BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Short Communication

Seasonality of the feeding behavior and condition factor of *Anchovia surinamensis* in the floodplains of the Madeira River (Rondônia, Brazil)*

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Received: August 08, 2021
Approved: January 26, 2022

ABSTRACT

The *Anchovia surinamensis* (Clupeiformes: Engraulidae) is known in Brazil as "sardinha-do-gato" and exists in the floodplains throughout Latin-America. It is highly appreciated by the Amazonian riverine communities as a source of animal protein. In this study, we analyzed the dietary preferences and abiotic parameters that influence the condition factor of *A. surinamensis* that inhabit Cujubim Lake during periods of drought and flood. A total of 105 specimens were captured using three batteries of monofilament nylon nets (measuring 20 m long, 2.5 m high, 40, 60, 80 and 100 mm mesh, measured between opposite knots). The nets were arranged in pre-established positions within the lake and inspected at the times of 18:00, 00:00, 06:00 and 12:00 h. This methodology was utilized to obtain the largest range of fish sizes and to avoid the influence of the nictimeral factor. The results of the analysis of the stomach contents of the individuals confirmed that the species is planktivorous and consumes mainly cladocera and bivalves in the Cujubim Lake, which indicates that there is good food availability in the lake. Our results also demonstrate that, among the physicochemical parameters of the water in Cujubim Lake, pH was the one that most affected the condition factor of *A. surinamensis*.

Keywords: allochthonous food; Amazon basin; fish ecology; flooded area; freshwater fish; seasonality.

Sazonalidade do comportamento alimentar e fator de condição da *Anchovia surinamensis* na várzea do Rio Madeira (Rondônia, Brasil)

RESUMO

Anchovia surinamensis (Clupeiformes: Engraulidae) é conhecida no Brasil como "sardinha-do-gato" e existe em áreas de várzea ao longo da América Latina. É muito apreciada pelas comunidades ribeirinhas da Amazônia como fonte de proteína animal. Neste estudo, foram analisadas as preferências alimentares e os parâmetros abióticos que influenciam o fator de condição da espécie *A. surinamensis*, que habita o Lago Cujubim durante os períodos de seca e cheia. Um total de 105 espécimes foram capturados usando três baterias de redes de náilon monofilamento (medindo 20 m de comprimento, 2,5 m de altura, 40, 60, 80 e 100 mm de malha, medida entre nós opostos). As redes foram dispostas em posições pré-estabelecidas dentro do lago, e inspecionadas nos horários de 18:00, 00:00, 06:00 e 12:00 h. Esta metodologia foi utilizada para obter a maior variedade de tamanhos de peixes e evitar a influência do fator nictimeral. Os resultados da análise do conteúdo estomacal dos indivíduos confirmaram que a espécie é planctívora e consome principalmente cladóceros e bivalves no Lago Cujubim, revelando que há boa disponibilidade de alimento no lago. Nossos resultados indicaram que entre os parâmetros físico-químicos da água no Lago Cujubim, o pH foi o que mais afetou o fator de condição de *A. surinamensis*.

Palavras-chave: alimentos alóctones; bacia amazônica; ecologia de peixes; área inundada; peixes de água doce; sazonalidade.

INTRODUCTION

Anchovia surinamensis (Bleeker, 1865) is a species of anchovy of commercial interest, mainly for riverine communities. It belongs to the order Clupeiformes and the subfamily Engraulinae and is a small fish with a tapered and pointed snout, which is a characteristic that distinguishes it from the other species of the genus (Queiroz et al., 2013). The species is known in northern Brazil as "sardinha-do-gato", and it occurs in Central and South America (Rapp Py-Daniel et al., 2007), especially in the

Amazon basin, where it colonizes floodplains (Claro-Jr. et al., 2004), including the floodplain lakes of the Madeira River basin (Queiroz et al., 2013). They tend to inhabit freshwater and brackish places (Mérona et al., 2001; Mol et al., 2012).

The diet of *A. surinamensis* may be correlated with the type of environment, in addition to seasonal variability. Thus, the analysis of stomach contents can be important in studies related to feeding ecology, trophic habits, food webs, and is essential for a better understanding of the colonization behavior of the species (Bennemann et al., 2006), though there is scarce information for the Madeira River basin. In addition, it is necessary to understand changes in abiotic factors (e.g., temperature, pH, transparency), which can influence the condition factor of specimens (Mazumder et al., 2016).

