BOLETIM DO INSTITUTO DE PESCA
Scientific Article

Dietary aspects at the population and individual level of *Pimelodus argenteus*, a native fish species from the southern Pantanal, Brazil

Bruna Caroline Kotz Kliemann[1]*, Nayara Yuri Mitsumori Alvares[1], Lidiane Franceschini[2], Bianca da Silva Miguel[3], Aymar Orlandi Neto[3], Igor Paiva Ramos[1,3]

[1]Universidade Estadual Paulista, Faculdade de Engenharia, Departamento de Biologia e Zootecnia – Ilha Solteira (SP), Brazil.
[2]Universidade Estadual Paulista, Instituto de Biociências, Letras e Ciências Exatas – São José do Rio Preto (SP), Brazil.
[3]Universidade Estadual Paulista, Instituto de Biociências – Botucatu (SP), Brazil.
*Corresponding author: bruna.kli@gmail.com

ABSTRACT

Pantanal is highly important environmentally and economically and suffers from environmental changes and anthropization. *Pimelodus argenteus* is a native species from the southern Pantanal and important for artisanal fishing and feeding of riverside populations. Given the assumptions, this study aimed to characterize the diet and feeding habits of *P. argenteus* and verify if there is variation and individual specialization in the diet in the evaluated period. For this, the specimens were acquired from an artisanal fisherman in October 2017 in the Miranda River, southern Pantanal, Mato Grosso do Sul state, Brazil. The population's diet was variable, composed of 18 food items, and its trophic guild was determined as carnivorous/malacophagous. We observed individual variation and specialization in the diet at the individual level. The consumption of bivalves with high invasive potential and non-organic items was also observed, indicating anthropic influences. These results raise questions about the possible long-term impacts on the native and economically important species. In addition, we suggest that individual specialization may have occurred in response to competitive pressures. Finally, our results can contribute to ecological information and support conservation plans for this native species and this biome with important ecosystem functions.

Keywords: Fish, Populational diet; Individual specialization; Individual variation; Biosphere reserve; World heritage site

Aspectos alimentares a nível populacional e individual de *Pimelodus argenteus*, uma espécie de peixe nativa do Pantanal Sul, Brazil

RESUMO

O pantanal é altamente importante do ponto de vista ambiental e econômico e sofre com as mudanças ambientais e a antropização. *Pimelodus argenteus* é uma espécie nativa do pantanal sul, Mato Grosso do Sul, e importante para a pesca artesanal e alimentação das populações ribeirinhas. Diante dos pressupostos, este estudo teve como objetivos caracterizar a dieta e os hábitos alimentares de *P. argenteus* e verificar se há variação e especialização individual na dieta no período avaliado. Para isso, os exemplares foram adquiridos de um pescador artesanal em outubro de 2017 no Rio Miranda, Pantanal sul-matogrossense. A dieta da população foi variável, composta de 18 itens alimentares, e sua guilda trófica foi determinada como carnívora/malacófaga. Observamos variação individual e especialização na dieta em nível individual. Também foi observado o consumo de bivalves com alto potencial invasivo e itens não orgânicos, indicando influências antrópicas. Esses resultados levantam questões sobre os possíveis impactos a longo prazo sobre as espécies nativas e economicamente importantes. Além disso, sugerimos que a especialização individual possa ter ocorrido em resposta a pressões competitivas. Por fim, nossos resultados podem fornecer informações ecológicas para fundamentar planos de conservação dessa espécie nativa e desse bioma com importantes funções ecossistêmicas.

Palavras-chave: Peixes, Dieta populacional; Especialização individual; Variação individual; Reserva da biosfera; Patrimônio mundial.

Received: October 7, 2023 | **Approved:** July 6, 2024
Section editor: Raniere Garcez C. Sousa

INTRODUCTION

Pantanal is the most extensive continuous floodplain in the world (Alho et al., 2019; Pozer & Nogueira, 2004), with approximately 150,000 km^2 of wetlands forming a mosaic of landscapes with high richness and diversity of fauna and flora (Alho et al., 2019; Fernandes et al., 2010; Pozer & Nogueira, 2004). This mosaic of landscapes provides a wide variety of food and reproductive resources for fish (Alho, 2011), resulting in the occurrence of 386 species of fish (Gimênes Júnior & Rech, 2022). In addition, wetlands such as the Pantanal have important ecosystem functions such as maintaining microclimates, habitat for endangered species, and river flow control (Clarkson et al., 2013; Mitsch et al., 2015). Due to these characteristics, Pantanal is considered a biosphere reserve and a world heritage site by the United Nations Educational, Scientific, and Cultural Organization (Stevaux et al., 2020).

Pantanal is highly important economically for artisanal, commercial, and sport fishing (Chiaravalloti, 2019; Chiaravalloti et al., 2022; Da Silva & Simoni, 2012; Kakuru et al., 2013). Fishing practiced by the riverside population and artisanal professional fishermen generates employment and income for thousands of people (Chiaravalloti et al., 2022). However, this biome has been modified by human actions that interfere with the aquatic environment (Tomas et al., 2019). Degradation of natural habitats through fragmentation, deforestation, fires, pollution, and replacement of vegetation with pasture are some examples of these anthropic impacts (Alho et al., 2019). In addition, the introduction of non-native species (Alho et al., 2011; Gimênes Júnior & Rech, 2022) and excessive use of natural resources as predatory fishing (Bertolino et al., 2022) are reported.

Pimelodus argenteus Perugia, 1891, a fish species with economic and environmental importance, is a native to the southern Pantanal, Mato Grosso do Sul state, and presents the potential for artisanal fishing, serving as a source of income for riverside populations (Ramos Filho et al., 2010; Gimênes Júnior & Rech, 2022). Although *P. argenteus* is classified under conservation status as least concern (ICMBio, 2018), conservation measures for this species are necessary, and information on biology can contribute to future conservation plans. In this context, through fish feeding, it is possible to know a little about the species' biology and evaluate the interactions between aquatic organisms and the environment (Chase & Leibold, 2003). Neotropical fishes show plasticity and trophic opportunism that allow the consumption of food items available in time and space, thus reflecting the relationships between aquatic and terrestrial environments (Abelha et al., 2001). In the case of omnivorous species, such as *P. argenteus* (Resende et al., 2000), foods of various origins are consumed, whether aquatic or terrestrial, organic, or non-organic (Novakowski et al., 2008).

