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Feeding habits of *Gobiopterus brachypterus* (Gobiiformes: Oxudercidae) in Ranu Grati Lake, East Java, Indonesia and their relationship with food availability

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Abstract. *Anitasari S, Arfiati D, Susilo, Marhendra APW. 2024. Feeding habits of* Gobiopterus brachypterus *(Gobiiformes: Oxudercidae) in Ranu Grati Lake, East Java, Indonesia and their relationship with food availability. Biodiversitas 25: 2925-2936.* Ranu Grati, a volcanic lake located in Pasuruan District, East Java, Indonesia, is home to the endemic *Gobiopterus brachypterus* (Bleeker 1855) locally known as the *lempuk* fish. This research aims to elucidate the feeding habits of *G. brachypterus* and their relationship with food availability in Ranu Grati. The study investigates the food ecology of including their diet composition, habitat preferences, and feeding habits in relation to natural food availability including plankton abundance, relative abundance, uniformity index, dominance index plankton sampling was conducted at five stations by with the samples preserved in formalin and concentrated in the lab for analysis under a microscope. Fish were also collected at these stations using random sampling, dissected in the field, and their digestive tracts were preserved and later examined microscopically to identify the food types down to the lowest taxonomic level. The results reveal that the phytoplankton community in Ranu Grati Lake includes nine classes: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Coscinodiscophyceae, Trebouxiophyceae, Dinophyceae, Zygnematophyceae, Raphidophyceae, and Euglenoidea. The zooplankton community comprises four classes: Monogononta, Copepoda, Branchiopoda, and Tubulinea. Phytoplankton in Ranu Grati Lake exhibit high diversity, with a diversity index of 3.739, and high uniformity, indicated by an evenness index of 0.957, showing no dominance (dominance index: 0.115). In contrast, zooplankton demonstrate moderate diversity (diversity index: 2.528), moderate evenness (evenness index: 0.647), and similarly show no dominance (dominance index: 0.216). The relative lengths of the intestines of *G. brachypterus*. are 0.163 and 0.132, indicating a carnivorous diet. The index of preponderance values highlights that *Bacillaria* sp., *Oscillatoria* sp., *Microcystis* sp., *Oocystis* sp., and *Volvox* sp. are significant dietary components for *G. brachypterus*, whereas *Pinnularia* sp., *Entomoneis* sp., *Cymbella* sp., *Thalassiosira* sp. and others contribute minimally or are absent. This highlights the dietary preferences of *G. brachypterus*. The stomach contents confirm that *G. brachypterus* exhibit a preference for phytoplankton, demonstrating opportunistic, carnivorous feeding behavior based on the availability of food in their natural environment.

Keywords: Dietary preference, *Gobiopterus brachypterus*, habitat preference, microalgae, zooplankton

INTRODUCTION

Ranu Grati is a volcanic lake located in Pasuruan District, Indonesia, situated between three villages: Ranu Klindungan, Sumberdawesari, and Gratitunon (Anitasari et al. 2024). It is approximately 16 km east of Pasuruan City, East Java Province, and covers an area of around 11.6 hectares. The lake is in a lowland area at an altitude ranging from 6 to 91 meters above sea level (Darmawan et al. 2019). In Ranu Grati, there is an endemic fish *Gobiopterus brachypterus* (Bleeker 1855) with local name *lempuk* which measures 2-3 cm. As an endemic species, the presence of the *Gobiopterus* sp. is limited to the waters of Ranu Grati and cannot be found elsewhere. *G. brachypterus* are small in size and are part of the food web in the Ranu Grati aquatic ecosystem (Anitasari et al. 2024).

The presence of *G. brachypterus* demonstrates the importance of Ranu Grati as a unique and crucial habitat for the survival of this species. The study of fish feeding habits is both important and fundamental to fisheries ecology. Information about the types of food consumed by fish, feeding frequency, and food preferences can provide a better understanding of the functional role of fish in their ecosystem (Gerking 2014). This is important for identifying interactions between fish and other species in the ecosystem, nutrient cycles, and their impacts on the structure and function of aquatic ecosystems. Fish in nature are part of the food web, referring to their role in ecosystems as consumers that eat other organisms (predators) or as a food source for other predators (prey) (Traugott et al. 2021). In the food web, fish can occupy various trophic levels, depending on the type of food they consume (Potapov 2019). Fish play an important role in regulating the populations of other organisms in aquatic ecosystems and in transferring energy and nutrients through various trophic levels in the food web (Villéger et al. 2017). Measuring plankton in the waters of Ranu Grati Lake is crucial for comprehending the dynamics of the aquatic ecosystem and supporting sustainability (Schmid et al. 2023). Plankton is a key component in the food chain of aquatic ecosystems, as it serves as the primary food source for fish species, including *G. brachypterus* (Lomartire et al. 2014). By understanding the composition, abundance, diversity index, uniformity index, and dominance index of plankton, we can identify the food availability for *G. brachypterus* and study how changes in plankton communities can affect the feeding patterns and growth of these fish (Harrison et al. 2022). The feeding habits of *G. brachypterus* in Ranu Grati Lake provide valuable insights into the ecology of this endemic species and its importance within its habitat. Understanding the feeding preferences and patterns of *G. brachypterus* is crucial for assessing their role in the aquatic ecosystem (Manko 2016). The species composition of *G. brachypterus* including their aquatic habitats within the lake, is being investigated to delve into the intricacies of their food and its relationship to their environment. The analysis of stomach contents and the assessment of differences in feeding habits based on location compared to food availability are shedding light on how these fish interact with their surroundings (Amundsen and Sánchez 2019).

The importance of feeding habits in endemic fish refers to the significant role of specific feeding patterns exhibited by fish found only in certain regions (Neves et al. 2015). These feeding habits can influence the ecosystem where the fish live and provide valuable information about environmental health and food resource availability in their native habitat. One of the main aspects of studying fish biology is to determine their food and feeding habits, as well as food availability in nature (Manko 2016).

