Acta Scientiarum

http://periodicos.uem.br/ojs
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v45i1.61884

AQUACULTURE

Proximal and mineral composition of native fish species from Amazonas, Brazil

Antônio Fábio Lopes de Souza[1*], Antonio José Inhamuns da Silva[2], Alexandre Augusto Barai[2], João Paulo Ferreira Rufino[2] and Tiago Viana da Costa[1]

[1]Instituto de Ciências Sociais, Educação e Zootecnia, Universidade Federal do Amazonas, Estrada Parintins-Macurany, 1805, 69153-010, Parintins, Amazonas, Brazil. [2]Faculdade de Ciências Agrárias, Universidade Federal do Amazonas, Manaus, Amazonas, Brazil. *Author for correspondence. E-mail: fabiofish@ufam.edu.br

ABSTRACT. For decades, researches were developed about the diversity of fishes in the Amazon basin and their consumption by the people. In this context, an important gap identified was a lack of information about the nutritional composition of some of the main Amazon fish species consumed and traded. Front this, the objective of this study was to evaluate the chemical composition and mineral content of filets from 10 fish species with the highest landing volume in Amazonas State. The fish species selected were curimatã, jaraqui, mapará, matrinxã, pacu, piramutaba, sardinha, surubim, tambaqui and tucunaré. Were collected 20 samples (fishes) from each species according to the hydrological cycles of the region (20 samples in the flood and 20 samples in drought). Ten fish samples were processed to determine the proximal composition and 10 fish samples were used to determine mineral content (macro and micro minerals). The proximal composition of fish species analysed varied widely between species and seasons, with an emphasis on moisture and lipid content. Fishes in the flood season presented higher content of nutrients than drought season. This result also was observed in the minerals profile, where fishes in the flood season presented the highest ($p < 0.05$) minerals content.

Keywords: Amazon; chemical composition; freshwater fish; mineral content.

Received on December 16, 2021.
Accepted on April 4, 2022.

Introduction

The Amazon basin has a rich ichthyofauna distributed throughout its natural freshwater environments (Noveras, Yamamoto, & Freitas, 2012; Soares, Freitas, & Oliveira, 2014; Lobón-Cerviá, Hess, Melack, & Araujo-Lima, 2015). Fisheries represent a traditional activity in this region (Lima, Doria, & Freitas, 2012; Alho, Reis, & Aquino, 2015), where fishes are the primary source of protein for most people and are consumed at much higher rates than those recommended by the World Health Organization (Can, Gunlu, & Can, 2015).

However, most piece of this fishing is limited to 11 fish groups with less than 100 species explored (Doria, Ruffino, Hijazi, & Da Cruz, 2012; De Alcântara et al., 2015). Little is the known about the nutritional value of these species, and how these influence the diet of the Amazon people. Recently, some studies were developed to understand and solve these research gaps, such as Yuyama et al. (2011) and Tavares et al. (2012) that carried out nutritional studies in several cities across the Amazonas state and detected a deficiency in some nutrients; while Barai, Souza, Viana, and Inhamuns (2021) evaluated meat yield and centesimal composition of some of the main Amazonian fish species in the drought and flood hydrological cycle.

Fish consumption is an important source of nutrients, helping the maintenance of heart rate, muscle contractility, neural conductivity, and cellular metabolism (Can et al., 2015; Maciel, Sonati, Galvão, & Oetterer, 2019). Front this, Barai et al. (2021) suggested that the determination and quantification of nutritional elements in Amazon fishes might help to reduce the issues related to the nutritional profile of native people, improving their nutritional aspect and the local public health. In addition, this information went on to describe several public policies designed to establish nutritional goals and food guides that should improve the diet and nutritional status of these regions.

It is important to mention that the Amazon is marked by a flood pulse, characterized by high waters (flood and flood peak) or low waters (dry season/drought and ebb), where the floods occur between December and

June when shoals are formed, and spawning migrations occur in streams or lakes. The drought occurs from July to November when fish begin to leave flooded areas of the forest (Costa & Freitas, 2013; Arantes, Winemiller, Petrere Júnior, & Freitas, 2019). As the volume of water reduces, the fish become more vulnerable to predation and are exposed to low oxygen concentrations in water and toxic compounds (Barai et al., 2021). These hydrological cycles directly affect the nutritional and commercial values of fish and, consequently, its consumption by the native people (Araújo et al., 2018; Oliveira et al., 2020). Thus, the objective of this study was to evaluate the centesimal and mineral composition of 10 native fish species from Amazonas, Brazil in two hydrological cycles (flood and drought).

Material and methods

Sample collection

To determine the fish species to will be analyzed, it was considered the IBAMA reports (Table 1). The samples were collected in the Fish Landing Terminal located at Manacapuru town, Amazonas State (Latitude: 3° 17' 39'' S; Longitude: 60° 38' 4'' W). 20 samples (fishes) from each species were collected according to the hydrological cycles of the region (20 samples in the flood and 20 samples in drought).

Table 1. Amazon fish species analyzed.