From the perspective of evaluating the interactions of fish with the environment, considering individuals' behavior is paramount. Studies demonstrated that individuals respond differently to environmental variations considering their requirements, aptitude, and life experience (Araújo et al., 2008, 2010; Cunha et al., 2018; Jirka & Kraft, 2017). Individuals may vary in the exploration and consumption of food items resulting in generalist populations composed of specialist individuals (Pires et al., 2011; Coblentz et al., 2017; Correa & Winemiller, 2014). According to Bolnick et al. (2003), the variation in individuals' use of food resources indicates individual specialization and can result in greater food amplitude for the population. In this context, the population will be more resistant to trophic imbalance since, in the scarcity of a food resource, for example, few individuals will be affected (Bolnick & Ballare, 2020).

Considering the economic and environmental importance of the Pantanal biome (Chiaravalloti, 2019; Chiaravalloti et al., 2022) and the importance of *P. argenteus* for artisanal fishing and feeding of riverside populations (Gimênes Júnior & Rech, 2022), studies on this species in the Pantanal are important to populations' maintenance. In addition, the knowledge about biological aspects of this species is incipient and poorly studied, and the Pantanal biome has suffered from the effects of climate change, fires, and anthropic actions that culminate in the loss of habitats (Chiaravalloti et al., 2022; Tomas et al., 2019). In this sense, assessing the food resources consumed by *P. argenteus* at the population and individual levels can support claims and decisions in future conservation plans. Given the assumptions, this study aimed to characterize the diet and feeding habits of *P. argenteus*, a native species from the southern Pantanal, Mato Grosso do Sul state, and to verify possible variation and individual specialization in the diet in the evaluated period.

MATERIAL AND METHODS

Study area

The collections were carried out on the right bank of the Miranda River, in the Passo do Lontra, southern Pantanal, Mato Grosso do Sul state, Brazil (Fig. 1). The Pantanal wetland is in the Upper Paraguay River Basin between Mato Grosso and Mato Grosso do Sul states. The climate is tropical, with an average annual temperature of 25°C and well-defined seasons (Stevaux et al., 2020). In the southern Pantanal, the flooding period occurs

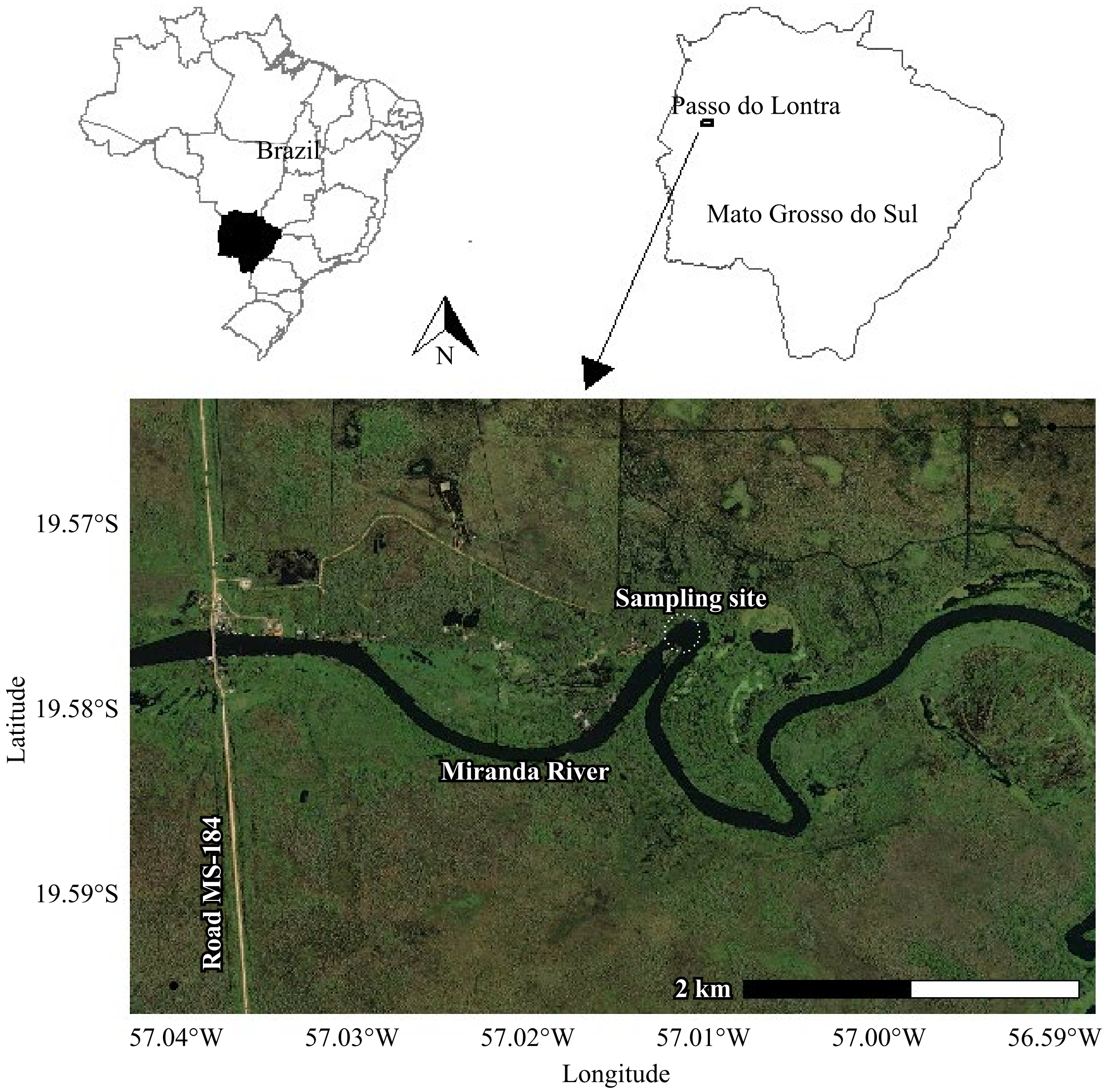

Figure 1. Study area on the Miranda River, Passo do Lontra, southern Pantanal, Mato Grosso do Sul state, Brazil. Source: OpenStreetMap (OSM).

between April and June; in other months, the water levels are minor (dry period; Junk & Cunha, 2005). Although rainfall is less frequent in April and June, flooding occurs between these months because of the slow drainage of the headwaters (Boin et al., 2019).

