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Short communication

Diet of Nile tilapia in the Cachoeira Alta do Tarumã stream, Tarumã-Açu hydrographic basin (Manaus, Amazonas, Brazil)

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ABSTRACT

Trophic plasticity is an important factor in assessing the ability of a species to remain in an altered environment or its ability to be introduced into a new environment. The Nile tilapia is a species that has been illegally introduced for aquaculture purposes in the central portion of the Amazon. Its escape into the natural environment has occurred, and it is already possible to find specimens in streams around Manaus, capital of the state of Amazonas, Brazil. This study aimed to investigate the diet of Nile tilapia in the stream known as Cachoeira Alta do Tarumã (Manaus, Amazonas, Brazil), a small tributary of the Tarumã-açu river that has been affected by anthropogenic actions. To identify its feeding habit, 43 stomachs were analyzed according to their degree of repletion, frequency of occurrence of food items, volumetric method, and the food importance index. The species was identified as being detritivores with a tendency to herbivory. Plastic was identified in the diet of this species, which indicates generalist and opportunistic habits when inserted in habitats with a low supply of food.

Keywords: Feeding habits; Stomach contents; Exotic species; *Oreochromis niloticus*.

Dieta da tilápia-do-nilo no igarapé da Cachoeira Alta do Tarumã, Bacia Hidrográfica de Tarumã-Açu (Manaus, Amazonas, Brasil)

RESUMO

A plasticidade trófica é um fator importante para avaliar a capacidade de uma espécie de permanecer em um ambiente alterado ou ser introduzida em um novo ambiente. A tilápia-do-nilo é uma espécie que vem sendo introduzida ilegalmente em aquiculturas na porção central da Amazônia. O escape para o ambiente natural vem ocorrendo, e já é possível encontrar exemplares em igarapés do entorno de Manaus, capital do estado do Amazonas. Este trabalho teve como objetivo investigar a dieta da tilápia-do-nilo no igarapé conhecido como Cachoeira Alta do Tarumã (Manaus, Amazonas), um pequeno tributário do Rio Tarumã-açu, impactado por ações antrópicas. Para demonstrar a preferência alimentar dessa espécie, foram analisados 43 estômagos, por meio do grau de repleção, frequência de ocorrência, método volumétrico e índice de importância alimentar. A espécie foi identificada como detritívora com tendência à herbivoria. Foi identificado plástico na dieta dessa espécie, indicando hábitos generalista e oportunista, quando inserida em hábitats com baixa oferta de alimento.

Palavras-chave: Hábito alimentar; Conteúdo estomacal; Espécie exótica; *Oreochromis niloticus*.

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INTRODUCTION

Studying the natural diet of fish allows us to identify the trophic relationships that exist in aquatic environments, and characterize the food composition, structure, and stability of food webs in these ecosystems (Wootton, 1990; Adeyemi, 2009; Otieno et al., 2014). In this sense, understanding the trophic dynamics of fish and the specific interactions of these individuals, such as foraging, migratory behavior, habitat use and energy gain, can help to understand ecological structures (Ross, 1986; Garvey et al., 1998; Bonato et al., 2012; Gandini et al., 2012). In tropical regions, despite there being fish with specific feeding habits, most ichthyofauna has high trophic plasticity (Lowe-McConnell, 1999) with ontogenic and seasonal variations. The trophic plasticity of ichthyofauna may be related to the need for adaptation due to seasonal variations of environmental conditions, which influence food supply and/or habitat characteristics (Abelha et al., 2001). Nevertheless, this plasticity could be related to the need to adapt to environmental degradation, which reduces the diversity and abundance of food items.

The Amazon basin has the most extensive freshwater system on the Earth (Junk et al., 2007; Tedesco et al., 2017), and the Negro river is one of its main tributaries. The Tarumã-Açu basin is formed by a dense hydrographic network and is located on the left bank of the lower Negro river; and the Cachoeira Alta do Tarumã stream is one of its tributaries (Vasconcelos et al., 2015; Melo and Romanel, 2017). It is located on the outskirts of Manaus (AM), Brazil, and is affected by anthropogenic stressors that have occurred on its banks in recent decades (Pascoaloto et al., 2009; Silva, 2016).

