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RESEARCH PAPER

Gut analysis of the freshwater shrimp *Caridina nilotica* ("Ochong'a") for its conservation in the face of its extensive utilization in aquaculture and climate change in Lake Victoria, Kenya

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Abstract

The aquaculture industry is expected to double by the year 2050 but has not yet reached its full potential in East Africa. Tilapia makes up 75% of the freshwater fish production in Kenya, but the high cost of commercial fish feed is limiting the expansion of the industry. The freshwater shrimp *Caridina nilotica* is an established alternative to fishmeal in the production of the commercial feed, but its accessibility is limited to the natural stocks in Lake Victoria. Towards this end, this study investigated the gut contents of *Caridina nilotica*. One hundred specimen of *C. nilotica* were caught from Usoma Beach, in Winam Gulf of Lake Victoria. They were dissected and their gut samples were examined under a microscope. Every observed gut content were photographed and their frequency of occurrence recorded. Our findings showed that the main food for the *C. nilotica* was algae. The algal species were identified based on their morphology, color, and overall shape. The mean total body length of the examined *C. nilotica* was 2.12 ±0.29cm (±SD). Thirteen genera were identified from 6 divisions. The identified genus included; *Microcystis* sp., *Surirella* sp., *Staurostrium* sp., *Synechococcus* sp., *Pediastrium* sp., *Synedra* sp., *Oocystis* sp., *Hantzschia* sp., *Oscillatoria* sp., *Fragilaria* sp., and *Glaucocystis* sp. *Merismopedia* sp. (Cyanobacteria) and *Botryococcus* sp. (Chlorophyta) were abundant. *C. nilotica* mainly feed on algae from the division Chlorophyta, with diatoms and Cyanobacteria also being common. The information obtained in this study can be used to develop protocols for mass *C. nilotica* cultivation.

Introduction

On a global scale, there is an urgent need to address the current challenges of climate change and world population growth. With an estimated 9.7 billion people to feed by the year 2050, agricultural production must increase by 70% to meet this demand (UNDESA, 2022; FAO, 2009a). Currently, aquaculture is the second fastest-growing food sector after biotechnology. The demand for aquaculture products is estimated to nearly double during this period (Naylor et al., 2021). As it stands now, the fishery industry is not operating in a way that is sustainable or able to be expanded upon virtually. Overfishing, unsustainable practices, pollution, habitat destruction, disease, and the spread of invasive species are significantly reducing the productivity of the fisheries industry and causing substantial harm to surrounding ecosystems. These factors not only deplete fish stocks but also disrupt the balance of aquatic environments, threatening biodiversity and long-term sustainability. Specifically in the tropics, the fisheries industry is vulnerable to the direct and indirect effects of climate change (Pickering et al., 2011).

In Kenya, commercial cultivation of freshwater fish was established in the 1920's and was commonplace by the 1960s (Opiyo et al., 2018). In the 1960s, the "Eat More Fish Campaigns" led to the growth of rural fish farming production, until the 2000's when further investment in the sector caused production in Kenya to quadruple (1000 MT to 4000 MT) (FAO, 2016). Production stayed steady until 2010 when the government introduced the Economic Stimulus Project – Fish Farming Enterprise Productivity Program. Through this program, farmers received subsidies for pond construction, fingerlings, and feed. As a result of the program, production was projected at 24,096 MT in 2014. Unfortunately, the system was not sustainable, and production later decreased to 18,542MT in 2019 (Obwanga et al., 2017; Munguti et al 2021).

Aquaculture in Kenya includes many varieties of fish and utilize different cultivation methods. Freshwater fish production in Kenya is limited to four main species: Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), common carp (*Cyprinus carpio*), and the Rainbow trout (*Oncorhyncus mykiss*). Nile tilapia makes up 75% of the fish that is produced through freshwater aquaculture in Kenya (Farm Africa, 2016). Nile tilapia can be farmed in ponds or in cages in Lake Victoria (Opiyo et al., 2018). Outdoor ponds are a common method of cultivation, as they have a wide range of applications and can be modified to different environments by adding Ultraviolet-treated liners (Munguti et al., 2014). Cage farming on the Kenyan side of Lake Victoria is relatively new, taking off in 2013 (Njiru et al., 2019). The only fish currently being cultivated in cages in Lake Victoria is Nile tilapia. As of 2017 there were approximately 3400 cages and was expected to increase (Njiru et al., 2019).

