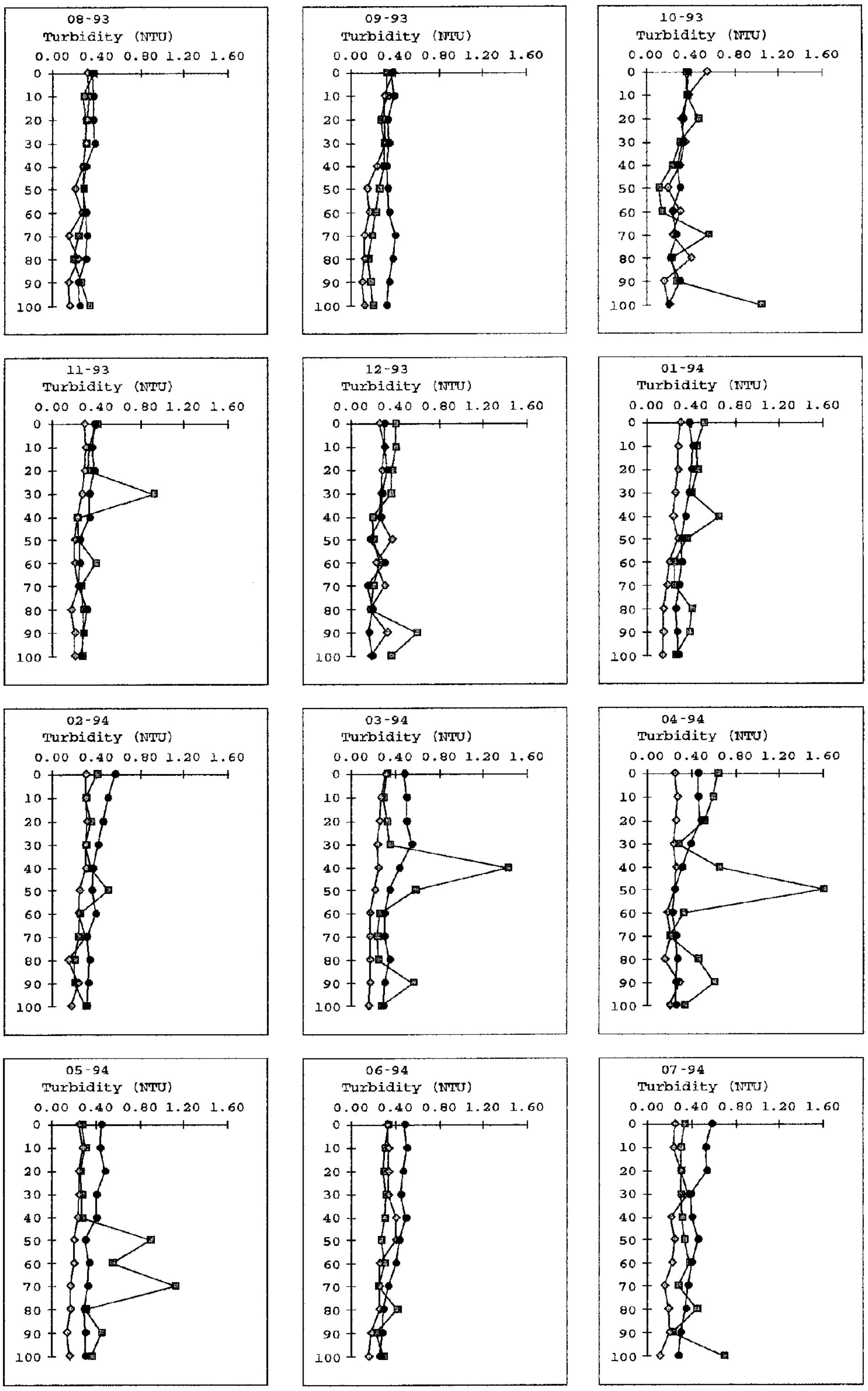


Fig. A.9.3. Monthly median profiles of turbidity (NTU) measured at site A, Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994.

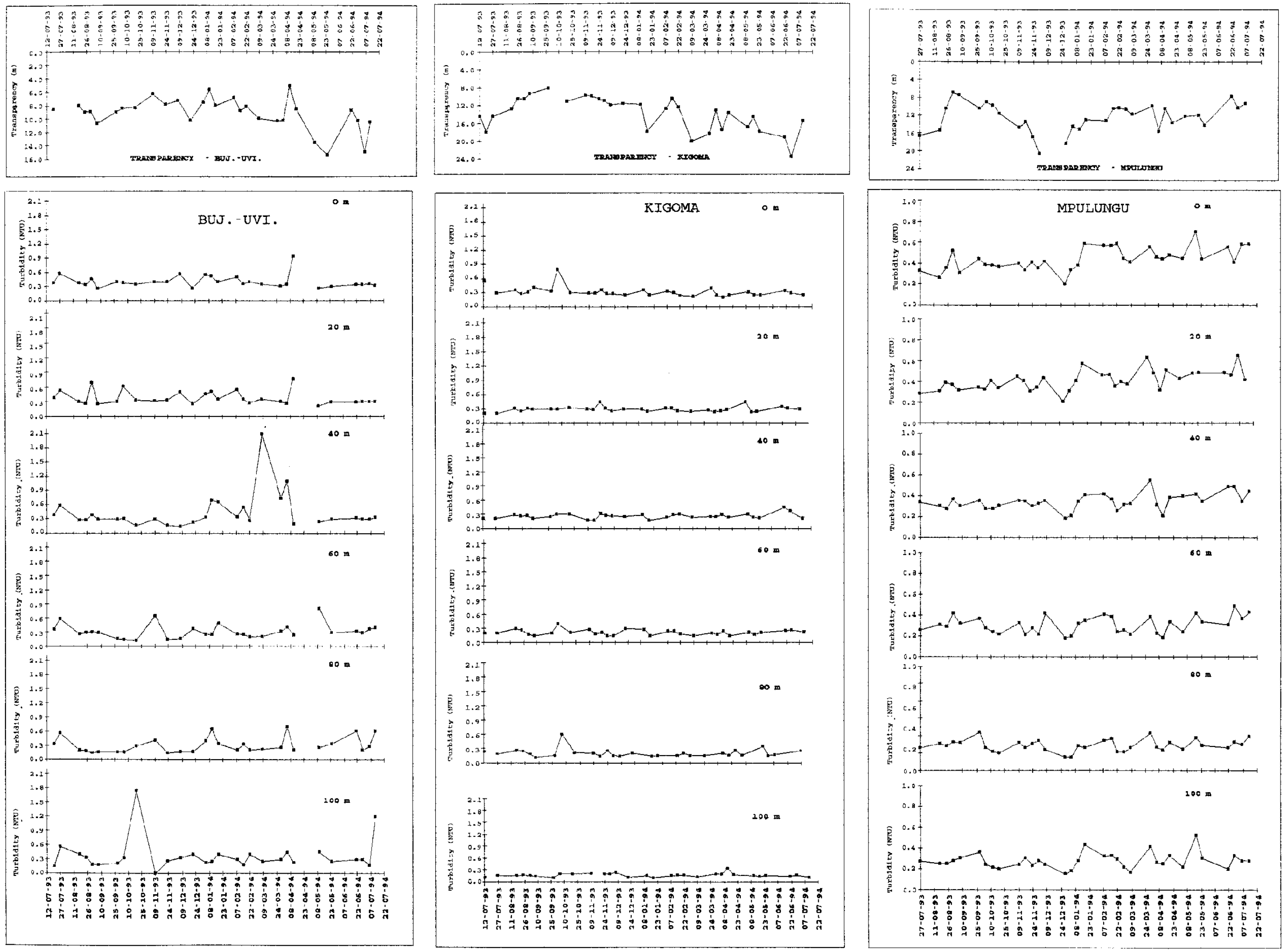


Fig. A.9.4. Changes in turbidity (NTU), every 20 m from 0 to 100 m, and changes in transparency, at site A, Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	0.36	0.32	0.43	0.39	0.28	0.43	0.37	0.30	0.43
	Av.	0.37	0.32	0.44	0.42	0.31	0.45	0.40	0.32	0.44
	St.d.	0.08	0.05	0.12	0.16	0.12	0.11	0.13	0.11	0.11
	N	11	9	10	18	21	24	29	30	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	0.30	0.31	0.38	0.34	0.29	0.41	0.32	0.3	0.41
	Av.	0.36	0.30	0.41	0.39	0.30	0.41	0.38	0.30	0.41
	St.d.	0.14	0.04	0.11	0.14	0.06	0.09	0.14	0.05	0.10
	N	11	9	10	18	21	24	29	30	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	0.30	0.27	0.36	0.31	0.26	0.34	0.30	0.27	0.35
	Av.	0.34	0.29	0.37	0.49	0.26	0.34	0.43	0.27	0.35
	St.d.	0.09	0.08	0.08	0.48	0.05	0.08	0.38	0.06	0.08
	N	11	9	10	18	21	24	29	30	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	0.31	0.23	0.35	0.25	0.21	0.27	0.29	0.22	0.31
	Av.	0.33	0.23	0.36	0.31	0.21	0.29	0.32	0.22	0.31
	St.d.	0.11	0.05	0.07	0.18	0.06	0.08	0.15	0.06	0.08
	N	11	9	10	18	21	24	29	30	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	0.21	0.19	0.32	0.27	0.16	0.27	0.27	0.19	0.28
	Av.	0.32	0.20	0.32	0.31	0.20	0.27	0.31	0.20	0.29
	St.d.	0.19	0.05	0.06	0.16	0.1	0.07	0.17	0.09	0.07
	N	11	9	10	18	21	24	29	30	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	0.29	0.16	0.28	0.30	0.19	0.26	0.30	0.16	0.28
	Av.	0.36	0.15	0.28	0.40	0.18	0.28	0.39	0.17	0.28
	St.d.	0.30	0.02	0.04	0.36	0.05	0.09	0.33	0.05	0.08
	N	11	9	10	17	20	24	28	29	34

Table A.9.1. Turbidity (NTU) recorded from site A (0900-1000 h) at Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994 for each season and for the whole year. Medians, means, standard deviations and number of observations for depths of 0, 20, 40, 60, 80 and 100 m.

Source :	DF	F test	Pr > F	
Station (A)	2	34.25	0.0001	***
Season (B)	1	3.88	0.0493	NS
Depth (C)	10	9.64	0.0001	***
AB	2	4.68	0.0001	***
AC	20	0.88	0.6203	NS
BC	10	0.76	0.6730	NS
ABC	20	0.91	0.5795	NS
Error	910			

Table A.9.2. ANOVA for turbidity measured every 10 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A). season (B) and depth (C).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001).

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	0.30	0.25	0.35	0.33	0.25	0.33	0.32	0.25	0.33
Av.	0.34	0.24	0.36	0.43	0.25	0.33	0.40	0.25	0.34
St.d.	0.14	0.09	0.09	0.34	0.09	0.11	0.29	0.09	0.10
N	100	85	114	194	230	261	294	315	375

Table A.9.3. Turbidity (NTU) (recorded at site A (0900-1000 h) of Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994 for each season and for the whole year. Medians, means, standard deviations and number of observations for water column from 0 to 100 m.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	***	***	***

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	***					
	Mpu.	NS	***				
Rain season	Buj.	***	***	**			
	Kig.	***	NS	***	***		
	Mpu.	NS	***	NS	***	***	

Table A.9.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for turbidity (NTU), 0 to 100 m water column at site A, from August 1993 to July 1994.
A = between stations and B = between seasons at each station.
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

A.10 Dissolved oxygen

The results of dissolved oxygen (DO) measurements were preliminary as they did not encompass a whole year. An oxygen meter was not available during the first 3 months at Bujumbura/Uvira and during the first 8 months at Kigoma and Mpulungu.

The mean depth where anoxia (DO = 0 mg/l) was first detected (site A) was 84.6 m at Bujumbura/Uvira (November 1993 to July 1994) and 85.0 m at Kigoma, (April to July 1994). At Mpulungu the water was always oxygenated down to 100 m (mean 3.8 mg/ l at 100 m). The water temperature at 84.6 m, Bujumbura/Uvira, was 24.5 (C. Insufficient data were available for the others stations.

The isopleths of DO measured at Bujumbura/Uvira are presented in Figure A.10.1. Maximum DO was observed in November 1993 when supersaturation (121 %) occurred. For the range of temperatures observed in Lake Tanganyika, 100 % oxygen saturation was from 7.1 to 7.6 mg/l. In December DO was between 90 and 100 % saturation between O - 40 m. Lowering of the oxygenated layer was recorded from February to July. It corresponded to the descent of the thermocline (Figs A.4.1 and A.7.2).

DO decreased between 20 and 30 m in April at Mpulungu (when the thermocline depth was nearer the surface). In May the upper layers increased in DO (Fig. A.10.2). The shape of the DO profile in July probably resulted from mixing caused by upwelling.

In the present study DO was recorded occasionally down to 300 m at site B of each station. Previous records of DO were down to 240 m (Capart, 1952). For example at Mpulungu on 7 June 1994 2.1 mg/l were recorded at 1200 h and 1.4 mg/l at 1800 h at 300 m. Some temporary incursions of DO were possible in lower depths due to turbulence.

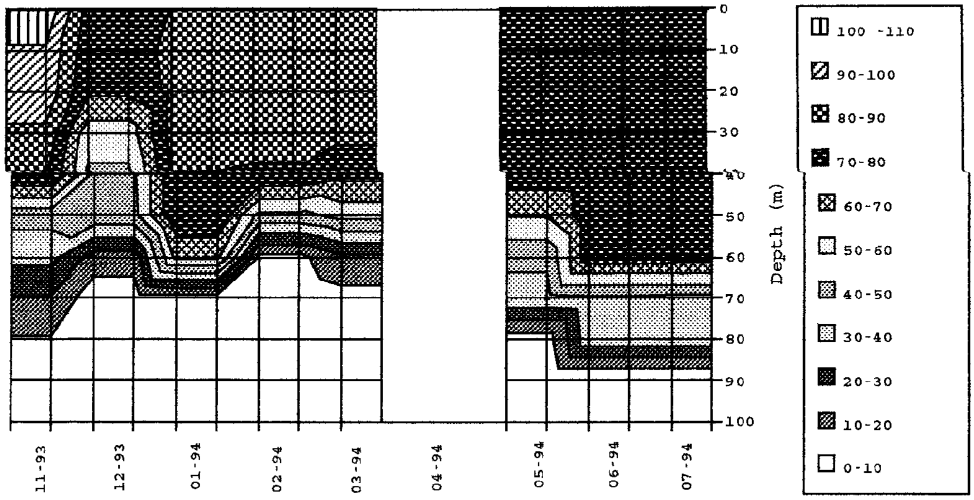


Fig. A.10.1. Isopleths of dissolved oxygen (% of saturation) at site A, Bujumbura/Uvira, November 1993 to July 1994

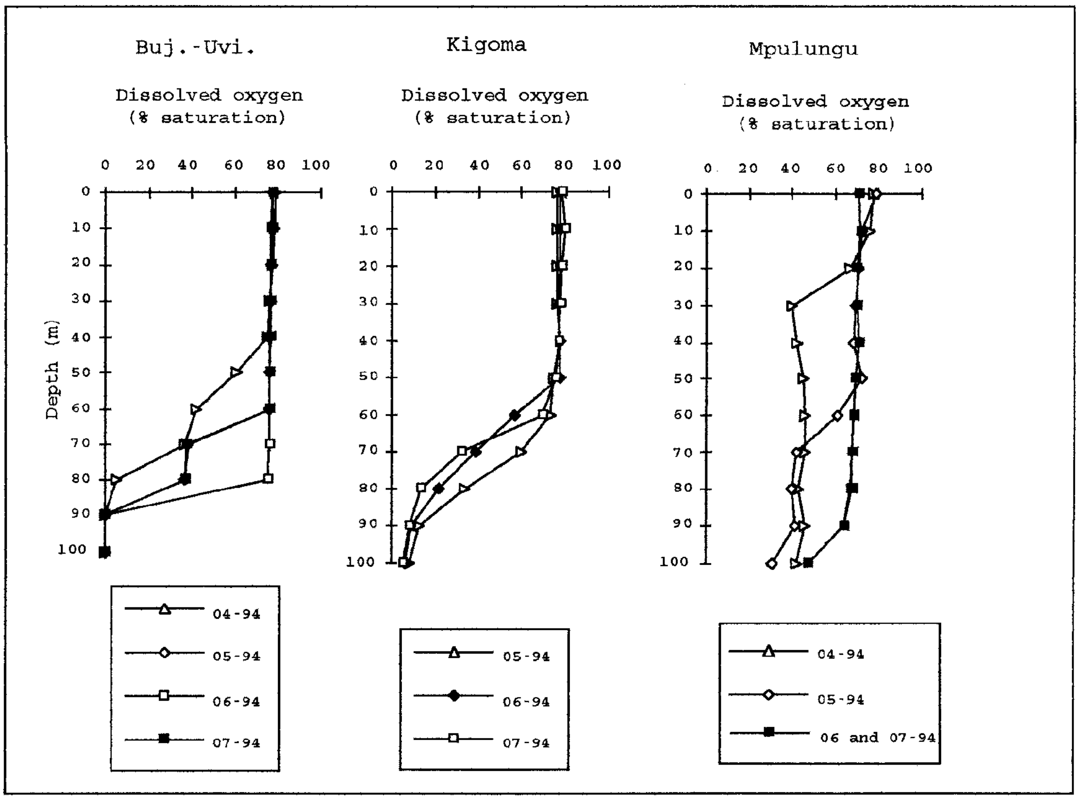


Fig. A.10.2. Profiles of dissolved oxygen (% of saturation) at site A, Bujumbura/Uvira, Kigoma and Mpulungu, April/May 1994 to July 1994.

A.11 Conductivity

The majority of the African lakes show a conductivity between 96 (S/cm (Lake Victoria) and 925 (S/cm (Lake Edward). During the present sampling period, the mean conductivity, was 659 (S/cm at Bujumbura/Uvira, 653 (S/cm at Kigoma and 658 (S/cm at Mpulungu (Table A.11.3). Conductivity at Kigoma was significantly ($p<0.001$) lower than at Bujumbura/Uvira and Mpulungu but there was no significant difference between Bujumbura/Uvira and Mpulungu (Table A.11.4).

Variation in conductivity was most pronounced at Bujumbura/Uvira (Fig. A.2.1). Minimum and maximum values for the 0-100 m water column were 520 and 728 (S/cm at Bujumbura/Uvira, 553 and 702 (S/cm at Kigoma and 607 and 704 (S/cm at Mpulungu (Table A.2.1). Conductivity increased with depth at all stations (Fig. A.3.1) although variation at each depth was more pronounced at Bujumbura/Uvira and Kigoma than at Mpulungu.

There was variation in the conductivity of the water between stations, depths and seasons and the station-season interaction (Table A.11.2 and Figs A.11.1 to A.11.3)). Important differences were noted at the end of the dry season and at the beginning of wet season. At Bujumbura/Uvira, minimum of values of conductivity were recorded in September at 20 m (Fig. A.11.3). In October, water of conductivity 700 (S/cm, normally detected at *c.* 300 m (Fig. A.3.1), was measured at all depths >50 m. On 19 October 1993, conductivity at the surface reached 686 (S/c, a value normally found at *c.* 200 m. At Kigoma a reduction in conductivity at 40 to 60 m was observed in September (Figs A.11.1 and A.11.3). At Mpulungu "pulses" of deep, conductive water were measured. These corresponded with the changes in thermocline depth (cf Fig. A.11.1 with Figs A.4.1 and A.7.2). Variation in conductivity showed an "absorbed oscillation" shape (Fig. A.11.2). This was particularly clear at Bujumbura/Uvira. The amplitude of the variation was significant on 7 September when conductivity decreased at several depths (particularly 0 to 30 m). It was followed by a rise in conductivity on 19 October and subsequent oscillations of decreasing amplitude towards the end of the sampling year. Similar but less significant changes were recorded at Kigoma (Fig. A.11.2). A significant decrease in conductivity was noted on 5 October. Variation tended to be less pronounced towards the end of the sampling year. At Mpulungu oscillations in conductivity values were noted but the pattern was different. After significant fluctuations during the dry season and at the beginning of the wet season, there was little variation in conductivity from November 1993 to January 1994, a period of stable stratification in this area.

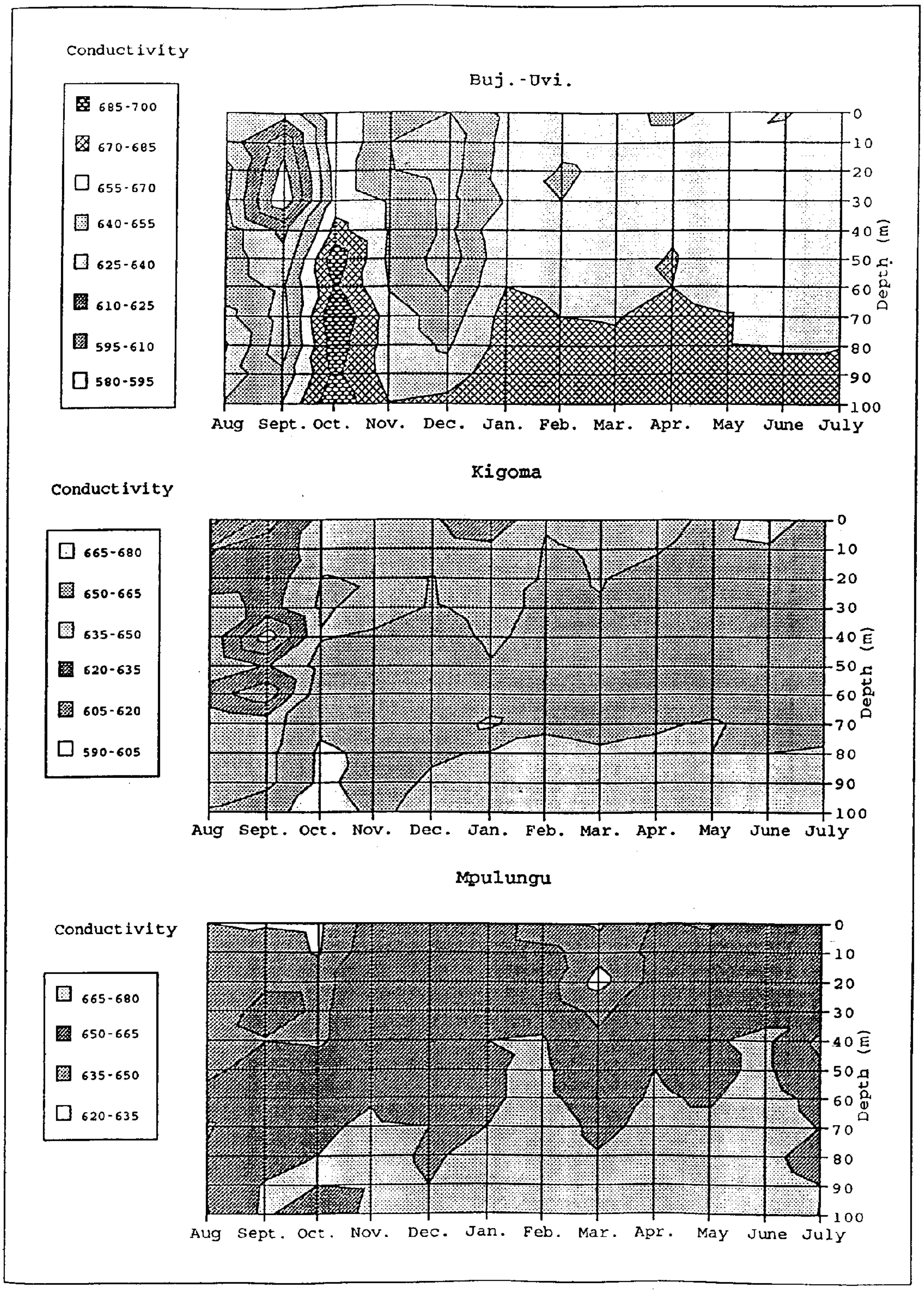


Fig. A.11.1. Isopleths of median conductivity (at 25 °C, µS/cm) measured at sites A (0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu, from August 1993 to July 1994.

