Human land use drives to trophic structure change of apex fish in Neotropical wetlands

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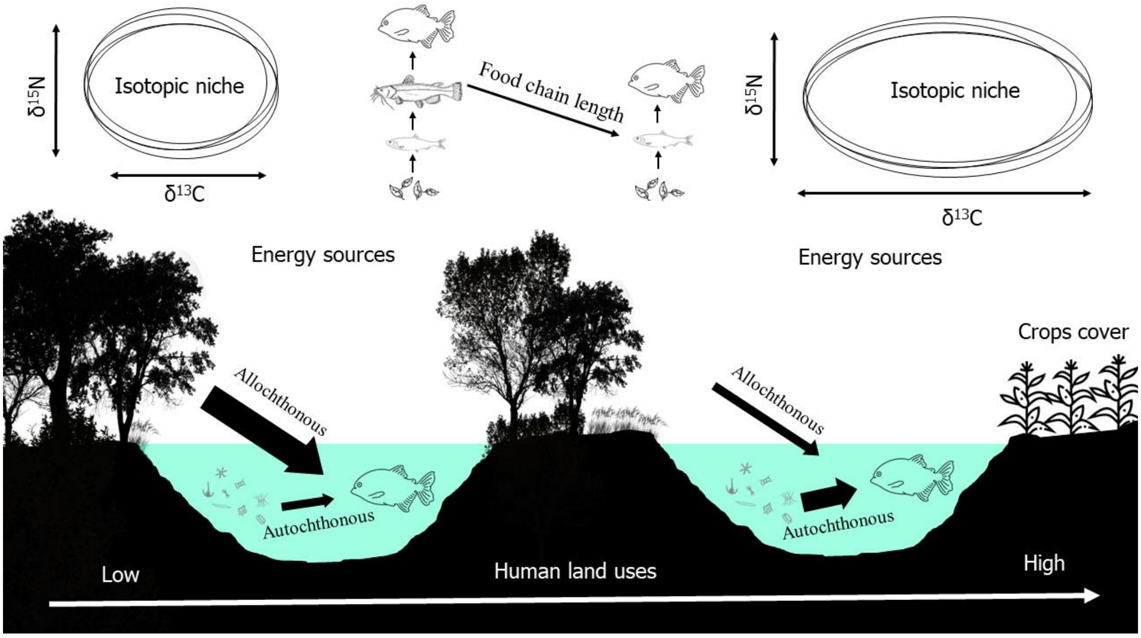
Graphic abstract



Highlights

- Effect of human land use by multiple pathways on wetlands trophic structure;

- Agribusiness is invading the Brazilian wetlands;

- Deforestation is decreased availability of the main energy source for apex fish;

- Landscape-scale human pressures determine the trophic structure of apex fish;

- Brazilian law is not enough to protect their wetland’s trophic structure;

Abstract

The conversion of natural remnants to human land use is a primary catalyst for biodiversity loss worldwide, resulting in trophic structure changes in ecosystems. This study aimed to investigate the percentage of human land use at multiple spatial scales, trophic state and environmental size and its potential relationship with basal energy sources, food chain length (FCL), and the isotopic niche for apex fish in four large neotropical wetlands. The hypothesis postulates that: (i) increased human land use will be negatively associated with the contributions of allochthonous energy sources, FCL, and the isotopic niche; (ii) the trophic state will be directly associated with an FLC, autochthonous energy source and niche area and; (iii) the environmental size will determine the FCL. Evidence reveals that C_3 riparian vegetation is the primary energy source for apex consumers. As also, human land uses are indirectly associated with allochthonous basal energy source assimilation and directly with niche area. The FCL was lower in environments with greater human land use and, as also the allochthonous energy source assimilation exerces an important role in FCL. Therefore, conserving riparian vegetation surround water bodies is a crucial protective factor for these environments, as it serves as the primary energy source for food webs. The decrease in FCL with the increase in human activities demonstrates the sensitivity of these environments to trophic link losses due to human invasion. Conversely, the growth in isotopic niche areas in environments with high human activities may be attributed to the introduction of new energy sources by consumers, from human activities. Hence, the loss of natural cover due to human activities may be a significant factor in the trophic structure changes observed in aquatic environments.

key-words: Assimilation; environmental impact; niche; riparian vegetation; stable isotope.

1. Introduction

Human activities have emerged as one of the primary catalysts for global biodiversity loss (Merz et al., 2023). Among various ecosystems, wetlands face particularly severe threats from land use changes, notably the replacement of natural habitats due to human expansion (Foley et al., 2005), the construction of hydropower dams, and alterations to river channels to facilitate navigation (Wantzen et al., 2024). These threats not only led to a reduction in biodiversity but also contributed to a decline in functional diversity (Moi et al., 2022) and significant changes in the energy dynamics of wetlands, consequently altering the trophic structure of ecosystems (Felden et al., 2021; Isbell et al., 2022). In addition, land use pressures can result in deteriorating water quality due to nutrient inputs from human activities (Britton et al., 2019), thereby affecting biological communities and trophic interactions (Carvalho et al., 2015; Albrecht et al., 2021; de Carvalho et al., 2017; Wang et al., 2022). Hence, comprehending the trophic structure and the dynamics of energy flow within wetlands, amidst human-induced pressures, is crucial for their effective conservation and management. (Wang et al., 2014; Freitas et al., 2018).

Various conceptual models have been proposed to explain energetic dynamics in aquatic environments, including the River Continuum Concept (RCC), which emphasizes the importance of upstream organic matter (Vannote et al., 1980), the Flood Pulse Concept (FPC), which highlights the significance of lateral carbon inputs during seasonal flood events (Junk et al., 1989), and the Riverine Productivity Model (RPM), which underscores the importance of autochthonous and riverine production (Thorp & Delong, 1994). However, due to the complexity of wetland ecosystems and their interactions with surrounding environments, it is often necessary to integrate multiple concepts for a comprehensive understanding of their energetic dynamics (Wang et al., 2014; Alves et al., 2017b). This complexity is significantly increased by the abovementioned human activities, which are having a growing impact on wetlands (Moi et al., 2022). Therefore, it is essential to examine human pressures across multiple scales surrounding wetlands (Freitas et al., 2018) to develop effective measures for mitigating biodiversity loss and conserving these vital ecosystems.

