# DIEL VERTICAL MIGRATION OF ZOOPLANKTON IN THE TANZANIAN WATERS OF LAKE VICTORIA

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## ABSTRACT

The *diel vertical migration of zooplankton was studied in the Southern part of Lake Victoria in January and July 2002. A van dorn water sampler was used to collect zooplankton. In January 2002, zooplankton showed a pronounced diel vertical migration whereby zooplankton were moving upward at around sunset and swimming downward at sunrise. In July 2002 zooplankton showed diel vertical migration, but at around midnight* Thermodiaptomus galeboides, Thermocyclops emini, Tropocyclops tenellus, *cyclopoid copepodites, nauplius larvae and some rotifers showed downward movement. The diel vertical migration of zooplankton seems to be influenced by food, predation and light.*

## INTRODUCTION

The diel vertical migration of zooplankton – swimming upward during or around sunset and swimming downward during or around sunrise is a universal behavioral characteristic of zooplankton (Hutchinson 1957). Zooplankton vertical migration occurs in many different types of lakes and in tropical, temperate and polar oceans. The behaviour has been observed not only in crustacean zooplankton but also in a wide array of different marine zooplankton groups (Russell 1927, McLaren 1963). Thus there is no doubt that vertical migration is a widespread behavior of polyphyletic origin. Such behavior occurring in so many different animals in such diverse aquatic habitats seems certain to have potent selective advantages. However the nature of these selective advantages is still debatable (Enright 1977).

There are some hypotheses for the selective force behind diel vertical migration. One of them is what may be termed a resource hypothesis; that migrating populations achieve some energetic benefit either by regularly leaving and returning to their food source or by entering a cool hypolimnion (McLaren 1963, 1974, Enright 1977). The second hypothesis contends that the migrants lessen predation by moving where light intensities are too low for visual planktivores to find and catch them efficiently (Zaret and Suffern 1976). This is a predation or death rate-dictated selective advantage.

However, information on diel vertical migration in East Africa is still limited (Mavuti 1992, Kizito 1998; Worthington 1931). This paper reports the diel vertical migration of zooplankton in the southern part of Lake Victoria.

## MATERIALS AND METHODS

### Study Sites

The study was conducted in the Tanzanian waters of Lake Victoria at Lamadi & Bulamba station located within Speke Gulf (Fig. 1). Water samples were taken in vertical profiles at two-meter intervals from the surface to the bottom using a 4-litre van dorn water sampler at Lamadi on 24th January 2002. Samplings were made at 09:20 hrs, 14:19 hrs, 17:00 hrs, 22:00 hrs, 01:00 hrs and 06:00 hrs. On 30th July 2002 the 24-hrs sampling was conducted at Bulamba. The sampling times were 08:16 hrs, 11:43 hrs, 15:31 hrs, 19:10 hrs, and 01:00 hrs and 06:00 hrs. The sampling times between Lamadi and Bulamba were different due to the technical problems of the boat. A van-dorn sampler of 1 litre was used to collect zooplankton samples at 3 m. Four replicate samples were combined to make a composite sample. Together with zooplankton samples, temperature (oC), oxygen (mg/l), and conductivity (Mv) were measured by using Wagtech probes. Phytoplankton biomass was determined as chlorophyll 'a' concentration following the procedure described by Wetzel and Likens (1991).

