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Uses of an estuarine amazonian island by the ichthyofauna

ICHTHYOFAUNA FROM AN AMAZONIAN ISLAND: DIVERSITY, REPRODUCTION, AND FEEDING ASPECTS

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Abstract: The high productivity in estuaries supports a high biomass of fishes, making them important environments for feeding, development, and reproduction of larvae and juveniles of many economically and ecologically important species. Many islands compose the landscape of the Amazon estuary given the large deposition of soil caused by the Amazon River waterflow. Given the importance of estuarine environments to coastal ecosystems, this study aims to diagnose the fish community inhabiting a typical island of the Amazon estuary and describe the temporal patterns in community composition, reproductive and feeding activity. Specimens were collected in the main channel and a tidal creek of Onças Island, quarterly between September 2006 and 2008, using gillnets

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and block-off nets. Captured fishes were identified, sexed, measured (total length and weight), had reproductive and feeding activities described, and were classified into environmental and feeding guilds. Abundance and biomass were expressed by the Capture per Unit of Effort in number of individuals (CPUEn) and biomass (CPUEb). The island was characterized as a nursery ground (high abundance of individuals with immature and at maturity gonads), reproduction ground (high abundance of individuals with mature and spawned/spent gonads) and feeding ground (high abundance of individuals with stomachs containing food). A total of 37 species distributed in 21 families and 1,177 individuals were captured. Richness varied significantly throughout the collections but there were no significant differences in fish abundance (CPUEn) or biomass (CPUEb) between periods in any habitat type. Individuals displayed different feeding activity between hydrological periods and feeding guilds. Freshwater species dominated through all collection periods and most species were zoobenthivore, piscivore, or planktivore. Our results indicated that the island serves as a feeding and reproduction ground for several freshwater fish species, possibly reflecting the importance of other islands in Amazonian estuarine systems and highlighting their importance for conservation.

Keywords: Feeding; Guilds; List of species; Nursery; Onças Island.

INTRODUCTION

Estuaries are transition zones between marine and freshwater ecosystems where the salinity is constantly changing (Dame 2008). On average, estuarine waters are biologically more productive than those of rivers and the adjacent ocean due to hydrodynamic characteristics of the circulation, which stimulates productivity by trapping nutrients, algae, and plants on the system (Chilton *et al.* 2021). Due to greater productivity and high environmental variability, estuaries support high abundance and biomass of fishes, generally with dominance of few species adapted to varying

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salinities (Rundle *et al.* 1998; Camargo *et al.* 2003; Castro & Huber 2012), including both secondary freshwater species and primary marine species (Barletta & Lima 2019).

Seasonal changes in the river discharge constantly alter environmental conditions, including salinity, which is a major variable shaping biological communities in coastal areas (Barletta *et al.* 2005; Dantas *et al.* 2010; Vergès *et al.* 2022; Soares *et al.* 2021; Marceniuk *et al.* 2023). For example, freshwater species may use estuaries during the entire year, but they become more abundant during the rainy season when there is increased discharge of continental waters into the estuary. The opposite happens in the dry season, when sea water invades estuaries and primarily marine fishes become more frequent (Potter *et al.* 2010). Therefore, the ichthyofauna that inhabits estuaries as feeding, breeding, and nursery grounds are a combination of freshwater, estuarine resident, and marine species (Selleslagh *et al.* 2009; Pichler *et al.* 2015; Molina *et al.* 2020), of which many are economically and ecologically important (Chaves *et al.* 2002; Franco *et al.* 2008; Guebert-Bartholo *et al.* 2011).

In addition to having high ecological value, estuaries suffer constant anthropogenic pressure (Dias *et al.* 2013, De Araújo-Barbosa *et al.* 2016), which is one of the leading factors in the decline of estuarine biodiversity and habitat quality, leading to the loss of ecosystem services worldwide (Firth *et al.* 2016, Chaudhary *et al.* 2018). Among the multiple anthropogenic impacts that affect estuarine fishes are: (i) overfishing, which contributes to the reduction of fish populations and unbalance of community dynamics (Raz-Guzmán & Huidobro 2002); (ii) biological invasions that interfere with local trophic relationships (Barletta & Lima 2019); (iii) discharges from industrial pollutants, agricultural waste and domestic sewage, damaging water quality and directly threatening the fishes' health (Costa *et al.* 2012); (iv) climate change, including rising water temperatures, ocean acidification, and sea level rise, impacting environmental conditions and the capacity of fishes to deal with seasonal changes (Blaber 2013); and (v) the loss or change of critical habitats, compromising essential areas for reproduction and feeding (Viana *et al.* 2010).

These direct human disturbances also threaten the environmental conditions of the Amazon estuary, the largest in terms of freshwater discharge in the world (Kennish 2002; Latrubesse *et al.* 2017; Lessa *et al.* 2018). The enormous discharge carries considerable amounts of nutrients and organic matter and creates a very unstable coastal region, subject to erosion processes that result in high deposition of soil that contributes to the development of a large number of islands (Lessa *et al.* 2018). Surrounding Belém, one of the largest Brazilian cities in the Amazon that is home for more than 1,3 M habitants (IBGE 2022), extends a set of Amazonian estuarine islands (Gregório & Mendes, 2009) that are inhabited by multiple euryhaline fishes of high commercial value for industrial fisheries and the subsistence of riverside human communities (Bentes *et al.* 2012; Viana & Frédou 2014; Marceniuk *et al.* 2021a; Prestes *et al.* 2022). Since 1980, the region has been subject to the effects of ore and soy outflow through a large port project (CDP 2023), but only in the last decade a rampant tourism started to develop (Nunes & Furtado 2023), and the lack of scientific information about these stressors and its effects in the aquatic environment hamper the development of mitigation and conservation strategies.