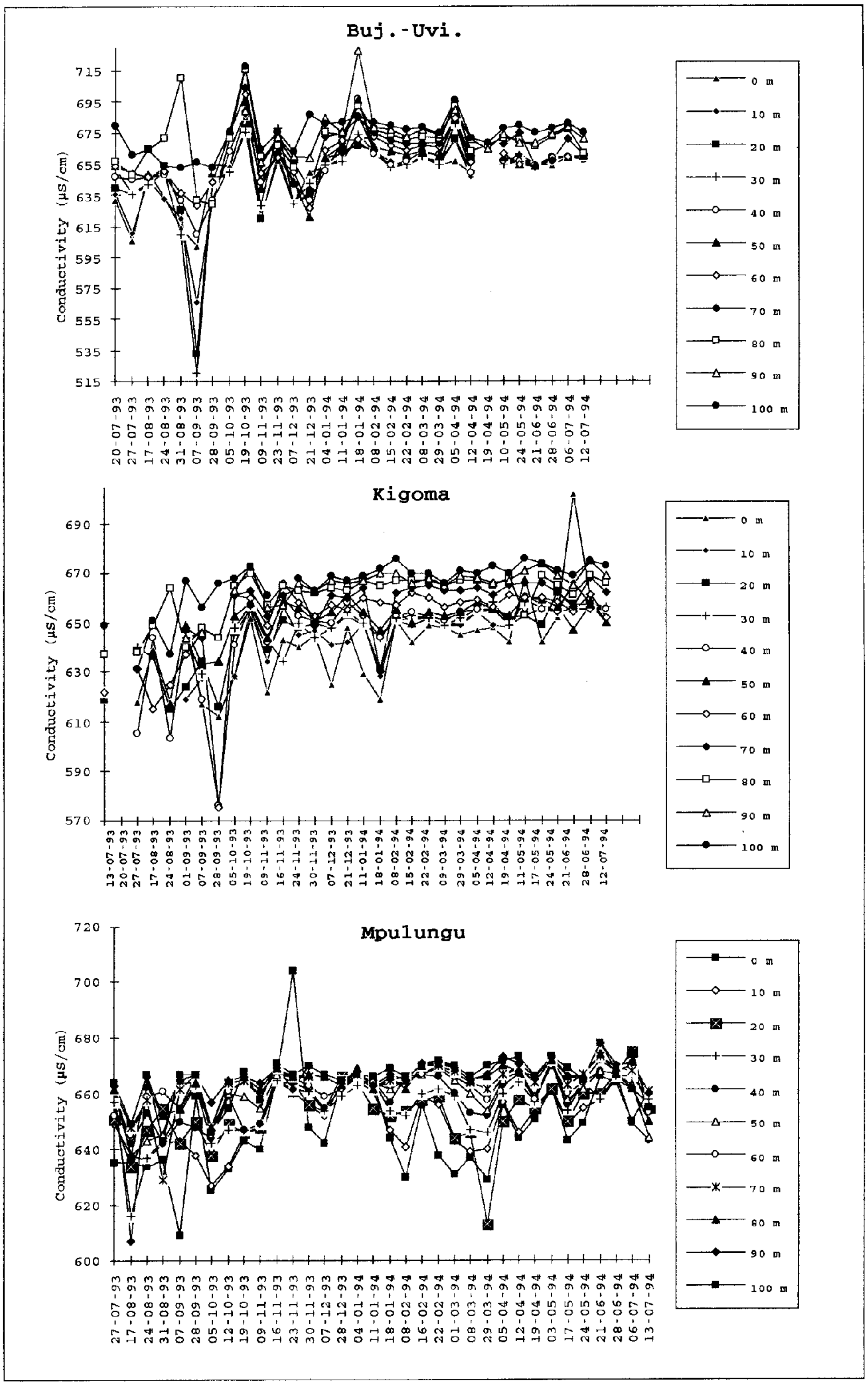


Fig. A.11.2 Changes in conductivity (µS/cm) at site A, Bujumbura/Uvira, Kigoma and Mpulungu, from July 1993 to July 1994.

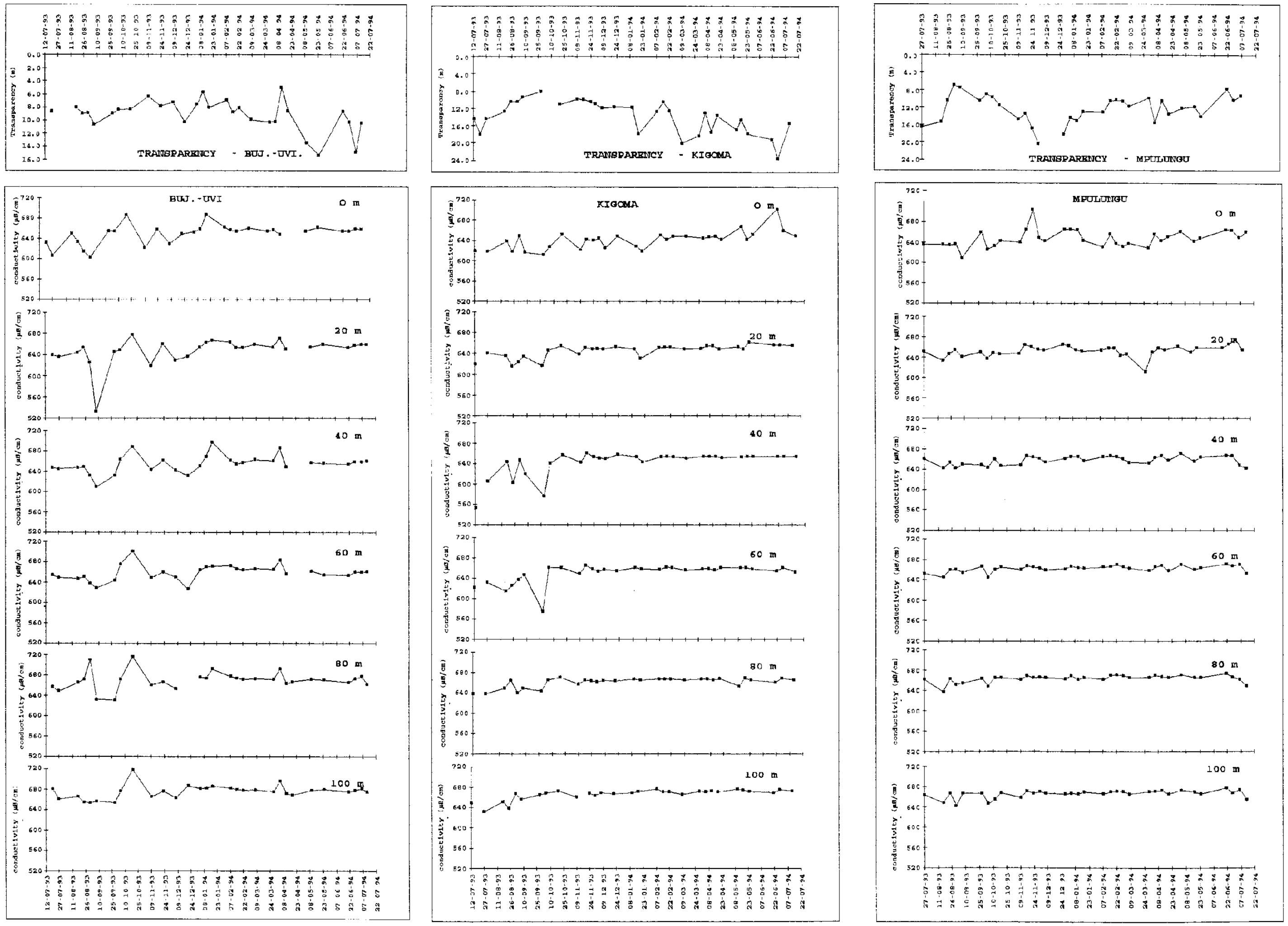


Fig. A.11.3 Changes in conductivity (µS/cm), at 20 m intervals from 0 to 100 m, and in transparency at site A, Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

Depth	Station	Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	650	639	643	656	645	646	655	644	646
	Av.	638	641	645	656	642	649	649	642	647
	St.d.	22	29	18	15	12	17	20	18	17
	N	11	9	10	18	21	24	29	30	34

Depth	Station	Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	646	636	653	655	650	655	654	650	655
	Av.	637	637	654	655	650	653	648	646	653
	St.d.	36	17	12	14	6	11	26	12	11
	N	11	9	10	18	21	24	29	30	34

Depth	Station	Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	647	644	650	659	653	662	656	653	660
	Av.	645	629	652	661	652	660	655	645	658
	St.d.	15	29	10	16	5	7	17	19	9
	N	11	9	10	18	21	24	29	30	34

Depth	Station	Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	651	637	660	665	658	664	659	658	664
	Av.	649	633	660	664	658	663	659	651	662
	St.d.	10	26	9	15	3	5	15	18	7
	N	11	9	10	18	21	24	29	30	34

Depth	Station	Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	665	649	662	672	665	666	672	665	666
	Av.	663	653	659	675	665	666	670	661	664
	St.d.	22	12	10	14	4	5	18	9	7
	N	11	9	10	18	21	24	29	30	34

Depth	Station	Dry season			Rain season			Year		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	665	666	667	679	670	668	677	669	668
	Av.	666	658	663	680	670	667	675	666	666
	St.d.	12	16	11	12	4	6	13	11	8
	N	11	9	10	19	20	24	30	29	34

Table A.11.1. Conductivity (µS/cm), site A (0900-1000 h) at Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for depths 0,20,40,60,80 and 100 m are given.

Source :	DF	F test	Pr>F	
Station (A)	2	20.921	0.0001	***
Season (B)	1	96.523	0.0001	***
Depth (C)	10	27.363	0.0001	***
AB	2	8.135	0.0003	***
AC	20	2.247	0.0014	**
BC	10	0.932	0.5026	NS
ABC	20	1.228	0.2227	NS
Error	914			

Table A.11.2. ANOVA of conductivity measured every 10 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A), season (B) and depth (C).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	654	648	658	663	656	663	659	655	662
Av.	648	645	655	665	656	660	659	653	658
St.d.	26	21	14	17	10	10	22	15	12
N	100	87	114	197	230	261	297	317	375

Table A.11.3. Conductivity (µS/cm) measured at site A (0900-1000 h) at Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for water column 0-100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	***	NS	***

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	**	***				
Rain season	Buj.	***	***	***			
	Kig.	***	***	NS	***		
	Mpu.	***	***	**	**	**	

Table A.11.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for conductivity (µS/cm), 0 to 100 m water column at site A, from August 1993 to July 1994.
A = between stations and B = between seasons at each station.
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

A.12 pH

Lake Tanganyika water is alkaline but becomes less so with depth. During the study year the mean surface water pH was 9.01 at Bujumbura/Uvira, 9.06 at Kigoma and 9.02 at Mpulungu and at 100 m was 8.90, 8.94 and 8.93 respectively (Table A.12.1). The differences between Bujumbura/Uvira and Kigoma were significant ($p<0.001$) (Table A.12.4) at all depths sampled (from 0 to 100 m). The pattern of variation in pH was similar to conductivity, in the 0 to 100 m column it was highest at Bujumbura/Uvira (Figs A.2.1 and A.3.2). The lowest variation was seen at Kigoma. At Mpulungu, besides the general decrease of median values, it was noted that the 10 % percentiles were similar between 0 and 100 m. This corresponded to mixing of the water column during upwelling.

A decrease in pH just below the thermocline (*c.* 80 m) was recorded at Bujumbura/Uvira and Kigoma while at Mpulungu a decrease in pH was measured well below the thermocline, just below the deep oxycline, between 140 m and 200 m.

ANOVA showed that the interaction between season and station was highly significant($p<0.001$) at Bujumbura/Uvira and Kigoma and significant($p<0.05$) at Mpulungu (Table A.12.4). At Bujumbura/Uvira the mean pH decreased during the dry season while at Kigoma it increased (Table A.12.3). Differences were noted at similar depths between stations. For example the surface pH was 9.14 at Kigoma compared to 8.85 at Bujumbura/Uvira during the dry season (Table A.12.1). The above differences were confirmed by LSD tests (Table C.5). At Mpulungu, as at Kigoma, the pH increased during the dry season. At Bujumbura/Uvira low values in August 1993 but high values in October and November 1993 were observed. In the latter months there was greater phytoplankton production. During the wet season, there were no significant differences between stations (Table A.12.4).

Variation in pH was greatest from September-December (Figs A.12.1 and A.12.2). The isopleths of pH were related to changes in thermocline depth (cf Fig. A.12.2 to Figs A.4.1 and A.7.2).

Upward pulses of deep water were recorded at site B from isopleths of low pH rising from depths >300 m to 80-100 m at Bujumbura/Uvira from September to December, to 60 to 80 m at Kigoma in December and to 140-200 m at Mpulungu from September to November (Fig. A.12.2). A second pulse of deep water with lower pH values was recorded in March at Kigoma and in March-April at Bujumbura/Uvira. It corresponded to the upward movement of the thermocline at this time (Fig. A.7.2).

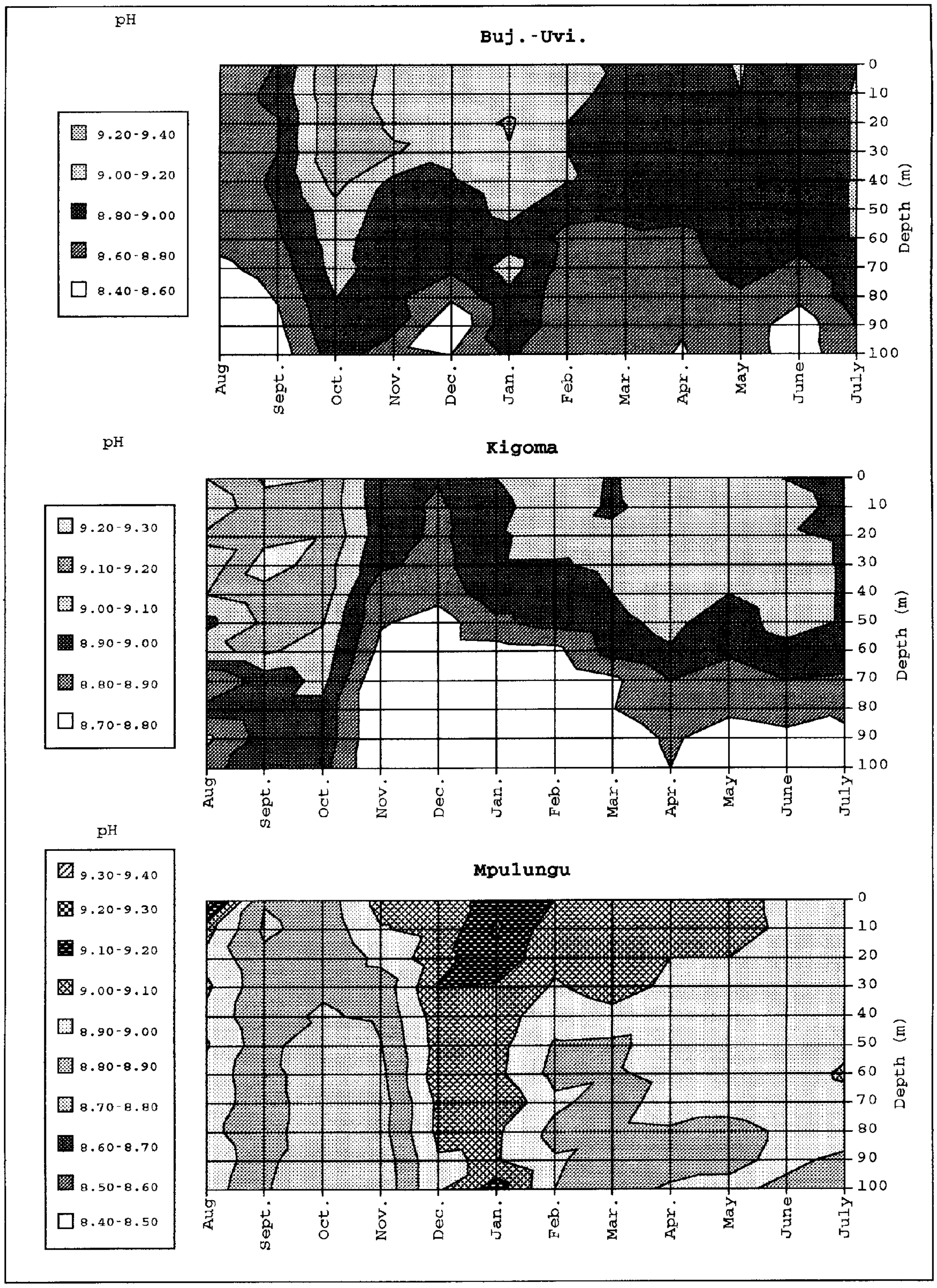


Fig. A.12.1. Isopleths of median pH values measured at site A (0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994.

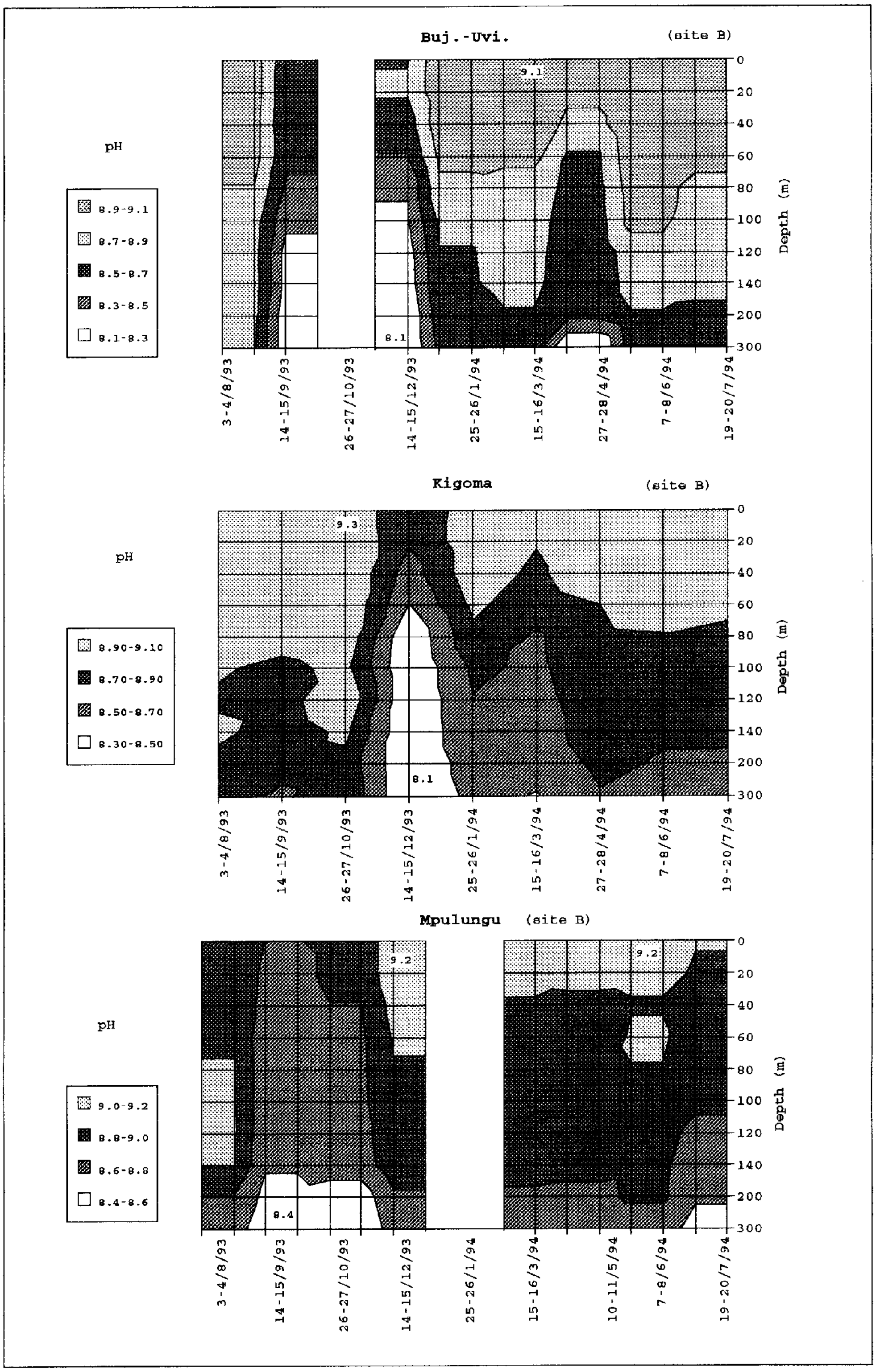


Fig. A.12.2. Isopleths of median pH values measured at site B (0 to 300 m), Bujumbura/Uvira, Kigoma and Mpulungu during nine intensive sampling periods from 3-4 August 1993 to 19-20 July 1994.

