GCP/RAF/271/FIN-TD/51(En) October 1996

# THE RESULTS OF ZOOPLANKTON SAMPLING AT THREE LOCATIONS IN LAKE TANGANYIKA: JULY 1993 - DECEMBER 1995

by

H. Kurki

FINNISH INTERNATIONAL DEVELOPMENT AGENCY

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

Bujumbura, October 1996

# PREFACE

The Research for the Management of the Fisheries on Lake Tanganyika project (LTR) 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 Development Agency (FINNIDA) and the Arab Gulf Program for the United Nations Development Organization (AGFUND).

LTR's objective is 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 is 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.

**Prof. O.V. LINDQVIST**
**LTR Scientific Coordinator**

**Dr. George HANEK**
**LTR Coordinator**

**LAKE TANGANYIKA RESEARCH (LTR)**
**FAO**
**B.P. 1250**
**BUJUMBURA**
**BURUNDI**

**Telex: FOODAGRI BDI 5092**

**Tel: (257) 229760**

**Fax: (257) 229761**

# GCP/RAF/271/FIN PUBLICATIONS

Publications of LTR are issued in two series:

* A series of **technical documents (GCP/RAF/271/FIN–TD)** related to meetings, missions and research organized by the project; and

* A series of **manuals and field guides (GCP/RAF/271/FIN–FM)** related to training and field work activities conducted in the framework of the project.

For both series, reference is further made to the document number **(01)**, and the language in which the document is issued: English **(En)** and/or French **(Fr)**.

For bibliographic purposes this document should be cited as follows:

**Kurki, H.,** The results of zooplankton sampling at three
**1996** locations in Lake Tanganyika: July 1993 – December 1995 FAO/FINNIDA Research for the Management of the Fisheries of Lake Tanganyika **GCP/RAF/271/FIN–TD/51 (En): 27p.**

# TABLE OF CONTENTS

# SUMMARY

This report presents the results of two and a half years of zooplankton sampling by LTR. It covers the period from July 1993 to December 1995.

The pelagic zooplankton fauna of Lake Tanganyika is varied spatially and temporally. The northern end of the lake is characterised by the dominance of Cyclopidae and the high variation in abundance both annually and over shorter periods of time. In this region the Cyclopoida copepod dominance of the zooplankton fauna and the annual abundance peak is probably associated with secondary upwelling (Plisnier *et al.*, 1996). In the southern end of the lake the changes in annual abundance of Copepoda are low in comparison to the northern end. Furthermore in the former area, shrimps play a more significant role in the pelagic zooplankton community than in the north. Medusae are more numerous in the north. The north could be characterised as a “clupeid – Cyclopoida - medusa” community while the south could be a *“Lates stappersii* – Calanoida – shrimp” community. Variable mixing and stratification conditions in the north-south axis of the lake (Plisnier *et al.*, 1996) many shape the zooplankton communities and lead to the conclusion that there are at least two separate ecosystems in the pelagic of Lake Tanganyika.

## 1. INTRODUCTION

The zooplankton study of Lake Tanganyika Research (LTR) is one of the components which has been operational since July 1993. A high level of competence has been achieved both in the field and in the laboratory. Annual reports have been prepared at all the LTR stations by the co-operation of the national and international staff. Therefore the monitoring programme can be continued after the phasing out of LTR if other logistic requirements are met.

Pelagic zooplankton plays an important role in channeling the carbon from primary producers to the zooplanktivorous predators (mainly *Stolothrissa tanganicae* and *Limnothrissa miodon*) of Lake Tanganyika. Hydrodynamic processes regulate the primary production (Plisnier *et al.* 1996). A comprehensive understanding of the functioning of the pelagic zooplankton ecosystem will make it possible to connect trophic levels with hydrodynamic events.

## 2. OBJECTIVES

This report is partly based on the following manuscripts:

Kurki, H., I. Vuorinen, E. Bosma & D. Bwebwa: Spatial and temporal changes in mesozooplankton communities in Lake Tanganyika;

Vuorinen, I., H. Kurki, E. Bosma, A. Kalangali, H. Mölsä & 0. Lindqvist: Vertical distribution of pelagic Copepoda in Lake Tanganyika;

Kurki, H., P. Mannini, I. Vuorinen, E. Aro, H. Mölsä & 0. Lindqvist: Macrozooplankton communities in Lake Tanganyika.

This study aimed to:

I) Investigate seasonal, temporal and spatial changes of the crustacean mesozooplankton. Uniform methods have been used over two and half years on a weekly basis at three localities on Lake Tanganyika. North to south differences in the structure of the crustacean planktonic ecosystem, annual zooplankton production and carbon transfer efficiency were investigated. The consequences to the functioning of predator-prey relationships are discussed in this report.

II) Determine the differences in the vertical distribution and migration between species. The relationship between life stages and seasons was studied. Regional differences in vertical distribution patterns of zooplankton in Lake Tanganyika were determined.

III) Determine the abundance of macrozooplankton, medusae and shrimps, at three localities. The study extended over two and half years. The differences between the macroplanktonic composition in the north and south stations are discussed.

## 3. MATERIAL AND METHODS

Two type of sampling methods were used:

**a) Regular zooplankton sampling:**

There were two sampling localities in the northern part of Lake Tanganyika, one near Bujumbura(03°28.00'S, 29°17.00'E), Burundi, in the relatively shallow, northernmost end of the lake, and one near Kigoma (04°51.00'S, 29°35.00'E), Tanzania. The third sampling area was near Mpulungu (08°43.98'S, 31°02.43'E), Zambia at the extreme southern end of the lake (Fig. 1). For a short period (November 1993 - August 1994) sampling was also done off Kipili, Tanzania (approximately 07°50.00'S, 30°60.00'E). Sampling was done on a weekly basis by taking a single haul from 100 m depth with a plankton net (mesh 100 µm, mouth diameter 25 cm, hauling speed < 0.5 $ms^{-1}$) from July 1993 to July 1994. From August 1994 to December 1995 three replicate hauls were made and treated separately. Most of the nauplii passed through the 100 µµm mesh, so the results relate mainly to the adult and copepodid stages. The samples were preserved in 4% formalin. Subsamples were taken until at least 100 specimens of the micro and meso zooplankton (protozoans, nauplii, copepodid and adult stages of Copepoda) and 300 specimens of the macrozooplankton (shrimps, medusae and fish larvae) had been counted. Sampling, subsampling and counting were done according to Vuorinen (1993) and Kurki (1993). Individuals were identified to species , except for the Cyclopoida, which were counted as one group. From August 1994 at Kigoma and from January 1995 at Bujumbura and Mpulungu, the cyclopoid copepods were divided into two groups, small and large. Small ones included species *Microcyclops cunningtoni, Thermocyclops oblongatus* and *Propocyclops tenellus.* Into large ones were counted *Mesocyclops aeguatorialis aequatorialis.* For abundance analyses the data were grouped into nauplii and post-naupliar stages although egg carrying females were kept separately. For dry weight biomass calculations the copepodid and adult stages, including the ovigerous females, were pooled together. Dry weight values were used as follows: adult calanoida = 4.5 µg, calanoid copepodids = 2.6 µg, calanoid nauplii = 0.4 µg, adult cyclopoida = 4.0 µg, cyclopoid copepodids = 1.5 µg, and cyclopoid nauplii 0.3 µg (Schindler & Noven 1971; and Bottrell *et al*. 1976).

During the first year of SSP (the scientific sampling programme) of LTR, zooplankton sampling was performed two to three times per month and from August 1994 weekly (Table 1). Due to problems such as the boat being out of order, bad weather and civil disorder in Bujumbura some days had to be omitted.

Table 1. Number of samples taken at each sampling station during July 1993 - December 1995

| Year | Bujumbura | Kigoma | Mpulungu |
|---|---|---|---|
| 7/93—6/94 | 26 | 33 | 33 |
| 7/94—6/95 | 117 | 147 | 135 |
| 7/95—12/95 | 81 | 75 | 78 |

Table 2 shows the distance from the shore and the maximum depth of the collection during regular sampling.

Table 2. Distance from the shore (kin) and the maximum depth (m) of the collection during regular sampling.

| station | km | depth (m) |
|---|---|---|
| Bujumbura | 5.5 | 120 |
| Kigoma | 2.5 | 250—500 |
| Mpulungu | 6.5 | 120 |
| Kipili | 5.0 | >100 |

The data were divided into two solar years, July 1993 to June 1994 and July 1994 to June 1995. A third sampling period covered in this report was July 1995 to December 1995. The data were split into two seasons within the year, the dry season from June to September, and the wet season, from October to May.

Non—parametric Mann-Whitney U—tests were used to compare zooplankton dry weight biomass and density between years, seasons, stations and zooplankton groups. The Spearman rank correlation coefficient was calculated to test the seasonal similarity of the zooplankton dry weight biomass between the years, and between the zooplankton groups. A Coefficient of variation was calculated for the data.

b) Vertical zooplankton sampling:

Vertical zooplankton sampling was carried out in three areas. Near Bujumbura (03°45.00’S, 29°15.00’ E), Kigoma (04°50.69’ 5, 29°34.65’ E) and Mpulungu (08°34.45’ 5, 30°50.10’ E) (Fig. 1). Zooplankton were sampled every six or eight weeks from August 1993 (except at Mpulungu where data collected during 1993 were not used) to July 1995. Four series of samples were taken on each sampling day, at 1200, 1800, 2400 and 0600 hrs, at 20 m intervals, starting from the surface. Sampling was extended to a depth where no animals were found. Zooplankton in a volume of approximately 13 l of water was collected with a tube sampler at the desired depth. The sample was first poured into a bucket and then sieved into a bottle through a 50 µm mesh. Samples were preserved in 4 % formalin. Methods are described in detail by Kurki (1993), Vuorinen (1993) and Vuorinen & Kurki (1994). For analysis of the data were identified three seasons: the dry season, the wet warming season and the season of maximum stability (Coulter, 1991).

Table 3. gives the distance from the shore and depth at the sampling point during vertical sampling. The number of samples collected during July 1993 - July 1995 is also indicated.