Given the importance of understanding how species use different ecosystems and their responses to environmental changes (Beck *et al.* 2003), this study aims to analyze the fish community inhabiting an Amazonian island under anthropogenic activities, using a dataset prior to the recent intensification of the described impacts. We tested the hypothesis that the island served as a nursery area, feeding, and breeding ground for fish species, and we expect to generate a baseline to understand how the establishment and intensification of threats will affect the local ichthyofauna.

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MATERIAL AND METHODS

Study area

The Onças Island, it is approximately 19 km long, and is part of the Barcarena County in the state of Pará and is at 2.5 km northwest of the capital Belém by waterway (). The climate is tropical type Af in the Köppen system (Peel *et al.* 2007), and during the collection period the accumulated values of monthly rainfall in the capital Belém showed a pattern similar to the mean climate based on the average of the last 30 years (INMET 2013), with well-defined rainy (March), rainy/dry (June), dry (September), and dry/rainy (December) periods.

Water temperature (28.6 ± 0.65 °C), pH (6 ± 0.45), and salinity (0 ppm) do not show significant variation throughout the year. Tidal variation is the most striking environmental factor in the region, reaching up to 3.6 m in spring tide conditions (Gregório & Mendes 2009) and creating multiple tidal channels that cross the island. Tidal channels, hereafter named as tidal creeks, are narrow inlets near marine coastlines exhibiting water fluctuations and currents according with the tide regimen, and are very common in estuarine islands (Healy, 2005).

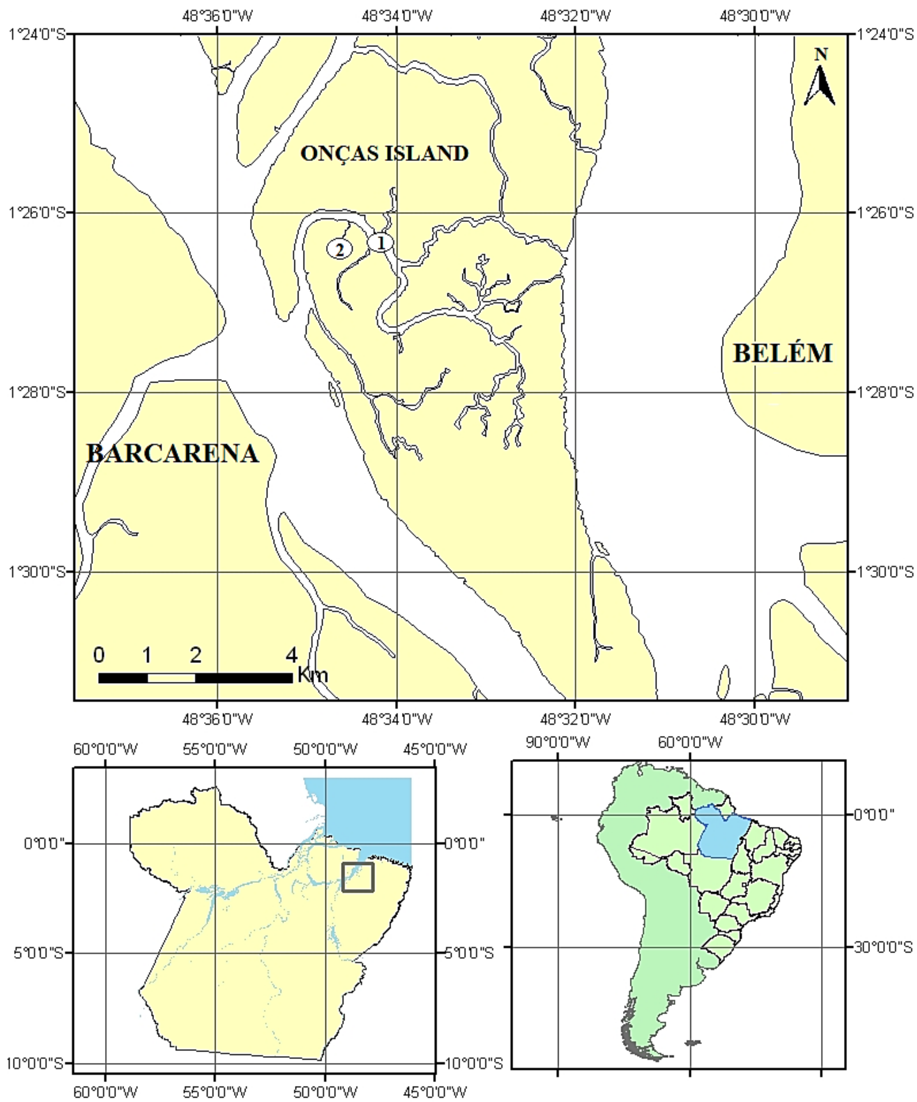

Figure 1. Sampling stations in the (1) Main Channel and (2) Tidal Creek in Onças Island, Pará, Brazil.

Sampling and Laboratorial Procedures

At the tidal creek, sampling was carried out quarterly between September 2006 and 2008 in nights of spring tide using a block nylon multifilament net (35 m x 7 m and 0.75 mm knot-to-knot mesh) set at the mouth of a creek (Figure 1, Site number 2). At the river channel, sampling was carried out quarterly between September 2007 and 2008 in nights of spring tide using monofilament nylon gill nets (knot-to-knot meshes of 25 mm, 30 mm, 40 mm and total length of 210 m) set in three different points at the river channel (Figure 1, Site number 1). Different knot-to-knot mesh sizes were selected for each environment because small fishes tend to avoid open waters and nets with small knot-to-knot mesh sizes could be damaged and/or obstructed with the high volume of debris in the main channel. The block net was fixed to the bottom of the creek during the low tide and raised during high tide while buoyancy devices allowed them to occupy the entire water column when the water levels increased, then capturing all individuals that entered the habitat for approximately 12 hours. The main channel was sampled twice per sampling expedition, with nets being underwater for nine hours each, between 6 am and 6 pm.