Collection of biological material

Twenty-eight specimens of *P. argenteus* were acquired from an artisanal fisherman in October 2017 (SISBio authorization no. 54583-1; SISGEN certificate no. A120E5C; Ethics Committee on Animal Experimentation of Universidade Estadual Paulista "Júlio de Mesquita Filho" authorization no. 005/2019). Voucher specimens were deposited in the Fish Collection, Coleção Ictiológica de Três Lagoas (CITL), Universidade Federal do Mato Grosso do Sul, Brazil (CITL 1176).

Laboratory analyses

All specimens had their standard length (cm) and total mass (g) measured using an ichthyometer (0.1 cm) and analytical balance (0.01 g), respectively. Subsequently, the stomachs were removed, fixed in a 4% formalin solution, and preserved in 70% alcohol. Stomach contents were examined under an optical stereomicroscope, and food items were identified to the lowest possible taxonomic level (Bicudo & Bicudo, 1970; Mugnai et al., 2010). The food items were quantified according to the gravimetric method (Hyslop, 1980) using the mass of each food item obtained on a precision analytical balance (0.0001 g). In the case of small items, a percentage was assigned concerning the total mass of stomach contents. The food item earthworm, when found, was removed from the analysis because it corresponded to the bait used by the fishermen.

Data analysis

For data analysis, the mass values of the food items were subjected to an adjustment to the mass of the consuming fish to minimize the effect of fish size on the amounts of food consumed. For this, Eq. 1 was adapted from Ahlbeck et al., (2012):

$$AIW = WI/WF \tag{1}$$

Where: AIW: the weight of the food item consumed adjusted for fish weight; WI: the weight of the food item; WF: the weight of the fish.

Then, a matrix with the adjusted mass consumption data (decimal numbers) was used for all the analyses.

Food items consumed by the population and individuals were identified using bar graphs representing the percentage of consumption. The trophic guild of the population was determined considering the predominance of a type of food resource (≥ 51% of the total volume) in the population's diet (adapted from Corrêa et al., 2011).

Diet variation between individuals was verified using an inter-individual variation index (E). The calculation of E is according to Eq. 2 (Araújo et al. 2008):

$$E = 1 - w_{ij} \tag{2}$$

Where: w_{ij}: the measure of the niche pairwise overlap between individual *i* and *j*.

Values of E index closer to 0 indicate identical individual diets, and values closer to 1 indicate inter-individual dietary variation (Araújo et al., 2008).

Individual specialization (V) was measured using the Eq. 3, proposed by Bolnick et al. (2007):

$$V = 1 - IS \tag{3}$$

Where: IS: the average of individual PSi values (proportional similarity index). PSi was calculated by comparing the distribution of the individual's diet with that of the population (Bolnick et al., 2002; Schoener, 1968). High values of V close to 1 indicate that individuals' diets are more specialized (Bolnick et al., 2007).

The E and Psi indices, presented descriptively, were calculated by the *Eindex* and *Psicalc* functions, respectively, using the RInSP package in the RStudio programming environment (RStudio Team, 2022).

RESULTS

The stomach contents of 28 individuals were analyzed, and the population's diet consisted of 18 food items of different origins. Aquatic and terrestrial insects, fish, mollusks, algae, plants, and detritus comprise the diet of *P. argenteus* (Fig. 2). The non-native freshwater mussel *Limnoperna fortunei* (Dunker 1857) (Bivalvia) was the leading food consumed, followed by detritus and terrestrial insects (Fig. 2; Kliemann et al., 2024). The consumption percentage of 54% of *L. fortunei* characterizes this population as carnivorous/malacophagous (Fig. 2; Kliemann et al., 2024). Synthetic items were also observed in the stomach contents of four individuals, such as dishwashing sponges, plastics, plastic monofilament thread, and bubble gum.

When evaluating feeding individually, we observed that the consumption of food items varied between individuals, with some individuals consuming only *L. fortunei* and terrestrial insects and other individuals consuming aquatic insects, algae, and detritus (Fig. 3). However, we observed that *L. fortunei* and terrestrial insects were consumed by most individuals. In addition, index E (0.73) and V (0.62) showed an inter-individual variation and individual specialization in the diet, respectively.

DISCUSSION

The specimens of *P. argenteus* analyzed in the present study consumed food items from various sources, such as aquatic and terrestrial insects, fish, mollusks, algae, plants, and detritus. In addition, we observed the main consumption of the non-native freshwater mussel *L. fortunei*, which characterizes this population as carnivorous/malacophagous. When evaluating feeding individually, the individuals presented differences in the consumption of food items, corroborating the inter-individual variation and individual specialization in the diet observed by the E and V indices, respectively.

The population of *P. argenteus* consumed a wide variety of food items of animal and plant origin, corroborating the trophic opportunism and generalist diet observed in another study in southern Pantanal/Miranda River (Resende et al., 2000). Resende et al. (2000) reported the consumption of aquatic and terrestrial invertebrates and plants and the degree of digestion of these items, which indicated a benthic foraging strategy. Here, we observed a high percentage of detritus and terrestrial insect consumption, confirming the benthic foraging of *P. argenteus*.