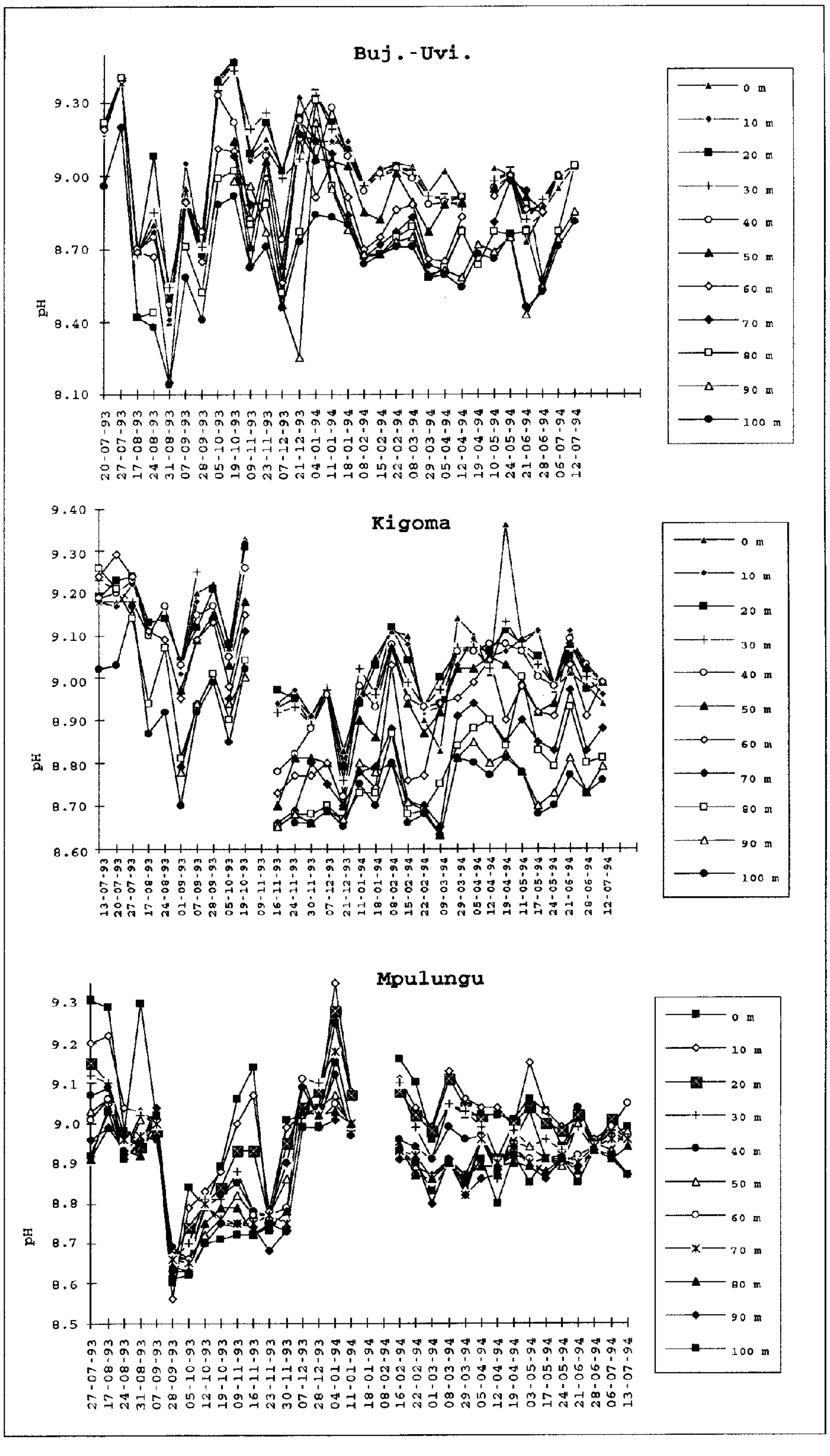


Fig. A.12.3. Fluctuations in pH at site A, Bujumbura/Uvira, Kigoma and Mpulungu, July 1993 to July 1994.

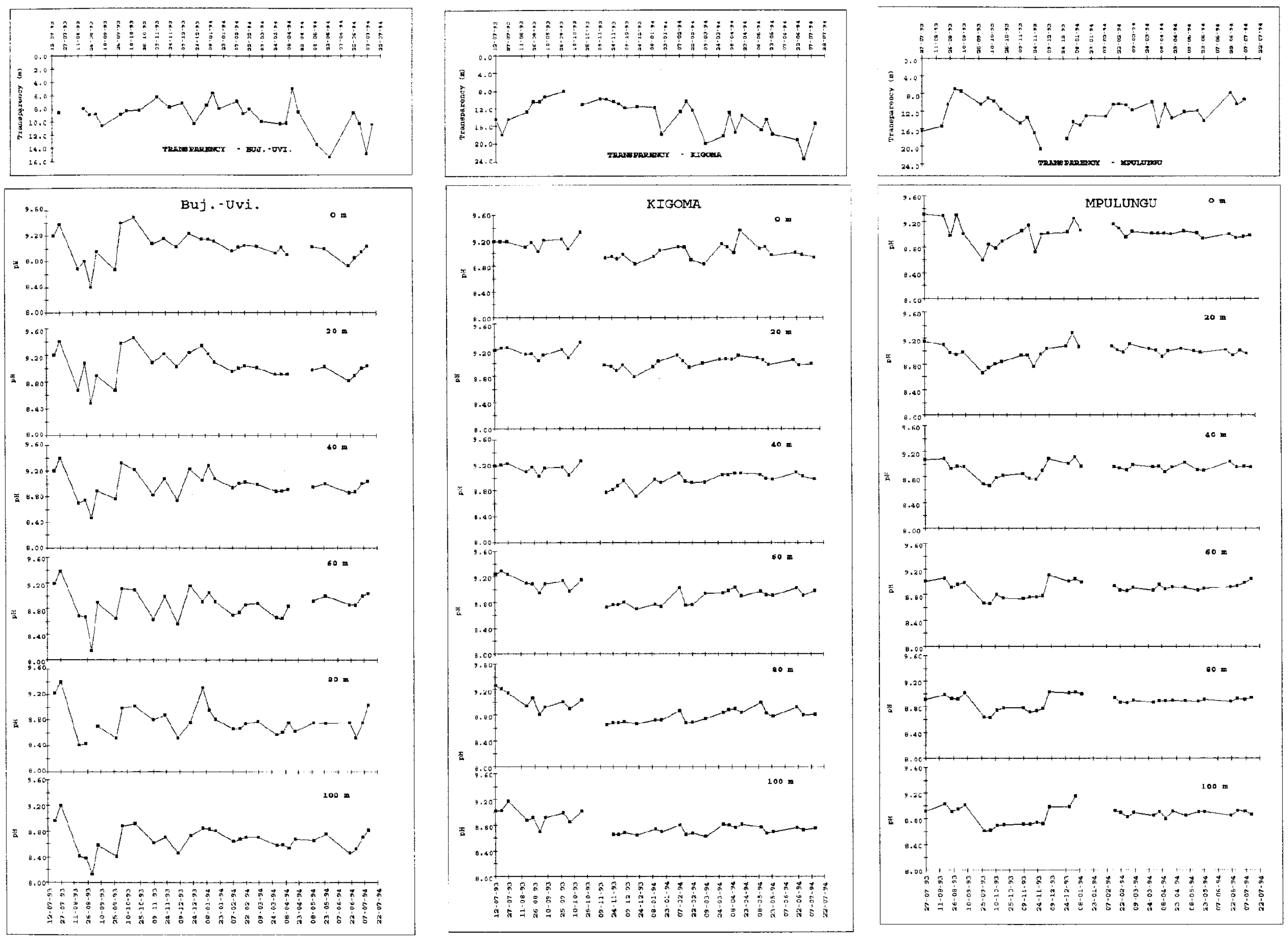


Fig. A.12.4. Fluctuations in pH at 20 m intervals from 0 to 100 m, and changes in transparency at site A, Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	8.85	9.14	9.00	9.05	9.03	9.02	9.03	9.06	9.02
	Av.	8.88	9.10	9.04	9.10	9.04	9.01	9.01	9.06	9.02
	St.d.	0.27	0.10	0.22	0.15	0.14	0.12	0.23	0.13	0.15
	N	11	10	10	18	20	22	29	30	32

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	8.89	9.13	8.98	9.03	9.04	9,00	9.02	9.05	8.99
	Av.	8.92	9.11	8.97	9.10	9.02	8.98	9.03	9.05	8.98
	St.d.	0.26	0.1	0.13	0.17	0.11	0.12	0.22	0.11	0.12
	N	11	10	10	18	20	22	29	30	32

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	8.87	9.13	8.97	9.01	8.98	8.93	8.99	9.04	8.96
	Av.	8.90	9.12	8.96	9.02	8.98	8.92	8.98	9.03	8.93
	St.d.	0.25	0.08	0.11	0.16	0.12	0.11	0.20	0.13	0.11
	N	11	10	10	18	20	22	29	30	32

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	8.86	9.09	8.98	8.90	8.91	8.88	8.88	8.95	8.91
	Av.	8.85	9.08	8.95	8.87	8.88	8.88	8.86	8.95	8.90
	St.d.	0.32	0.12	0.11	0.18	0.13	0.11	0.24	0.16	0.11
	N	11	10	10	18	20	22	29	30	32

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	8.74	8.94	8.93	8.77	8.77	8.89	8.77	8.84	8.90
	Av.	8.78	8.97	8.91	8.79	8.79	8.87	8.79	8.85	8.88
	St.d.	0.34	0.14	0.10	0.18	0.11	0.11	0.24	0.15	0.10
	N	10	10	10	19	20	22	29	30	32

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	8.52	8.90	8.92	8.71	8.7	8.85	8.68	8.77	8.90
	Av.	8.60	8.89	8.90	8.70	8.74	8.85	8.66	8.79	8.86
	St.d.	0.30	0.15	0.12	0.12	0.09	0.12	0.21	0.13	0.12
	N	11	10	10	19	19	21	30	29	31

Table A.12.1. pH measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for depths of 0, 20, 40, 60, 80 and 100 m are given.

Source :	DF	F test	Pr>F	
Station (A)	2	16.46	0.0001	***
Season (B)	1	2.44	0.119	NS
Depth (C)	10	27.43	0.0001	***
AB	2	29.81	0.0001	***
AC	20	2.56	0.0002	***
BC	10	1.74	0.0683	NS
ABC	20	0.45	0.9826	NS
Error	887			

Table A.12.2. ANOVA of pH measured every 10 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A), season (B) and depth (C)
(NS: non significant, * = $0.05 \geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$)

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	8.85	9.03	8.96	8.95	8.93	8.91	8.91	8.95	8.94
Av.	8.84	9.02	8.96	8.93	8.91	8.91	8.90	8.94	8.93
St.d.	0.28	0.14	0.13	0.22	0.16	0.13	0.25	0.16	0.13
N	99	95	114	198	219	237	297	314	351

Table A.12.3. pH measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for water column from 0 to 100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
	**	NS	NS

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	***					
	Mpu.	***	**				
Rain season	Buj.	***	***	NS			
	Kig.	**	***	*	NS		
	Mpu.	***	***	*	NS	NS	

Table A.12.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for pH, 0 to 100 m water column at site A, from August 1993 to July and B = between seasons at each station. (NS: non significant, * = $0.05 \geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$)

A.13 Total phosphorus

Means of total phosphorus (TP) (as $PO4^{3-}$) for the 0-100 m water column were similar for Bujumbura/Uvira and Mpulungu, 0.13 and 0.15 mg/l respectively (Table A.13.2). At Kigoma, high values were regularly recorded. The mean was 0.47 mg/l.

Median values of TP at Kigoma were higher than at the other stations (Fig. A.2.1). Increased values were observed in August, September, October and December. Other parameters such as pH and conductivity also varied significantly in these months.

A comparison between seasons showed that the greatest variation in TP was at Mpulungu were the concentrations of TP were 0.32 and 0.12 mg/l during the dry and wet seasons respectively. Upwelling occurred during the dry season and at this time, at Kigoma, TP concentrations increased but decreased at Bujumbura/Uvira (Table A.13.2).

Source :	DF	F test	Pr>F	
Station (A)	2	47.71	0.0001	***
Season (B)	1	0.899	0.3436	NS
Depth (C)	7	3.061	0.0037	**
AB	2	4.839	0.0083	**
AC	14	1.436	0.1328	NS
BC	7	0.864	0.5346	NS
ABC	14	1.323	0.1897	NS
Error	435			

Table A.13.1. ANOVA of total phosphorus measured every 20 m, 0 to 100 m, at site A, 1993-1994
Variables were station (A), season (B) and depth (C).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	0.03	0.35	0.13	0.06	0.40	0.07	0.03	0.39	0.08
Av.	0.10	0.52	0.32	0.15	0.45	0.12	0.13	0.47	0.15
St.d.	0.38	0.35	0.41	0.24	0.26	0.13	0.29	0.29	0.22
N	32	59	32	68	150	151	100	209	183

Table A.13.2. Total phosphorus (mg/l PO43-) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for the water column from 0 to 100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	***	NS	***

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	***					
	Mpu.	***	***				
Rain season	Buj.	NS	***	**			
	Kig.	***	NS	**	***		
	Mpu.	NS	***	***	NS	***	

Table A.13.3. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for total phosphorus, 0 to 100 m water column at site A, from August 1993 to July 1994.
A = between stations and B = between seasons at each station.

A.14 Phosphates

The average concentration of total reactive phosphorus (TRP) in the 0 to 100 m column was significantly lower in Mpulungu (0.05 mg/l as $PO4^{3-}$) compared to Bujumbura/Uvira and Kigoma (0.15 mg/l as $PO4^{3-}$) (Table A.14.3 and A.14.4). Phosphate concentrations increased with depth (Figure A.3.2). Differences between the means were significant (P<0.001 or <0,01) for all the criteria (station, season and depth) and all their interactions except station x season x depth (Table A.14.2).

At Bujumbura/Uvira, the concentration of TRP in the 0 t0 100 m water column was significantly (P<0.001) lower during the dry season (0.09 mg/l as $PO4^{3-}$) compared to the wet season (0.19 mg/l as $PO4^{3-)}$. Phosphate rich layers reached the epilimnion at 20-40 m in October then sank during the year with some upward pulses in December and March (Fig. A.14.1). The deepening of phosphate rich layers corresponded with the deepening of the thermocline (Figure A.7.2) and the pulses were probably linked with internal waves.

At Kigoma, a more patchy distribution was identified with pulses in September, January and particularly May (Fig. A.14.1). These fluctuations need further investigations.

At Mpulungu, phosphate concentrations were linked with the dry season (and its upwelling) and the end of the wet season when the thermocline became shallower (compare Figs 36 and 37 with Fig. 10). The influence of stratification on the input of nutrients such as phosphates was particularly well inferred from the data. During most of the wet season phosphates might have limited production near Mpulungu particularly during low phases of internal waves.

Pulses of TRP were noted during the whole year at Bujumbura/Uvira and Kigoma (Fig. A.14.2). At Mpulungu pulses were not detected during December and January, a time of the year with the strongest stratification when the thermocline acted as an effective barrier.

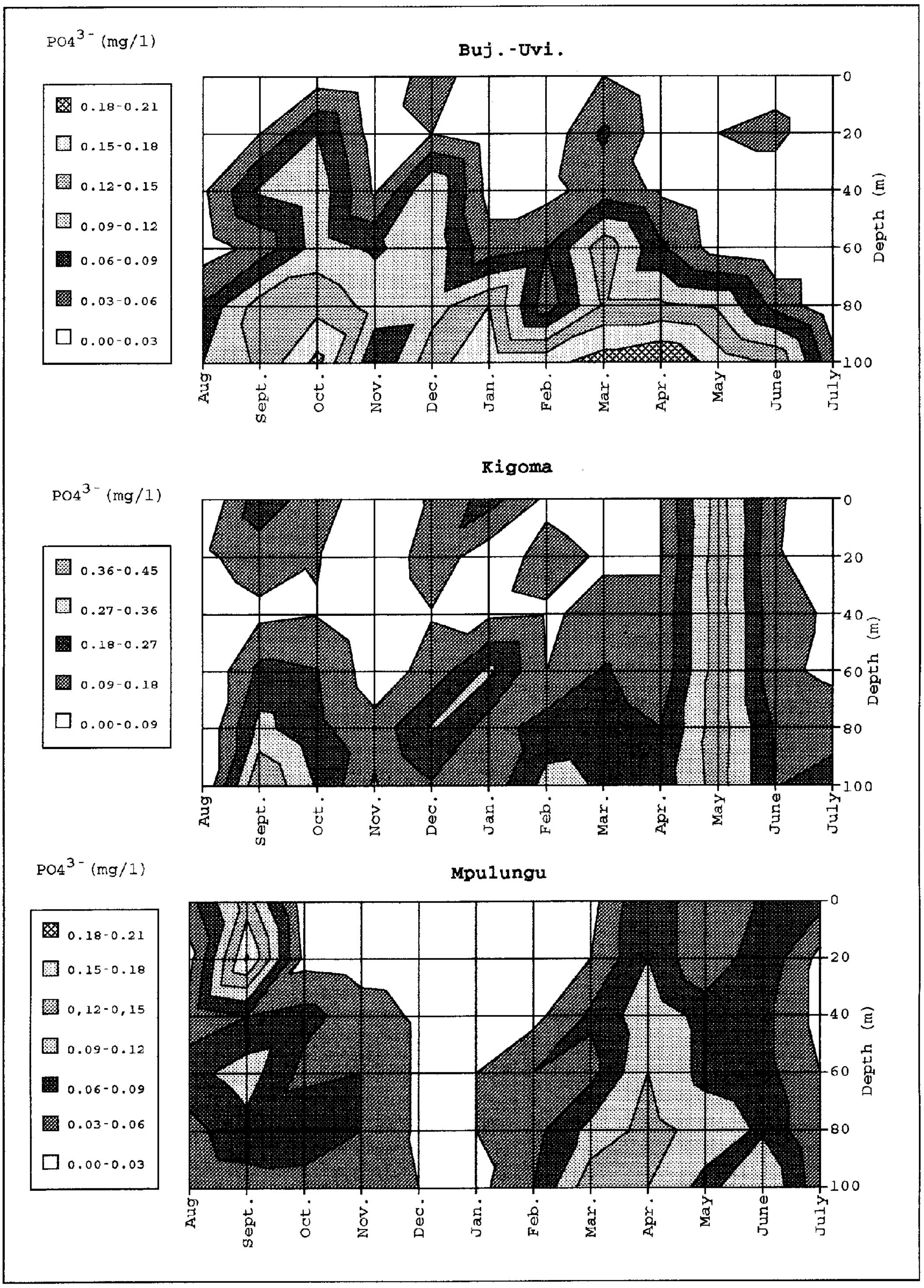


Fig. A.14.1. Isopleths of monthly median phosphates values (mg/l PO4---) measured at sites A (0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu, August

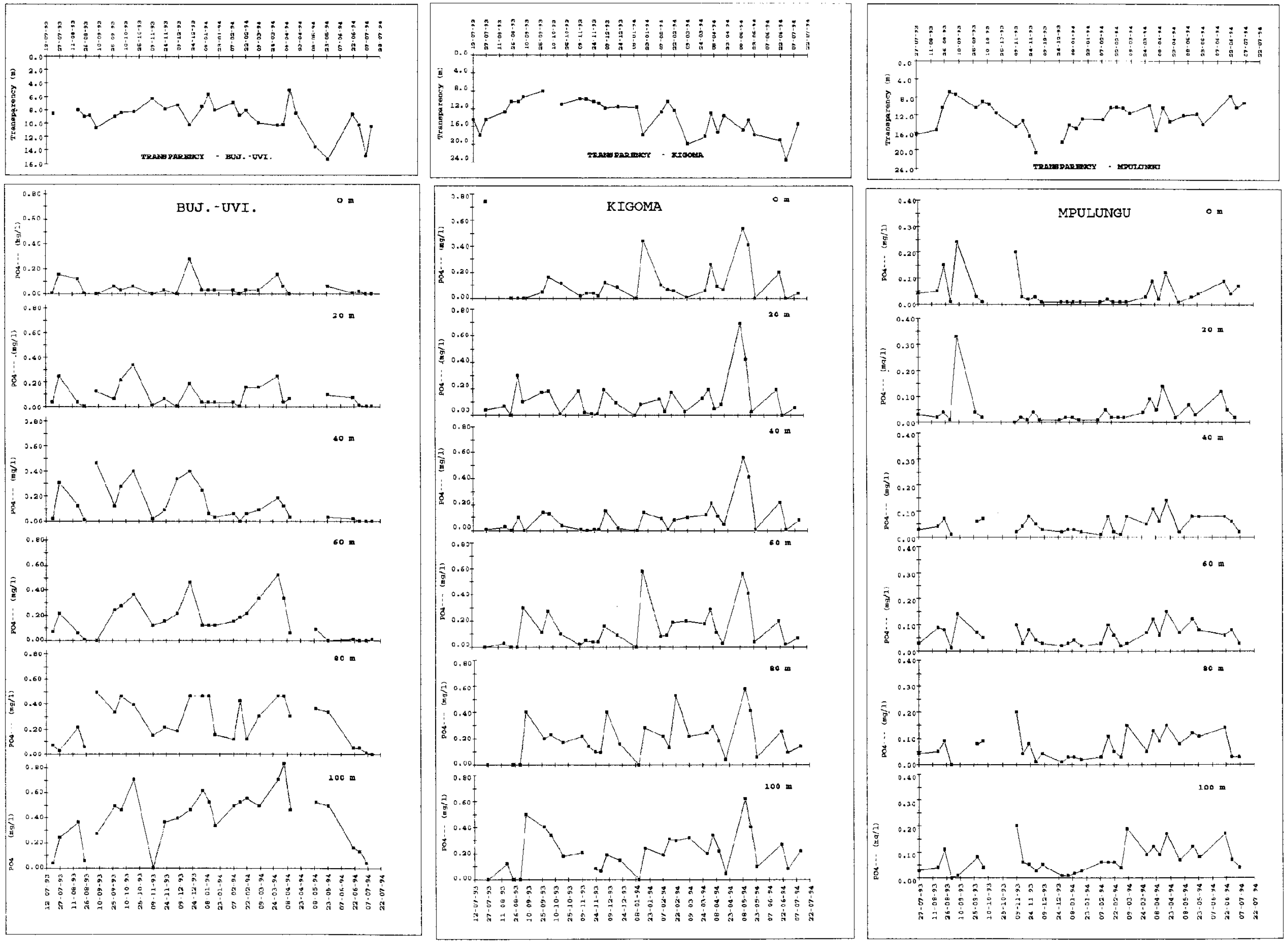


Fig. A.14.2. Fluctuations in phosphates (TRP), every 20 m, 0 to 100 m, and changes in transparency at site A, Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	0.01	0.02	0.05	0.03	0.07	0.02	0.03	0.06	0.03
	Av.	0.04	0.13	0.08	0.05	0.13	0.03	0.05	0.13	0.05
	St.d.	0.06	0.26	0.07	0.07	0.15	0.05	0.06	0.18	0.06
	N	10	8	9	17	21	22	27	29	31

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	0.03	0.07	0.04	0.06	0.08	0.02	0.03	0.09	0.02
	Av.	0.06	0.10	0.07	0.10	0.13	0.03	0.08	0.12	0.04
	St.d.	0.08	0.10	0.10	0.10	0.16	0.03	0.09	0.15	0.06
	N	10	9	9	17	21	22	27	30	31

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	0.02	0.03	0.05	0.09	0.08	0.05	0.06	0.07	0.05
	Av.	0.11	0.07	0.05	0.14	0.11	0.05	0.13	0.10	0.05
	St.d.	0.16	0.08	0.03	0.14	0.14	0.03	0.14	0.13	0.03
	N	10	9	8	17	21	22	27	30	30

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	0.01	0.03	0.07	0.17	0.10	0.06	0.12	0.09	0.06
	Av.	0.06	0.08	0.07	0.21	0.17	0.06	0.16	0.14	0.06
	St.d.	0.09	0.11	0.04	0.14	0.17	0.04	0.14	0.16	0.04
	N	10	9	9	18	21	22	28	30	31

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	0.06	0.12	0.05	0.35	0.22	0.07	0.26	0.18	0.07
	Av.	0.13	0.14	0.06	0.33	0.22	0.08	0.26	0.20	0.07
	St.d.	0.16	0.14	0.04	0.13	0.15	0.05	0.17	0.15	0.05
	N	10	8	8	18	21	22	28	29	30

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	0.16	0.12	0.04	0.49	0.21	0.07	0.46	0.20	0.06
	Av.	0.20	0.18	0.06	0.50	0.23	0.08	0.40	0.21	0.07
	St.d.	0.16	0.18	0.05	0.17	0.14	0.05	0.22	0.16	0.05
	N	9	9	9	18	20	22	27	29	31

Table A.14.1. Phosphates (mg/l PO4--- as TRP) measured at site A (0900-1000 h) Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means standard deviations and number of observations for depths 0, 20, 40, 60, 80 and 100 m are given.