Therefore, the objective of this study was to analyze the stomach contents of the *A. surinamensis* population that inhabits Cujubim Lake, in the Madeira River basin, Rondônia, to test the hypothesis that the variability in food preference and condition factor of this species between periods of flood and drought does not vary. It is hoped that the resulting information will increase knowledge on *A. surinamensis* and assist future studies, as well as management policies for stocks in the Amazonian floodplain lakes.

MATERIALS AND METHODS

The Madeira River is the largest tributary of the Amazon River at approximately 3,315 km² in area (Goulding, 1979). It is a river of muddy or white waters, which are characterized by the presence of floodplain lakes on its banks (Rapp Py-Daniel et al., 2007). In this region, we find Cujubim Lake, which is located on the lower stretch and on the right bank of the Madeira River (8°29'25.49"S; 63°29'58.48"W; Figure 1). This environment is used as a fishing area by the existing riverine populations in this region.

The collections of specimens of *A. surinamensis* were carried out in two experimental fisheries, the first in 2019 (October, drought period) and the second in 2020 (February, flood period). The specimens were captured using three batteries of monofilament nylon nets (measuring 20 m long, 2.5 m high, 40, 60, 80 and, 100 mm mesh, measured between opposite knots). The nets were arranged in pre-established positions within Cujubim Lake and inspected for the removal of specimens at the times of 18:00, 00:00, 06:00 and 12:00 h. In addition, an analysis of the gill arch was used, with the use of a biological microscope (B60, BIOPTIKA) to confirm the species (Bornbusch, 1988).

In conjunction with the collection of fish, the following physical and chemical parameters of the lake water were measured: temperature (°C), dissolved oxygen (mg L^{-1}), potential of hydrogen (pH), electrical conductivity (µS cm^{-1}), with the aid of a multi-parameter probe (AK88, AKSO), and transparency using the Secchi disk. In the field, biometrics were performed with the specimens of *A. surinamensis*, and the weight (g) and total length (cm) of each individual were measured. This was followed by a ventral incision for stomach extraction. These organs were fixed in 10% formaldehyde and, after 48 hours, were stored in 70% diluted alcohol (Gandini et al., 2012) for subsequent analysis of contents.

Each food item found in the stomachs of the *A. surinamensis* specimens was quantitatively related using the frequency of occurrence method (FO%) (Kawakami and Vazzoler, 1980). Gastric contents were examined using a biological microscope (B60, BIOPTIKA). The food items were identified at the lowest possible taxonomic level, considering the presence of fragments as indicative of the occurrence of a certain food item, the most diluted items were named digested content.

Each item was classified according to the methods proposed by Hyslop (1980), considering: I) frequency of occurrence (FO%), using the equation $FO\% = EA/E$ x 100, where, EA = amount of stomachs with item A, and E = total number of stomachs analyzed. Empty stomachs were considered in the analysis when content was absent. In the seasonal condition analysis of the specimens from the Cujubim Lake and for comparison of individuals with another population of the species, the Fulton condition factor ($K = W/L^3$), and the relative weight (Wr = 100 x ($W/a(L^b)$) were used (Fulton, 1904; Wege and Anderson, 1978), where, W is the weight and L the standard length of the fish. The parameters a (intercept) and b (allometric coefficient) were extracted from the relationship between weight and length of *A. surinamensis* recorded in Fishbase, and which were 0.00960 and 3.010, respectively (Froese and Pauly, 2019). Student's t-test (a = 0.05) was used to compare seasonal differences between individuals in relation to condition factor (K) and relative weight (Wr).

In the evaluation of the effect of the physicochemical variables of water in relation to the condition factor of the captured specimens, permutational multivariate analysis of variance was used (PERMANOVA-Bray-Curtis index obtained with 9999 random permutations), which is a non-parametric method used to test the homogeneity of multivariate dispersions (Anderson et al., 2006). The explanatory variables were pH, electrical conductivity, transparency, temperature, and dissolved oxygen. All estimates were made using the R program (R Core Team, 2021) and for PERMANOVA, the vegan package was used (Oksanen et al., 2018).

