

Feeding habits and some other biological aspects of *Oreochromis niloticus* (L.) and *Cyprinus carpio* (L.) in Lake Ardibo

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Abstract. Ethiopian freshwater bodies support a substantial fishing population; however, their sustainable utilization has been limited due to the lack of comprehensive scientific information on the feeding ecology, reproductive biology, and length–weight relationships (LWRs) of commercially important fish species. This study investigated the feeding habits and selected biological characteristics of *Oreochromis niloticus* and *Cyprinus carpio* in Lake Ardibo from June 2022 to September 2023 based on monthly sampling campaigns. Fish specimens were collected using gillnets and hooks. Selected physicochemical parameters of the water, including temperature, pH, and dissolved oxygen, were measured and found to be within ranges suitable for fish survival. The LWRs of both species indicated nearly isometric growth patterns. The mean condition factor (K) was 1.77 for *O. niloticus* and 1.75 for *C. carpio*, with no significant differences between sexes ($P > 0.05$). Both species exhibited omnivorous feeding strategies, consuming a wide range of prey items. In *O. niloticus*, detritus occurred in 40% of the stomachs and contributed 41.38% of the total food volume, while *Microcystis* was present in 73.33% of the stomachs and accounted for 62.99% of the volume. In *C. carpio*, detritus and diatoms contributed 49% and 33.2% of the total food volume, respectively. Based on the Index of Food Preponderance (%IFP), detritus constituted 46.40% and 63.79% of the diet in *O. niloticus* and *C. carpio*, respectively. Ontogenetic analysis

revealed an increase in the contribution of plant-origin diets with fish size in *O. niloticus*. Overall, the results indicate that both species adopt an omnivorous feeding strategy with a tendency toward detritivory and herbivory in larger individuals.

Keywords: Condition factor, lake fisheries, relative abundance, sex ratio.

Introduction

Fish distribution, growth, and movement are strongly influenced by the interaction between anthropogenic pressures and the physicochemical and biological characteristics of aquatic ecosystems (Hossain et al. 2012). In Ethiopia, freshwater ecosystems are increasingly affected by intense human activities (Eyayu and Getahun 2022). Monitoring the biological and physicochemical conditions of water bodies is therefore essential to assess the extent of anthropogenic impacts and to develop appropriate conservation and management strategies (Temesgen and Getahun 2016).

Lake Ardibo is a multipurpose freshwater system that supports domestic water supply, agriculture, and fisheries production (Asnake and Mingist 2018, Mohammed et al. 2023). However, increasing

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human pressure, including improper waste disposal, agricultural runoff containing pesticides and herbicides, and illegal fishing practices (e.g., small mesh gillnets and poisoning), poses a significant threat to the lake's ecological integrity and fish resources.

The Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) are the two most commercially important fish species in Lake Ardibo. Despite their economic significance, there is limited information on their biological characteristics, including feeding ecology, length–weight relationships, and condition factors. Insufficient biological knowledge may lead to unsustainable fisheries management practices in tropical freshwater ecosystems (Eyayu et al. 2023).

Previous studies have investigated the biology of these species in other Ethiopian lakes (e.g., Engdaw et al. 2013, Dadebo et al. 2015), indicating that such research is feasible and valuable. However, comparable information is lacking for Lake Ardibo, particularly in the context of a multipurpose lake exposed to increasing anthropogenic pressure.

Understanding fish feeding ecology is essential for effective fisheries management, as it provides insight into trophic interactions, resource utilization, and ecosystem functioning. Food availability directly influences fish growth, condition, and reproductive capacity (Dadebo et al. 2015).

Moreover, knowledge of feeding habits supports the identification of suitable species for aquaculture and the development of culture-based fisheries. Therefore, the aim of this study was to investigate the feeding habits and selected biological characteristics of *O. niloticus* and *C. carpio* in Lake Ardibo. Specifically, the study aimed to (i) quantify diet composition, (ii) evaluate feeding strategies using multiple dietary indices, and (iii) assess ontogenetic shifts in feeding patterns. The findings are expected to provide baseline

information for the sustainable management and conservation of fish resources in Lake Ardibo.