Order*	Family**	Usual name	Scientific name	Ranking of landing***
CHA	Prochi	Jaraqui	*Semaprochilodus insignis*	15,368 ton. (1st)
		Curimatã	*Prochilodus nigricans*	6,212 ton. (2nd)
	Charac	Pacu manteiga	*Mylossoma duriventre*	6,012 ton. (3rd)
		Matrinxã	*Brycon amazonicus*	2,986 ton. (5th)
		Tambaqui	*Colossoma macropomum*	2,596 ton. (6th)
		Sardinha	*Triportheus auritus*	2,111 ton. (8th)
SIL	Pimelo	Mapará	*Hypophythalmus edentates*	2,104 ton. (9th)
		Piramutaba	*Brachyplatystoma vaillantii*	3,326 ton. (4th)
		Surubim	*Pseudoplatystoma fasciatum*	1,952 ton. (10th)
PER	Cichli	Tucunaré	*Cichla monoculus*	2,115 ton. (7th)

* Taxonomic abbreviations: CHAR - Characiforms; SILU - Siluriforms; PERC - Perciforms. ** Taxonomic abbreviations: Prochi - *Prochilodontidae*; Charac - *Characidae*; Pimelo - *Pimelodidae*; Cichli - *Cichlidae*. *** Data obtained from Instituto Brasileiro do Meio Ambiente (IBAMA, 2005).

Sample's preparation

The fish samples were maintained on ice in isothermal boxes at a 1: 1 ratio (ice: fish) and transported to the Fish Technology Laboratory, Federal University of Amazonas (Manaus, Amazonas, Brazil), where 10 fish samples were processed to determine the centesimal composition and 10 fish samples were used to determine mineral content. Each fish sample was washed using a water chain to remove any superficial mucus, weighed, beheaded, gutted, and fileted. The filets were packed into airtight plastic bags and frozen at -20°C for posterior analysis.

Proximal composition

To determine the proximal composition of each sample, the analyses were performed according to the following analytical procedures: moisture content was determined from the difference between the weight of crushed fillet pre-lyophilization and the lyophilized fillet. The samples were lyophilized using a lyophilization machine (Terroni model 3000) according to the manufacturer's recommendations. Total lipid content was evaluated using the cold extraction method as described by Bligh and Dyer (1959). Total mineral content (ashes) was determined from the inorganic residue contribution method by weighing the sediment of the samples after carbonizing it using a muffle oven at 550°C until it reached a light gray or white color (Association of Official Analytical Chemist [AOAC], 1990). Crude protein content was estimated using the Kjeldahl method to evaluate the total nitrogen content of the sample (AOAC, 1990) and convert it using a conversion factor of 6.25. Finally, carbohydrate content was estimated by subtracting the values for the moisture, protein, lipid, and ash content from 100% of the total nutrients content.

Mineral composition

All materials used to analyze the mineral composition of the filets were sterilized and demineralized in a 20% acid solution of nitric acid (HNO_3) for a minimum period of 24h before use. The filets were washed with deionized distilled water, crushed, and lyophilized. After, the samples were subjected to Bligh and Dyer method for preparation and, subsequently, to acid digestion (HNO_3/H_2O_2). Finally, the samples were diluted for mineral quantification using atomic flame absorption spectrometry (Perkin-Elmer 3300 equipment), being analyzed macro minerals (calcium, magnesium, potassium, and sodium) and microminerals (iron, zinc, copper, chromium, and manganese). Phosphorus content was determined by a colorimetric method (Brasil, 2011) using an Oleman 35-D spectrophotometer.

Statistical analysis

Data collected considering the different hydrological cycles (flood and drought) as the determining factor on the variables of proximal composition and mineral composition. Data in blocks were evaluated using one-way ANOVA and, subsequently, the Tukey test at 5% of significance (Zar, 1999). A multivariate analysis of the Principal Components Analysis-PCA (correlation matrix) was used to order the main species of fish landed in the state of Amazonas in relation to their mineral composition (macro and micro minerals) (Zar, 1999).

Results and discussion

It was observed in the proximal composition that most Amazon fish species evaluated presented variations in their composition according to the hydrological cycle (Table 2). All species evaluated, except matrinxã and surubim, presented moisture content in the fillets higher in the drought than in the flood season. Furthermore, surubim presented the highest water content results in both the flood (80.1%) and drought (80.0%), while the mapará presented lower water content in both the flood (56.6%) and drought (65.03%).

Table 2. Proximal composition of 10 Amazon fish species with higher landing volume in two hydrological cycles.