The Nile tilapia was introduced in Brazil in the 1970 (Silva et al., 2012) in order to eradicate hunger in the northeastern region of the country (Bittencourt et al., 2014). This species presents aggressive habits and trophic plasticity (McKaye et al., 1995), which facilitates its adaptation when inserted into a new habitat, even when it is subject to anthropogenic impacts (Teixeira and Attayde, 2015; Cardoso, 2016). Several studies have identified the trophic plasticity of Nile tilapia, due to its ability to adapt not only in environments with a greater supply of plants and phytoplankton, which are characteristic of shallow waters and lentic rivers (Kour et al., 2014; Tesfahun and Temesgen, 2018; Abidemi-Iromini, 2019; Fiuza, 2023), but also in environments with the predominance of invertebrates, benthic animals, mature fish eggs, zooplankton, and suspended foods (Trewavas, 1982; Peng et al., 2021; Tesfaye et al., 2021).

Trophic plasticity and generalist and opportunistic eating habits are determining factors for the establishment of *Oreochromis niloticus* in environments that are different from its original area of distribution, even when it has a low food supply and/or in environments affected by anthropogenic stressors (Temesgen et al., 2022; Yongo et al., 2023). Furthermore, the dietary flexibility of Nile tilapia causes an increase in its biomass and, consequently, a greater volume of nutrient excretion, thus contributing to the eutrophication/pollution of water bodies and the extinction of native ichthyofauna (Bittencourt et al., 2014; Shuai et al., 2023).

Then, investigating the composition of the stomach contents of *O. niloticus* helps us to identify the nutrients available in the habitat, in addition to helping us to understand the versatility of this species in terms of its eating habits (Abidemi-Iromini, 2019; Wing et al., 2021). Here, we studied the diet of Nile tilapia in the Cachoeira Alta do Tarumã stream, an urban water course that has been heavily affected by anthropic activities, to demonstrate its ability to survive in a degraded environment with low feeding resource availability.

MATERIALS AND METHODS

Study area

The study was carried out in the Cachoeira Alta do Tarumã stream (3°00'30.3"S and 60°03'19.2"W), a tributary of the Tarumã-Açu river, which is a tributary of the left bank of the Negro river (Melo and Romanel, 2017) (Fig. 1). The Tarumã-Açu basin is on the western edge of the city of Manaus. The Tarumã-Açu river has been affected by several anthropogenic actions over the last decades (Santana and Barroncas, 2007; De Vasconcelos et al., 2019). Part of the hydrographic network of the Tarumã-Açu river receives the runoff from the landfill site located on the AM-010 highway at km 19 and also untreated sewage from the houses on the banks of the river and its tributaries, as well as from adjacent neighborhoods (Santos et al., 2006).

Data collection

The capture of specimens of Nile tilapia occurred in October 2021, which corresponds to the dry season in the lower Amazon region. Batteries of eight gill nets were placed in the water for 15 hours a day, from 4 a.m. to 7 p.m., which is the period of greatest fish activity. To avoid the possible loss of nets and losses of caught specimens due to attacks by predatory species, the fishing took place at intervals of 1 hour. The nets in the batteries were 200-m long × 2-m high, with mesh sizes ranging between 20, 30, 40 and 50 mm between opposite knots. In addition, cast