Materials and Methods

Study area and sampling sites

Lake Ardibo is located in the South Wollo Zone of the Amhara Regional State, Ethiopia (Fig. 1), at an elevation of approximately 2000 m a.s.l. (11°10'26.9" N and 39°45'19.2" E). The lake has a maximum depth of 65 m and a surface area of approximately 21 km², with a catchment area of about 52.6 km² (Asnake and Mingist 2018). It is part of the Awash River Basin and is characterized by a sub-humid climate, with a mean annual temperature of 18°C and annual rainfall of approximately 1158 mm. The lake is surrounded by extensive papyrus swamps that provide important habitats and food resources for aquatic organisms. It supports populations of economically important fish species, particularly *Oreochromis niloticus* and *Cyprinus carpio*. Fish and water samples were collected from three sampling sites representing different levels of anthropogenic influence: (i) pelagic (open water, relatively low

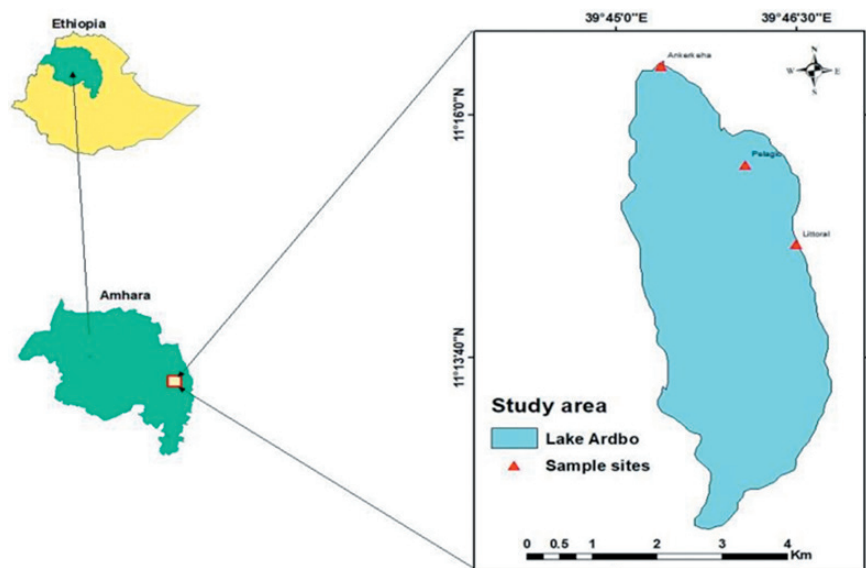


Figure 1. Map of Lake Ardibo showing the study sites.

human disturbance), (ii) littoral (near a road, exposed to higher anthropogenic pressure), and (iii) Menafesha (adjacent to human settlements).

Fish sampling, measurement and gut collection

Fish samples of *O. niloticus* and *C. carpio* were collected monthly from June 2022 to September 2023 over a period of 15 months using gillnets and hooks. Gillnets with mesh sizes ranging from 6 to 10 cm were used in accordance with local regulations. Nets were set in the late afternoon (16:30 h) and retrieved the following morning (08:00 h) to maximize catch efficiency during peak fish activity periods. To minimize sampling bias, similar fishing effort (number of gears and sampling duration) was maintained across all sites and sampling periods. Immediately after capture, fish were measured for total length (TL, cm) using a measuring board and weighed (TW, g) using a digital balance. Sex was determined by dissection, and gonads were examined following the maturity scale described by Murua et al. (2003). The digestive tract was removed near the esophagus to minimize regurgitation. Gut contents were preserved in 5% formalin and transported to the laboratory for analysis. For ontogenetic dietary analysis, *O. niloticus* individuals were categorized into size classes: small (<15 cm TL, n = 21) and medium (15-25 cm TL, n = 42). Due to the narrow size range of collected specimens, *C. carpio* was analyzed as a single size group.

Estimation of fish relative abundance

The relative abundance of fish species was estimated using the Index of Relative Importance (IRI) following Kolding (1989). The IRI incorporates numerical abundance (%N), weight contribution (%W), and frequency of occurrence (%FO) and was calculated as:

$$\%IRI = \frac{(\%Wt_i + \%N_i)\%FO_i}{\sum_{j=1}^{i=1} (\%W_j + \%N_j)\%F_j} \times 100$$

where %Ni is the percentage in number, %Wi is the percentage in weight, and %FOi is the frequency of occurrence of each species.