Aquatic environments subjected to various human pressures frequently experience a transition in consumer energy sources, moving from natural sources to anthropogenically derived carbon inputs, including sugar cane, pasture, and sewage. (Carvalho et al., 2015; Carvalho et al., 2017; Alonso et al., 2019). The replacement of natural vegetation surrounding aquatic ecosystems diminishes the availability of allochthonous carbon sources, prompting consumers to alter their natural energy sources accordingly (Pereira et al., 2023). Also, regulation of rivers by hydropower dams can disrupt the downstream availability of energy sources by retaining organic matter and nutrients in reservoirs, leading to river oligotrophication and a reduction in autochthonous energy sources (Agostinho et al., 2008). Furthermore, dam regulation alters natural flood patterns in wetlands, decreasing the input of allochthonous organic matter, which serves as a primary energy source in these environments (Junk et al., 1989).

Changes in the availability of energy sources pose a significant threat to consumer communities, as evidenced by the collapse of fisheries in the Nile River delta following a decrease in allochthonous energy sources due to river dam regulation (Oczkowski et al., 2009). Numerous studies have highlighted the pivotal role of nutritional value in food resource selection, irrespective of their abundance (Marcarelli et al., 2011; Brett et al., 2017). Freshwater algae, for instance, are known for their high nutritional value (Brett et al., 2017), primarily due to their higher C:N ratio compared to allochthonous sources like riparian vegetation (Machado-Silva et al., 2022). Benedito-Cecilio et al. (2000) observed a significant contribution of phytoplankton to food webs in Amazonian rivers, underscoring the importance of these energy sources in environments with higher autochthonous production. However, other studies have reported a substantial contribution of allochthonous carbon to secondary production in large rivers, particularly in oligotrophic environments characterized by lower autochthonous production (Correa & Winemiller, 2018; Zheng et al., 2018; de Carvalho et al., 2023).

Furthermore, a direct correlation has been observed between vegetation cover area and the contribution of allochthonous sources to aquatic consumers (Champagne et al., 2022). Felden et al. (2021) noted an increase in the contribution of allochthonous energy sources to fish populations in forested environments compared to deforested areas, highlighting the importance of vegetative cover in the trophic structuring of aquatic populations. Despite the significance of allochthonous energy sources to consumers, previous studies have not found a relationship between these energy sources and food chain length (FCL) (Takimoto & Post, 2013). Predominantly, FCL regulation has been attributed to autochthonous production, coupled with ecosystem size (Post et al., 2000), underscoring the significance of autochthonous productivity in trophic structuring. Moreover, realized trophic niches have been associated with human pressures (Pereira et al., 2023) due to alterations in consumer energy sources.

For a comprehensive understanding of ecological processes, especially at the landscape level, determining stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) can be valuable tools for assessing impacts originating from human activities (Callaghan et al., 2021). $\delta^{15}N$ exhibits a fractionation of approximately 3.4‰ per trophic level (Post, 2002), making it useful for estimating consumer trophic positions (McCutchan Jr et al., 2003). Meanwhile, δ13C reflects consumer diets (Manetta & Benedito-Cecilio, 2003), with plant carbon fixation mechanisms (i.e., C_3, C_4, or CAM) and carbon sources (i.e., atmospheric or dissolved CO_2) serving as the main modulators of these stable isotope values in biota (Fry, 2006). Therefore, the combination of $\delta^{13}C$ and $\delta^{15}N$ values can estimate the isotopic niche of consumers, serving as a proxy for animal trophic niches (Swanson et al., 2015).

In the face of growing human pressures in wetland ecosystems, it is imperative to quantify human land use expansion and its impact on biota to guide conservation policies, given its negative effects on biodiversity (Moi et al., 2023). Developing countries pose the greatest threats to biodiversity due to agricultural expansion driven by population growth (Laurance et al., 2014). Therefore, to provide useful information to assist in the drafting of conservation legislation, this study aimed to investigate: (i) the impact of human land use at multiple scales, (ii) the trophic state of aquatic environments, and (iii) environmental size on the trophic structure of apex fishes in four large neotropical wetlands. We hypothesize that an increase in human activities at the landscape scale will be inversely associated with allochthonous energy sources, FCL, and isotopic trophic niche, based on the premise that landscape scale most significantly affects the abundance of consumers in wetlands (Freitas et al., 2018). Additionally, we assume that the trophic state will exhibit a positive association with autochthonous energy source assimilation, FLC, and isotopic niche, stemming from the understanding that oligotrophic environments have lower autochthonous primary production, resulting in fish biomass primarily sustained by allochthonous carbon sources (Correa & Winemiller, 2018; Zheng et al., 2018; de Carvalho et al., 2023). Finally, we predict that environmental size will be positively associated with FCL.

2. Material and methods

2.1. Study area

The study area encompasses 34 lagoons associated with four large Neotropical wetlands: the Upper Paraná River floodplain (PR), the Pantanal floodplain (PA), the Araguaia River floodplain (AR), and the Amazon River floodplain (AM), representing the Atlantic Forest, Pantanal, Cerrado, and Amazon Rainforest biomes, respectively (Figure 01 and Table II, SI). These environments encompass different levels of human impact, mainly resulting from land use pressures and operation of hydroelectric dams.

The Amazon biome features an extensive floodplain with great morphological heterogeneity of water bodies and diversity in the physical and chemical composition of water (Bonnet et al., 2017). The margins of floodplain lagoons are predominantly composed of herbaceous vegetation that remains submerged during the flood season, and this vegetation is responsible for supporting a dense ichthyological community (Freitas et al., 2018; Pereira et al., 2023). The sampled lagoons are associated with the Solimões River, characterized by white waters, and the Amazon River, formed by the confluence of the Solimões and Negro Rivers, with the latter characterized by black waters due to the high content of humic substances in suspension (Sioli, 1989). Conversely, this biome faces challenges due to human expansion (Renó et al., 2011). This issue is exemplified by the proximity of Manaus, one of northern Brazil's largest cities with a population exceeding two million (IBGE, 2022), to our collection points.

The Araguaia River is the main river system responsible for draining the Brazilian Cerrado (Aquino et al., 2008), a biome with a high degree of biodiversity, classified as a biodiversity hotspot (Myers et al., 2000) and covered by an Environmental Protected Area (EPA), characterized by sustainable use (Brazil, 1997). The Araguaia River basin can be divided into three sections: upper, middle, and lower (Latrubesse & Stevaux, 2002), with an increase in the establishment of human activities surrounding water bodies from downstream to upstream (Alves et al., 2019). The increasing deforestation has caused modifications in the river's hydrodynamics due to erosion and sedimentation (Latrubesse & Stevaux, 2002).