Food is a critical factor in the growth and well-being of fish (Stavrescu-Bedivan et al. 2016). Understanding the relationship between fish and their food organisms is crucial for predicting and managing fish populations (Lomartire et al. 2021). Food organisms, such as plankton and small fish, are primary food sources for fish. The availability and quality of food can affect fish growth, physical condition, and reproduction (Abo-Taleb 2019). Understanding fish feeding patterns, food preferences, and food interactions in the environment is also important in planning sustainable management strategies (Abrantes et al. 2015). By knowing these aspects, the balance of the ecosystem and the sustainability of existing fish populations can be ensured (Cooke et al. 2016). This study aimed to clarify the feeding habits of *G. brachypterus* and their relationship with food availability in Ranu Grati Lake, Pasuruan District, East Java, Indonesia. We sought to understand the food ecology of - *G. brachypterus* including their diet composition, habitat preferences, and feeding habits in relation to natural food availability.

MATERIALS AND METHODS

Study area

This study was conducted from July to August 2023. Samples were taken at five stations in Ranu Grati Lake, East Java, Indonesia (Table 1, Figure 1).

Table 1. The sampling stations in Ranu Grati Lake, East Java, Indonesia

Stations	Geographical position
Station 1	7° 43' 34"S 113° 00' 43"E
Station 2	7° 43' 34"S 113° 00' 30"E
Station 3	7° 43' 52"S 113° 00' 40"E
Station 4	7° 43' 53"S 113° 00' 20"E
Station 5	7° 43' 40"S 113° 00' 17"E

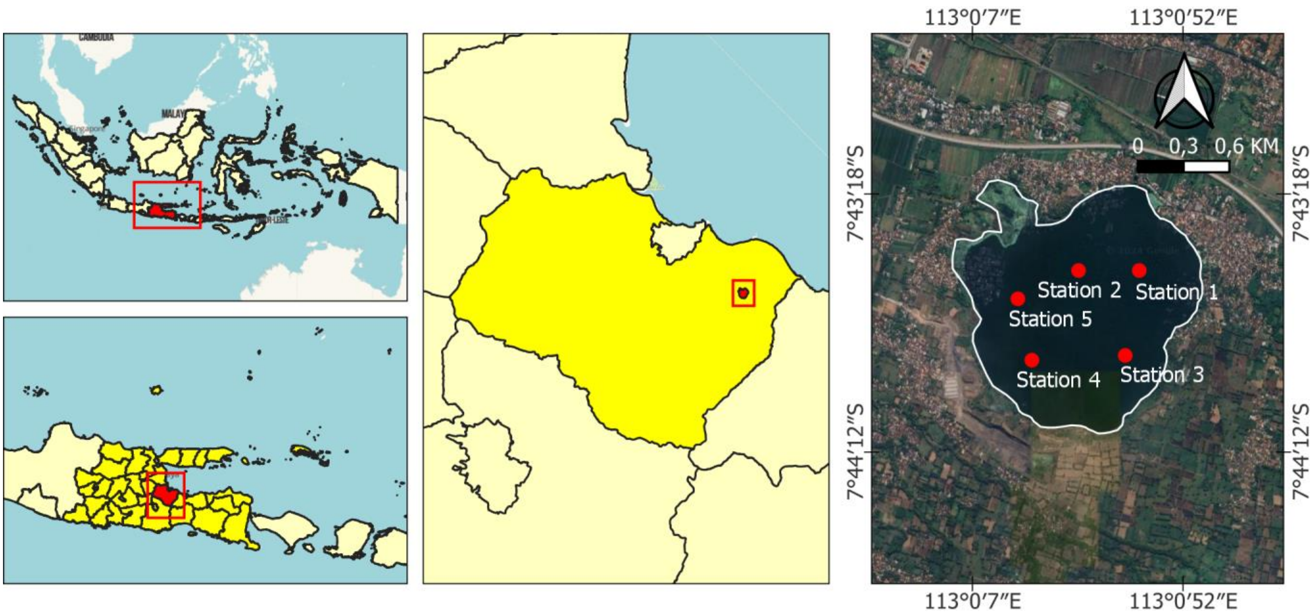

Figure 1. Location of sampling sites in Ranu Grati Lake, Pasuruan District, East Java Province, Indonesia

Plankton collection in the environment

Plankton sampling was carried out at five stations. This process involved filtering 50 liters of surface water through standard plankton nets with mesh sizes of 55 mm for zooplankton and 10 mm for phytoplankton. The collected plankton samples were then preserved in a 5% neutral formalin solution for further examination. In the laboratory, each sample was concentrated to a suitable volume (100 mL) (Alprol et al. 2021). Three separate samples, each of 3 mL, were examined in a Sedgwick Rafter Counting Cell (SRCC) under a binocular microscope (Tambaru et al. 2021). Fish collection and plankton observation in stomach content analysis fish collection was conducted at five stations concurrently with plankton collection, resulting in a total of 155 fish. This process involved the use of a 3x3 square meter net made of fishing net material, with a mesh size of 3 mm, to which a Fish Aggregation Device (FAD) was attached. Fish sampling is performed using the simple random sampling method, which entails selecting fish randomly from the population to ensure that each fish has an equal probability of being chosen. This method ensures that each individual has an equal chance of being selected, resulting in a representative sample and reducing bias, while also facilitating statistical analysis and allowing for more valid and generalizable research outcomes (Conquest et al. 2023).

The fish sample is dissected using a dissection set, starting from the anus and moving towards the upper part of the abdomen below the lateral line, then along the lateral line towards the back of the operculum, and finally ventrally towards the base of the abdomen. The muscles are opened, and the digestive organs, along with their contents, are carefully extracted using a needle. The obtained fish intestines are then preserved in 10% formalin. This activity is conducted in the field, and the analysis of the digestive tract content is later carried out in the laboratory. The digestive tract is placed in a petri dish, diluted with 10 mL of water, and. The method described is microscopic analysis, observed directly under a microscope to identify the type or name of the food to the lowest possible taxonomic level (Castellani and Edwards 2017)

Data analysis

Observations to determine the type of plankton in the environment and as a food source, as well as their level in the digestive tract, can be accurately identified and analyzed at the Department of Hydrobiology, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya, Malang. Plankton species are identified to the lowest possible taxonomic keys Edmondson (1959) as cited in Manickam et al. (2019). Data were analyzed using the microsoft excel program version 2021. The obtained data were used to calculate parameters for plankton as *G. brachypterus* food in water, including total abundance, relative abundance, diversity index, uniformity index, dominance index, and parameters to determine feeding habits such as relative length of the gut, frequency of occurrence (%), volumetric methods (%), index of preponderance, and preference index.

