

DIET AND FEEDING BEHAVIOR OF *Distichodus rostratus* (GUNTHER, 1864) IN LAKE AKATA, BENUE STATE, NIGERIA

*¹IKONGBEH, O. A., ¹S. G. SOLOMON AND ¹R. A. OBANDE

¹ Dept. of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, Makurdi, P.M.B. 2373 Makurdi, Nigeria *¹Corresponding Author: tonikongbeh@gmail.com, +23407035510505, 0000-0001-6188-7213

ABSTRACT

In this research, we analyzed the diet and feeding behavior of *Distichodus rostratus* from samples collected between May, 2022 - April, 2023 in Lake Akata. 97 fish specimens obtained from fishermen operating on Lake Akata were used for the study. The research examined dietary patterns and feeding habits through the utilization of point and frequency of occurrence methodologies. During the study, the researchers observed seasonal variations, alterations in dietary composition with size, and the monthly feeding index in the stomach contents of *Distichodus rostratus*. Grass stems formed the dominant food items of the fish with a total point of 50.1 % and a frequency of occurrence of 33.0 %. Plant material was secondary in importance, with a total point of 28.8 % and a frequency of occurrence of 18.6 %. Fish measuring 1-15 cm primarily consumed algae, those between 16-25 cm exhibited a higher preference for algae, while those within the 26-35 cm range fed on grass stems. Fish in the 36-45 cm and 46-55 cm size ranges also showed a preference for feeding on grass stems. More than 50 % of the fish were feeding in most months, particularly between May – November, January - April, in December only 45.5 % were feeding. The result indicated that *Distichodus rostratus* is a herbivore.

Keywords: *D. rostratus*, (Perch), food, grass stem, algae, Lake Akata, Nigeria

INTRODUCTION

Inland waters are defined by the Food and Agriculture Organization of the United Nations (FAO) as lakes, rivers, streams, canals, reservoirs, and other land-locked waters (FAO, 2014a). Worldwide, the combined area of lakes, reservoirs, and wetlands is 7.8 million square kilometers, offering a fertile setting for inland capture fisheries (De Graaf *et al.*, 2015). A Lake (from a Latin word “lacus”) is a terrain feature (or physical feature) that is considerable inland body of water, not part of the ocean, that is larger and deeper than a pond, and may or may not be moving slowly, and is localized to the bottom of basin (another type of landform or terrain feature) and is fed by a river (Britannica online, 2008). Lakes, dams and reservoirs are mainly built for irrigation, power generation, flood control, recreation, navigation and water supply. According to FAO (2014b) report that, approximately 2.9 billion individuals depend on fish as a vital source of animal protein in their diets. Fish serves as a valuable protein source, particularly for the growing global population, with a significant impact in developing regions such as Africa, Asia, and South America (Belton and Thilsted, 2014) and (Fish StatJ, 2016). *Distichodus* is a clade of tropical freshwater fishes comprising 25 named species distributed continent-wide of Africa throughout the Nilo-Sudan and most Sub-Saharan drainages (Arroyave1 *et al.*, 2020). *Distichodus rostratus* is a prominent member of the family Distichodontidae and a subfamily of Citharinidae, commonly called grass eaters. *Distichodus rostratus* inhabit lakes and rivers of Africa: Senegal, Chad Basin, Nilo-Sudan, Niger, Volta and Nile Basin, but absent in coastal basins between southern Gambia and Sassandra (Arroyave1 *et al.*, 2020). *D. rostratus* is found

primarily in lentic habitats, shoaling in and around grasses along vegetated river banks and swamps in the dry season when the water level is low (Shinkafi *et al.*, 2013). *Distichodus species* is also of considerable ecological and socio-economic importance, as many species constitute a highly valued but increasingly over-exploited component of artisanal and commercial fisheries across the continent, due to their high fecundity and herbivorous diet, are increasingly being cultured in fish farms and lentic water bodies (Shinkafi *et al.*, 2013). *D. rostratus* is readily abundant from August to December (Elijah *et al.*, 2019). Research has been done on the diets of cichlids and other fish species from different water bodies, such as lakes, rivers and reservoirs in Nigeria and abroad. A significant account is the one by Shinka *et al.* (2013), who documented the presence of *D. rostratus* in the Rima River located in northwestern Nigeria. Ikongbeh *et al.* (2012; 2014) reported the food and feeding habits of *Clarotes laticeps* and *Auchenoglanis occidentalis* in Lake Akata, respectively. Goli Bi *et al.* (2019) reported *D. rostratus* in Man-made Lake Buyo (River Sassandra, Côte d'Ivoire, Segun *et al.* (2022) reported *D. rostratus* in the Jebba Dam, North-Central Nigeria. Kouakou *et al.* (2022) reported *D. rostratus* in Lakes Taabo, Kossou and Faé (Côte d'Ivoire). Ipinmoroti *et al.* (2022) reported *D. rostratus* in Asejire Lake, South-western Nigeria. Differences in the composition of foods from one location to another could be explained by the fact that in a given body of water, fish use the food available and which are accessible to them (Lo *et al.*, 2020). In juveniles, the main foods are made up of plant debris. According to Shinkafi and Rasaq (2013), nature offers a great diversity of organisms used as food by the fishes, which differ in size and