Table 3. Distance from the shore, depth at the sampling point and number of vertical zooplankton samples taken during July 1993 - July 1995

| Station | Distance | Depth (m) | No. of samples |
|---|---|---|---|
| Bujumbura | 9.0 | >300 | 415 |
| Kigoma | 4.0 | 250–500 | 472 |
| Mpulungu | 4.0 | 320 | 442 |

## 4. RESULTS

### 4.1. Seasonal, temporal and spatial changes of the crustacean mesozooplankton

#### 4.1.1. Abundance

Table 4 provides values of yearly mean density, standard deviation, coefficient of variation, number of samples and percentage contribution, to the total Copepoda number of the pelagic crustacea at Bujumbura (4a), Kigoma (4b) and Mpulungu (4c) stations.

The yearly mean number of Copepoda was highest at Bujumbura during 1., 2. and 3. year (Table 4). Second highest it was off Kigoma during 1. and 2. year but during the 3. sampling year Mpulungu had higher mean Copepoda number than Kigoma.

During the 1. year Calanoida and Cyclopoida had approximately similar abundance (47.5% and 52.4% of the total Copepoda mean number, respectively) off Mpulungu but during 2. and 3. year the share between Calanoida and Cyclopoida was similar at all the stations (Table 4) with high dominance of Cyclopoida in the pelagic zooplankton fauna.

Post - naupliar stages formed the majority of the fauna at all the sampling localities. Their shares of the total Copepoda assemblage was 70% off Bujumbura, 72% off Kigoma and 70% off Mpulungu when all the samples were considered.

Small cyclopoids contributed to the Cyclopoida community by 32.8% off Bujumbura, 90.6% off Kigoma and 10.3% off Mpulungu (post-nauplii stages) and the share of the large ones was 67.2%, 9.4% and 89.7%, respectively.

Table 4: Yearly mean density (number mµ$^3$**)**, standard deviation (SD), coefficient of variation (CV), number of samples (n) and percentage contribution to the total Copepoda (% of tot cop) of the pelagic mesozooplankton a) off Bujumbura, b) off Kigoma and c) off Mpulungu.

NAUPTR= nauplii of *Tropodiaptomus simplex*
COPADTR=copepodids and adults of *P. simplex*
OVTR= ovigerous females of *T. simplex*
TOTTR= total number of *P. simplex*
NAUPCY= nauplii of Cyclopidae
COPADCY= copepodids and adults of Cyclopidae
OVCY=ovigerous females of Cyclopidae
TOTCY= total number of Cyclopidae
COPAD=post-naupliar stages of Copepoda

a)

| BURUNDI | | NAUPTR | COPADTR | OVTR | TOTTR | NAUPCY | COPADCY | OVCY | TOTCY | NAUPLII | COPAD | TOTCOP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. year | mean | 1626 | 2786 | 64 | 4476 | 1489 | 6385 | 34 | 7909 | 3116 | 9171 | 12385 |
| n= | SD | 952 | 3234 | 76 | 3516 | 1205 | 3452 | 43 | 3874 | 1794 | 5306 | 6129 |
| 26 | CV | 0.59 | 1.16 | 1.19 | 0.79 | 0.81 | 0.54 | 1.25 | 0.49 | 0.58 | 0.58 | 0.49 |
| % OF | TOT COP | 13.1% | 22.5% | 0.5% | 36.1% | 12.0% | 51.6% | 0.3% | 63.9% | 25.2% | 74.8% | |
| 2. year | mean | 2412 | 1658 | 60 | 4130 | 2524 | 7208 | 27 | 9759 | 4936 | 8866 | 13889 |
| n= | SD | 2458 | 1147 | 56 | 3089 | 3980 | 4730 | 23 | 7511 | 6080 | 5505 | 10275 |
| 39 | CV | 1.02 | 0.69 | 0.95 | 0.75 | 1.58 | 0.66 | 0.88 | 0.77 | 1.23 | 0.62 | 0.74 |
| % OF | TOT COP | 17.4% | 11.9% | 0.4% | 29.7% | 18.2% | 51.9% | 0.2% | 70.3% | 35.5% | 64.2% | |
| 3. year | mean | 3047 | 1758 | 109 | 4914 | 3489 | 14717 | 54 | 18259 | 6536 | 16475 | 23173 |
| n= | SD | 2544 | 1806 | 97 | 3914 | 2644 | 12433 | 62 | 14229 | 4738 | 13902 | 17553 |
| 27 | CV | 0.83 | 1.03 | 0.89 | 0.80 | 0.76 | 0.84 | 1.16 | 0.78 | 0.72 | 0.84 | 0.76 |
| % OF | TOT COP | 13.1% | 7.6% | 0.5% | 21.2% | 15.1% | 63.5% | 0.2% | 78.8% | 28.2% | 71.8% | |

b)

| TANZANIA | | NAUPTR | COPADTTR | OVTR | TOTTR | NAUPCY | COPADCY | OVCY | TOTCY | NAUPLII | COPAD | TOTCOP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. year | mean | 1533 | 1075 | 15 | 2621 | 924 | 5550 | 4 | 6477 | 2457 | 6625 | 9098 |
| n= | SD | 849 | 651 | 13 | 1263 | 594 | 4087 | 5 | 4241 | 1007 | 4484 | 5050 |
| 33 | CV | 0.55 | 0.61 | 0.87 | 0.48 | 0.64 | 0.74 | 1.19 | 0.65 | 0.41 | 0.68 | 0.56 |
| % OF | TOT COP | 16.8% | 11.8% | 0.2% | 28.8% | 10.2% | 61.0% | 0.0% | 71.2% | 27.0% | 73.0% | |
| 2. year | mean | 1175 | 1242 | 22 | 2439 | 1355 | 6242 | 8 | 7606 | 2530 | 7484 | 10045 |
| n= | SD | 747 | 766 | 28 | 1246 | 923 | 2764 | 21 | 3275 | 1338 | 3083 | 4006 |
| 49 | CV | 0.64 | 0.62 | 1.30 | 0.51 | 0.68 | 0.44 | 2.45 | 0.43 | 0.53 | 0.41 | 0.40 |
| % OF | TOT COP | 11.7% | 12.4% | 0.2% | 24.3% | 13.5% | 62.1% | 0.1% | 75.7% | 25.2% | 74.8% | |
| 3. year | mean | 1576 | 1043 | 21 | 2640 | 1516 | 5431 | 4 | 6950 | 3092 | 6474 | 9590 |
| n= | SD | 1807 | 1078 | 26 | 2470 | 1831 | 3733 | 6 | 4082 | 2874 | 4131 | 6000 |
| 25 | CV | 1.15 | 1.03 | 1.26 | 0.94 | 1.21 | 0.69 | 1.47 | 0.59 | 0.93 | 0.64 | 0.63 |
| % OF | TOT COP | 16.4% | 10.9% | 0.2% | 27.5% | 15.8% | 56.6% | 0.0% | 72.5% | 32.2% | 67.7% | |

c)

| ZAMBIA | | NAUPTR | COPADTR | OVTR | TOTTR | NAUPCY | COPADCY | OVCY | TOTCY | NAUPLII | COPAD | TOTCOP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. year | mean | 675 | 1963 | 32 | 2670 | 767 | 2174 | 6 | 2946 | 1442 | 4137 | 5617 |
| n= | SD | 411 | 1412 | 73 | 1627 | 571 | 1342 | 16 | 1715 | 859 | 2451 | 3057 |
| 33 | CV | 0.61 | 0.72 | 2.32 | 0.61 | 0.74 | 0.62 | 2.44 | 0.58 | 0.60 | 0.59 | 0.54 |
| % OF | TOT COP | 12.0% | 34.9% | 0.6% | 47.5% | 13.7% | 38.7% | 0.1% | 52.4% | 25.7% | 74.3% | |
| 2. year | mean | 571 | 1659 | 21 | 2252 | 1384 | 3631 | 9 | 5022 | 1955 | 5290 | 7274 |
| n= | SD | 671 | 935 | 27 | 1274 | 955 | 2560 | 13 | 3271 | 1351 | 3418 | 4403 |
| 45 | CV | 1.17 | 0.56 | 1.28 | 0.57 | 0.69 | 0.71 | 1.39 | 0.65 | 0.69 | 0.65 | 0.61 |
| % OF | TOT COP | 7.9% | 22.8% | 0.3% | 31.0% | 19.0% | 49.9% | 0.1% | 69.0% | 26.9% | 73.1% | |
| 3. year | mean | 1020 | 2445 | 16 | 3480 | 3698 | 5020 | 6 | 8725 | 4718 | 7466 | 12206 |
| n= | SD | 512 | 857 | 15 | 1019 | 1515 | 1640 | 9 | 2523 | 1687 | 2262 | 3181 |
| 26 | CV | 0.50 | 0.35 | 0.93 | 0.29 | 0.41 | 0.33 | 1.51 | 0.29 | 0.36 | 0.30 | 0.26 |
| % OF | TOT COP | 8.4% | 20.0% | 0.1% | 28.5% | 30.3% | 41.1% | 0.1% | 71.5% | 38.7% | 61.4% | |

### 4.1.2. Dry weight biomass

Table 5 provides values of yearly mean dry weight, standard deviation, coefficient of variation and percentage contribution to the total Copepoda dry weight of the pelagic crustacean at a) Bujumbura, b) Kigoma and c) Mpulungu. Table 6 gives the mean dry weight, standard deviation, coefficient of variation and contribution to the total Copepoda dry weight of Calanoida and Cyclopidae during the whole sampling period.

Cyclopoids contributed to the total dry weight of Copepoda by 76%, 77% and 57% off Bujumbura, Kigoma and Mpulungu, respectively. The proportion of the post-nauplii stages was similar at all the sampling stations, namely 96% off Bujumbura and 95% off Kigoma and Mpulungu.

The dry weights of Calanoida and Cyclopoida did not vary between years off Kigoma. Off Bujumbura during year 3 (July -December 1995) the mean dry weight of Cyclopoida was higher than during the second sampling year ($p<0.01$). The yearly mean dry weight of Copepoda increased in Mpulungu (Table 5c).