Fish farmers, face barriers to producing a quality product while making a reasonable profit. Quality seed stock is inaccessible and expensive, and the cost of production is high due to the cost of fish feed. As of 2023, the average cost of fish feed is 147ksh/kg. In addition to high cost, the feeds available have decreased in quality due to the high demand (Munguti et al., 2014). As a result, many small-scale farmers formulate their own feed using the available resources or feed their fish with either poultry or livestock feed. These alternative practices do not meet the nutrient requirements for Nile tilapia and can introduce unnecessary antibiotics or hormones to the fish (National Research Council, 1993; Opiyo et al., 2018).

A common source of protein in farmer-formulated fish feed is the freshwater shrimp *Caridina nilotica* found in Lake Victoria. *Caridina nilotica* is a freshwater shrimp species of the family Atyidae. It can be found in Lake Victoria and is known locally as 'Ochonga'. The biomass of *C. nilotica* in Lake Victoria has been estimated at 22,694 metric tonnes (Getabu et al., 2003). Within Lake Victoria, *C. nilotica* is abundant in the littoral region, but can also be found in offshore waters (Fryer, 1960; Lehman et al., 1996). Nearshore populations are benthic, while offshore populations are mainly (86%) planktonic (Lehman et al., 1996). *Caridina nilotica* can reach a maximum length of 2.5 cm and have a slim body form with attenuated appendages (Fryer, 1960). While small individuals are transparent in appearance, the larger individuals tend to be darkly pigmented. Dark blue, black, and an emerald-green individual have been documented. Not much is known of the feeding mechanisms of *C. nilotica* except of one key study (Fryer, 1960). *C. nilotica* is caught as a bycatch when fishing for *Rastrineobola argentea* (Kubiriza et al., 2018). *Caridina nilotica* makes up approximately 10% of the *R. argentea* that is landed. *C. nilotica* is typically sun dried alongside *R. argentea* on tarps before being separated. Farmers then mix the dried shrimp with rice bran or maize bran and sometimes *R. argentea* meal (Ngugi et al., 2007). This shrimp is an important feed component for fish and other animals for small-scale and commercial farming in East Africa (Bundi et al. 2013; Mwamburi 2013). The current dependence on the freshwater shrimp *C. nilotica* for use in animal feed has not only resulted in a high cost for fish farmers in Kenya but also threatened the natural population of *C. nilotica* in Lake Victoria. *Caridina nilotica* is the most common source of protein in fish feed and is also used as a protein source in other livestock feeds. In general, the cost of fish feed accounts for approximately over 50% of the total cost of production (FAO 2009b). This expense is the greatest limiting factor for increasing profit and improving the livelihoods of fish farmers in Kenya. In East Africa, *C. nilotica* is only sourced from Lake Victoria. Without a sustainable alternative source of *C. nilotica*, the cost of fish feed will remain high and the natural population in Lake Victoria will be vulnerable. The population, diet, and behaviors of *C. nilotica* in Lake Victoria are largely understudied. The feeding habits and mechanisms have been described in detail by Fryer (1960), but even in this case, the diet of *C. nilotica* is described mainly as "an amorphous mass of grey-green material." It has been more than six decades since Fryer (1960) published his work, with climate change, lake dynamics, urbanization, catchment use changes reported, fish species, and population changes, a revisit of the diet composition of *C. nilotica* is necessary. There is yet to be a detailed study on the diet of *C. nilotica* in Lake Victoria since these changes.