taxonomic group. In their study, Keratin and Ashenafi (2021) found that examining the stomach contents of fish can yield valuable insights into the trophic dynamics of aquatic ecosystems. This analysis helps identify the types of food fish consume, their feeding patterns, and the overall stability and structure of the food web. Such information is crucial for effective fisheries management. A comprehensive understanding of the biology of *D. rostratus* is essential for planning effective management strategies for this fish species in Lake Akata. Although, general aspects of the biology of the genus are poorly documented. Hence,

this study examined the dietary preferences and feeding patterns of *D. rostratus* in Lake Akata.

MATERIALS AND METHODS

Study area

The study area Lake Akata, is a meander cutoff lake (ox-bow lake) formed by the River Katsina-Ala. It is located between longitude 9°16' and 9°17' East and latitude 7°11' and 7°13' North (Figure 1). The study area is characterize with two distinct seasons, the raining (April - October) and the dry season (November – March). In the flood plains irrigation farming and fishing activities is practiced.

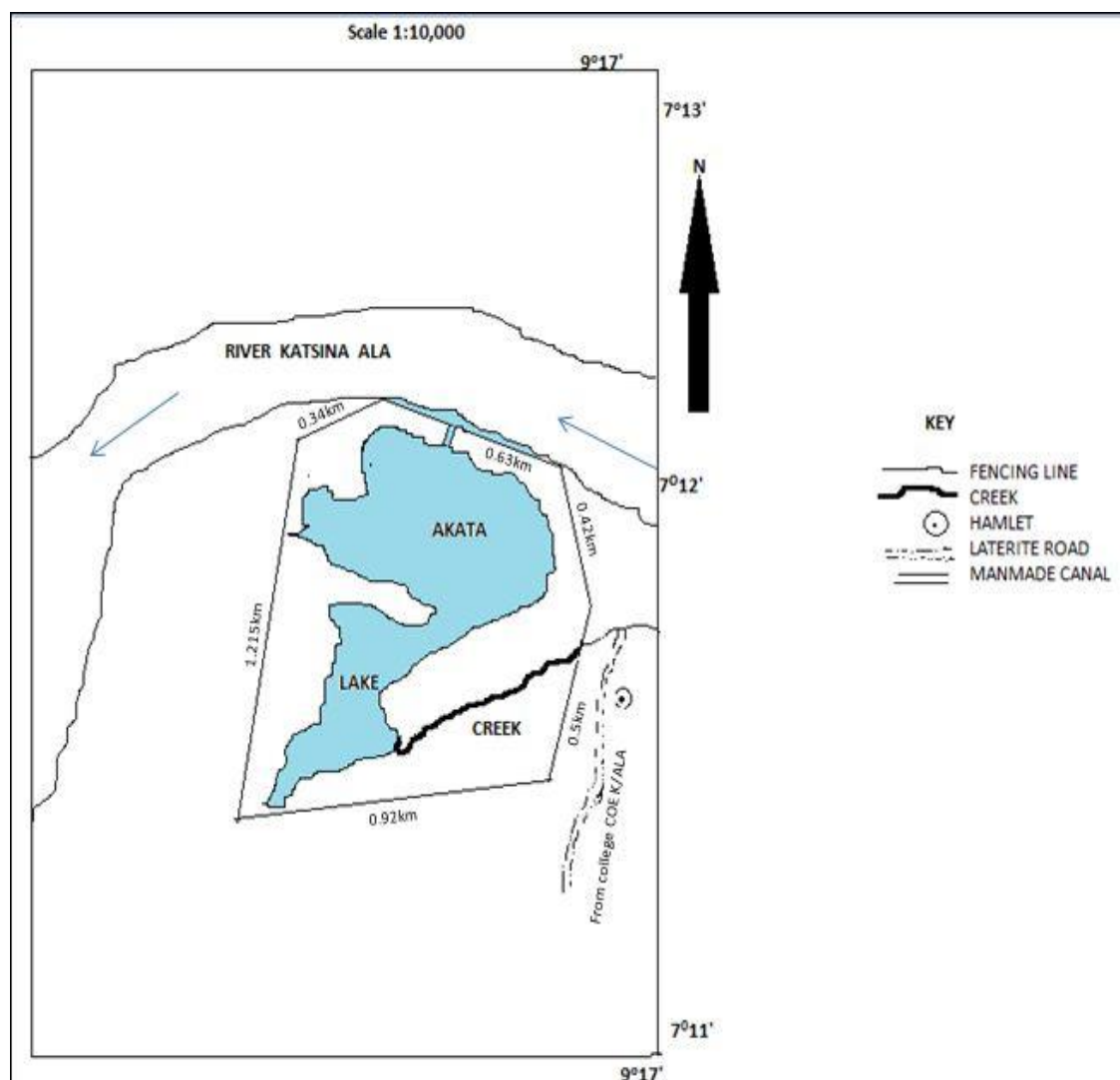


Figure 1: Map of Lake Akata

Source: Ministry of Agriculture and Natural Resources, Makurdi, Benue State, Nigeria. (MANR, 1984)