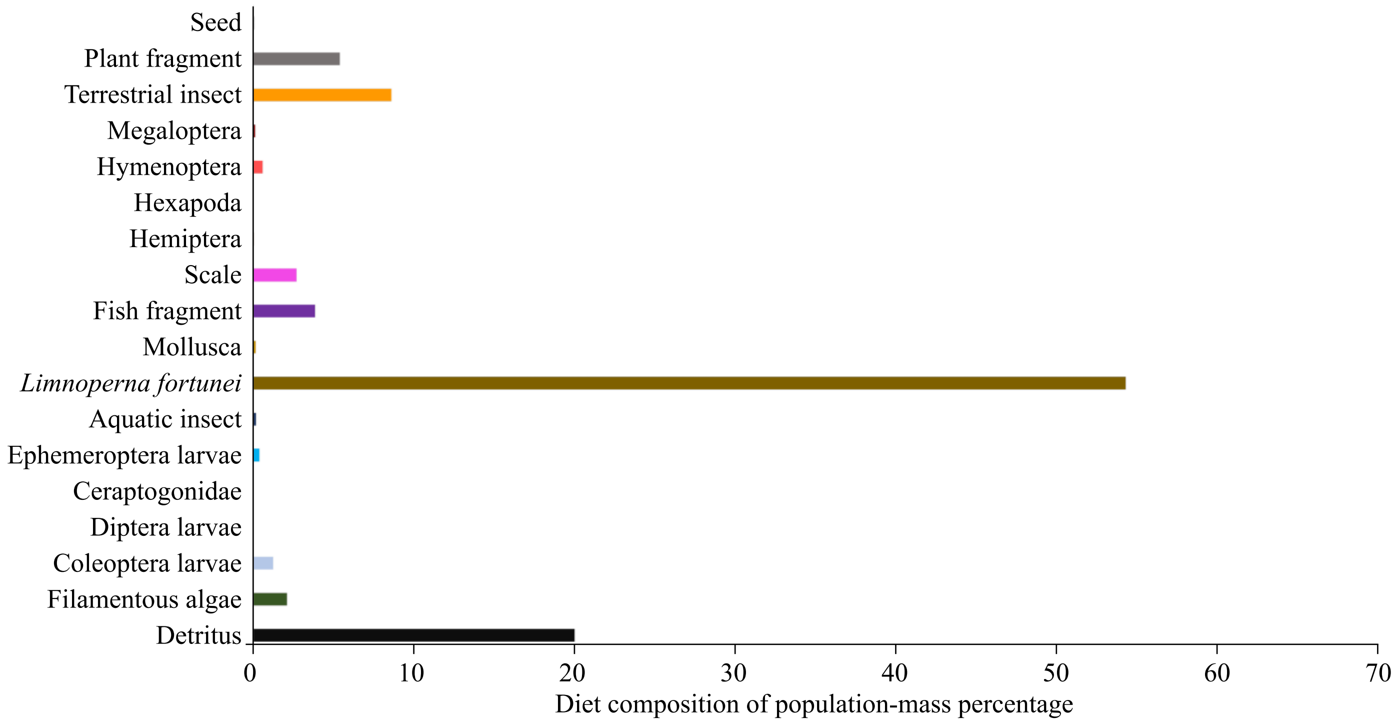

Figure 2. Percentage mass of the diet composition of the population level of *Pimelodus argenteus* sampled in October 2017 in the Miranda River, Passo do Lontra, southern Pantanal, Mato Grosso do Sul state, Brazil.

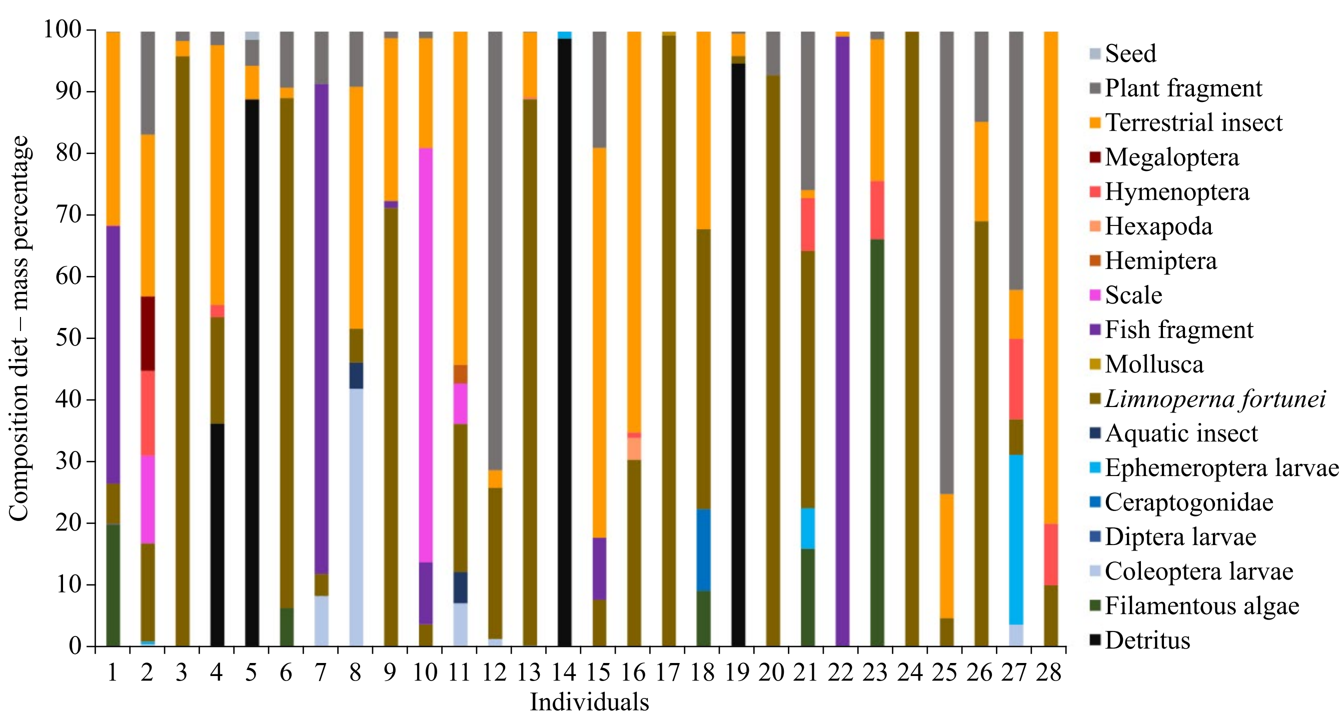

Figure 3. Percentage mass of the diet composition of individuals of *Pimelodus argenteus* from the Miranda River, Passo do Lontra, southern Pantanal, Mato Grosso do Sul state, Brazil. Each bar represents the food items consumed by an individual.

Despite a diet with a wide variety of food resources, *P. argenteus* consumed much *L. fortunei* (Bivalvia) compared to other food items. Studies show that the fish's diet reflects the availability of food in the environment (Kliemann et al., 2019; Neves et al., 2020) since fish are trophic opportunists (Chase & Leibold, 2003; Gerking, 1994; Pires et al., 2011). In addition, the energy cost in the search, capture, handling time, and digestion determines the cost-benefit ratio during foraging (Gerking, 1994; Pires et al., 2011; Schoener, 1971). Thus, we suggest that the high availability and ease of capturing *Limnoperna fortunei* in the study area justify its high consumption. *Limnoperna fortunei*, known as golden mussel, was recorded in 2003 in Passo do Lontra (study area) on floating platforms made of wood and plastic gallons (De Oliveira et al., 2004).

