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Ethnoichthyological knowledge of commercial fishermen of edible fish in the city of Barcelos, middle Rio Negro, Amazonas

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ABSTRACT

The fishers' knowledge of artisanal has been an important tool in the construction of scientific studies and measures for the management of fishery resources in different regions of the world, providing information on the ecology and biology of fish species. In January 2016, we examined the ethnoichthyological knowledge of artisanal fishermen on the biological and ecological aspects of the target species of commercial fishing in the Middle Rio Negro basin, Amazonas. Interviews were conducted (total= 97 fishermen) using semi-structured questionnaires containing open and closed questions with artisanal fishermen from the urban area (55 fishermen) and six riverside communities (42 fishermen) of Barcelos. In total, 30 folk-named fish were cited, belonging to two categories locally called "scaled fish" and "smooth fish". Of these, 22 were identified based on the descriptions of the fishermen, corresponding to seven families and 16 genera. The most cited species were *Pseudoplatystoma fasciatum* (*rural* = 13.26% and *urban* = 13.86%) and *Leporinus agassizii* (*rural* = 11.05% and *urban* = 12.87%). Most species belonged to the Serrasalmidae family (ten species). According to the fishermen, most of the species of local commercial interest are composed of omnivorous and carnivorous fish, some groups such as aracus (Anostomidae), acarás (Cichlidae) and pacus (Serrasalmidae) have diversified diets. Meanwhile, the group of "smooth fish" were fish with predominantly carnivorous habits, feeding exclusively on fish. For most fishermen, the reproductive period of commercial fish species occurs from January to June, during periods of flooding and high water in the region's rivers. The peacock bass (*Cichla* spp.) was the only species whose reproductive period extends throughout the year. No significant differences were observed between the information patterns among the category of fishermen interviewed. The fishers' knowledge revealed relevant information about the diet and reproductive behavior of local fish species of interest to commercial fishing. Such information should be considered, heard and acknowledged by local fishery resource managers as auxiliary data in the construction of public measures for the management of fishery resources in the region.

Keywords: Fisherman; Ethnoknowledge; Ethnoichthyology; Commercial fishing.

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SIGNIFICANCE STATEMENT

The fishers' knowledge of artisanal has been a relevant tool in studies that aim to understand the biological and ecological aspects of fish species targeted by commercial fishing, especially in the tropical region. For this reason, we examined the traditional fishing knowledge of artisanal fishermen related to the classification, morphology, reproduction and diet of species of commercial interest in the Middle Rio Negro basin, Amazonas. We note that fishermen have a rich ethnoichthyological knowledge about local commercial fish species, being able to identify sexual dimorphism, diets and reproductive times of the species, with the fishers' knowledge in agreement with the information described in the scientific. Therefore, we hope that fishers' knowledge will be recognized as an essential tool in the construction of management plans for local fishing resources.

INTRODUCTION

Ethnoichthyology seeks to understand the interactions of human populations with fish (Costa-Neto et al. 2002), going beyond the act of fishing (prey and predator interaction) and reaching playful, religious, and symbolic implications (Marques 2012). In the tropical region, information on the biological and ecological aspects of target species for fishing is still developing or non-existent, making decision-making difficult when creating management plans for the activity (Begossi et al. 2016). Given this scenario, the study of traditional fishing knowledge has contributed to learning about the ecology of fishing resources and actions for the management and sustainable use of resources (Silvano 2013; Ladislau et al. 2021a).

In the Amazon, fishing is an activity of great social, cultural, and economic importance (Mandai et al. 2024). This activity is estimated to generate annual income in the region of approximately R$ 389 million, employing around 168 thousand people (Almeida et al. 2004). Amazonian fishing is a highly complex activity due to the diversity of countless aquatic environments (streams, rivers, lakes, floodplain forests and igapó), techniques and equipment, and fish species (Oliveira et al. 2023; Pereira et al. 2024). Five categories of fishing coexist in the region: subsistence fishing, industrial fishing, sport fishing, ornamental fishing, and commercial fishing (multi or monospecific) (Batista et al. 2004).

Amazonian fishers' knowledge studies provide relevant information on the morphological aspects (Almeida 2017), migration (Nunes et al. 2019), feeding habits (Souza et al. 2015), and reproduction (Serrão et al. 2019) of local fish species. Especially species of greater commercial interest (Pereira et al. 2021), such as the jaraqui *Semaprochilodus* spp. (Batista and Lima 2010), pacu (Characiformes: Serrasalmidae) (Santos et al. 2016), arapaima *Arapaima gigas* (Lima and Batista 2012), peacock bass *Cichla* spp. (Lima et al. 2021) and in some cases, stingrays (Potamotrygonidae) (Oliveira et al. 2020).

In the middle Negro River basin region in the state of Amazonas, as in other rivers in the Amazon region, fishing is an activity of great social and economic relevance, directly influencing the way of life of local riverside populations, representing one of the main sources of income and subsistence for families (Reis et al. 2022). However, unlike other regions of the Amazon, the Negro River, due to its physical, chemical and biological characteristics, such as acidic waters and low productivity, presents less favorable conditions for the replenishment of fish stocks, which reinforces the need for studies that help conserve local fish stocks and promote the sustainability of the activity (German 2001). Currently, in the scientific literature there are many

studies in the country that use the fishers' knowledge of artisanal to examine biological and ecological aspects of different species of commercial fish, whether in freshwater or marine environments. However, studies addressing fishers' knowledge of commercial fish species in blackwater rivers are still scarce (Silvano et al. 2022). Therefore, the aim of the present study was to examine the ethnoichthylogical knowledge of artisanal fishermen of commercial fish in the middle Rio Negro region, in the state of Amazonas, Brazil.

MATERIAL AND METHODS

Study area

The study was carried out in urban and rural areas of the municipality of Barcelos (Figure 1), which is located in the middle Rio Negro region, 496 km by river from the municipality of Manaus, Amazonas, Brazil (Inomata and Freitas 2015a). The municipality of Barcelos, founded in 1758, has approximately 18.834,00 inhabitants and 122,461.086 km2 of territorial extension, being considered the largest municipality in terms of extension in the state of Amazonas and the second in the country (IBGE 2023). The largest freshwater archipelago in the world is located in this region, called Mariuá, with around 700 islands (Inomata and Freitas 2015a). The Rio Negro basin is recognized for its high diversity of fish species, as well as for presenting low biomasses for stocks of a single species when compared to white water rivers (Barthem and Goulding 2007). However, fishing represents one of the leading local economic activities, and fish constitute the primary source of protein consumed by the riverside populations of the Negro River (Barra and Dias 2013).