Sample Collection

Specimens of *D. rostratus* (97) were randomly sampled monthly for one year. Typically, fish sampling is conducted during the morning hours, spanning from 7:00 am to 9:00 am, and in the evenings from 4:30 pm to 6:30 pm. The study period was from May, 2022 - April, 2023. The fish

specimens utilized for the investigation were acquired from artisanal fishermen operating along These fishermen employ a range of fishing equipment, such as hand nets, cast nets, and gill nets with different mesh sizes (20.2, 25.4, and 30.5 mm). A canoe was employed as a fishing craft by the fishermen. The fish specimens were rinsed with

water and after that stored in an insulated container filled with ice. They were then transported to the laboratory for further analysis.

Laboratory procedure

In the laboratory, each specimen was dissected to remove the gut. The entire stomach of the fishes were removed and graded according to fullness. The graded stomach of each specimen was dissected length-wise and emptied into a petri-dish for examination and identification. Each stomach content was dispersed with small amount of distilled water; sub-samples were taken from the stock and observed under a stereo zoom binocular dissecting microscope.

The degree of fullness (volume) of the stomach and point allotted to each stomach was based on a table described by (Olatunde, 1978), as in Table 1.

Point Method

The point method involves scoring points to different food items depending on their numbers and sizes; one large organism being equivalent to many small organisms. All the points accumulated by each food item were summed-up and expressed as a percentage of the total number of points accumulated by all the food items as follows:

$$\% \text{ points of a food item} = \frac{\text{Number of points of the particular food item}}{\text{Total number of points of all food items}} \times 100$$

Frequency of Occurrence Method

The food items occurring in each of the stomach were examined. The food organisms were identified using keys by Yoloeye, (1994) and Waife and Frid, (2001). Frequency of occurrence is the number of times a particular food item occurs in the stomach is counted and expressed as a percentage of the total number of stomachs with food (empty stomachs excluded). This is expressed as:

$$\% \text{ occurrence of a food item} = \frac{\text{Total No. of stomachs with particular food item}}{\text{Total No. of stomachs with food}} \times 100$$

This method presents the food spectrum of the species. Consequently, it was probably possible to infer the significance of the food items in relation to the species' population. The merit of this method is that it gives good information on the various types of organisms fed upon, while the demerits are that

(i) it does not give information on the quantities or numbers of food items, and (ii) it does not give consideration to the accumulation of food organism which are resistant to digestion.

RESULTS

Food and Feeding Habits

Table 2 shows the list of food items found in the stomach of *D. rostratus*. 97 stomachs were examined, out of which 63(64.9 %) were found to contain food; Grass stem formed the dominant food items of the fish with a total point of 50.1 % and a frequency of occurrence of 33.0 %. Plant material was secondary in importance with a total point of 28.8 % and a frequency of occurrence of 18.6 %. Other food item found in the stomachs includes *Spyrogyra* with a total point of 12.1 % and a frequency of occurrence of 9.9 % and Blue green algae with a total point of 9.1 % and a frequency of occurrence of 6.6 % are of minor importance. Digested materials contributed 0 % of the total point and occurred in (30.9 %) of the stomachs. Detailed analysis of the result revealed that plant material contributed substantially to the total food items seen in 50.1 % and occurred in 33.0 % of the stomachs. Grass stems were found to be the most essential plant food, forming 28.8 % of points and a frequency of occurrence of 18.6 %. The result indicated that *Distichodus rostratus* is a herbivore.

Seasonal Variations in the Dietary Composition of *Distichodus rostratus* from Lake Akata

Figures 2 and 3 depict the histogram illustrating the seasonal fluctuations in dietary composition throughout both the dry and rainy seasons. The analysis of the food items revealed no discernible seasonal fluctuation in the chosen items. The grass stem was the primary dietary component throughout the rainy and dry seasons. The plant held a subordinate position in terms of significance during both seasons.

Changes in the dietary composition with Standard Length of *Distichodus rostratus* from Lake Akata

The variation of diet with standard length groups (Figure 4) shows that all the five groups of fish ranging between 1-15 cm, 16-25 cm, 26-35 cm, 36-45 cm and 46-55 cm fed more on algae than any other food item. With increasing standard length, researchers found that the quantity of plant material consumed increased.

Table 1: Classification of Stomach Size

Stomach Size	Description	Points
Full stomach	The stomach bulges considerably with food, stomach wall very thin and transparent.	100
¾ full stomach	The stomach is almost full, does not bulge.	75
½ full stomach	Food occupied about 50% of the stomach	50
¼ full stomach	The stomach was very flabby, sometimes looked as if emptied.	25
Empty stomach	No visible food in the stomach when dissected and examined under the microscope.	0

(Olatunde, 1978).