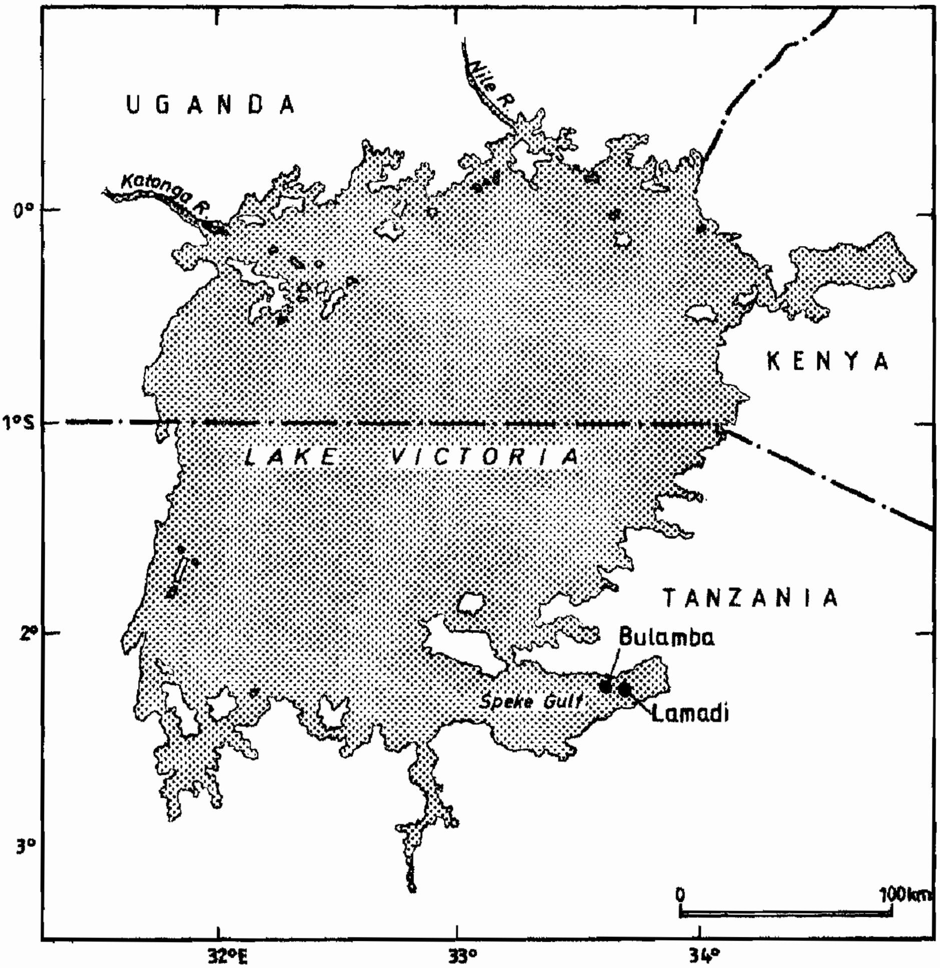

**Figure 1**: A map of Lake Victoria showing sampling sites

## RESULTS

Overall results show that nearly all species undergoes diel migration, being in the surface layers during the night and in the deeper layers during the day. On 24th January 2002 at 14:19 hrs the highest number of zooplankton were found at 6 m and 4 m. At 17:00 hrs, 2200 hrs and 01:00 hrs the zooplankton show an ascend of their populations and were concentrated at 2 m. At 06:00 hrs the highest number of zooplankton were at the surface and lowest at the bottom (Fig. 2).

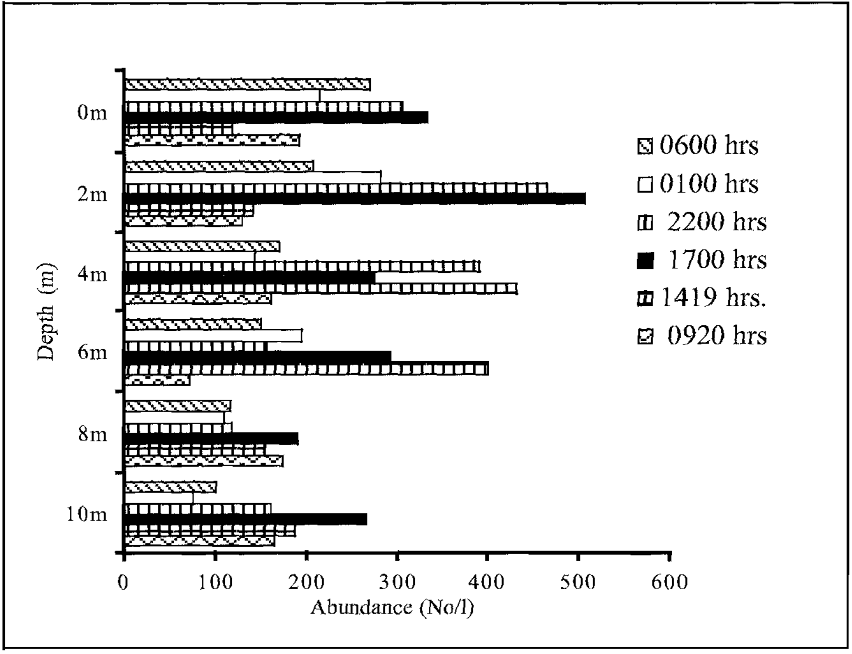

**Figure 2**: Diel Vertical migration of Zooplankton at Lamadi

On 31st January, 2002 at 08:16 hrs zooplankton were concentrated between 12 to 6 m. The highest number of zooplankton was observed at 6 m. At 11:43 hrs the peak of zooplankton was at 9 m. At 15:31 hrs the peak was at 12 m and at 19:10 the animals were ascending and the peak was at 3 m. At 01:19 the peaks were between 3 m to 0 m. At 06:00 the highest number of zooplankton was at the surface (Figure 3).

Results also showed that different species of zooplankton migrate differently and developmental stages of copepods behave differently from adults (Tables 1 & 2). During July 2002, *Thermodiaptomus galeboides*, *Tropocyclops tenellus Thermocyclops neglectus*, *Filinia opoliensis*, *Keratella cochlearis*, calanoid copepodite, and cyclopoid copepodite showed clear diel vertical migration. They concentrated between 0 – 4 m during the night and between 4 - 10 m during the day. Other species and nauplius larvae didn't show clear migration. During July 2003 in the night times (19:00 – 06:00 hrs) large number of zooplankton was between 0 – 6 m and fewer between 9 – 12 m (Table 2).