The high availability of *L. fortunei* in Brazilian aquatic ecosystems is directly related to its use as a food resource by wild ichthyofauna. According to Cataldo (2015), after the introduction of *L. fortunei*, the diet of several fish species changed. Omnivorous species varied from a low-quality diet based on plants and few animals to a high-energy diet dominated by these mollusks (Boltovskoy et al., 2006; Garcia & Protogino, 2005; Ferriz et al., 2000). Several researchers evaluated the predatory ability of *L. fortunei* by fish and reported the main predators: *Pterodoras granulosus* (Valenciennes 1821) (wild fish; Ferriz et al., 2000), *Rhinodoras dorbignyi* (Kner 1855), *Brochiloricaria chauliodon* (Isbrücker 1979) (wild fish; Garcia & Protogino, 2005), *Megaleporinus obtusidens* (Valenciennes 1837) (wild and cultivated fish; Garcia & Protogino, 2005; Rosa et al., 2014; de Melo Rosa et al., 2019), *Leporinus friderici* (Bloch 1794), *Piaractus mesopotamicus* (Holmberg 1887), *Pimelodus maculatus* Lacepède 1803, and *Geophagus sveni* Lucinda, Lucena & Assis 2010 (syn. *Geophagus proximus* (Castelnau 1855) (wild fish; Rosa et al., 2014). Specifically, in *P. maculatus*, golden mussels were found in large numbers and intact in their stomachs (Rosa et al., 2014; ICMBio, 2018), corroborating the observations reported in this study.

At the population level, we observed trophic generalism of the *P. argenteus*, but, at the individual level, we observed a variation and specialization in the diet of individuals. Generalist populations composed of specialist individuals were previously observed in fish studies (Araújo et al., 2010; Cunha et al., 2018; Paz Cardozo et al., 2021). Researchers observed a broad population diet with items of animal and plant origins (Cunha et al., 2018; Neves et al., 2020). However, at the individual level, they observed specialists consuming subsets of the population's diet and varying food items consumed among themselves (Cunha et al., 2018; Neves et al., 2020). This diet variation among individuals is paramount for population stability, reducing risks when some food resources are scarce (Bolnick & Ballare, 2020).

Some studies associate the high variation and individual specialization with dry periods in response to increased intraspecific competition (Araújo et al., 2010; Cobain et al., 2019; Kovalenko et al., 2012). In this context, individuals add new resources to their diet to reduce intraspecific competition (Araújo et al., 2010; Svanback & Bolnick, 2005, 2007). Thus, individuals tend to vary in the use of resources, which is lower due to the contraction of ecosystems and less ecological opportunity (Cachera et al., 2017; Paz Cardozo et al., 2021). In the case of floodplains, the contraction of the ecosystem in the dry period is very evident compared to periods of flooding, in which the wetlands are connected to the river channels (Stevaux et al., 2020). Here, although we observed the consumption of *L. fortunei* and terrestrial insects by most individuals, other food items were also consumed, indicating variation among individuals. Moreover, we observed an inter-individual variation (*E*). Likewise, we suggest that in the scenario of less food availability (dry period, October), the individuals share the most abundant food item *L. fortunei*, and terrestrial insects. However, other food items (less abundant; see Fig. 2) are also consumed to supply energy demands and decrease intraspecific competition.

Another relevant aspect observed in our results was the occurrence of synthetic food items, such as plastic, bubble gum, and dishwashing sponges. The ingestion of synthetic materials indicates anthropic influence on the Miranda River, as suggested by Camargo et al. (2022), De Faria et al. (2021), and Marchini (2003). Pantanal is going through a series of environmental impacts that degrade the environment and interfere with the aquatic environment (Tomas et al., 2019). The microplastics in fish from the southern Pantanal have been reported to be associated with water contamination by industrial and urban pollutants and tourism, and fishing residues (Camargo et al., 2022; De Faria et al., 2021). Plastics and toxins in aquatic organisms concern researchers globally since adverse physiological effects are associated with the consumption of microplastics by fish (Fu et al., 2020; Lönnstedt & Eklöv, 2016). Due to the small size of the microplastics, they can be consumed by fish of all sizes and thus reach all levels of development (Azevedo-Santos et al., 2019). In this context, we emphasize the importance of studies with aquatic organisms to obtain data on the contamination of plastic waste in aquatic environments.

CONCLUSION

Research on a population of native fish in the southern Pantanal, Mato Grosso do Sul state revealed their generalist diet and carnivorous/malacophagous feeding habits. The study found that the primary food item for *P. argenteus* is a non-native bivalve species with high invasive potential, alongside synthetic materials like plastic, dishwashing sponges, and bubble gum in their stomachs. These findings suggest significant anthropic influences on the fish, raising concerns about long-term impacts on this economically important species. Additionally, the study confirms anthropic impacts on the Pantanal biome. Individual specialization in diet was observed during the dry period, possibly due to competitive pressures. Future research comparing flood and dry periods could provide insights into behavioral adaptations to seasonal food availability. Overall, these findings are valuable ecological information for conservation efforts in the Pantanal biome and the preservation of *P. argenteus*.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

Supplementary data are available at https://zenodo.org/records/12584903

AUTHORS' CONTRIBUTIONS

Conceptualization: Kliemann BCK, Alvares NYM, Franceschini L, Miguel BS, Orlandi Neto A, Ramos IP; **Methodology:** Alvares NYM, Franceschini L, Miguel BS, Ramos IP; **Investigation:** Franceschini L, Ramos IP; **Formal analysis:** Kliemann BCK, Orlandi Neto A; **Data curation:** Alvares NYM, Franceschini L, Ramos IP; **Supervision:** Franceschini L, Ramos IP; **Resources:** Ramos IP; **Writing – original draft:** Kliemann BCK; **Writing – review & editing:** Kliemann BCK, Franceschini L, Miguel BS, Orlandi Neto A, Ramos IP; **Final approval:** Miguel BS.