Data collect

The primary data for this work came from the Project "Socioeconomic Profile and Ethnoichthyological Knowledge of Fishermen from the Middle Rio Negro, Amazonas: implications for orderly use and sustainability" funded by the Amazonas State Research Support Foundation - FAPEAM (announcement no. 010/2014 – PROPESCA/RIO NEGRO).

The choice of riverside communities was based on preliminary information obtained through informal conversations with experienced fishermen in the urban areas of Barcelos. To define the participants and riverside communities included in the research, we considered the social and economic importance of artisanal fishing for edible fish. In addition, when choosing the communities, we also considered logistical issues of access, due to variations in the water levels of local rivers. The locations were georeferenced using a Garmin Etrex 22x GPS device (Garmin®, Olathe, USA) to identify study points and create geographic maps.

In the communities, research participants were selected based on researchers' observations obtained through interactive actions with the resident's daily routine, where they verified which identified themselves as professional fishermen, and through the "snowball" method (Biernacki and Waldorf 1981). Subsequently, interviews were conducted using semi-structured questionnaires ($n = 97$). Artisanal edible fish fishermen were interviewed in the urban area ($n = 55$) and rural riverside communities ($n = 42$) in January and April 2016, respectively (Table 1). All artisanal fishermen who identified themselves as "professional fishermen" were considered for participation in the research. Artisanal fishermen who practiced or were involved in other types of local fishing, such as artisanal fishing for ornamental fish and sport fishing, were excluded. The questionnaires contained open and closed questions about the ethnoichthyological knowledge of artisanal fishermen about edible fish species from commercial fishing in the middle Rio Negro region. The questions were: a) what are the edible fish species in the area? b) how do you identify fish species? c) can you identify any difference? d) what are the main foods of fish? and e) what is the reproductive period of fish?

Before the interviews, the fishermen were presented with the Free and Informed Consent Form – TCLE with the interviewees' objectives, risks, and rights. Therefore, photographic records, video, and audio recordings were made. All stages of the present study were authorized and followed the protocols established by the Human Research Ethics Committee (CEP) of the Federal University of Amazonas, being registered with "Plataforma Brasil" (Nº53847316.6.0000.5015 and 2.238.505).

Data analysis

The data (quantitative variables) obtained in the interviews were organized and tabulated in electronic spreadsheets, later using descriptive statistics to calculate the absolute frequency (ni) and relative frequency (fi) of the interviewees' responses (Marques 1991). Furthermore, cognitive tables (qualitative variables) were constructed, where we compared information from the ethnoichthyological knowledge of artisanal fishermen about local edible fish species (emic knowledge) and that described in the scientific literature (ethical knowledge) (Marques 1991). To guarantee the fidelity of the information obtained in the interviews, the original expressions of the interviewees

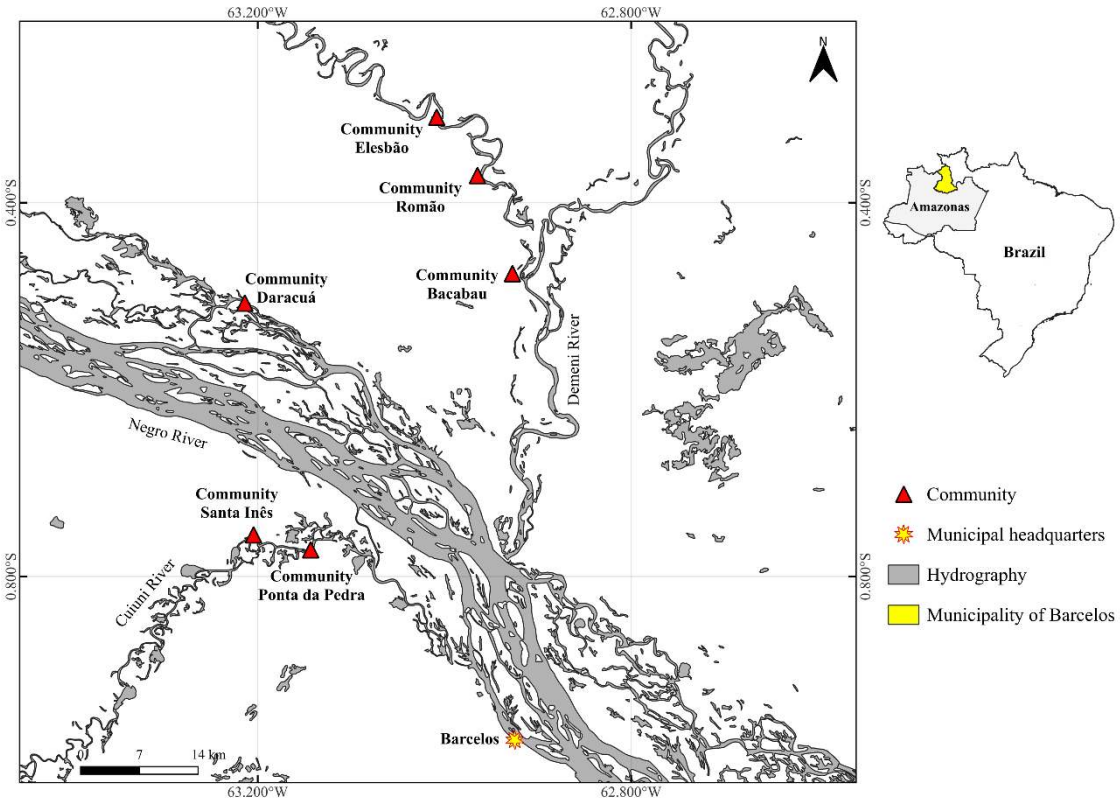

Figure 1. The region of the municipality of Barcelos in the middle Negro river basin, state of Amazonas.

were kept in full (Table 2).

The Student's t-test for independent samples was used to compare proportions in relation to the frequency of information. The assumption of normality was assessed by the Kolmogorov-Smirnov test and homoscedasticity by the Bartlett test. The statistical tools of the Statistica 7.0 software were used to perform the analyses.