**Table 1**: Diel vertical migration of different species of zooplankton no/l at Lamadi, 24/1/2002

| | 2200 hrs | | | | | | 0100 hrs | | | | | | 0600 hrs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | 0m | 2m | 4m | 6m | 8m | 10m | 0m | 2m | 4m | 6m | 8m | 10m | 0m | 2m | 4m | 6m | 8m | 10m |
| **Cladocera** | | | | | | | | | | | | | | | | | | |
| *Moina micrura* | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Calanoida** | | | | | | | | | | | | | | | | | | |
| Calanoid copepodites | 11 | 0 | 0 | 4 | 0 | 18 | 0 | 0 | 0 | 0 | 5 | 11 | 0 | 0 | 6 | 15 | 9 | 15 |
| *Thermodiaptomus galeboides* | 0 | 0 | 0 | 4 | 0 | 15 | 0 | 0 | 6 | 0 | 0 | 8 | 6 | 0 | 0 | 15 | 23 | 15 |
| **Cyclopoida** | | | | | | | | | | | | | | | | | | |
| Cyclopoid copepodite | 68 | 25 | 20 | 23 | 51 | 45 | 25 | 18 | 75 | 200 | 75 | 105 | 75 | 39 | 44 | 79 | 45 | 75 |
| *Mesocyclops sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| *Thermocyclops emini* | 4 | 0 | 0 | 0 | 0 | 12 | 0 | 9 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 23 | 25 |
| *Thermocyclops incisus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| *Thermocyclops neglectus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 9 | 5 |
| *Tropocyclops confinnis* | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 5 | 11 | 0 | 0 | 0 | 11 | 0 | 15 |
| *Tropocyclops tenellus* | 8 | 20 | 5 | 11 | 12 | 12 | 13 | 0 | 31 | 50 | 25 | 23 | 13 | 0 | 6 | 11 | 18 | 45 |
| **Nauplius larvae** | 60 | 60 | 80 | 8 | 69 | 42 | 56 | 88 | 225 | 119 | 20 | 11 | 131 | 237 | 156 | 98 | 32 | 20 |
| **Rotifera** | | | | | | | | | | | | | | | | | | |
| *Ascomorpha sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 22 | 6 | 0 | 0 | 0 |
| *Asplanchna spp.* | 8 | 0 | 10 | 0 | 0 | 6 | 0 | 0 | 44 | 0 | 0 | 8 | 31 | 33 | 13 | 0 | 0 | 5 |
| *Brachionus angularis* | 0 | 0 | 20 | 0 | 12 | 3 | 13 | 0 | 6 | 0 | 0 | 0 | 25 | 6 | 0 | 4 | 5 | 0 |
| *Brachionus calyciflorus* | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| *Brachionus caudatus* | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 9 | 6 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 |
| *Brachionus falcatus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Brachionus forficula* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euclanis sp* | 0 | 0 | 0 | 11 | 9 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 11 | 0 | 8 | 0 | 0 |
| *Filinia longiseta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 5 |
| *Filinia opoliensis* | 4 | 5 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 22 | 6 | 0 | 0 | 5 |
| *Keratella cochlearis* | 4 | 5 | 0 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 19 | 39 | 13 | 8 | 18 | 5 |
| *Keratella tropica* | 0 | 5 | 0 | 0 | 3 | 3 | 0 | 9 | 6 | 0 | 0 | 0 | 0 | 6 | 0 | 8 | 0 | 0 |
| *Keratella quadrata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lecane bulla* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 5 |
| *Polyarthra spp.* | 0 | 0 | 5 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 72 | 0 | 15 | 0 | 20 |
| *Synchaeta spp.* | 8 | 0 | 10 | 0 | 0 | 0 | 6 | 9 | 13 | 0 | 0 | 0 | 6 | 0 | 0 | 8 | 5 | 0 |
| *Trichocerca spp.* | 15 | 10 | 5 | 0 | 6 | 3 | 6 | 0 | 19 | 25 | 5 | 0 | 6 | 11 | 19 | 0 | 0 | 0 |
| **Total no/l** | **191** | **130** | **160** | **71** | **174** | **165** | **119** | **140** | **431** | **400** | **155** | **188** | **331** | **506** | **275** | **293** | **189** | **265** |