The fish collections in this study were authorized by ICMBIO under license number 66945-2 and the research project was approved by the Ethics Committee for Animal Use (CEUA) of the Federal University of Rondônia, under registration number 018/2019.

RESULTS

The confirmation of the species *A. surinamensis* was obtained through the observation of the morphology of the gill rakers and gill arches that exhibited denticles, as described by Bornbusch (1988) for the species (Figure 2).

For the study, 105 stomachs of *A. surinamensis* individuals were analyzed. Of these, 60 of the fish were captured in the flood period and had standard lengths ranging from 5.8 to 8.3 cm (average of 6.09 ± 0.50 cm), while in the drought period, 45 individuals were

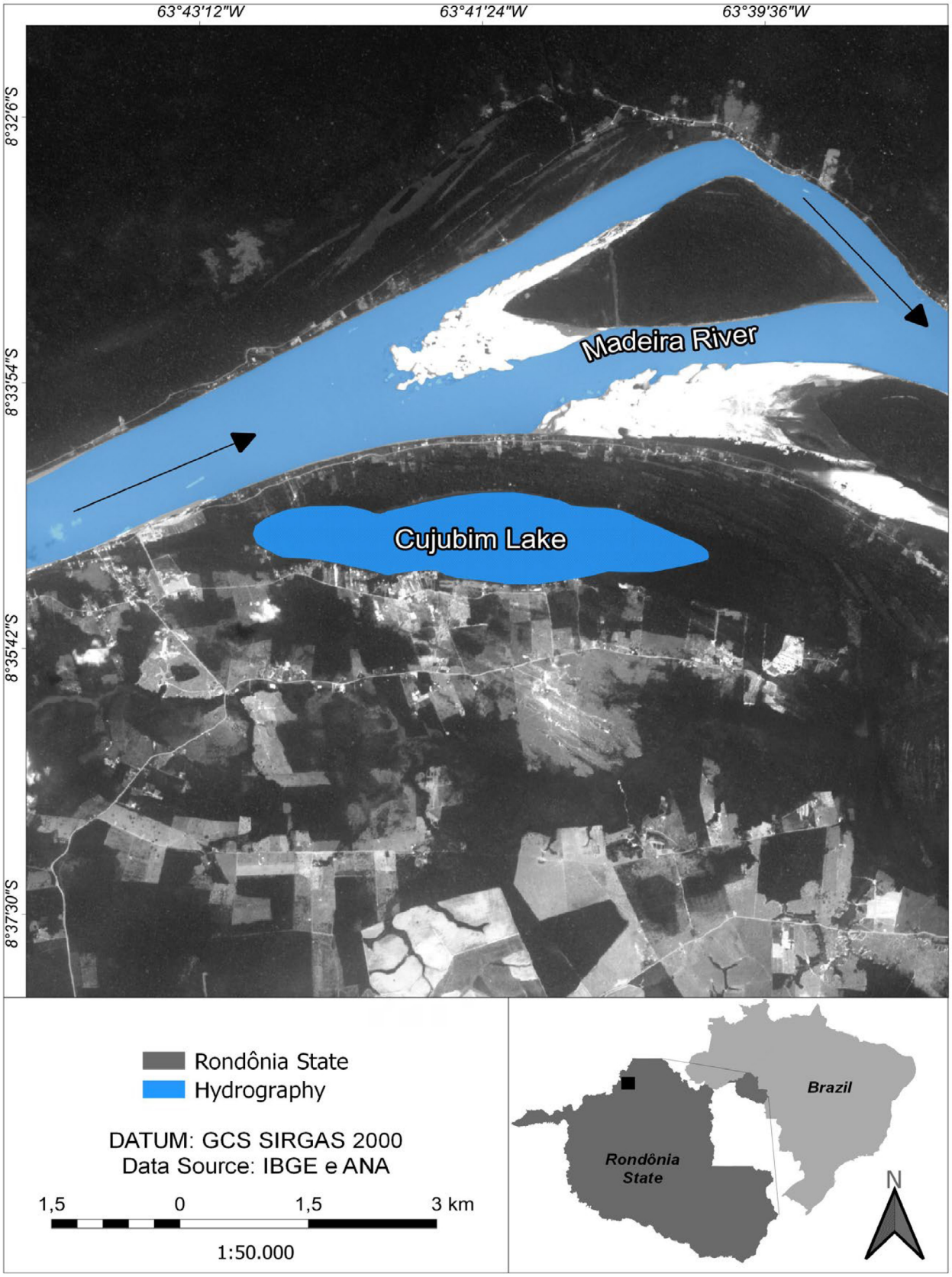

Figure 1. Location of Cujubim Lake in the Madeira River basin (Rondônia, Brazil). Arrows indicate direction of river flow.