Individuals were captured under the SISBio collection license number 17250-1 and identified according to the identification guide of Van Der Sleen and Albert (2017) and with the help of experts for each taxonomic group. In the laboratory, specimens had their total length (TL; 0.1 cm) and total weight (TM; 0.1 g) measured. One ventral-longitudinal incision was performed to remove the gonads and stomachs. The gonadal development was classified using a macroscopic scale adapted from Núñez and Duponchelle (2009): A – immature (Females: small, circular, thin, and pinkish ovaries with no oocytes visible to the naked eye; Males: small and silvery/translucent testes); B – maturing (Female: bigger ovaries filled with white or yellowish oocytes of different sizes; Male: testes are longer and with whitish to pinkish color); C – mature or ripe (Female: the ovary reaches its maximal development and the oocytes can be expelled with a light pressure; Male: testes are fuller, completely white, and sperm can be expelled with a light pressure); and D –spent (Female: ovaries are empty, often bloody, with ripe oocytes still visible; Male: large, flaccid and empty testes). The macroscopical characterization of gonadal stages is proven effective for several fish species and the estimation of reproductive parameters such as the length at first maturity (Hashiguti *et al.* 2017; 2019; Soares *et al.* 2020), especially for community-level approaches and studies with budget and logistic limitations.

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For feeding aspects, our objective was exclusively to assess whether individuals were feeding in the main channel and/or accessing tidal creeks to feed, and the stomachs were categorized according to the repletion degree as "with food" (WF) and "no food" (NF, the absence of organic material in stomach content). Although stomach content analysis provides a narrow view of recent food items, it is still a common and widely accepted method for categorization (Amundsen and Sánchez-Hernández, 2019).

Data analysis

Species diversity was characterized by the number of species (observed richness), the equity in the distribution of individuals among species (Pielou's evenness, J), abundance, and biomass. Using each sampling event in main channel and tidal creek as samples, observed richness was tested using a Kruskal-Wallis test (H) with 5% significance level, followed by Dunn's multiple comparisons test (Dunn 1961) for significative results. Considering the differences in sample size and sampling effort between habitat type (tidal creek and main channel), we chose to use an individual-based (based on the abundance of the community standardized by the smallest number of individuals) rarefaction method with the iNEXT package (iNterpolation and EXTrapolation) in the R program (R Core Team 2022), using the Hill number estimator for species richness (q=0) (Hill 1973), to compare communities between habitat types. The Capture per Unit of Effort in number of individuals (CPUEn) and biomass (CPUEb) were calculated using the following equations: $CPUEn = \left({}^{n}/_{A * t}\right) * 100$ and $CPUEn = \left({}^{b}/_{A * t}\right) * 100$ where A = the net area (m^2) and t = the immersion time (hours). Differences in CPUEn and CPUEb between grouped hydrological periods (rainy, rainy/dry, dry, and dry/rainy) for each habitat type (main channel and tidal creek) were tested by Analysis of Variance (ANOVA), followed by a Tukey post-hoc for significative results (Zar 1996).

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The habitat type was classified as a reproduction site for the species that displayed significant amounts of individuals with mature (C) and spent (D) gonads; and as feeding area characterized by the predominance of individuals with stomachs with food (WF). The frequency of feeding (WF vs. NF) and reproducing (A/B vs. C/D) fish was compared using chi-squared tests across hydrological periods and habitat type. The effect of the trophic group over feeding individuals was evaluated using the percentage of stomachs with organic content (WF) for each feeding group using an ANOVA. Species were classified in feeding (DV: detritivore; OV: omnivore; PL: planktivore; PV: piscivore; CV: carnivore; HV: herbivore and ZB: zoobenthivore) and environmental guilds (ES: estuarine; FS: freshwater; FM: freshwater migrants) according to Franco *et al.* (2008) and Fishbase (Froese & Pauly 2018). Differences in feeding guilds (abundance) by collection periods (rainy, rainy/dry, dry, and dry/rainy) and habitat type (main channel and tidal creek) were tested by a PERMANOVA using a Bray Curtis similarity matrix (Zar 1996). All analyzes were carried out using the R program (R Core Team 2022) using the “vegan” package (Oksanen *et al.* 2019), with a significance level of 5%.

RESULTS

A total of 1,177 individuals belonging to 37 species and 21 families were captured (Table 1 and Appendix A), with 25 species captured at the main channel (9 exclusive) and 27 captured at the tidal creek (12 exclusive). The Aspredinidae, Sciaenidae and Pimelodidae families correspond to 65% of all collected individuals. Evenness ($J = 0.7 \pm 0.1$) was similar throughout collection period, but observed richness was significantly higher in March 2008 (Appendix A; $H = 18.02$; $p = 0.0009$). The rarefied richness was similar between habitat types (overlapping confidence intervals), with an estimate of 39 species for the island with an increase effort (main channel = 29 and tidal creek = 30; Appendix B). There were no significant differences in the fish abundance (CPUEn) or biomass (CPUEb) between periods in any habitat type (Figure 2).

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Table 1. Species captured, range in total length (TL), feeding species (WF), gonadal development (A/B: Immature and maturing, C/D: mature and spent) feeding (PV: Piscivore; OV: Omnivore; HV: Herbivore, PL: Planktivore; ZB: Zoobenthivore, DV: Detritivore) and environmental guilds (ES: Estuarine, FS: Freshwater, FM: Freshwater Migrants), and place of occurrence on Onças Island, Pará, Brazil.