Source :	DF	F test	Pr > F	
Station (A)	2	23.55	0.0001	***
Season (B)	1	18.52	0.0001	***
Depth (C)	7	13.36	0.0001	***
AB	2	9.34	0.0001	***
AC	14	5.1	0.0001	***
BC	7	3.26	0.0021	**
ABC	14	1.44	0.1289	NS
Error	632			

Table A.14.2. ANOVA of phosphates (TRP) measured every 20 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A), season (B) and depth (C). (NS: non significant, * = 0.05 $\geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$).

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	0.03	0.07	0.05	0.12	0.1	0.03	0.06	0.09	0.04
Av.	0.09	0.14	0.06	0.19	0.15	0.05	0.15	0.15	0.05
St.d.	0.12	0.19	0.06	0.19	0.16	0.04	0.18	0.17	0.05
N	79	73	61	136	167	176	215	240	237

Table A.14.3. Phosphates (mg/l PO4--- as TRP) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for the water column from 0 to 100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	NS	***	***

B.		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	*					
	Mpu.	NS	**				
Rain season	Buj.	***	*	***			
	Kig.	***	NS	***	NS		
	Mpu.	NS	***	NS	***	***	

Table A.14.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for phosphates (TRP), 0 to 100 m water column at site A, from August 1993 to July 1994. A = between stations and B = between seasons at each station. (NS: non significant, * = 0.05 $\geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$)

A.15 Nitrates

Mean concentrations of nitrates in the 0 to 100 m water column were 0.06 mg/l (NO_3-N) at Bujumbura/Uvira and 0.08 mg/l at Kigoma and Mpulungu (Table A.15.3). Differences between Bujumbura/Uvira and the other stations were significant ($p<0.001$ with Kigoma and $p<0.01$ with Mpulungu (Table A.15.4)).

Medians and percentiles of all observations at site A are presented in Figure A.2.1 Below the surface nitrates increased to reach a maximum, 0.10 mg/l at 60 m at Bujumbura/Uvira, 0.12 mg/l at 80 m at Kigoma and 0.10 mg/l at 100 m at Mpulungu (Table A.15.1). Maximum values were related to the oxycline (Fig. A.3.3). Below the oxycline average nitrate values decreased to 0.04 mg/l at 300 m at Bujumbura/Uvira (N = 3), 0.07 mg/l at Kigoma (N = 12) and 0.05 mg/l at Mpulungu (N = 8) at site B. No deeper samples were taken during the first year.

At Bujumbura/Uvira, during the dry season and from October to December, nitrate concentrations were homogeneous in the water column (Figs A.15.1, A.15.2 and A.15.3). From January to April there was a well defined peak near the thermocline at 60 m and from May to June at 80 m when the thermocline deepened. At site B maximum concentrations were also observed from 60 to 80 m (Fig. A.15.2). At Kigoma the lowest values of nitrates were recorded during the dry season (Table A.15.4). Maximum values of nitrate were generally recorded at a lower depth than at Bujumbura/Uvira (*c.* 80-100 m), particularly from March to June (Fig. A.15.3). Fluctuations in nitrate values at Mpulungu were related to changes in thermocline depth (cf. Figs A.15.2 and A.15.4 with Fig. A.4.1). Pulses of nitrate concentrations were recorded near the surface at Kigoma and Mpulungu (Figs A.15.2 and A.15.4).

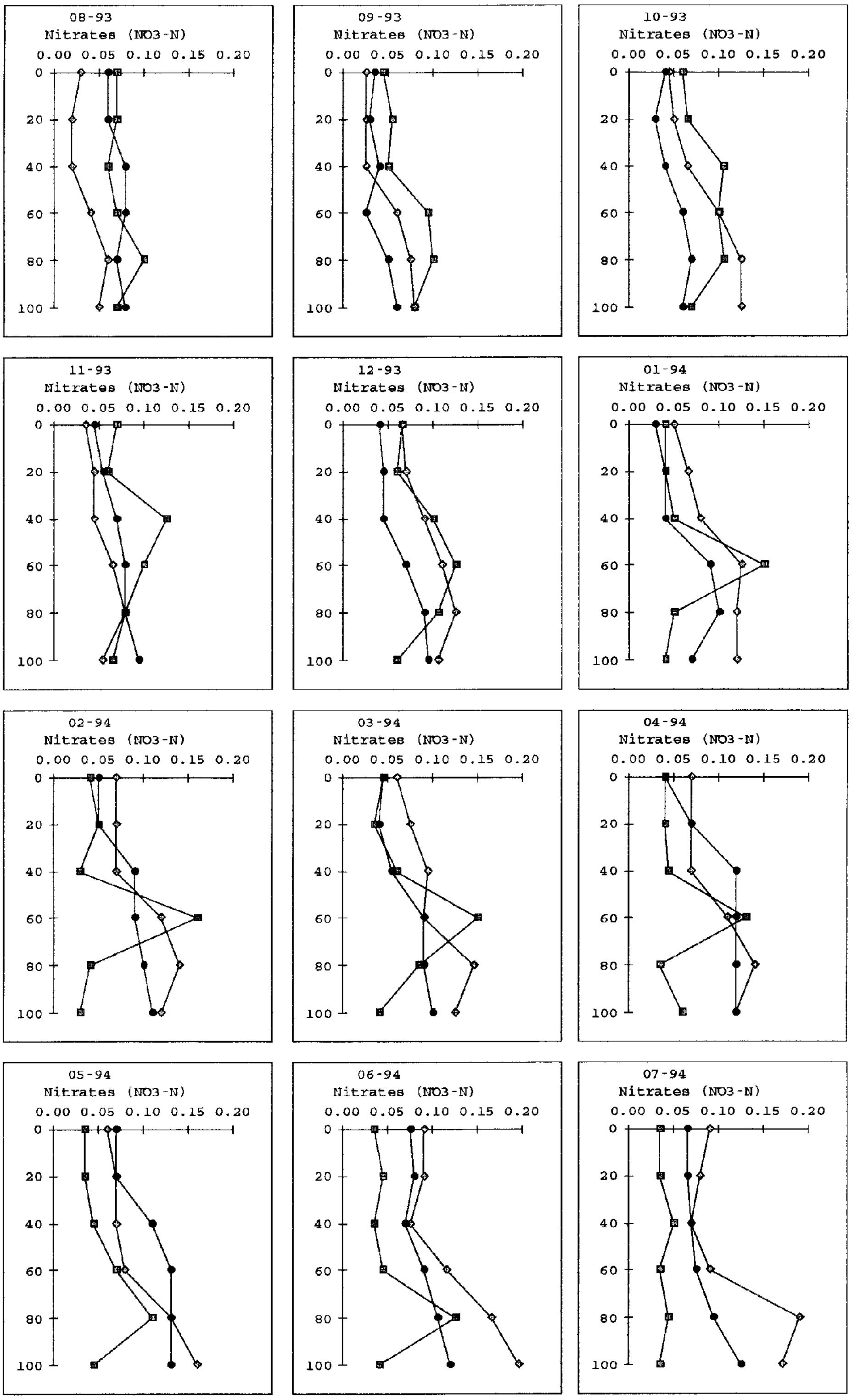


Fig A.15.1. Monthly median profiles of nitrates (NO_3-N) measured at site A (from 0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994.

Buj.-Uvi
Kigoma
Mpulungu

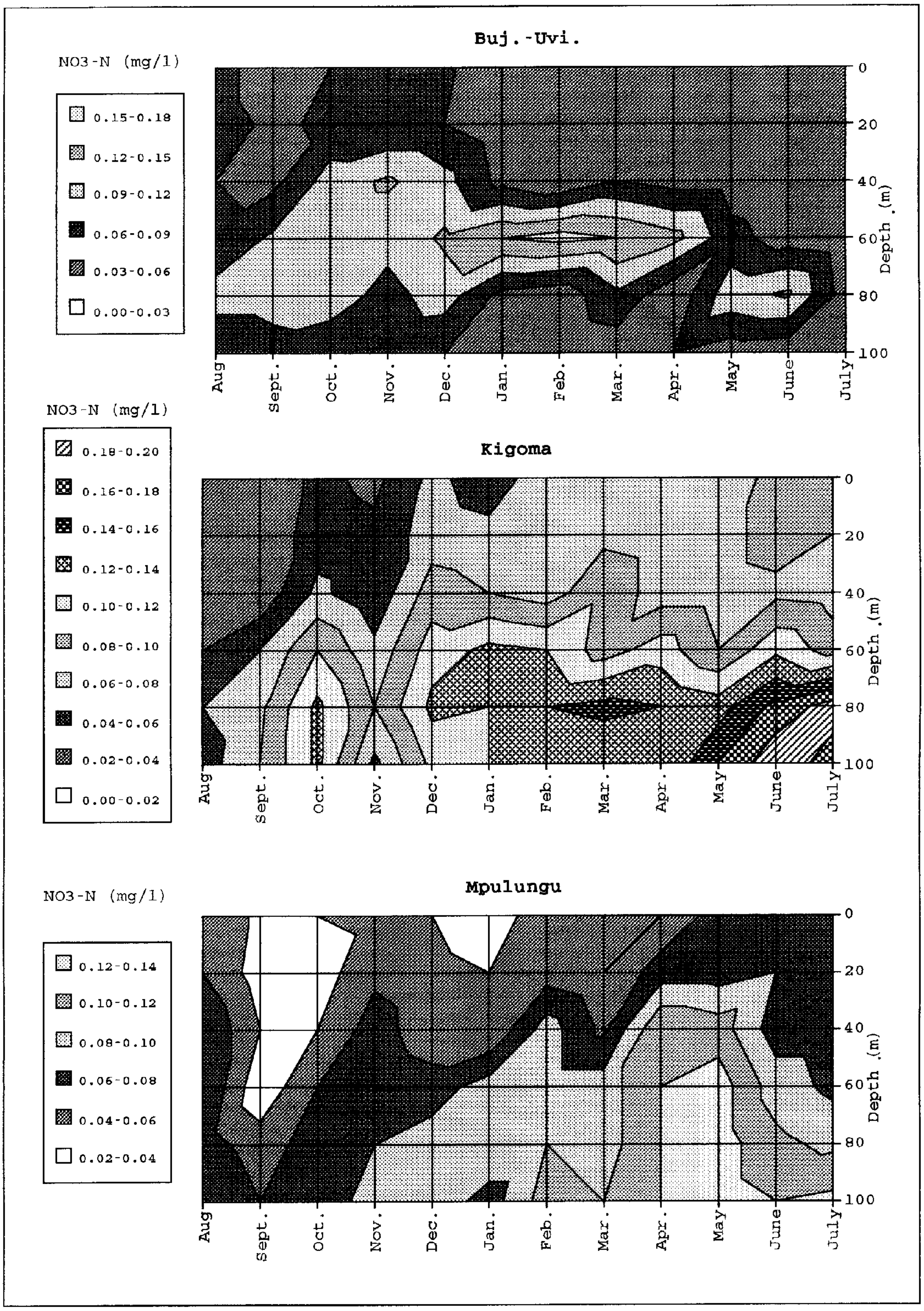


Fig. A.15.2. Isopleths of monthly median values of nitrates (mg/l NO3-N) measured at site A (0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu from August 1993 to July 1994.

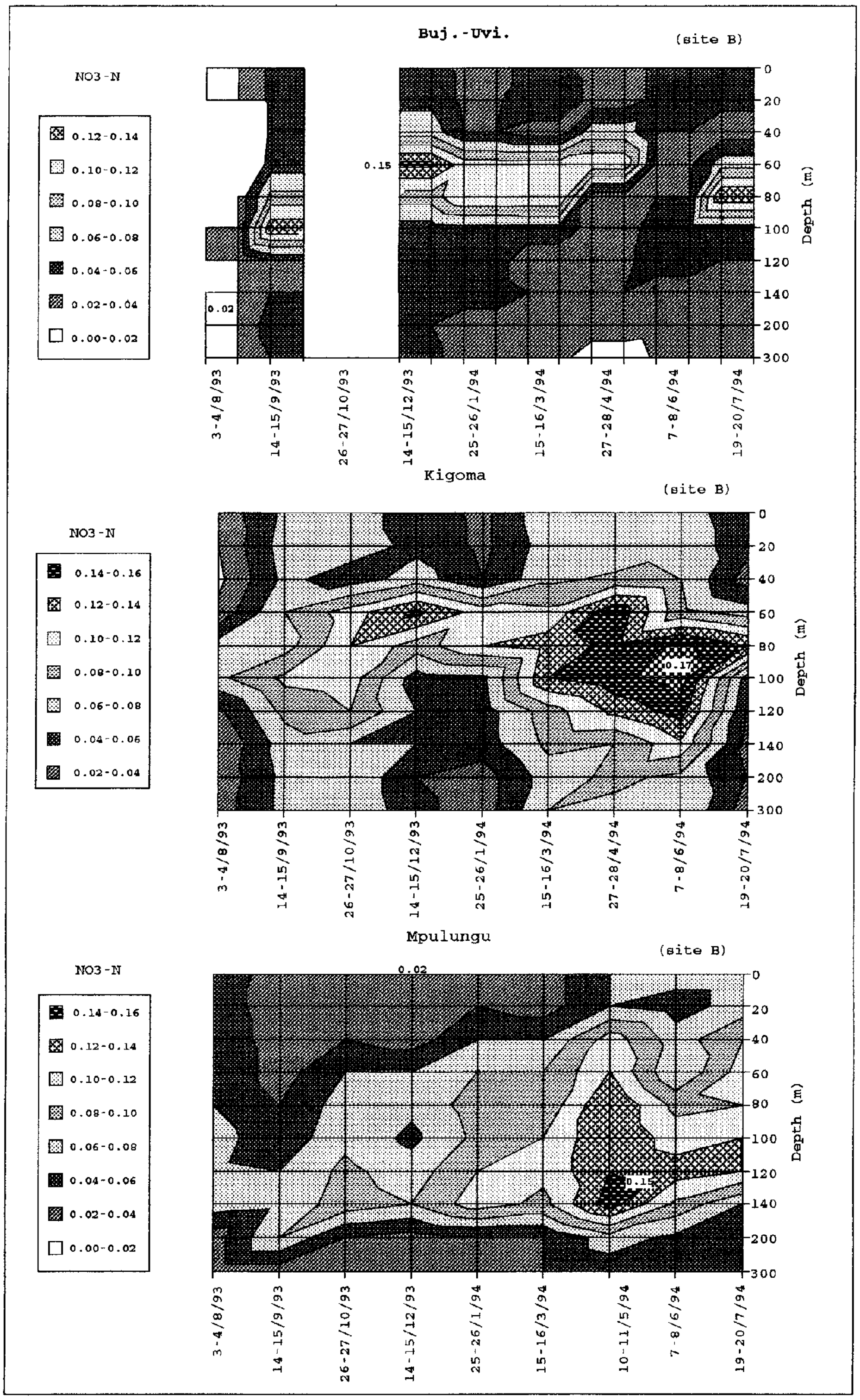


Fig. A.15.3. Isopleths of monthly median values of nitrates (mg/l NO3-N) measured at site B (0 to 300 m), Bujumbura/Uvira, Kigoma and Mpulungu, during nine intensive sampling periods from 3-4 August 1993 to 19-20 July 1994.

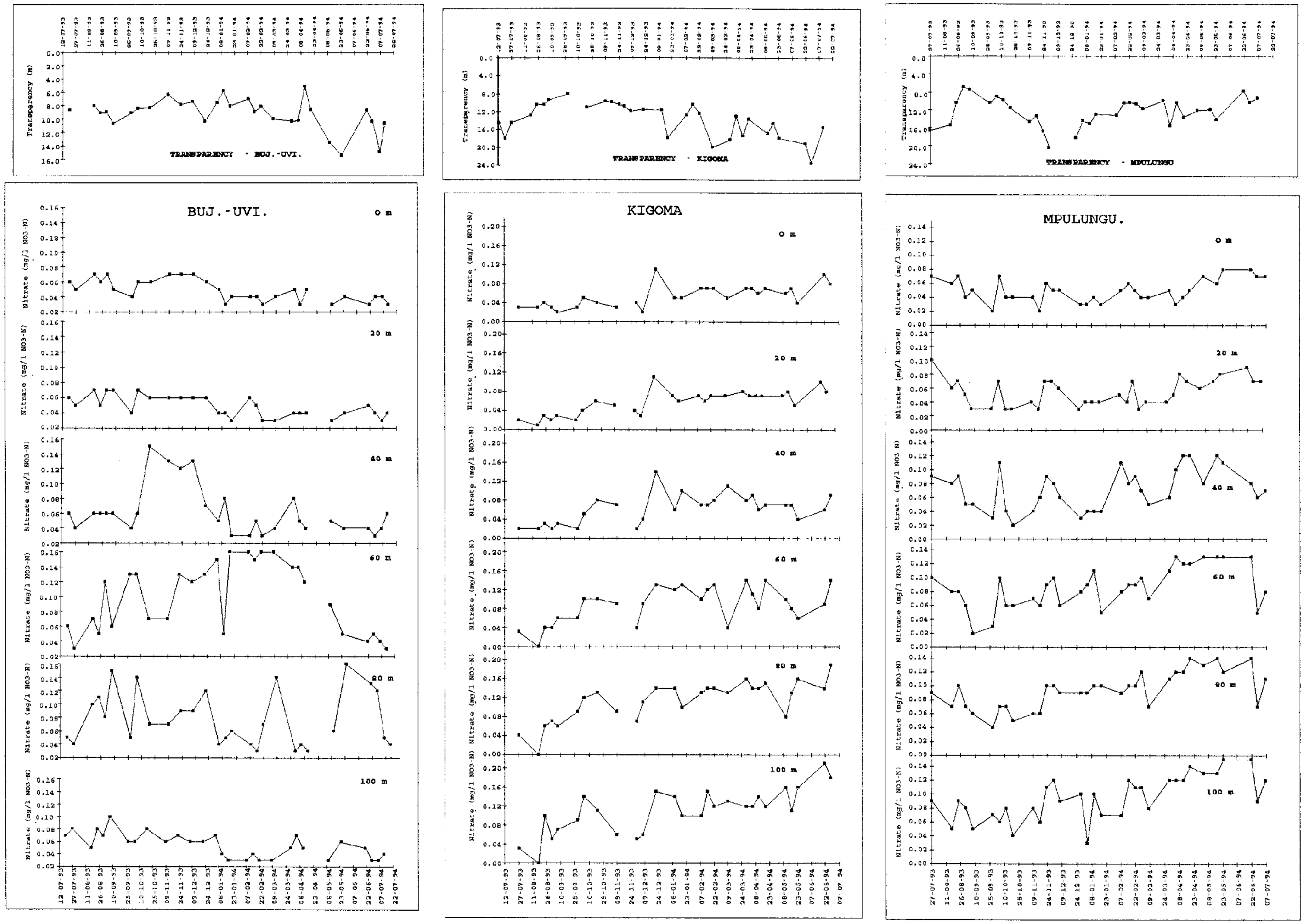


Fig. A.15.4. Fluctuations in nitrates (mg/l NO3-N) every 20 m from 0 to 100 m, and changes in transparency, Bujumbura/Uvira, Kigoma and Mpulungu, from August 1993 to July 1994

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	0.05	0.03	0.07	0.05	0.06	0.05	0.05	0.05	0.06
	Av.	0.05	0.05	0.06	0.05	0.06	0.05	0.05	0.06	0.05
	St.d.	0.01	0.03	0.02	0.01	0.02	0.01	0.01	0.02	0.02
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	0.05	0.03	0.07	0.04	0.07	0.05	0.05	0.07	0.06
	Av.	0.05	0.04	0.06	0.05	0.06	0.05	0.05	0.06	0.05
	St.d.	0.01	0.03	0.02	0.01	0.02	0.02	0.01	0.03	0.02
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	0.06	0.03	0.07	0.05	0.07	0.08	0.05	0.07	0.07
	Av.	0.05	0.04	0.07	0.07	0.07	0.07	0.06	0.06	0.07
	St.d.	0.01	0.03	0.02	0.04	0.03	0.03	0.03	0.03	0.03
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	0.05	0.06	0.08	0.13	0.10	0.09	0.12	0.09	0.09
	Av.	0.06	0.06	0.07	0.12	0.10	0.09	0.10	0.09	0.09
	St.d.	0.03	0.04	0.03	0.04	0.03	0.03	0.05	0.04	0.03
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	0.08	0.07	0.08	0.07	0.13	0.10	0.07	0.13	0.1
	Av.	0.08	0.09	0.08	0.07	0.13	0.10	0.08	0.12	0.09
	St.d.	0.04	0.07	0.03	0.04	0.03	0.03	0.04	0.04	0.03
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	0.06	0.09	0.09	0.06	0.12	0.11	0.06	0.12	0.10
	Av.	0.06	0.10	0.09	0.05	0.12	0.10	0.05	0.11	0.10
	St.d.	0.02	0.07	0.03	0.02	0.03	0.03	0.02	0.05	0.03
	N	11	9	10	18	19	24	29	28	34

Table A.15.1. Nitrate (mg/l NO3-N) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for depths of 0, 20, 40, 60, 80 and 100 m are given.

Source :	DF	F test	Pr > F	
Station (A)	2	9.437	0.0001	***
Season (B)	1	23.097	0.0001	***
Depth (C)	5	31.45	0.0001	***
AB	2	5.059	0.0067	***
AC	10	5.028	0.0001	***
BC	5	5.829	0.0001	***
ABC	10	1.303	0.2256	NS
Error	510			

Table A.15.2. ANOVA of nitrates measured every 20 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A), season (B) and depth (C). (NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001).

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	0.05	0.05	0.07	0.07	0.09	0.07	0.05	0.08	0.07
Av.	0.06	0.06	0.07	0.07	0.09	0.08	0.06	0.08	0.08
St.d.	0.03	0.05	0.03	0.04	0.04	0.03	0.03	0.04	0.03
N	72	70	61	108	114	144	180	184	205

Table A.15.3. Nitrates (mg/l NO3-N) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for water column from 0 to 100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	***	**	NS

		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	*	NS				
Rain season	Buj.	NS	NS	NS			
	Kig.	***	***	**	***		
	Mpu.	***	**	NS	NS	**	

Table A.15.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for nitrates, 0 to 100 m water column at site A, from August 1993 to July 1994. A = between stations and B = between seasons at each station. (NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001).

A.16 Nitrites

Mean nitrite values for the 0 to 100 m water column was 0.003 mg/l (NO_2-N) at each station. There were no significant differences between stations (Tables A.16.2 and A.16.3). A peak of <0.005 mg/l at 80 m during the wet season at Bujumbura/Uvira was statistically different from concentrations at other depths (Table C.8). At Mpulungu nitrites were significantly less ($p<0.01$), 0.002 mg/l, during the wet season than at other stations, 0.003 mg/l (Table A.16.4).

Between the dry season and the wet season, isopleths of nitrite concentrations (Fig. A.16.1) indicated higher values at Bujumbura/Uvira. This corresponded with a period of mixing and upwelling of deep water (see Fig. A.11.1). Other peaks were measured at 80 m, in December, in February and in June (Fig. A.16.1).