Fish species	HC[1]	Variables[2]				
		MO, %	CP, %	FT, %	AS, %	CHO, %
Curimatã	Flood	$74.51^{b}\pm0.55$	$20.44^{a}\pm0.39$	$3.55^{a}\pm0.02$	$1.03^{a}\pm0.09$	0.47^{b}
	Drought	$76.69^{a}\pm0.26$	$18.85^{b}\pm0.64$	$2.57^{b}\pm0.02$	$0.92^{b}\pm0.07$	0.97^{a}
Effect		*	*	*	*	*
Jaraqui	Flood	$75.24^{b}\pm0,65$	$20.19^{a}\pm0.50$	$2.64^{a}\pm0.28$	$1.20^{a}\pm0.27$	0.73^{b}
	Drought	$78.21^{a}\pm0.28$	$18.29^{b}\pm0.32$	$1.65^{b}\pm0.08$	$0.85^{b}\pm0.03$	1.00^{a}
		*	*	*	*	*
Mapará	Flood	$56.54^{b}\pm3.06$	$15.29^{a}\pm0.55$	$26.90^{a}\pm0.12$	$1.14^{a}\pm0.06$	0.13^{b}
	Drought	$65.03^{a}\pm0.65$	$14.23^{b}\pm0.21$	$19.63^{b}\pm0.44$	$0.93^{b}\pm0.02$	0.18^{a}
Effect		*	*	*	*	*
Matrinxã	Flood	71.51 ± 0.49	$18.39^{b}\pm0.21$	$8.53^{a}\pm0.79$	$1.08^{a}\pm0.05$	0.49^{a}
	Drought	71.80 ± 1.51	$25.50^{a}\pm1.01$	$1.75^{b}\pm0.01$	$0.88^{b}\pm0.01$	0.07^{b}
Effect		ns	*	*	*	*
Pacu	Flood	$68.96^{b}\pm1.12$	19.43 ± 1.71	$9.67^{a}\pm0.34$	0.90 ± 0.05	0.04^{b}
	Drought	$74.29^{a}\pm1.28$	19.43 ± 0.33	$4.63^{b}\pm0.73$	0.90 ± 0.02	0.75^{a}
Effect		*	ns	*	ns	*
Piramutaba	Flood	$74.58^{b}\pm0.77$	18.37 ± 0.12	$5.67^{a}\pm0.50$	0.82 ± 0.02	0.56^{a}
	Drought	$77.67^{a}\pm1.46$	18.63 ± 0.08	$2.64^{b}\pm0.12$	0.85 ± 0.01	0.21^{b}
Effect		*	ns	*	ns	*
Sardinha	Flood	$73.52^{b}\pm2.31$	$20.54^{a}\pm0.34$	$4.76^{a}\pm0.32$	$1.06^{a}\pm0.07$	0.12^{b}
	Drought	$79.60^{a}\pm0.16$	$15.22^{b}\pm0.18$	$2.23^{b}\pm0.07$	$0.77^{b}\pm0.02$	0.18^{a}
Effect		*	*	*	*	*
Surubim	Flood	80.11 ± 0.87	$16.38^{b}\pm0.19$	$2.63^{a}\pm0.02$	0.75 ± 0.01	0.13^{b}
	Drought	80.07 ± 0.10	$17.08^{a}\pm0.13$	$1.59^{b}\pm0.05$	0.80 ± 0.04	0.46^{a}
Effect		ns	*	*	ns	*
Tambaqui	Flood	$77.94^{b}\pm0.49$	17.88 ± 0.29	$2.10^{a}\pm0.04$	$1.03^{a}\pm0.01$	1.05^{a}
	Drought	$79.86^{a}\pm1.41$	17.80 ± 0.15	$1.22^{b}\pm0.23$	$0.89^{b}\pm0.01$	0.23^{b}
Effect		*	ns	*	*	*
Tucunaré	Flood	$76.08^{b}\pm0.61$	$21.04^{a}\pm0.07$	$1.11^{a}\pm0.03$	1.01 ± 0.09	0.76
	Drought	$77.59^{a}\pm0.46$	$19.60^{b}\pm0,29$	$1.02^{b}\pm0.04$	1.05 ± 0.01	0.74
Effect		*	*	*	ns	ns

* Significant effect ($p < 0.05$) between hydrological cycles on the species result. ns – non-significant result ($p > 0.05$). [1] HC – hydrological cycles. [2] MO – Moisture. CP – Crude Protein. FT – Fats. AS – Ashes. CHO – Carbohydrates.

The protein content results in all species evaluated were little affected by hydrological cycles, including some species (pacu, piramutaba and tambaqui) that were not present a significant effect (p >

0.05) of hydrological cycles on their protein content. The fillets of all species evaluated presented a significant effect ($p < 0.05$) of the hydrological cycles on the total lipid content, where all species presented higher total lipid content in flood season. The mapará presented the highest total lipid content among the species evaluated, where these fillets presented higher lipid content in the flood (26.9%) than in drought (19.6%). On the other hand, the tucunaré presented the lowest ($p < 0.05$) total lipid content, regardless of the hydrological cycle.

Total mineral content (ashes) had a significant response to hydrological cycles, where all species evaluated (except pacu, piramutaba, surubim, and tucunaré) presented higher ($p < 0.05$) total mineral content in the flood than in the drought. It is important to mention that only the pacu presented a stable mineral condition under both hydrological cycles. On the other hand, the carbohydrates content results presented a significant variation between species according to hydrological cycles. Front this, most species evaluated (curimatã, jaraqui, mapará, pacu, sardinha, and surubim) presented higher carbohydrates content in drought, while matrinxã, piramutaba, and tambaqui presented higher carbohydrates content in flood. Only the carbohydrate content of tucunaré was not affected by the hydrological cycles.

In general, these results disagree with those reported by De Souza, Petenuci, Camparim, Visentainer, and Silva (2020), which evaluated seasonal variations in nine fish species of the *Pimelodidae* family in the Amazon and reported that six of nine species studied were negatively affected by the flood period. However, Petenuci et al. (2016) also reported that some fish species from *Characiformes* order present a positive effect of flood period in their chemical composition, especially in lipids content, corroborating with the results found in this study.

These factors may explain the higher content of nutrients in the flood period found in the fillets of fish species evaluated in this study, indicating this period as the most abundant in food available to the fishes, consequently resulting in carcasses with the most nutritional content (Cajado, Oliveira, Suzuki, & Zacardi, 2020; Souza et al., 2020; Petenuci, Lopes, Camparin, Schneider, & Visentainer, 2021). Monteiro, Benedito, and Marques (2007), for example, observed two moments of energy mobilization of mapará, with the first caused by gonadal maturation and the second promoted by spawning, and reported that the higher content of total lipids during the flood versus drought is related to its reproduction period. Similar behavior was observed in mapará collected during the flood period in the Itaipu reservoir according to Oliveira, Agostinho, and Makoto (2003).

According to Mortillaro et al. (2015) and Arantes et al. (2019), the herbivorous and omnivorous species, predominant in Amazon ichthyofauna and the species evaluated in this study, in the drought period tend to move and/or stay in areas with water retreats from the flooded areas, which naturally cause a significant increase in the density of the local ichthyofauna and competition for food, causing a decrease in the food access to the fishes and, consequently, in their carcass nutrients content.