Plankton abundance

The total plankton is stated per milliliter (mL) and computed using the subsequent formula by Santhanam and Srinivasan (1994) cited as (El-Naggar et al. 2019), following formula: N = n×v/V; where N: total number of plankton per liter of water filtered; n: average number of plankton in 1 mL of plankton sample; v: volume of plankton concentrated (mL); and V: volume of total water filtered (liter).

Diversity index

Calculation of the diversity using The Shannon-Weaver Diversity Index (Shannon and Weaver 1949; Odum 1971) as cited in Arfiati et al. (2024), the calculation as follows:

$$H' = -\sum_{n=1}^{n} (pi^{*} \ln\ p_{\mathrm{i}})$$

Where H′ is the diversity index, pi is the proportion of each species in the sample and ln pi is the natural logarithm of this proportion. The diversity index criteria are as follows: H<1 = low diversity, 1<H<3 = moderate diversity, H>3 = high diversity.

Uniformity index

Uniformity index (E) measures how evenly distributed the individuals are among the species in a community. The uniformity index (E) can be calculated using the Shannon-Wiener diversity index (H') (Shannon and Weaver 1949) as cited in Arfiati et al. (2024), as follows:

$$E = \frac{H'}{\ln(S)}$$

Where E: the evenness index. Index type H': the Shannon-Wiener diversity index, S: number of types found, ln(S): the natural logarithm of the number of species. The values ranging from 0 to 1. An E value close to 1 indicates a more even distribution of individuals among species, while an E value close to 0 indicates a less even distribution, where some species are much more abundant than others.

Dominance index

The dominance index can be calculated using the formula provided (Odum 1971) as cited in Arfiati et al. (2024):

$$C = \sum \left(\frac{n_i}{N}\right)^2$$

Where: C: dominance index, N: total number of individuals across all genera, ni: number of individuals of genus i. The dominance index ranges from 0 to 1. If the value of C approaches 0, it means that there is no extreme dominance of one species over others in the observed community structure, indicating a stable community structure. If the value of C approaches 1, it indicates dominance by certain biota within the community structure, suggesting a labile community structure. The classification of biota community conditions based on their dominance level is as follows: C<0.5 = low dominance, 0.5<C<0.75 = moderate dominance and 0.75<C<1=high dominance (Khaeriyah and Burhanuddin 2015).

Relative abundance

This formula expresses relative abundance as a percentage, indicating the proportion of individuals of a particular species relative to the total number of individuals in the community. Relative abundance can be calculated using the following formula (Sheir et al. 2020):

Relative abundance = $ni/N \times 100\%$

Where: *ni* is the number of individuals of species *i*, *N* is the total number of individuals of all species.

Relative length of the gut

Analyzing the relative relative length of the gut is necessary to determine the feeding type of fish based on their diet. This analysis helps determine whether the fish is herbivorous, omnivorous, or carnivorous obtained by comparing the length of gut with its total length. The relative length of the gut in fish can be determined by comparing the length of the fish's gut with its total body length. The relative length of the gut value was calculated using the formula provided by Al-Hussaini (1949), as cited in Rahmi et al. (2022).

Relative Length of Gut (RLG) = Length of the gut/ total length of the fish

Where: Length of the gut is the total length of the digestive tract of the fish. The total length of the fish is measured from the tip of the snout to the end of the tail. The (RLG) indicates the digestive capacity of the fish relative to its body size. Carnivorous fish typically have an RLG of less than 1, as they have relatively short intestines because meat is easier to digest. Omnivorous fish usually have an RLG between 1 and 3, with a moderate intestine length because they consume a mix of animal and plant-based food. Herbivorous fish, on the other hand, generally have an RLG greater than 3, as they have longer intestines to digest plant material, which is more difficult to break down (Rahmi et al. 2022)

The number of each food items present inside gut and it was calculated using the formula (Hynes 1950) as cited in Manko (2016):

Fi = 100 ni / N

Where: Fi: frequency of occurrence (%) of the i food item in the sample, ni: number of stomachs in which the i item is found, N: total number of stomachs with food in the sample. Here for each size group frequency (%) of individual food items and groups of food items were calculated

Index of preponderance

This index provides a concise overview of the frequency of occurrence and the bulk of various food items. It offers a definite and measurable basis for grading these food elements (Saraswati and Perdhana 2020). The bulk of food items can be evaluated by volumetric or gravimetric methods. If Ii are the indeks preponderance, Vi and Oi are the volume and occurrence index of food:

$$Ii = \frac{Vi \ x \ Oi}{\Sigma \, Vi \ xOi} \ X \ 100\%$$

Preference index

The preference index analysis is a useful method for understanding the types of food most frequently consumed by fish, in this case, the *G. brachypterus*. This method involves comparing the amount of plankton found in the fish's digestive tract with the abundance of plankton species in the water where the fish lives. The formula for calculating the preference index, as described by Effendie (1979) and cited in Rahmi et al. (2022), is as follows:

$$E = \frac{ri - Pi}{ri + Pi}$$

Where: E: preference index, ri: the relative quantity of organism types consumed. Pi: the relative quantity of organism types found in the waters. The value of the preference index ranges from +1 to -1. If 0<E<1, it indicates that the food is preferred and if -1<E<0, it means the fish avoids the food. If the value of E= 0 it indicates that the fish neither prefers nor avoids the food.