| | 0920 hrs | | | | | | 1419 hrs | | | | | | 1700 hrs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | 0m | 2m | 4m | 6m | 8m | 10m | 0m | 2m | 4m | 6m | 8m | 10m | 0m | 2m | 4m | 6m | 8m | 10m |
| **Cladocera** | | | | | | | | | | | | | | | | | | |
| *Moina micrura* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Calanoida** | | | | | | | | | | | | | | | | | | |
| Calanoid copepodites | 5 | 35 | 6 | 16 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 8 | 0 | 0 | 0 | 0 | 0 |
| *Thermodiaptomus galeboides* | 20 | 45 | 72 | 10 | 25 | 7 | 6 | 19 | 0 | 13 | 0 | 13 | 8 | 5 | 0 | 19 | 0 | 13 |
| **Cyclopoida** | | | | | | | | | | | | | | | | | | |
| Cyclopoid copepodite | 65 | 125 | 116 | 39 | 13 | 22 | 22 | 69 | 45 | 46 | 20 | 6 | 68 | 58 | 69 | 31 | 0 | 38 |
| *Mesocyclops sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Thermocyclops emini* | 0 | 5 | 6 | 3 | 6 | 0 | 11 | 0 | 8 | 0 | 5 | 0 | 8 | 8 | 0 | 6 | 4 | 6 |
| *Thermocyclops incisus* | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0 |
| *Thermocyclops neglectus* | 10 | 5 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Tropocyclops confinnis* | 0 | 15 | 0 | 3 | 0 | 0 | 0 | 19 | 0 | 7 | 0 | 0 | 15 | 0 | 0 | 0 | 38 | 0 |
| *Tropocyclops tenellus* | 85 | 50 | 39 | 13 | 0 | 65 | 28 | 25 | 8 | 0 | 15 | 6 | 23 | 13 | 25 | 13 | 0 | 6 |
| **Nauplius larvae** | 70 | 80 | 110 | 0 | 50 | 44 | 55 | 100 | 68 | 59 | 35 | 44 | 68 | 22 | 25 | 50 | 0 | 25 |
| **Rotifera** | | | | | | | | | | | | | | | | | | |
| *Ascomorpha sp.* | 0 | 5 | 0 | 7 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 6 | 8 | 0 |
| *Asplanchna spp.* | 15 | 30 | 6 | 13 | 0 | 0 | 11 | 19 | 15 | 13 | 0 | 0 | 23 | 0 | 0 | 6 | 0 | 6 |
| *Brachionus angularis* | 0 | 0 | 0 | 3 | 0 | 0 | 17 | 0 | 0 | 20 | 15 | 0 | 0 | 15 | 0 | 0 | 0 | 0 |
| *Brachionus calyciflorus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| **Table 1 Continued** | **0920 hrs** | | | | | | **1419 hrs** | | | | | | **1700 hrs** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | 0m | 2m | 4m | 6m | 8m | 10m | 0m | 2m | 4m | 6m | 8m | 10m | 0m | 2m | 4m | 6m | 8m | 10m |
| *Brachionus caudatus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 15 | 0 |
| *Brachionus falcatus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 19 | 0 |
| *Brachionus forficula* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| *Euclanis sp* | 0 | 20 | 6 | 3 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 6 | 6 | 0 | 0 |
| *Filinia longiseta* | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 12 | 0 | 0 | 0 | 0 |
| *Filinia opoliensis* | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| *Keratella cochlearis* | 10 | 10 | 6 | 13 | 0 | 0 | 17 | 6 | 0 | 7 | 5 | 0 | 23 | 12 | 6 | 6 | 0 | 0 |
| *Keratella tropica* | 0 | 5 | 0 | 3 | 6 | 0 | 6 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Keratella quadrata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lecane bulla* | 5 | 0 | 0 | 7 | 0 | 7 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 6 | 0 | 0 | 6 |
| *Polyarthra spp.* | 0 | 20 | 11 | 16 | 0 | 0 | 6 | 0 | 0 | 7 | 5 | 0 | 8 | 0 | 6 | 0 | 0 | 0 |
| *Synchaeta spp.* | 5 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 4 | 0 |
| *Trichocerca spp.* | 15 | 15 | 0 | 0 | 0 | 7 | 22 | 13 | 0 | 20 | 0 | 0 | 0 | 18 | 25 | 6 | | 0 |
| **Total no/l** | **305** | **465** | **391** | **156** | **119** | **160** | **215** | **281** | **143** | **195** | **110** | **75** | **270** | **208** | **169** | **150** | **116** | **100** |