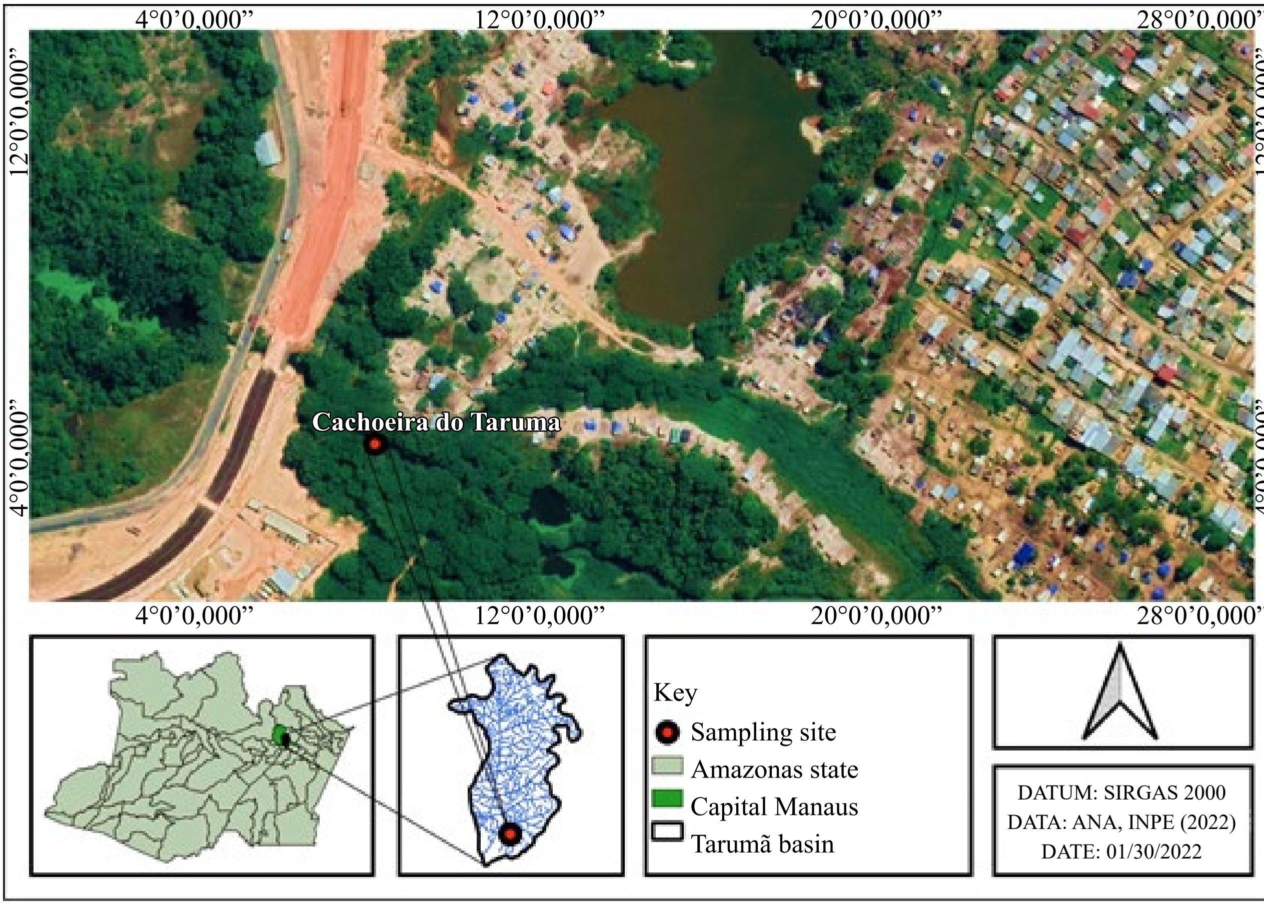

Figure 1. Location of the sampling site on the Cachoeira Alta do Tarumã stream, Manaus, state of Amazonas, Tarumã-açu basin.

nets were thrown 10 times in each sampling site. These cast nets were 3-m tall × 6-m radius when extended and had mesh dimensions of 40 mm between opposite knots.

The collected fish were packed in Styrofoam boxes with ice, thus inducing thermal shock and consequently the death of the individuals. The fish were then transported to the Fisheries Ecology Laboratory at the Universidade Federal do Amazonas. This research was conducted under a license obtained from SISBio (No. 65838-5) and ethical approval by Comissão de Ética no Uso de Animais-Universidade Federal do Amazonas (No. 012/2021).