Data relating to the ecology and biology of edible fish species from the middle Rio Negro basin, as well as the taxonomic identification of the species mentioned above, were obtained through a bibliographical review of published scientific literature, as well as through the compilation of scientific articles, technical reports, books, dissertations and theses specialized in the subject. In addition, we consulted the Fishbase platform

Table 1. Interview locations in the municipality of Barcelos, middle Negro River basin, Amazonas.

Locations	Fishers interviewed (n)	Relative frequency (%)
City of Barcelos	55	56.70
Daracuá	10	10.31
Ponta da Terra	10	10.31
Bacabal	8	8.25
Romão	7	7.22
Elesbão	4	4.12
Santa Inês	3	3.09
Total	97	100

database (https://www.fishbase.se/search.php).

Given the quantity and diversity of species mentioned in this study, we grouped the species according to the morphological, aesthetic and ethological characteristics established by fishermen (Marques 1991; Cerdeira 2000). Furthermore, we considered information on the biological and ecological aspects of families and species with the highest number of citations in the interviews.

RESULTS

A total of 97 fishermen (69 men and 28 women) were interviewed, 55 in the city center of Barcelos and 42 in riverside communities on the banks of the Rio Negro. The average age of the interviewees was 49.07 years in the city center and 45.05 years in the riverside communities. The average time in the activity was 17.44 years for those interviewed in the urban area and 17.26 years for those in the rural area. Among the survey participants, 54.55% were artisanal subsistence fishermen and 45.45% were commercial fishermen. In total, 12 types of fishing gear were mentioned by the fishermen, with the gillnet being the most used instrument in fishing by fishermen in both areas (*rural* = 14.08% and *urban* = 27.22%).

Ethnotaxonomy of fishermen

In total, the fishermen cited 30 vernacular taxa belonging to two categories locally called “peixe de escama” (scaled fish) and “peixe liso” (smooth fish). Of these, 22 were identified based on the fishermen’s description, corresponding to seven families and 16 genera. The main families cited were Serrasalmidae (ten vernacular taxa), Cichlidae (eight vernacular taxa) and Anostomidae (six vernacular taxa). The most cited species were the surubim *Pseudoplatystoma fasciatum* (*rural* = 13.26% and *urban* = 13.86%) and the aracu-branco *Leporinus agassizii* (*rural* = 11.05% and *urban* = 12.87%) (Table 3).

Comparing fishers’ LEK and literature

Information regarding coloration ($p = 0.863$; $p < 0.05$), morphology ($p = 0.572$; $p < 0.05$) and reproduction ($p = 0.141$; $p < 0,05$) were not different for urban and riverine fishermen. According to the CEL of urban fishermen (10.58%), the fish popularly known as "aracu" have different colors and shapes (Table 4). Among rural fishermen (13.25%), the color tones presented by the "black and white" surubim *P. fasciatum* stood out.

Among the morphological characteristics of the commercial fish species most cited by fishermen, the body shape of the "aracus" was in evidence, with the majority referring to the shape of the fish’s body, considering it a "long" fish (*urban* = 13.33%). In addition to the body shape of the fish in the "aracu" group, fishermen also highlighted their large scales, called "graúdas" (*rural* = 18.11%).

The fishermen were also able to make observations regarding the sexual dimorphism of some groups. For the "aracus" fish, the urban fishermen reported that "the males are red" (17.24%). In addition, the fishermen also highlighted that the male fish belonging to this group are "larger" (*rural* = 26.92%) than the females. In addition to the distinction in color patterns between the sexes, the fishermen also highlighted for some species the occurrence of parental care (e.g.: acará-açu *Astronotus crassipinnis*) and changes in physical characteristics (e.g.: peacock bass *Cichla monoculus*) during the reproductive period.

Diet

According to the fishermen, the diet of commercial fish in the Middle Rio Negro Basin is diverse. Among the food items mentioned by the interviewees, the "buritĺ" fruit was the most cited and common in the diet of the fish, especially among fish belonging to the "scaled fish" group (Table 5). There was no exclusivity of any fruit for any species. For the urban and rural fishermen, fish in the categories aracu (Anostomidae), acará (Cichlidae) and pacus (Serrasalmidae) are animals with omnivorous eating habits, as they prefer diets composed of fruits and invertebrates. The fish in the “smooth fish” group are carnivorous, as they have a diet based on fish (*urban* = 88.89% and *rural* = 95.65%), including species such as the young *B. filamentosum* (100% for both) and the surubim *P. fasciatum* (urban=78.99% and *rural* = 83.33). The tucunaré *Cichla* spp. (*urban* = 100% and *rural* = 88.46%) was the only fish belonging to the “scale fish” group described by the fishermen as carnivorous. In the case of the matrinxã fish *B. amazonicus*, information about diet was cited only by fishermen from rural areas. In the view of these fishermen, the species feeds preferentially on fruits such as "buritĺ" and insects such as grasshoppers (19.05% each). Information regarding diet was not different for urban and riverine fishermen ($p = 0.946$; $p < 0.05$).

Reproductive period

The reproduction period for most commercial fish species in the middle Rio Negro was between January and June, a period considered by fishers to be a period of flooding and high water in local rivers. Peacock bass (*Cichla* spp.) was the only commercial fish species that fishers reported reproducing annually (Table 6). Information on the reproduction period of commercial species in the Rio Negro Basin was not different for urban and riverine fishers ($p = 0.655$; $p < 0.05$).

Table 2. Descriptions of the main vernacular terms and expressions cited by the interviewees.