In the minerals composition results, it was observed in the macro minerals content that most Amazon fish species evaluated presented variations in their composition according to the hydrological cycles (Table 3). All species evaluated, except mapará, matrinxã, and surubim, presented Ca values in the fillets higher ($p < 0.05$) in the drought than in the flood season. It is important to mention that the Ca content of sardinha and surubim was not affected ($p > 0.05$) by the hydrological cycles.

The same behavior was observed in P and K results, where all species evaluated, except piramutaba, presented higher ($p < 0.05$) results in the drought than in the flood season. On the other hand, all species evaluated, again except piramutaba, presented Mg and Na values in the fillets higher ($p < 0.05$) in the flood than in the drought season. It is important to mention that the Mg content of piramutaba was not affected ($p > 0.05$) by the hydrological cycles.

In the micro minerals content, it was observed that most Amazon fish species evaluated presented variations in their composition according to the hydrological cycles (Table 4). All species evaluated presented Fe, Zn, Cr, and Mn values in the fillets higher ($p < 0.05$) in the flood than in the drought season. Only the Cr content of tucunaré was not affected ($p > 0.05$) by the hydrological cycles. On the other hand, Cu values presented variable results, where curimatã, mapará, pacu, sardinha, surubim, and tambaqui presented better ($p < 0.05$) results in flood; while matrinxã, piramutaba, and tucunaré presented better ($p < 0.05$) results in drought. Cu values of jaraqui were not affected ($p > 0.05$) by the hydrological cycles.

Table 3. Macro minerals content of 10 Amazon fish species with higher landing volume in two hydrological cycles.

Fish species	HC[1]	Variables[2]				
		Ca, %	Mg, %	P, %	K, %	Na, %
Curimatã	Flood	0.33±0.02[b]	33.81±1.16[a]	0.48±0.00[b]	0.63±0.02[b]	0.04±0.00[a]
	Drought	1.07±0.02[a]	0.06±0.00[b]	1.85±0.00[a]	0.96±0.01[a]	0.02±0.00[b]
Effect		*	*	*	*	*
Jaraqui	Flood	0.33±0.02[b]	34.62±0.13[a]	0.52±0.00[b]	0.57±0.03[b]	0.04±0.00[a]
	Drought	0.72±0.02[a]	0.06±0.00[b]	1.85±0.00[a]	0.74±0.01[a]	0.02±0.00[b]
		*	*	*	*	*
Mapará	Flood	0.77±0.07[a]	34.42±0.21[a]	0.50±0.00[b]	0.62±0.06 [b]	0.06±0.00[a]
	Drought	0.58±0.01[b]	0.07±0.00[b]	2.67±0.00[a]	1.25±0.08[a]	0.02±0.00[b]
Effect		*	*	*	*	*
Matrinxã	Flood	0.83±0.07[b]	34.29±0.67[a]	0.51±0.00[b]	0.64±0.01[b]	0.05±0.00[a]
	Drought	1.13±0.13[a]	0.06±0.00[b]	1.59±0.00[a]	1.21±0.01[a]	0.02±0.00[b]
Effect		*	*	*	*	*
Pacu	Flood	0.71±0.01[b]	33.22±2.30[a]	0.50±0.00[b]	0.61±0.05[b]	0.04±0.00[a]
	Drought	1.14±0.07[a]	0.06±0.00[b]	1.59±0.00[a]	0.96±0.00[a]	0.02±0.00[b]
Effect		*	*	*	*	*
Piramutaba	Flood	0.41±0.02	0.06±0.00	1.85±0.00[a]	1.46±0.02[a]	0.03±0.05[a]
	Drought	0.41±0.02	0.06±0.00	1.19±0.00[b]	0.97±0.00[b]	0.02±0.00[b]
Effect		ns	ns	*	*	*
Sardinha	Flood	0.04±0.01[b]	36.54±2.92[a]	0.56±0.00[b]	0.67±0.01[b]	0.06±0.00[a]
	Drought	1.96±0.12[a]	0.06±0.00[b]	1.78±0.00[a]	1.26±0.07[a]	0.02±0.00[b]
Effect		*	*	*	*	*
Surubim	Flood	0.26±0.01	33.97±0.77[a]	0.48±0.00[b]	0.72±0.01[b]	0.06±0.00[a]
	Drought	0.26±0.01	0.06±0.00[b]	1.94±0.00[a]	1.42±0.02[a]	0.02±0.00[b]
Effect		ns	*	*	*	*
Tambaqui	Flood	0.23±0.01[b]	34.31±0.14[a]	0.50±0.00[b]	0.64±0.00[b]	0.05±0.00[a]
	Drought	0.40±0.03[a]	0.06±0.00[b]	1.82±0.00[a]	1.18±0.05[a]	0.02±0.00[b]
Effect		*	*	*	*	*
Tucunaré	Flood	0.16±0.01[b]	33.86±0.39[a]	0.57±0.00[b]	0.65±0.03[b]	0.06±0.00[a]
	Drought	0.27±0.02[a]	0.06±0.01[b]	1.66±0.00[a]	1.21±0.00[a]	0.02±0.00[b]
Effect		*	*	*	*	*

* Significant effect ($p < 0.05$) between hydrological cycles on the species result. ns – non-significant result ($p > 0.05$). [1] HC – hydrological cycles. [2] Ca – Calcium. Mg – Magnesium. P – Phosphorus. K – Potassium. Na – Sodium.

Table 4. Micro minerals content of 10 Amazon fish species with higher landing volume in two hydrological cycles.