Order, Family and Species	TL	WF	Gonadal development		Feeding Guild	Environmental Guild	Main Channel	Tidal Creek	Total
			A/B	C/D					
ACANTHURIFORMES									
Sciaenidae									
Micropogonias furnieri (Desmarest, 1823)	15.5-24.5	46.67%	80%	20%	ZB	ES	15		15
Pachypops fourcroi (Lacepède, 1802)	11.5-17.5	18.75%	25%	75%	ZB	FS	6	10	16
Plagioscion squamosissimus (Heckel, 1840)	13-30	75.85%	63.3%	36.7%	PV	FS	76	142	218
BELONIFORMES									
Belonidae									
Strongylura timucu (Walbaum, 1792)	34-34	0.0%	100%	0.0%	PV	ES	1		1
CHARACIFORMES									
Characidae									
Psalidodon aff. *fasciatus* (Cuvier, 1819)	6.7-11.5	25.0%	87.5%	12.5%	ZB	FS	1	11	12
Curimatidae									
Curimata inornata Vari, 1989	13-17.5	71.43%	100%	0.0%	HV	FS	7		7
Erythrinidae									
Hoplias malabaricus (Bloch, 1794)	17.4-20	33.33%	66.67%	33.33%	PV	FS		3	3
CICHLIFORMES									
Cichlidae									
Cichla ocellaris (Bloch & Schneider, 1801)	21-50	100%	50%	50%	PV	FS	1	1	2
Crenicichla semifasciata (Heckel, 1840)	23.5-36	33.33%	33.33%	66.67%	PV	FS	1	2	3
Geophagus gr. *altifrons* Heckel, 1840	14-19	0.0%	90%	10%	DV	FS	1	16	17
CLUPEIFORMES									
Engraulididae									
Anchovia surinamensis (Bleeker, 1865)	10-22	73.68%	45%	55%	PL	ES	2	18	20

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Order, Family and Species	TL	WF	Gonadal development		Feeding Guild	Environmental Guild	Main Channel	Tidal Creek	Total
			A/B	C/D					
Lycengraulis batesii (Günther, 1868)	8-24	22.62%	82.89%	17.11%	ZB	FM	46	39	85
Pristigasteridae									
Pellona flavipinnis (Valenciennes, 1837)	17-42.7	66.67%	100%	0.0%	PV	FM	6		6
GYMNOTIFORMES									
Gymnotidae									
Gymnotus gr. *carapo* Linnaeus, 1758	-	100%	100%	0.0%	PV	FS		1	1
Hypopomidae									
Steatogenys elegans (Steindachner, 1880)	22-22	0.0%	100%	0.0%	-	FS		4	4
Rhamphichthyidae									
Rhamphichthys rostratus (Linnaeus, 1766)	55-77	100%	60%	40%	ZB	FS		6	6
Sternopygidae									
Sternopygus macrurus (Bloch & Schneider, 1801)	38.5-39.7	100%	100%	0.0%	-	FS		2	2
Sternopygus sp.1	10.3-22.5	0.0%	100%	0.0%	-	FS		25	25
Sternopygus sp.2	32.4-46	87.5%	50%	50%	-	FS		8	8
PLEURONECTIFORMES									
Cyclopsettidae									
Citharichthys spilopterus Günther, 1862	19-19	33.33%	100%	0.0%	ZB	FM	2	2	4
SILURIFORMES									
Aspredinidae									
Aspredo aspredo (Linnaeus, 1758)	18-21	47.14%	84.62%	15.38%	ZB	ES	301		301
Aspredinichthys filamentosus (Valenciennes, 1840)	1-20.5	100%	50%	50%	ZB	ES	2		2
Auchenipteridae									
Ageneiosus aff. *ucayalensis* Castelnau, 1855	13-27.5	63.54%	100%	0.0%	ZB	FS	14	82	96
Trachelyopterus galeatus (Linnaeus, 1766)	14.4-23.2	80%	100%	0.0%	OV	FS		5	5
Doradidae									

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Order, Family and Species	TL	WF	Gonadal development		Feeding Guild	Environmental Guild	Main Channel	Tidal Creek	Total
			A/B	C/D					
Lithodoras dorsalis (Valenciennes, 1840)	12-62.5	100%	100%	0.0%	OV	FS	2	45	47
Heptapteridae									
Pimelodella cristata (Müller & Troschel, 1849)	11.5-26.6	82.35%	63.33%	36,67%	ZB	FS		34	34
Loricariidae									
Peckoltia sp.1	11-13	0.0%	100%	0.0%	DV	FS	2		2
Peckoltia sp.2	13.5-13.5	0.0%	100%	0.0%	DV	FS		1	1
Ancistrus sp.1	10-12	25.0%	33.33%	66.67%	DV	FS	3	1	4
Pseudacanthicus spinosus (Castelnau, 1855)	13-13	0.0%	100%	0.0%	DV	FS	1		1
Loricaria cf. *cataphracta* Linnaeus, 1758	14-19	0.0%	100%	0.0%	DV	FS	1	3	4
Pimelodidae									
Brachyplatystoma rousseauxii (Castelnau, 1855)	17.5-17.5	100%	100%	0.0%	PV	FM	1		1
Brachyplatystoma vaillantii (Valenciennes, 1840)	32-38	100%	100%	0.0%	PV	FM		2	2
Hypophthalmus marginatus Valenciennes, 1840	13.5-44.5	35.44%	100%	0.0%	PL	FS	8	200	208
Sorubim lima (Bloch & Schneider, 1801)	28-34	100%	50%	50%	CV	FS	2		2
Pimelodidae									
Pimelodus blochii Valenciennes, 1840	16.5-27.5	100%	66.67%	33.33%	ZB	FS		9	9
TETRAODONTIFORMES									
Tetraodontidae									
Colomesus asellus (Müller & Troschel, 1848)	5.5-13	0.0%	33.33%	66.67%	OV	ES	2	1	3
Total Geral							**504**	**673**	**1177**