The Pantanal floodplain, recognized as one of the world's most expansive wetland ecosystems, holds the distinction of being an UNESCO World Natural Heritage and Biosphere Reserve (UNESCO, 2000). It is celebrated for its vast wetland expanse and remarkable habitat diversity (Bao et al., 2017). It has a floodable area of approximately 160.000 km² (Melack & Hess, 2023) and is considered relatively well-preserved, with around 80% vegetation cover (Alho et al., 2019). However, in recent decades, this biome has suffered from the conversion of natural remnants for human land uses, such as pasture and agriculture, in addition to facing fires caused mainly by farmers in pasture renewal practices (Alho, 2012; Alho et al., 2019). These factors have contributed to habitat loss, consequently diminishing biodiversity in the Pantanal (Alho, 2012). Furthermore, the existence of over 165 dam enterprises in the floodplain surrounding the Pantanal (Calheiros et al., 2018) poses a significant threat to this biome.

The Upper Paraná River floodplain is predominantly composed of the Atlantic Forest biome, exhibiting a high degree of endemism and species richness (Ribeiro, 2009), making it also a biodiversity hotspot (Myers et al., 2000) and covered by a Environmental Protected Area (EPA), characterized by sustainable use (Brazil, 1998). This area includes three different riverine subsystems: Paraná, Baía, and Ivinhema. The Paraná subsystem stands out as the last free stretch of the Paraná River without dams (Agostinho et al., 2002), presenting a high degree of oligotrophication (de Souza & Monteiro, 2005) due to the cascade of more than 130 larger dams upstream (Agostinho et al., 2004) and a high percentage of agro-pastoral activities on its shores (Urbano et al., unpublished data). The Baía subsystem is strongly influenced by agricultural activities established on its shores (Arnildo et al., 2014). The Ivinhema subsystem encompasses the State Park of the

Ivinhema River Floodplains, characterized by a high degree of conservation (de Carvalho, 2019), featuring a large percentage of natural vegetation on its shores (Urbano et al. unpublished data), despite having a high percentage of agricultural activities in its watershed (Teixeira & Hespanhol, 2016).

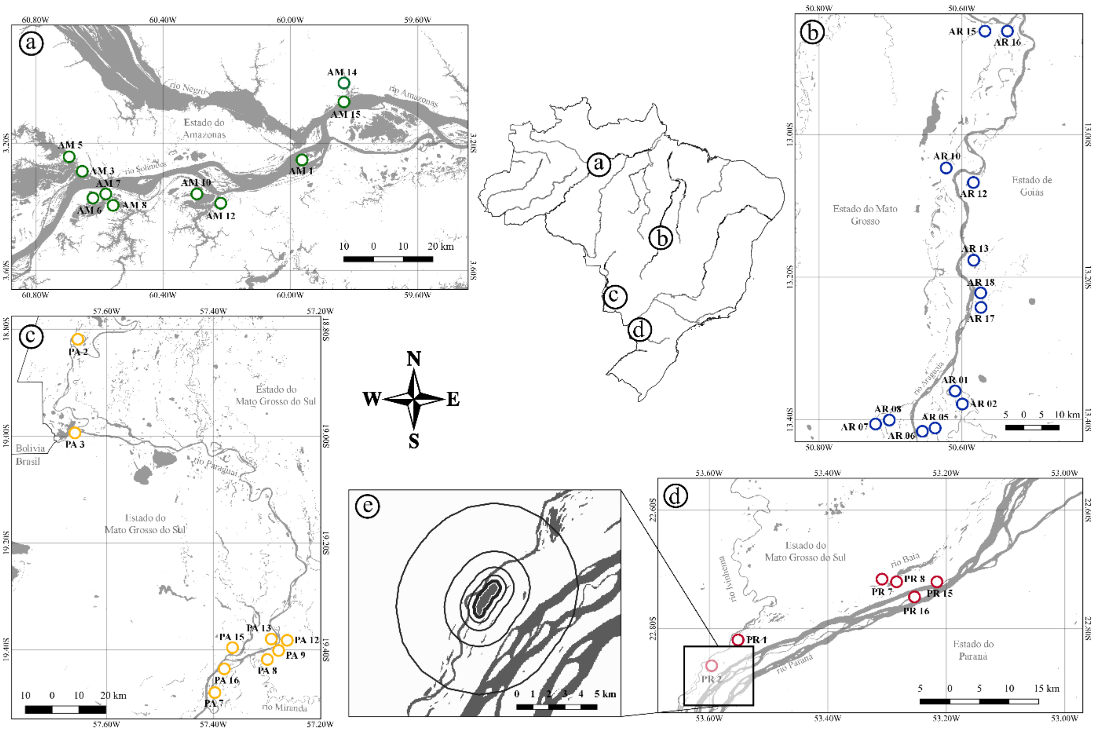


Fig 1. Study area. Each of the points indicated on the maps represents a lagoon associated with each floodplain: a = Amazonas; b = Araguaia; c = Pantanal; d = Upper River Paraná, e = *buffers* example around a lagoon.

2.2.Sampling

The sampling was conducted during the dry season of each floodplain (September 2011 in PR, March 2012 in PA, November 2012 in AR, and October 2011 in AM), a period when the fish are restricted to lagoons (Alves et al., 2017a). The samples were financially supported by CNPq for the SISBIOTA project: Biodiversity and ecology in different aquatic communities in four important Brazilian floodplains (process nº 563243/2010-4).

For abiotic variation analyses, values of water transparency were obtained using a Secchi disk (m). Measurements of dissolved oxygen (DO), turbidity, and pH were conducted using a portable potentiometer. Chlorophyll-a (µg/L) values were obtained using a fluorimeter. For total phosphorus (TP), phosphate (PO_4^{3-} µg/L), total nitrogen (TN), nitrate (NO_3^- µg/L), and ammonium ions (NH_4^+µg/L), water samples were collected from the limnetic region and stored in 500 ml polyethylene containers for subsequent laboratory analyses.

