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DRIVERS OF ZOOPLANKTON DIEL VERTICAL MIGRATION

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ABSTRACT

Vertical migratory behavior, a daily synchronized up-and-down movement practiced by zooplankton shaping the availability of zooplankton to fish as food, was studied in Liberty Reservoir in the Jos North Local Government Area of Plateau State in August 2018, November 2018 and March 2019. The distribution of zooplankton at different times of the day was investigated alongside some physicochemical parameters. Water samples were collected at three hours intervals from 6 a.m. to 6 p.m. on sampling days. Data on zooplankton abundance was analyzed using the SPSS statistical package. A two-way analysis of variance showed that water temperature, pH, water transparency, and dissolved oxygen varied significantly ($P<0.05$) significantly during the daytime. Pearson correlation analysis showed that zooplankton abundance correlated positively with air temperature, pH, and dissolved oxygen. Variation in zooplankton abundance at different depths and times of the day revealed that vertical migration is taking place in these reservoirs. Abundance is more at the top by 6 a.m. and at 3 p.m. at the reservoir's bottom. Temperature, water transparency, pH, and water transparency were attributed to the drivers of daytime migration in these reservoirs.

Keywords: Zooplankton, vertical migration, abundance, diel and physicochemical parameters

Introduction

The word 'diel' is derived from the word deis, which means 24 hours' period; therefore, diel vertical migration involves vertical migration over the 24-hour period of up and down movement of some aquatic organisms in the water column (Forward & Coh1n, 2010; Bandara *et al*., 2022, Oyedapo, 2024). This phenomenon involves the upwards movement of organisms to the water surface during the night to feed and their sinking to the bottom during the day to hide from predators on a daily basis. This migratory behavior is an adaptative strategy for feeding and predator avoidance as the saying goes "better to be

hungry than dead" (Freer and Hobbs, 2020). Zooplankton species show marked vertical migration over large distances on a daily basis, just like many other pelagic aquatic organisms (Iwasa, 1982; De Meester, 2009; Cullin *et al*., 2014; Bandara *et al*., 2022). Furthermore, Forward and Cohen (2010) and Berge *et al*., (2014) explained that there are three patterns of vertical migration exhibited which are nocturnal, twilight, and reverse. Freer and Hobb (2020) liken this spectacular up-and-down behavior to a hide-and-seek game between prey and predator. Several studies have been conducted that have revealed the different drivers of DVM behavior in zooplankton. According to Ringerberg and Van Gool (2003), both proximate and ultimate factors are drivers of DVM. Ultraviolent rays of the sun (Leech *et al*., 2005a; Fischer *et al*., 2006; De Meester, 2009), light intensity, temperature, and food are termed proximate driving factors, while the ultimate factor is predator avoidance (Ringerberg and Van Gool, 2003; Doulka and Kehayias, 2011; Cullin *et al*., 2014; Freer and Hobbs, 2020). Lampert (1989) also explained that zooplankton may either migrate up and down together in a narrow band or may be sharply stratified in deep waters during the day but spread through the water column at night. This up-and-down movement is made possible by tides (Forward & Cohen, 2010) since zooplankton have limited power of locomotion. They explained that during selective tidal-stream transport, animals migrate vertically relative to tides, while during flood-tide transport, animals move up estuaries by swimming in the water column during flood tide. They descend to the bottom during ebb tides, but the opposite occurs during ebb tide transport (Forward & Cohen, 2010). So far, causes of zooplankton diurnal or diel migration in water bodies include searching for food, avoiding predators, and the harsh effects of ultraviolent rays of the sun heating the water surface. However, scientists are continually generating new ideas about what controls the timing, depths and duration of DVM. Evidence now suggests that temperature and oxygen levels of the water and even the genetic make-up of individual animals determine where animals are positioned in the water column over the daily cycle (Brierley, 2014). Information on zooplankton migratory patterns in water bodies on the Jos plateau is absent, and the effect of physicochemical parameters of DVM is not documented in this locality. Therefore, the results from this work will serve as baseline information for subsequent researchers.

Materials And Methods

Description of the Study Area

The study area is liberty Reservoir in Jos metropolis. The map of the study site is shown on the Figure 1. The description of the Study Area is summarized in Table 1.