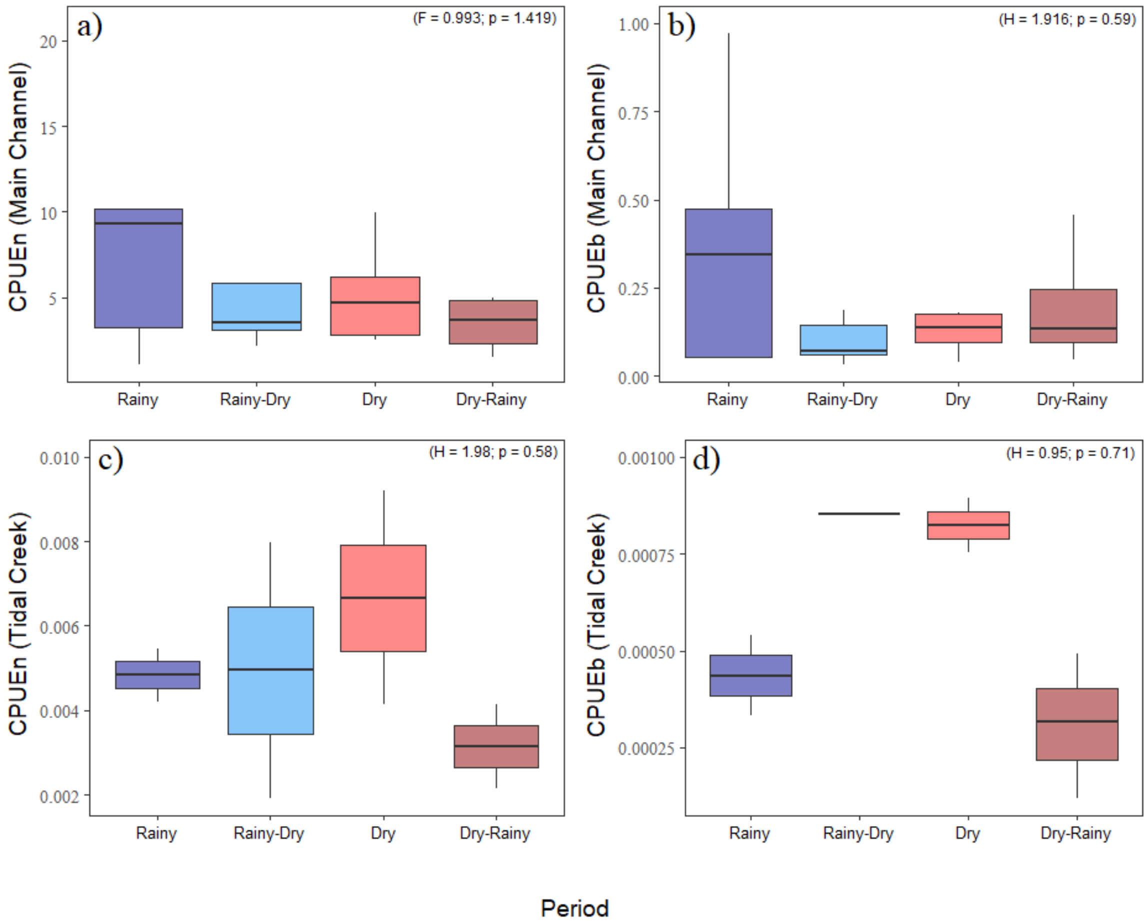

Figure 2. Capture per unit of effort in number (CPUEn) and biomass (CPUEb) by collection period (Rainy, transition from Rainy to Dry, Dry, and transition Dry to Rainy) and habitat type (Main channel and Tidal Creek), between September 2006 and September 2008, Onças Island, Pará, Brazil.

In terms of abundance and biomass, the most representative species in the main channel and tidal creek were similar, in except for *Lithodoras dorsalis* and *Aspredo aspredo*, which were one of the most representative ones in tidal creek and main channel, respectively (Figure 3). In general, the species caught were small and medium-sized or juveniles of larger species, with approximately 80% specimens with less than 25 cm total length (Appendix C), with a predominance of females (67%) and immature individuals (A = 64%). The creek harbored a higher number of immatures and feeding individuals than the main channel, as well as larger and heavier specimens (Table 2). The island serves as reproduction area for 19 species, functioning both as nursery and reproduction grounds.

Table 2. Distribution of the ichthyofauna sex (M – Male, F- Female), Total Length in cm (TL), Total Weight in grams (TW), gonadal development (A - immature, B - at maturity, C – mature, and D – spawned or spent) and feeding behavior (NF - No Food, WF - With Food) among environments at Onças Island, Pará, Brazil.

Environment	Sex	TL (SD)	TW (SD)	Gonadal Development (%)				Feeding (%)	
				A	B	C	D	NF	WF
Tidal Creek	F = 74.34	22.9 ±9.87	102 ±156.88	42.86	17.86	38.1	1.19	34.51	65.49
	M = 25.66	22.1 ±8.67	112.1 ±248.9	57.47	27.59	14.94	0	28.74	71.26
	Total	**23.18 ±9.09**	**109.81 ±199.69**	**71.7**	10.73	17.11	0.47	42.84	**57.16**
Main Channel	F = 60.18	16.04 ±4.6	34.3 ±72.12	28.36	36.82	34.33	0.5	45.36	54.64
	M = 39.82	17.1 ±3.37	46.2 ±55.14	55.64	41.35	3.01	0	52	48
	Total	15.91 ±4.53	31.60 ±58.79	52.66	30.23	16.98	0.23	54.12	45.88
Tidal Creek and Main Channel	**F = 67.36**	19.9 ±8.54	72.1 ±130.09	36.42	26.27	36.42	0.88	39.2	60.8
	M = 32.64	18.9 ±6.36	72.2 ±165.44	56.36	35.91	7.73	0	42.45	57.55
	Total	19.89 ±8.22	76.32 ±160.50	**64.03**	18.55	17.05	0.37	40.24	**59.76**