FUNDING

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

Finance Code 001

Conselho Nacional de Desenvolvimento Científico e Tecnológico

Grant No.: PIBIC 47816; 303311/2018-5

ACKNOWLEDGMENTS

The authors would like to thank the Universidade Estadual Paulista "Júlio de Mesquita Filho", Faculdade de Engenharia de Ilha Solteira, Laboratório de Ictiologia Neotropical, for the logistical support and facilities provided during this work.

REFERENCES

Abelha, M.C.F.; Agostinho, A.A. & Goulart, E. (2001). Plasticidade trófica em peixes de água doce. *Acta Scientiarum. Biological Sciences*, 23: 425-434. Available at: https://periodicos.uem.br/ojs/index.php/ActaSciBiolSci/article/view/2696

Ahlbeck, I.; Hansson, S. & Hjerne, O. (2012). Evaluating fish diet analysis methods by individual-based modelling. *Canadian Journal of Fisheries and Aquatic Sciences*, 69(7): 1184-1201. https://doi.org/10.1139/f2012-051

Alho, C.J. (2011). Biodiversity of the Pantanal: its magnitude, human occupation, environmental threats and challenges for conservation. *Brazilian Journal of Biology*, 71(Suppl. 1): 229-232. https://doi.org/10.1590/S1519-69842011000200001

Alho, C.J.R.; Mamede, S.B.; Benites, M.; Andrade, B.S. & Sepúlveda, J.J. (2019). Threats to the biodiversity of the Brazilian Pantanal due to land use and occupation. *Ambiente & Sociedade*, 22: e01891. https://doi.org/10.1590/1809-4422asoc201701891vu2019L3AO

Alho, C.J.R.; Mamede, S.B.; Bitencourt, K. & Benites, M. (2011). Introduced species in the Pantanal: implications for conservation. *Brazilian Journal of Biology*, 71(Suppl. 1): 321-325. https://doi.org/10.1590/S1519-69842011000200011

Araújo, M.S.; Guimarães Jr., P.R.; Svanback, R.; Pinheiro, A.; Guimarães, P.; Reis, S.F. & Bolnick, D.I. (2008). Network Analysis reveals contrasting effects of intraspecific competition on individuals vs. population diets. *Ecology*, 89(7): 1981-1993. https://doi.org/10.1890/07-0630.1

Araújo, M.S.; Martins, E.G.; Cruz, L.D.; Fernandes, F.R.; Linhares, A.X.; Dos Reis, S.F. & Guimarães Jr., P.R. (2010). Nested diets: A novel pattern of individual-level resource use. *Oikos*, 119(1): 81-88. https://doi.org/10.1111/j.1600-0706.2009.17624.x

Azevedo-Santos, V.M.; Gonçalves, G.R.L.; Manoel, P.S.; Andrade, M.C.; Lima, F.P. & Pelicice, F.M. (2019). Plastic ingestion by fish: a global assessment. *Environmental Pollution*, 255(Part 1): 112994. https://doi.org/10.1016/j.envpol.2019.112994

Bertolino, M.E.S.; Oliveira Junior, E.S. & Muniz, C.C. (2022). Comportamento alimentar de *Brycon hilarii* (Valenciennes, 1850) (Characiformes, Bryconidae) no Pantanal Norte, Brasil: uma relação de oferta e vulnerabilidade. *Revista de Gestão de Água da América Latina*, 19: e4. https://doi.org/10.21168/rega.v19e4

Bicudo, C.E.M. & Bicudo, R.M.T. (1970). *Algas de águas continentais brasileiras: chave ilustrada para identificação de gêneros*. São Paulo: Fundação Brasileira para o Desenvolvimento do Ensino das Ciências.

Boin, M.N.; Martins, P.C.S.; Silva, C.A.D. & Salgado, A.A.R. (2019). Pantanal: the Brazilian wetlands. In: Salgado, A.A.R.; Santos, L.J.C.; Paisani, J.C. (Eds.). *The Physical Geography of Brazil*. Cham: Springer, p. 75-91.

Bolnick, D.I. & Ballare, K.M. (2020). Resource diversity promotes among-individual diet variation, but not genomic diversity, in lake stickleback. *Ecology Letter*, 23(3): 495-505. https://doi.org/10.1111/ele.13448

Bolnick, D.I.; Svanbäck, R.; Araújo, M.S. & Persson, L. (2007). Comparative support for the niche variation hypothesis that more generalized populations also are more heterogeneous. *Proceedings of the National Academy of Sciences*, 104(24): 10075-10079. https://doi.org/10.1073/pnas.0703743104

Bolnick, D.I.; Svanbäck, R.; Fordyce, J.A.; Yang, L.H.; Davis, J.M.; Hulsey, C.D. & Forister, M.L. (2003). The ecology of individuals: incidence and implications of individual specialization. *The American Naturalist*, 161(1): 1-28. https://doi.org/10.1086/343878

Bolnick, D.I.; Yang, L.H.; Fordyce, J.A.; Davis, J.M. & Svanbäck, R. (2002). Measuring individual-level resource specialization. *Ecology*, 83(10): 2936-2941. https://doi.org/10.1890/0012-9658(2002)083[2936:MILRS]2.0.CO;2

Boltovskoy, D.; Correa, N.; Cataldo, D. & Sylvester, F. (2006). Dispersion and ecological impact of the invasive freshwater bivalve *Limnoperna fortunei* in the Río de la Plata watershed and beyond. *Biological Invasions*, 8: 947-963. https://doi.org/10.1007/s10530-005-5107-z

Cachera, M.; Ernande, B.; Villanueva, M.C. & Lefebvre. S. (2017). Individual diet variation in a marine fish assemblage: Optimal Foraging Theory, Niche Variation Hypothesis and functional identity. *Journal of Sea Research*, 120: 60-71. https://doi.org/10.1016/j.seares.2016.08.004

Camargo, A.L.G.; Girard, P.; Sanz-Lazaro, C.; Silva, A.C.M.; De Faria, É.; Figueiredo, B.R.S.; Caixeta, D.S. & Bletter, M.C.M. (2022). Microplastics in sediments of the Pantanal Wetlands, Brazil. *Frontiers in Environmental Science*, 10: 1-12. https://doi.org/10.3389/fenvs.2022.1017480

Cataldo, D. (2015). Trophic Relationships of *Limnoperna fortunei* with Adult Fishes. In: Boltovskoy, D. (Ed.). *Limnoperna fortunei:* The Ecology, Distribution and Control of a Swiftly Spreading Invasive Fouling Mussel. Cham: Invading Nature - Springer Series in Invasion Ecology, p. 231-248. https://doi.org/10.1007/978-3-319-13494-9_13

Chase, J.M. & Leibold, M.A. (2003). *Ecological Niches: Linking Classical and Contemporary Approaches*. London: University of Chicago Press.