Fish ranging from 1-15 cm fed on algae, 16-25 cm fed more on algae, 26-35 cm fed on grass stem, 36-45 cm fed on grass stem, and 46-55 cm fed on grass stem.

The percentage of fish feeding each month is given in (Figure 5). More than 50 % of the fish were feeding in most of the months, particularly between May - November and January - April; in December, only 45.5 % of the fish were feeding.

Monthly Feeding Index of *Distichodus rostratus* from Lake Akata

Table 2: Frequency of Occurrence and Total point gained of Dietary Items in the Stomach of *Distichodus rostratus* from Lake Akata, Katsina-Ala

Dietary items	Frequency of occurrence	% Total point gained
Plants:		
Plant material	18.60	28.80
Grass stem	33.00	50.09
Total plant	51.60	78.88
Algae:		
Spyrogyra	9.90	12.14
Blue green algae	6.60	9.05
Total Algae	16.50	21.19
Empty stomach	35.05	-
Digested food	30.92	-
Unidentified food	-	-
TOTAL	-	100.07

No. of stomachs examined =97

No. of stomach with food =63

% of stomachs with food =64.9 %

No. of empty stomach =34

% of empty stomach =35.1 %

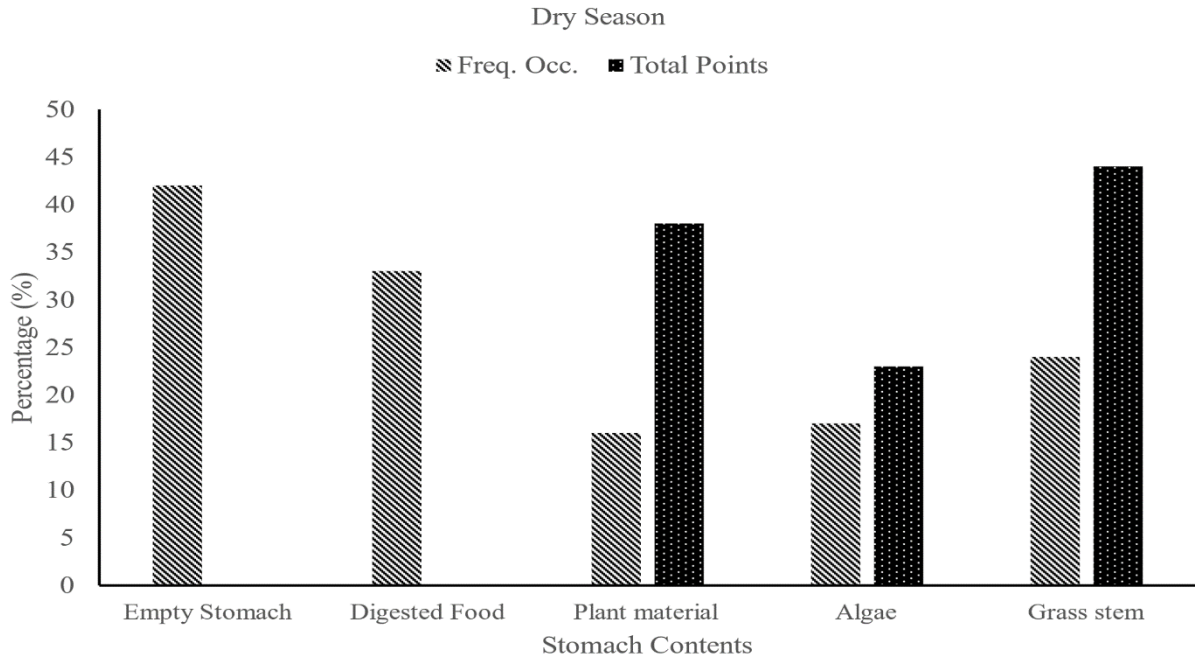


Figure 2: Food Items in Stomach of *Distichodus rostratus* from Lake Akata Katsina-Ala, during the dry Season