Fish species	HC[1]	Variables[2]				
		Fe, %	Zn, %	Cu, %	Cr, %	Mn, %
Curimatã	Flood	237.07±13.78[a]	165.67±6.33[a]	3.91±0.77[a]	80.73±1.03[a]	6.79±0,72[a]
	Drought	32.88±0.91[b]	80.73±1.03[b]	2.72±0.16[b]	13.46±1.48[b]	0.04±0.07[b]
Effect		*	*	*	*	*
Jaraqui	Flood	232.60±14.23[a]	217.43±2.49[a]	5.31±0.59	79.81±1.27[a]	8.45±0.11[a]
	Drought	38.32±1.21[b]	79.81±1.27[b]	5.05±0.15	12.67±1.11[b]	0.35±0.10[b]
		*	*	ns	*	*
Mapará	Flood	262.30±6.85[a]	516.87±2.84[a]	3.74±0.44[a]	79.21±1.12[a]	3.16±1.05[a]
	Drought	9.12±0.70[b]	79.21±1.12[b]	1.15±0.28[b]	22.85±1.42[b]	0.01±0.00[b]
Effect		*	*	*	*	*
Matrinxã	Flood	283.87±25.03[a]	321.60±3.70[a]	3.27±0.68[b]	83.48±0.66[a]	6.91±0.63[a]
	Drought	28.63±1.42[b]	83.48±0.66[b]	6.24±0.01[a]	15.27±1.46[b]	0.24±0.10[b]
Effect		*	*	*	*	*
Pacu	Flood	248.47±9.43[a]	246.40±2.15[a]	4.31±0.27[a]	80.93±2.83[a]	8.07±0.38[a]
	Drought	13.80±1.14[b]	80.93±2.83[b]	2.33±0.14[b]	15.42±1.64[b]	0.97±0.53[b]
Effect		*	*	*	*	*
Piramutaba	Flood	200.62±0.24[a]	396.33±18.37[a]	0.21±0.04[b]	80.00±0.00[a]	5.84±0.35[a]
	Drought	10.30±0.14[b]	80.00±0.00[b]	2.46±0.11[a]	15.16±1.40[b]	0.01±0.00[b]
Effect		*	*	*	*	*
Sardinha	Flood	245.63±22.29[a]	359.63±8.57[a]	3.78±0.96[a]	83.33±2.61[a]	10.46±0.68[a]
	Drought	15.51±1.15[b]	83.33±2.61[b]	1.62±0.08[b]	20.61±1.84[b]	0.12±0.21[b]
Effect		*	*	*	*	*
Surubim	Flood	223.87±19.06[a]	218.37±4.44[a]	3.32±0.75[a]	80.01±4.73[a]	2.71±0.14[a]
	Drought	7.98±0.01[b]	80.01±4.73[b]	0.38±0.06[b]	20.91±1.01[b]	0.01±0.00[b]
Effect		*	*	*	*	*

Tambaqui	Flood	211.03±4.62[a]	179.80±17.15[a]	2.49±0.50[a]	76.99±1.74[a]	4.33±0.26[a]
	Drought	10.78±1.43[b]	76.99±1.74[b]	1.65±0.12[b]	20.85±1.20[b]	0.01±0.00[b]
Effect		*	*	*	*	*
Tucunaré	Flood	220.37±17.78[a]	206.30±3.82[a]	1.99±0.35[b]	81.84±2.36	81.84±2.36[a]
	Drought	4.98±0.68[b]	81.84±2.36[b]	2.30±0.04[a]	81.84±2.36	0.01±0.00[b]
Effect		*	*	*	ns	*

* Significant effect ($p < 0.05$) between hydrological cycles on the species result. ns – non-significant result ($p > 0.05$). [1] HC – hydrological cycles. [2] Fe – Iron. Zn – Zinc. Cu – Copper. Cr – Chromium. Mn – Manganese.

The PCA results in the drought period pointed out a summarized 60% of the total variability of the composition data in its first two axes, revealing four distinct groups of fish (Figure 1). Principal Component 1 (PC1; with 38.8% variance) was positively associated with Cr and K and negatively associated with Fe, Cu, Mn, and Ca. This component produced two groups, where the curimatã, jaraqui, matrinxã, and pacu were grouped as a result of their high iron, copper, manganese, and calcium content. However, the other group, which was represented by tambaqui, surubim, and mapará, were grouped on the strength of their high Cr and P concentrations and low Fe, Cu, Mn, and Ca levels. The second component (PC2) was influenced positively by Na concentration and negatively by Zn, P, Mn and Ca, explaining 21.1% of the variance. These five minerals allowed for species segregation in group 1 (sardinha and mapará) and group 2 (piramutaba and tucunaré). Sardinha presented with high levels of Zn, Ca, and Mn while mapará presented with the highest levels of P. On the other hand, PC2 isolated piramutaba and tucunaré, due to their reduced Ca, P, and Mn levels. However, tucunaré presented with high levels of Cr and Zn.