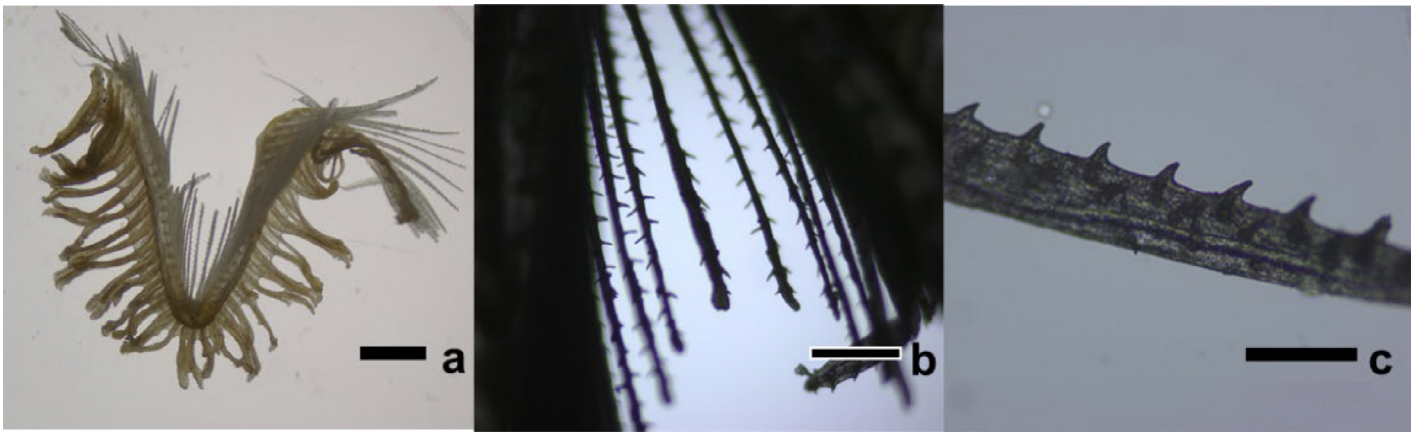

Figure 2. Details of a gill arch with gill rakers and filaments from *A. surinamensis* captured in Cujubim Lake, in the Madeira River basin, Brazil. a = gill arch, b = gill rakers, and c = denticle details. Scale bars = 2.0 mm (a), 0.25 mm (b), and 0.25 mm (c).

obtained (six fish were recorded as having empty stomachs in this period), and which presented the largest lengths, ranging from 6.4 to 15.6 cm (average of 7.80 ± 2.10 cm). The results of the analysis of the diet of the species indicated the predominance of cladocera and bivalves (Figures 3a and 3b). However, crustaceans, sphaeropleales and decapods were also observed and are autochthonous items (items of aquatic origin) (Figure 3).

The food items found in the fish's stomachs were triturated to varying degrees. Of these, only 4.4% were not identified. The items that obtained higher frequency of occurrence (FO%) were cladocera and bivalves, which were present in 100% of the stomachs analyzed during the flood period (N = 60), and 86.7% to 80.0%, respectively, in the drought period (N = 45) (Table 1).

In the periods of flood and drought, significant differences occurred both for the estimates of the condition factor (df = 87.959, t = 2.392, p = 0.019) and for the relative weight (df = 87.660, t = 2.204, p = 0.016) (Figure 4). The means of the condition factor were 1.87 and 1.76 for flood and drought, while for relative weight the mean values were 190.99 g and 179.50 g, respectively (Figure 4).

Table 2 shows the mean and seasonal standard deviations of the physicochemical variables of the water, in addition to the results of the PERMANOVA. In the analysis, a significant relationship was only observed for the pH with the condition factor. The correlations of all variables with the condition factor were low, especially for transparency (r^2 = 0.003).