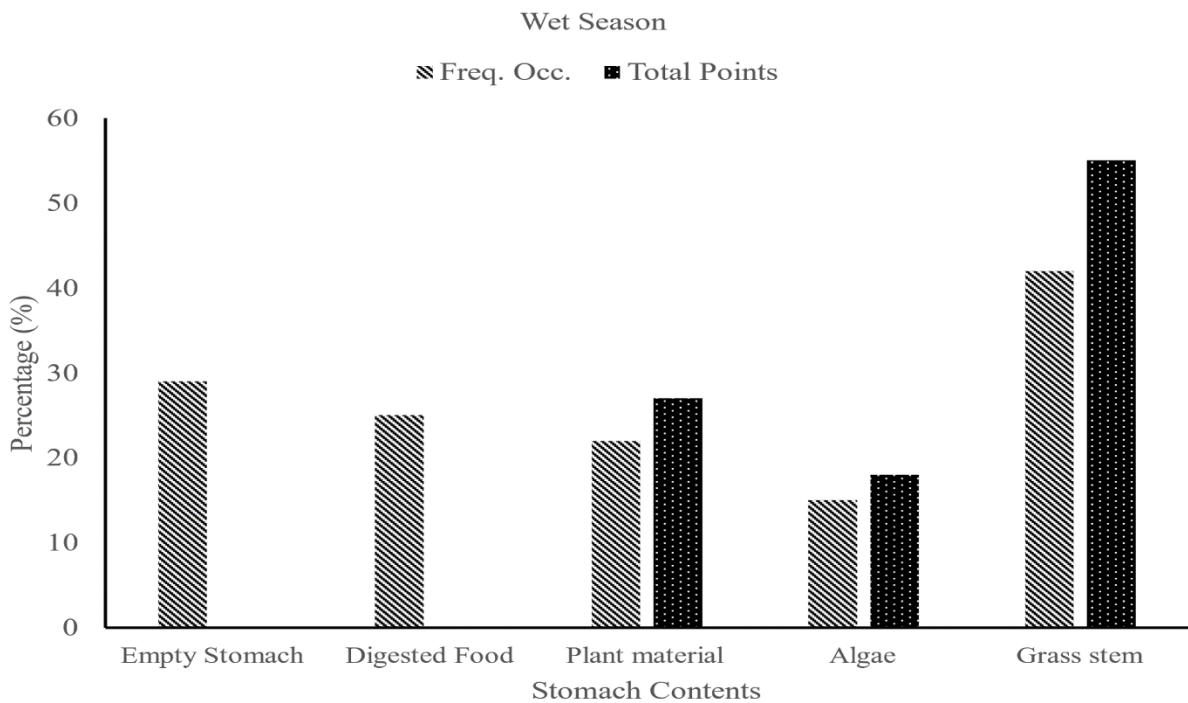


Figure 3: Food Items in Stomach of *Distichodus rostratus* from Lake Akata Katsina-Ala, during the wet Season

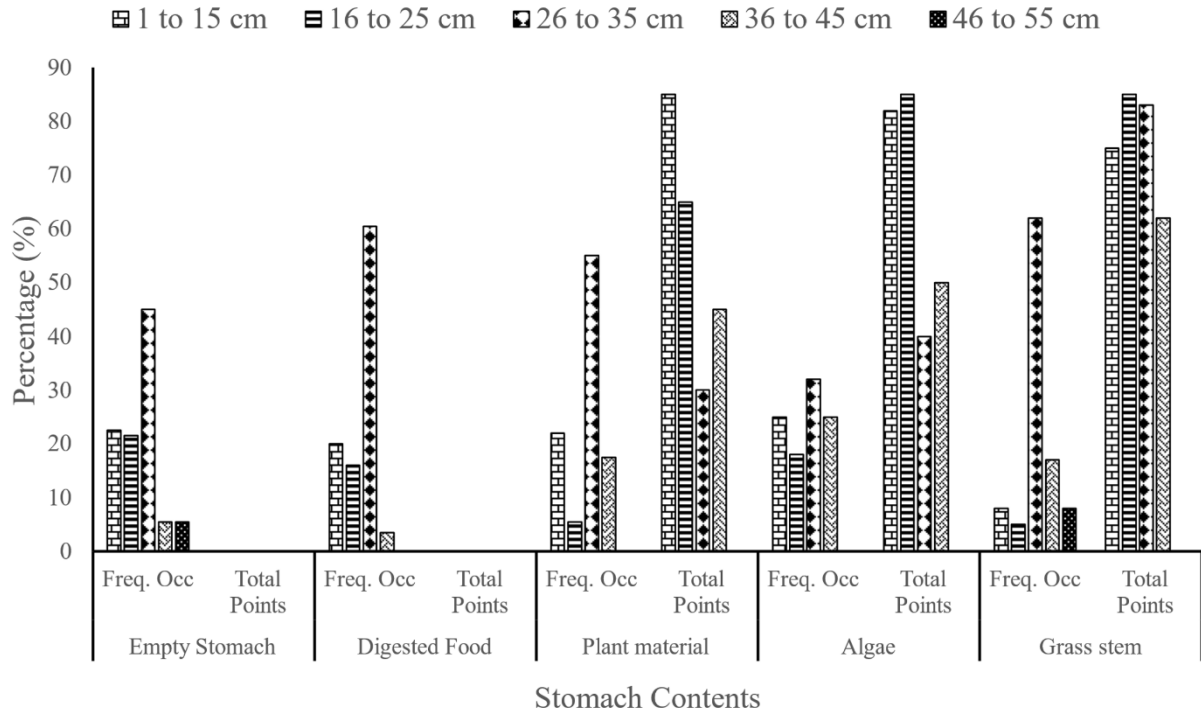


Figure 4: Changes in the Dietary composition with Standard Length of *Distichodus rostratus* from Lake Akata, Katsina-Ala