Sex ratio

The sex ratio of each species was determined as the proportion of females to males (F:M) following Peña-Mendoza et al. (2005). Differences between observed and expected ratios (1:1) were tested using the chi-square test.

Length-weight relationship (LWR) and condition factor (K)

The length-weight relationship (LWR) was described using the power function (Bagenal and Tesch 1978):

$$TW = aTL^b$$

where TW is the total weight (g), TL is the total length (cm), and a and b are regression parameters.

The condition factor (K) was calculated according to Bagenal and Tesch (1978) as:

$$K = \frac{TW}{TL^3} \times 100$$

Differences in K between sexes were evaluated using an independent t-test and one-way ANOVA.

Gut content analysis

Gut contents were examined under a dissecting microscope in Petri dishes. Food items were identified using standard taxonomic keys (Needham and Needham 1962). The volumetric contribution of each food item was estimated using the displacement method, whereby the volume of water displaced by the sample was measured in a graduated cylinder (Hyslop 1980). Diet composition was quantified using percentage frequency of occurrence (%FO), and percentage volume (%V). To reduce biases associated with single dietary indices, compound indices were applied. The Geometric Index of Importance

Table 1

Catch composition and Index of Relative Importance (IRI) of fish species in Lake Ardibo. N = number of individuals; %N = percentage by number; %W = percentage by weight; %FO = percentage frequency of occurrence; %IRI = percentage by Index of Relative Importance.

Species	N	%N	%W	%FO	IRI	%IRI
<i>O. niloticus</i>	95	60.9	54.3	75	7885	67.5
<i>C. carpio</i>	61	39.1	45.7	40	3795	32.5
Total	156	100	100	-	11680	100

(GIII) (Assis 1996) and the Index of Food Preponderance (%IFP) (Natarajan and Jhingran 1961) were used to evaluate prey importance.

Data analysis

Differences between observed and expected sex ratios were tested using the chi-square test. Variations in condition factor (K) between sexes were analyzed using an independent t-test and one-way ANOVA.

The percentage frequency of occurrence (%FO) and percentage volume (%V) of each prey item were calculated using descriptive statistics.

The Geometric Index of Importance (GIII) was calculated following Assis (1996) as:

$$GIII = \left(\sum (RMPQi) / (\sqrt{n}) \right)$$

where n represents the number of dietary metrics used and RMPQi corresponds to the relative measures of prey quantity.

The Index of Food Preponderance (%IFP) was calculated according to Natarajan and Jhingran (1961) as:

$$IFP = \frac{Vi \times FOi}{\sum (Vi \times FOi)} \times 100$$

All statistical analyses were performed using PAST version 3.07 (Hammer et al. 2001), SPSS version 24.0, and Microsoft Excel 2013. Statistical significance was accepted at $p < 0.05$.

Results

Relative abundance of fish in Lake Ardibo

A total of 156 fish specimens were collected during the study period, comprising 95 individuals of *O. niloticus* (60.9%) and 61 individuals of *C. carpio* (39.1%). In terms of biomass contribution, *O. niloticus* accounted for 54.3% of the total catch, whereas *C. carpio* contributed 45.7%. The frequency of occurrence (%FO) was higher for *O. niloticus* (75%) compared to *C. carpio* (40%). Consequently, the Index of Relative Importance (%IRI) indicated that *O. niloticus* was the dominant species in Lake Ardibo, contributing 67.5% of the total IRI, while *C. carpio* accounted for 32.5% (Table 1). Spatial variation in relative abundance was observed among sampling sites, with the littoral zone exhibiting higher %IRI values compared to pelagic and Menafesha sites. Additionally, males contributed more to the overall IRI than females in both species.