Term	Description
Acará or cará	• Popular names generally attributed to various species of fish of the Cichlidae family in the Amazon region.
Aracu (s)	• Popular names generally given to various species of fish in the Anostomidae family in the Amazon region.
Burití	•Popular names generally attributed to plants of the genera Mauritia, Mauritiella, Trithrinax and Astrocaryum, of the Arecaceae family.
Graúda (s)	•Popular expression of riverside residents of the Amazon region generally used to highlight something of large size.
Piranha (s)	Popular names generally given to various species of fish in the Serrasalmidae family in the Amazon region.
Pacu (s)	• Popular names generally attributed to several species of characid fish of the Myleinae and Serrasalmidae families, typical of the Amazon rivers.
Peixe liso	• Term referring to several species of fish of the order Siluriformes, also popularly known as leather fish, due to the absence of scales and the presence of large barbels.
Peixe de escama	• Popular term that refers to several species of freshwater bony fish that have their bodies covered in scales, belonging to the Osteichthyes class.
Peixe achatado or chato	• Popular term referring to fish that have a long, flat body, associated with the bottom of rivers and lakes in the Amazon region.
Rural fishers	• Artisanal fishermen who live on the banks of rivers, lakes or other bodies of water.
Tucunaré (s)	• Popular names generally attributed to several species of fish of the genus *Cichla* sp. belonging to the Cichlidae family, typical of the Amazon rivers.
Urban fishers	• Artisanal fishermen who live in urban areas but fish in nearby rivers, lakes and bodies of water.

Table 3. Folk-named fish cited by commercial fishermen of edible fish in the municipality of Barcelos, middle Rio Negro, Amazonas.

	Common name/scientific name	Rural fishers		Urban fishers	
		N	%	N	%
Anostomidae	Aracu-branco *Leporinus agassizii* Steindachner, 1876	20	**11.05**	26	**12.87**
	Aracu-camatí*	5	2.76	10	4.95
	Aracu-pinima (flamenguista) *Leporinus fasciatus* (Bloch, 1794)	6	3.31	8	3.96
	Aracu-camunário*	5	2.76	2	0.99
	Aracu-domé (dumé)*	3	1.66	2	0.99
	Aracu-comum *Schizodon fasciatus* Spix & Agassiz, 1829	2	1.10	1	0.50
Serrasalmidae	Pacu-riscado (listrado) *Myloplus schomburgkii* (Jardine, 1841)	2	1.10	1	0.50
	Pacu-branco *Myloplus rubripinnis* (Müller & Troschel, 1844)	15	8.29	18	8.91
	Pacu-tiuí (manteiga) *Mylossoma duriventre* (Cuvier, 1818)	1	0.55	1	0.50
	Pacu-galo *Metynnis lippincottianus* (Cope, 1870)	8	4.42	10	4.95
	Pacu-boala (buala)*	1	0.55	1	0.50
	Pacu-erudá*	1	0.55	1	0.50
	Pacu-vermelho*	8	4.42	6	2.97
	Pacu-paçuir*	1	0.55	1	0.55
	Piranha-preta *Serrasalmus rhombeus* (Linnaeus, 1766)	2	1.10	5	2.48
	Piranha-branca *Serrasalmus gouldingi* Fink & Machado-Allison, 1992	2	1.10	6	2.97
Bryconidae	Matrinxã *Brycon amazonicus* (Spix & Agassiz, 1829)	1	0.55	1	0.50
Cichlidae	Tucunaré-açu *Cichla monoculus* Agassiz, 1831	15	8.29	22	10.89
	Tucunaré-paca *Cichla temensis* Humboldt, 1821	8	4.42	7	3.47
	Tucunaré-tauá *Cichla nigromaculata* Jardine & Schomburgk, 1843	7	3.87	2	0.99
	Acará-preto*	1	0.55	1	0.50
	Acará-baru *Uaru amphiacanthoides* Heckel, 1840	1	0.55	1	0.50
	Acará-peneira *Heros efasciatus* Heckel, 1840	1	0.55	1	0.50
	Acará-açu *Astronotus ocellatus* (Agassiz, 1831)	5	2.76	8	3.96
	Acará-azulão *Hoplarchus psittacus* (Heckel, 1840)	1	0.55	1	0.50
Osteoglossidae	Aruanã (sulamba) *Osteoglossum bicurrhosum* (Cuvier, 1829)	1	0.55		
Pimelodidae	Surubim *Pseudoplatystoma fasciatum* (Linnaeus, 1766)	24	**13.26**	28	**13.86**
	Filhote (piraíba) *Brachyplatystoma filamentosum* (Lichtenstein, 1819)	17	9.39	20	9.90
	Pirarara *Phractocephalus hemioliopterus* (Bloch & Schneider, 1801)	18	9.94	12	5.94
Auchenipteridae	Mandubé Ageneiosus inermis (Linnaeus, 1766)	1	0.55		
	Total	181	100	202	100

Legend: RF= Rural fishers, UF= Urban fishers and * Species for which it was impossible to identify based on the interviewees' description.

Table 4. Comparative cognition table on color, morphology and reproduction of commercial fish species in the Middle Rio Negro basin.

Common name / scientific name	**Characteristics of commercial species according to fishers' LEK (%)**			
	Color	**Morphology**	**Reproduction**	**Literature**
Aracu* (Anostomidae)	**Different color and shape (10.58)**	Large (10.67) **Long (13.33)** **Large scale "graúda" (18.11)**	Milk comes out of the male (15.52) **Male is red, and female is not (17.24)** **Male is bigger (26.92)**	Anostomids include both large (up to 75cm LW and 5.5kg) and small (<10cm LW) species (Santos and Feitosa 2013). All anostomid species (except Abramites) have a relatively elongated or fusiform body and a rounded post-ventral region (Santos and Feitosa 2013). They have an elongated, fusiform body (Family Anostomidae: *Leporinus* spp.) (Santos et al. 2009).
Aracu-branco (aracu-cabeça-gorda) *Leporinus agassizii* Steindachner, 1876 	White (6.88) All white with black stripe (10.60)	Large scale (8.00)	Male releases milk and female has eggs (8.62)	Brownish gray color, with a dark stripe along the body, starting at the level of the dorsal fin and extending to the end of the caudal peduncle (Santos et al. 2009).

to be continued...

Common name / scientific name	Characteristics of commercial species according to fishers' LEK (%)			Literature
	Color	**Morphology**	**Reproduction**	
Aracu-comum *Schizodon fasciatus* Spix & Agassiz, 1829 	White with black Stripes (0.53)	""		Gray coloring, interspersed with four dark transverse bands on the trunk and a rounded spot at the end of the caudal peduncle (Santos et al. 2009; Santos and Feitosa 2013).
Aracu-pinima (flamenguista) *Leporinus fasciatus* (Bloch, 1794) 	Black and yellow (4.23) Black and red (3.97)			Yellowish color, more intense on the back, with ten dark transverse bars on the trunk, slightly inclined (Santos and Feitosa 2013).
Pacu-branco *Myloplus rubripinnis* (Müller & Troschel, 1844) 	White (7.41) Black (2.12) White and red (6.62) Greyish (1.32) Striped and streaked (1.99)	Big (5.33) Wide (5.51) Small "escama" (4.72)	Female is "white" (6.41) Male is red (6.41)	

to be continued...