**Table 2**: Diel vertical migration of different species of zooplanktonzooplankton at Bulamba, 30/7/2002

| | **0816 hrs** | | | | | **1145 hrs** | | | | | **1530 hrs** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | 0m | 3m | 6m | 9 m | 12m | 0m | 3m | 6m | 9 m | 12m | 0m | 3m | 6m | 9m | 12m |
| **Cladocera** | | | | | | | | | | | | | | | |
| *Bosmina longirostris* | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Diaphanosoma excisum* | 0 | 0 | 11 | 6 | 11 | 0 | 6 | 0 | 6 | 0 | 6 | 6 | 6 | 11 | 6 |
| **Calanoida** | | | | | | | | | | | | | | | |
| Calanoid copepodites | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 11 | 0 | 0 |
| *Thermodiaptomus galeboides* | 22 | 6 | 11 | 0 | 44 | 0 | 17 | 44 | 33 | 0 | 0 | 0 | 6 | 56 | 128 |
| **Cyclopoida** | | | | | | | | | | | | | | | |
| Cyclopoid copepodite | 22 | 39 | 122 | 56 | 56 | 0 | 28 | 22 | 44 | 0 | 50 | 50 | 0 | 17 | 28 |
| *Mesocyclops sp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| *Thermocyclops emini* | 0 | 0 | 11 | 6 | 17 | 0 | 11 | 11 | 22 | 0 | 0 | 6 | 0 | 11 | 28 |
| Thermocyclops incisus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Thermocyclops neglectus* | 0 | 6 | 0 | 0 | 11 | 0 | 11 | 11 | 11 | 6 | 0 | 0 | 6 | 11 | 11 |
| *Tropocyclops confinnis* | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 11 |
| *Tropocyclops tenellus* | 44 | 6 | 0 | 6 | 0 | 0 | 6 | 6 | 33 | 0 | 0 | 6 | 11 | 6 | 17 |
| **Nauplius larvae** | 78 | 56 | 56 | 44 | 44 | 0 | 44 | 22 | 89 | 0 | 128 | 128 | 56 | 50 | 17 |
| **Rotifera** | | | | | | | | | | | | | | | |
| *Asplanchna spp.* | 0 | 6 | 11 | 11 | 0 | 0 | 0 | 0 | 11 | 0 | 6 | 17 | 0 | 0 | 0 |
| *Brachionus angularis* | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Brachionus calyciflorus* | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 0 | 11 | 11 | 0 | 0 | 0 |
| *Filinia longiseta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euclanis sp* | 0 | 0 | 11 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Keratella cochlearis* | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Keratella tropica* | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Synchaeta spp.* | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| *Trichocerca cylindrica* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Trichocerca spp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total no/l** | 189 | 117 | 244 | 150 | 194 | 6 | 128 | 128 | 289 | 6 | 206 | 222 | 94 | 167 | 250 |

| | **1910 hrs** | | | | | **0119 hrs** | | | | | **0600 hrs** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | 0m | 3m | 6m | 9m | 12m | 0m | 3m | 6m | 9 m | 12m | 0m | 3m | 6m | 9 m | 12m |
| **Cladocera** | | | | | | | | | | | | | | | |
| *Bosmina longirostris* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Diaphanosoma excisum* | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 11 | 0 | 0 | 9 | 3 | 6 |
| **Calanoida** | | | | | | | | | | | | | | | |
| Calanoid copepodites | 0 | 0 | 0 | 11 | 0 | 6 | 6 | 6 | 11 | 6 | 5 | 5 | 8 | 8 | 6 |
| *Thermodiaptomus galeboides* | 17 | 28 | 0 | 22 | 6 | 11 | 67 | 17 | 22 | 44 | 65 | 14 | 42 | 22 | 14 |
| **Cyclopoida** | | | | | | | | | | | | | | | |
| Cyclopoid copepodite | 56 | 144 | 33 | 72 | 22 | 67 | 67 | 28 | 39 | 56 | 66 | 64 | 54 | 39 | 28 |

| **Table 2 cont'** | **1910 hrs** | | | | | **0119 hrs** | | | | | **0600 hrs** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taxa** | 0m | 3m | 6m | 9m | 12m | 0m | 3m | 6m | 9 m | 12m | 0m | 3m | 6m | 9 m | 12m |
| *Mesocyclops sp.* | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| *Thermocyclops emini* | 17 | 22 | 6 | 0 | 0 | 11 | 28 | 0 | 6 | 17 | 28 | 10 | 16 | 6 | 0 |
| Thermocyclops incisus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Thermocyclops neglectus* | 0 | 11 | 0 | 0 | 0 | 17 | 6 | 0 | 0 | 11 | 8 | 16 | 9 | 2 | 0 |
| *Tropocyclops confinnis* | 6 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Tropocyclops tenellus* | 17 | 6 | 0 | 17 | 6 | 44 | 6 | 6 | 0 | 0 | 6 | 42 | 0 | 0 | 6 |
| **Nauplius larvae** | 89 | 167 | 100 | 78 | 39 | 28 | 39 | 44 | 17 | 44 | 41 | 28 | 41 | 20 | 44 |
| **Rotifera** | | | | | | | | | | | | | | | |
| *Asplanchna spp.* | 6 | 6 | 6 | 6 | 6 | 11 | 11 | 6 | 0 | 0 | 12 | 11 | 0 | 0 | 6 |
| *Brachionus angularis* | 0 | 0 | 0 | 11 | 0 | 6 | 6 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 |
| *Brachionus calyciflorus* | 0 | 0 | 0 | 0 | 6 | 6 | 6 | 0 | 0 | 6 | 7 | 7 | 6 | 0 | 0 |
| *Filinia longiseta* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euclanis sp* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Keratella cochlearis* | 0 | 11 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Keratella tropica* | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| *Synchaeta spp.* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Trichocerca cylindrica* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Trichocerca spp.* | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 |
| **Total no/l** | **217** | **400** | **150** | **222** | **89** | **217** | **250** | **117** | **94** | **194** | **253** | **212** | **184** | **100** | **114** |