Materials and Methods

Study area

Lake Victoria is the largest tropical lake in the world, and is shared between Tanzania, Uganda and Kenya. Only 6% of the total lake area is in the Republic of Kenya. The lake lies in a shallow continental sag between the two arms of the Great Rift Valley, 1170 m above sea level. The lake has a maximum depth of 84 m, a volume of 2760 km^3, an average depth of 40 meters and a surface area of 68,800 km^2 (Bootsma and Hecky, 1993; Crul, 1995). The mean surface temperature is about 25ºC, while the temperature of deeper layers is about 1 to 2 degrees lower (Witte and Van Densen, 1995). The primary inflows into the lake basin originate from the slopes of the western ridge of the East African Rift Valley including; Sio, Nzoia, Yala, Nyando, Sondu Miriu, Kuja, Kibos and Kisat rivers. The present study was conducted in Usoma beach next to Kisumu International Airport (0.0819° S, 34.7295° E) (Fig 1).The surface water temperatures range between 23.5º C and 29.0 ºC. Wind induced currents influence water mixing in the gulf. The Secchi transparency ranges from 35 to 155 cm.

Sampling

Samples of the *C. nilotica* were collected from the Winam Gulf (Kenyan side) of Lake Victoria. Offshore waters were accessed with a boat, and samples were collected using a seine net. Collection occurred at night when the study species exhibited diel vertical migration (Lehman et al., 1996). After collection, samples were stored in plastic bags containing water from Lake Victoria and then transported to Egerton University. The Egerton Njoro campus is located in Nakuru County, Kenya, approximately 140 km northwest of Nairobi, and 190 km east of Lake Victoria, approximately 4 hours.

Acclimatization of the samples

Once the live samples arrived at Egerton Njoro campus, they were acclimatized to their new environment. The samples while within the polythene bags were gently placed into the 50 L aquarium and left for about 30-45 min, to attain the ambient water temperature. The polythene bags were then opened, and the shrimps were allowed to freely swim into the tank.

Sample analysis

Freshly dead samples were examined for their gut contents. Before dissection, each sample was measured from the rostrum to the end of the telson in centimeters to determine the total length. Using a scalpel and forceps, under a dissecting microscope, the specimens were cut transversely along the midsagittal plane. Then, the gut contents were located based on their color and consistency and removed from the specimen. Using a pipette, the gut contents were transferred to a slide to then be examined under a light microscope. Under 40x and 100x magnification, photos were taken of the gut contents for later identification based on the size, morphology, pattern, and color of the contents. The dominant species-most frequent was noted, as well as the lack of gut contents in individual samples. The gut contents were identified using identification keys (Komarek and Anagnostidis, 1998; Prescott, 1970) and online resources such as AlgaeBase. The sex of each individual was also noted based on the presence of eggs on the abdomen and shape (Females have a wider, more rounded abdomen, while males have a narrower, more triangular abdomen).

Results

Caridina nilotica size and sex ratio

The mean total body length was 2.12 ± 0.29 cm (Mean ± SD, n=100). The shrimps were grouped into two groups based on their sizes as follows; small with a size of <1cm and large >1cm body lengths. Nineteen specimens were females, while there were 81 males.

Gut content analysis

Thirteen genera were identified from 6 divisions (Figure 1). The divisions represented by the samples include: Cyanobacteria, Chlorophyta, Gyrista, Bacillariophyta, Charophyta, and Archaeplastida. Approximately 34 species remain unidentified. Some of the algae identified included: *Microcystis sp, Surirella sp., Staurostrum sp., Synechococcus sp., Pediastrium sp., Synedra sp., Oocystis sp., Hantzschia sp., Oscillatoria sp., Fragilaria sp. and Glaucocystis sp.* Three algae were most commonly found: *Merismodpedia* (Cyanobacteria), *Botryococcus sp* (Chlorophyta) and unidentified species.

There were three most frequent food items in the gut of *C. nilotica* as shown (Figure 2).