Table 5: Yearly mean dry weight (mg dw mµ$^2$), standard deviation (SD), coefficient of variation (CV) and percentage contribution to the total Copepoda (% of tot cop) of the pelagic mesozooplankton a) off Bujumbura, b) off Kigoma and c) off Mpulungu. Sample number and definitions as for Table 4.

a)

| BURUNDI | | NAUPTR | COPADTR | TOTTR | NAUPCY | COPADCY | TOTCY | TOTCOP |
|---|---|---|---|---|---|---|---|---|
| 1. year | mean | 65 | 1117 | 1182 | 45 | 2251 | 2296 | 3478 |
| | SD | 38 | 1137 | 1145 | 36 | 1177 | 1182 | 1794 |
| | CV | 0.59 | 1.02 | 0.97 | 0.81 | 0.52 | 0.52 | 0.52 |
| % OF | TOT COP | 1.9% | 32.1% | 34.0% | 1.3% | 64.7% | 66.0% | |
| 2. year | mean | 96 | 634 | 731 | 86 | 2205 | 2291 | 3021 |
| | SD | 98 | 434 | 479 | 121 | 1314 | 1372 | 1725 |
| | CV | 1.02 | 0.68 | 0.65 | 1.41 | 0.60 | 0.60 | 0.57 |
| % OF | TOT COP | 3.2% | 21.0% | 24.2% | 2.8% | 73.0% | 75.8% | |
| 3. year | mean | 122 | 818 | 940 | 105 | 5471 | 5576 | 6516 |
| | SD | 102 | 813 | 875 | 79 | 4714 | 4762 | 5490 |
| | CV | 0.83 | 0.99 | 0.93 | 0.76 | 0.86 | 0.85 | 0.84 |
| % OF | TOT COP | 1.9% | 12.6% | 14.4% | 1.6% | 84.0% | 85.6% | |

b)

| TANZANIA | | NAUPTR | COPADTR | TOTTR | NAUPCY | COPADCY | TOTCY | TOTCOP |
|---|---|---|---|---|---|---|---|---|
| 1. year | mean | 61 | 392 | 453 | 28 | 1794 | 1822 | 2274 |
| | SD | 34 | 234 | 248 | 18 | 1572 | 1576 | 1728 |
| | CV | 0.55 | 0.60 | 0.55 | 0.64 | 0.88 | 0.87 | 0.76 |
| % OF | TOT COP | 2.7% | 17.2% | 19.9% | 1.2% | 78.9% | 80.1% | |
| 2. year | mean | 47 | 415 | 462 | 41 | 1605 | 1645 | 2107 |
| | SD | 30 | 272 | 284 | 28 | 807 | 820 | 941 |
| | CV | 0.64 | 0.66 | 0.61 | 0.68 | 0.50 | 0.50 | 0.45 |
| % OF | TOT COP | 2.2% | 19.7% | 21.9% | 1.9% | 76.2% | 78.1% | |
| 3. year | mean | 63 | 356 | 419 | 45 | 1359 | 1405 | 1824 |
| | SD | 72 | 374 | 410 | 55 | 913 | 909 | 1122 |
| | CV | 1.15 | 1.05 | 0.98 | 1.21 | 0.67 | 0.65 | 0.62 |
| % OF | TOT COP | 3.5% | 19.5% | 23.0% | 2.5% | 74.5% | 77.0% | |

c)

| ZAMBIA | | NAUPTR | COPADTR | TOTTR | NAUPCY | COPADCY | TOTCY | TOTCOP |
|---|---|---|---|---|---|---|---|---|
| 1. year | mean | 27 | 774 | 801 | 23 | 655 | 678 | 1479 |
| | SD | 16 | 538 | 542 | 17 | 381 | 389 | 810 |
| | CV | 0.61 | 0.70 | 0.68 | 0.74 | 0.58 | 0.57 | 0.55 |
| % OF | TOT COP | 1.8% | 52.3% | 54.2% | 1.6% | 44.3% | 45.8% | |
| 2. year | mean | 23 | 586 | 608 | 42 | 999 | 1041 | 1649 |
| | SD | 27 | 301 | 308 | 29 | 726 | 746 | 1023 |
| | CV | 1.18 | 0.51 | 0.51 | 0.69 | 0.73 | 0.72 | 0.62 |
| % OF | TOT COP | 1.4% | 35.5% | 36.9% | 2.5% | 60.6% | 63.1% | |
| 3. year | mean | 41 | 838 | 878 | 111 | 1284 | 1395 | 2274 |
| | SD | 20 | 263 | 263 | 45 | 378 | 387 | 584 |
| | CV | 0.50 | 0.31 | 0.30 | 0.41 | 0.29 | 0.28 | 0.26 |
| % OF | TOT COP | 1.8% | 36.8% | 38.6% | 4.9% | 56.5% | 61.4% | |

### 4.1.3. Comparison among the stations in dry weight

The dry weight decreased at the sampling sites in the order Bujumbura>Kigoma>Mpulungu when the whole sampling period (July 1993 - December 1995) (Table 5b) was considered.

In the first year of sampling *Tropodiaptomus simplex* had the lowest dry weight biomass off Kigoma. Off Bujumbura and Mpulungu the dry weight was similar. Cyclopoids had the highest dry weight level off Bujumbura (Bujumbura - Kigoma U= 296, p<0.05 and Bujumbura - Mpulungu U= 87, p<0.001). Off Mpulungu the mean dry weight of Cyclopoida post-naupliar stages was lowest. When Cyclopoida and Calanoida were pooled together, the dry weight of Copepoda was highest off Bujumbura, but Kigoma and Mpulungu did not differ significantly in their Copepoda dry weight (Fig. 2).

In the second year of sampling, the order was similar to the first year. The total Copepoda dry weight was highest off Bujumbura (U=649 and 421 between Bujumbura - Kigoma and Kigoma - Mpulungu, respectively, both p<0.00l). *T. simplex* had the lowest dry weight off Kigoma, while Cyclopidae had lowest off Mpulungu. The total dry weight of Copepoda was lowest off Mpulungu.

During the period July 1995 - December 1995, Calanoida had the similar mean dry weight off Bujumbura and Mpulungu while off Kigoma they had lowest mean dry weight (Bujumbura - Kigoma U= 175 p<0.01, Kigoma - Mpulungu U=109 p<0.OOl). Cyclopoids had highest dry weight off Bujumbura (p<0.00l), but they had the same mean dry weight off Kigoma and Mpulungu. Bujumbura had the highest mean dry weight of Copepoda (p<0.00l when compared with both Kigoma and Mpulungu) and Kigoma and Mpulungu had similar values (Fig. 2)

For the whole period the total mean dry weight of Copepoda was 4176 ± 3615 mg dw mµ$^2$ off Bujumbura, 2093 ±1271 mg dw mµ$^2$ off Kigoma and 1751 ±912 mg dw mµ$^2$ off Mpulungu.

In the Kipili area, copepod densities were comparable to those in the Kigoma and Mpulungu areas. During the sampling period the mean dry weight of *T. simplex* copepodids plus adults was 651 ± 469 mg $m^{-2}$(coefficient of variation (CV) = 0.70), of Cyclopoids 1487 ± 946 (CV = 0.63).

Table 6: Mean dry weight (mg dw $m\mu^2$) standard deviation (SD), coefficient of variation (CV) and contribution to the total Copepoda (% of tot cop) of main mesozooplankton groups at three localities during July 1993 - December 1995.

| | Bujumbura | Kigoma | Mpulungu |
|---|---|---|---|
| | *Tropodiaptomus simplex* | | |
| mean | 920 | 449 | 737 |
| SD | 842 | 306 | 403 |
| CV | 0.92 | 0.68 | 0.55 |
| % of tot cop | 24.2 | 23.1 | 43.3 |
| | Cyclopidae | | |
| mean | 3256 | 1644 | 1014 |
| SD | 3148 | 1124 | 628 |
| CV | 0.97 | 0.68 | 0.62 |
| % of tot cop | 75.8 | 76.9 | 56.7 |
| | Total Copepoda | | |
| mean | 4176 | 2093 | 1751 |
| SD | 3615 | 1271 | 912 |
| CV | 0.87 | 0.61 | 0.52 |

**4.1.4. Periodicity and temporal changes**

Off Bujumbura the annual peak of *T. simplex* occurred regularly in July - August. Data from 2 1/2 year showed that after the peak in July-August, density decreased gradually but abruptly peaked again in the next year (Fig 3a).

Cyclopoida unlike Calanoida did not have the yearly maximum in the first year in August - September but the peak was observed in succeeding years (Fig 4a). The CVs of the whole sampling period were for total Copepoda, Calanoida and Cyclopoida 0.79, 0.78 and 0.86, respectively.

Abundance of Calanoid post—naupliar stages and ovigerous females were significantly correlated (r=0.36, p<0.00l) while that between Cyclopoida copepodids and adults and ovigerous females was not significant. Abundance of Calanoida and Cyclopoida post-nauplii stages were positively correlated (r=0.45, p<0.OOl).

Three abundance maxima were observed yearly in Cyclopoida off Kigoma though the timing varied from year to year (Fig 4b). In 1993 the first abundance peak was in November, preceded by a smaller increase in September. From November 1993 the abundance decreased but peaked again in May 1994. The same periodicity was repeated in the second year with a clearer peak in September and less distinct peaks in November and May compared to the first year. In the third sampling year abundance peaks were earlier than in the previous years.

*T. simplex* abundance peaked in 1994 and 1995 in August and in 1993, 1994 and 1995 in November, January and April-May (Fig 3b). Abundance peaks of *T. simplex* occurred more frequently than those of Cyclopoida but the overall change of abundance of *T. simplex* and Cyclopoids was significantly correlated (r=0.42 n=107, Spearman correlation). Both Calanoida and Cyclopoida abundance were positively correlated with the ovigerous females. The CVs for the whole period, for total Copepoda, P. *simplex* and Cyclopoids were 0.50, 0.63 and 0.53, respectively.

Off Mpulungu the periodicity of Copepoda was not as distinct as off Bujumbura and Kigoma. The abundance of both Calanoida and Cyclopoids rose every year in July-August and slightly in October, February and May (Figures 3a and 4c). Overall *T. simplex* abundance decreased from September 1993 to December 1994 when its minimum was reached. After December 1994 abundance increased. For the whole period the CVs for total Copepoda, Calanoida and Cyclopoida were 0.56, 0.53 and 0.65, respectively. Variability in numbers of Calanoida and Cyclopoids with time was similar (r=0.70, p<0.001).

Table 7 provides Spearman rank correlation coefficient of densities between post-naupliar stages of Calanoida and Cyclopoida, copepodids—adults and ovigerous females of Calanoida and copepodids—adults and ovigerous females of Cyclopoida.