Chiaravalloti, R.M. (2019). The Displacement of Insufficiently "Traditional" Communities: Local Fisheries in the Pantanal. *Conservation and Society*, 17(2): 173-183. https://doi.org/10.4103/cs.cs_18_58

Chiaravalloti, R.M.; Catella, A. & Siqueira, A.L. (2022). Pesca Profissional Artesanal no Pantanal Sul: Histórico, Manejo dos Recursos e Recomendações para a Sustentabilidade. Biodiversidade Brasileira, 12: 1-15. https://doi.org/10.37002/biobrasil.v12i2.1987

Clarkson, B.R.; Ausseil, A.E. & Gerbeaux, P. (2013). Wetland ecosystem services. In: Dymond, J.R. (Ed.). *Ecosystem services in New Zealand: Conditions and trends*. Lincoln: Manaaki Whenua Press, p. 192-202.

Cobain, M.R.D.; Steward, W.; Trueman, C.N. & Jensen, A. (2019). Individual trophic specialization in juvenile European seabass: Implications for the management of a commercially important species. *ICES Journal of Marine Science*, 76(6): 1784-1793. https://doi.org/10.1093/icesjms/fsz045

Coblentz, K.E.; Rosenblatt, A.E. & Novak, M. (2017). The application of Bayesian hierarchical models to quantify individual diet specialization. *Ecology*, 98(6): 1535-1547. https://doi.org/10.1002/ecy.1802

Corrêa, C.E.; Albrecht, M.P. & Hahn, N.S. (2011). Patterns of niche breadth and feeding overlap of the fish fauna in the seasonal Brazilian Pantanal, Cuiabá River Basin. *Neotropical Ichthyology*, 9(3): 637-646. https://doi.org/10.1590/S1679-62252011000300017

Correa, S.B. & Winemiller, K.O. (2014). Niche partitioning among frugivorous fishes in response to fluctuating resources in the Amazonian floodplain forest. *Ecology*, 95(1): 210-224. https://doi.org/10.1890/13-0393.1

Cunha, A.F.; Wolff, L.L. & Hahn, N.S. (2018). Seasonal changes at population and individual levels in the diet of juvenile catfish in a Neotropical floodplain. *Journal of Freshwater Ecology*, 33(1): 273-284. https://doi.org/10.1080/02705060.2018.1442371

Da Silva, C.J. & Simoni, J. (2012). *Água Biodiversidade e Cultura do Pantanal: Estudos Ecológicos e Etnobiológicos no Sistema de Baías Chacororé*. Cuiabá: Carlini e Caniato.

De Faria, É.; Girard, P.; Nardes, C.S.; Moreschi, A.; Christo, S.W.; Ferreira, A.L.J. & Costa, M.F. (2021). Microplastics pollution in the south American pantanal. *Case Studies in Chemical and Environmental Engineering*, 3: 100088. https://doi.org/10.1016/j.cscee.2021.100088

De Melo Rosa, D.; Costa Gaspar, M.R.; Silva, F.A. & Pompeu, P.S. (2019). Impacts of predation by piapara *Megaleporinus obtusidens* (Valenciennes, 1837) on the population densities of the invasive golden mussel *Limnoperna fortunei* (Dunker, 1857). *Biological Control*, 129: 158-163. https://doi.org/10.1016/j.biocontrol.2018.10.012

De Oliveira, M.D.; Pellegrin, L.A.; Barreto, R.R.; Dos Santos, C.L. & Xavier, I.G. (2004). *Área de ocorrência do mexilhão dourado (*Limnoperna fortunei*) na bacia do Alto Paraguai, entre os anos de 1998 e 2004*. Corumbá: Embrapa Pantanal.

Fernandes, I.M.; Signor, C.A. & Penha, J. (2010). *Biodiversidade no Pantanal de Poconé*. Cuiabá: Centro de Pesquisas do Pantanal.

Ferriz, R.; Villar, C.; Colautti, D. & Bonetto, C. (2000). Alimentación de *Pterodoras granulosus* (Valenciennes) (Pisces, Dorademae) en la baja cuenca del Plata. *Revista del Museo Argentino de Ciencias Naturales*, 2(2): 151-156.

Fu, Z.; Chen, G.; Wang, W. & Wang J. (2020). Microplastic pollution research methodologies, abundance, characteristics and risk assessments for aquatic biota in China. *Environmental Pollution*, 266(Part 3): 115098. https://doi.org/10.1016/j.envpol.2020.115098

Garcia, M.L. & Protogino, L.C. (2005). Invasive freshwater mollusks are consumed by native fishes in South America. *Journal of Applied Ichthyology*, 21: 34-38. https://doi.org/10.1111/j.1439-0426.2004.00570.x

Gimênes Júnior, H. & Rech, R. (2022). *Guia ilustrado dos peixes do Pantanal e entorno*. Campo Grande: Julien Design.

Gerking, S.D. (1994). Larval feeding. In: Gerking, S.D. (Ed.). *Feeding Ecology of Fish*. San Diego: Academic Press, p. 139-170.

Hyslop, E.J. (1980). Stomach content analysis: a review of methods and their applications. *Journal of Fish Biology*, 17(4): 411-429. https://doi.org/10.1111/j.1095-8649.1980.tb02775.x

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). (2018). *Livro Vermelho da Fauna Brasileira Ameaçada de Extinção*. Brasília: Instituto Chico Mendes de Conservação da Biodiversidade. v. 6.