Sex ratio

Of the 95 *O. niloticus* specimens examined, 62 (65.26%) were males and 33 (34.74%) were females. The observed sex ratio significantly deviated from the expected 1:1 ratio ($\chi^2 = 8.85$, $df = 1$, $P < 0.05$). In *C. carpio*, 49 individuals (80.33%) were males and 12 (19.67%) were females, also showing a significant deviation from the expected ratio ($\chi^2 = 22.44$, $df = 1$, $P < 0.05$). Overall, males were more

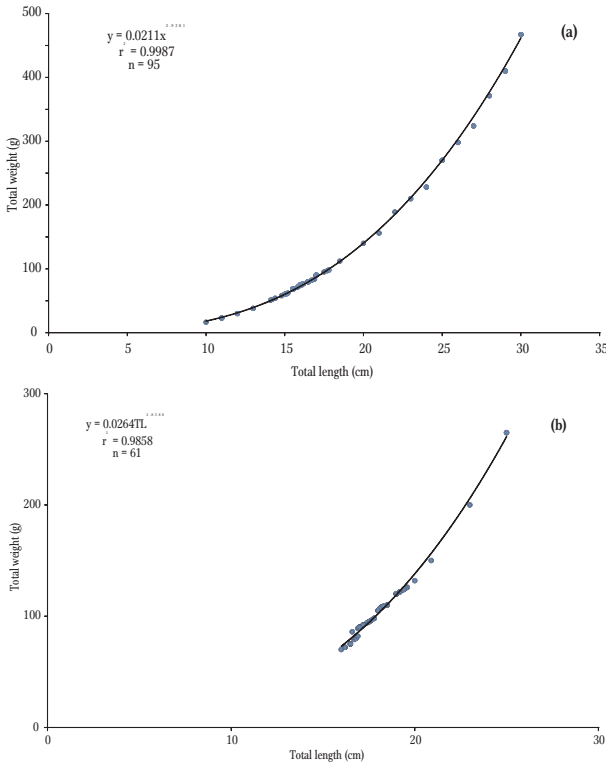


Figure 2. Length-weight relationships (LWRs) of *Oreochromis niloticus* (a) and *Cyprinus carpio* (b) in Lake Ardibo.

abundant than females in both species throughout the sampling period

Length-weight relationships of fishes

The total length of *O. niloticus* ranged from 10.1 to 30 cm, with corresponding weights between 46.4 and 467 g. The length-weight relationship was described by the equation:

$$TW = 0.021TL^{2.938} (r^2 = 0.9987, n = 95)$$

For *C. carpio*, total length ranged from 16 to 25 cm, and body weight ranged from 70 to 265 g. The LWR equation was:

$$TW = 0.026TL^{2.858} (r^2 = 0.9858, n = 61)$$

The estimated b values for both species were close to 3, indicating nearly isometric growth patterns (Fig. 2).

Condition factor (K)

The mean condition factor (K) for *O. niloticus* was 1.77 ± 0.005 , with values of 1.78 ± 0.008 for males and 1.76 ± 0.009 for females. Similarly, *C. carpio* exhibited a mean K value of 1.75. No significant differences in condition factor were detected between sexes in either species (independent t-test, $P > 0.05$), although males showed slightly higher mean values.

Diet composition and feeding habits

A total of 95 gut samples of *O. niloticus* were analyzed, of which 21.05% were empty. In *C. carpio*, 61 gut samples were examined, with 10.8% empty. Both species consumed a wide variety of food items, including detritus, phytoplankton, macrophytes, zooplankton, benthic macroinvertebrates, and insects (Table 2). In *O. niloticus*, the dominant dietary components in terms of volume (%V) were phytoplankton (62.92%), detritus (41.38%), and copepods (16.92%). In *C. carpio*, detritus (49%) and diatoms (33.2%) were the most important dietary components.

According to the Index of Food Preponderance (%IFP), detritus was the most significant food item for both species, contributing 46.40% in *O. niloticus* and 63.79% in *C. carpio*. Diatoms (34.36%) were also important in the diet of *C. carpio*, while *Microcystis* (33.67%) and copepods (9.48%) contributed substantially to the diet of *O. niloticus* (Table 2).

Ontogenetic dietary analysis

Ontogenetic variation in feeding habits was observed in *O. niloticus*. Smaller individuals (< 15 cm TL) primarily consumed animal-based food items, particularly copepods and detritus. In contrast, larger individuals (≤ 25 cm TL) showed increased consumption of plant-based food items, such as macrophytes and phytoplankton (*Microcystis*). Intermediate size classes exhibited mixed feeding patterns, indicating a gradual dietary shift with increasing body size (Fig. 3). Due to the limited size

Table 2

Frequency of occurrence (FOi), percentage frequency of occurrence (%FOi), volume (V), percentage volume (%V), and Index of Food Preponderance (%IFP) of dietary items in *Oreochromis niloticus* and *Cyprinus carpio*. BGA = blue-green algae.