Table 7: Spearman rank correlation coefficient (R) values for tests between different zooplankton group densities, July 1993 — December 1995. ns= non significant, *=p<0.05, ***=p<0.001. Other definitions as for Table 4.

| station | copadtr—copadcy | copadtr—ovtr | copadcy—ovcy |
|---|---|---|---|
| Bujumbura | n=92<br>R= 0.45<br>*** | n=92<br>R= 0.36<br>*** | n=92<br>R= 0.15<br>ns |
| Kigoma | n=107<br>R= 0.44<br>*** | n=102<br>R= 0.44<br>*** | n=102<br>R= 0.22<br>* |
| Mpulungu | n=104<br>R= 0.70<br>*** | n=104<br>R= 0.21<br>* | n=104<br>R= 0.16<br>ns |

### 4.1.5. Seasonal changes

In general no significant difference were found in mean dry weights and densities between seasons (dry and wet). Off Bujumbura waters *T. simplex* dry weight biomass level in the second dry season was higher compared to the second wet season (U= 46, p<0.01). Off Kigoma the dry weight biomass of Cyclopidae did not vary between seasons until the third wet season (October 1995 - December 1995) when the level rose compared to the dry season of 1995. Off Mpulungu, contrary to Kigoma, Cyclopoida had higher mean dry weight biomass during the third dry season than during the third wet season.

Generally, seasonal biomass correlations were low between the first and second dry seasons, and between the first and second wet seasons in all the sampling localities and in all the zooplankton groups. Only total Copepoda dry weight biomass showed a positive correlation ($r= 0.826$, $p<0.05$) off Kigoma between the first and second dry season, but the number of samples (6) was low. Off Bujumbura *T. simplex* copepodites and adults had a negative correlation between the first and second wet season ($n=14$, $r=-0.591$, $p<0.05$), which may indicate cycles or trends occurring over time scales longer than one year.

### 4.2. Vertical distribution and migration

Vertical migration of Copepoda was evident at all the sampling localities for all species and development stages. The layer from 0 to 20 in contained fewer animals in the day than at night. Often there were no animals in this layer in the day. There were apparent differences in all aspects of migration studied between Bujumbura waters and the other two stations, Mpulungu and Kigoma. When species composition was considered, the dominant Cyclopoida in the north tended to be more closer to the surface. The vertical zone containing zooplankton was from 20 m to c. 60 off Bujumbura. Animals were found to a depth of 140 m. Off Mpulungu the layer containing crustaceans extended down to 220 m. The peak of abundance off Bujumbura was always between 20 and 40 in for both Cyclopoida and Calanoida adults as well as their naupliar stages. Peak abundance of *T. simplex* off Kigoma and Mpulungu was between 80 to 100 m in the daytime, but the animals came closer to the surface at night. Cyclopoids did not descend so deeply during the day. Very often there was a secondary peak at about 80 to 120 m, and in Mpulungu at 160 - 180 m (Fig 5).

Ovigerous females of both *T. simplex* and Cyclopoida also migrated vertically. Their numbers were generally low except in Bujuinbura waters, where they were usually found at 40 to 80 m at 1200 h, but at the surface at 2400 h. At 0600 and 1800 h they were usually found at intermediate depths (Fig 6).

When seasonal and ontogenetic migrations were studied, copepodid and adult stages of *T. simplex* showed a distinct vertical migration in all of the sampling locations. It was most pronounced during the season of maximum thermal stratification. Nauplii of Copepoda and Cyclopoida usually avoided surface layers during the daylight hours, but preferred depths 20 and 40 m at all times.

### 4.3. Macrozooplankton

Every solar year and also in the last sampling year, the Mpulungu sampling site had higher shrimp densities in the samples than the Bujumbura site (U-test, $p<0.001$). In the first year there was no difference in the abundance between Kigoma and Mpulungu but in years 2 and 3, Mpulungu had greater numbers than Kigoma. In the last sampling period (July 1995 - December 1995) off Bujumbura and off Kigoma there was no difference in the mean number of shrimps caught. When the whole sampling period was considered the order was Mpulungu ($n=104$)> Kigoma ($n=104$)>

Bujumbura (n=92). The CV values for Bujumbura, Kigoma and Mpulungu were 1.73, 1.30 and 1.19, respectively.

Medusae were the predominant macrozooplankton by abundance in the north (Figures 7a and b). Medusae were found throughout the year but their abundance was more variable in the north: the CV values for Bujumbura, Kigoma and Mpulungu were 1.11, 0.79 and 0.79, respectively. No seasonality was apparent in the abundance. In Bujumbura samples the maximum number observed was > 500 individuals $m^{-1}$, and very often abundance was c. 100 $m^{-3}$ for several successive weeks. The decrease in the maximum and mean numbers was evident from north to south. Over the whole sampling period, the largest medusa densities (76 ± 84 ind $m^{-3}$)were counted off Bujumbura. In the first sampling year the lowest abundance (14 ± 20 ind $m^{-3}$ was off Mpulungu. In the second year Kigoma and Mpulungu had similar abundance and during the last half year the fewest medusa were caught off Kigoma while the mean number of medusae in Bujumbura and Mpulungu were similar.

## 5. DISCUSSION

### I) Time series data:

Cyclopidae clearly formed the majority of the pelagic mesozooplankton community in the northern part of the lake. Their numerical share of the total pelagic Copepoda was 71% in the Bujuinbura area and 73% in the Kigoma area, and when converted to dry weight biomass the share was 76% and 77%, respectively. In the south Cyclopidae also dominated the pelagic Copepoda fauna. Burgis (1984) reported P. *simplex* to be the major pelagic zooplankton species in the lake. Also Rufli (1976), based on a lake wide survey in May 1975, estimated *T. simplex* to form numerically 51% of the pelagic zooplankton community. These results underestimated the proportion of Cyclopidae, because sampling devices used did not effectively catch small sized Cyclopidae. Burgis used 300 and 400 µm mesh size plankton nets and Rufli a 120µm net. Narita *et al.* (1984), using a 70 µm closing plankton net, stated that cyclopoid copepodites dominated the biomass in the pelagic zooplankton assemblage (off Myako, some 250 km south of Kigoma), which is in agreement with the present results. The use of a single dry weight value for all the cyclopoid species in this study is misleading since there are three important species in the pelagic, *M. aeguatorialis, T. tenellus,* and *M. cunningtoni* (Coulter 1991), which differ in their size. In the northern end of the lake the percentage of small cyclopoids of the total was 33%, off Kigoma it was 91% and in Mpulungu waters 10%. Thus the analysis probably overestimated the cyclopoid biomass in Kigoma waters, while off Mpulungu area it may have been an underestimated.

Burgis (1984) reports carbon transfer efficiency for Lake Tanganyika of 17%, compared to 13% off Bujumbura, 9% off Kigoma and 7% off Mpulungu in the present study. These values are based on the primary production of 290 g C $m^{-2}$ (Hecky & Fee 1981) which does not take into consideration spatial or/and temporal differences. Also the dry weight values used in this report to calculate the carbon contents of different life stages and copepod species are not exact but show only general levels. Thus these carbon transfer efficiency values should be taken with precautions.

In the northern part of the lake the fisheries are strongly based on the clupeids. S. *tanganicae* forms 70.1% and *L. miodon* 3.9% of the total catch in the Kigoma area, based on the data collected during LTR regular fish sampling (Piero Mannini, pers. comm). According to several authors (for a review see Coulter 1991) *T. simplex* is the major prey of clupeids. Indeed, the difference between Cyclopoida and Calanoida as food for clupeids is significant; a calanoid nauplius is comparable with a small cyclopoid copepodid stage in biomass. Lake Tanganyika Cyclopidae are clearly smaller than Calanoida and thus the latter are more vulnerable to predation due to their larger size. Therefore some of the Carbon stored in Cyclopoida maybe lost if fishes are feeding selectively preferring Calanoida.

Zooplankton of Lake Tanganyika have a clear periodicity in their abundance which is repeated annually. The primary peak, usually found in November off Kigoma, is likely to be connected to maximum phytoplankton production (c.f. Hecky, 1991) and to the secondary upwelling (Plisnier *et al.,* 1996). *Tropodiaptomus cunningtoni* in Lake Malawi was found to have maximum abundance in August – December and minimum between January and April (Irvine *et al.,* 1995). The timing of peaks varies from one year to another and thus the seasonal correlation between the same seasons of successive years (estimation of the similarity between the samples collected during the same week in two successive years) is usually low. Twombly (1983) obtained similar results in her study of seasonal changes of zooplankton of Lake Malawi, but speculated that the overall patterns of zooplankton abundance can vary between years, or the same pattern be repeated but the timing of population increase and decrease differ from one year to another. Rufli & Chapman (1976) suggested that the predatory clupeids in Lake Tanganyika move from one area to other and can crop heavily on zooplankton. When the predators move away the zooplankton may recover.

Results were compared as suggested by the “moonlight trap”-theory (Gliwicz, 1986), but no periodicity or overlapping between the full moon periods and zooplankton abundance was found. Contrary to the results of LTR, the decrease of zooplankton density coincided with the full moon in Lake Malawi (Irvine, 1995). The sampling was performed daily in Lake Malawi for one month and thus it is suggested that the “moonlight trap” might have been found also in Lake Tanganyika if sampling had been performed daily over a short period.

Yearly, mean standing dry weight biomass of pelagic Copepoda was highest off Bujumbura and lowest off Mpulungu. Burgis (1984) estimated for the whole lake mean standing dry weight biomass of 4820 mg dw $m^{-2}$ $yr^{-1}$ (for 1974–75), which is approximately x 2 higher than the present results if all the data from all the sampling stations are pooled together (mean value is 2334 mg dw $m^{-2}$ $yr^{-1}$). Burgis used a correction factor (of 10) for net efficiency, not used in the present study. In Lake Malawi, the overall mean crustacean biomass found to be 1608 ± 528 mg dw $m^{-2}$ $yr^{-1}$ (Irvine, 1995).

**II) Vertical distribution and migration:**

The vertical distribution of zooplankters differed at three stations. The calanoid *T. simplex* was found over a larger depth range off Mpulungu than at the other two sites. Vertical migration patterns of Cyclopoida were more confined to the surface layer. This was noted also by Mulimbwa & Bwebwa (1987) and Mizuno (1988).

Intensive visual predation by planktivore fishes may cause distinct diel but ontogenetically vertical migration of zooplankton (Lampert, 1989). Egg—carrying females have been shown to be selected by predacious clupeids (Sandström 1980, Flinkman *et al.* 1992). The present study confirmed the earlier findings of Narita (1983) and Mulimbwa (1988,1991) as the egg-carrying females were found in deeper water than other adult stages. It was also shown that during the season of maximum stability they daily migrate from 80 m up to the surface. This, indirectly suggests selective predation on egg-carrying Copepoda at this time.