Common name / scientific name	Characteristics of commercial species according to fishers' LEK (%)			
	Color	**Morphology**	**Reproduction**	**Literature**
Pacu-galo *Metynnis lippincottianus* (Cope, 1870) 	White (4.23) Red (0.53) Black (0.53) Striped (0.66) Grayish (4.64)	Big (5.33) Big flap "fin" (4.72)	Female is white, and male is red (6.90) The male is red and the female is silver (8.97)	Small size, up to 15 cm, light gray, with numerous rounded and elongated dark spots, most visible on the belly (Santos et al. 2009). Length around 13cm CP; characterized by presenting a small, circular-shaped humeral spot with dark macules on the body (Ota et al. 2013). It presents sexual dimorphism, the anal fin in both sexes being orange or reddish during the reproductive period (Ota et al. 2013). In some individuals, an intense red spot appears, surrounding the opercular opening and numerous dark or reddish smears on the lateral line scales, standard in males during the reproduction period (Santos et al. 2009) externally.

to be continued...

Common name / scientific name	**Characteristics of commercial species according to fishers' LEK (%)**			
	Color	**Morphology**	**Reproduction**	**Literature**
Pacu-riscado (listrado) *Myloplus schomburgkii* (Jardine, 1841) 	Black (0.53) Red (0.53) Risk in the middle (1.32)	Round (0.67)	The female has a red stripe (1.28)	
Pacu-tiuí (manteiga) *Mylossoma duriventre* (Cuvier, 1818) 	Red (0.53) All Black (0.53) tambaqui (*Colossoma macropomum*) color (0.53) Grayish (0.66) White (0.66)	Big (0.67) It looks like piranha and roelo (fish weighing up to 3.0 kg) (0.67)	Female is white (0.86) Male is red (0.86)	Medium size, up to 25cm, with a whitish color, the head and ventral region normally yellow-orange, with a dark spot on the operculum (Santos et al. 2009; Ota et al. 2013).

to be continued...

Common name / scientific name	**Characteristics of commercial species according to fishers' LEK (%)**			
	Color	**Morphology**	**Reproduction**	**Literature**
Tucunaré-açu *Cichla monoculus* Agassiz, 1831 	Black or yellow stripe (9.52) Bluish (2.12) Black and green (5.30) Three black stripes (2.65) Black (1.99)	Big (10.67) Big fish (4.00) He (fish) is very big (11.02)	Male has a "knot" on his head (12.93) Açu males have a knot on the back of their heads (5.17) Knot on the coast (0.86) Loin on the head (15.38) Tenderloin on the head (2.56) The female is smaller (1.28)	Large size, up to 40cm; three to four dark vertical bands on the trunk, not reaching the ventral region; a continuous or even interrupted horizontal spot at the level of the base of the pectoral fin (Santos et al. 2009). Mature males have a post-occipital cephalic protuberance of an extragenital secondary sexual nature, with a lipid reserve, which disappears after the reproductive period (Chellappa et al. 2003). Males (194-338 mm/492g) of *C. monoculus* reached greater length and weight than females (178-322mm/448g) (Chellappa et al. 2003).
Tucunaré-paca *Cichla temensis* Humboldt, 1821 	Painted (2.65) Striped (1.06) Painted the color of paca (rodent *Cuniculus paca*) (5.30) All painted over (4.67)	They have white dots (6.30)		Numerous light spots in the form of dots are distributed in regular longitudinal bands over the body (Santos et al. 2009).

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Common name / scientific name	**Characteristics of commercial species according to fishers' LEK (%)**			
	Color	**Morphology**	**Reproduction**	**Literature**
Tucunaré-tauá (borboleta) *Cichla orinocensis* Humboldt, 1821 	Painted (0.53) Yellow (1.06) Black dots (1.06) Yellow and green (3.31) Black polka dots (1.32)	Small (1.33) It looks like a butterfly (1.33) Small, doesn't grow much (3.94) Butterfly Painting (5.51)		Large size, up to 50 cm; three ocellus-shaped spots on the median horizontal line of the body (Santos et al. 2009).
Piranha-branca *Pristobrycon striolatus* (Steindachner, 1908) 	A little bluish (0.53) Half blue (0.53) Silver (2.12) Silver (1.32)	Similar to pacu (fish) (0.67)	Long male (1.72) Round female (3.45) Fatter female and longer male (2.56)	Variable coloration, formed by small dark spots on a light background or by numerous dark and light transverse bands, alternately and more concentrated on the dorsal flank, fins with whitish ends (Santos et al. 2009; Ota et al. 2013).
Piranha-preta *Serrasalmus rhombeus* (Linnaeus, 1766) 	All black from the red eye (1.59) All black (1.32)		Fattest female (2.59) Slimmer male (2.59) Males are thinner (2.56) Fattest female (2.56)	Uniformly dark gray in adults; in young people, there are numerous rounded dark spots; in these, too, the tip of the caudal and anal fins has a dark band, while in adults, it is uniformly dark gray; a shady spot, in the shape of a crescent or triangular, in the humeral region (Santos et al. 2009; Ota et al. 2013).

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Common name / scientific name	Characteristics of commercial species according to fishers' LEK (%)			
	Color	**Morphology**	**Reproduction**	**Literature**
Acará-baru *Uaru amphiacanthoides* Heckel, 1840 	Reddish and black stripes (0.53) Grayed (0.66)		Stay close to your son (0.86)	Light brown, with a large dark triangular spot starting under the pectoral fin and going to the base of the caudal fin (Santos et al. 2009).
Acará-peneira *Heros efasciatus* Heckel, 1840 	Black and green spots (0.53) Painted (0.53)	White scale (0.66)	Stay close to the puppies (0.86)	Olive color, with black dots forming regular longitudinal lines on the body, presents six to seven inconspicuous vertical dark bands on the trunk, the last, most evident, located between the soft rays of the dorsal and anal fins (Santos et al. 2009). It has external fertilization, with great parental care (Favero et al. 2010).