Prey items	<i>O. niloticus</i>						<i>C. carpio</i>					
	FOi	%FOi	V (ml)	%V	%IFP	%GIi	FOi	%FOi	V (ml)	%V	%IFP	%GIi
Detritus	30	40	19.2	41.4	46.4	22.2	25	83.3	14.1	49	63.8	39.5
IMicrocystis	55	73.3	7.6	62.9	33.7	37.2	2	6.7	0.02	0.1	0.007	2.0
Diatoms	14	18.7	2.2	4.8	2.5	6.4	21	70	9.0	33.2	34.4	30.7
<i>Cyclotella</i>	-	-	-	-	-	-	3	10	0.03	0.1	0.02	2.9
Macrophytes	16	21.3	1.8	3.9	2.4	6.9	3	10	0.6	1.9	0.3	3.6
Cyanobacteria (BGA)	11	14.7	4.7	10.2	4.2	6.8	-	-	-	-	-	-
<i>Moina</i>	1	1.3	0.01	0.01	0.001	0.4	1	3.3	0.01	0.03	0.001	1.0
Copepods	15	20	7.9	16.9	9.5	10.1	3	10	1.5	5.3	0.8	4.6
Cladocerans	6	8	1.8	3.8	0.9	3.2	1	3.3	0.01	0.03	0.001	1.0
Chironomidae	5	6.7	0.08	0.2	0.03	2.6	6	20	0.4	1.2	0.4	6.3
Coleoptera	2	2.7	0.02	0.04	0.003	0.7	1	3.3	0.01	0.03	0.001	1.0
Insect parts	4	5.3	1.03	2.2	0.3	2.1	5	16.7	0.3	1.1	0.3	5.3
Ephemeroptera	3	4	0.5	1.2	0.1	1.4	2	6.7	0.1	0.2	0.02	2.1

Note: FOi = frequency of occurrence; %FOi = percentage frequency of occurrence; V = volume (mL); %V = percentage volume; %IFP = Index of Food Preponderance; %GIi = Geometric Index of Importance. “-” indicates absence of a given prey item in the diet.

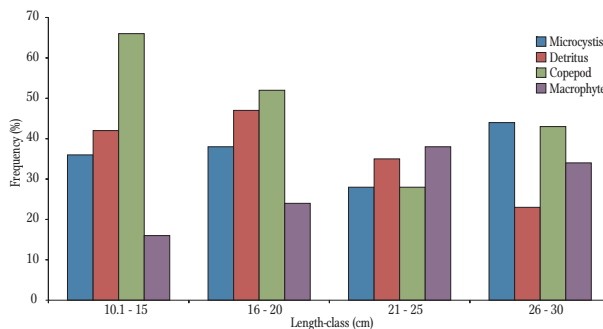


Figure 3. Relationship between total length (TL) and diet composition of *Oreochromis niloticus* based on the percentage frequency of occurrence (%FO) of major food items.

range of sampled individuals, ontogenetic dietary variation could not be assessed for *C. carpio*.

Discussion

Relative abundance

The dominance of *O. niloticus* in Lake Ardibo is consistent with previous studies reporting its ecological

plasticity and competitive advantage in tropical freshwater ecosystems (Njiru et al. 2008, Mekonnen et al. 2019). Its high %IRI suggests strong adaptability to a wide range of environmental conditions and food resources. The higher abundance observed in the littoral zone may be attributed to increased habitat complexity, availability of food resources, and shelter provided by macrophytes. Similar patterns have been reported in other Ethiopian lakes (Tewabe 2014, Tessema 2020, Eyayu and Getahun 2022).

Sex ratio

The observed male-biased sex ratios in both species may be influenced by several ecological and methodological factors, including differential habitat use, gear selectivity, and behavioral differences between sexes during feeding or spawning periods (Admasu 1994, Tewabe 2014). Similar male dominance has been reported in other Ethiopian water bodies (Tadesse 1997, Tessema 2020), although contrasting patterns have also been observed in some lakes

(Njiru et al. 2014, Worie and Getahun 2014). These inconsistencies suggest that sex ratios may vary spatially and temporally depending on environmental conditions and fishing practices.