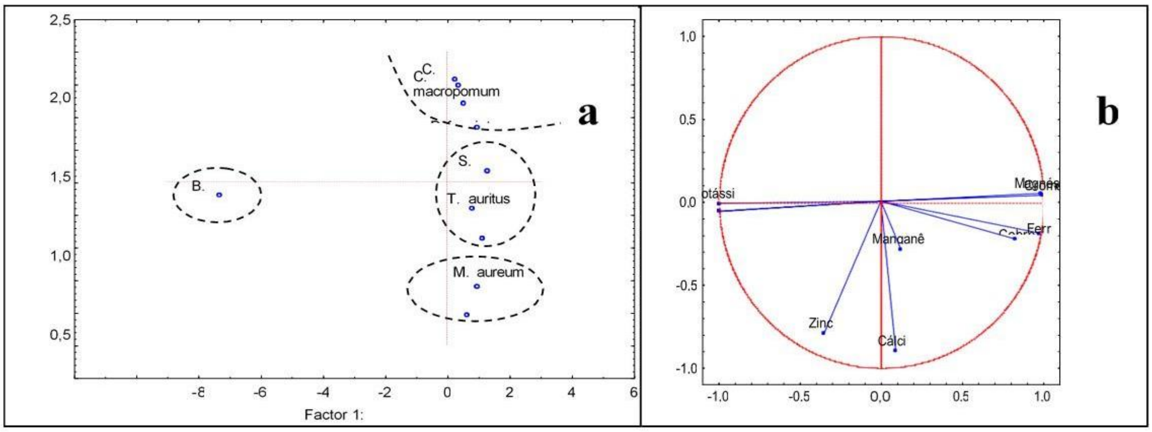

Figure 1. PC1 and PC2 show the projections of the minerals (macro and micro minerals) (a), and the ordering of the fish species analyzed in the drought (b).

The PCA results in the flood period pointed out a summarized 83% of the total variability in the mineral composition data in its first two axes, revealing the isolation of piramutaba (Figure 2). Principal component 1 (PC1; 66.8% variance) isolated piramutaba, due to its high levels of Na, K, and P. In that same period, a group composed of the jaraqui, pacu, and sardinha, presented with the highest levels of Fe, Cu, Cr, and Mn. The second component (PC2) was negatively influenced by both Ca and Zn and explained 16.1% of the variance. Mapará and matrinxã presented with the highest Zn and Ca concentrations during the flood season. It is worth noting that both piramutaba and sardinha also presented with high levels of Zn. Other species such as tambaqui, tucunaré, surubim, and curimatã, presented with lower values for all of the minerals when compared with the other species described in this analysis, during the same period. This is evidenced by the isolation of these along with component 2.

Front these results of mineral content (macro and micro), when was analysed the influence of hydrological cycles, it was noted that the better results were recorded in the samples collected in the flood when the shoals leave the estuary and are caught in the Amazon region. The estuary, where these species live for long periods, is known to have a higher mineral concentration than the rivers used in their migration. Ogawa (1999) has suggested that the water quality is one of the most important determining factors in the mineral composition of fish and it is likely that the long period in the estuary directly influences the mineral content in these species, which may explain the increased mineral concentrations during the flood.

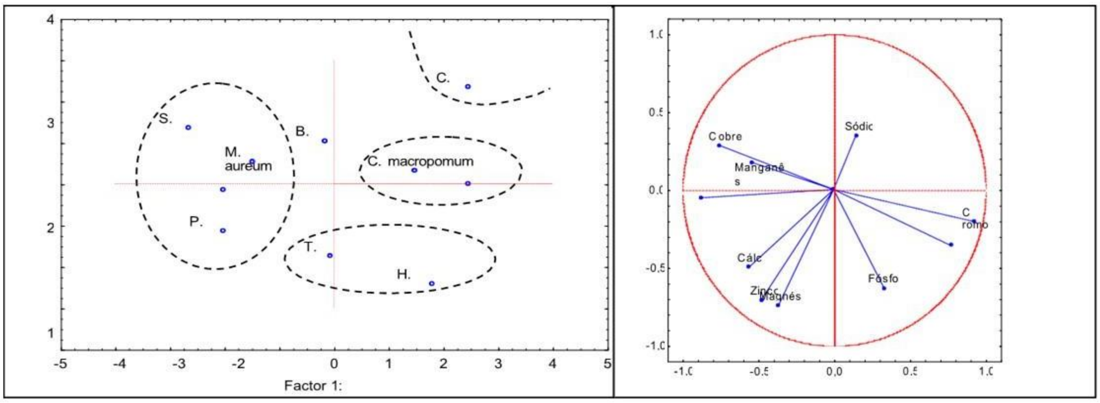

Figure 2. PC1 and PC2 show the projections of the minerals (macro and micro minerals) (a), and the ordering of the fish species analyzed in the flood (b).

In addition, it is possible to attribute the higher levels of minerals (macro and micro minerals) in the musculature of these species to the increased diversity of food found in the flooded forests during the flood periods (Mortillaro et al., 2015; Garcez, Souza, Frutuoso, & Freitas, 2017; Silva, Arantes, Freitas, Petrere, and Ribeiro, 2020; Hurd, Baccaro, Pouilly, & Freitas, 2021). During the flood, pacu, matrinxã, curimatã, sardinha, and jaraqui are often found in flooded forests feeding mainly on fruits, seeds, insects, vegetable matter, and debris (Costa & Freitas, 2013; Mortillaro et al., 2015; Silva et al., 2020); which may explain their high Fe, Cu, Ca, and Mn values during flooding. For piramutaba, the high levels of Na and K observed during the flood season may be related to the natural history of the species, which spend a large part of their life cycle in the Amazon River estuary, in brackish waters, migrating upstream from May to October (full to low) to reproduce in the high Amazon.

In the drought season, the water retraction decreases food supply, forcing many species to move towards the main channel of the great rivers, where the food supply is low (Mortillaro et al., 2015; Garcez et al., 2017; Silva et al., 2020; Hurd et al., 2021). This would explain, in part, the lower macro and mineral values in the musculature of fish species during that time. Therefore, it is likely that the seasonal flood cycle (which makes larger and larger quantities of food) is a key factor that directly influences the mineral concentrations in the musculature of the main fish species of the Amazon.