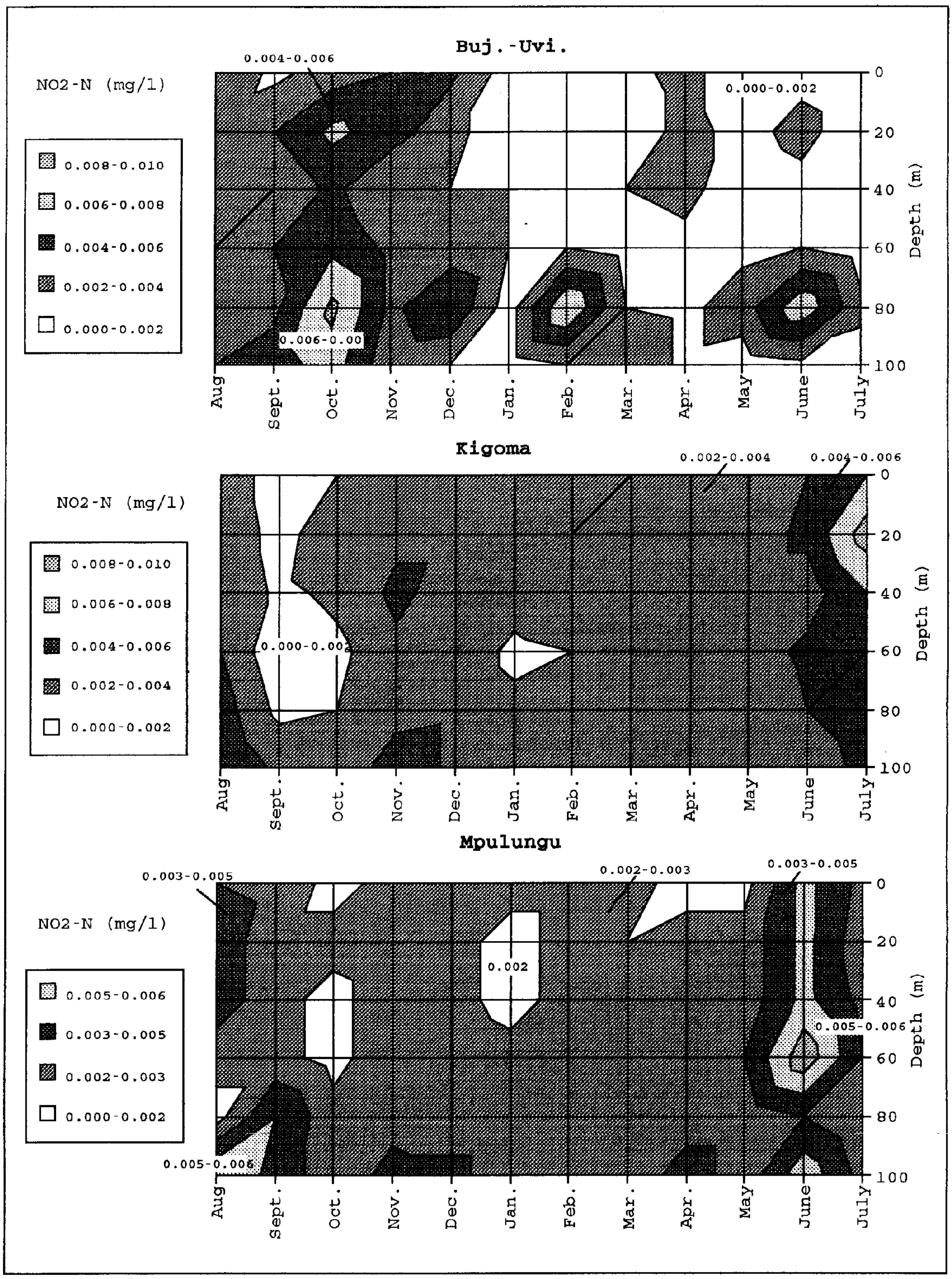


Fig. A.16.1. Isopleths of monthly median values of nitrites (mg/l NO2-N) measured at site B (0 to 300 m), Bujumbura/Uvira, Kigoma and Mpulungu during nine intensive sampling periods from 3-4 August 1993 to 19-20 July 1994.

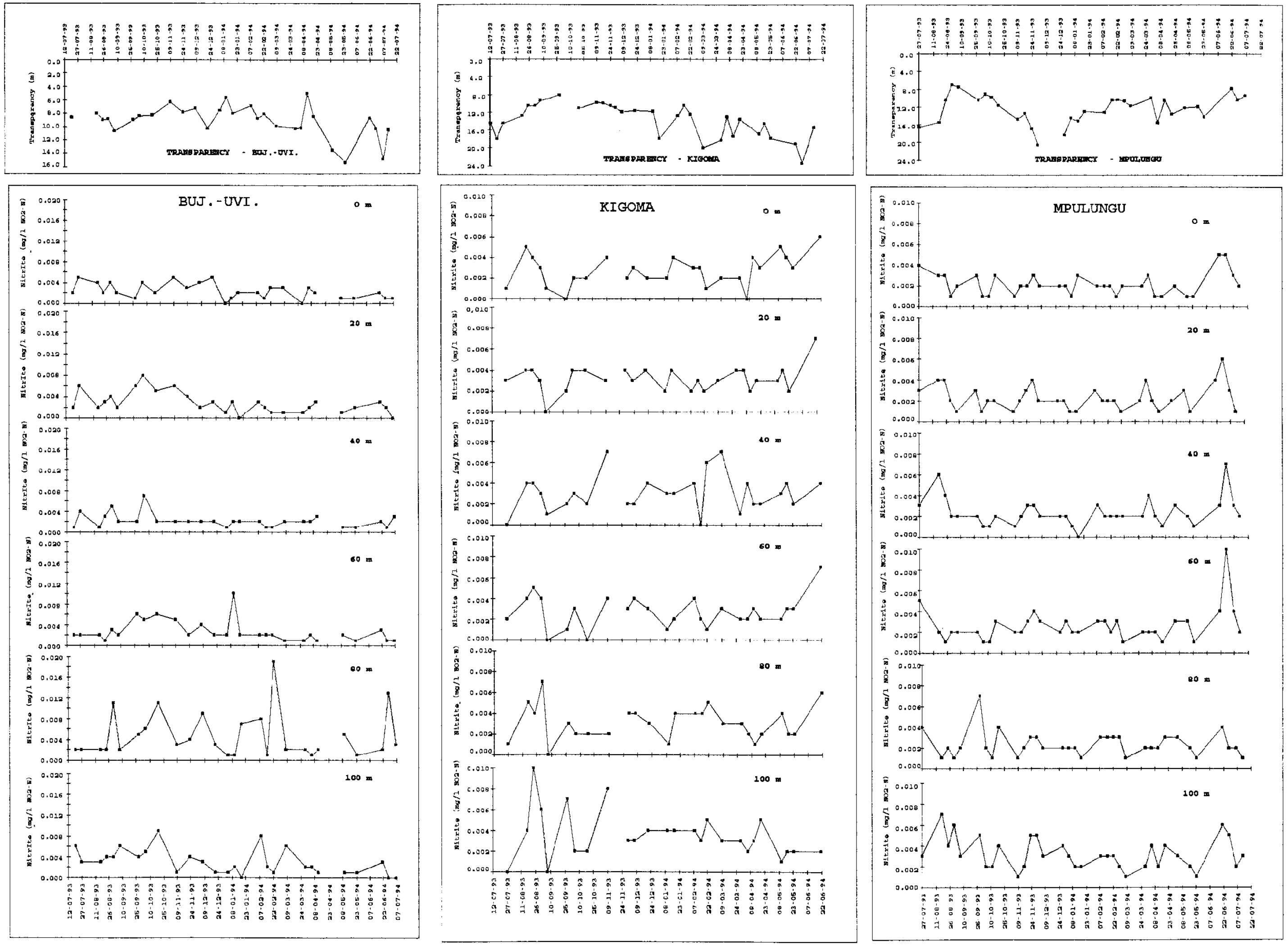


Fig. A.16.2. Fluctuations in nitrites (mg/l NO2-N) every 20 m from 0 to 100 m, and changes in transparency, at site A, Bujumbura/Uvira, Kigoma and Mpulungu, from August 1993 to July 1994.

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	0.002	0.003	0.004	0.002	0.003	0.002	0.002	0.003	0.003
	Av.	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.003	0.002
	St.d.	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.002	0.001
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.003	0.002
	Av.	0.003	0.004	0.003	0.003	0.003	0.002	0.003	0.003	0.002
	St.d.	0.002	0.003	0.002	0.002	0.001	0.001	0.002	0.002	0.001
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.003	0.002
	Av.	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.003	0.002
	St.d.	0.001	0.002	0.002	0.001	0.002	0.001	0.001	0.002	0.001
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	0.002	0.004	0.002	0.002	0.003	0.002	0.002	0.003	0.002
	Av.	0.002	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.003
	St.d.	0.001	0.002	0.003	0.002	0.001	0.001	0.002	0.002	0.002
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	0.002	0.004	0.002	0.004	0.003	0.002	0.002	0.003	0.002
	Av.	0.004	0.004	0.003	0.005	0.003	0.002	0.005	0.003	0.002
	St.d.	0.004	0.002	0.002	0.005	0.001	0.001	0.004	0.002	0.001
	N	11	9	10	18	19	24	29	28	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	0.003	0.004	0.005	0.002	0.003	0.003	0.002	0.003	0.004
	Av.	0.003	0.004	0.004	0.003	0.003	0.003	0.003	0.004	0.003
	St.d.	0.002	0.003	0.002	0.003	0.002	0.001	0.002	0.002	0.002
	N	11	9	10	18	19	24	29	28	34

Table A.16.1. Nitrite (mg/l NO2-N) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for depths of 0, 20, 40, 60, 80 and 100 m are given.

Source :	DF	F test	Pr > F	
Station (A)	2	2.87	0.0579	NS
Season (B)	1	10.72	0.0011	**
Depth (C)	5	3.16	0.008	**
AB	2	5.34	0.005	**
AC	10	2.17	0.0186	*
BC	5	0.31	0.9083	NS
ABC	10	0.4	0.9466	NS
Error	510			

Table A.16.2. ANOVA of nitrites measured every 20 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A), season (B) and depth (C). (NS: non significant, * = 0.05 $\geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$).

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.004	0.002
Av.	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003
St.d.	0.002	0.002	0.002	0.003	0.001	0.001	0.003	0.002	0.001
N	72	70	61	108	114	144	180	184	205

Table A.16.3. Nitrites (mg/l NO2-N) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for water column from 0 to 100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	NS	*	**

		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	NS	NS				
Rain season	Buj.	NS	NS	NS			
	Kig.	NS	NS	NS	NS		
	Mpu.	**	***	***	**	***	

Table A.16.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for nitrites, 0 to 100 m water column at site A, from August 1993 to July 1994. A = between stations and B = between seasons at each station. (NS: non significant, * = 0.05 $\geq p \geq 0.01$, ** = $0.01 \leq p > 0.001$ and *** = $p \leq 0.001$).

A.17 Ammonia

Mean concentrations of ammonia (NH_4-N) for the 0 to 100 m water column were 0.04 mg/l at Bujumbura/Uvira and 0.02 mg/l at Kigoma and Mpulungu (Table A.17.3). The value for Bujumbura/Uvira was significantly ($p<0.001$) higher (Tables A.17.2 and A.17.4). During the wet season means of NH4-N were 0.12 mg/l at Bujumbura/Uvira compared to 0.01 in mg/l at Kigoma and Mpulungu. Medians and percentiles of ammonia (Fig. A.2.1) indicated that higher values of ammonia were recorded more frequently at Bujumbura/Uvira. The maximum value there was 0.37 mg/l NH4-N on 1 January 1994 at 100 m. Concentrations at 100 m were statistically ($p<0.05$ to <0.001 depending of the depth considered) different from all other depths at all stations (Table C.9). Ammonia concentrations increased in the anoxic zone.

Fluctuations of ammonia were similar to those of nitrites (Fig. A.16.1). Ammonia concentrations were significantly different ($p<0.01$) between seasons in the water column from 0 to 100 m only at Kigoma where 0.01 mg/l NH4-N was recorded during the wet season and 0.04 mg/l NH4-N during the dry season (Table A.17.3 and A.17.4). During the dry season there were significant differences ($p<0.001$) in concentrations between Bujumbura/Uvira, 0.05 mg/l NH4-N, and Mpulungu, 0.01 mg/l NH4-N which probably reflected differences in oxygenation in the upper layers at these stations. In September and October 1993 isopleths of ammonia indicated higher values in the epilimnion at Bujumbura/Uvira (Fig. A.17.1). There was no precipitation at the time. Isopleths at Kigoma and Mpulungu at site A (Fig. A.17.1) fluctuated irregularly during the year probably resulting from local mixing or precipitation. Ammonia in the upper layers was detected following mixing or precipitation before it was absorbed by organisms or converted to nitrite and nitrate.

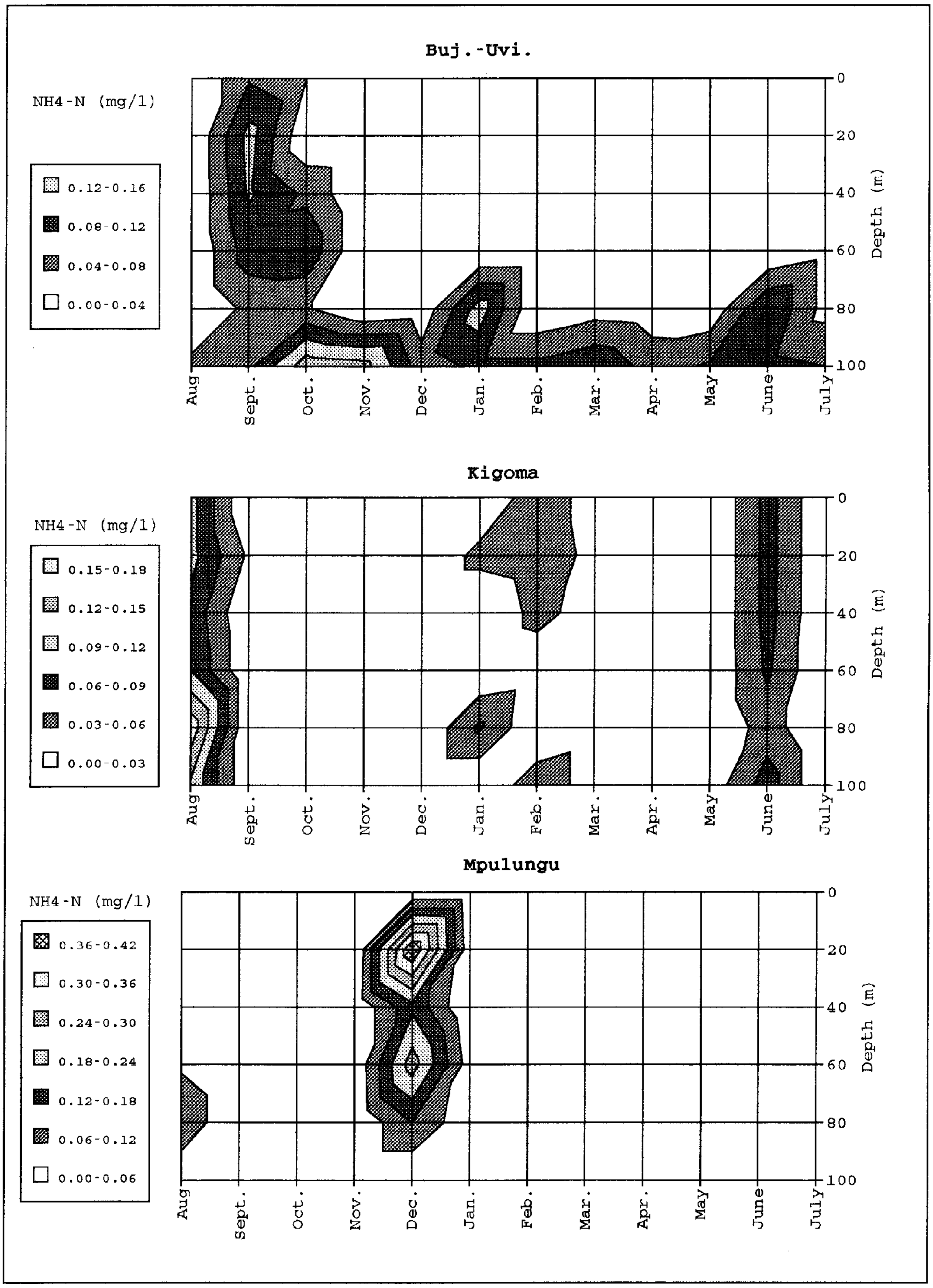


Fig. A.17.1. Isopleths of ammonia NH3-N (mg/l) measured at sites A (0 to 100 m), Bujumbura/Uvira, Kigoma and Mpulungu, from August 1993 to July 1994.

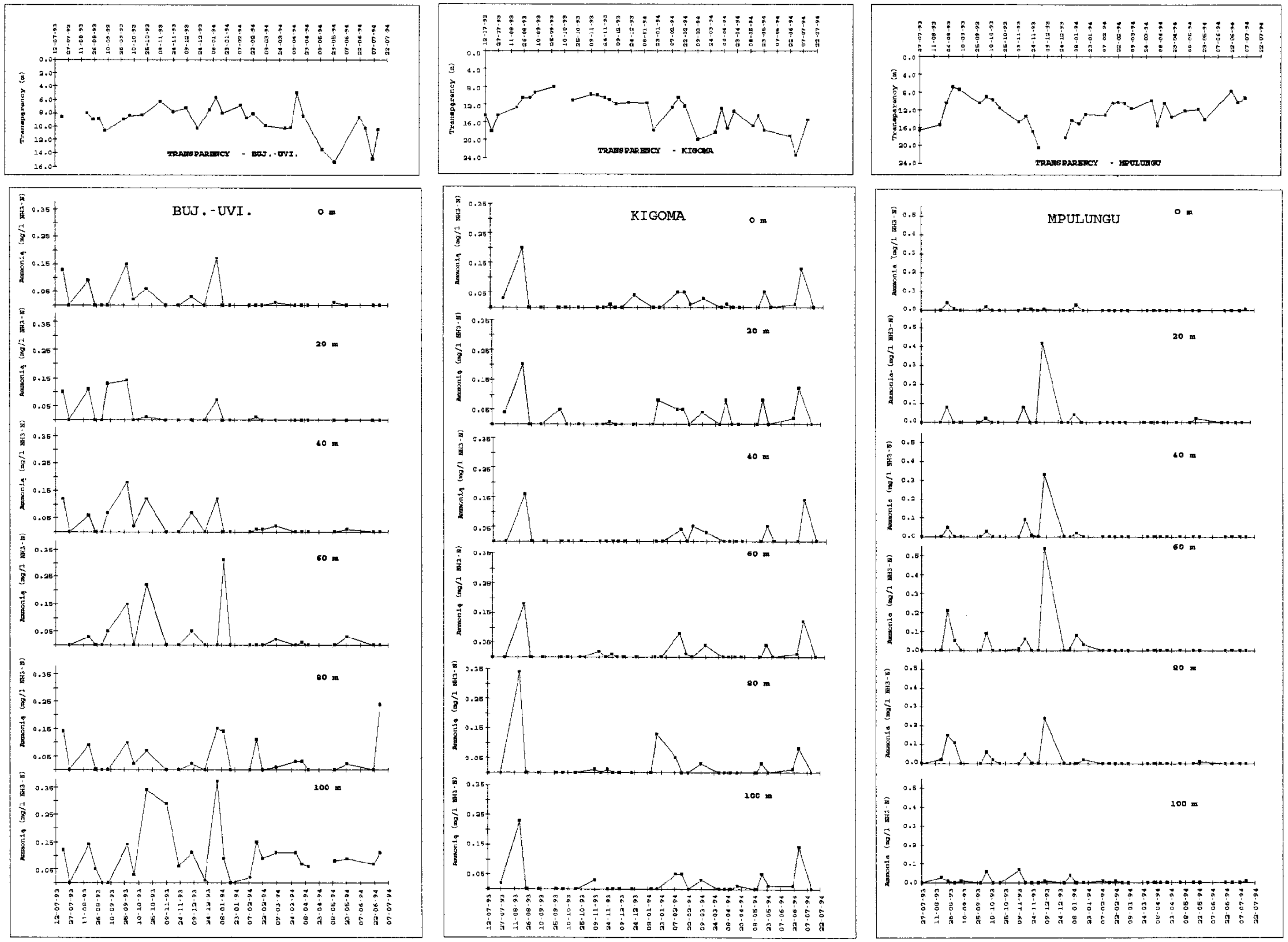


Fig. A.17.2. Fluctuations in ammonia (mg/l NH3-N) every 20 m from 0 to 100 m, and changes in transparency, at site A, Bujumbura/Uvira, Kigoma and Mpulungu, from August 1993 to July 1994.

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
0	Median	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Av.	0.03	0.05	0.01	0.02	0.01	0,00	0.02	0.02	0,00
	St.d.	0.06	0.08	0.01	0.04	0.02	0.01	0.05	0.04	0.01
	N	11	8	10	18	21	24	29	29	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
20	Median	0.00	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
	Av.	0.04	0.05	0.01	0.01	0.02	0.02	0.02	0.03	0.02
	St.d.	0.06	0.07	0.03	0.02	0.03	0.09	0.04	0.05	0.07
	N	11	8	10	18	21	24	29	29	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
40	Median	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	Av.	0.04	0.04	0.01	0.02	0.01	0.02	0.03	0.02	0.02
	St.d.	0.06	0.07	0.02	0.04	0.02	0.07	0.05	0.04	0.06
	N	11	8	10	18	21	24	29	29	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
60	Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Av.	0.03	0.04	0.03	0.04	0.01	0.03	0.03	0.02	0.03
	St.d.	0.05	0.07	0.07	0.09	0.02	0.11	0.07	0.04	0.10
	N	10	8	10	18	21	24	28	29	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
80	Median	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00
	Av.	0.06	0.05	0.03	0.03	0.01	0.02	0.04	0.02	0.02
	St.d.	0.08	0.12	0.05	0.05	0.03	0.05	0.06	0.07	0.05
	N	11	8	10	18	21	24	29	29	34

Depth		Dry season			Rain season			Year		
	Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
100	Median	0.07	0.01	0.00	0.09	0.00	0.00	0.09	0.00	0.00
	Av.	0.07	0.05	0.01	0.12	0.01	0.01	0.1	0.02	0.01
	St.d.	0.05	0.09	0.01	0.11	0.02	0.02	0.09	0.05	0.02
	N	11	8	10	18	20	24	29	28	34

Table A.17.1. Ammonia (mg/l NH_3-N) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for depths of 0, 20, 40, 60, 80 and 100 m are given.

Source :	DF	F test	Pr > F	
Station (A)	2	8.27	0.0003	***
Season (B)	1	5.30	0.0217	*
Depth (C)	5	1.80	0.1106	NS
AB	2	4.62	0.0103	*
AC	10	2.36	0.0098	**
BC	5	0.60	0.702	NS
ABC	10	0.68	0.7443	NS
Error	514			

Table A.17.2. ANOVA of ammonia measured every 20 m, 0 to 100 m, at site A, 1993-1994. Variables were station (A), season (B) and depth (C). (NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001).

	Dry season			Rain season			Year		
Station	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Av.	0.05	0.04	0.01	0.04	0.01	0.02	0.04	0.02	0.02
St.d.	0.06	0.07	0.04	0.07	0.02	0.07	0.07	0.05	0.06
N	69	57	61	108	125	144	177	182	205

Table A.17.3. Ammonia (mg/l NH3-N) measured at site A (0900-1000 h), Bujumbura/Uvira, Kigoma and Mpulungu, August 1993 to July 1994. Medians, means, standard deviations and number of observations for water column from 0 to 100 m are given.