At a depth of 20 to 40 m, at all three sampling sites, zooplankton were abundant throughout 24 hrs. Another peak was found at 80 to 120 m, off Mpulungu and sometimes even down to 160 — 180 m. A deep peak at 100 m was found by van Meel (1954). Van Meel (1954) found maximum concentrations of phytoplankton at 30 -40 m. Hecky *et al* (1996) described rapid inactivation of phytoplankton chlorophyll at the surface due to increasing radiation in the morning. This may explain the total lack of animals at the surface in the daytime often observed in this study. Järvinen *et al.* (1996) also reported maximum relative fluorescence at 30 to 40 m. The most abundant occurrence of zooplankton found at 20 to 40 m may be related to primary production. The lower limit was probably determined by oxygen. The peak in abundance in deeper water may have been due to high bacterial production. Alternatively the zooplankters may have been seeking refuge from fish predation at low oxygen levels, which fish could not tolerate (Hecky, 1991).

Kalangali *et al.* (1995) demonstrate, in the Kigoma area, that the thermocline did not restrict the vertical migration of Copepoda as they were found, although in low numbers, below the thermocline most of the time. Calanoida copepodids and adults were most abundant below the thermocline in the day during December to May, when the thermocline was at 40 to 60 m. Copepoda were distributed in the water partly in response to the oxygen concentration. Evidently titling of the oxy-anoxic interface causes differences in the vertical distribution of planktonic copepoda between sampling sites in the north and south.

Zooplankton were restricted to more shallow depths in the northernmost part of the lake, as has also been reported by Mulimbwa (1988). The northernmost sampling station was also characterised by more Cyclopoida. Small sized and rapidly reproducing cyclopoids are typical of littoral waters and also classified as *r*-strategists (Allan 1976). The present results show a relatively more littoral-like condition in the northernmost part of the lake with high abundance of Cyclopoida and suggest that food chains in the area are long, resulting in lower production of fish. In the south, zooplanton are *k*–strategists, with a traditional grazing food chain ending in a relatively high production of fish.

Daily vertical migration of nauplii has been little studied. Most often they are reported not to migrate (Begg, 1976) and migration behaviour is usually found to intensify with increasing size of the animals (Narita *et al.,* 1986).

## III. Macrozooplankton

The freshwater medusa, which appear to be extremely common in lake Tanganyika, is probably an important link in the cycling of carbon. The species has received only minor attention in zooplankton research, probably due to its presumed insignificant importance in terms of fish production.

The medusae are commonest at the northern end of the lake. The northern area is relatively shallow and probably therefore more suitable for the sedentary polyp-stage. High numbers of clupeids in the north also possibly renders the area suitable for fish egg predation, on which the medusae predominantly feed (Dumont, 1994). Van Meel (1954) recorded medusa densities < 20 ind. $m^{-3}$ at the southern end of the lake. Consequently the higher densities were found in the northern area. Earlier findings had limited temporal coverage, thus it is impossible to compare temporal between the 1940’s and the present day.

There are no known predators of the medusae. however, they play an interesting role in the planktonic ecosystem. In a preliminary survey on the lake, Salonen (personal communication) studied the medusae with an epifluorescence microscope and found picoplankton of c. 1 µm diameter. The fact that picoplankton were seen in regular elongated formations inside the gastrovascular system of the medusae suggests that they were symbiotic. At the same time medusae were seen to contain copepods in their mouth cavity. All this indicates that they may have an important role in the planktonic ecosystem.

Shrimps were difficult to catch with ordinary plankton nets which were designed to catch copepoda. The animals probably easily avoided the nets. The predominance of shrimps in the macrozooplankton community off Mpulungu is probably typical of the main basins, especially the southern basin of lake Tanganyika. The shrimp species were not identified in the present study. The most common species in the plankton recorded by Matthes (1968) were *Macrobrachium moorei* (Calman), *Limnocaridina parvula* (Calman) and *Limnocaridina tanganyicae* (Calman). The first two are more pelagic in nature (Matthes, 1968). from the stomach analysis of *L. stappersii* some specimens could be identified as *Limnocaridina parvula, Macrobrachium moorei* and *Atyella sp.* (Charles Fransen, personal communication). Shrimps have been found to be the staple food for *L. stappersii* in the southern part of the lake (Mannini *et al.* 1995).

## 6. CONCLUSIONS

The results suggest that the northern pelagic ecosystem could be characterised as “Clupeids – Cyclopoida – medusa” community, while the southern one could be characterised as the *“L. stappersii* - Calanoida - shrimp” community. Evidently there are differences in this respect also between the Kigoma area and Mpulungu, although most clear differences are between the extreme south and north of the lake. It appears that the production from primary producers to fish is channeled in the north differently from the south.

The zooplankton abundance is more constant in south than in the north. On the other hand the stratification never breaks down in the north while very deep mixing takes place in the south (Plisnier *et al.,* 1996). This leads to the theory that there are at least two distinct ecosystems in the lake. The theory of pulse production created by internal waves must be connected to the zooplankton periodicity. Furthermore, the statements by Plisnier *et al.* (1996) that the lake is extremely dynamic and heterogeneous during the annual cycle is evidently true for the pelagic crustacean communities.

The importance of shrimps in the functioning of the pelagic ecosystem has had little attention and their quantitative contribution to the pelagic zooplankton fauna is not yet known. Lake wide cruise should provide a better understanding of the spatial differences and similarities of the zooplankton fauna. Zooplankton sampling with appropriate gears, trawling and stomach content analysis should give an insight into the kind of crustacean communities available utilised by predators.

**AKNOWLEDGEMENTS**

I wish to thank Dr. John Craig for his critical and constructive reading, editing and commenting of this report. I also wish to thank Mrs. Hilary Craig for editing.

My sincere thanks are due to the project co—ordinator Dr. George Hanek, who has encouraged and supported this work. I wish to thank the scientific coordinator Prof. 0. V. Lindqvist and deputy scientific coordinator Prof. H. Mölsä.

I deeply appreciate and sincerely thank the Bujumbura, Uvira, Kigoma and Mpulungu LTR zooplankton teams without whom this work would not have been possible. This work has been supported by Dr. Ilpo Vuorinen, the scientific coordinator of LTR zooplankton study.

Special thanks are addressed to fisheries biologist Piero Mannini with whom I worked at LTR Kigoma for three years during which most of this work was accomplished.

**REFERENCES**


Allan, D. J. 1976. Life history patterns of zooplankton. Am. Nat. 110: 165–179.

Begg, G. W. 1976. The relationship between the diurnal movements of some of the Zooplankton and the sardine *Limnothrissa miodon* in Lake Kariba, Rhodesia. Limnol Oceanogr 21: 529-539.

Bottrell, H. H., A. Duncan, Z. M. Gliwics, E. Grygierek, A. Herzig, A. Hillbricht-Ilkowska, H. Kurasawa, P. Larsson & T. Weglenska, 1976. A review of some problems in zooplankton production studies. Norw. J. Zool. 24: 419-456.

Burgis, M. J., 1974. Revised estimates for the biomass and production of zooplankton in Lake George, Uganda. Freshwater Biol. 4: 535–541.

Burgis, M. J., 1984. An estimates of zooplancton biomass for lake Tanganyika. Verh. Internat. Verein. Limnol. 22: 1199-1203.

Chene, G., 1975. Etudes des problèmes relatifs aux fluctuations piscicoles du lac Tanganyika. Memoire de licence, Université de Liège, Belgium, 1-108.

Coulter, G. W. 1991 (ed.). Lake Tanganyika and its life. Oxford University Press. London, 354p.

Dumont, H. J. 1994. The distribution and ecology of the fresh- and brackish-water medusae of the world. Hydrobiologia 272: 1-12.

Flinkman, J., I. Vuorinen & E. Aro 1992. Planktivorous Baltic herring prey selectively on reproducing copepods and cladocerans.– Can. J. Fish. Fish. Aquat. Sci. 49: 73–77.

Gliwicz, M. 1986. A lunar cycle in zooplankton. Ecology 67: 883-897.

Hecky, R. E. 1991. The pelagic ecosystem. In: Coulter G. W. (ed.) Lake Tanganyika and its Life. Oxford University Press. London. 90–110.

Hecky, R. E., E. J. Fee, H. J. Kling & J. W. Rudd 1978. Studies on the planktonic ecology of Lake Tanganyika. Canadian Department of Fish and Environment. Fisheries and Marine Service Technical report, 816: 1-51.

Irvine, K. 1995. Standing biomasses, production, spatial and temporal distributions of the crustacean zooplankton. In: Menz, A. (ed.) The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa. Chatham, UK: Natural Resources Institute: 85-108.

Järvinen, M., K. Salonen & Sarvala 1996. Experiments on phytoplankton and bacterial production ecology in Lake Tanganyika: The results of the first lake–wide research cruise on *R/V Tanganyika Explorer.* FAO/FINNIDA Research for the Management of the Fisheries of Lake Tanganyika. GCP/RAF/271/FIN-TD (En): 43p.

Kalangali, A., H. Kurki, D. Chitamwebwa & S. Muhoza 1995. Diel vertical migration of the pelagic zooplankton with respect to seasonality, temperature and oxygen in Lake Tanganyika off Kigoma waters. Journal of Fisheries Management and Ecology (in press).

Kurki, H. 1993. Field notes on zooplankton. FAO/FINNIDA Research for the Management of the Fisheries of Lake Tanganyika. GCP/RAF/271/FIN–FM/09 (En): 26p.

Lampert, W. 1989. The adaptive significance of diel vertical migration of zooplankton. Functional Ecology 3: 21-27.

Lévéque, C & L. Saint-Jean 1983. Secondary production (zooplankton and benthos). In J. P. Carmouze, J. R. Durand & C. Lévéque (eds), Lakes Chad, ecology and productivity of a shallow tropical ecosystem. Dr. W. Junk Publ., The Hague.

Mannini, P., E. Aro, I. Katonda, B. Kissaka, G. Milindi, P. Paffen & P. Verburg 1995. Observations on commercial pelagic fish stocks of Lake Tanganyika. A manuscript

Matthes, H. 1968. A study of some Lake Tanganyika shrimps with a view to their introduction into Lake Kariba. an unpublished manuscript in the documentation centre of Lake Tanganyika Research, Bujumbura, Burundi.