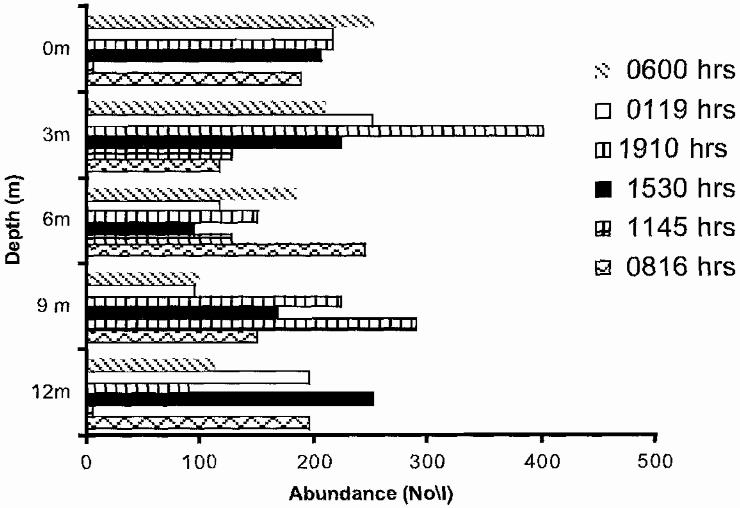

**Figure 3**: Diel Vertical migration of Zooplankton at Bulamba

Results indicated that, chlorophyll a had low correlation with total number of species at the different depths, r = 0.492 for *T. galeboides*, r = 0.4848 for cyclopoid copepodite, r = 0.055 for nauplius larvae, n = 4, but the total number of species at different the different depth indicated high correlation with oxygen, r = 0.508 for *T. galeboides*, r = 0.6180 for cyclopoid copepodite, r = 0.865 for nauplius larvae, n = 4.

## Chlorophyll (Chl a) and physical chemical parameters

Table 3 shows the physical chemical parameters for Lamadi during January 2002. A relatively higher phytoplankton biomass of 11.2 µg/l was recorded at 22:00 hrs at 2 m. and the lowest (6.64 µg/l) at 01:00 hrs at 10 m. Temperature shows very small vertical variations. Water temperature ranged between $25.4^0$C – $24.4^0$C. Conductivity was more or less the same through the water column except at 09:20 hrs at 10 m where the highest conductivity of 109.21 mv was recorded. Maximum values of dissolved oxygen were repeatedly found near the surface although oxygen shows very small vertical variation, the dissolved oxygen values ranged between 6.12 mg/l – 4.97 mg/l. Temperature readings and chlorophyll a values for Bulamba in July 2002 are shown in Table 4. The water was warmer in January ($25.4^0$C – $24.4^0$C) than in July ($23.6^0$C – $20.9^0$C). A relatively higher phytoplankton biomass (chlorophyll a) of 14.52 µg/l was observed in Bulamba at 19:10 hrs at 3 m. It was not possible to measure dissolved oxygen and conductivity at Bulamba due to technical problems.