The consumers selected for this study were apex fishes (Table II, SI), as they serve as reliable indicators of aquatic quality (de Carvalho et al., 2020). These fishes, being at the top of the food chain, reflect in their biomass the $\delta^{13}C$ values of their prey, which, in turn, mirror the $\delta^{13}C$ values of the primary producers (Albrecht et al., 2021). Therefore, apex predators exhibit a broader spectrum of the food web in their biomass. Fish were collected in the AM, AR, and PA wetlands using a 20 m dragging net and seine nets (0.54 cm mesh size), with standardized effort of 3 drag, while in the PR, consumers were collected using a mesh waiting net with 2 cm by 16 cm (between nodes), exposed for 24 hours and checked every 8 hours. The fish were anesthetized with benzocaine diluted and subsequently sacrificed as recommended by Directive 2010/63/EU of the European Parliament and of the Council (2010). A muscle sample (approximately 2 cm²) near the dorsal fin insertion was extracted from each fish for stable isotope analyses (Lopes et al., 2009).

Basal energy sources were collected based on their availability at the sampling points. Periphyton and phytoplankton (autochthonous sources) were sampled, along with C_3 and C_4 riparian vegetation (allochthonous sources). Aquatic macrophytes were not included in the analysis due to their absence as a basal energy source in the AR lagoons. Consequently, we standardized four basal energy sources across the entire floodplain.

Riparian vegetation sampling involved collecting multiple leaves from the most abundant plants in each lagoon, using pruning shears for assistance and, the samples were separated by species. Periphyton was obtained by scraping macrophyte petioles or other submerged structures. Phytoplankton sampling utilized a plankton net (mesh size of 15 μm), dragged twice in the limnetic and pelagic zones, generating approximately four samples per collection point. Phytoplankton samples were stored in 500 ml pots. Both phytoplankton and periphyton samples were filtered through glass fiber with an opening of 47 mm (Whatman GFC), pre-burned at 400ºC for 4 hours.

2.3.Sample preparation

The samples were identified and placed in a forced ventilation greenhouse at 60 °C for 72 hours. Subsequently, the samples were grounded to obtain a fine and homogeneous powder. For fish, 1.5 mg of powder was added into a tin capsule, while for plants, 4 mg of powder was used. Filters containing phytoplankton or periphyton were cut in the middle, and the contents were added to tin capsules for isotopic measurements. The samples were sent to the Davis Stable Isotope Facility (University of California), and isotopic determination of carbon and nitrogen was performed using a PDZ Europa ANCA-GSL mass spectrometer with the PDZ Europa 20-20 interface (Sercon Ltd., Cheshire, United Kingdom). Limestone rock PeeDee Belemnite (PDB) was used as the standard for δ^{13}C values, and atmospheric air was used for nitrogen. The data were expressed in per mil (‰) and delta notation (δ). The standard deviation for δ^{13}C and δ^{15}N for five replicate analyses ranged between 0.04‰ and 0.13‰ for δ^{13}C and 0.09‰ and 0.22‰ for δ^{15}N. The analyses were conducted following the expression proposed by Lajtha & Michener (1994):

$$\delta\ (‰) = \left(\frac{R_{sample} - R_{standard}}{R_{standard}}\right) * 1000$$

Where:

R = ^{13}C:^{12}C ou ^{15}N:^{14}N

2.4. Data analyses

2.4.1. Land use and environment size

For land use analyses at various spatial scales, six distinct scales were established. These were categorized as local scales with 100 m, 200 m, and 500 m buffers covering various consumer feeding habits. Additionally, landscape scales with buffers of 1000 m, 2000 m, and 5000 m were defined to encompass the secondary channel and the riverbed, as outlined by Freitas et al. (2018). This broader landscape scale was chosen to account for the homogenization of the floodplain during the flooding period, resulting from the interconnectedness of different environments (Junk et al., 1989).

The land cover data for 2011 were obtained from the MapBiomas platform, which provides maps at a resolution of 30 m² for Brazilian biomes from 1985 to 2022 in shapefile format (Souza et al., 2020; https://mapbiomas.org/en). In the QGIS software, the coordinates were converted from degrees to meters using the Albers equivalent EPSG:7390 projection, as proposed by IBGE for calculating the areas of Brazilian states (IBGE, 2019), through the "coordinates reproject" function. Polygons were generated covering the area of each lagoon. These were used to create buffers of 100, 200, 500, 1000, 2000, and 5000 meters (Fig. 01e). As also, to estimate the land use in the PR and AR EPA it was used polygonuns of the area of each EPA available in Brazilian Ministry of the Environment site (MMA, 2024). The generated buffers and EPA polygonum were overlapped with the MapBiomas shapefiles. They were used as masks through the "extract raster by mask layer" function, generating a raster of land use for each lagoon and each scale. The percentage of each land use category and the size of each lagoon was extracted using the "Landscape ecology" plugin and the "Landscape statistic" function, using the raster of land use generated for each lagoon in each scale and using the polygonum that cover each lagoon, respectively. Finally, different land use types were grouped into human land use (pasture, agriculture, forestry, mosaic of agriculture and pasture, urban area, and other non-vegetated areas) and natural land use (forest formation, non-arboreal vegetated area, and water bodies).

2.4.2. Trophic state

The primary production was estimated using the trophic state of each lagoon as a proxy. To achieve this, the trophic state index (TSI) of the lagoon was calculated using the equation proposed by Cunha et al. (2013) for lentic environments. The concentrations of chlorophyll (Chl) and phosphorus (TP) were utilized in the equation below, and the trophic state was classified according to table 1.

$$TSI = \frac{TSI\ (PT)\ +\ TSI\ (Chl)}{2}$$

Where:

$$TSI\ (TP) = 10\ [\ 6 - \frac{(-0.27637\ x\ ln\ ln\ (TP)\ +\ 1.329766)}{ln\ ln\ (2)}]$$

$$TSI\ (Chl) = 10\ [\ 6 - \frac{(-0.2512\ \ x\ ln\ ln\ (Chl)\ +\ 0.842257)}{ln\ ln\ (2)}]$$

Table 1. Categories of trophic states according to the calculated TSI values according Cunha et al. (2013).