Conclusion

The proximal composition of the 10 fish species with the highest landing volume in Amazonas State (curimatã, jaraqui, mapará, matrinxã, pacu, piramutaba, sardinha, surubim, tambaqui, and tucunaré) varied widely between species and seasons, where fishes in the flood season presented better nutritional composition than drought season. This result also was observed in minerals profile, where fishes in the flood season presented highest minerals (macro and minerals) content than drought season.

Acknowledgments

To the Fundação de Amparo à Pesquisa do Estado do Amazonas (FAPEAM) and the Programa de Pós-Graduação em Ciência Animal e Recursos Pesqueiros (PPGCARP) da Universidade Federal do Amazonas (UFAM) by the support to develop this study.

References

Association of Official Analytical Chemist [AOAC]. (1990). *Official Methods of Analysis*. Washington, D.C.: AOAC.

Alho, C. Jr., Reis, R. E., & Aquino, P. P. (2015). Amazonian freshwater habitats experiencing environmental and Socioeconomic threats affecting subsistence fisheries. *Ambio*, *44*, 412-425. DOI: https://dx.doi.org/10.1007/s13280-014-0610-z

Arantes, C., Winemiller, K. O., Petrere Júnior, M., & Freitas, C. E. C. (2019). Spatial variation in aquatic food webs in the Amazon River floodplain. *Freshwater Science*, *38*. DOI: https://dx.doi.org/10.1086/701841

Araújo, C. K., Cirne, L. G. A., Souza, W. S., Silva, J. R., Feltran, R. B., Melo, D. R., ... Maciel, E. S. (2018). Características morfométricas, rendimento de filé e composição química da traíra. *Agroecossistemas*, *10*(2), 25-36.

Barai, A. A., Souza, A. F. L., Viana, A. P., & Inhamuns, A. J. (2021). Seasonal influence on centesimal composition and yield of Amazonian fish. *Food Science and Technology, Ahead of Print*, *42*. DOI: https://dx.doi.org/10.1590/fst.55320

Blig, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*(8), 911-917. DOI: https://dx.doi.org/10.1139/o59-099

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. (2011). *Instrução Normativa n° 25, de 2 de junho de 2011. Métodos analíticos físico-químicos para controle de pescado e seus derivados*. Brasília, DF: Diário Oficial da União.

Cajado, R. A., Oliveira, L. S., Suzuki, M. A. L., & Zacardi, D. M. (2020). Spatial diversity of icththyoplankton in the lower stretch of the Amazon river, Pará, Brazil. *Acta Ichthyologica et Piscatoria*, *50*(2), 127-137. DOI: https://dx.doi.org/10.3750/AIEP/02786

Can, M. F., Gunlu, A., & Can, H. Y. (2015). Fish consumption preferences and factors influencing it. *Food Science and Technology*, *35*(2), 339-346. DOI: https://dx.doi.org/10.1590/1678-457X.6624

Costa, I. D., & Freitas, C. E. C. (2013). Trophic ecology of the ichthyofauna of a stretch of the Urucu River (Coari, Amazonas, Brazil). *Acta Limnologica Brasiliensia*, *25*(1), 54-67. DOI: https://dx.doi.org/10.1590/S2179-975X2013000100007

De Alcântara, N. C., Gonçalves, G. S., Braga, T. M. P., Santos, S. M., Araújo, R. L., Pantoja-Lima, J., ... Oliveira, A. T. (2015). Avaliação do desembarque pesqueiro (2009-2010) no município de Juruá, Amazonas, Brasil. *Biota Amazônia*, *5*, 37-42. DOI: https://dx.doi.org/10.18561/2179-5746/biotaamazonia.v5n1p37-42

De Souza, A. F. L., Petenuci, M. E., Camparim, R., Visentainer, J. V., & Silva, A. J. I. (2020). Effect of seasonal variations on fatty acid composition and nutritional profiles of siluriformes fish species from the amazon basin. *Food Research International*, *132*, 109051. DOI: https://dx.doi.org/10.1016/j.foodres.2020.109051

Doria, C. R. C., Ruffino, L. M., Hijazi, N. C., & Da Cruz, R. L. (2012). A pesca comercial na bacia do rio Madeira no estado de Rondônia, Amazônia brasileira. *Acta Amazônica*, *42*, 29-40. DOI: https://dx.doi.org/10.1590/S0044-59672012000100004

Garcez, R. S., Souza, L. A., Frutuoso, M. E., & Freitas, C. E. C. (2017). Seasonal dynamic of Amazonian small-scale fisheries is dictated by the hydrologic pulse. *Boletim do Instituto de Pesca*, *43*(2), 207-221. DOI: https://dx.doi.org/10.20950/1678-2305.2017v43n2p207

Hurd, L. E., Baccaro, F. B., Pouilly, M., & Freitas, C. E. C. (2021). Editorial: The ecology, evolution, and preservation of biodiversity in Amazonian floodplain ecosystems. *Frontiers in Ecology and Evolution*, *9*, 1-3, 2021. DOI: https://dx.doi.org/10.3389/fevo.2021.794472

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis [IBAMA]. (2005). *Estatísticas da Pesca 2004, Brasil - Grandes regiões e unidades da federação* (p. 98). Brasília, DF: IBAMA.