Table 1: Description of the Study Area

Dam	Latitude	Longitude	Elevation	Length	Width	Vegetation	Geology
Liberty	8º55'	9º53'	1275	2072	659	Wetland, shrubby and farmlands	Granite

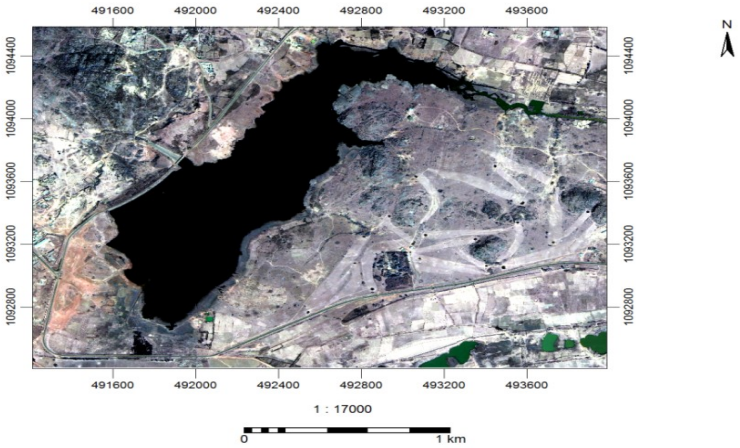


Figure 1: Landsat Image of Liberty Reservoir.

Source: National Centre for Remote sensing Jos, Nigeria (2008).

Zooplankton Sampling

Sampling covered a period of 12 hours (dawn to dusk) starting from 6:00 a.m. in the morning to 6:00 p.m.in the evening. Water samples were also taken at three different depths in all four reservoirs from 6:00 a.m. to 6:00 p.m. hours at a 3-hour interval in August 2018, November 2018, and February 2019. Water samples were taken from three different depths of 0-0.2 m, 3 m and 6 m in the four reservoirs. A 5-litre water sampler was used to take water samples at different depths. 30 litres of water were filtered through the plankton of 60 µm and 25 cm in diameter as described by Akindele, Adeniyi & Ndabawa (2013). The concentrated sample was stored in a 100 ml plastic bottle, preserved in 10% formalin and taken to the Applied Hydrobiology and Fisheries Laboratory, University of Jos for identification.

Zooplankton Enumeration and Abundance

Zooplankton samples were allowed to settle for about 48 hours. The 100 ml filtrate was then decanted to 10 ml. A 1.0 ml subsample of the concentrated zooplankton suspension was pipetted into an Immuno-Cell Black Teflon printed counting slide (series 6 walls, 10mm, 61.100.86) and observed under an Olympus ordinary light microscope. All the zooplankton observed were counted. The number of

organisms per ml recorded was then converted to the number of organisms per litre (abundance) was then calculated using Equation 1 as described by Ovie (1993).

$$Organism\ \ per\ \ litre = \frac{Organism\ \ per\ \ ml\ \ of\ \ concentration}{Litres\ \ of\ \ filtered\ \ concentration} \times 1000 \quad (1)$$

Statistical Analysis

Data on zooplankton abundance were compiled on the SPSS version and ANOVA was used to analyze the variation between the mean abundance with respect to different hours of the day. The mean values were separated using the Duncan's Multiple Range Test option of the same software. P-values < 0.05 were considered statistically significant. Pearson's product moment correlation was used to determine the relationship between the abundance of zooplankton and physico-chemical parameters.

RESULTS

Zooplankton Abundance and Physico-Chemical Attributes in Relation to Time of the Day in Reservoirs

The result of mean zooplankton and physico-chemical attributes in relation to time of day in Liberty Reservoir is shown in Table 2. The mean abundance of zooplankton obtained was high (968.17±102.75). The mean air temperature (22.02±1.53°C) was colder than mean water temperature reading (23.57±0.19°C). Dissolved oxygen (DO) of 7.68±0.15 mg/l, Free carbon dioxide (CO_2) concentration of 11.4±0.10 mg/l were high enough to support aquatic life. Slightly acidic mean pH value (6.56±0.09) was obtained in this reservoir. Very low mean alkalinity value (14.2±0.17 mg/l) but high mean transparency (114.75±8.16 cm) was obtained.