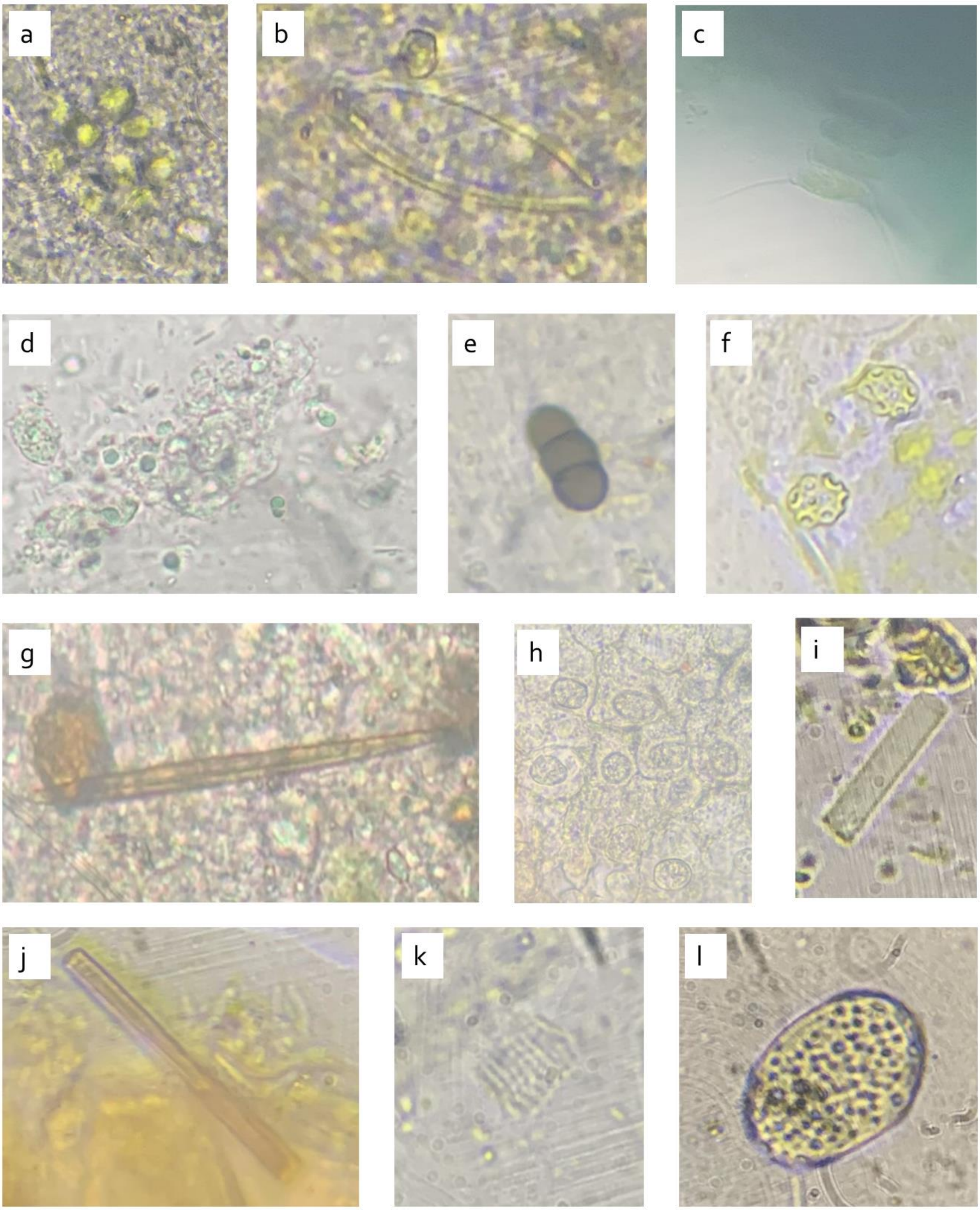

Figure 1. a, *Microcystis sp*. b, *Surirella sp.,* c, *Staurostrum sp,* d, *Synechococcus sp,* e, *Unidentified sp.* ,f, *Pediastrum, g, Synedra sp.,* h, *Oocystis sp.,* i, *Hantzschia sp.,* j, *Oscillatoria sp.,* k, *Fragilaria sp.,* l, *Glaucocystis sp.*