**Table 3**: Physical chemical parameters recorded at Lamadi, January 2002

| Time | Depth (m) | Temp.($^o$ C) | DO (mg/L) | Cond. (mv) | Chl. a µg/l |
|---|---|---|---|---|---|
| 0920 | 0 | 24.4 | 5.54 | 91.9 | 9.17 |
| | 2 | 24.47 | 5.45 | 95.3 | 9.49 |
| | 4 | 24.48 | 5.39 | 95.2 | 9 |
| | 6 | 24.48 | 5.35 | 95.2 | 8.71 |
| | 8 | 24.47 | 5.42 | 95.75 | 9.12 |
| | 10 | 24.47 | 5.37 | 109.21 | 8.67 |
| 1419 | 0 | 24.49 | 5.11 | 94.7 | 7.3 |
| | 2 | 24.5 | 5.06 | 94.6 | 7.28 |
| | 4 | 24.5 | 5.07 | 94.5 | 6.91 |
| | 6 | 24.49 | 5 | 94.5 | 6.74 |
| | 8 | 24.48 | 5.01 | 94.54 | 6.85 |
| | 10 | 24.48 | 5.01 | 94.4 | 6.89 |
| 1700 | 0 | 25.4 | 5.82 | 96.6 | 8.21 |
| | 2 | 25.4 | 5.84 | 96.5 | 9.04 |
| | 4 | 24.89 | 5.7 | 95.25 | 9.48 |
| | 6 | 24.49 | 5.15 | 94.4 | 7.43 |
| | 8 | 24.47 | 5.07 | 94.4 | 6.98 |
| | 10 | 24.47 | 4.98 | 96.37 | 7.47 |
| 2200 | 0 | 25.01 | 6.12 | 77.8 | 10.43 |
| | 2 | 25.04 | 6.09 | 96.06 | 11.2 |
| | 4 | 25.03 | 6.05 | 96.19 | 10.83 |
| | 6 | 24.89 | 6.01 | 95.83 | 10.13 |
| | 8 | 24.69 | 5.73 | 95.28 | 9.31 |
| | 10 | 24.5 | 5.17 | 95.1 | 8.87 |
| 0100 | 0 | 24.8 | 5.92 | 95.1 | 9 |
| | 2 | 24.82 | 5.91 | 94.9 | 8.81 |
| | 4 | 24.82 | 5.89 | 94.9 | 8.69 |

Table 3 continued

| | | | | | |
|---|---|---|---|---|---|
| | 6 | 24.76 | 5.72 | 94.83 | 8.34 |
| | 8 | 24.65 | 5.47 | 94.69 | 7.58 |
| | 10 | 24.47 | 4.97 | 94.69 | 6.64 |
| ,0600 | 0 | 24.65 | 6.2 | 94.29 | 9.09 |
| | 2 | 24.65 | 6.2 | 94.29 | 9.08 |
| | 4 | 24.97 | 6.17 | 94.19 | 9.03 |
| | 6 | 24.58 | 5.92 | 93.93 | 7.48 |
| | 8 | 24.38 | 5.34 | 93.79 | 6.74 |
| | 10 | 24.38 | 5.16 | 93.7 | 6.77 |

**Table 4**: Physical chemical parameters recorded at Bulamba, July 2002

| Time | Depth (m) | Temp. (° C) | DO (mg/L) | Cond. (mv) | Chl. a µg/l |
|---|---|---|---|---|---|
| 0816 | 0 | 22.8 | _ | _ | 13.13 |
| | 3 | 22.82 | _ | _ | 13.2 |
| | 6 | 22.82 | _ | _ | 13 |
| | 9 | 22.8 | _ | _ | 13.22 |
| | 12 | 21.8 | _ | _ | 13.3 |
| 1145 | 0 | 22.8 | _ | _ | 13.12 |
| | 3 | 22.82 | _ | _ | 12.98 |
| | 6 | 22.81 | _ | _ | 12.93 |
| | 9 | 22.7 | _ | _ | 13.98 |
| | 12 | 22.6 | _ | _ | 12.85 |
| 1530 | 0 | 23.1 | _ | _ | 13.13 |
| | 3 | 23.31 | _ | _ | 13.25 |
| | 6 | 23.23 | _ | _ | 13.89 |
| | 9 | 23 | _ | _ | 13.88 |
| | 12 | 20.9 | _ | _ | 14.28 |
| 1910 | 0 | 23.4 | _ | _ | 13.32 |
| | 3 | 23.42 | _ | _ | 14.52 |
| | 6 | 23.42 | _ | _ | 13.52 |
| | 9 | 23.51 | _ | _ | 13.34 |
| | 12 | 22.4 | _ | _ | 12.86 |
| 0119 | 0 | 23.6 | _ | _ | 13.15 |
| | 3 | 23.62 | _ | _ | 13 |
| | 6 | 23.63 | _ | _ | 12.85 |
| | 9 | 23.55 | _ | _ | 12.75 |
| | 12 | 22.45 | _ | _ | 11.8 |
| 0600 | 0 | 23.72 | _ | _ | 13.27 |
| | 3 | 23.72 | _ | _ | 13.23 |
| | 6 | 23.78 | _ | _ | 13.18 |
| | 9 | 23.6 | _ | _ | 12.6 |
| | 12 | 23 | _ | _ | 12.62 |

## DISCUSSION

From the current study, it is obvious that most species undergo a well-marked diel migration, coming to the surface by or very soon after sunset and descending at dawn. This migration is more marked in some species than in others, but generally they are concentrated together in different water layers at different times of the day. This suggests that the same factors are stimulating the diurnal migration of all species.