Lima, M. A. L., Doria, C. R. C., & Freitas, C. E. C. (2012). Pescarias artesanais em comunidades ribeirinhas na amazônia brasileira: perfil socioeconômico, conflitos e cenário da atividade. *Ambiente and Sociedade*, *15*(2), 73-90. DOI: https://dx.doi.org/10.1590/S1414-753X2012000200005

Lobón-Cerviá, J., Hess, L. L., Melack, J. M., & Araujo-Lima, C. A. M. (2015). The importance of forest cover for fish richness and abundance on the Amazon floodplain. *Hydrobiologia*, *750*, 245-255. DOI: https://dx.doi.org/10.1007/s10750-014-2040-0

Maciel, E. S., Sonati, J. G., Galvão, J. A., & Oetterer, M. (2019). Fish consumption and lifestyle: a cross-sectional study. *Food Science and Technology*, *39*(suppl. 1), 141-145. DOI: https://dx.doi.org/10.1590/fst.40617

Monteiro, V., Benedito, E., & Marques, D. W. (2007). Efeito da estratégia de vida sobre as variações no conteúdo de energia de duas espécies de peixes (*Brycon hilarii* e *Hypophthalmus edentatus*), durante o ciclo reprodutivo. *Acta Scientiarum. Biological Sciences*, *29*(2), 151-159. DOI: https://dx.doi.org/10.4025/actascibiolsci.v29i2.521

Mortillaro, J. M., Pouilly, M., Wach, M., Freitas, C. E. C., Abril, G., & Meziane, T. (2015). Trophic opportunism of central Amazon floodplain fish. *Freshwater Biology*, *60*(8), 1659-1670. DOI: https://dx.doi.org/10.1111/fwb.12598

Noveras, J., Yamamoto, K. C., Freitas, C. E. C. (2012). Use of the flooded forest by fish assemblages in lakes of the National Park of Anavilhanas (Amazonas, Brazil). *Acta Amazônica*, *42*(4), 561-566. DOI: https://dx.doi.org/10.1590/S0044-59672012000400015

Ogawa, M. (1999). O pescado como alimento. In M. Ogawa, & E. L. Maia (Ed.), *Manual de Pesca, Ciência e Tecnologia do Pescado*. São Paulo, SP: Livraria Varela.

Oliveira, E. R. N., Agostinho, A. A., & Makoto, M. (2003). Effect of biological variables and capture period on the proximate composition and fatty acid composition of the dorsal muscle tissue of Hypophthalmus edentates (Spix, 1829). *Brazilian Archives of Biology and Technology*, *46*, 105-114. DOI: https://dx.doi.org/10.1590/S1516-89132003000100015

Oliveira, D. L. de, Grassi, T. L. M., Bassani, J. S., Diniz, J. C. P., Paiva, N. M., & Ponsano, E. H. G. (2020). Enrichment of fishburgers with proteins from surimi washing water. *Food Science and Technology*, *40*(4), 822-826. DOI: https://dx.doi.org/10.1590/fst.21319

Petenuci, M. E., Rocha, I. N. A., Sousa, S. C., Schneider, V. V. A., Costa, L. A. M. A., & Visentainer, J. V. (2016). Seasonal variations in lipid content, fatty acid composition and nutritional profiles of five freshwater fish from the Amazon Basin. *Journal of the American Oil Chemists' Society*, *93*(10), 1373-1381. DOI: https://dx.doi.org/10.1007/s11746-016-2884-8

Petenuci, M. E., Lopes, A. P., Camparin, R., Schneider, V. V. A., & Visentainer, J. V. (2021). Fatty acid composition in fractions of neutral lipids and phospholipids of *Hemisorubim platyrhynchos* with seasonal distinction. *Journal of Food Composition and Analysis*, *99*, 103885. DOI: https://dx.doi.org/10.1016/j.jfca.2021.103885

Silva, P. B., Arantes, C. C., Freitas, C. E. C., Petrere, M., & Ribeiro, F. R. V. (2020). Seasonal hydrology and fish assemblage structure in the floodplain of the lower Amazon River. *Ecology of Freshwater Fish*, *30*(2), 162-173. DOI: https://dx.doi.org/10.1111/eff.12572

Soares, M. G. M., Freitas, C. E. C., & Oliveira, A. C. B. (2014). Fish assemblage associated with aquatic macrophytes bank in mananged lakes of Central Amazon, Amazonas, Brazil. *Acta Amazônica*, *44*, 143-152. DOI: https://dx.doi.org/10.1590/S0044-59672014000100014

Tavares, B. M., Da Veiga, G. V., Yuyama, L. K. O., Bueno, M. B., Fisberg, R. M., & Fisberg, M. (2012). Estado Nutricional e consumo de energia e nutrientes de pré-escolares que frequentam creches no Município de Manaus, Amazonas: existem diferenças entre creches públicas e privadas. *Revista Paulista de Pediatria*, *30*(1), 42-50. DOI: https://dx.doi.org/10.1590/S0103-05822012000100007

Yuyama, L. K., Aguiar, J. P., Schwertz, M. C., Benzecry, S., Fisberg, R. M., & Veloso, M. P. (2011). Realidade alimentar de crianças assistidas em creches públicas e privadas de Manaus AM. *Nutrire*, *36*, 286-286.

Zar, J. H. (1999). *Biostatistical Analysis* (3a ed., p. 662). New Jersey, NJ: Prentice Hall.

Antônio Fábio Lopes de Souza,
Antonio José Inhamuns da Silva, Alexandre Augusto Barai,
João Paulo Ferreira Rufino, Tiago Viana da Costa
Proximal and mineral composition of native fish species from Amazonas, Brazil

Acta Scientiarum. Animal Sciences
vol. 45, e61884, 2023
Editora da Universidade Estadual de Maringá - EDUEM,
ISSN: 1806-2636
ISSN-E: 1807-8672

DOI: https://doi.org/10.4025/actascianimsci.v45i1.61884