Table 2: Mean Zooplankton Abundance and Physico-chemical Attributes

Parameters	Mean
Zooplankton Abundance (ind. l-1)	669.246±193.47
Water Temperature	23.00±0.62
Air Temperature	17.27±3.56
pH	6.89±0.27
DO	7.44±0.16
Free CO2	10.00±1.81
Alkalinity	13.00±0.81
Transparency	107.48±34.16

The vertical migration trend of zooplankton from the water surface to the benthic zone from 6am to 6pm during the three months in the four reservoirs is also evidently illustrated in Figure 2. Zooplankton abundance fluctuated throughout the study but on the overall, zooplankton abundance was highest at 6 am in the month of August. It was also observed that when the abundance of zooplankton at the top is high, abundance is low at the bottom (benthic zone) and vice versa. Zooplankton abundance was highest at the surface (top) in the early morning (6:00 am) and reduced gradually until afternoon then increased again in the late afternoon and at sunset while the reverse was the case at the bottom (benthic zone) in the month of August. The same pattern was observed in the months of November and February in this reservoir.

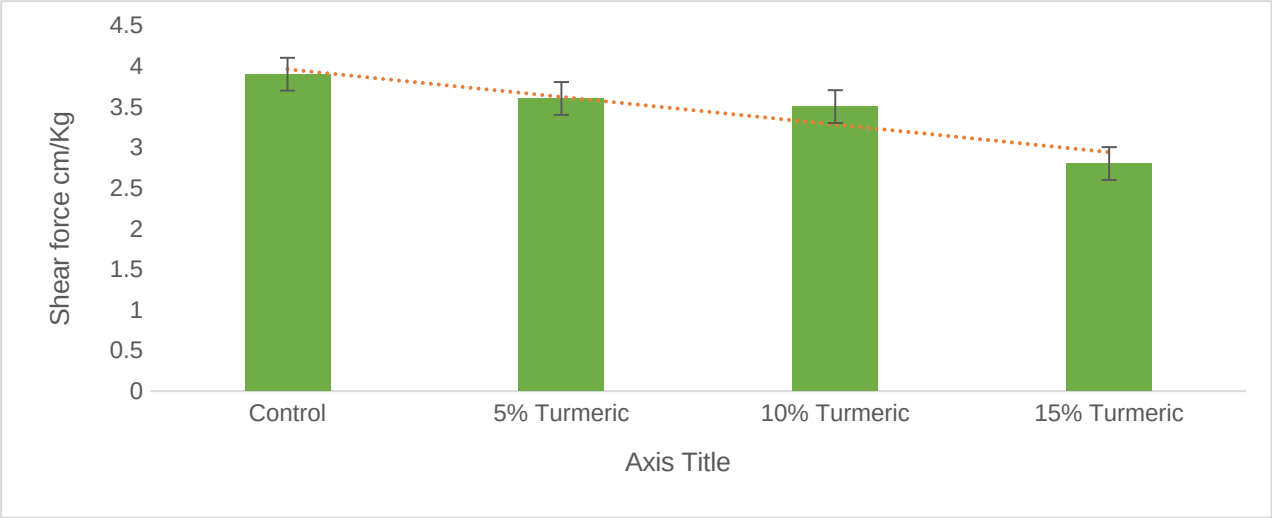


Figure 2: The Day Time Trend of Vertical Migration in Liberty Reservoir

Table 3 shows the relationship between zooplankton abundance and selected physicochemical parameters during the study period. Water temperature was the only parameter that showed a significant negative correlation with zooplankton abundance ($r = –0.322$, $P < 0.05$), indicating that zooplankton abundance decreased as water temperature increased. All other parameters, including air temperature, transparency, pH, dissolved oxygen, free carbon dioxide, and alkalinity, had weak and non-significant correlations ($P > 0.05$) with zooplankton abundance. Overall, the results suggest that water temperature was the major environmental factor influencing zooplankton distribution, while the other physicochemical variables had little effect during the study period.