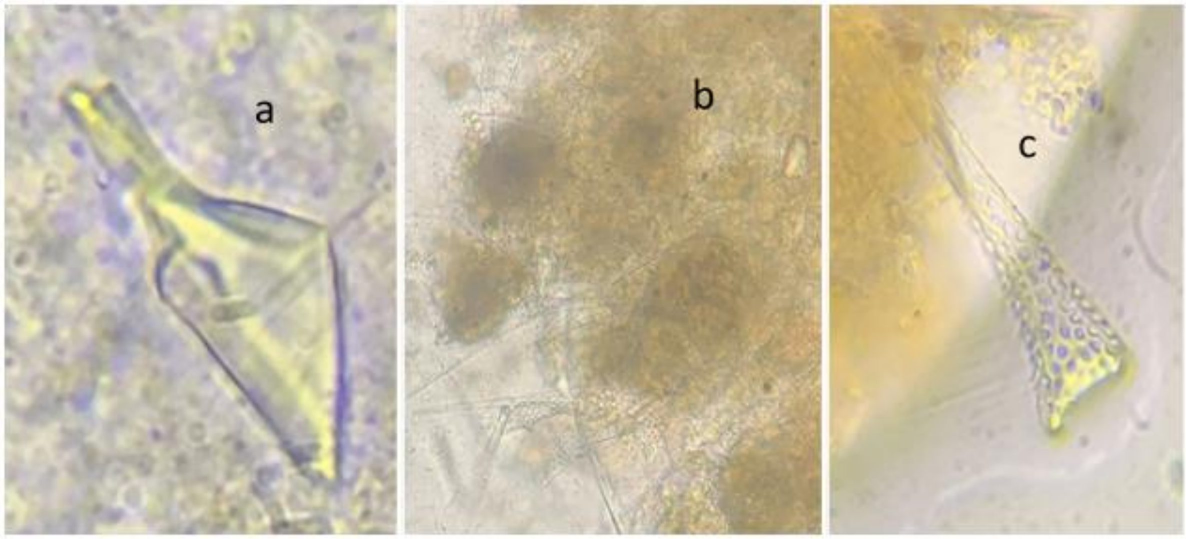

Figure 2. Three most frequently occurring species in order of the most abundant (unidentified>Botryococcus sp.>*Merismopedia sp.*)

Food distribution in Small and Large Caridina nilotica

Samples were noted as having a dominant genus when possible. The percentage of the samples with each dominant genus were compared between the small and large groups (Figure 3a). The percentage of the samples were also compared between the two groups based on the divisions that were represented (Figure 3b). The results clearly showed that smaller *C. nilotica* prefer Cyanobacteria whereas larger ones prefer Chlorophyta (Figure 3b).