RESULTS AND DISCUSSION

Plankton abundance and relative abundance

The phytoplankton found in Ranu Grati Lake comprises nine classes, which are: Bacillariophyceae, including species such as *Nitzschia* sp., *Bacillaria* sp., *Pinnularia* sp., *Entomoneis* sp., *Cymbella* sp., *Thalassiosira* sp., *Diadesmis* sp., *Cyclotella* sp., and *Semiorbi* sp.; Chlorophyceae, consisting of the species *Chlorococcum* sp., *Chlamydomonas* and *Volvox*; Cyanophyceae, which includes the genera *Cylindrospermopsis*, *Oscillatoria* and *Microcystis* sp.; Coscinodiscophyceae, which contains the species *Coscinodiscus* sp. and *Stephanodiscus* sp.; Trebouxiophyceae, comprising the species *Coccomyxa* sp., *Oocystis* sp. and *Chlorella* sp.; *Dinophyceae*, represented by the species *Gymnodinium* sp.; Zygnematophyceae, which includes the species *Zygnema* sp.; Raphidophyceae, represented by the genera *Gonyostomum* sp.; and Euglenoidea, which includes the species *Euglena* sp.

The zooplankton in Ranu Grati Lake consists 4 classes, which are: Monogononta, including species such as *Keretella* sp., *Brachionus* sp., *Natholca* sp. and *Asplancha* sp.; Copepoda, consisting of the species *Cyclops* sp. and *Aglaodiaetomus* sp.; Branchiopoda, represented by the species *Leptodora* sp.; and Tubulinea, which includes the species *Arcella* sp. The plankton found can be seen in Figure 2.

Table 2 shows the average abundance of cells per milliliter of water for phytoplankton and individuals per milliliter of water for zooplankton, as well as the total abundance and relative abundance of each genus within their respective classes.

The class Bacillariophyceae has the highest number of genera in the waters, totaling 9 genera. The diatom class Bacillariophyceae commonly dominates the phytoplankton community. This can be attributed to the ability of these phytoplankton to adapt to various environmental conditions, such as temperature, acidity, light, and nutrient availability. Bacillariophyceae also have a strong and durable cell structure, which allows them to survive in changing environmental conditions and also have a life cycle that can last for several weeks (Archibald et al. 2017).

Chlamydomonas sp. from the class Chlorophyceae is the species with the highest density. *Euglena* sp. and *Gymnodinium* sp. have low abundances, with each accounting for only 1% of the total phytoplankton population. The low abundance of *Euglena* sp. and *Gymnodinium* sp. can disrupt the aquatic food chain (Charette and Derry 2016). The abundance of *Chlamydomonas* in Ranu Grati can be influenced by various factors, including nutrient availability, light, water temperature, and interactions with other organisms in the aquatic ecosystem (Sasso et al. 2018). Sufficient nutrient availability, such as nitrogen and phosphorus, can support excessive growth of *Chlamydomonas* sp. if not controlled, which can lead to water quality issues such as eutrophication (Oz Yasar et al. 2023).

High populations of *Chlamydomonas* are often associated with nutrient enrichment (eutrophication) caused by increased levels of nitrogen and phosphorus, leading to excessive algal growth (blooms) that can indicate nutrient pollution (Glibert et al. 2018). Additionally, *Chlamydomonas* sp. play a role in nutrient cycles, including the carbon and nitrogen cycles, with changes in their populations reflecting variations in nutrient availability and cycling within the aquatic ecosystem (Bärlocher and Rennenberg 2014). These organisms are crucial as primary producers, providing food for zooplankton and other organisms (Lomartire et al. 2021). When the abundance of *Euglena* sp. and *Gymnodinium* sp. is low, the availability of food for organisms dependent on them may be disrupted, threatening the survival and population balance within the food chain.

Table 2. The average value of abundance and relative abundance of phytoplankton and zooplankton

Division, Class	Species	Total (cell/mL)	Relative abundance
Phytoplankton			
Bacillariophyceae	*Nitzschia* sp.	389	18.25%
	Bacillaria sp.	32	1.50%
	Pinnularia sp.	28	1.31%
	Entomoneis sp.	24	1.13%
	Cymbella sp.	12	0.56%
	Thalassiosira sp.	14	0.66%
	Diadesmis sp.	21	0.99%
	Cyclotella sp.	23	1.08%
	Semiorbis sp.	64	3.00%
Chlorophyceae	*Chlorococcum* sp.	64	3.00%
	Chlamydomonas sp.	507	23.79%
	Volvox sp.	101	4.74%
Cyanophyceae	*Cylindrospermopsis* sp.	54	2.53%
	Oscillatoria sp.	28	1.31%
	Microcystis sp.	83	3.89%
Coscinodiscophyceae	*Coscinodiscus* sp.	32	1.50%
	Stephanodiscus sp.	72	3.38%
Trebouxiophyceae	*Coccomyxa* sp.	158	7.41%
	Oocystis sp.	134	6.29%
	Chlorella sp.	116	5.44%
Dinophyceae	*Gymnodinium* sp.	16	0.75%
Zygnematophyceae	*Zygnema* sp.	126	5.91%
Raphidophyceae	*Gonyostomum* sp.	23	1.08%
Euglenoidea	*Euglena* sp.	10	0.47%
Zooplankton			
Monogononta	*Keratella* sp.	44	35.77%
	Brachionus sp.	10	8.13%
	Natholca sp.	4	3.25%
	Asplancha sp.	4	3.25%
Copepoda	*Cyclops* sp.	24	19.51%
	Aglaodiaetomus sp.	23	18.70%
Branchiopoda	*Leptodora* sp.	6	4.88%
Tubulinea	*Arcella* sp.	8	6.50%