A.	Buj./Kig.	Buj./Mpu.	Kig./Mpu.
Year	***	***	NS

		Dry season			Rain season		
		Buj.	Kig.	Mpu.	Buj.	Kig.	Mpu.
Dry season	Buj.						
	Kig.	NS					
	Mpu.	***	*				
Rain season	Buj.	NS	NS	*			
	Kig.	***	**	NS	***		
	Mpu.	***	*	NS	**	NS	

Table A.17.4. Comparison between means by least significant difference (Sokal and Rohlf, 1995) for ammonia, 0 to 100 m water column at site A, from August 1993 to July 1994. A = between stations and B = between seasons at each station. (NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001).

APPENDIX B

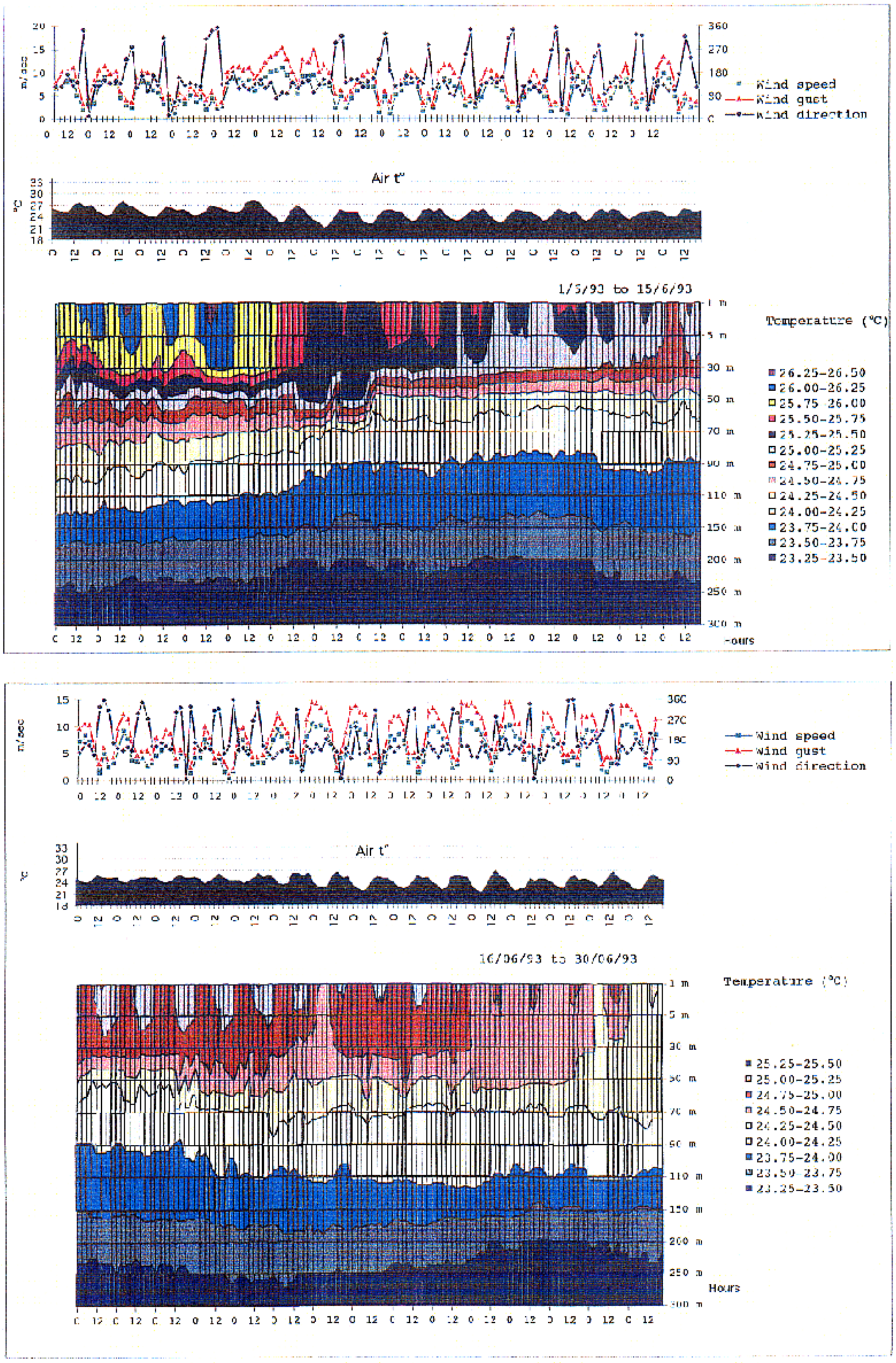


Fig. B.1. Isopleths of temperature (°C) every 3 hours in June 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

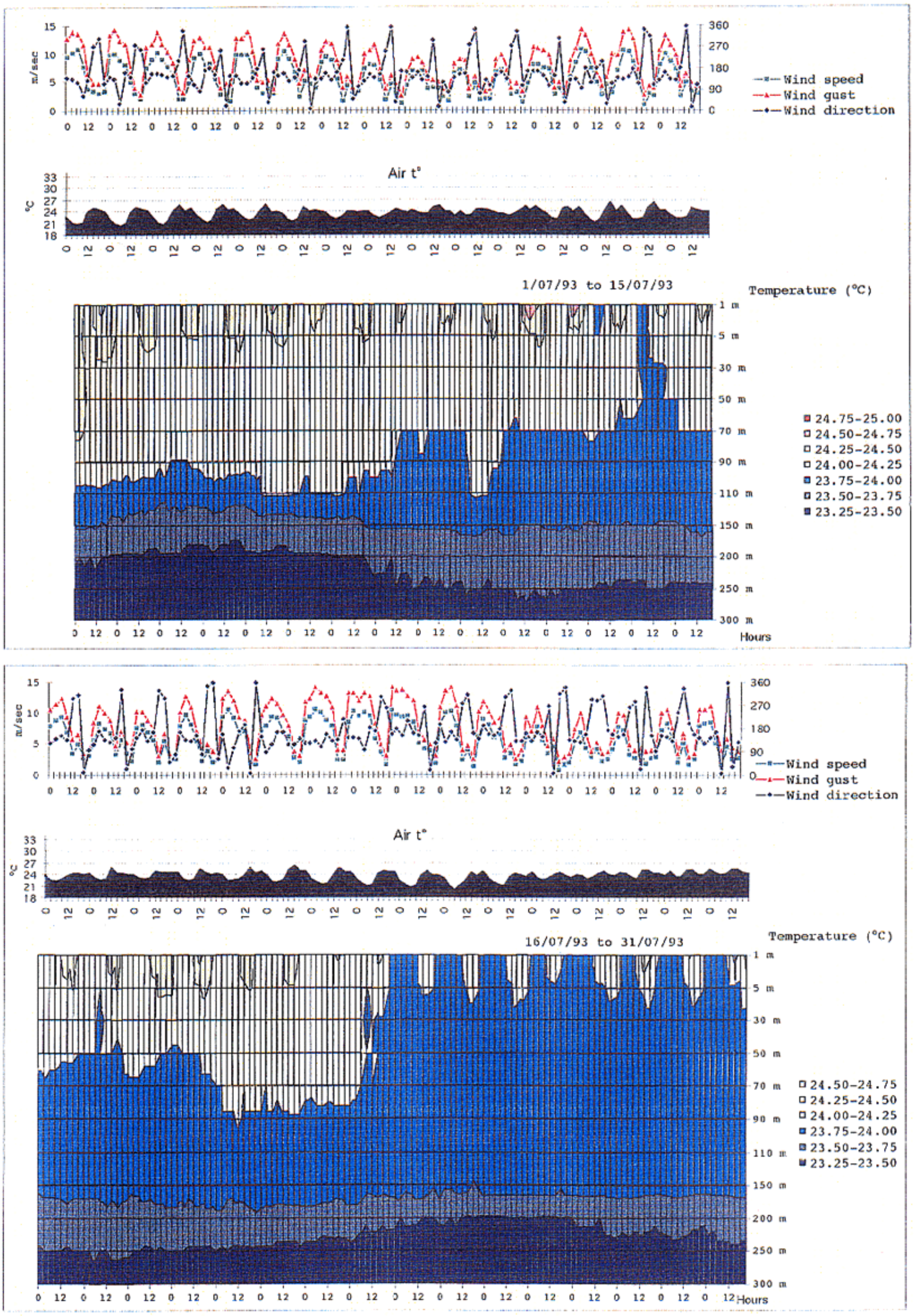


Fig. B.2. Isopleths of temperature (°C) every 3 hours in July 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

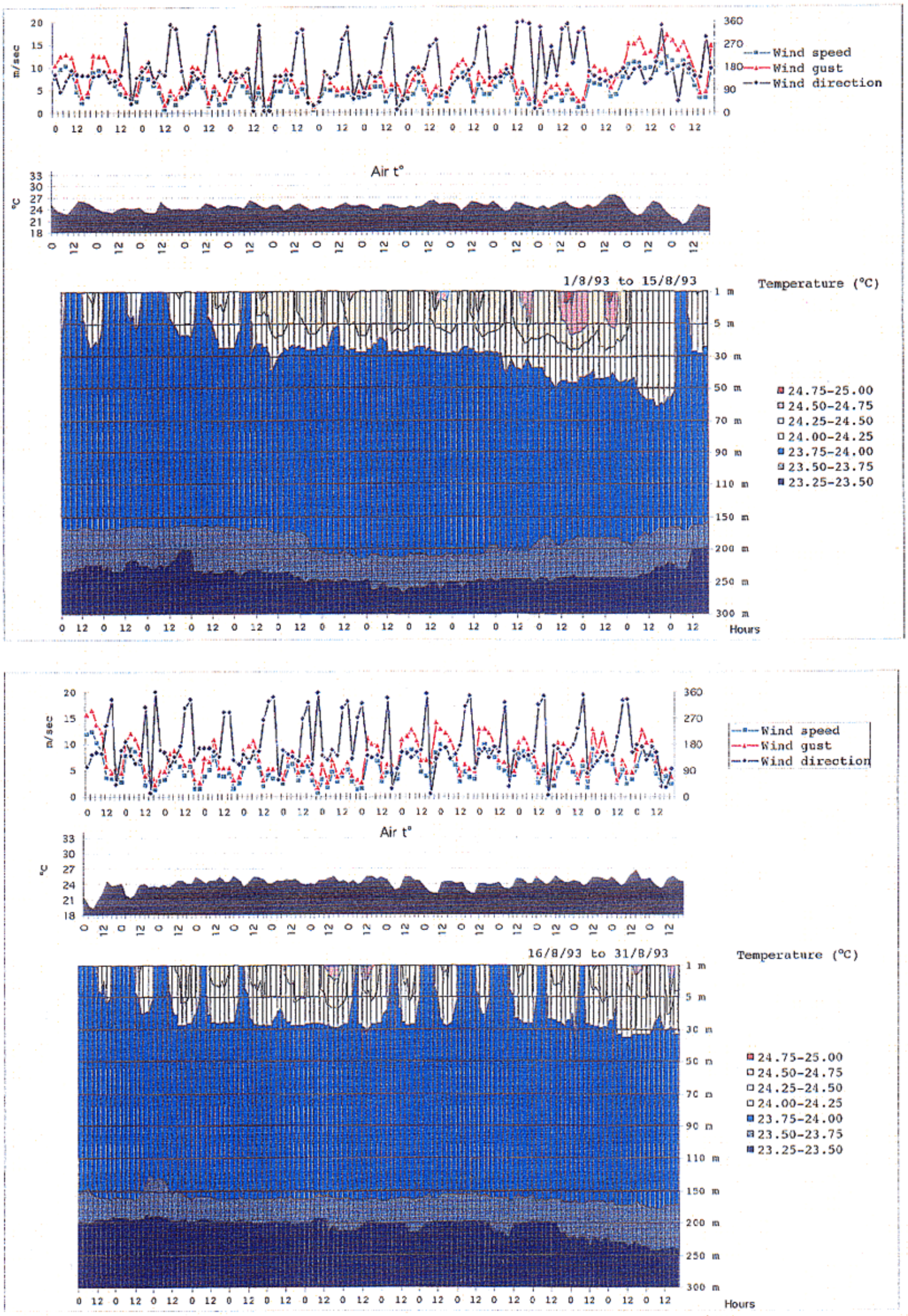


Fig. B.3. Isopleths of temperature (°C) every 3 hours in August 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

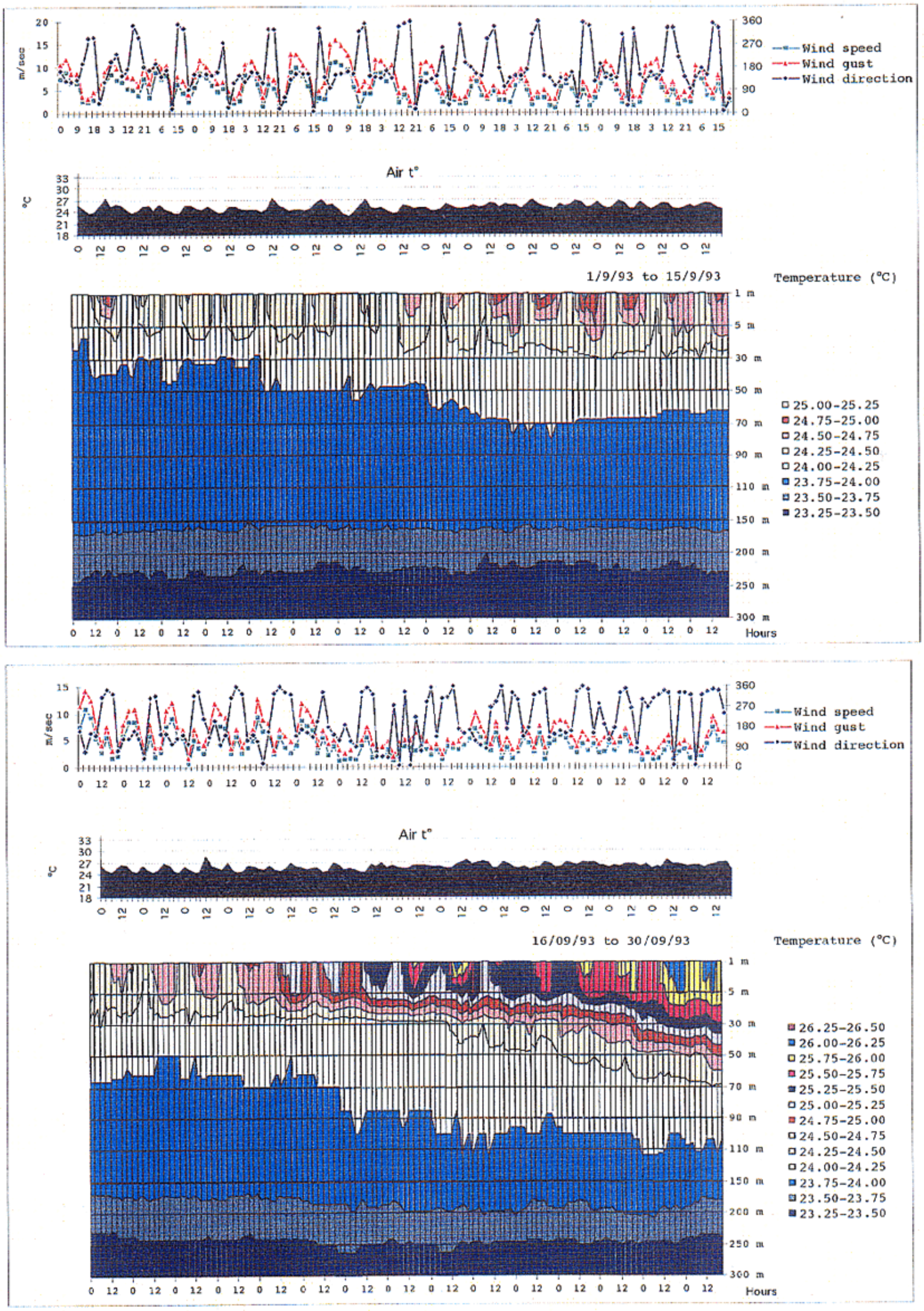


Fig. B.4. Isopleths of temperature (°C) every 3 hours in September 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

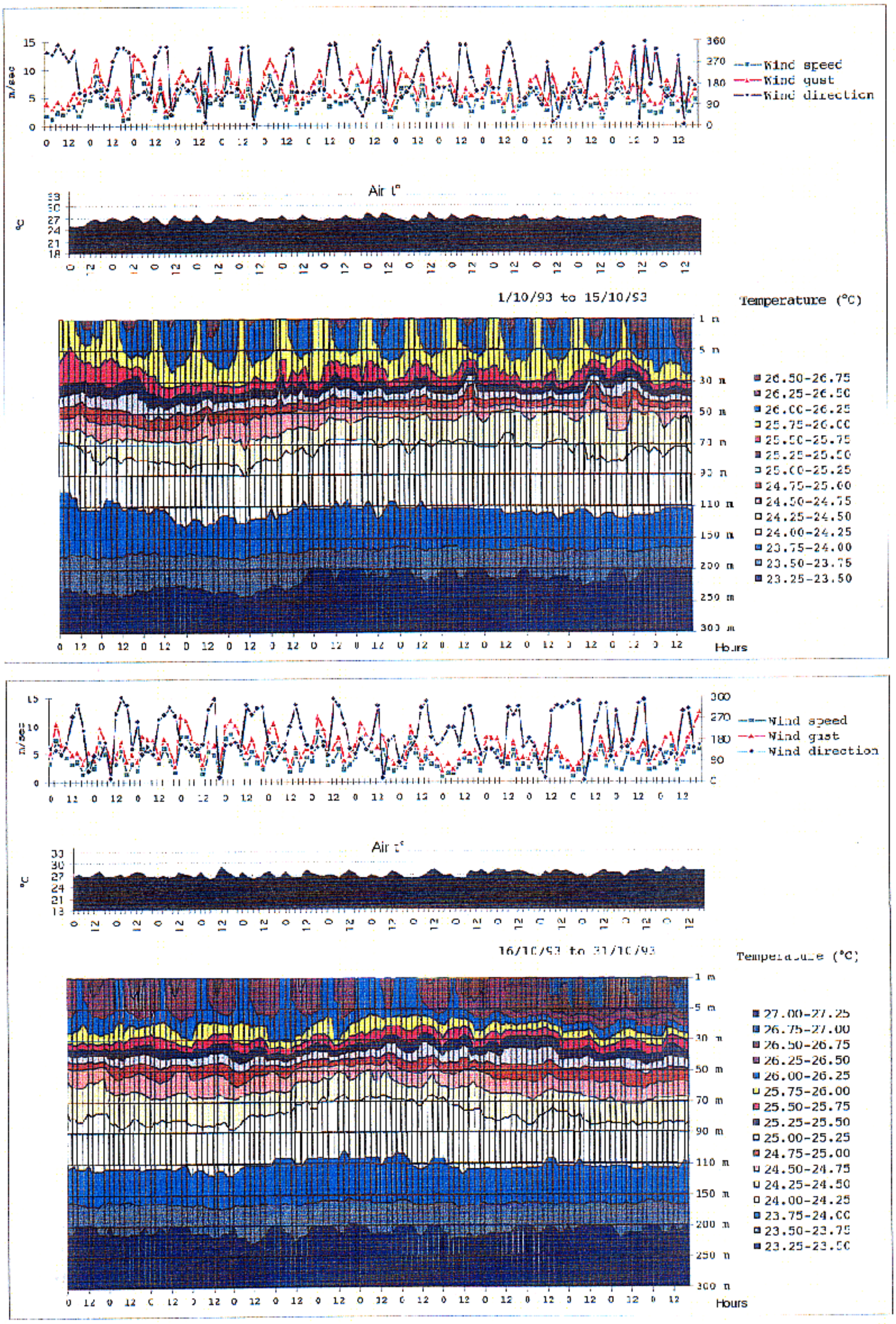


Fig. B.5. Isopleths of temperature (°C) every 3 hours in October 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

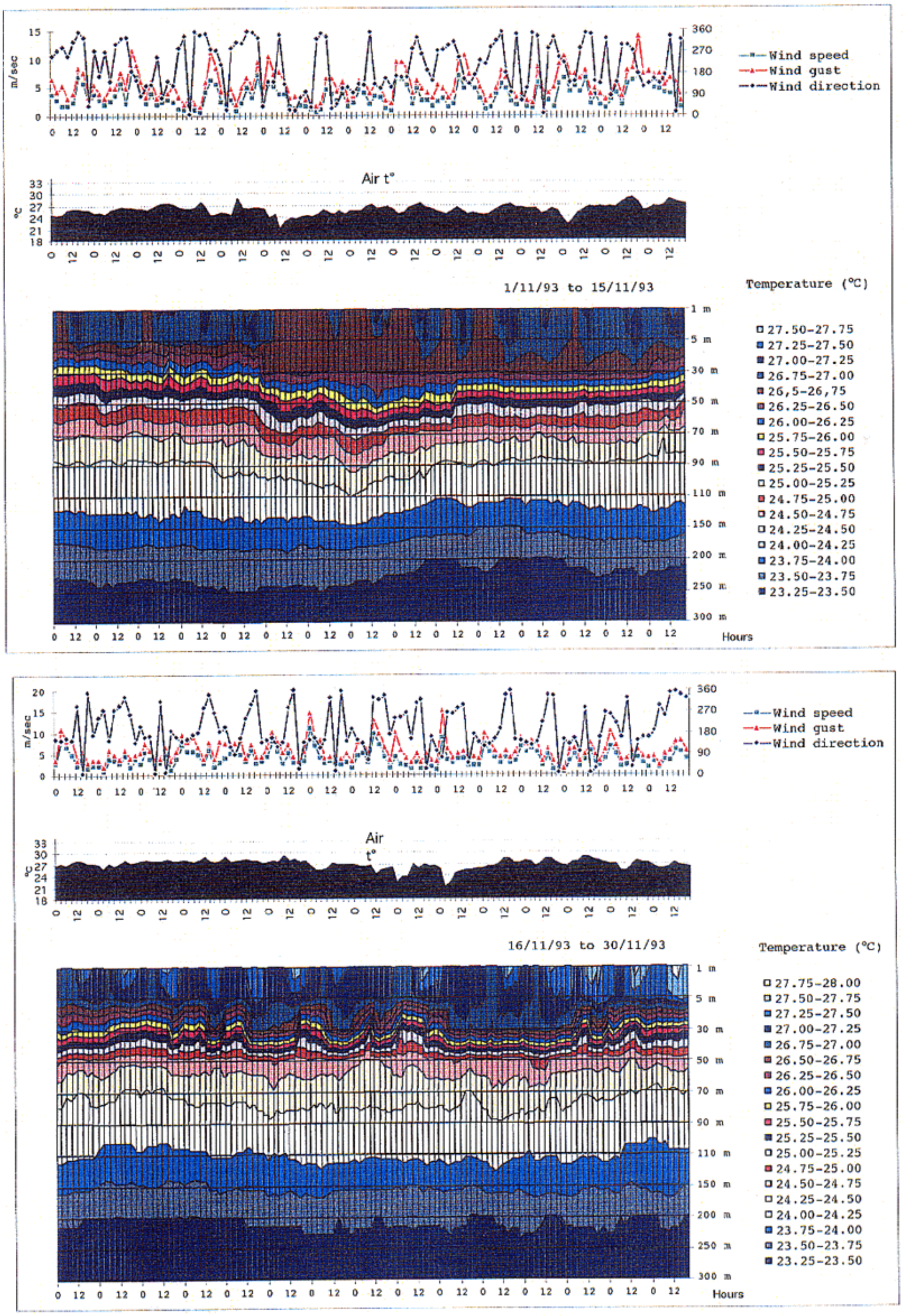


Fig. B.6. Isopleths of temperature (°C) every 3 hours in November 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