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Common name / scientific name	Characteristics of commercial species according to fishers' LEK (%)			
	Color	**Morphology**	**Reproduction**	**Literature**
Acará-açu *Astronotus crassipinnis* (Heckel, 1840) 	Red spots on the tail (caudal fin) (2.12) Color of the pirarucu (*Arapaima gigas*) (1.06) White dot in the middle and red (3.31)	Red spots on the butt (2.00) White spot in the middle and red (1.33) They have red spots on their tail, just like an arapaima (2.00) Like the pirarucu (*Arapaima gigas*) (3.15) Just like the pirarucu (*A. gigas*) (0.79)	They always go as a couple (5.17) The male is bigger than the female, and they always go as a couple (5.13)	An ocellus on the upper part of the base of the caudal fin and two or more rounded spots, usually ocellus-shaped, on the bottom of the dorsal fin (ecological information cited for *Astronotus ocellatus*) (Santos et al. 2009). During the breeding season, it forms pairs that build nests and care for their offspring (Cichlidae Family: acará-açu *Astronotus* spp.) (Santos et al. 2009).
Acará-azulão *Hoplarchus psittacus* (Heckel, 1840) 	Blue stripes on the flap (fins) (1.06)			

to be continued...

Common name / scientific name	Characteristics of commercial species according to fishers' LEK (%)			
	Color	**Morphology**	**Reproduction**	**Literature**
Aruanã (sulamba) *Osteoglossum bicirrhosum* (Cuvier, 1829) 		Big (0.79)	Males carry children on their cheeks (1.28) The male releases milk, and the female releases the egg (1.28) Males are big (1.28) Male bigger than female (1.28)	It can reach up to 90cm in length (Ferreira 2013). Large size, reaching more than one meter and five kg (Santos et al. 2009). O comprimento médio de maturação é de 525mm para machos e 520mm para fêmeas, que é atingido com cerca de dois anos de idade (Ferreira 2013).
Pirarara *Phractocephalus hemioliopterus* (Bloch & Schneider, 1801) 	Black stripe (2.12) Yellow and white (3.17) Yellow (1.06) Black, white chest (5.30) Brown (0.66) Black (0.66) Yellow and black (5.30)	Big head (5.33) Red tail (2.67) Red tail (9.45) White breast (6.30)		Dark gray to olive back and yellowish-white belly, with a well-defined limit between the two areas of color; head covered with dark spots; caudal fin and dorsal and pectoral ends orange to red (Santos et al. 2009). Bright color formed by brown back, light belly and red fins, or the reniform pre-dorsal plate (Rocha and Zuanon 2013).

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Common name / scientific name	Characteristics of commercial species according to fishers' LEK (%)			
	Color	**Morphology**	**Reproduction**	**Literature**
Surubim *Pseudoplatystoma fasciatum* (Linnaeus, 1766) 	Painted black and white (8.99) Painted, like a jaguar (*Panthera onca*) (0.53) "Malhado" (Tabby) (5.29) **Black and White (13.25)** Gray body with white belly (2.65)	Long (10.67) Long flat-headed (8.00) Long head (6.30) Big and long (12.60)	Milk comes out of the male during breeding season (13.79) The male's head is longer than the female's (10.26)	Dark back and whitish ventral region, with narrow black bars on the sides of the body interspersed with white vertical stripes (Santos et al. 2009). Muzzle uniformly broad (Santos et al. 2009). It is considered a protogynous hermaphrodite species; all offspring are born as females, with some later transforming into males (Santos et al. 2009).
Filhote (piraíba) *Brachyplatystoma filamentosum* (Lichtenstein, 1819) 	Brown (0.53) White (3.17) Grayed (6.35) Dark gold (0.53) "Branquecento" (light gray) (5.30) White belly (3.97) Black (1.99)	Very big! There are fish that reach 150 kg (0.67)		Uniform coloring, gray on the back and light on the belly (Santos et al. 2009). The Amazonian catfish reaches the largest size, reaching around 2.5m and 150kg (Santos et al. 2009). It is the largest species of Neotropical Siluriformes (Rocha and Zuanon 2013).
Mandubé *Ageneiosus inermis* (Linnaeus, 1766) 	Grayed (0.66) Light black (0.66) Light black (0.79)	He has a beard and a stinger on his head (1.28)	It releases milk is male, and releases eggs are female (1.28)	Uniform bluish-gray color and light gray belly (Santos et al. 2009).

RF= Rural fishers, UF= Urban fishers e * Species for which it was impossible to identify based on the interviewees' description. Source images: FishBase (www.fishbase.org).

Table 5. Diet of edible commercial fish according to the knowledge of fishermen in rural and urban areas in the municipality of Barcelos, middle Rio Negro, Amazonas.

Diet (%)		**Locally recognized fish groups**															
		Scaled fish "Peixes de escama"										**Smooth fish "Peixes-liso"**					
		Aracu* (Anostomidae)		**Acará/cará* (Cichlidae)**		**Matrinxã *B. amazonicus***		**Pacu* (Serrasalmidae)**		**Tucunaré* (Cichlidae)**		**Surubim *P. fasciatum***		**Filhote *B. filamentosum***		**smooth fish***	
		UF	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**
Fruits	"apuí" *Ficus* spp. (Moraceae)	3.13	2.20					3.51	5.26								
	"urucurana" *Sloanea brachypetala* (Elaeocarpaceae)	9.38	4.40					3.51	7.89								
	"buritĩ" *Mauritia flexuosa* (Arecaceae)	**25.00**	13.19	17.24	11.76		**19.05**	14.04	18.42		3.85						
	"careca" (unidentified)	12.50	4.40		5.88		9.52	12.28	10.53				8.33				
Invertebrates	Worm (Annelid: Oligochaeta)	18.75	**16.48**	**27.59**	**35.29**		9.52	**17.54**	**21.05**				5.26				
	Crab (crustacean: Decapoda)	1.56	3.30				14.29	8.77	3.95				5.26				
	Spider (arthropods: Arthropoda)	4.69	6.59	6.90	5.88		9.52	10.53	10.53								
	Locust (arthropods: Orthoptera)	1.56	6.59	3.45	5.88		**19.05**	10.53	5.26								

to be continued...