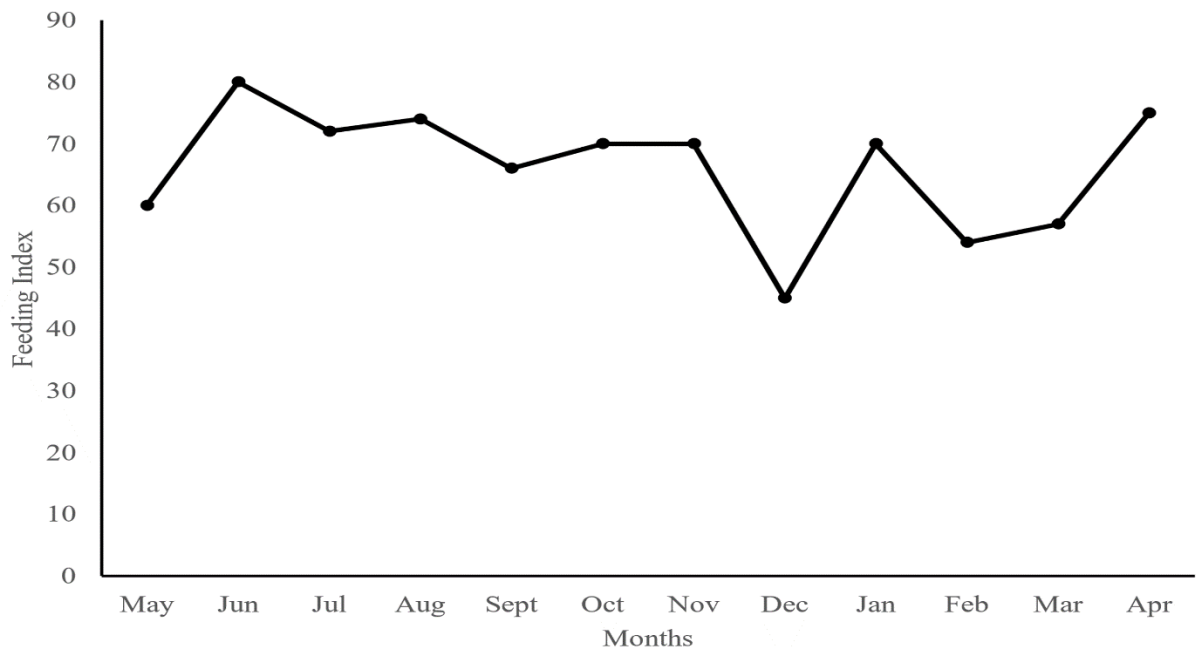


Figure 5: Monthly Feeding Index for *Distichodus rostratus* from Lake Akata, Katsina-Ala

DISCUSSION

In this study, we observed that the most essential food items in the stomach content analysis of *D. rostratus* were grass stems, spirogyra, and blue-green algae. This finding aligns with Bailey's (1994)

observation, which stated that *Distichodus* function as macro-herbivores, consuming submerged plants, *Eichornia* roots, and periphyton. The majority of species are predominantly herbivorous, consuming periphyton, macrophytes, algae, and detritus as their

main sources of food (Dietoa *et al.*, 2014; Zebe *et al.*, 2014). In a similar study, some species, such as *D. lusosso*, have been characterized as dietary generalists feeding on various plant and animal materials (Zebe *et al.* 2014). Umaru *et al.* (2014) noted that the presence of small, single-pointed teeth in the fish's mouth indicates a herbivorous feeding behavior, as these fish species are likely to consume plants, leaves, buds, and seeds of water lilies.

We also observed in this study that the seasonal variation of *D. rostratus* food revealed that they fed more on grass stems than on algae in both seasons. This fluctuation suggests that they were the prevailing dietary items during both seasons at that specific moment. This preference likely stems from the prevalence of various food items in the species' habitat during certain seasons. When the diet was compared with standard lengths of *D. rostratus*, the importance of plant material in the diet increased with size, while algae's contribution decreased with increased fish size. Fish measuring 1-15 cm primarily consumed algae, those between 16-25 cm exhibited a higher preference for algae, while those within the 26-35 cm range fed on grass stems. Fish in the 36-45 cm and 46-55 cm size ranges also showed a preference for feeding on grass stems. According to Leigh *et al.* (2017), the ability to eat large amounts of food material may be attributed to an increase in the mouth gap and the development of powerful jaws.

Heuvel *et al.*, (2019) have documented variations in fish diet based on their size and food availability during different seasons. Research on diet and feeding behaviour provides insights into the seasonal variations of fish. The type and quantity of available food, as well as the timing of its availability, play a crucial role in shaping the feeding habits of fish throughout their life history (Heuvel *et al.*, 2019). The elevated proportion of digested substances seen in *D. rostratus* is attributed to the consumption of soft and readily digestible food sources. Fabio *et al.* (2015) also elucidated that various fish species had distinct responses to capture in gill nets. They observed that certain species, caught during the early evening, had already digested a significant portion of their diet by the following morning when they were removed from the gill net. During the dry season, the stomach of *D. rostratus* primarily held digested materials. The monthly feeding index of *D. rostratus* revealed that the percentage of fish feeding each month is more than 50% of the fish that were feeding in most of the months, particularly between May - November and January - April in December, only 45.5%. The heightened feeding rate seen from May to October aligns with the rainy season, during which allochthonous food materials and minerals are introduced into the river through flooding, a

common occurrence in tropical rivers (Quang *et al.* 2022). The low mean feeding intensity by fish during the dry season (November-March) corresponds to period of inadequate food supply. It might account for the elevated proportion of instances where this species was found with empty stomachs during the months of the dry season. Quang *et al.* (2022) reported that feeding intensity is influenced by season and food availability. This result is consistent with the results of Onimisi *et al.* (2009), observed a similarly low feeding intensity during the dry season for *A. Occidentalis* in Zaria, Nigeria.