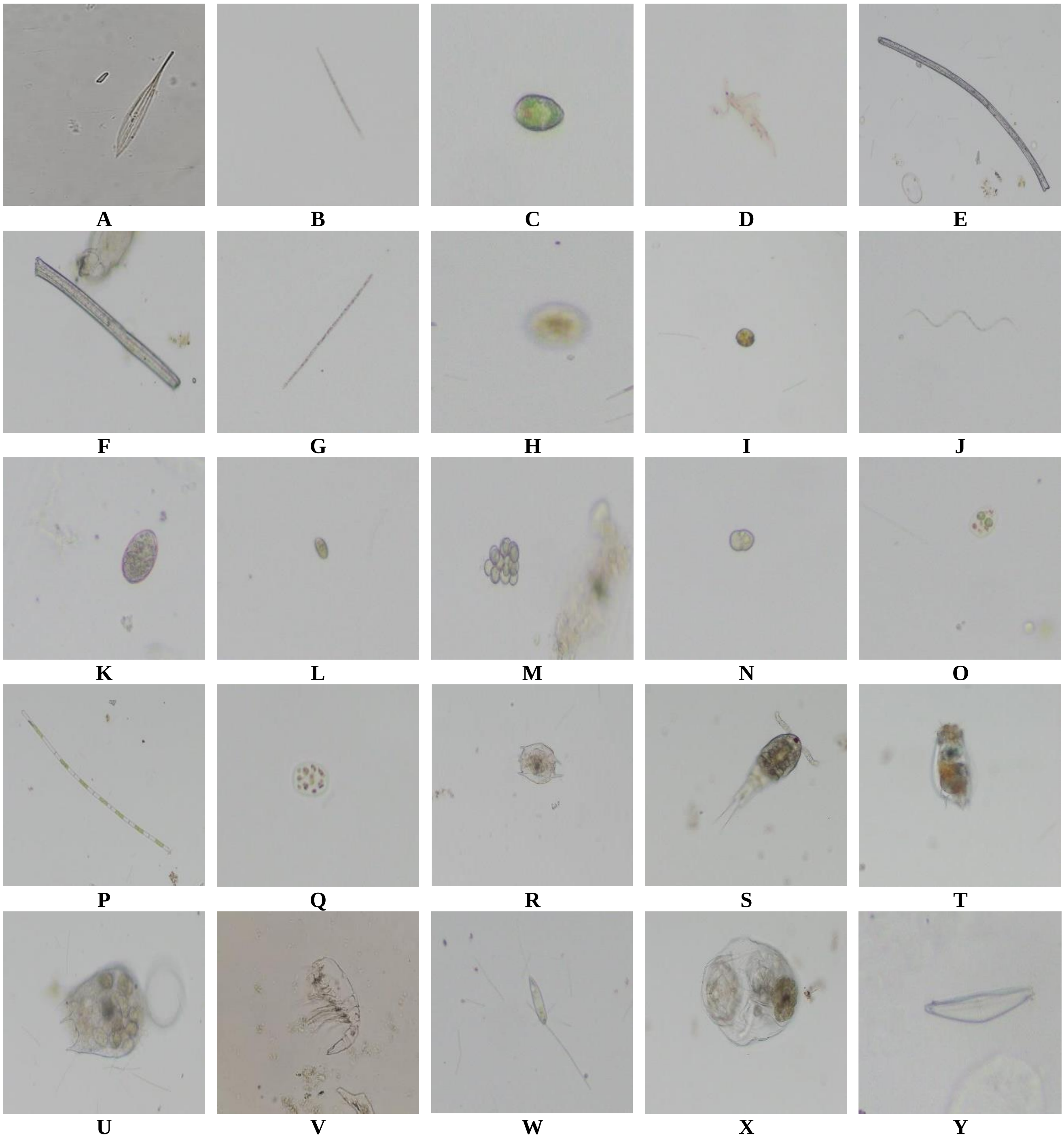

Figure 2. Species of plankton found in the water body o f Ranu Grati Lake, Pasuruan District, East Java, Indonesia; A. *Nitzschia* sp., B. *Bacillaria* sp., C. *Chlorococcum* sp., D. *Leptodora* sp., E. *Oscillatoria* sp., F. *Pinnularia* sp., G. *Cylindrospermopsis* sp., H. *Coscinodiscus* sp., I. *Stephanodiscus* sp., J. *Cylindrospermopsis* sp., K. *Gonyostomum* sp., L. *Coccomyxa* sp., M. *Chlamydomonas* sp., N. *Gymnodinium* sp., O. *Oocystis* sp., P. *Zygnema* sp., Q. *Chlorella* sp., R. *Brachionus* sp., S. *Cyclops* sp., T. *Keratella* sp., U. *Natholca* sp., V. *Aglaodiaptomus* sp., W. *Euglena* sp., X. *Asplancha* sp., Y. *Cymbella* sp.

Additionally, the presence of *Euglena* sp. and *Gymnodinium* sp. helps maintain the overall balance of the aquatic ecosystem. Their low abundance can lead to ecological imbalances that may affect the health of the ecosystem as a whole. Therefore, it is important to continuously monitor the abundance of *Euglena* sp. and *Gymnodinium* sp., as well as the overall water quality, to detect any changes that may occur in the aquatic ecosystem and take the necessary steps to maintain the ecosystem's balance (Riouchi et al. 2024).

For zooplankton, a high abundance of *Keratella* sp., reaching 48% of the total zooplankton population in a water body such as Ranu Grati Lake, can have significant implications for the ecosystem. *Keratella* sp., a genus of rotifers, plays a crucial role in the lake's ecosystem dynamics. Its high abundance indicates a healthy and productive environment, with ample food resources and favorable conditions for its growth (Umi et al. 2018). The high abundance of *Keratella* sp. may also indicate potential challenges. *Keratella* sp. grazing activities can significantly impact phytoplankton populations, potentially altering the composition and diversity of the plankton community. Additionally, the increased competition for food and resources among zooplankton species, including *Keratella* sp, influences the overall structure and dynamics of the aquatic food web (Bégin and Vincent 2017). Monitoring the abundance of *Keratella* sp. and its interactions with other plankton species is crucial for understanding and managing the ecosystem of Ranu Grati Lake. This information can provide valuable insights into the lake's ecological health, help identify potential issues or imbalances, and guide conservation and management efforts to maintain a sustainable and balanced aquatic ecosystem (Gilbert and Bogdan 2019). The low abundance of the Branchiopoda species *Leptodora* sp. and the Tubulinea species *Arcella* sp. among the existing zooplankton species can be attributed to several factors. These include intense competition for limited food resources, vulnerability to predation, sensitivity to environmental conditions, less favorable life history strategies, and specific habitat preferences. Collectively, these factors limit their ability to thrive and reproduce in the aquatic ecosystem, resulting in lower population numbers compared to other zooplankton species (Lomartire et al. 2021).