TSI	Trophic state
≤ 51.1	Ultraoligotrophic
51.2 < TSI > 53.1	Oligotrophic

53.2 < TSI > 55.7	Mesotrophic
55.8 < TSI > 58.1	Eutrophic
58.2 < TSI > 59.0	Supereutrophic
TSI ≥ 59.1	Hypereutrophic

2.4.3. Isotopic analyses

The Food Chain Length (FCL) was determined by assessing the trophic position (TP) of each apex consumer species across different lagoons. This approach allows for accounting for the complexity present in non-linear food webs (Post et al., 2000). Such an evaluation is crucial as these ecosystems do not feature simple linear food chains, but rather intricate food webs. The analyses were performed using the tRophicPosition package (Quezada-Romegialli et al., 2018) in the R software (R Core Team, 2023), following the trophic position equation developed by Post (2002):

$$TP_{consumer} = \frac{\delta^{15}N_{consumer} - (\delta^{15}N_{baseline1}\ x\ \alpha + \delta^{15}N_{baseline2}\ x\ (1 - \alpha))}{3.4} + 1$$

Where: $TP_{consumer}$: Consumer trophic position; $\delta^{15}N_{consumer}$: $\delta^{15}N$ from consumer; $\delta^{15}N_{baseline1}$: $\delta^{15}N$ from baseline 1; $\delta^{15}N_{baseline2}$: $\delta^{15}N$ from baseline 2; α : ^{15}N contribution from baseline 1.

As baseline, C_3 riparian vegetation was designated as baseline 1, and phytoplankton was assigned as baseline 2, using the fractionation factors of 3.4 ± 0.98 (average and standard deviation) for $\delta^{15}N$ and 0.39 ± 1.3 for $\delta^{13}C$, as proposed by Post (2002). The tRophicPosition package (Quezada-Romegialli et al., 2018) was employed to utilize the Bayesian model. The model underwent 10,000 interactions during the adaptive phase, followed by 10,000 interactions for recording, which were discarded.

Subsequently, 10,000 real interactions were performed to generate the median values of TP.

To estimate the contribution of autochthonous and allochthonous energy sources for each consumer species in each lagoon, a Bayesian stable isotope mixing model was employed using the SIMMr package (Parnell, 2013) in the R software (R Core Team, 2023). Due to the lower sample numbers for C_4 riparian vegetation in each floodplain, the average and standard deviation of $\delta^{13}C$ and $\delta^{15}N$ from each floodplain were utilized, given the lower isotope variation observed in these producers (Hoeinghaus et al., 2007). In cases where there were no periphyton samples for a particular lagoon, the average and standard deviation of $\delta^{13}C$ and $\delta^{15}N$ from periphyton in the respective floodplain were used after validating the absence of significant variation in the isotopic composition of these energy sources for each floodplain through PERMANOVA analyses (Table S3).

For the execution of the mixing model, the first step involved correcting the fractionation factor. This correction was performed by multiplying the trophic position (TP) calculated for the average and standard deviation of $\delta^{15}N$ fractionation (3.4 ± 0.98) and $\delta^{13}C$ (0.39 ± 1.3) according to Post (2002). The SIMMr package utilizes the JAGS (Just Another Gibbs Sampler) program for the execution of the Bayesian isotope mixing model. The model was run through the *simmr_out* function, incorporating the *sim_mcmc* argument, using Markov Chain Monte Carlo (MCMC) for stochastic simulations. Thousands of random simulations of carbon assimilation proportions were conducted, and these results were utilized to determine the values of energy source contributions that best fit the data. The initial interactions were discarded during the burn-in phase, and the posterior interactions were stored to obtain the posterior distribution. The best interactions according to the model were then used (Parnell, 2013). The results, including the average and standard deviation of energy source contributions, as well as confidence intervals

(2.5%, 25%, 50%, 75%, and 97.5%), were obtained through the summary function using the 'statistics' and 'quartiles' arguments, respectively.

The isotopic niche of the piscivore trophic guild in each lagoon was estimated using the SIAR package (Jackson et al., 2011). The SIAR package employs Bayesian inference to generate posterior distributions based on a priori estimates and likelihood of $\delta^{13}C$ and $\delta^{15}N$ data. This is achieved through Markov Chain Monte Carlo (MCMC), which conducts thousands of random simulations to estimate the area of the convex hull (TA), standard ellipse area (SEA), and corrected standard ellipse area (SEAc). To mitigate bias in TA and SEA results due to sample size, SEAc was employed in the isotopic niche analyses. This metric accounts for sample size variation (Jackson et al., 2011). The absence of bias between SEAc or PT values and the sample size was confirmed through a general linear model (GLM) using the Gamma distribution and log link function (Table S4).

2.4.4. Statistical analyses

To characterize the environment concerning abiotic variables, Principal Component Analysis (PCA) was conducted using the vegan package (Oksanen et al., 2019) in the R software (R Core Team, 2023). The dissimilarity matrix and Euclidean distance were employed for this analysis (Legendre & Legendre, 1998). To investigate the difference in the variation of the abiotic variables, it was employed Permutational Multivariate Dispersion Analysis (PERMIDISP; Anderson, 2006), calculing the distance of centroide using dissimilarity matrix. To investigate the presence of differences in the variation and composition of abiotic variables between wetlands, a Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson, 2001) and pairwise PERMANOVA analysis with Bonferroni correction were performed. Given the significant differences in abiotic variables, a Kruskal-Wallis test for each variable was conducted, followed by Dunn post-hoc tests. Subsequently, TSI values were subjected to a Kruskal-Wallis test, followed by Dunn post-hoc tests, to identify differences in the trophic state of each floodplain. To assess the contribution of variation between each energy source and each floodplain, as well as between wetlands, and the variation in TP and SEAc, normality and homoscedasticity tests were first conducted. Following this, the data underwent Kruskal-Wallis tests, followed by Dunn post-hoc tests when necessary.

The scale of effect of human land use on the contribution of allochthonous energy sources, TP, SEAc for consumers, and the potential relationship between TSI and autochthonous energy sources and environment size with FLC were analyzed through Generalized Linear Models (GLM). The models were constructed using the "stats" package in the R software (R Core Team, 2023), employing the Gamma distribution and log link. Model validation involved comparing them with a saturated model through ANOVA analysis, followed by graphic inspection, Half-normal plots with simulation envelopes (Moral et al., 2017), and residual analysis through the "DHARMa" package (Hartig & Hartig, 2017). Finally, the scale of effect for each response variable was defined as the GLM with the lowest AIC (Akaike Information Criterion) and $p < 0.05$, similar to the approach used by Huais (2018).