Mizuno, T. 1988. Vertical distribution of plankters in northern part of Lake Tanganyika. In: Kawanabe, H. & Kwetuenda, M. K. (eds.) Ecological and Limnological Study on Lake Tanganyika and its Adjacent Regions. V: 60-61, Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Mulimbwa, N. 1988. Seasonal changes in the abundance of zooplankters in the northwestern end of Lake Tanganyika during 1987. - In: Kawanabe, H. & Kwetuenda, M. K. (eds.) Ecological and Limnological Study on Lake Tanganyika and its Adjacent Regions. V: 57-59 Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Mulimbwa, N. 1991. Seasonal changes in the abundance of zooplankters in the northwestern end of Lake Tanganyika. In: Kawanabe, H. & Nagoshi, M. (eds.) Ecological and Limnological Study on Lake Tanganyika and its Adjacent Regions. VII: 96-97. Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Mulimbwa, N. & D. Bwebwa 1987. Seasonal changes in vertical distribution of zooplankters in Lake Tanganyika. — In: Kawanabe, H. & Nagoshi, M. (eds.) Ecological and Limnological Study on Lake Tanganyika and its Adjacent Regions. VI: 119-121, Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Narita, T. 1983. Species compositions, vertical distribution and density of zooplankters, and some limnological features off the coast of Mahale mountains in Lake Tanganyika. In: Kawanabe, H. (ed.) Ecological and Limnological Study on Lake Tanganyika and its Adjacent Regions II: 12-14. Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Narita, T., N. Mulimbwa & T. Mizuno 1986. Vertical distribution and seasonal abundance of zooplankters in Lake Tanganyika. African Study Monographs. 6: 6: 1-16.

Pearce, M. J. 1991. A note on the importance of the prawns to the ecology of southern Lake Tanganyika. In: Kawanabe, H. & Nagoshi, M. (eds.) Ecological and Limnological study on Lake Tanganyika and its adjacent regions VII: 72. Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606, Japan.

Plisnier, P.-D., V. Langenberg, L. Mwape, D. Chitamwebwa, K. Tshibangu & E. Coenen 1996. Limnological sampling during an annual cycle at three stations on Lake Tanganyika (1993-1994). FAO/FINNIDA Research for the Management of the Fisheries of Lake Tanganyika. GCP/RAF/271/FIN-TD/46 (En): 136.

Rufli, H. 1976. Preliminary analysis of zooplankton sampling in Lake Tanganyika in May 1976. FI:DP/URT/71/012/44:l-l0.

Rufli, H. & D. W. Chapman 1976. Preliminary analysis of zooplankton sampling and estimates of fish abundances in Lake Tanganyika in October 1975. FI:DP/URT/71/012/31:13p.

Sandström 1980. Selective feeding by Baltic herring. Hydrobiologia 69: 199—207.

Schindler, D. W. & B. Noven 1971. Vertical distribution and seasonal zooplankton abundance of zooplankton in two shallow lakes of Experimental Lakes Area (ELA), northwestern Ontario. J. Fish. Res. Board Can. 28: 245-256.

Twombly, 5. 1983. Seasonal and short term fluctuations in zooplankton abundance in tropical lake Malawi. Limnol. Oceanogr. 28 (6): 1214—1224.

Van Meel, L. 1954. Le phytoplancton. Résultats scientifiques de 1’exploration hydrobiologique du Lac Tanganyika (1946-1947). Institut Royal des Sciences Naturelles de Belgique, A. IV (1) 571—586.

Vuorinen, I. 1993. Sampling and counting zooplankton of Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries of Lake Tanganyika. GCP/RAF/271/FIN-FM/06:19p.

Vuorinen, I. & H. Kurki 1994. Preliminary results of zooplankton sampling in Lake Tanganyika. FAO/FINNIDA Research for the Management of the Fisheries of Lake Tanganyika. GCP/RAF/271/FIN-TD/22 (En) : 37p.

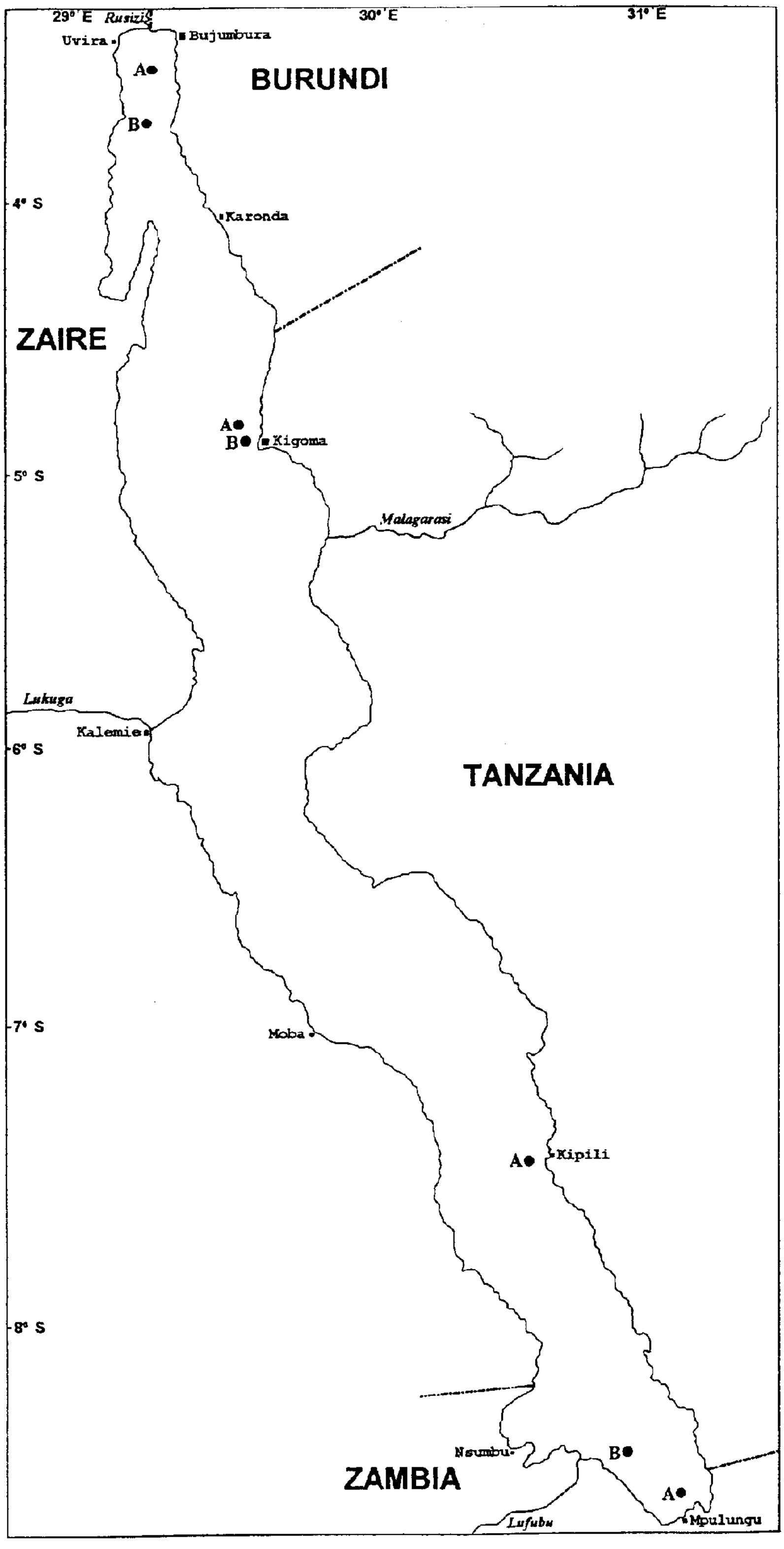


Fig 1: Sampling points during regular (A) and vertical (B) zooplankton sampling.

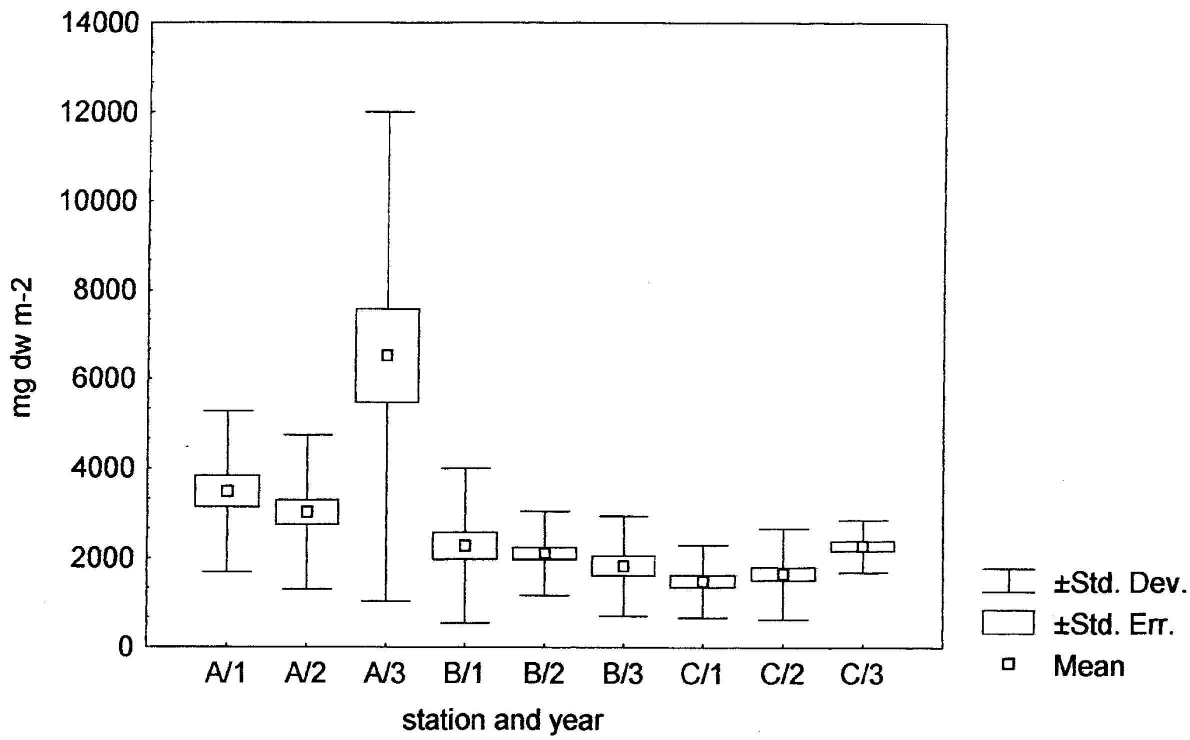


Figure 2: Yearly (1-3) mean dry weight of Copepoda off Bujumbura (A), Kigoma (B) and Mpulungu (C).