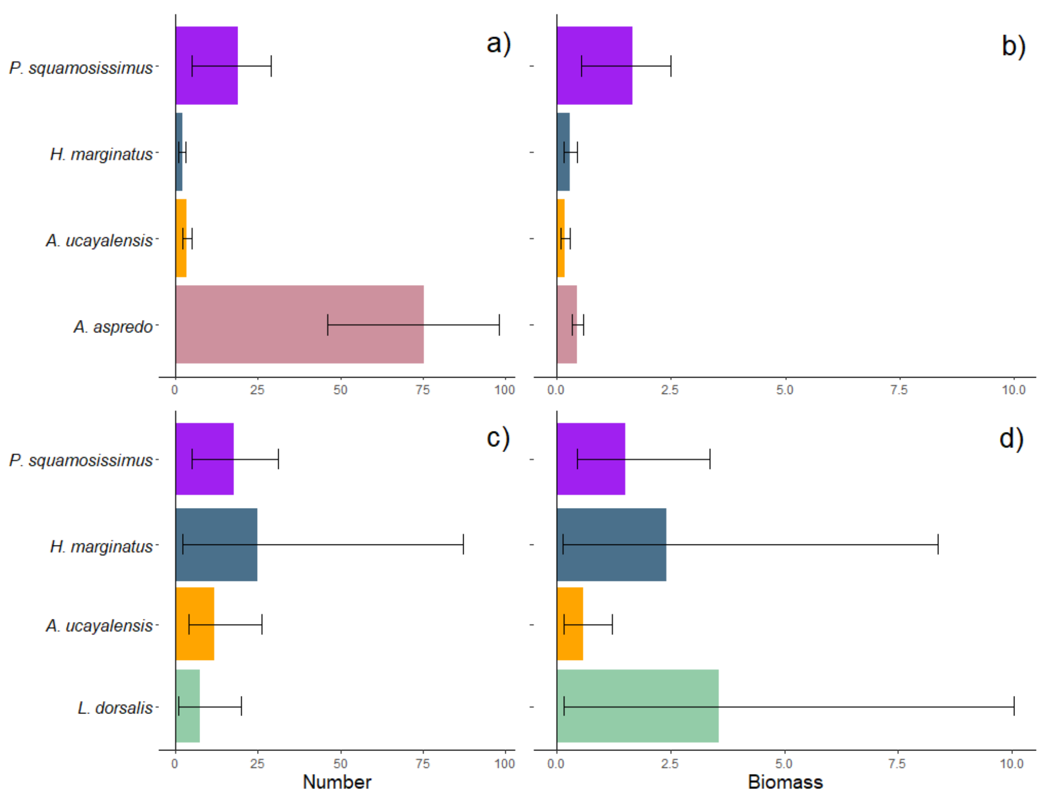

Figure 3. Percentage of the species with greater numerical and biomass participation in the main channel (**a and b**), and tidal creek (**c and d**), collected between September 2006 and September 2008, Onças Island, Pará, Brazil.

Among the 1,149 stomachs analyzed, approximately half presented stomach content (WF = 59%). Individuals fed differently throughout hydrological periods ($x^2 = 24$; $p < 0.001$) with higher amount of feeding individuals in September 2007 (dry period); habitat type ($x^2 = 5.40$; $p = 0.02$), with more feeding specimens in the tidal creek; and feeding guilds (F = 11.1; p <0.0001), with carnivores (WF = 100%), omnivores (WF = 92.73%), piscivores (WF = 74.9%), and herbivores (WF = 71.43%) presenting more than half of individuals with stomach contents (Appendix D).

The abundance of environmental guilds was similar over hydrological periods (F = 0.16; p = 0.96) but significantly different when comparing habitat type (F = 15.6; $r^2 = 0.6$; p = 0.002). Freshwater species (FS) were dominant through all collection periods in the tidal creek while estuarine species (ES) were dominant in the main channel (Figure 4). Most species were zoobenthivorous (ZB = 52%), piscivorous (PV = 20%), or planktivorous (PL = 19%) in the Onças Island (Figure 5). The abundance of feeding guilds differed between habitat types (F = 7.03; $r^2 = 0.41$ p = 0.007), but not through the year (F = 0.642; $r^2 = 0.19$ p = 0.893), with greater abundance of zoobenthivorous species in the main channel and zoobenthivorous, piscivorous, and planktivorous species well distributed in the tidal creek (Figure 6).