DISCUSSION

Anchovia surinamensis is often considered to be a planktivorous species (Noveras et al., 2012), possibly because most fish of the family Engraulidae have denticles in the gill rakers (Bornbusch, 1988). These structures function as "combs" and allow the retention of small items during the passage of water between the mouth and the gill chambers, as well as serving as a criterion for the definition of the ecomorphological guild of filter fish (Winemiller, 1991). However, there are records of *A. surinamensis* having diets that are not restrictively planktivorous, and they use different food options in wide dietary variations throughout the seasons (Lowe-McConnell, 1987). This can also occur when the fish are exposed to changes in their natural environment such as the installation of dams, which oblige to fish to live in new environments and forage the available food (Mérona et al., 2001; Mérona et al., 2005).

There are also evolutionary morphological modifications that originate from the dietary apparatus of Neotropical Engraulidae, such as decreasing groups of gill denticles, especially on the underside of the gill rakers, which favor a greater dietary amplitude, which, in this case, can vary from planktivorous to piscivorous (Bornbusch, 1988; Mérona et al., 2001). This author highlighted *A. surinamensis* in this coevolution because the species, in addition to the loss of the denticles of the lower face of the gill rakers, presents more apomorphies, such as the absence of edge denticles of the gill rakers in adults and smaller denticles (although more numerous) in the upper face of the gill rakers, which was observed in the present study.

The dietary diversity observed herein corroborated what has been recorded in the Mahuri River, in French Guiana, by which *A. surinamensis* was classified as non-specialized, since it consumes aquatic invertebrates (54.2%), plankton (25.8%), crustaceans (5.3%) and terrestrial invertebrates (2.6%) (Mérona et al., 2008). Restrictive specialization of the diet in Neotropical fish is feasible only if there is a need for food niche segregation through competition for resources (Winemiller, 1989). The seasonal dynamics of rivers and the multiplicity of food sources in freshwater environments favor generalism as a food strategy and opportunism as a foraging tactic, which is consistent with that which is recorded in the diet of *A. surinamensis* (Mérona et al., 2008).

The condition factor for *A. surinamensis* presented the high values in the flood period (K = 1.87), when the specimens had a more diverse diet. The possibility that this difference may have