Jirka, K.J. & Kraft, C.E. (2017). Diet niche width and individual specialization of brook trout in adirondack lakes. *Transactions of the American Fisheries Society*, 146(4): 716-731. https://doi.org/10.1080/00028487.2017.1290680

Junk, W. J. & Cunha, C. N.(2005). Pantanal: a large South American wetland at a crossroads. *Ecological Engineering*, 24(4): 391-401. https://doi.org/10.1016/j.ecoleng.2004.11.012

Kakuru, W.; Turyahabwe, N. & Mugisha, J. (2013). Total economic value of wetlands products and services in Uganda. *The Scientific World Journal*, 2013: 192656. https://doi.org/10.1155/2013/192656

Kliemann, B.C.K.; Baldasso, M.C.; Pini, S.F.R.; Makrakis, M.C.; Makrakis, S. & Delariva, R.L. (2019). Assessing the diet and trophic niche breadth of an omnivorous fish (*Glanidium ribeiroi*) in subtropical lotic environments: intraspecific and ontogenic responses to spatial variations. *Marine and Freshwater Research*, 70(8): 1116-1128. https://doi.org/10.1071/MF18149

Kliemann, B. C. K.; Alvares, N. Y. M.; Franceschini, L.; Miguel, B.; Orlandi Neto, A. & Paiva Ramos, I. (2024). Supplementary material to the article Dietary aspects at the population and individual level of Pimelodus argenteus, a native fish species from the southern Pantanal, Brazil. Avaiable at: https://zenodo.org/records/12584903

Kovalenko, K.E.; Thomaz, S.M. & Warfe, D.M. (2012). Habitat complexity: Approaches and future directions. *Hydrobiologia*, 685(1): 1-17. https://doi.org/10.1007/s10750-011-0974-z

Lönnstedt, O.M. & Eklöv, P. (2016). Environmentally relevant concentrations of microplastic particles influence larval fish ecology. *Science*, 352(6290): 1213-1216. https://doi.org/10.1126/science.aad8828

Marchini, S. (2003). *Pantanal:* Opinião pública local sobre meio ambiente e desenvolvimento. Manaus: Instituto de Desenvolvimento Sustentável Mamirauá MCT-CNPq.

Mitsch, W.J.; Bernal, B. & Hernandez, M.E. (2015). Ecosystem services of wetlands. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 11(1): 1-4. https://doi.org/10.1080/21513732.2015.1006250

Mugnai, R.; Nessimian, J.L. & Baptista, D.F. (2010). *Manual de identificação de macroinvertebrados aquáticos do estado do Rio de Janeiro*. Rio de Janeiro: Technical Books.

Neves, M.P.; Costa-Pereira, R.; Delariva, R.L. & Fialho, C.B. (2020). Seasonality and interspecific competition shape individual niche variation in co-occurring tetra fish in Neotropical streams. *Biotropica*, 53(1): 329-338. https://doi.org/10.1111/btp.12879

Novakowski, G.C.; Hahn, N.S. & Fugi, R. (2008). Diet seasonality and food overlap of the fish assemblage in a pantanal pond. *Neotropical Ichthyology*, 6(4): 567-576. https://doi.org/10.1590/S1679-62252008000400004

Paz Cardozo, A.L.; Quirino, B.A.; Yofukuji, K.Y.; Ferreira Aleixo, M.H. & Fugi, R. (2021). Habitat complexity and individual variation in diet and morphology of a fish species associated with macrophytes. *Ecology of Freshwater Fish*, 30(2): 184-196. https://doi.org/10.1111/eff.12574

Pires, M.M.; Guimarães, P.R.; Araújo, M.S.; Giaretta, A.A.; Costa, J.C.L. & Dos Reis, S.F. (2011). The nested assembly of individual-resource networks. *Journal of Animal Ecology*, 80(4): 896-903. https://doi.org/10.1111/j.1365-2656.2011.01818.x

Pozer, C.G. & Nogueira, F. (2004). Pastagens nativas inundáveis da região norte do Pantanal de Mato Grosso: biomassa e variações da produtividade primária. *Brazilian Journal of Biology*, 64(4): 859-866. https://doi.org/10.1590/S1519-69842004000500016

Ramos Filho, M.M.; Ramos, M.I.L.; Hiane, P.A. & Souza, E.M.T. (2010). Nutritional value of seven freshwater fish species from the Brazilian Pantanal. *Journal of the American Oil Chemists' Society*, 87(12): 1461-1467. https://doi.org/10.1007/s11746-010-1639-1

Resende, E.K.; Pereira, R.A.C.; Almeida, V.L.L. & Silva, A.G. (2000). *Peixes onívoros da planície inundável do rio Miranda, Pantanal, Mato Grosso do Sul, Brasil*. Corumbá: Embrapa Pantanal.

Rosa, D.M.; Santos, G.B.; Gomes, P.L.A.; Campos, M.C.S. & Dias, J.H.P. (2014). Occurrence of *Limnoperna fortunei* (Dunker, 1857) in the fish diet from a south-eastern Brazilian reservoir. *Journal of Applied Ichthyology*, 31: 188-191. https://doi.org/10.1111/jai.12623

RStudio Team. (2022). *RStudio: Integrated Development Environment for R*. Boston: RStudio. Available at: http://www.rstudio.com/. Accessed on: Nov. 24, 2022.

Schoener, T.W. (1968). The Anolis Lizards of Bimini: Resource Partitioning in a Complex Fauna. *Ecology*, 49(4): 704-726. https://doi.org/10.2307/1935534

Schoener, T.W. (1971). Theory of feeding strategies. *Annual Review of Ecology and Systematics*, 2: 369-404. https://doi.org/10.1146/annurev.es.02.110171.002101

Stevaux, J.C.; De Azevedo Macedo, H.; Assine, M.L. & Silva, A. (2020). Changing fluvial styles and backwater flooding along the Upper Paraguay River plains in the Brazilian Pantanal wetland. *Geomorphology*, 350, 106906. https://doi.org/10.1016/j.geomorph.2019.106906

Svanback, R. & Bolnick, D.I. (2005). Intraspecific competition affects the strength of individual specialization: An optimal diet theory method. *Evolutionary Ecology Research*, 7(7): 993-1012.

Svanback, R. & Bolnick, D.I. (2007). Intraspecific competition drives increased resource use diversity within a natural population. *Proceedings of the Royal Society B: Biological Sciences*, 274(1611): 839-844. https://doi.org/10.1098/rspb.2006.0198

Tomas, W.M.; De Oliveira Roque, F.; Morato, R.G.; Medici, P.E.; Chiaravalloti, R.M. & Tortato, F.R. et al. (2019). Sustainability agenda for the Pantanal Wetland: perspectives on a collaborative interface for science, policy, and decision-making. *Tropical Conservation Science*, 12. https://doi.org/10.1177/1940082919872634