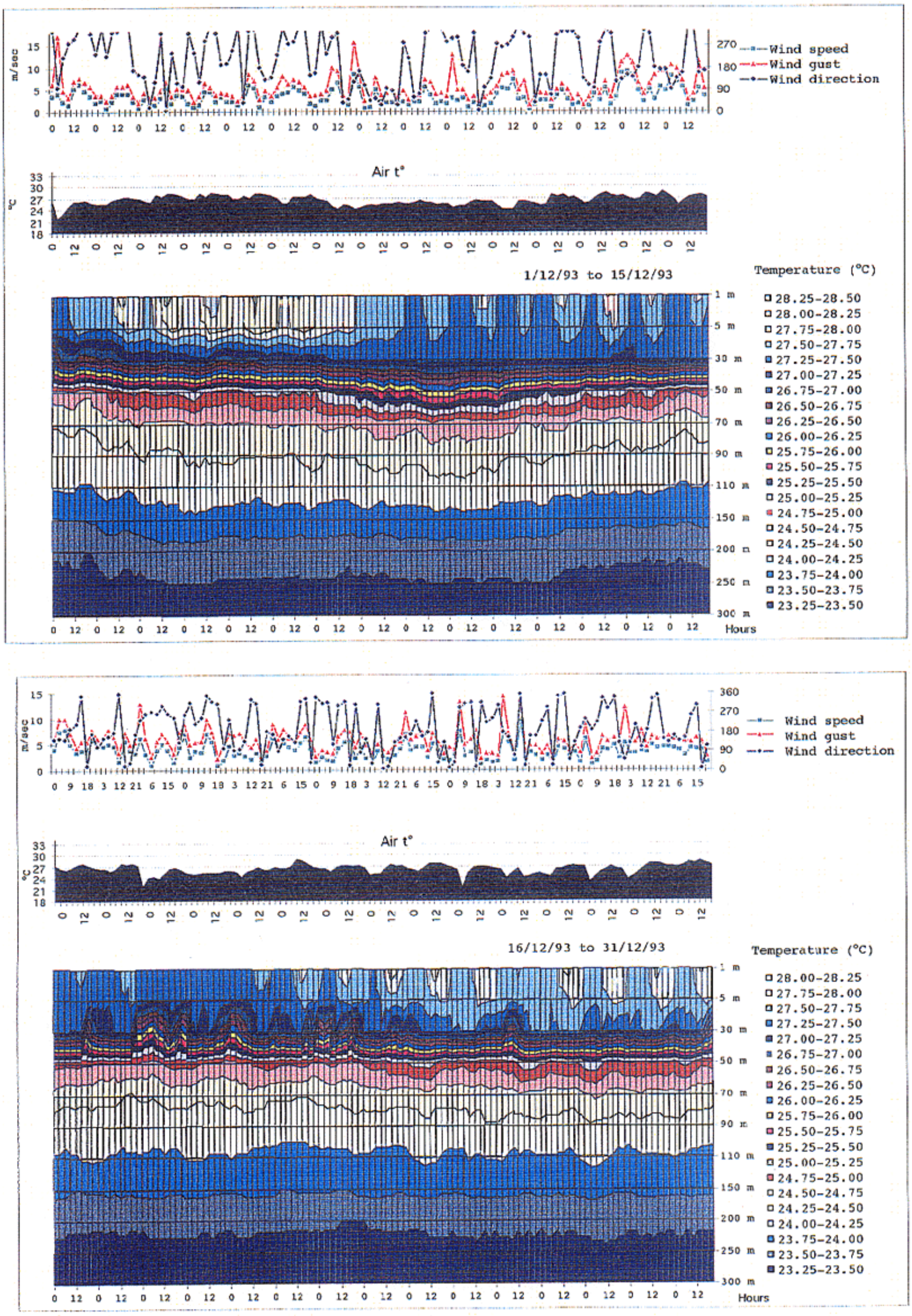


Fig. B.7. Isopleths of temperature (°C) every 3 hours in December 1993 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

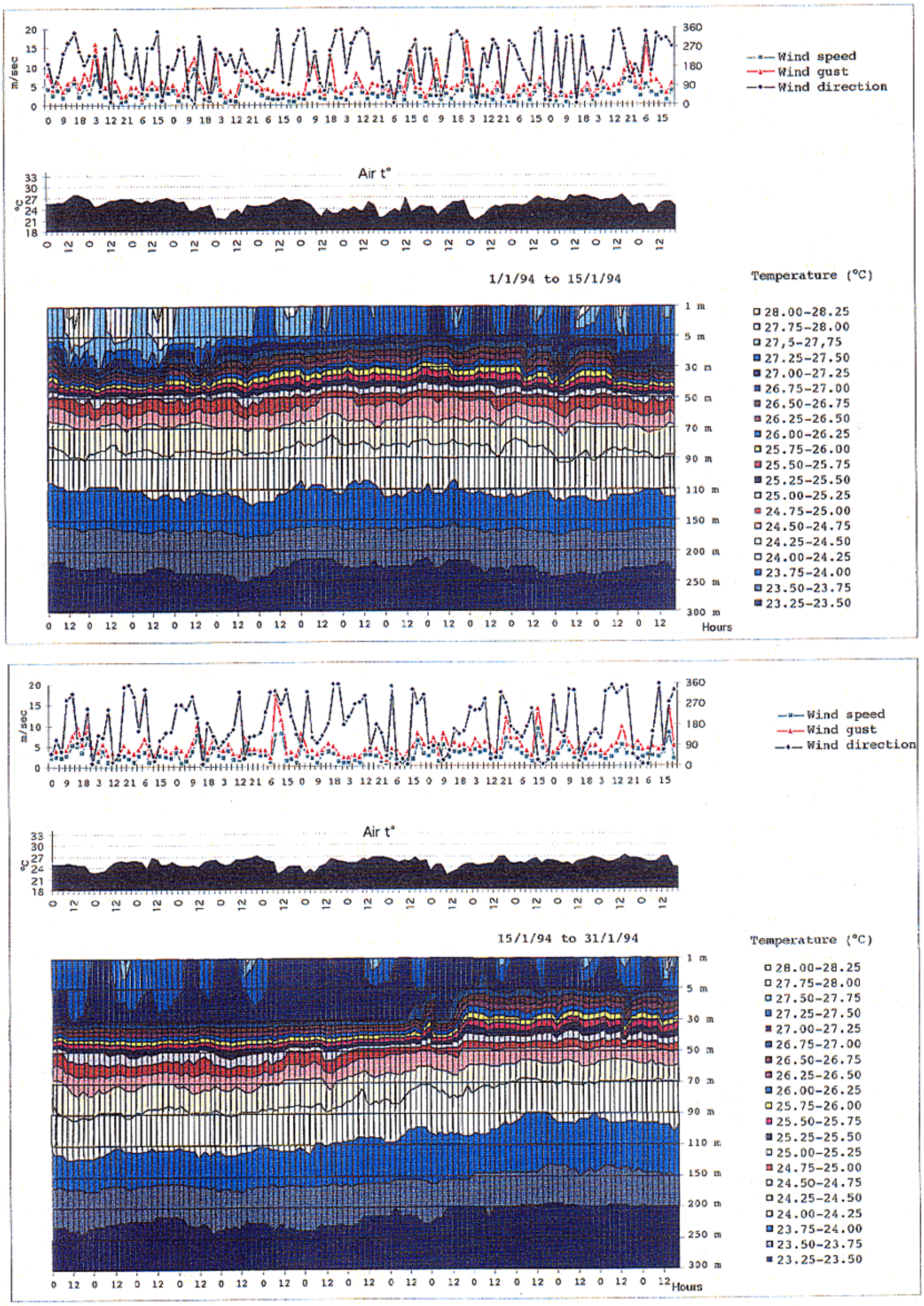


Fig. B.8. Isopleths of temperature (°C) every 3 hours in January 1994 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

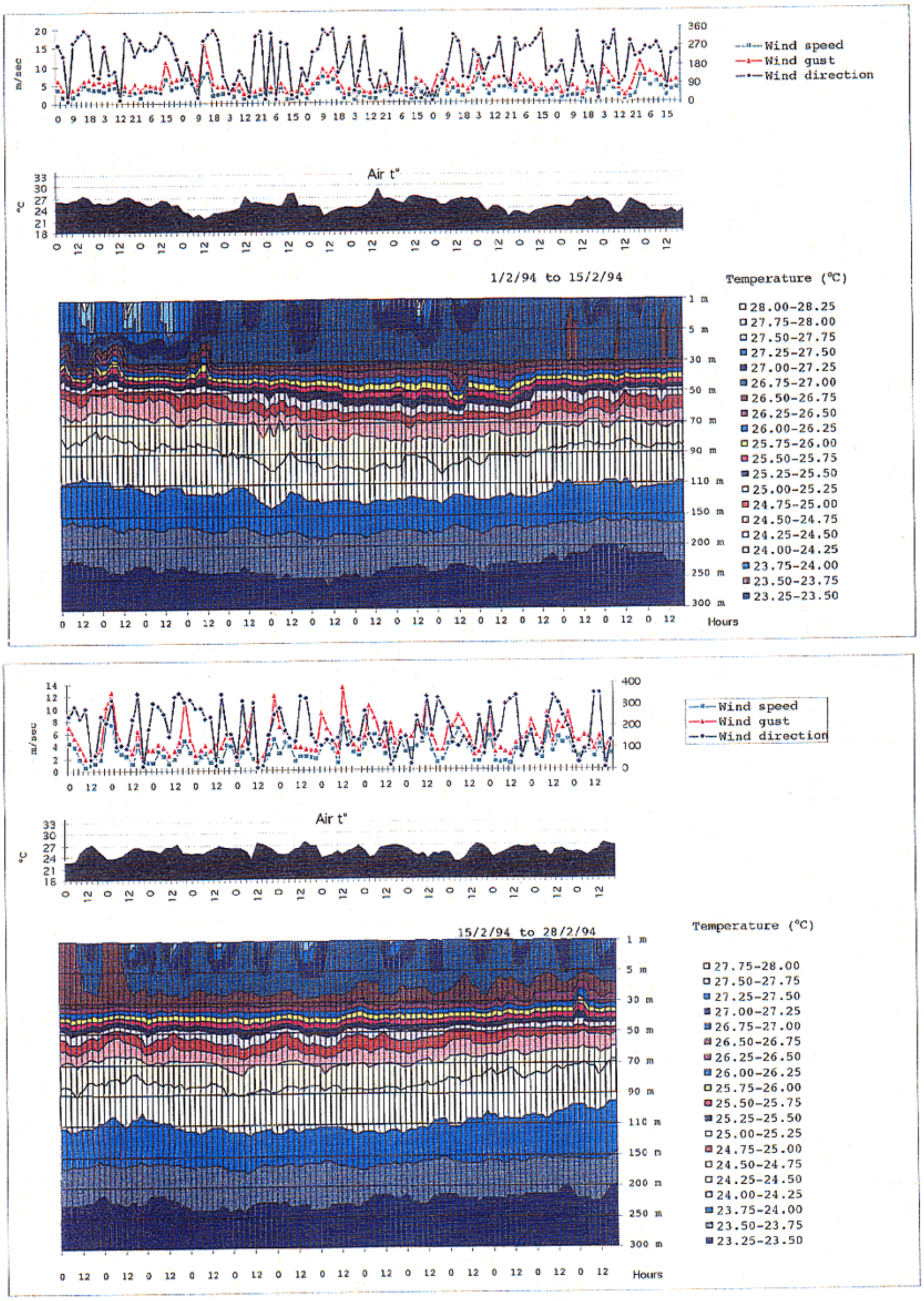


Fig. B.9. Isopleths of temperature (°C) every 3 hours in February 1994 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

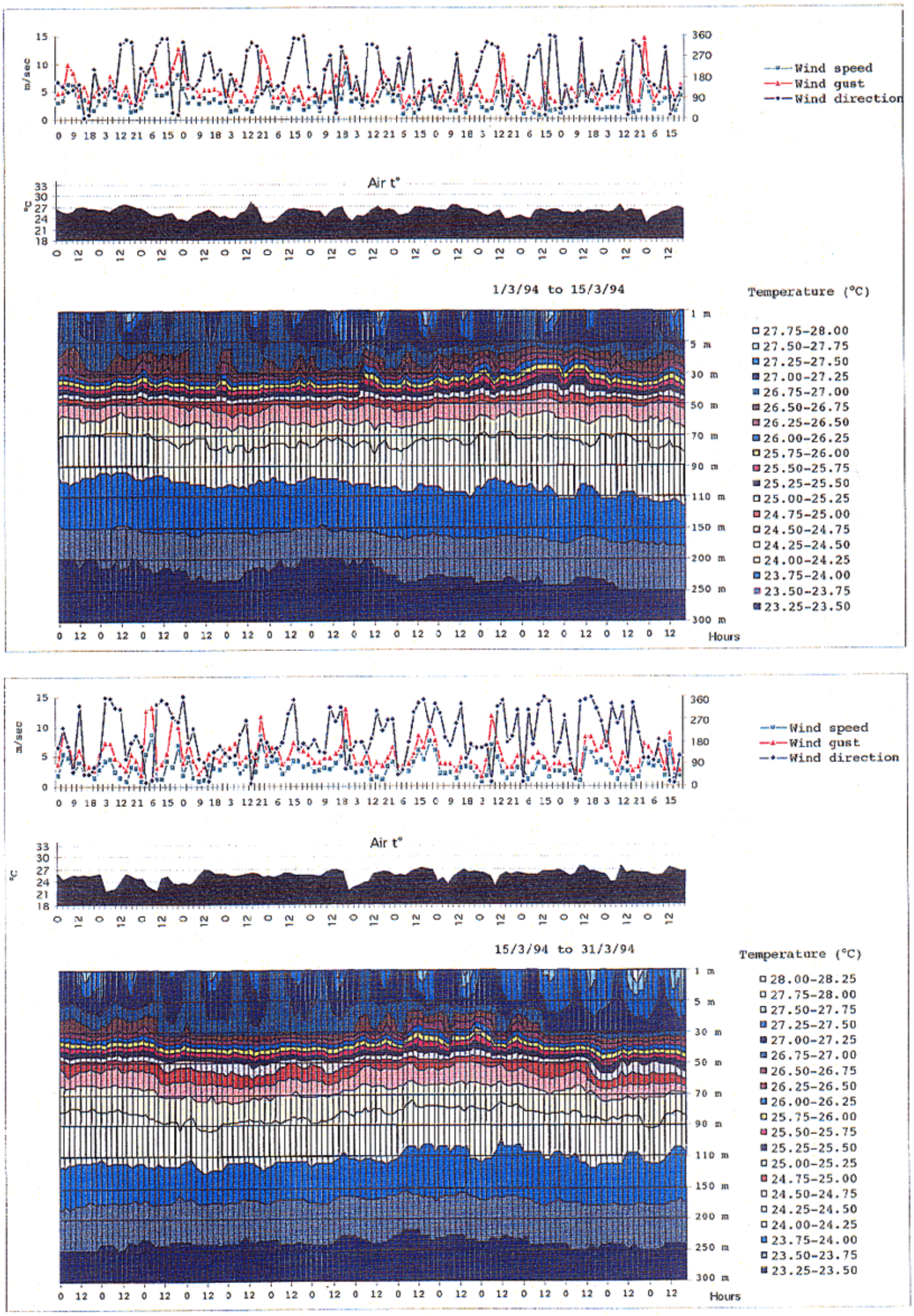


Fig. B.10. Isopleths of temperature (°C) every 3 hours in March 1994 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

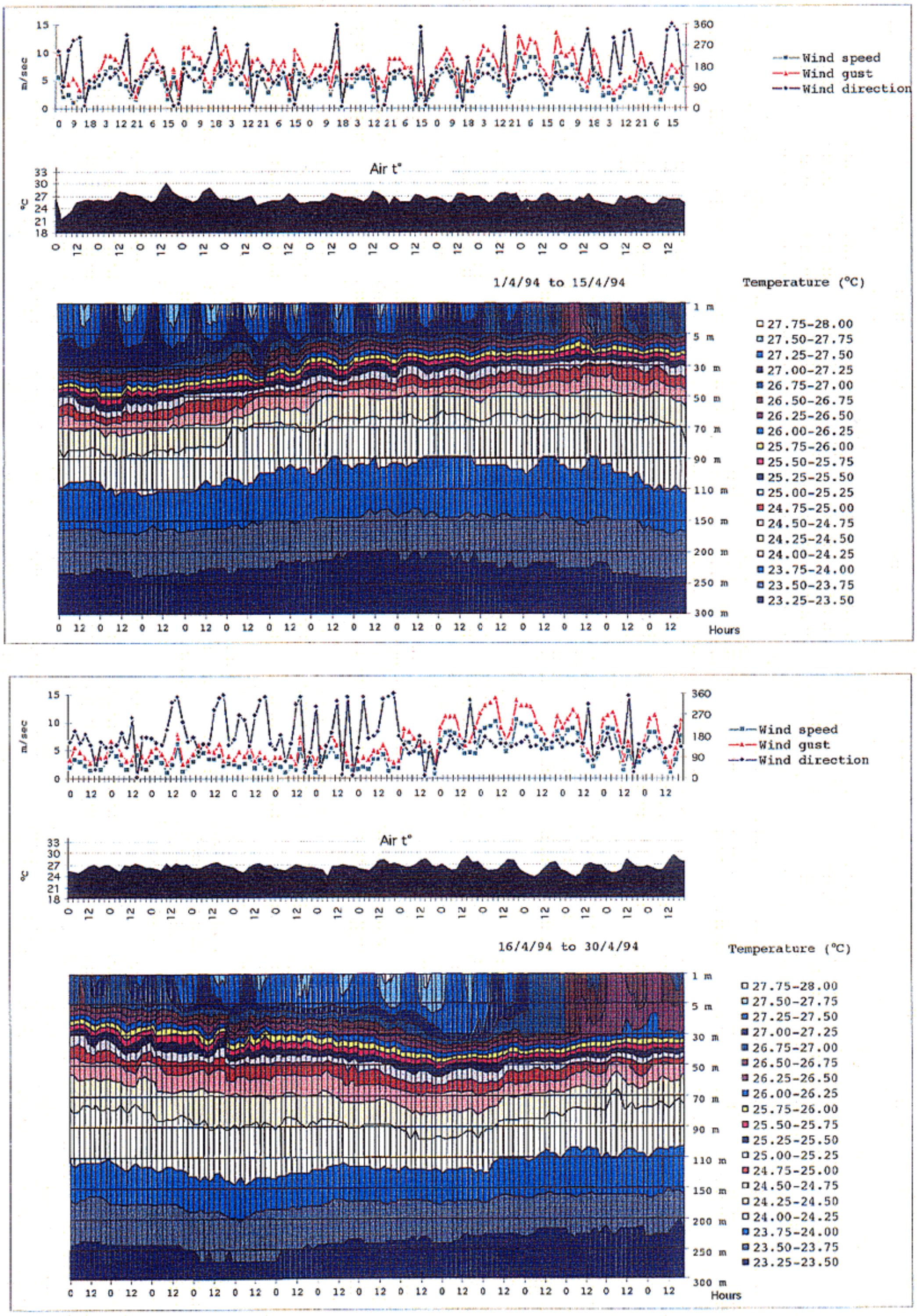


Fig. B.11. Isopleths of temperature (°C) every 3 hours in April 1995 at 11 depth by a thermistor chain in the southern part of Lake Tanganyika. Wind speed (m/s), wind gust (m/s), wind direction and air temperature (°C) are shown.

APPENDIX C

Station sites		
Buj.- Uvi.	Kigoma	Mpulungu
17-08-93	17-08-93	17-08-93
24-08-93	24-08-93	24-08-93
31-08-93	01-09-93	31-08-93
07-09-93	07-09-93	07-09-93
28-09-93	28-09-93	28-09-93
05-10-93	05-10-93	05-10-93
-	-	12-10-93
19-10-93	19-10-93	19-10-93
09-11-93	09-11-93	09-11-93
-	16-11-93	16-11-93
23-11-93	24-11-93	23-11-93
-	30-11-93	30-11-93
07-12-93	07-12-93	07-12-93
21-12-93	21-12-93	28-12-93
04-01-94	-	04-01-94
11-01-94	11-01-94	11-01-94
18-01-94	18-01-94	18-01-94
08-02-94	08-02-94	08-02-94
15-02-94	15-02-94	16-02-94
22-02-94	22-02-94	22-02-94
-	-	01-03-94
08-03-94	09-03-94	08-03-94
29-03-94	29-03-94	29-03-94
05-04-94	05-04-94	05-04-94
12-04-94	12-04-94	12-04-94
19-04-94	19-04-94	19-04-94
-	-	03-05-94
10-05-94	11-05-94	-
-	17-05-94	17-05-94
24-05-94	24-05-94	24-05-94
21-06-94	21-06-94	21-06-94
28-06-94	28-06-94	28-06-94
06-07-94	-	06-07-94
12-07-94	12-07-94	13-07-94

Table C.1. Dates of sampling at site A of Bujumbura/Uvira, Kigoma and Mpulungu.