To investigate the direct and indirect relationships between human land use, TSI and environment size with energy sources, TP and SEAc, a Structural Equation Model (SEM) was conducted using the *lavaan* package (Rosseel, 2012) in the R software (R Core Team, 2023). The model is based on regressions where the same variable can serve as a predictor variable in one regression and as a response variable in another. The SEM was fitted based on a priori model (Figure S1 and Table S5). To reduce the number of variables, only the land use scale that showed the greatest effect on biotic variables (i.e., basal energy sources and trophic metrics) were utilized. Additionally, to avoid the covariance effect of energy source contribution, only allochthonous energy sources were considered. Due to not fitting the environment size in the model, this variable was not used in the final analysis.

3. Results

Through Principal Component Analysis (PCA), we observed that the two first axes of the abiotic variables explained 58.1% of the data variation. The first axis distinctly separated Secchi and pH from chlorophyll-a concentration, TP, NT, NH_4^+, and water turbidity, while the second axis separated conductivity, NO_3^-, and PO_4^{3-} from the other variables (Fig 2). Significant differences in environmental homogeneity were observed through PERMIDISP ($F_3 = 13.87$ and $p = 0.001$), except between the PA and AR (Table S5), with greater centroid distance values for AM (Table S6). There were significant differences in abiotic composition between wetlands (PERMANOVA: $F_3 = 5.43$, $R^2 = 34$ and $p = 0.004$); however, the post-hoc test revealed that only PR did not differ from the other wetlands (Table S7). While the concentrations of NO_3^- and PO_4^{3-} did not differ between wetlands, the other abiotic variables showed statistical differences, with PA differing from AM and AR in most variables (Table S8). The TSI of lagoons was statistically different between wetlands ($X^2_3 = 74.35$ and $p < 0.001$), with higher values in the AM, followed by AR, PR, and PA (Table S1).

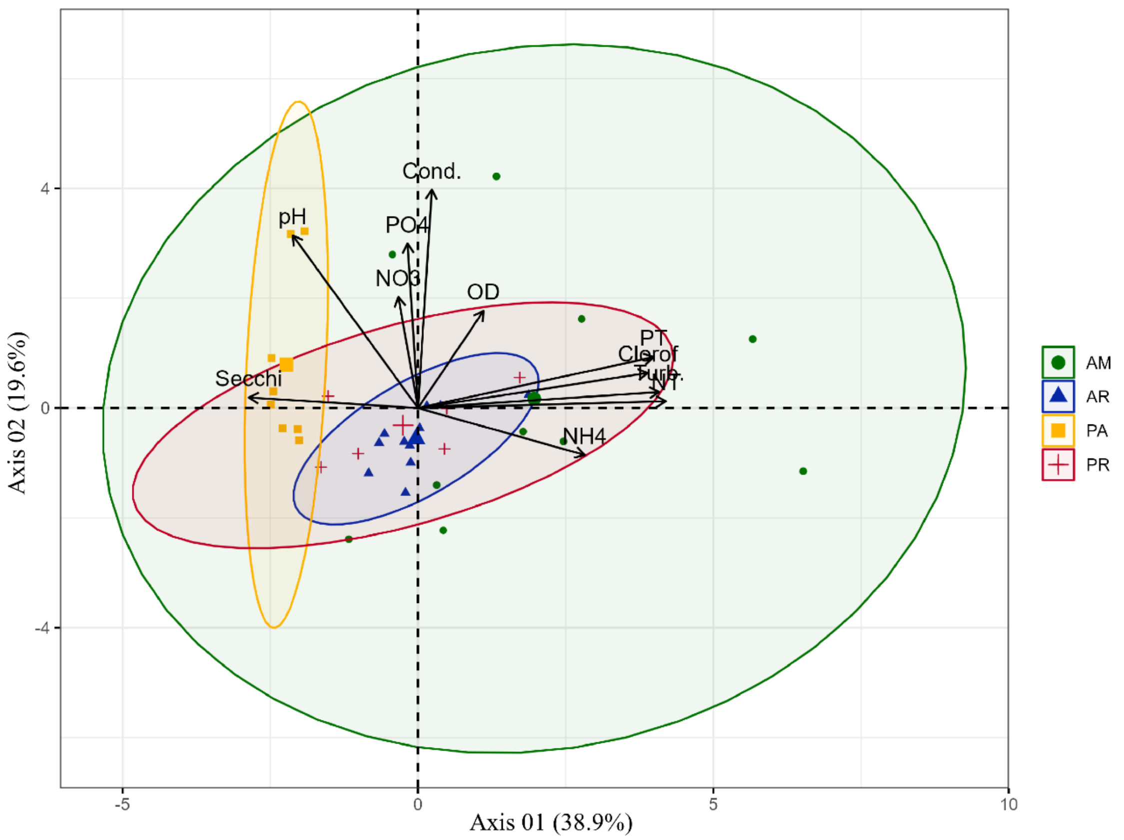


Figure 02. PCA of the abiotic variables, ellipse with confidence level of 95%.

The percentage of human land use significantly varied between wetlands and the analyzed buffers ($X^2_{23} = 128.24$ and $p < 0.001$). Human land use was most prevalent in the AM region across all spatial scales, and specifically at the 500 m scale for both the AR and PR regions. Conversely, in the PA region, human land use was notable only at the larger 5000 m scale. (Table 2, Fig 3 and, Table 10). We observed in the AR Environmental Protected Area (EPA) a greater percentage of natural land use (more than 80%) in comparison to the PR EPA (about 50%) (Table S9). The environmental size of the AM lagoons range to 58,500 at 44,688,600 m^2, the AR lagoons range to 43,200 at 624,600 m^2, the PA lagoon range to 12,600 at 1,563,419 and, PR lagoon range to 54,900 at 1,350,900 m^2 (Table S1).

Table 2. Land use percentage and type in the buffers of 100 at 5000m, in each floodplain.