There are a number of factors suggested to be the reason of the migration of zooplankton (Lampert 1993, Pijanowska 1993, Kizito 1998). These include abiotic environment variables like day length, temperature, dissolved oxygen and biotic factors like food availability, crowding and predators influence the zooplanktons physiological state which in turn influences the internal motivation to migrate (Ringelberg 1980).

Wetzel (1983) suggested some factors like age, sex, temperature, light, hydrogen-ion concentration of the water (pH) just to mention a few. However in the present study none of parameters measured seem to influence the diel vertical migration of zooplankton in Lake Victoria as temperature and conductivity varied very little with depth.

In Lake Victoria, among others light is considered the most important factor influencing the diel vertical migration because most species seem to concentrate in the deeper layers during the hours of daylight and undergoes a very sudden rise to the surface at about sunset and descent from the surface to the bottom at dawn. Similar observation has been reported by Bowers (1979), McNaught & Hasler (1964), Ringerlberg (1964), Teraguchi et al. (1975) and Buyokwe (1988).

In January 2002, the zooplankton showed vertical migration, as they ascended in the evening and descended in the morning, but the movement was not uniform to all species. A resource hypothesis seems to hold, that the migrating populations achieve some energy benefits by regularly leaving and returning to their food source. Similar results were obtained by Enright (1977); Kerfoot (1970) and McLaren (1963). Zooplankton moved to the available food at 2200 hrs when the highest number of *T. galeboides, T. neglectus, T. tenellus*, cyclopoid copepodite, nauplius larvae, *Asplanchna* spp., *K. cochlearis* and *Trichocerca* spp. were between 0 m and 4 m. At the same time and depth the chlorophyll a values were the highest compared to other depths, ranging between 10 µg/l and 11.2 µg/l. Also in July at 1145 hrs and 1910 hrs zooplankton were concentrated at 9 m. and 3 m. respectively where the higher values of chlorophyll a were recorded. However, the chlorophyll a was not correlated with total number of *T. galeboides*, cyclopoid copepodite and nauplius larvae. This implies that the availability of food may influence diel vertical migration. But the total number of *T. galeboides*, cyclopoid copepodite and nauplius larvae were correlated with oxygen. Sometimes zooplankton move to the place of enough oxygen but during the study the oxygen was almost uniform through the water column.

The results of July study only revealed a limited migration behavior of zooplankton. In Lake Victoria the predators on zooplankton are the *Rastrineobola argentea*, zooplanktivorous cichlids, juvenile fish of all species, and invertebrate predators mainly Chaoborus. The zooplankton community showed moderate migration but at 01:19 hrs, *T. galeboides*, *T. emini*, *T. tenellus*, cyclopoid copepodite, nauplius larvae and some rotifers show downward movement. Many instances of reversed migration of zooplankton of this kind have been described in literature (Bayly 1986, Kizito 1998). Reversed migration can in fact be an indirect effect of the avoidance of larger invertebrate predators that perform normal diel vertical migration (Lampert 1993, Neill 1990).

In the current study the zooplankton may be avoiding sharing the same space with *R. argentea*, which also show diurnal vertical migration (Wanink 1988), as they are mainly found at the surface of littoral and sub littoral waters. During this period the predation or death rate-dictated selective hypothesis seems to apply. Under conditions of relatively high light intensity planktivorous fish are extraordinary rapacious. Werner (1974) found that in small pools, 10 small blue gill sunfish could consume hundreds of daphnids prey in a matter of minutes. In a more long term experiment, Hall et al. (1970) found that blue gills, when added in reasonable densities to quarter-acre ponds, completely eliminated all crustacean zooplankton in one summer. The predation hypothesis would claim that the animals migrate to a depth where the light intensity is such that planktivorous fish may have difficulty locating the migrant. The same mechanism of avoiding predators has also been observed by Zaret (1976), Bollen (1991) Duncan et al. (1993) and Lampert (1993), where the Planktonic crustaceans migrating diurnally to trade off the benefits of reduced mortality by taking refuge.

It has been observed that diurnal vertical migration may not take place in lakes where predation pressure is not significant (Gliwicz 1986). This implies that in Lake Victoria there is significant predation pressure on zooplankton and the Planktonic animals seem to behave differently. Some animals remain in deep water, surviving on whatever food is available to avoid the risk of visual predation in the lit layers (Gliwicz and Pijanowksa 1988, Kizito 1998). Other planktonic preys adopt the strategy of "better dead than unfed" by remaining at the surface during the day (Huntley and Brooks 1982, Johnson and Jacobsen 1987). Others "better hungry than dead" spend the day in deeper waters and ascend to the surface at night (Kremer and Kremer 1988).

Whilst this study was conducted in the inshore waters of Lake Victoria. It is recommended that further studies be undertaken in the offshore waters of the lake to ascertain whether both R. argentea and chaoborus larvae affect diel vertical migration of zooplankton.

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