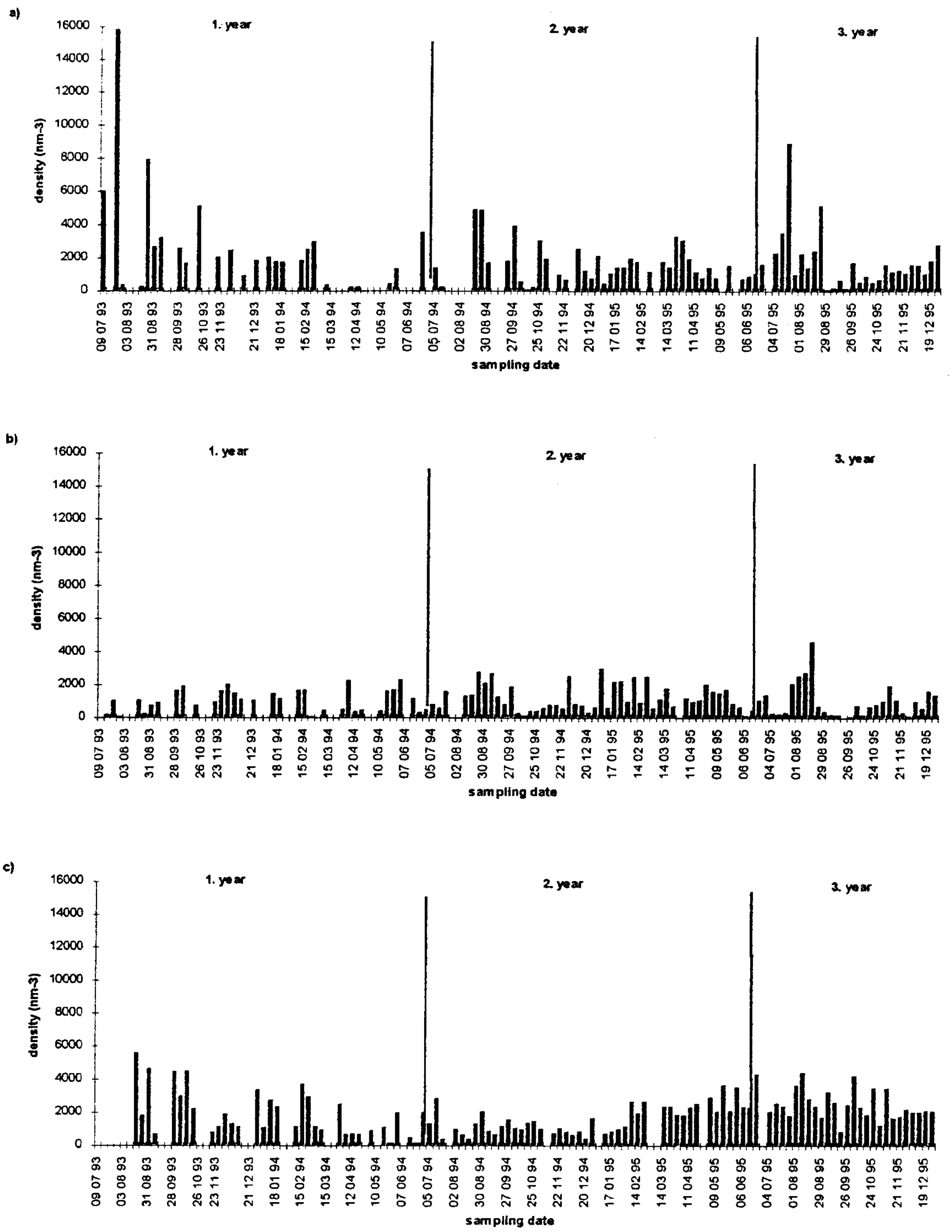


Fig 3: Abundance of post-naupliar stages of Calanoida off a) Bujumbura, b) Kigoma and c) Mpulungu from July 1993 to December 1995.

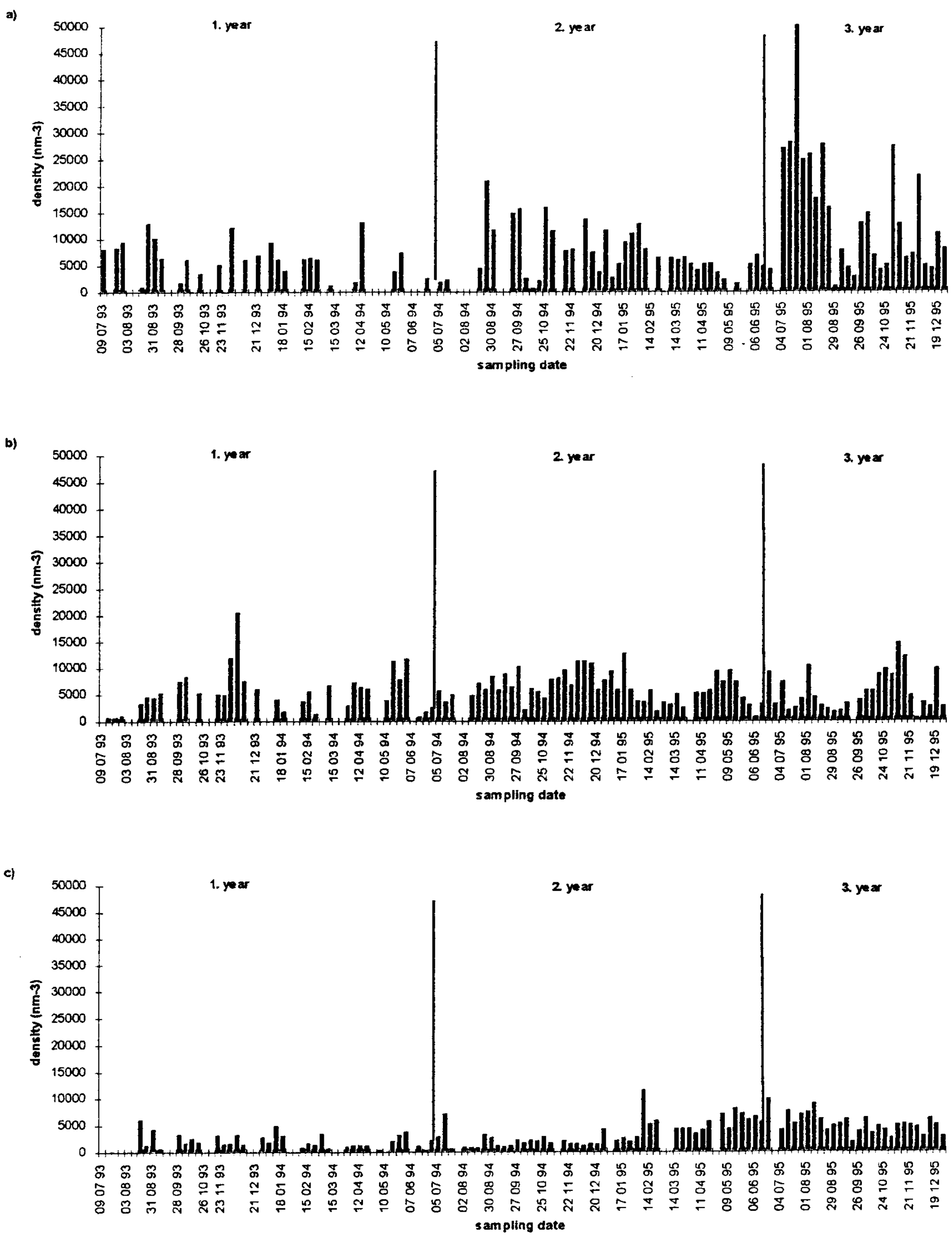


Fig 4: Abundance of post-naupliar stages of Cyclopoida off a) Bujumbura, b) Kigoma and c) Mpulungu from July 1993 to December 1995.