Buffer	Natural				Human					
(m)	Forest	Savannah	Wetland	Grassland	Pasture	Mosaic	Urban	Non-vegetated	Agriculture	Total human
AM 100	40.3+ 19.0		42.39+17.87	6.37+5.47	8.47+ 12.9					9.21±14.33
AM 200	46.2+ 14.1		34.34+15.31	5.77+4.41	10.8+ 12.8					11.52±14.33
AM 500	54.23+6.98		28.85+12.70	4.93+12.64	11.99+12.64		0.01+0.03			12.00±12.65
AM 1000	55.34+6.63		24.39+13.59	4.62+11.10	14.36+11.10		1.28+2.60			15.63±11.42
AM 2000	56.26+7.41		20.34+10.34	5.55+10.95	16.46+10.95		1.39+3.78			17.84±12.70
AM 5000	60.03+10.54	0.001+0.003	15.20+7.25	5.58+8.94	17.10+8.94		2.07+4.51			19.18±12.28
AR 100	91.0+ 13.0	43.85+35.79	10.47+13.93	1.22+2.49	0.74+ 1.50	0.26+ 1.39		0.22+ 1.27		1.29±2.72
AR 200	91.6+ 12.4	45.75+36.84	8.49+12.55	2.10+3.86	1.68+ 3.27	0.11+ 0.37		0.24+0.62	0.16+0.83	1.09±1.61
AR 500	41.41+41.41	46.72+34.32	6.35+7.44		3.57+4.06	1.18+2.61		0.30+0.53	0.45+0.84	7.20±7.48
AR 1000	38.18+40.45	49.83+34.22	4.76+4.29		3.99+5.10	1.37+1.93	1.61+3.85	0.29+0.42	0.42+0.62	7.23±8.01
AR 2000	33.39+33.94	50.50+28.20	5.29+3.55	0.009+0.02	6.63+5.84	2.26+2.44	0.45+1.50	0.43+1.50	0.47+0.65	10.80±9.51
AR 5000	29.35+21.56	48.10+13.23	10.18+8.02	0.27+0.58	7.11+5.27	3.36+2.47	0.17+0.38	0.64+0.55	0.80+1.64	12.09±8.54
PA 100	64.6+ 29.2	4.26+5.91	31.74+31.13	0.21+0.42						
PA 200	68.1+ 27.4	5.33+5.92	28.99+29.64	0.03+0.10						
PA 500	60.87+29.87	9.59+13.69	28.65+29.16	0.89+1.61						
PA 1000	55.38+26.36	12.35+13.97	30.59+26.35	1.67+3.19						
PA 2000	50.64+20.85	12.80+8.46	34.64+8.46	1.92+2.55						
PA 5000	38.59+12.74	14.61+16.74	41.74+16.74	3.80+3.18	1.25+3.15					1.24±3.15
PR 100	55.5+ 44.3		50.40+48.30		0.23+ 0.36					0.12±0.31
PR 200	37.4+ 42.4		66.75+44.31		0.16+ 0.32					0.12±0.31
PR 500	9.49+11.00		85.55+15.52		4.46+6.92	0.35+0.81			0.15+0.37	4.95±7.64
PR 1000	13.80+12.78		78.47+14.51		7.20+11.30	0.53+0.84			0.15+0.37	7.86±11.53
PR 2000	13.41+12.19		74.13+9.31		10.63+9.58	1.61+1.27	0.07+0.15	0.01+0.03	0.14+0.14	12.46±9.68
PR 5000	40.3+ 19.0		42.39+17.87	6.37+5.47	8.47+ 12.9					21.75±15.38

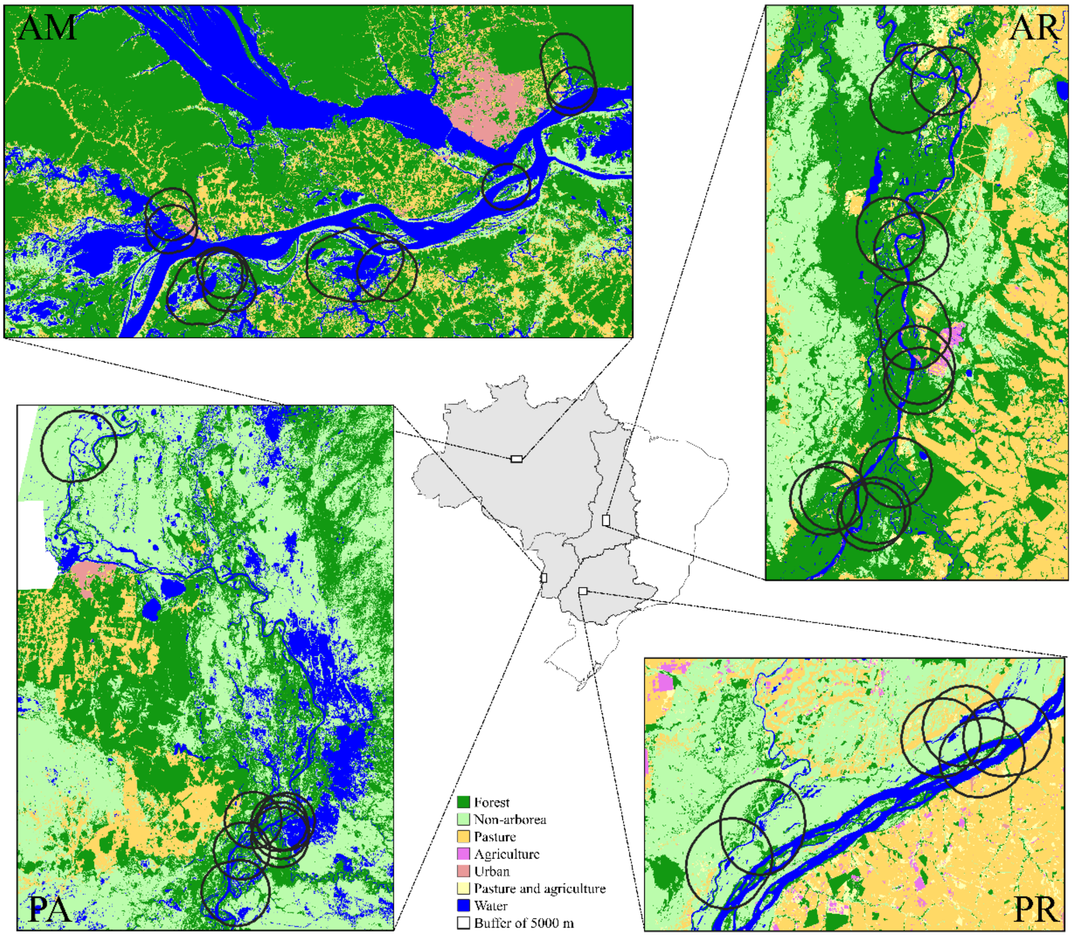


Fig 3. Land cover in each floodplain and representation of the buffer of 5000 m.