Diversity, uniformity, and dominance index

Ranu Grati Lake phytoplankton at five stations has average diversity index 3.739 (High diversity because H'>3), a uniformity index 0.957 ((high, e>6) and a dominance index 0.115 (no dominance because C is close to 0). Ranu Grati lake zooplankton at five stations has diversity index 2.528 (moderate diversity because 1<H'<3), a uniformity index 0.647 (moderate evenness because 4<e<6.) and a dominance index 0.216 (no dominance because C is close to 0). The diversity, uniformity, and plankton dominance index in Ranu Grati Lake can be seen in Table 3.

Table 3. The average of value diversity, uniformity, and dominance index of plankton

	Phytoplankton	Zooplankton
Diversity index	3.739	2.528
Uniformity index	0.957	0.647
Dominance index	0.115	0.216

The analysis of diversity, evenness, and dominance indices provides insights into the plankton community structure in Ranu Grati Lake (Francé et al. 2021). The diversity index (H') shows high diversity in the phytoplankton community across the five observation stations, indicating a rich variety of species contributing to the overall abundance (Winfree et al. 2015). In contrast, the zooplankton community shows moderate diversity. The evenness index (e) reflects high evenness in the distribution of individuals among phytoplankton species, indicating a balanced population. Similarly, the zooplankton community shows moderate evenness. These findings suggest that species within both communities are relatively evenly distributed, contributing to overall diversity. The dominance index (C) indicates that there is no significant dominance within either the phytoplankton or zooplankton communities. This suggests that no single species exerts a dominant influence on the population, resulting in a balanced and diverse community structure (Zatoń et al. 2017). Overall, the results highlight the ecological health and balance of the plankton communities in Ranu Grati Lake.

The high diversity and evenness in the phytoplankton community in Ranu Grati Lake may be attributed to several environmental factors that support a rich variety of species. Factors such as nutrient availability, water temperature, sunlight, and species interactions can influence plankton diversity. Sufficient nutrient availability, for instance, supports the growth of various plankton species, while suitable water temperature and sunlight affect photosynthesis and plankton growth. Species interactions, such as competition and predation, also influence plankton community structure.

For *G. brachypterus*, a balanced and diverse plankton community can have positive implications (Xu et al. 2024). Plankton serves as a primary food source for many fish species, including *G. brachypterus*. A diverse plankton community provides *G. brachypterus* with a wider range of food options, supporting their growth and reproduction. Furthermore, a balanced plankton community reflects the overall health of the ecosystem, which can impact the sustainability of fish populations as a whole (Suthers et al. 2019).

Relative length of the gut

The relative length of a fish's gut is determined by the ratio of the gut length to the total body length. After measuring the length of the intestines and the total body length, the RLG is calculated and presented in Table 4.

Table 4. Relative length of the gut of *Gobiopterus brachypterus*

Month	Total length of the body (mm)	Length of the gut (mm)	RLG (%)
July	21.16 ± 28.85	3.12 ± 5.75	0.163
August	23.18 ± 29 23.18 ± 29	2.43 ± 4.98	0.132

Gobiopterus brachypterus is considered a carnivore, as indicated by its relative gut length and the contents found in the digestive tracts of examined specimens. The RLG of this species varies between 0.44 and 0.65, placing it within the category of carnivorous fish with moderate feeding intensity. This means that *G. brachypterus* have a gut length relative to their body size which is typical of carnivorous fish. Therefore, the moderate RLG of *G. brachypterus* suggests that it primarily feeds on animal matter but may also consume some plant material or have a mixed diet. Fish feeding habits can be predicted by comparing the length of their digestive tract to their total body length (Steinberg 2018) Additionally, according to Anitasari et al. (2024), the presence of canine teeth and vomer teeth in *G. brachypterus* suggests a carnivorous diet. These teeth are specialized for grasping and tearing flesh, suggesting that *G. brachypterus* may feed on other fish or invertebrates. Predatory fish typically have similar specialized feeding adaptations, including sharp teeth and strong jaws, which help them catch and consume their prey effectively.

Determining fish feeding habits is based on the ratio of gut length to total body length. In general, most fish species undergo a transition in feeding habits as they mature, with some continuing to feed on phytoplankton. Changes in feeding habits occur at certain sizes, and these differences can be attributed to the type of food available, which is influenced by physiological adaptations. These adaptations include gut length and the physiological effects of water pollution (Colombo 2020). Understanding the dietary patterns and feeding behaviors of a species is crucial for comprehending its ecological role and position within the food web of ecosystems. Based on the carnivorous nature of the *G. brachypterus* digestive tract, it can be categorized as a primary consumer.

Frequency of occurrence (%), index of preponderance (%) and preference index

Based on the identification of food types in the stomach and intestines of *G. brachypterus.* the frequency of occurrence (%), index of preponderance (%), and preference index can be calculated. Detailed values for these indices are presented in Table 5.

Table 5. The average value frequency of occurrence, index of preponderance and preference index of each type of food for *G. brachypterus* during July-August 2023