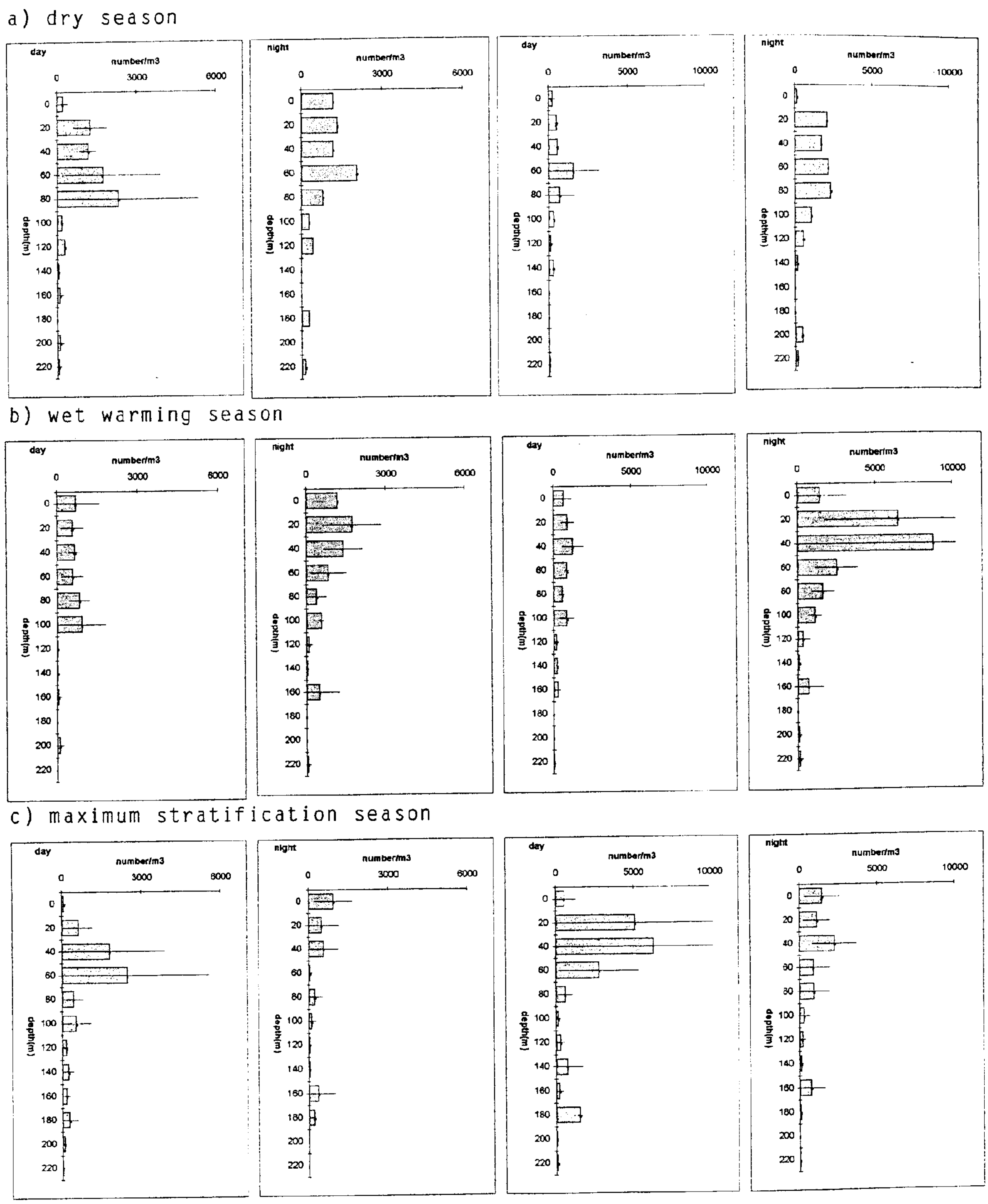


Fig 5: Vertical distribution of Cyclopoida off Mpulungu during a) dry, b) wet warm and c) maximum stability season.
Post-naupliar Cyclopoida two left panels and nauplii two right panels.

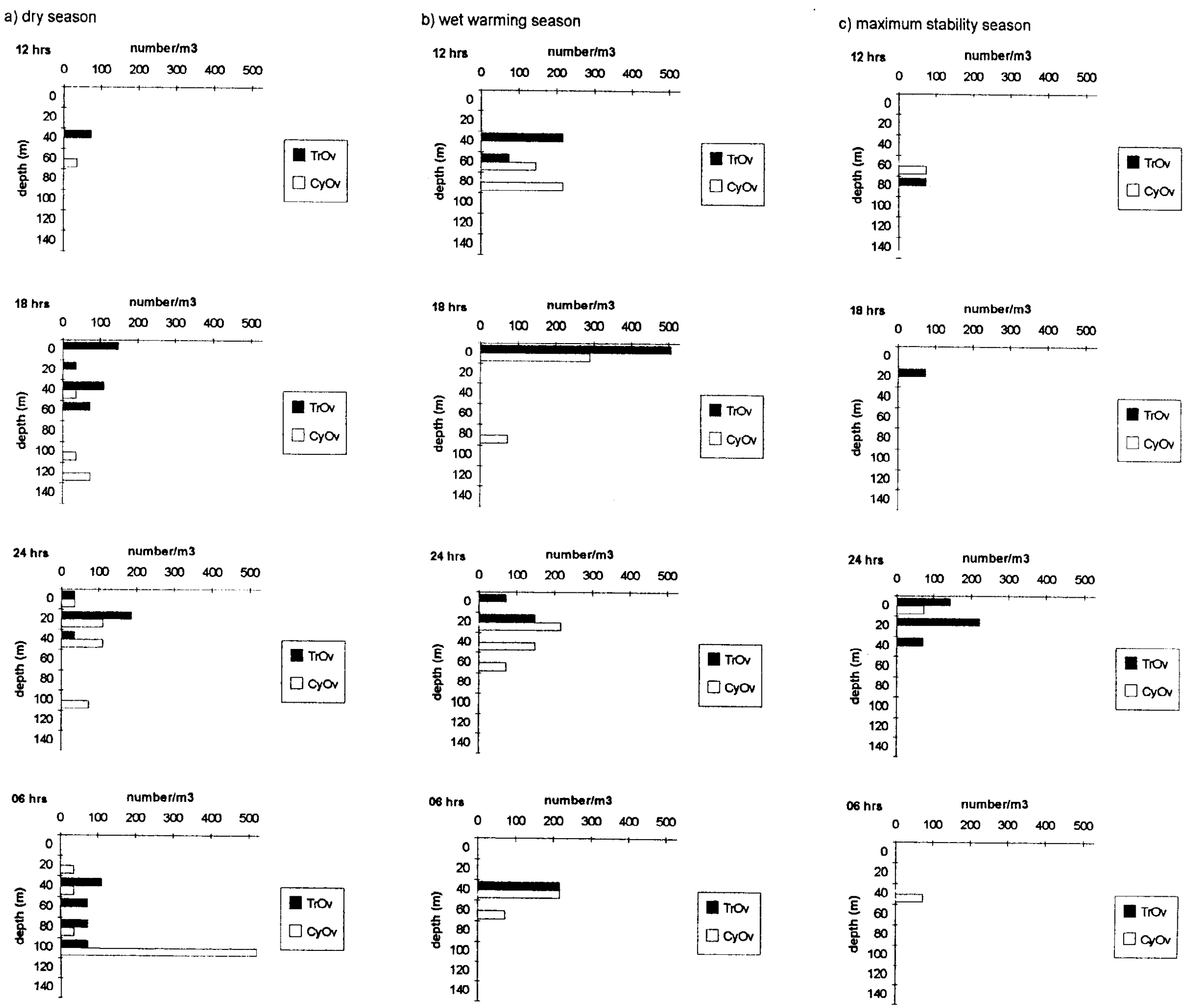


Fig 6: Medians of vertical distribution of ovigerous Calanoida (TrOv) and Cyclopoida (CyOv) during a) dry, b) wet warm and c) maximum stratification season off Bujumbura.

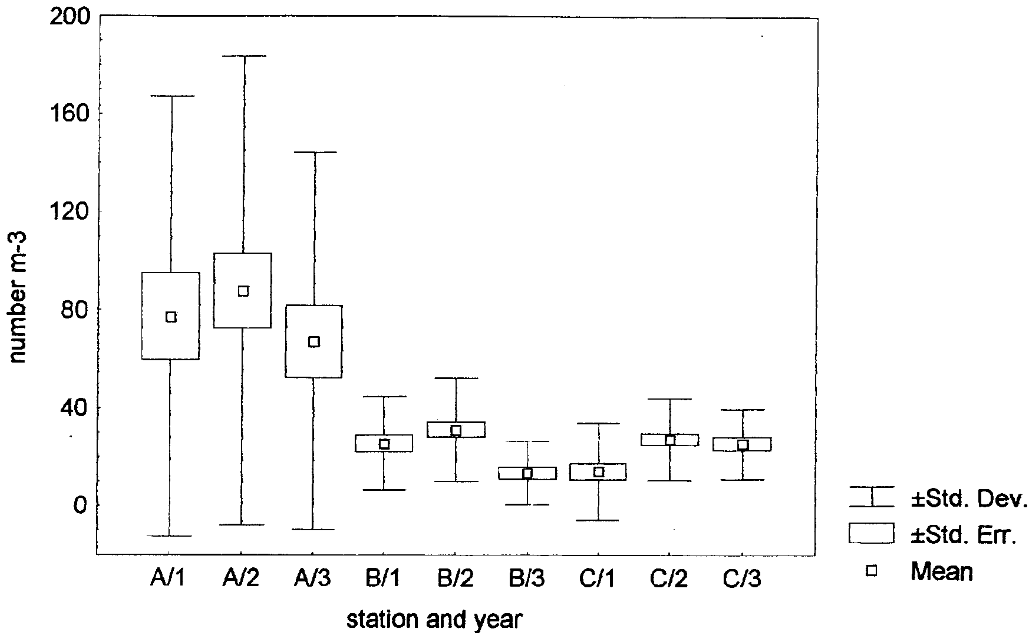


Figure 7a: Yearly (1-3) mean number of medusae off Bujumbura (A), Kigoma (B) and Mpulungu (C).

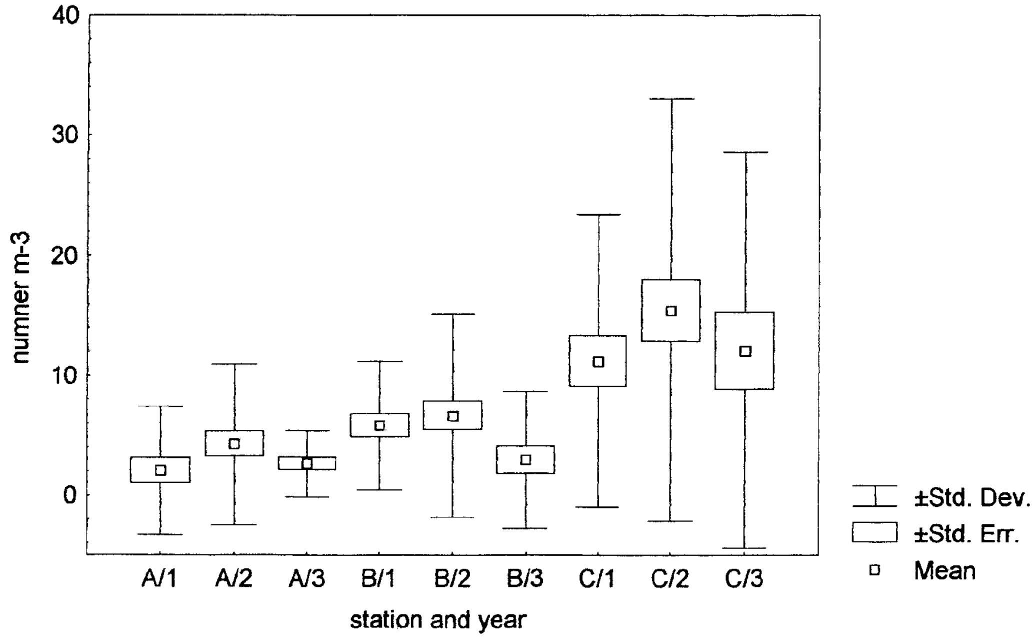


Figure 7b: Yearly (1-3) mean number of shrimps off Bujumbura (A), Kigoma (B) and Mpulungu (C).