CONCLUSION

The result indicated that *D. rostratus* is a herbivore. The analysis of seasonal food variation indicated a predominant consumption of grass stems by *D. rostratus*, with this preference being notable during both the rainy and dry seasons.

ACKNOWLEDGEMENTS

To the best of our knowledge, no conflict of interest exists. The authors appreciate the Department of Fisheries and Aquaculture, University of Agriculture, Makurdi, for approving the use of the laboratory and providing necessary facilities for this study.

AUTHORS CONTRIBUTION: IOA and SSG designed the study; IOA experimented and collected the data. IOA and ORA analysed the data and wrote the draft of the manuscript. All authors approved the manuscript for submission.

REFERENCES

- Arroyave1, J., John, S.S.D. and Melanie, L.J.S. (2020). Pattern and timing of diversification in the African freshwater fish Genus *Distichodus* (Characiformes: Distichodontidae), *BMC (Biomedcentral) Evolutionary Biology*, 20(1): 48. <https://doi.org/10.1186/s12862-020-01615-6>
- Bailey, R.G. (1994). Guide to the fishes of the River Nile in the Republic of the Sudan. *Journal of Natural History*, 28(4): 937-970. <https://doi.org/10.1080/00222939400770501>
- Belton, B and Thilsted, S.H. (2014). Fisheries in transition: Food and nutrition security implications for the global South. *Global Food Security*, 3:59–66. <https://doi.org/10.1016/j.gfs.2013.10.001>
- Brittanica online. (2008). "Lake (physical feature)". Retrieved on 2008-06-25.
- De Graaf, G.J., Bartley, D.M., Valbo-Jørgensen. and Marmulla, G. (2015). Inland capture

- fisheries: status and data issues. *Fisheries Management and Ecology*, 22: 71-77. <https://doi.org/10.1111/fme.12104>
- Dietoa, M.Y., Kone, W.M., Yao, J.K., Costa, S.D. (2014). Use of plant epidermis for determination of macrophytes consumed by *Distichodus rostratus* Günther, 1864 (Pisces: Distichodontidae), of Taabo artificial Lake (Basin of Bandama, Côte d'Ivoire). *Agronomie Africaine*. 26: 103–12. <https://www.ajol.info/index.php/aga/article/view/107194>
- Elijah, M.I., John, C. and Lamidi, B.T. (2019). Fish species composition and abundance of River Taraba in Bali Town, Taraba State, Nigeria. *IOSR Journal of Pharmacy and Biological Sciences*. (IOSR-JPBS). 14 (1): 50-57. <https://doi.org/10.9790/3008-1401055057>
- Fabio, G., Luca, B., Filippo, D., Gianna, F., Piero, P., Angela, S., Giuseppe, S. and AleSandra, S. (2015). The effect of monofilament thickness on the catches of gillnets for common sole in the Mediterranean small-scale fishery. *Fisheries Research*. 164: 170-177. <https://doi.org/10.1016/j.fishres.2014.11.014>
- FAO. (2014a). CWP Handbook of Fishery Statistical Standards. Section G: Fishing Areas - General. Rome, Italy. http://www.fao.org/fi/default_all.asp
- FAO (2014b). The State of World Fisheries and Aquaculture. Available from: <http://www.fao.org/3/a-i3720e>
- FishStatJ. (2016). Database and software for fishery statistical analysis. United Nations FAO. Accessed 28 June 2016. <http://www.fao.org/fishery/statistics/software/fishstatj/en>
- Goli, B.B.P.E., Kamelan, T.M., Berté, S., Kien, K.B., Ndiaye, S. and Kouamelan, E.P. (2019). The first data on the population parameters of the main fish species in Man-made Lake Buyo (River Sassandra, Côte d'Ivoire). *Egyptian Journal of Aquatic Biology and Fisheries* 23(2): 585-59. <https://doi.org/10.21608/ejabf.2019.34788>
- Heuvel, C.E., Haffner, G.D., Zhao, Y., Colborne, S.F., Despenic, A. and Fisk, A.T. (2019). The influence of body size and season on the feeding ecology of three freshwater fishes with different diets in Lake Erie. *Journal of Great Lakes Research* 45 (4):795-804. <https://doi.org/10.1016/J.JGLR.2019.05.001>
- Ikongbeh, O.A., Ogbe, F.G. and Solomon, S.G. (2012). Food and feeding habits of *Clarotes laticeps* (RÜPPEL, 1829) from Lake Akata, Benue State, Nigeria. *Nigerian Journal of Fisheries* 9 (2): 518-527. https://www.academia.edu/Nigerian_Journal_of_Fish
- Ikongbeh, O.A., Ogbe, F.G. and Solomon, S.G. (2014). Food and feeding habits of *Auchenoglanis occidentalis* (VALENCIENNES, 1775) from Lake Akata, Benue State, Nigeria. *Journal of Fisheries and Aquatic Science* 9 (4): 229-236. <https://doi.org/10.3923/jfas.2014.229.236>
- Ipinmoroti, M.O., Iyiola, A.O. and Akanmu, O.A. (2022). Association of some weather factors with fish assemblage in Asejire Lake, South-western Nigeria. *Journal of Agriculture and Environmental Sciences* 7 (2): 26-37. <http://ejol.ethernet.edu.et/JAES/article/view>
- Keredin, M.H., Ashenafi, A.A. (2021). Stomach content analysis of feed and feeding habit of *Oreochromis niloticus* fish species in Baro-Akobo Basin, South West Ethiopia in Case of Alwero Dam. *Journal of Biology, Agriculture and Healthcare* 11(3): 1-8. <https://doi.org/10.7176/JBAH/11-3-01>
- Kouakou, Z.S., Doumbia, L., Konan, K.M., Ouattara, M. and Ouattara, A. (2022). Reproductive biology of the main Fish Species in Lakes Taabo, Kossou and Faé (Côte d'Ivoire) with a view to Rational Fishing. *International Journal of Fisheries and Aquatic Studies* 10(1): 46-55. <https://doi.org/10.22271/fish.2022.v10.i1c.2635>
- Leigh, S.C., Papastamatiou, Y. and German, D.P. (2017). The nutritional physiology of sharks. *Reviews in Fish Biology and Fisheries* 27:561-585. <https://doi.org/10.1007/s11160-017-9481-2>
- Lo, M., Reed, J., Castello, L., Steel, E. A., Frimpong, E. A., and Ickowitz, A. (2020). The influence of forests on freshwater fish in the tropics: A systematic review. *Biological Science*, 70(5), 404-414. <https://doi.org/10.1093/biosci/biaa021>
- Ministry of Agriculture and Natural Resources Makurdi Benue State, Nigeria. MANR (1984).