Table 3: Pearson Correlation Coefficient® for Zooplankton and Physicochemical Attributes Studied during the Vertical Migration Study (2012-2014)

	Water temp	Air Temp	Transparency	pH	Dissolved Oxygen	Free Carbon	Alkalinity
Zooplankton Abundance	-0.322*	0.056	-0.040	0.056	0.111	-0.081	-0.005

Key

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

Zooplankton Abundance and Physico-Chemical Attributes in Relation to Time of the Day in Reservoirs

Reservoirs is resourceful in zooplankton species which ae useful food resource for fish. Therefore, water in this reservoir can be channeled into fish ponds for fish culture. Zooplankton species present can also be harvested for culturing and onward use to nurture fish fries in the nursery. Water quality parameters are all within range for fish farming and other aquatic life. Reservoir water is slightly acid but suitable for aquatic life. This is also a pointer that organic matter decomposition is going on and a warning of the reservoir approaching eutrophic status

The variation observed in zooplankton abundance at different depths and hours of the day confirms the zooplankton vertical migration pattern in the four reservoirs. The reduction in mean abundance at the water surface from early morning to afternoon (6:00 a.m. to noon) with a corresponding increase at the bottom implies vertical migration is taking place. The significant inverse relationship existing between zooplankton abundance and water temperature implies that when temperature is high , zooplankton abundance is low. We can therefore categorically say that position or distribution of zooplankton in the water column is influenced by sunlight intensity/atmospheric temperature. This results does not agree with Simoncelli *et al*. (2019) who reported a positive correlation between temperature and the upward velocity of zooplankton.

The accumulation of zooplankton at the bottom at 3 p.m., with very few at the top at the reservoirs, makes it obvious that they are avoiding the scotching effect from the sun which directly warms the surface water from 12 noon to 3pm according to Malcolm *et al*. (2008) and Brown *et al*. (2010), then begins to set after

this time of the day. They could also be seeking refuge in the darker zones of the water column (bottom) in order to avoid being eaten by the presence of visual predators in these reservoirs that were encountered during sampling such as *Hermichromis bimaculus, Oreochromis niloticus, Lates niloticus, Clarias garienpinus,* etc. The high transparency value recorded is also a pointer to the fact that predation pressure will be high due to the presence of these visual feeding fishes reported earlier in this reservoir by several authors (Gosselle, 2010; Akpa, Ajima and Oyedapo, 2020).

The observed increase in zooplankton by 6 p.m. at the surface and a corresponding decrease at the reservoir's bottom may be a result of reduced water temperature at the surface by sunset and reduced war transparency as reported by Leach *et al*. (2014) and Simoncelli *et al*. (2019). Zooplankton may to return to the surface to feed on pelagic phytoplankton where they will remain all through the night till day break when water temperature begins to rise and visual feeding fish begin to sport them. Similar findings have been reported in the literature (Knott, 2000; Uttieri *et al*., 2004; Forward and Cohen, 2010; Havermans *et al*., 2019). Freer and Hobbs (2020) link the scenario to a hide-and-seek game between prey and predator. In contrast to everything stated above, Simoncelli *et al*. (2019) came to the conclusion that the upward movement of zooplankton is not caused by the search for food but by the temperature of the water.

According to Lorda and Data (2023), physicochemical parameters, in particular oxygen, have a limiting effect on zooplankton because they are only found in high-oxygen areas of the water column (within 100 meters). However, in this study oxygen is not a limiting factor because this water body is high in dissolved oxygen. This may be due to the fact that the sampling period coincides with the period of active photosynthesis in the reservoir which releases oxygen as well as atmospheric oxygen being introduces by wind action.

CONCLUSION

The study examines the vertical migration of zooplankton in a reservoirs in Plateau State, Nigeria. The findings show that the zooplankton present constantly migrate downward during the day and emerge back to the surface by evening, as established by the variation in zooplankton abundance over the course of the sampling hours. The search for food in these reservoir causes the ascent at dusk, whereas changes in water temperature, dissolved oxygen levels, pH, and water transparency and probably predator avoidance may have contributed to the gradual descent during the daytime. There were noticeable, critical, and significant changes in the zooplankton abundance of the reservoirs at 6:00 am (dawn), 12 noon (when the sun is directly overhead the reservoirs), 3 pm (late afternoon), and 6:00 pm (sunset). Therefore, it follows that the sun's rise and set each day has a significant impact on zooplankton migration. On the Jos Plateau, the best times to collect samples of zooplankton are early in the day (6:00

a.m.) at the water's surface or late in the day (3:00 p.m.) at the reservoir bottoms. Result of this study is baseline information useful to subsequent researcher and fish farmers hoping to exploit zooplankton food resources as life food to feed fish thereby reducing the cost of production

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