Growth patterns and condition factor

The nearly isometric growth patterns observed for both species indicate balanced growth in length and weight, suggesting favorable environmental conditions and adequate food availability in Lake Ardibo. Comparable *b* values have been reported for *O. niloticus* and *C. carpio* in other Ethiopian lakes (Admasu 1994, Tadesse 1997, Abera et al. 2015, Dadebo et al. 2015), supporting the generality of this growth pattern in tropical freshwater systems. The relatively high condition factor values further indicate good physiological condition and habitat suitability. Slightly higher *K* values in males may reflect differences in energy allocation between sexes, particularly related to reproductive investment (Morgan 2004).

Feeding ecology

The results indicate that both *O. niloticus* and *C. carpio* exhibit omnivorous feeding strategies, consuming a broad spectrum of food resources. The dominance of detritus in the diet of both species suggests a strong reliance on detrital pathways, which are important components of energy flow in tropical lake ecosystems. The high contribution of phytoplankton, particularly *Microcystis*, in *O. niloticus* reflects its well-documented ability to exploit primary producers, while *C. carpio* showed a stronger association with benthic food resources such as detritus and diatoms. These findings are consistent with previous studies conducted in Ethiopian lakes, where both species have been described as opportunistic feeders with flexible dietary habits (Teferi et al. 2000, Engdaw et al. 2013, Dadebo et al. 2015).

Ontogenetic shifts

The observed ontogenetic dietary shift in *O. niloticus*, from animal-based to plant-based food sources, reflects changes in nutritional requirements and digestive capacity during growth. Juveniles typically require protein-rich diets to support rapid growth, whereas adults are more capable of utilizing plant material due to the development of specialized digestive structures and enzymes (Teferi et al. 2000). Similar ontogenetic shifts have been reported in other Ethiopian lakes (Temesgen 2017), indicating that such patterns are common in tropical freshwater fish species.

Ecological and management implications

The dominance of detritus and plant-based food items in the diet of both species suggests that Lake Ardibo may be characterized by high primary productivity and organic matter availability, potentially linked to anthropogenic inputs from surrounding areas. These findings highlight the importance of managing nutrient inputs and fishing practices to maintain ecosystem balance and ensure sustainable fisheries. Improved regulation of fishing gear and reduction of anthropogenic pressures could enhance fish population structure and productivity.

Conclusion

This study provides the first comprehensive assessment of the feeding ecology and selected biological characteristics of *Oreochromis niloticus* and *Cyprinus carpio* in Lake Ardibo, a multipurpose freshwater system exposed to increasing anthropogenic pressure. Both species exhibited nearly isometric growth patterns and relatively high condition factor values, indicating favorable environmental conditions and adequate food availability in the lake. The diet composition revealed that both species adopt an omnivorous feeding strategy with a strong reliance on detritus and plant-derived food

resources. This highlights the importance of detrital pathways and primary productivity in sustaining fish populations in Lake Ardibo. Ontogenetic shifts observed in *O. niloticus* suggest a transition from protein-rich, animal-based diets in smaller individuals to increased consumption of plant material in larger size classes, reflecting changes in energetic demands and digestive capacity during growth. The dominance of detritus and phytoplankton in the diet of both species may also indicate elevated nutrient input and organic matter availability, potentially associated with ongoing anthropogenic activities in the lake catchment. These findings provide important baseline information for fisheries management and conservation planning. Effective management strategies should focus on regulating fishing practices and reducing anthropogenic pressures to maintain ecosystem stability and ensure sustainable fish production in Lake Ardibo.

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Ethical approval and consent to participate. All procedures involving animals were conducted in accordance with established guidelines for the care and use of experimental animals. Ethical approval was not required for this study, as there is no formal ethical review process for fisheries research in Ethiopia.

Author contributions. A.E.: conceptualization, methodology development, supervision, and manuscript review; M.A.: data collection, laboratory analysis, and drafting of the manuscript; A.M.: manuscript review. All authors read and approved the final manuscript.

Conflict of interest. The authors declare no conflict of interest.

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