Class	Species	Frequency of occurrence (%)	Index of preponderance	Preference index
Bacillariophyceae	*Nitzschia* sp.	2.95%	4.23%	-0.91
	Bacillaria sp.	11.09%	10.03%	0.36
	Pinnularia sp.	0.00%	0.00%	-1.00
	Entomoneis sp.	0.50%	0.03%	-0.68
	Cymbella sp.	0.55%	0.04%	-0.56
	Thalassiosira sp.	0.69%	0.17%	-0.53
	Diadesmis sp.	1.20%	0.40%	-0.40
	Cyclotella sp.	2.44%	8.13%	-0.11
	Semiorbis sp.	0.36%	0.05%	-0.93
Chlorophyceae	*Chlorococcum* sp.	0.00%	0.00%	-1.00
	Chlamydomonas sp.	1.70%	0.05%	-0.95
	Volvox sp.	9.28%	7.42%	-0.15
Cyanophyceae	*Cylindrospermopsis* sp.	0.00%	0.00%	-1.00
	Oscillatoria sp.	21.52%	24.60%	0.67
	Microcystis sp.	16.86%	10.99%	0.25
Coscinodiscophycea	*Coscinodiscus* sp.	0.00%	0.00%	-1.00
	Stephanodiscus sp.	2.08%	0.29%	-0.64
Trebouxiophyceae	*Coccomyxa* sp.	0.00%	0.00%	-1.00
	Oocystis sp.	19.66%	31.67%	0.09
	Chlorella sp.	0.00%	0.00%	-1.00
Dinophyceae	*Gymnodinium* sp.	0.00%	0.00%	-1.00
Zygnematophyceae	*Zygnema* sp.	0.00%	0.00%	-1.00
Raphidophyceae	*Gonyostomum* sp.	1.90%	1.27%	-0.29
Euglenoidea	*Euglena* sp.	0.00%	0.00%	-1.00
Monogononta	*Keratella* sp.	1.38%	0.08%	-0.56
	Brachionus sp.	1.04%	0.05%	-0.09
	Natholca sp.	1.08%	0.06%	0.32
	Asplancha sp.	0.71%	0.02%	0.17
Copepoda	*Cyclops* sp.	0.77%	0.12%	-0.56
	Aglaodiaetomus sp.	0.46%	0.04%	-0.69
Branchiopoda	*Leptodora* sp.	0.00%	0.00%	-1.00
Gastropoda	*Peronia* sp.	0.96%	0.26%	-0.02
Tubulinea	*Arcella* sp.	0.88%	0.04%	1.00

The frequency of occurrence values for various genera in the diet of *G. brachypterus* provide insights into the relative abundance of each organism type. Among the species, *Bacillaria* sp. (11.09%), *Oscillatoria* sp. (21.52%), *Microcystis* sp. (16.86%), *Oocystis* sp. (19.66%) and *Volvox* sp. (9.28%) are frequently encountered, indicating their potential significance as key components of the fish's diet. These species are likely to play important roles in the nutritional intake of *G. brachypterus*. On the other hand, genera such as *Pinnularia, Cylindrospermopsis* sp., *Chlorococcum* sp., *Coscinodiscus* sp., *Coccomyxa* sp., *Chlorella* sp., *Gymnodinium* sp., *Zygnema* sp., *Euglena* sp., and *Leptodora* sp. are rarely encountered or absent in the diet, suggesting that they are not major components of the fish's diet. Species with moderate occurrence include *Nitzschia* sp. (2.95%), *Entomoneis* sp. (0.50%), *Cymbella* sp. (0.55%), *Thalassiosira* sp. (0.69%), *Diadesmis* sp. (1.20%), *Semiorbis* sp. (0.36%), *Chlamydomonas* sp. (1.70%), *Stephanodiscus* sp. (2.08%), *Gonyostomum* sp. (1.90%), *Keratella* sp. (1.38%), *Brachionus* sp. (1.04%), *Natholca* (1.08%), *Asplancha* (0.71%), *Cyclops* (0.77%), *Aglaodiaetomus* (0.46%), and *Peronia* (0.96%) (Havens 2014).

This data provides valuable information on the diversity and relative importance of different genera in the diet of *G. brachypterus*, highlighting the varying degrees of utilization of these organisms in their feeding habits. The frequency of occurrence of *Bacillaria* sp., *Oscillatoria*, *Microcystis* sp. and *Oocystis* sp. in the gut content of *G. brachypterus* can provide valuable insights into their diet and feeding habits. *Bacillaria* sp., a type of diatom commonly found in freshwater environments, indicates that the fish consume phytoplankton. *Oscillatoria*, a genus of filamentous cyanobacteria, suggests that the fish might also ingest cyanobacteria, particularly in nutrient-rich waters. The presence of *Microcystis* sp., known for forming harmful algal blooms, further supports the idea that *G. brachypterus* consume cyanobacteria. Additionally, *Oocystis* sp., a species of green algae, indicates the consumption of green algae. While *G. brachypterus* are primarily carnivorous, the frequent occurrence of phytoplankton and cyanobacteria in their gut content suggests a more opportunistic feeding behavior. This may involve the incidental ingestion of these organisms while preying on zooplankton or other small animals, highlighting the adaptability of their diet based on the available food sources in their environment.

Since *G. brachypterus* is carnivorous, it's possible that the absence of certain organisms like *Coccomyxa* sp., *Chlorella* sp., and *Euglena* sp. in the fish's gut could be due to dietary preferences or feeding behaviors. Carnivorous fish typically consume other organisms like small fish, invertebrates, or zooplankton, which may not include these particular phytoplankton species (Diana and Höök 2023). The absence of *Leptodora* sp. in the gut content of *G. brachypterus* may be due to the size mismatch between *Leptodora* sp. and the fish's mouth. *Leptodora* sp. is a relatively large zooplankton, and *G. brachypterus* may not be able to prey on or swallow organisms the size of *Leptodora* sp. As a result, *Leptodora* sp. would not be found in the gut content of *G. brachypterus* due to the mismatch in dietary requirements or predation capacity of the fish (Goldstein and Simon 2020). Interactions among fish populations are informed by dietary studies based on stomach content analysis, which provide significant insights into various aspects of fish biology and aquatic ecosystem ecology (Manko 2016).

The quality of the aquatic environment also affects natural food sources. As an environmental component, food plays a key ecological role in determining population density, population dynamics, growth, reproduction, and the condition of fish. The type of food a fish consumes usually depends on its age, location, and time. The feeding habits of a fish can be observed through the ecological relationships among organisms in the water, such as predation, competition, and food chains (Chen et al. 2022).