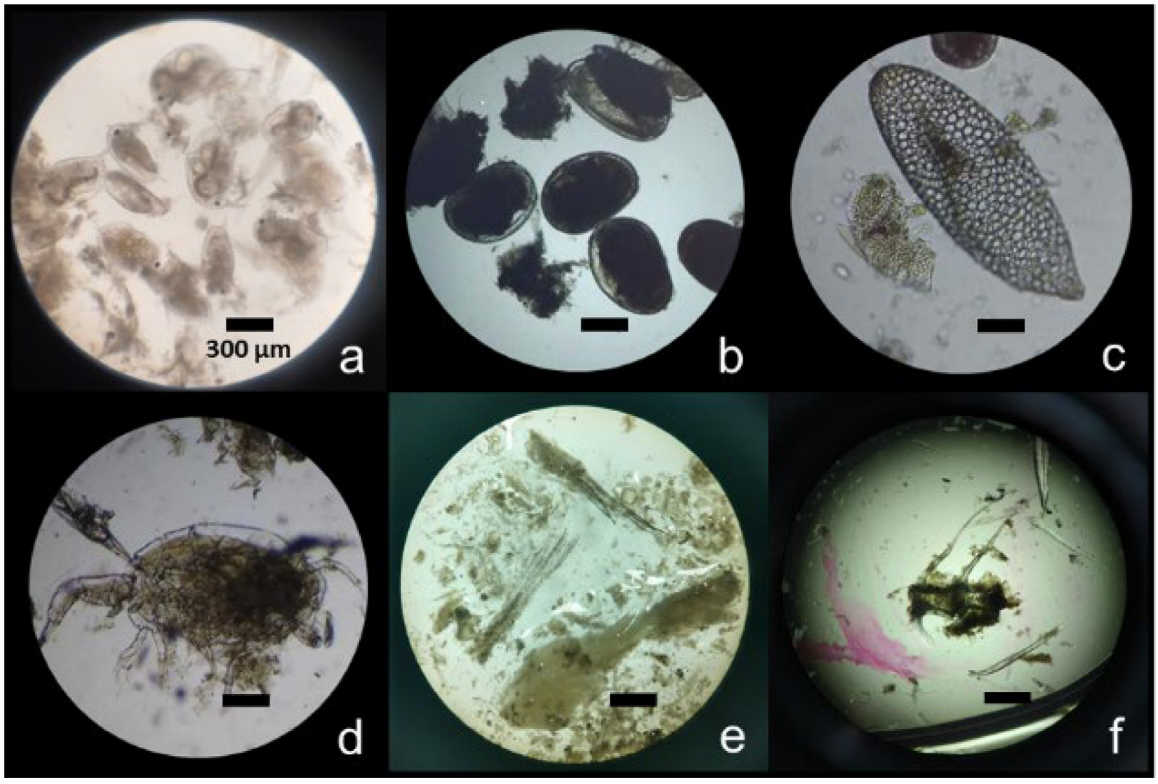

Figure 3. a = cladoceras, b = bivalves, c = sphaeropleales, d = decapods, e = crustacean fragments (shrimps) and f = fish remains (pre-caudal vertebrae of fish). Scale bars represent 300 µm.

Table 1. Absolute frequency (Af) and frequency of occurrence (FO%) of food items (Fi) obtained from *Anchovia surinamensis* from Cujubim Lake, Rondônia, Brazil.

Food items	Seasonal periods					
	Flood			Drought		
	Af	FO%	NFi	Af	FO%	NFi
Cladocera	60	100.0	3,319	39	86.7	3,158
Bivalves	60	100.0	5,957	36	80.0	1,699
Sphaeropleales	30	50.0	62	23	51.1	138
Decapods	57	95.0	583	17	37.8	166
Crustaceans	0	0.0	0	25	55.6	236
Fish remains	0	0.0	0	2	4.4	7

N = number of specimens of each food item.

occurred due to the predominance of males or females in one of the analyzed periods is implausible, although seasonal intraspecific variations of the condition have already been observed for fish due to gender and is related to the spawning period of females (Atobatele and Ugwumba, 2011). However, this statement cannot be confirmed, since in the present study no gender differentiations were made between captured individuals, which may become a topic for future research for this species.

In addition, it should be noted that the physicochemical characteristics of the water of the Cujubim Lake were a considerable factor for the best condition of the individuals, and this was observed during the flood period. Although only the pH has a significant correlation, the electrical conductivity in this period was approximately 25% higher, which may represent a greater availability of nutrients, and which contributes to a greater supply of food resources from plant and animal material carried from the areas surrounding the lake in rainy periods, thus improving feeding (Freitas et al., 2013). Transparency was also 38.6% higher in the flood period, and values below 40 cm for this parameter may represent eutrophication of environments due to the difficulty of light penetration. On the contrary, high transparency values (e.g., 60 cm), will allow the proliferation of aquatic vegetation that will serve as food for the populations and improvement of the condition factor (Feiden et al., 2015).

In general, the other parameters that were evaluated presented results between the optimal values for the permanence of aquatic life in lakes for both the evaluated periods, pH (6.0 – 9.0), temperature (26 and 30°C) and dissolved oxygen (>5.0 mg L^{-1}), (Kodom et al., 2018). Thus, Cujubim Lake and other floodplain lakes may represent favorable environments for the development of *A. surinamensis* and small fish in general, especially in the juvenile phase, a fact that is also evidenced by the values for relative weight estimated in both periods.