Diet (%)		Locally recognized fish groups															
		Scaled fish "Peixes de escama"										Smooth fish "Peixes-liso"					
		Aracu* (Anostomidae)		**Acará/cará* (Cichlidae)**		**Matrinxã** *B. amazonicus*		**Pacu* (Serrasalmidae)**		**Tucunaré* (Cichlidae)**		**Surubim** *P. fasciatum*		**Filhote** *B. filamentosum*		**smooth fish***	
		UF	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**	**UF**	**RF**
	Shrimp (arthropods: Decapoda)	3.13	3.30		5.88		9.52	10.53	5.26				8.33				
Fish	No identification	7.81	4.40	17.24	5.88		9.52			**100**	**88.46**	**78.95**	**83.33**	**100**	**100**	**88.89**	**95.65**
Others	Sludge (organic matter and algae)	6.25	6.59	13.79	11.76			8.77	5.26		7.69	10.53				11.11	
	Silt (clay and organic matter)	1.56	1.10	3.45					2.63								
	mud (clay and water)	1.56	1.10	3.45					2.63						4.35		
	Vegetable leftovers	3.13	4.40	6.90	11.76				1.32								
Total		**100**	**100**	**100**	**100**		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Legend: RF= Rural fishers, UF= Urban fishers, * Species for which it was impossible to identify based on the interviewees' description and vegetable leftovers (flower, leaf, vegetation debris of uncultivated plants).

Table 6. Reproductive period of edible commercial fish species according to edible commercial fish fishermen in rural and urban areas of the municipality of Barcelos, middle Rio Negro, Amazonas.

Local classification	Reproductive period (%)													
	Flood			Full			Ebb		Dry		Flood	Full-year		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Oct	Nov	Jan			
	UF		RF	UF	RF		UF	RF	UF		RF	UF	RF	
Aracu* (Anostomidae)	9.27		**8.24**	4.12	**18.55**									
Pacu* (Serrasalmidae)	**14.43**		5.15	**7.21**	12.37									
Tucunaré* (Cichla spp.)	1.03		5.15		6.18			1.03	1.03		1.03	**9.27**	**7.21**	
Piranha* (Serrasalmidae)	4.12		2.06		6.18						1.03			
Surubim (Pseudoplatystoma fasciatum)	6.18		2.06		6.18						1.03			
Acará/cará* (Cichlidae)	1.03		2.06		1.03			**3.09**						
Peixe achatado or chato* (Flatfish) (Siluriformes)	1.03		2.06		7.21						1.03			
Total	74.18		27.67	11.33	57.70			4.12	1.03		4.12	9.27	7.21	

Legend: RF= Rural fishers, UF= Urban fishers e * Species for which it was impossible to identify based on the interviewees' description.

DISCUSSION

Ethnotaxonomy of fishermen

The fish with popular edible names most exploited by fishermen in the present study are part of the main groups/species of Amazonian fishing production (Batista et al. 2012). Furthermore, they are among the main species landed in the central Amazon region (Batista 2004) and in the middle Rio Negro basin (Inomata and Freitas 2015b). According to Inomata and Freitas (2015a), fish such as pacus (Subfamily Myleinae), aracus (Anastomidae) and peacock bass *Cichla* spp. represent half of the species that landed in Barcelos.

Commercial fishermen in the middle Rio Negro identify and classify fish mainly based on the morphological aspects of the species. In the Brazil, studies show that artisanal fishermen present different ways of categorizing fish, generally forming groupings of species hierarchically based on ecological, behavioral and morphological criteria (Silvano 2013).

According to Begossi and Garavello 1990, fishermen generally classify and name essential fish species in more detail. Studies show that fishermen from the Negro River can identify fish species in greater detail than fishermen from the coastal region of the country, as riverside fishermen usually identify fish species using binomials (generic names associated with a specific name), while fishermen from the Atlantic coast use generic names (primary lexemes) (Begossi et al. 2016; Silvano et al. 2022). For example, Ladislau et al. (2021b) observed that fishermen of ornamental fish in the Rio Negro basin are capable of recognizing a vast diversity of fish species, having their way of classifying the target species of the aquarium trade and creating ethnocategories explicitly based on morphological aspects. Recently (Silvano et al. 2022) reported that fishermen on the Rio Negro can recognize and identify a large set of fish species that make up local fisheries, an average of 91 species, including small and rare species.

Diet of fish species according to fishermen

Of the 30 locally recognized types of fish mentioned by fishermen, 14 had a diet composed predominantly of plant material and invertebrates, especially fish from the Characiformes groups, such as aracu and pacu. Furthermore, fishermen generalized information regarding the species' diet to specific groups, mainly not specifying which species they were referring to, as demonstrated in the following statement: "The pacu eats berries." This possibly occurred because these groups of fish are composed of a variety of species with different eating habits (Baumgartner et al. 2012).

Based on the fishermen's reports, it was possible to infer that the species known as pacus and aracu are omnivorous, as they consume both plant and animal material. This information is in accordance with the scientific literature for the diet of some of the main edible fish species belonging to these groups, such as *Mylossoma duriventre* (Correa and Winemiller, 2014; Melo et al. 2019) and *Leporinus agassizii* (Weiss et al. 2024).

The annual flooding of Amazon rivers, through the flood pulse, causes excellent changes in areas subject to flooding (floodplains, igapós or flooded fields), influencing the productivity and interactions of aquatic biota (Marinho et al. 2015). According to Piedade et al. (2015), this phenomenon is of great importance for animals and plants in flooded areas, as well as for riverside residents, being responsible for developing these communities and the high diversity of environments and organisms. An example of this is the forests and beaches flooded with black water in the Negro River basin, which contain a variety of fish species that mainly seek refuge and food (Loebens et al. 2019; Amaral et al. 2020).

For most fishermen interviewed in the present study, the fish considered peacock bass *Cichla spp.*, surubim *P. punctifer* and pup *B. filamentosu* are species that have a diet based on fish. According to Santos et al. (2009) the peacock bass *C. temensis* is characterized as a predatory species, as it feeds on fish and shrimp, while the black peacock bass *C. monoculus* is piscivorous. Furthermore, according to Rocha and Zuanon (2013), most representatives of the Pimelodidae Family have carnivorous habits, being top predators of the food chain.