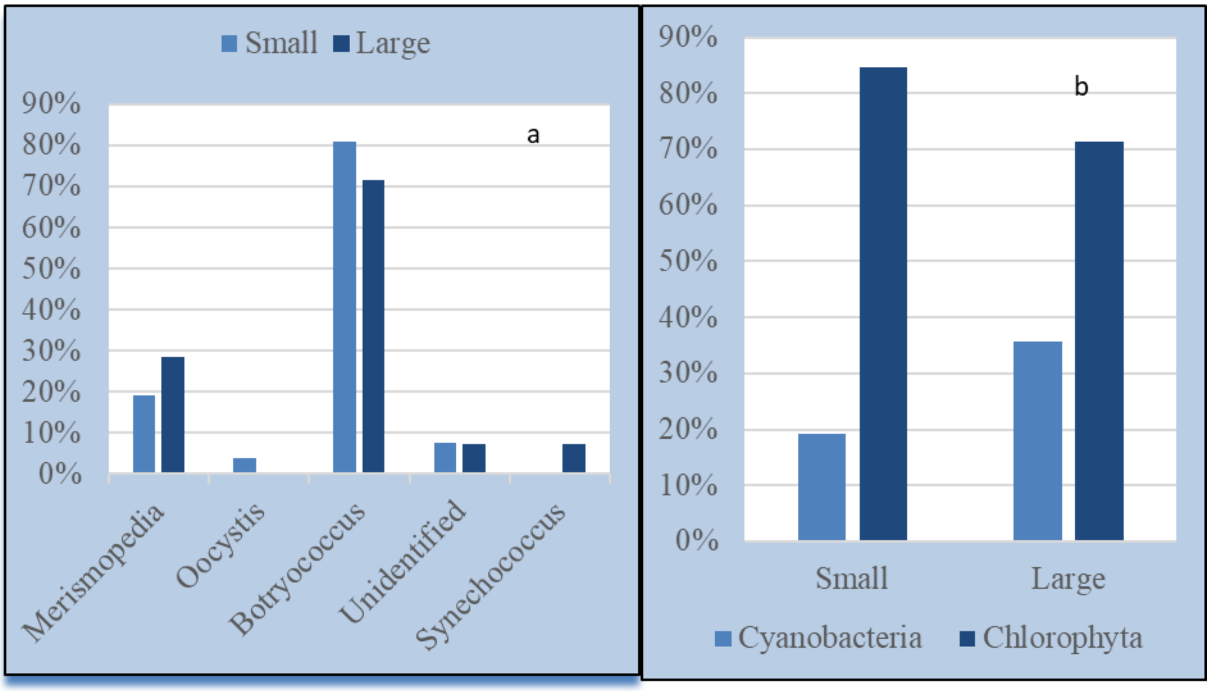

Figure 3. a, Comparison between the major algal species abundances in the small and large *C. nilotica*, and b showing a comparison of the two major algal divisions in the small and large *C. nilotica*

Discussion

Caridina nilotica is the only shrimp species known in Lake Victoria (Fryer 1960). In general, there are very few studies on the freshwater shrimp *Caridina nilotica* in Lake Victoria such as Fryer (1960), Lehman et al (1996), Bundi et al (2013), Mwamburi (2013) and Outa et al (2020).

Most of the studies on this species are mainly those focusing on its potential as a substitute for fishmeal in fish feeds in aquaculture.

The findings of this study have shed some light and useful insights into *C. nilotica*'s ecology in Lake Victoria. Firstly, the results showed that *C. nilotica* prefer feeding on algae. This finding while agreeing with the earliest study by Frier (1960), reveals further details of the "mass of greenish diet" that Fryer (1960) wrote about, but also, slightly differs on them being detritivores. It does appear that *C. nilotica* is highly selective in its diet. This study showed that *C. nilotica* feeds on algae mainly from the division Chlorophyta, Bacillariophyceae, and Cyanobacteria. Further, the study showed that there could be a potential ontogenetic shift in diet for *C. nilotica* as smaller *C. nilotica* preferred Cyanobacteria while the larger ones preferred Bacillariophyceae and Chlorophyta. There could be some possible reasons, one of them being a possibility of an ecological niche partitioning, with the smaller ones possibly feeding in surface waters, where Cyanophyta dominate due to their floating adaptive potential, and the larger ones, being benthic feeders, where the bacillariophyceae are known to be periphytic, attaching to substrates in water. In agreement with our findings, a study by Lehman et al (1996), while focusing on the abundance, biomass and diel migration of C. nilotica in Lake Victoria, it was reported that only about 9% (night) to 14% (day) of the population appeared to be epibenthic. They also suggested that the behavior of the animal is consistent with the hypothesis that it is not a strict detritivore as previously reported; rather it may engage in facultative planktivory, especially at night.

Conclusions

From the findings of this study, we make the following conclusions: first, *C. nilotica* mainly feed on algae from the division Chlorophyta, with diatoms and Cyanobacteria also being common. Secondly, there was a difference in diet between the small and large individuals. Thirdly, the data produced from this study can be used to develop *C. nilotica* cultivation and feeding techniques. This study further recommends the possibility of Genomic sequencing of gut contents to confirm identification and future research examining the ecological role of *C. nilotica* in Lake Victoria (Community structure, preferred habitat, predator-prey interactions).

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Ethical approval

The authors declare that this study complies with research and publication ethics.

Informed consent

Not available.

Conflicts of interest

There is no conflict of interests for publishing this study

Data availability statement

The authors declare that data are available from authors upon reasonable request

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Author contribution

Elick Otachi: Writing original draft, Conceptualization, Data curation, Formal analysis

Anne Osano: Investigation, Methodology, Software, Funding acquisition, Resources, Writing original draft,

Joshua Ogendo: Supervision, Validation, Visualization, Project administration, Review, Editing.

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