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	***	***	***	**																																
DB100	***	***	***	***	**																															
RB00	NS	**	**	***	***	***																														
RB20	NS	**	*	**	***	***	NS																													
RB40	NS	NS	NS	NS	***	***	*	NS																												
RB60	***	***	***	***	NS	NS	***	***	***																											
RB80	***	***	***	***	***	NS	***	***	***	**																										
RB100	***	***	***	***	***	NS	***	***	***	***	NS																									
DK00	NS	NS	NS	NS	***	***	NS	NS	NS	***	***	***																								
DK20	NS	NS	NS	NS	***	***	*	NS	NS	***	***	***	NS																							
DK40	NS	NS	NS	NS	***	***	*	NS	NS	***	***	***	NS	NS																						
DK60	NS	NS	NS	NS	**	***	**	*	NS	***	***	***	NS	NS	NS																					
DK80	***	**	**	*	NS	**	***	***	***	NS	***	***	***	***	***	**																				
DK100	***	***	***	***	*	NS	***	***	***	NS	NS	*	***	***	***	***	**																			
RK00	***	***	***	***	***	***	*	*	***	***	***	***	**	***	***	***	***	***																		
RK20	**	***	***	***	***	***	NS	NS	***	***	***	***	*	**	**	***	***	***	NS																	
RK40	NS	NS	NS	NS	***	***	*	NS	NS	***	***	***	NS	NS	NS	NS	***	***	***	***																
RK60	***	***	***	***	NS	**	***	***	***	NS	***	***	***	***	***	***	NS	**	***	***	***															
RK80	***	***	***	***	**	NS	***	***	***	NS	NS	**	***	***	***	***	***	NS	***	***	***	***														
RK100	***	***	***	***	***	NS	***	***	***	***	NS	NS	***	***	***	***	***	NS	***	***	***	***	NS													
DM00	***	***	***	***	***	NS	***	***	***	**	NS	NS	***	***	***	***	***	NS	***	***	***	***	NS	NS												
DM20	***	***	***	***	***	NS	***	***	***	**	NS	NS	***	***	***	***	***	NS	***	***	***	***	NS	NS	NS											
DM40	***	***	***	***	***	NS	***	***	***	***	NS	NS	***	***	***	***	***	NS	***	***	***	***	NS	NS	NS	NS										
DM60	***	***	***	***	***	NS	***	***	***	**	NS	NS	***	***	***	***	***	NS	***	***	***	***	NS	NS	NS	NS	NS									
DM80	***	***	***	***	***	*	***	***	***	***	NS	NS	***	***	***	***	***	**	***	***	***	***	**	NS	NS	NS	NS	NS								
DM100	***	***	***	***	***	**	***	***	***	***	*	NS	***	***	***	***	***	**	***	***	***	***	***	NS	NS	NS	NS	NS	NS							
RM00	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	**	***	***	***	***	***	***	***	***	***	***	***						
RM20	***	***	***	***	***	***	*	**	***	***	***	***	**	***	***	***	***	***	NS	NS	***	***	***	***	***	***	***	***	***	***	**					
RM40	*	NS	NS	NS	**	***	***	***	*	***	***	***	**	*	NS	NS	*	***	***	***	**	***	***	***	***	***	***	***	***	***	***	***				
RM60	***	***	***	***	NS	NS	***	***	***	NS	**	***	***	***	***	***	*	NS	***	***	***	*	NS	***	*	**	**	**	***	***	***	***	***			
RM80	***	***	***	***	***	NS	***	***	***	***	NS	NS	***	***	***	***	***	NS	***	***	***	***	*	NS	NS	NS	NS	NS	NS	NS	***	***	***	***		
RM100	***	***	***	***	***	NS	***	***	***	***	NS	NS	***	***	***	***	***	*	***	***	***	***	**	NS	NS	NS	NS	NS	NS	NS	***	***	***	***	NS	

Table C. 2. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for temperature (°C) (D = dry season, R = rain season, B = Buj.-Uvi., K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.4.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	NS	NS	NS	NS																																
DB100	NS	NS	NS	NS	NS																															
RB00	NS	NS	NS	NS	NS	NS																														
RB20	NS	NS	NS	NS	NS	NS	NS																													
RB40	*	*	*	**	**	*	NS	*																												
RB60	NS	NS	NS	NS	NS	NS	*	NS	***																											
RB80	NS	NS	NS	NS	NS	NS	*	NS	***	NS																										
RB100	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS																									
DK00	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS																								
DK20	NS	NS	NS	NS	NS	NS	*	NS	**	NS	NS	NS	NS																							
DK40	NS	NS	NS	NS	NS	NS	*	NS	***	NS	NS	NS	NS	NS																						
DK60	*	NS	NS	NS	NS	*	**	**	***	NS	NS	**	NS	NS	NS																					
DK80	*	*	*	NS	NS	*	***	**	***	NS	NS	**	NS	NS	NS	NS																				
DK100	***	**	**	**	*	**	***	***	***	**	**	***	*	*	NS	NS	NS																			
RK00	NS	NS	NS	NS	NS	NS	*	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	**																		
RK20	NS	NS	NS	NS	NS	NS	*	NS	***	NS	NS	*	NS	NS	NS	NS	NS	*	NS																	
RK40	*	NS	NS	NS	NS	NS	***	**	***	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS																
RK60	**	*	*	*	NS	**	***	***	***	*	*	***	NS	NS	NS	NS	NS	NS	*	NS	NS															
RK80	**	**	*	*	*	**	***	***	***	*	*	***	*	NS	NS	NS	NS	NS	*	*	NS	NS														
RK100	***	**	**	**	*	**	***	***	***	*	**	***	*	NS	NS	NS	NS	NS	**	*	NS	NS	NS													
DM00	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	*	*	**	***	***	*	*	**	***	***	***												
DM20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	***	NS	NS	*	***	***	***	NS											
DM40	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	*	*	**	NS	NS	NS	**	**	**	NS	NS										
DM60	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	*	**	NS	NS	NS	*	**	**	NS	NS	NS									
DM80	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	*	NS	NS	NS	NS								
DM100	NS	NS	NS	NS	NS	NS	*	NS	***	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS							
RM00	NS	NS	NS	*	*	NS	NS	NS	NS	**	**	NS	*	*	**	***	***	***	**	**	***	***	***	***	NS	NS	NS	NS	*	**						
RM20	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	*	**	***	***	*	**	***	***	***	***	NS	NS	NS	NS	NS	*	NS					
RM40	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	*	**	NS	NS	NS	**	**	***	NS	NS	NS	NS	NS	NS	*	NS				
RM60	NS	NS	NS	NS	NS	NS	**	*	***	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	**	*	NS	NS	NS	NS	***	**	NS			
RM80	NS	NS	NS	NS	NS	NS	**	*	***	NS	NS	**	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	**	*	NS	NS	NS	NS	***	**	NS	NS		
RM100	NS	NS	NS	NS	NS	NS	**	*	***	NS	NS	**	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	**	*	NS	NS	NS	NS	***	**	NS	NS	NS	

Table C.3. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for turbidity (NTU) (D = dry season, R = rain season, B = Buj.-Uvi., K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.9.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	*	NS																																	
DB80	***	***	**	*																																
DB100	***	***	***	**	NS																															
RB00	***	***	*	NS	NS	NS																														
RB20	**	***	NS	NS	NS	*	NS																													
RB40	***	***	**	*	NS	NS	NS	NS																												
RB60	***	***	***	**	NS	NS	NS	*	NS																											
RB80	***	***	***	***	*	NS	***	***	**	*																										
RB100	***	***	***	***	***	**	***	***	***	***	NS																									
DK00	NS	NS	NS	NS	***	***	**	*	***	***	***	***																								
DK20	NS	NS	NS	NS	***	***	***	**	***	***	***	***	NS																							
DK40	NS	NS	**	***	***	***	***	***	***	***	***	***	NS	NS																						
DK60	NS	NS	NS	**	***	***	***	***	***	***	***	***	NS	NS	NS																					
DK80	*	**	NS	NS	NS	*	NS	NS	NS	*	***	***	NS	*	***	**																				
DK100	**	***	*	NS	NS	NS	NS	NS	NS	NS	**	***	**	**	***	***	NS																			
RK00	NS	NS	NS	NS	***	***	**	**	***	***	***	***	NS	NS	*	NS	*	**																		
RK20	*	*	NS	NS	*	**	NS	NS	*	***	***	***	NS	*	***	**	NS	NS	NS																	
RK40	**	**	NS	NS	*	**	NS	NS	NS	**	***	***	*	**	***	***	NS	NS	*	NS																
RK60	***	***	**	NS	NS	NS	NS	NS	NS	NS	***	***	**	***	***	***	NS	NS	***	*	NS															
RK80	***	***	***	**	NS	NS	NS	*	NS	NS	*	***	***	***	***	***	*	NS	***	***	**	NS														
RK100	***	***	***	***	NS	NS	**	***	*	NS	NS	*	***	***	***	***	**	*	***	***	***	**	NS													
DM00	NS	NS	NS	NS	**	***	*	NS	**	***	***	***	NS	NS	*	NS	NS	*	NS	NS	NS	*	***	***												
DM20	**	**	NS	NS	NS	*	NS	NS	NS	*	***	***	*	**	***	**	NS	NS	*	NS	NS	NS	*	**	NS											
DM40	*	*	NS	NS	NS	*	NS	NS	NS	*	***	***	NS	*	***	**	NS	NS	NS	NS	NS	NS	*	***	NS	NS										
DM60	***	***	*	NS	NS	NS	NS	NS	NS	NS	**	***	**	***	***	***	NS	NS	***	*	NS	NS	NS	NS	*	NS	NS									
DM80	***	***	*	NS	NS	NS	NS	NS	NS	NS	**	***	**	***	***	***	NS	NS	**	NS	NS	NS	NS	*	*	NS	NS	NS								
DM100	***	***	**	*	NS	NS	NS	NS	NS	NS	*	**	***	***	***	***	NS	NS	***	*	*	NS	NS	NS	**	NS	NS	NS	NS							
RM00	*	*	NS	NS	**	***	NS	NS	**	***	***	***	NS	*	***	**	NS	NS	NS	NS	NS	*	***	***	NS	NS	NS	*	*	**						
RM20	**	**	NS	NS	*	**	NS	NS	NS	**	***	***	*	**	***	***	NS	NS	*	NS	NS	NS	**	***	NS	NS	NS	NS	NS	*	NS					
RM40	***	***	**	*	NS	NS	NS	NS	NS	NS	***	***	***	***	***	***	NS	NS	***	*	NS	NS	NS	*	**	NS	NS	NS	NS	NS	**	NS				
RM60	***	***	***	**	NS	NS	NS	*	NS	NS	**	***	***	***	***	***	NS	NS	***	**	**	NS	NS	NS	***	NS	*	NS	NS	NS	***	**	NS			
RM80	***	***	***	***	NS	NS	*	**	NS	NS	*	***	***	***	***	***	*	NS	***	***	***	NS	NS	NS	***	*	**	NS	NS	NS	***	***	NS	NS		
RM100	***	***	***	***	NS	NS	*	**	NS	NS	NS	**	***	***	***	***	*	NS	***	***	***	*	NS	NS	***	*	**	NS	NS	NS	***	***	NS	NS	NS	

Table C.4. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for conductivy (µS/cm) (D = dry season, R = rain season, B = Buj.-Uvi., K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.11.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	NS	*	NS	NS																																
DB100	***	***	***	***	**																															
RB00	***	**	**	***	***	***																														
RB20	***	**	**	***	***	***	NS																													
RB40	*	NS	*	**	***	***	NS	NS																												
RB60	NS	NS	NS	NS	NS	***	***	***	**																											
RB80	NS	*	NS	NS	NS	**	***	***	***	NS																										
RB100	**	***	***	*	NS	NS	***	***	***	**	NS																									
DK00	**	*	**	***	***	***	NS	NS	NS	***	***	***																								
DK20	***	**	**	***	***	***	NS	NS	NS	***	***	***	NS																							
DK40	***	**	**	***	***	***	NS	NS	NS	***	***	***	NS	NS																						
DK60	**	*	**	***	***	***	NS	NS	NS	***	***	***	NS	NS	NS																					
DK80	NS	NS	NS	NS	**	***	*	*	NS	NS	**	***	NS	*	*	NS																				
DK100	NS	NS	NS	NS	NS	***	***	***	*	NS	NS	**	**	**	**	**	NS																			
RK00	**	NS	*	**	***	***	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*																		
RK20	*	NS	*	**	***	***	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*	NS																	
RK40	NS	NS	NS	*	**	***	*	*	NS	*	***	***	*	*	*	NS	NS	NS	NS	NS																
RK60	NS	NS	NS	NS	NS	***	***	***	**	NS	NS	***	***	***	***	***	NS	NS	**	**	*															
RK80	NS	*	NS	NS	NS	**	***	***	***	NS	NS	NS	***	***	***	***	**	NS	***	***	***	NS														
RK100	*	**	**	NS	NS	*	***	***	***	*	NS	NS	***	***	***	***	***	*	***	***	***	**	NS													
DM00	*	NS	*	**	***	***	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***												
DM20	NS	NS	NS	NS	**	***	*	*	NS	NS	**	***	NS	*	*	NS	NS	NS	NS	NS	NS	NS	**	***	NS											
DM40	NS	NS	NS	NS	*	***	*	*	NS	NS	**	***	*	*	*	NS	NS	NS	NS	NS	NS	NS	**	***	NS	NS										
DM60	NS	NS	NS	NS	*	***	*	*	NS	NS	*	***	*	*	*	NS	NS	NS	NS	NS	NS	NS	*	***	NS	NS	NS									
DM80	NS	NS	NS	NS	NS	***	**	**	NS	NS	NS	***	**	**	**	*	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS	NS								
DM100	NS	NS	NS	NS	NS	***	**	**	*	NS	NS	**	**	**	**	*	NS	NS	*	*	NS	NS	NS	*	*	NS	NS	NS	NS							
RM00	*	NS	NS	**	***	***	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS						
RM20	NS	NS	NS	*	***	***	*	*	NS	*	***	***	*	*	*	NS	NS	NS	NS	NS	NS	*	***	***	NS	NS	NS	NS	NS	NS	NS					
RM40	NS	NS	NS	NS	*	***	***	***	*	NS	*	***	**	**	***	**	NS	NS	*	*	NS	NS	*	***	*	NS	NS	NS	NS	NS	NS	NS				
RM60	NS	NS	NS	NS	NS	***	***	***	**	NS	NS	***	***	***	***	***	NS	NS	**	**	*	NS	NS	**	**	NS	NS	NS	NS	NS	**	*	NS			
RM80	NS	NS	NS	NS	NS	***	***	***	**	NS	NS	***	***	***	***	***	NS	NS	***	**	*	NS	NS	*	**	NS	NS	NS	NS	NS	**	*	NS	NS		
RM100	NS	NS	NS	NS	NS	***	***	***	***	NS	NS	**	***	***	***	***	NS	NS	***	***	**	NS	NS	*	**	*	NS	NS	NS	NS	***	**	NS	NS	NS	

Table C.5. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for pH (D = dry season, R = rain season, B = Buj.-Uvi., K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.12.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	NS	NS	NS	NS																																
DB100	**	**	NS	*	NS																															
RB00	NS	NS	NS	NS	NS	**																														
RB20	NS	NS	NS	NS	NS	*	NS																													
RB40	*	NS	NS	NS	NS	NS	*	NS																												
RB60	***	***	*	**	NS	NS	***	**	NS																											
RB80	***	***	***	***	***	*	***	***	***	**																										
RB100	***	***	***	***	***	***	***	***	***	***	***																									
DK00	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	***																								
DK20	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	***	***	NS																							
DK40	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS																						
DK60	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS																					
DK80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	***	NS	NS	NS	NS																				
DK100	*	*	NS	*	NS	NS	**	NS	NS	NS	**	***	NS	NS	*	NS	NS																			
RK00	*	NS	NS	NS	NS	NS	*	NS	NS	*	***	***	NS	NS	NS	NS	NS	NS																		
RK20	*	NS	NS	NS	NS	NS	*	NS	NS	*	***	***	NS	NS	NS	NS	NS	NS	NS																	
RK40	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS																
RK60	**	*	NS	*	NS	NS	**	NS	NS	NS	***	***	NS	NS	*	NS	NS	NS	NS	NS	NS															
RK80	***	***	*	***	*	NS	***	**	*	NS	**	***	NS	*	***	**	NS	NS	**	**	**	NS														
RK100	***	***	**	***	*	NS	***	**	*	NS	**	***	NS	*	***	**	NS	NS	**	**	**	NS	NS													
DM00	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**												
DM20	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	**	**	NS											
DM40	NS	NS	NS	NS	NS	**	NS	NS	NS	***	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	*	***	***	NS	NS										
DM60	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	*	***	***	NS	NS	NS									
DM80	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	*	***	***	NS	NS	NS	NS								
DM100	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	*	***	***	NS	NS	NS	NS	NS							
RM00	NS	NS	NS	NS	*	***	NS	NS	**	***	***	***	NS	NS	NS	NS	*	**	**	**	*	***	***	***	NS	NS	NS	NS	NS	NS						
RM20	NS	NS	NS	NS	*	***	NS	NS	**	***	***	***	*	NS	NS	NS	*	**	**	**	*	***	***	***	NS	NS	NS	NS	NS	NS	NS					
RM40	NS	NS	NS	NS	NS	**	NS	NS	*	***	***	***	NS	NS	NS	NS	NS	**	*	*	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS				
RM60	NS	NS	NS	NS	NS	**	NS	NS	*	***	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS			
RM80	NS	NS	NS	NS	NS	**	NS	NS	NS	***	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
RM100	NS	NS	NS	NS	NS	**	NS	NS	NS	***	***	***	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table C.6. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for phosphates (mg/l PO4---) (D = dry season, R = rain season, B = Buj.-Uv K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.14.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	**	*	**	NS																																
DB100	NS	NS	NS	NS	NS																															
RB00	NS	NS	NS	NS	**	NS																														
RB20	NS	NS	NS	NS	**	NS	NS																													
RB40	NS	NS	NS	NS	NS	NS	*	*																												
RB60	***	***	***	***	***	***	***	***	***																											
RB80	*	*	*	NS	NS	NS	**	**	NS	***																										
RB100	NS	NS	NS	NS	**	NS	NS	NS	NS	***	*																									
DK00	NS	NS	NS	NS	*	NS	NS	NS	NS	***	*	NS																								
DK20	NS	NS	NS	NS	**	NS	NS	NS	*	***	*	NS	NS																							
DK40	NS	NS	NS	NS	***	NS	NS	NS	*	***	**	NS	NS	NS																						
DK60	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS																					
DK80	***	**	***	*	NS	*	***	***	*	*	NS	***	**	***	***	*																				
DK100	***	***	***	**	NS	**	***	***	**	NS	*	***	***	***	***	**	NS																			
RK00	NS	NS	NS	NS	*	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	**	***																		
RK20	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	*	NS	*	**	NS																	
RK40	*	NS	*	NS	NS	NS	*	**	NS	***	NS	*	NS	*	**	NS	NS	*	NS	NS																
RK60	***	***	***	***	NS	***	***	***	**	*	**	***	***	***	***	**	NS	NS	***	***	**															
RK80	***	***	***	***	***	***	***	***	***	NS	***	***	***	***	***	***	**	*	***	***	***	**														
RK100	***	***	***	***	**	***	***	***	***	NS	***	***	***	***	***	***	*	NS	***	***	***	NS	NS													
DM00	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	*	**	NS	NS	NS	***	***	***												
DM20	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	*	**	NS	NS	NS	**	***	***	NS											
DM40	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	*	NS	*	*	NS	NS	NS	**	***	***	NS	NS										
DM60	NS	NS	NS	NS	NS	NS	NS	*	NS	***	NS	NS	NS	*	*	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS									
DM80	**	*	*	NS	NS	NS	**	**	NS	***	NS	**	*	**	**	NS	NS	NS	*	NS	NS	NS	***	**	NS	NS	NS	NS								
DM100	***	**	**	*	NS	*	***	***	*	*	NS	***	**	***	***	*	NS	NS	**	*	NS	NS	**	*	*	*	NS	NS	NS							
RM00	NS	NS	NS	NS	***	NS	NS	NS	*	***	**	NS	NS	NS	NS	NS	***	***	NS	NS	**	***	***	***	NS	NS	NS	*	**	***						
RM20	NS	NS	NS	NS	**	NS	NS	NS	NS	***	*	NS	NS	NS	NS	NS	***	***	NS	NS	*	***	***	***	NS	NS	NS	NS	**	***	NS					
RM40	*	*	*	NS	NS	NS	**	**	NS	***	NS	*	*	**	**	NS	NS	*	NS	NS	NS	**	***	***	NS	NS	NS	NS	NS	NS	**	**				
RM60	***	***	***	**	NS	**	***	***	**	**	*	***	***	***	***	**	NS	NS	***	**	*	NS	***	**	**	**	*	*	NS	NS	***	***	*			
RM80	***	***	***	***	NS	***	***	***	**	**	**	***	***	***	***	**	NS	NS	***	***	**	NS	**	*	***	**	**	*	NS	NS	***	***	**	NS		
RM100	***	***	***	***	NS	***	***	***	**	**	**	***	***	***	***	**	NS	NS	***	***	**	NS	**	*	***	**	**	*	NS	NS	***	***	**	NS	NS	

Table C.7. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for nitrates (mg/l NO3-N) (D = dry season, R = rain season, B = Buj.-Uvi. K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.15.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	*	NS	*	*																																
DB100	NS	NS	NS	NS	NS																															
RB00	NS	NS	NS	NS	*	NS																														
RB20	NS	NS	NS	NS	*	NS	NS																													
RB40	NS	NS	NS	NS	**	NS	NS	NS																												
RB60	NS	NS	NS	NS	NS	NS	NS	NS	NS																											
RB80	***	**	***	***	NS	*	***	***	***	**																										
RB100	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**																									
DK00	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS																								
DK20	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS																							
DK40	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS																						
DK60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS																					
DK80	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS																				
DK100	*	NS	*	*	NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS																			
RK00	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS																		
RK20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS																	
RK40	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS																
RK60	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	*	NS	NS	NS															
RK80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS														
RK100	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS													
DM00	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS												
DM20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS											
DM40	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS										
DM60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS									
DM80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS								
DM100	**	NS	**	**	NS	NS	**	*	**	*	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS	**	*	NS	NS	NS	NS	NS	*							
RM00	NS	NS	NS	NS	***	*	NS	NS	NS	NS	***	NS	NS	**	NS	NS	**	**	NS	*	*	NS	NS	**	NS	NS	*	*	NS	***						
RM20	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	***	NS	NS	*	NS	NS	*	**	NS	*	*	NS	NS	*	NS	NS	*	*	NS	***	NS					
RM40	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	***	NS	NS	*	NS	NS	*	**	NS	*	*	NS	NS	*	NS	NS	*	*	NS	***	NS	NS				
RM60	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	***	NS	NS	*	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS			
RM80	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	***	NS	NS	*	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS		
RM100	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	

Table C.8. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for nitrites (mg/l NO2-N) (D = dry season, R = rain season, B = Buj.-Uvi. K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.16.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)

	DB00	DB20	DB40	DB60	DB80	DB100	RB00	RB20	RB40	RB60	RB80	RB100	DK00	DK20	DK40	DK60	DK80	DK100	RK00	RK20	RK40	RK60	RK80	RK100	DM00	DM20	DM40	DM60	DM80	DM100	RM00	RM20	RM40	RM60	RM80	RM100
DB00																																				
DB20	NS																																			
DB40	NS	NS																																		
DB60	NS	NS	NS																																	
DB80	NS	NS	NS	NS																																
DB100	NS	NS	NS	NS	NS																															
RB00	NS	NS	NS	NS	NS	*																														
RB20	NS	NS	NS	NS	*	**	NS																													
RB40	NS	NS	NS	NS	NS	*	NS	NS																												
RB60	NS	NS	NS	NS	NS	NS	NS	NS	NS																											
RB80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS																										
RB100	***	**	***	***	**	*	***	***	***	***	***																									
DK00	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**																								
DK20	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	*	NS																							
DK40	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS																						
DK60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS																					
DK80	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	*	NS	NS	NS	NS																				
DK100	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS																			
RK00	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS																		
RK20	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS																	
RK40	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS																
RK60	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS															
RK80	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS														
RK100	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS													
DM00	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS												
DM20	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS											
DM40	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS										
DM60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS									
DM80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS								
DM100	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS							
RM00	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	*	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS						
RM20	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS					
RM40	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				
RM60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			
RM80	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
RM100	NS	NS	NS	NS	*	**	NS	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table C.9. Comparison between means by least significant difference (SOKAL and ROHLF, 1995) for ammonia (mg/l NH4-N) (D = dry season, R = rain season, B = Buj.-Uvi., K = Kigoma, M = Mpulungu) for depths of 0, 20, 40, 60, 80 and 100 m (site A, August 1993 to July 1994)
(means, standard deviations and number of observations are presented in Table A.17.1).
(NS: non significant, * = 0.05 ≥p≥0.01, ** = 0.01≤p>0.001 and *** = p≤0.001)