The Anostomidae family is composed of approximately 140 species of fish, with a wide distribution throughout the South American river basins. However, the Amazon region holds the greatest diversity of fish belonging to this group, around 45% (Santos and Feitosa 2013). In the present study, the fish belonging to this group, together with acaras (Cichlidae), were those with the highest proportions of food items cited by the fishermen and are considered omnivorous fish with a tendency towards carnivory. An example of this is the acará-açu *Astronotus crassipinnis* (Cichlidae), also known as "oscar" or "apaiari", an omnivorous species with a tendency towards carnivory that modifies its feeding strategy according to its life stage. As demonstrated by Lopes et al. (2022) in their study with *A. crassipinnis* introduced into a floodplain of the upper Paraná River in southern Brazil, where researchers observed that the species in the juvenile stage presented an omnivorous diet, consuming differ-

ent food items. Meanwhile, in the adult stage the fish presented a specialist strategy, feeding mainly on fish and mollusks.

The matrinxã *Brycon amazonicus*, in the view of fishermen living in the rural area of Barcelos, is an omnivorous fish species. In areas flooded by the waters of the Solimões River in the Amazon region, the natural diet of juvenile *B. amazonicus* is broad, varying according to the availability of prey in the environment, including microcrustaceans (Cladocera, Copepoda), rotifers and plant remains (e.g., leaves, roots and stems) (Leite 2004). A generalist diet can also be observed for other species of fish of the genus Brycon in other regions of the country. For example, the diet of *Brycon hilarii* in flooded forest areas in the Pantanal region of Mato Grosso is directly influenced by the hydrological regime of the region's rivers, with the species preferring consuming the fruits of the "abobreiro" *Erythrina fusca*, especially during the flood period when food availability is abundant (Bertolino et al. 2021).

Reproductive aspects of fish species according to fishermen

According to fishermen, most of the target species of local commercial fishing reproduce during the floods and high waters of the rivers (January to June). The flood pulse of the rivers in the Amazon region influences not only the diet of different fish species, but also their distribution and reproduction, including those that are migratory, such as part of the Amazonian Characiformes and Siluriformes (Anostomia, Serrasalmidae, Characidae and Pimelodidae) that generally spawn at the beginning of the flood (June and July) (Hurd et al. 2016; Villamil-Rodríguez et al. 2018; Sousa et al. 2022). The various floodplains of the Amazon (floodplains, igapós, flooded fields), in addition to shelter, the fish find greater availability of food, whether in the form of fruits, seeds, planktonic and periphytic algae, as well as organic matter in inclusion (Marinho et al. 2015; Piedade et al. 2015).

Reproductive behavior may differ among tropical fish species, with some tending to spawn year-round, with peaks associated with the rainy season, and others where rain is only a decisive event in final maturation and spawning (Bailly et al. 2008). Peacock bass (*Cichla* spp.) were the only group reported by fishermen to spawn all year round. Some Neotropical cichlids, such as the acarás and peacock bass *Cichla* spp., present parental care of their offspring, sexual dimorphism, including changes in color patterns and the presence of a hump in the post-occipital region in adult males, in addition to being considered in most cases as oviparous species with split spawning, which occurs during all months of the year (Graça et al. 2013). In the study developed by Horie et al. (2024), on the population structure and fishing stock of the peacock bass *Cichla vazzoleri* in the Balbina Hydroelectric Power Plant reservoir, in the state of Amazonas, the researchers observed that the species presents multiple spawning events throughout the year, mainly between October and January.

Among the different reproductive strategies of freshwater fish, there are species that mainly care for their eggs and others for their offspring (Lima et al. 2013). In addition to cichlids, in the view of fishermen, other groups of fish also exhibit parental care, such as the arowana *Osteoglossum bicirrhosum*, which according to them "the male carries its young in its cheek". During the reproductive period, males of this species keep the fertilized eggs inside their mouths until the young can begin to feed exogenously (Ferreira 2013). In some regions of the South American Amazon, the breeding season of the arowana *O. bicirrhosom* occurs during the dry season and the beginning of the rising waters, with females breeding several times during the season (Duponchelle et al. 2015).

For the most part, artisanal fishermen's knowledge of commercially important fish in the Middle Rio Negro basin was homogeneous, with no distinctions between the information regarding the ecological aspects of the target species in the different study areas (rural and urban). Furthermore, most of the information was consistent with the scientific literature. Divergences in some areas, such as the diet and reproduction of some local species, may be related to variations in food availability at different times of the year, or even to the fact that reproductive events in this region are generally short, making observations difficult for fishermen (Lima et al. 2021).

The convergence between fishermen's local knowledge and scientific knowledge, as observed in this study, constitutes a way of validating local knowledge from a scientific perspective (Prado and Murrieta 2015). Observations made by local residents can be useful, providing valuable information about species and the ecosystem, helping to clarify gaps and providing new hypotheses about bioecological processes (Cebrián-Piqueras et al. 2020). Furthermore, the use of participatory methods (including interviews with fishermen) can provide useful data on the state of fish stocks, especially fish species of commercial interest in the Brazilian Amazon, in addition to providing additional benefits, such as the inclusion of stakeholders in local monitoring, management, and research activities (Silvano and Hallwass 2020).

CONCLUSION

Our study showed that fishermen can accurately portray details and information regarding the diet and reproductive behavior of most of the target fish species of local commercial fisheries. In addition, fishermen also provide concise information on the morphological characteristics of the species and use them as criteria for categorizing the main groups of commercial fish in the region. Therefore, we believe that the ethnoichthyological knowledge of artisanal fishermen of commercial fish should be considered and recognized as an essential tool to assist in the creation of management plans for commercial fisheries in the middle Rio Negro basin region. We hope that the information presented in this study can assist the various social segments involved in local commercial fisheries, such as managers, researchers and students, in the development of measures for the use and management of fisheries resources in a sustainable manner.

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DATA AVAILABILITY

The database used to support the conclusions of this study are available upon reasonable request from the corresponding author.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

CONTRIBUTION STATEMENT

Conceived from the idea presented: ATO. Performed the experiment: MMTR, ATO, DSL, MWSR. Performed data analysis: MMTR, ATO. Wrote the first draft of the manuscript: MMTR, ATO. Review and final writing of the manuscript: ARSL, DSL, ANAS, PHRA, ATO. Supervision: ATO.

FUNDING DECLARATION

DISCLOSURE OF AI USE

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