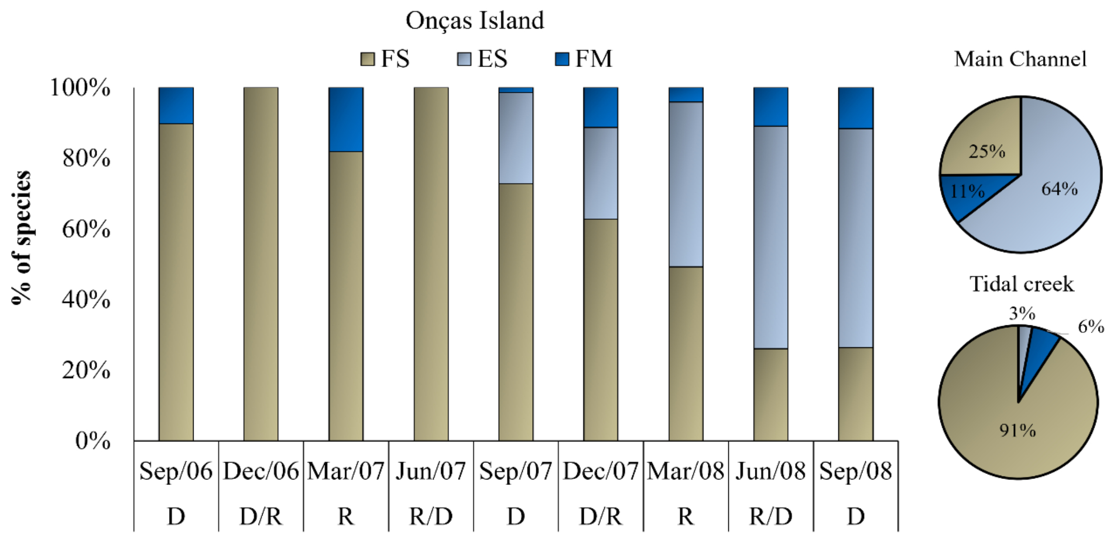

Figure 441: Percentage of environmental guilds: (ES) estuarine species; (FS) freshwater species and (MM) marine migrants by dry (D), dry/rainy (D/R), rainy (R), and rainy/dry (R/D) periods, between September 2006 and September 2008, at Onças Island, Pará, Brazil.

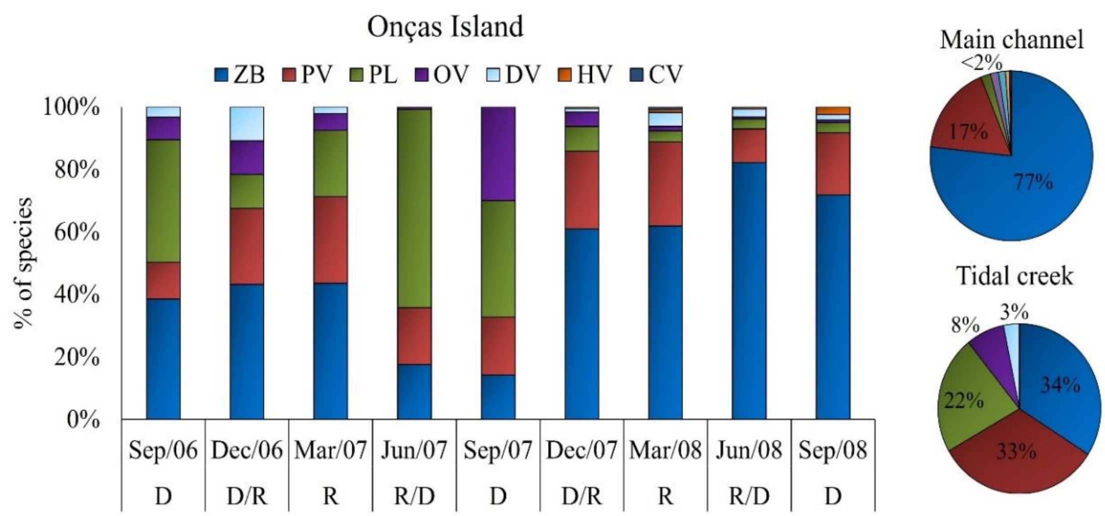

Figure 55. Percentage of feeding guilds DV: detritivorous; OV: omnivorous; PL: planktivorous; PV: piscivorous; CV: carnivorous; HV: herbivorous and ZB: zoobenthivorous by dry (D), dry/rainy (D/R), rainy (R), and rainy/dry (R/D) periods, between September 2006 and September 2008, at Onças Island, Pará, Brazil.

DISCUSSION

The Onças island is strongly influenced by the Guajará Bay, featuring an environment influenced by continental waters and zero salinity, that served as a nursery, reproduction ground, and feeding ground for fishes, with individuals feeding differently throughout hydrological periods and feeding guilds. Richness varied significantly between periods, but there were no differences in the fish abundance (CPUEn) or biomass (CPUEb) between periods in any habitat type. Freshwater species dominated through all collection periods and most species were zoobenthivore, piscivore, or planktivore.

The observed richness of Onças Island (S = 37) was low compared with estuaries receiving a stronger marine influence in the Amazon (73 species at the Curuçá River in Hercos 2006, 40 species at the Guajará Bay in Viana *et al.* 2010, Guajará and 108 species at the Marajó Bay and 94 ate the Guajará Bay in Mourão *et al.* 2015) and other regions (79 species at the Paraná Estuary in Barletta *et al.* 2008, 122 species at the Itapissuma, Suape, Sirinhaém, and Rio Formoso in Merigot *et al.* 2017, 102 species at the São Francisco River in Silva *et al.* 2023). No significant differences in the fish number and biomass were observed over time, which could be a result of three factors. First, a very dynamic and highly disturbed surrounding area with strong tidal currents and wind generated waves (Pinheiro 2002, Ribeiro 2004) that may work as a geographic barrier. Second, the null salinity, since salinity is one of the most important environmental variable influencing fish assemblage and structure in estuaries (Bulger 1993, McLusky & Elliot 2004, Harrison & Whitfield 2006), where fish richness, abundance and biomass tend to increase with the rise in salinity at the lower estuary (predominance of marine species) and decrease with the river input at the upper estuary (predominance of freshwater species) (Whitfield & Harrison 2003, Kolpakov & Milovankin 2010, Whitfield *et al.* 2012). Third, sampling limitations, since we did not use other fishing gears (e.g. longlines and trawl nets) and sampled only on a few sites in the island (e.g. more tidal creeks and river channels). By doing so, abundant species in the region, such as *Cynoscion acoupa*, *Menticirrhus americanus*, *Plagioscion surinamensis*, *Stellifer microps* and *S. rastrifer* (Mourão *et al.* 2014), could possibly be registered.