The index of preponderance offers insights into the relative importance of different food items in the diet of the fish species being studied. By calculating this index for various food items found in the stomach contents of a sample of fish, researchers can identify which food items are most commonly consumed and contribute significantly to the diet of the fish population under investigation. The index of preponderance values for various species in the diet of *G. brachypterus* provide insights into the relative abundance of each organism type in the fish's diet. Among the species, *Bacillaria* sp. (10.03%), *Oscillatoria* sp. (24.60%), *Microcystis* sp. (10.99%), *Oocystis* (31.67%) and *Volvox* (7.42%) show relatively high percentages, indicating their significant presence and potential importance in the diet. These genera are likely to be key components of the *G. brachypterus* diet. On the other hand, genera such as *Pinnularia* sp. (0.00%), *Entomoneis* sp. (0.03%), *Cymbella* sp. (0.04%), and *Thalassiosira* sp. (0.17%) are present in very low percentages, suggesting a minimal contribution to the diet. Similarly, *Chlorococcum* sp., *Cylindrospermopsis* sp., *Coscinodiscus* sp., *Coccomyxa* sp., *Chlorella* sp., *Gymnodinium* sp., *Zygnema* sp., *Euglena* sp. and *Leptodora* are absent or have negligible presence in the diet, indicating that *G. brachypterus* do not heavily rely on these species for nutrition. Overall, these findings provide valuable insights into the dietary composition of *G. brachypterus* highlighting the diversity and importance of certain genera within their diet.

The examination of the digestive tract of *G. brachypterus* indicates that it is a carnivore. Various phytoplankton and zooplankton are found in the stomach of *G. brachypterus*. The food preference index of *G. brachypterus* shows a dominant preference for phytoplankton, as evidenced by the contents of the fish's stomach. This indicates that *G. brachypterus* exhibits opportunistic feeding behavior, where it consumes whatever food is easily available rather than specifically targeting certain types of prey. This behavior is often observed in animals that can adapt their diet based on the current availability of food resources in their environment. The calculation of the largest part index of *G. brachypterus* indicates that the difference in the fish's diet from July to August is influenced by various environmental factors in the waters of Ranu Grati Lake. These factors include the increasing number of floating net cages around the lake and continuous fishing of *G. brachypterus* without considering the population level of the fish itself.

Gobiopterus brachypterus show preferences in their diet based on the preference index values. They prefer to consume species such as *Bacillaria* sp., *Oscillatoria* sp., *Microcystis* sp., *Oocystis* sp., *Natholca* sp., *Asplancha* sp. and *Arcella* sp., which are consumed more frequently than their availability in the environment suggests. *Arcella* sp. is particularly favored. Genera such as Peronia are consumed in proportion to their availability, indicating a neutral preference. On the other hand, species such as *Nitzschia* sp., *Pinnularia* sp., *Entomoneis* sp., *Cymbella* sp. and others are avoided by *G. brachypterus* being consumed less frequently than their availability suggests. This preference index data provides insights into the selective feeding habits of *G. brachypterus* and the types of organisms they prefer or avoid in their diet.

The preference index shows the relative preference of *G. brachypterus* for different food items in their natural environment compared to what is found in their stomachs, providing insights into their feeding behavior and dietary preferences. It illustrates the food preference index of *G. brachypterus* in their environment compared to what is found in their stomach. In general, it can be observed that the difference between sampling in July and August is not significant. The relationship between fish and their natural food sources (Assan et al. 2021) highlights the importance of food availability and preference in the survival of fish species. Factors such as size, age, season, and habitat play significant roles in determining the types of food fish prefer. Additionally, environmental factors such as water temperature, oxygen levels, and water quality, as well as interactions with predators and other fish, can influence the feeding behavior of fish.

Conducting research over a two-month period in July and August presents several important considerations. Firstly, this timeframe allows researchers to study specific seasonal phenomena, such as peak plankton growth, which can significantly influence the findings. Environmental conditions during these months, including temperature, rainfall, and sunlight, can impact data collection and the dynamics of the aquatic ecosystem (Harris and McCauley 2018). The short duration allows for an emphasis on immediate ecological interactions, including predator-prey dynamics and nutrient cycling, which may reach their peak during this period. This targeted approach enhances the understanding of how seasonal variations influence the distribution and abundance of aquatic organisms (Suzuki et al. 2023).

As carnivorous fish, *G. brachypterus* can adapt to digest diatoms, allowing them to utilize various food sources available in their environment. Although they are more efficient at digesting animal matter, this adaptability may be attributed to specific enzymes in their digestive systems that enable them to process diverse food types efficiently. Carnivorous fish like *G. brachypterus* which have shorter intestines, may possess more active or specialized digestive enzymes that help them quickly and efficiently digest various types of food. Their flexible feeding behaviors enable them to consume easily digestible food, such as small animals, before switching to plant material. Despite having short intestines, their intestinal structure and absorption capacity might be highly efficient, enabling them to extract maximum nutrients from the food they consume. Additionally, carnivorous fish may have a different and richer gut microbiota community that assists in the digestion of plant material, helping to break down cellulose and other tough plant components. These adaptations, as described by Colombo (2020), enable them to survive in diverse environments with varying food sources. The adaptability of *G. brachypterus* in digesting various types of food, including diatoms and plant material, demonstrates significant potential for domestication, as it can reduce reliance on expensive animal-based feed. Based on the data, *G. brachypterus* tend to consume food that is abundant in their environment, such as *Bacillaria* sp., *Oscillatoria* sp., *Microcystis* sp., *Oocystis* sp. and *Volvox* sp., indicating their flexibility in selecting available food sources. This adaptability allows for the development of *G. brachypterus* and enables them to survive in various environmental conditions, enhancing the prospects for their domestication. Based on the data, the findings suggest a clear relationship between the types of food found in the stomachs of *G. brachypterus* and the availability of food in their natural environment. The most frequently found types of food in their stomachs, such as *Bacillaria* sp., *Oscillatoria* sp., *Microcystis* sp., *Oocystis* sp. and *Volvox* sp., also have relatively high availability in their natural habitat. This indicates that *G. brachypterus* tend to consume food that is abundant in their environment. Conversely, types of food that are rarely found in their stomachs, such as *Pinnularia* sp., *Cylindrospermopsis* sp., and *Chlorococcum* sp., have low availability in their natural habitat. This suggests that although these foods exist in their habitat, *G. brachypterus* doesn't rely heavily on them as a primary food source. Therefore, the data provide a clear understanding of the food preferences of *G. brachypterus* and their relationship with food availability in their natural environment. These fish tend to select food that is abundant, but they also demonstrate the ability to adapt to less common food sources when necessary, as they are carnivorous opportunists.

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