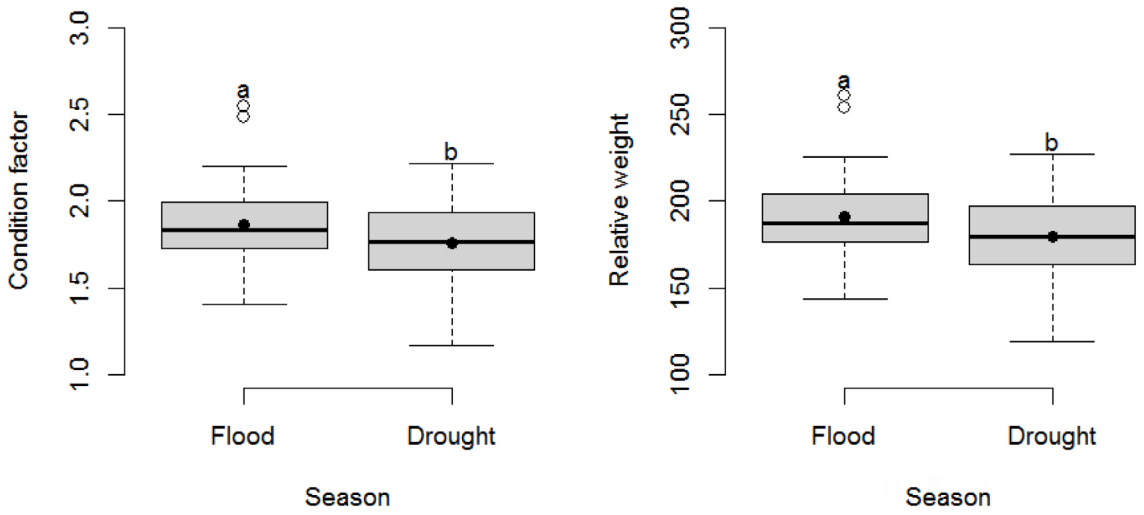

Figure 4. Box diagrams for estimates of condition factor and relative weight of *Anchovia surinamensis* captured in the flood and drought seasons in Cujubim Lake, Rondônia. Black dots correspond to the mean values.

Table 2. PERMANOVA based on Bray-Curtis similarity for condition factor of *Anchovia surinamensis* caught seasonally in Cujubim Lake, Rondônia, Brazil. Factors: pH – Hydrogen-ion potential; EC – Electrical conductivity; Transp – Transparency (depth in cm); Temp – Temperature; DO – Dissolved oxygen; df – degrees of freedom; SS – square sum; r^2 – correlation coefficient; F – pseudo-F; *p*-value.

Variable	Water level seasonality		df	Condition factor			
	Flood	Drought		SS	r^2	F	p
pH	6.68±0.60	6.11±0.74	1	0.026	0.061	6.455	0.012
EC (µS cm^{-1})	38.93±6.30	29.13±1.58	1	0.003	0.008	0.809	0.371
Transp. (cm)	66.11±11.08	40.55±5.80	1	0.001	0.003	0.346	0.563
Temp. (°C)	30.87±0.77	30.05±0.71	1	0.002	0.005	0.517	0.485
DO (mg L^{-1})	6.47±4.76	7.78±1.54	1	0.003	0.006	0.632	0.438
Residual			97	0.392	0.912		
Total			103	0.429	1.000		

The physicochemical analysis of the water of Cujubim Lake was a significant factor that indicated the aquatic living conditions that are essential for the diet of *A. surinamensis*. This confirms it to be a non-specialist planktivore, since several types of food ranging from plankton, crustaceans and small fish were found in the individuals' stomach contents.

ACKNOWLEDGEMENTS

This research was supported by Fundação Rondônia de Amparo ao Desenvolvimento das Ações Científicas e Tecnológicas e à Pesquisa do Estado de Rondônia (Fapero - PAP-INTEC/PISCICULTURA, Processo: 0012427793201817.061/2018). We are also grateful to Netz Consultoria Ambiental em Comunidades Aquáticas Ltd, for identifying some of the items in the stomach contents, providing some of the older bibliographic references, and checking the manuscript.

Conflict of interests

Nothing to declare.

Financial Support

This research was supported by Fundação Rondônia de Amparo ao Desenvolvimento das Ações Científicas e Tecnológicas e à Pesquisa do Estado de Rondônia (Fapero - PAP-INTEC/PISCICULTURA, Processo: 0012427793201817.061/2018)

Authors' Contributions

Sousa, R.G.C.: conceptualization, funding acquisition, investigation, methodology, project administration, visualization, writing – original draft, writing – review & editing. Alves, J.A.: formal Analysis, investigation, methodology, original

draft Writing. Amaral, R.V.A.: Data curation, investigation, methodology, original draft Writing. Lima, S.A.O.: Data curation, formal Analysis, investigation, methodology, Writing – original draft Writing.

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