The predominance of females among the captured species corresponds to the expected tendency of females to remain in estuarine systems (Secor 1999, Bartulović *et al*. 2004, Walsh *et al*. 2004, Callihan *et al.* 2013, Earl 2014), and the presence of 64% of immature individuals captured supports the idea of these areas as natural nurseries, important habitats for the life cycle of many fish species, providing protection against predators and food availability (Beck *et al.* 2001, Barletta *et al.* 2010, Barros *et al.* 2011). When comparing environments, the tidal creek presented a higher number of immature, mature, and feeding individuals than the main channel, as well as larger and heavier specimens, mostly caused by the presence of large immature *L. dorsalis* individuals in the creek, and of *A. aspredo* in the main channel, a small sized species. The use of estuarine streams as breeding areas was also observed in Viana *et al.* (2010) and Mourão *et al.* (2015). This difference suggests that the stream environment may offer more suitable conditions for the growth, feeding, and development of juvenile fish (Muller & Strydom 2017, James *et al.* 2019). Preserving and conserving these creeks can be crucial to ensuring successful reproduction and recruitment of new individuals to fish populations.

The freshwater environmental group (FS) was dominant during the study period, followed by estuarine species (ES) that can get around throughout the estuary. This might be explained by the fact that this island presents weak marine influence due to the huge discharge of freshwater, with null salinity but still subject to tidal influence. This riverine dominated system can be classified as a river-mouth estuary (Whitfield & Elliott 2011), where conditions can range from freshwater (<0.5 salinity) to oligohaline waters (0.5 – 4.9 salinity) (Whitfield 2015), which selects freshwater and excludes most estuarine and marine species.

Seven different trophic guilds were observed at Onças Island, wherein zoobenthivores and piscivores predominated throughout the year, corroborating with what is observed at most estuaries (Blaber 2008, Barletta & Blaber 2007, Franco *et al.* 2008, Ferreira *et al.* 2019). Categorizing communities into trophic groups can help simplify the complexity of certain communities and help understand different ecological processes (Austen *et al.* 1994, Benoit *et al.* 2021). In addition, as the number of trophic guilds and their spatial and temporal variations are positively linked to habitat integrity and structure (Elliot *et al.* 2007, Henriques *et al.* 2008, An *et al.* 2013, Mourao *et al.* 2014), the Onças Island can possibly be considered a healthy environment with good integrity.

Plankton carries out an important role in estuaries, which present the bigger productivity in all marine and estuarine ecosystems: the inorganic carbon and nutrients consumed by phytoplankton is linked to the higher trophic levels by zooplankton, a secondary consumer that serves as the major food source for higher trophic species, including commercial fishes (Selleslagh *et al.* 2012, Mitra & Zaman 2016). Accordingly, zoobenthivore species were dominant in all hydrological periods and habitat types in the Onças Island, but the presence of planktivorous species was higher in the tidal creek when compared to the main channel, mostly during dry periods, which is expected, since their main source of food is more abundant at this time of year (Breckenridge *et al.*, 2015). During the dry season, the volume of water inflow into the Guajará bay becomes smaller due to the reduced rainfall, expanding the photic layer and increasing phytoplankton productivity (Lancelot & Muylaert 2011, Cavalcanti *et al.* 2020). Moreover, the highly abundant aquatic insects, annelids, and crustaceans in Amazonian estuarine environments (da Rocha Leite *et al.* 2013, Filho & Aviz 2013) may use the protection from tidal creeks to spawn (Lucena-Fredou *et al. 2010*, Nóbrega *et al.* 2013; 2014), which may increase the intake of zooplankton by zoobenthivore and planktivore species. Furthermore, planktivore fishes are important to the ecosystem by being the main prey for piscivorous fishes and controlling plankton populations (Soe *et al.* 2021).

Previous studies in other Amazonian estuarine ecosystems have showed changes in the composition of fish communities between seasons (Barthem 1985; Barletta *et al.* 2003; Camargo & Isaac 2001; Hercos 2006, Begot *et al.* 2016), but in Onças Island the variation in the relative abundance of freshwater and estuarine species through the year was small. In conclusion, the Onças Island serves as nursery, reproduction, and feeding area. The results were similar to those found in adjacent areas of Onças Island, such as Guarajá Bay and Guamá River (Mourão *et al.* 2014; Mourão *et al.* 2015; Viana *et al.* 2010). When compared to Amazonian estuaries with greater marine influence, the island showed less diversity because, in these environments, the higher salinity favors a greater diversity of species (Kennish 1986; Marceniuk *et al.* 2021b). The Onças Island is important to the development of several fish species, possibly reflecting the importance of the other islands in Guarajá

Bay and other similar Amazon systems, highlighting the need of conservation strategies that reduce anthropogenic impacts on these areas.

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SUPPLEMENTARY MATERIAL

Appendix A. Monthly general data of precipitation, richness, abundance, and evenness of fish collected between September 2006 and September 2008, Onças Island, Pará, Brazil.

Appendix B. Rarefaction analysis presenting the interpolation with observed data (solid lines) and extrapolation (dotted lines) curves using Hill-number for species richness (q = 0) by habitat type (Main Channel, Tidal Creek, and the Onças Island), Pará, Brazil. Shaded areas represent 95 % confidence intervals.
Appendix C. Total length frequency of captured fish, presented by class intervals (5cm), between September 2006 and September 2008, Onças Island, Pará, Brazil.
Appendix D. Percentage of individuals with any amount of visible organic material in the stomach (With food) for each feeding guild (CV: Carnivore, OV: Omnivore, PV: Piscivore, HV: Herbivore, ZB: Zoobenthivore, PL: Planktivore; DV: Detritivore), in fish collected between September 2006 and September 2008, Onças Island, Pará, Brazil.

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