Data analysis

The fish were measured using an ichthyometer to obtain their total length (Lt) and the standard length (Ls), in cm, and using a scale to obtain the total weight (Wt), in g. After the stomachs were sectioned, the specimens had their guts removed. Then, measurements, such as the weight of the full stomach and the weight of the empty stomach, in g, were obtained, and the degree of repletion was estimated using the following scale: 0% (empty), 25, 50, 75 and 100% (full) (Zavala-Carmin, 1996).

The stomach contents were transferred to Petri dishes, and a stereoscope was used to aid visualization. The analysis was done using the methods frequency of occurrence (FO%), which consists of the percentage of stomachs with the occurrence of a certain food item, in relation to the total amount of stomachs with some type of food; and the volumetric method (V%), which is expressed by the relative food volume in relation to the absolute food volume in the analyzed stomachs (Hynes, 1950; Hyslop, 1980; Zavala-Carmin, 1996). The food importance index (FII) was estimated to determine the relative importance of each item in the diet of the species (Kawakami and Vazzoler, 1980).

RESULTS

The total of 75 fish was collected, and the stomach contents analysis was conducted on 43 specimens since the other individuals were in an advanced state of decomposition.

Three individuals were registered at the Ichthyology Laboratory at Universidade Federal do Amazonas under the identification code UFAM470. The Lt of the tilapia specimens ranged between 13 and 15.75 cm, and the Ls between 10 and 12 cm, while the Wt ranged from 36.5 to 62.5 g. The composition of the diet of Nile tilapia specimens consisted of detritus, plant material, digested material, and plastic. Most of the fish had a repletion rate of 25%, and only three had a completely full stomach. Detritus was the food item that presented the highest volume, which was followed by plant material, digested material, and plastic (Table 1).

Table 1. Variation in the stomach contents of Nile tilapia in the Cachoeira Alta do Tarumã stream*.

Composition	
Stomach contents	**Number of specimens**
D/PM	28
D/PM/DM	4
D/PM/DM/P	3
ES	8
Degree of repletion (%)	
Number of stomachs	**Degree of repletion**
8	0
28	25
2	50
2	75
3	100
Volume (%)	
D	72.28
PM	25.57
DM	1.42
P	0.71

D: detritus; PM: plant material; DM: digested material; P: plastic; ES: empty stomachs; *degree of repletion of the stomachs of the exotic species Nile tilapia in the Cachoeira Alta do Tarumã stream. Volume (%) of food items present in the stomachs of the exotic species Nile tilapia in the Cachoeira Alta do Tarumã stream.

Regarding the frequency of occurrence, it was observed that 43% of the tilapia analyzed presented detritus (sand, stone, decomposing organic matter) and plant material (branches, leaves, roots) in their diet. The other specimens had digested material in the stomach (9%), though it was not possible to determine the type of material. In 5% of the stomachs, the presence of plastic was observed. Detritus was the most important food item (73.59%) in the diet of the Nile tilapia sampled in the Cachoeira Alta do Tarumã stream. A high importance of plant material (26.03%) was observed, which was followed by digested material (0.29%) and plastic (0.08%). Thus, the studied species was characterized as a detritivore with a tendency to herbivory (Fig. 2).

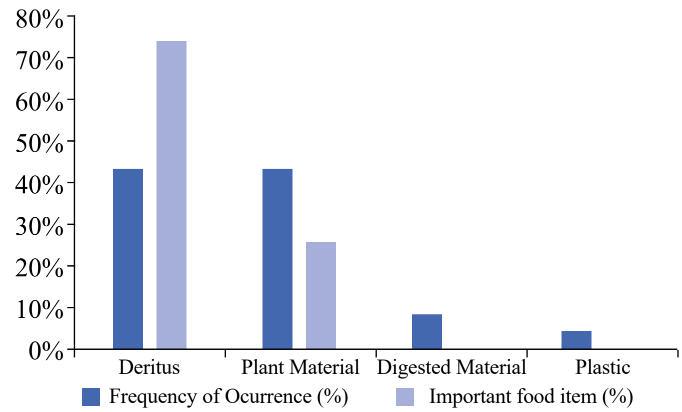

Figure 2. Frequency of occurrence of food items in the stomachs analyzed. Dietary preferences of the exotic species Nile tilapia of the Cachoeira Alta do Tarumã stream.