- Olatunde, A.A. (1978). The food and feeding habits of *Eutropius niloticus* (Ruppell), family Schilbeidae (Osteichthyes: Siluriformes) in Lake Kainji, Nigeria. *Hydrobiologia* **57**, 197–207 (1978). <https://doi.org/10.1007/BF00014574>
- Onimisi, H.U., Oniye, S.J., Balogun, J.K., Aken'Ova, T.O.L. (2009). Food and feeding habits of *Auchenoglanis occidentalis* (Vallenciennce, 1840) in Zaria, Nigeria. *Zoologist* **7**: 57-64. <https://doi.org/10.4314/tzool.v7i1.52092>
- Quang, M..D., Ngon, T.T., Gieo, H.P., Nam, S.T. and Ton, H.D.N. (2022). Factors influencing food composition, feeding habits and intensity of *Glossogobius giuris* caught from the Vietnamese Mekong Delta. *Journal of King Saud University Science* **34**(6): 102159. <https://doi.org/10.1016/j.ejar.2021.12.004>
- Segun, O.O., Lotanna, M.N., Akinkunle, V.A., Olutomi, A.A. and Kehinde, M.A. (2022). Environmental correlates of some selected fish species in the Jebba Dam, North-Central Nigeria. *Journal of Tropical Ecology*, **38**(3): 107 – 117. <https://doi.org/10.1017/S0266467421000511>
- Shinkafi, B.A, Salim, A.M. and Yusuf, M.A. (2013). Some aspects of the biology of *Distichodus rostratus* (GUNTHER, 1864) in River Rima, North western Nigeria, *Greener Journal of Biological Sciences* **3**(4): 136-145. <https://doi.org/10.15580/GJBS.2013.4.040213559>
- Umaru, B.W., Haruna, A.B., Gwana, A.M., Wanas, L.N., Bukar-Kolo, M.Y., Mohammed, U.K. (2014). Examinations of the stomach contents of two fish species (*Clarias gariepinus* and *Oreochromis niloticus*) in Lak Alau, North – Eastern Nigeria *Agriculture, Forestry and Fisheries* **3**(5): 405-409. <https://doi.org/10.11648/j.aff.20140305.23>
- Waife, G. and Frid, C.I. (2001). Marine zooplankton of West Africa. Darwin initiative. Report 5: 120pp
- Yoloye, V.L.A. (1994). Basic invertebrate zoology. 3rd Edition, Codes and Quantal Publications, Lagos 320pp.
- Zebe, V.M., Micha, J.C., Moreau, J. and Bekeli, M.N. (2014). Age and growth of *Distichodus antonii* (Schilthuis, 1891) (Pisces, Teleostei, Distichontidae) in Pool Malebo, Congo River. *African Journal of Environmental Science and Technology*. <https://doi.org/10.5897AJESTO9.211>.