DISCUSSION

Studies on the diet of tilapia in non-anthropized environments of their area of natural distribution showed that they have a more diverse diet (Assefa and Getahun, 2015; Abdelghany, 2020). Abdulhakim et al. (2015) investigated the diet of Nile tilapia in Lake Alau, Nigeria, and detected a variety of food items such as algae, sand, mud, insects, and fish remains present in the stomach of this species, though with the predominance of plant material. This preference was also highlighted by Moriarty and Moriarty (1973), when investigating the diet of this species in Lake George, Uganda. However, Tesfahun and Temesgen (2018), after conducting research in Ethiopian water bodies, classified this species as omnivorous, noticing that the food items present in the diet of this species are basically composed of phytoplankton, macrophytes, insects, detritus, and zooplankton.

On the other hand, the population of *O. niloticus* that was studied in Cachoeira Alta do Tarumã showed the ability to exploit the food items available in the anthropized environment. Alam et al. (2015) and Cala and Bernal (1997) analyzed the diet of Nile tilapia in the Yamuna river, India, and in the Betania reservoir, Colombia, respectively, and observed similar characteristics, with detritus being the most important food item in the diet of this species. This is evidence of its trophic plasticity in a eutrophicated habitat with low food supply. Shalloof and Khalifa (2009) conducted research in a mining lake in Egypt and observed that, due to the low food supply in the environment, the most important food item for the species was algae.

The presence of plastic was already observed in the diet of Amazonian fishes of different trophic guilds, with variation of the fragment size related to its feeding behavior (Andrade et al., 2019). Although only small quantities of plastic had been observed in the diet of *O. niloticus*, it is necessary to highlight this finding, since the people living in the Cachoeira Alta do Tarumã stream eats this fish.

Pauly et al. (1998) conducted research related to cancer in humans and observed that plastic can play a significant role in the development of this pathology. This health alert was already highlighted by Biginagwa et al. (2016), who evidenced the presence of microplastics in the diet of Nile tilapia inhabiting African lakes. Plastics are increasingly used around the world and have become a major concern due to their high quantity, persistence in the environment, and adverse consequences for aquatic life and human health (Lebreton et al. 2017; Pabortsava and Lampitt, 2020; Ribeiro-Brasil et al., 2020).

CONCLUSION

The Nile tilapia population that was sampled in the Cachoeira Alta do Tarumã stream presented a detritivore habit with a tendency to herbivory. Food variations demonstrate the trophic plasticity of this species when introduced into anthropized environments with little food available. This adaptive capacity reported in our study points to the need for rigorous monitoring in order to avoid a legal authorization to introduce this species in the Amazon basin, since the impact on the native ichthyofauna is still unknown. The presence of tilapia in urban water courses of Manaus is evidence that small quantities of illegally introduced individuals is enough for this species colonize Amazonian aquatic environments. The presence of plastic found in the stomachs of some specimens of Nile tilapia indicates the need to intensify studies related to this subject, since this fish is eaten by residents of the region, thus constituting a public health issue.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

All data sets were generated or analyzed in the current study.

AUTHORS' CONTRIBUTIONS

Conceptualization: Freitas CEC, Ramos MAR; **Data Curation:** Freitas CEC; **Validation:** Freitas CEC; **Supervision:** Freitas CEC, Ramos MAR; **Funding Acquisition:** Freitas CEC; **Writing — Original Draft:** Lopes GCS, Freitas CEC; **Writing — Review & Edition:** Freitas CEC; **Final approval:** Ramos MAR

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