A total of 485 fish (Table S11) and 602 energy sources (Table S12) were analyzed. The FCL varied between 3 and 5 trophic levels, with only the FLC from the AR being greater than the FLC from the AM ($X^2_3 = 11.89$ and $p < 0.01$) (Fig 4 and Table S13). We observed a higher isotopic contribution of C_3 riparian vegetation followed by phytoplankton, except in the PR, where C_3 riparian vegetation, phytoplankton, and periphyton were not different. There was a smaller contribution of C_4 riparian vegetation to consumers, except in the PA, where this source was not different from periphyton (Figure 2). Both allochthonous and autochthonous sources were different only in the PA (greater allochthonous contribution) and PR (greater autochthonous contribution) (Table S14). The C_3 riparian vegetation contribution in the PR (31.61%) was significantly lower than in the AR and AM (40.77% and 41.77%, respectively). Phytoplankton in the AM showed a greater contribution (31.08%) than in the PA (26.73%), while periphyton was significantly more important in the PR (26.66%). C_4 riparian vegetation showed a statistically higher contribution in both the PR and PA (13.80% and 16.15%, respectively) (Fig 5 and Fig 2). The allochthonous contributions were greater only in PA and lower in the PR (Table S15).

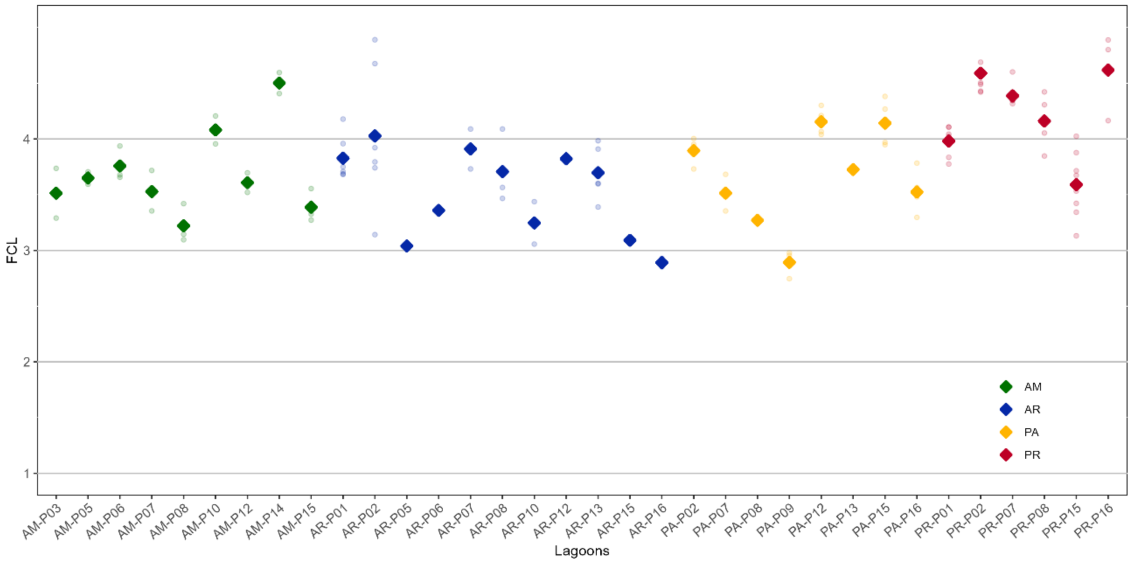


Fig 4. FCL for each consumer species in each lagoon from each wetland (circle). The lozangue is the median of FCL for lagoon.

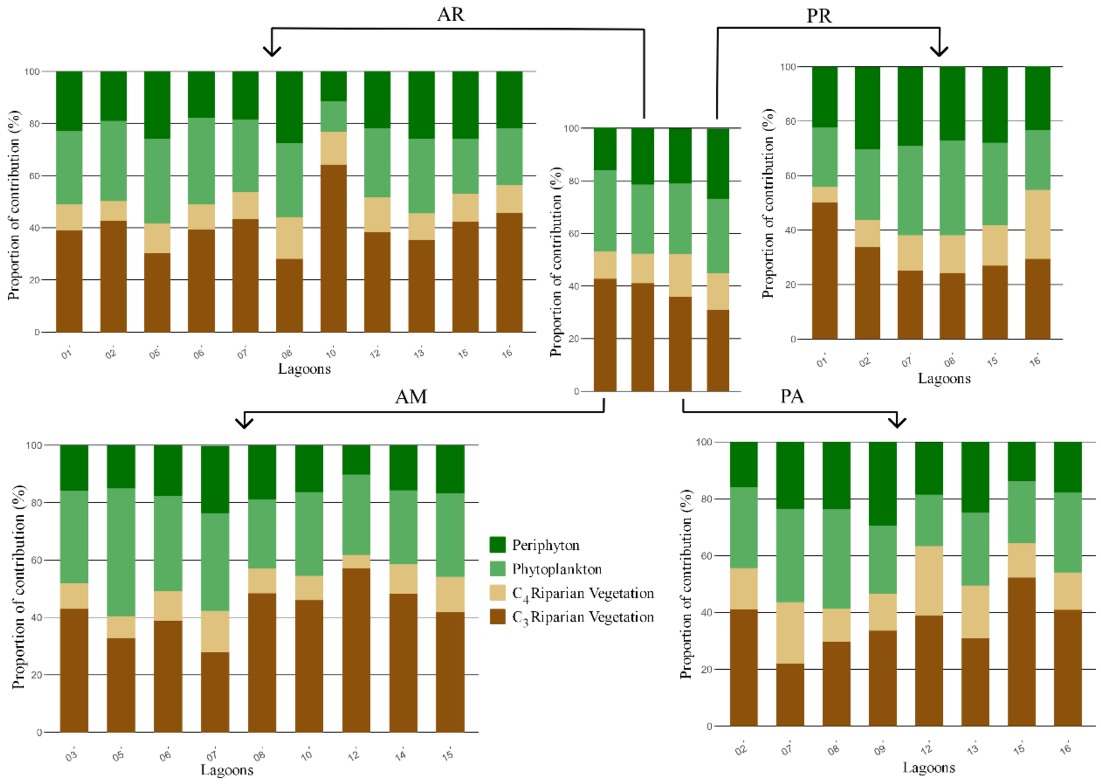


Fig 5. Average of basal energy sources contribution values (%) for consumers in each lagoon in each wetland.

The standard ellipse niche area (SEAc) of the piscivore guild in each lagoon was not different between wetlands ($X^2_3 = 5.65$ and $p = 0.13$). However, the SEAc of the ichthyic community in the AM displayed greater homogeneity compared to other floodplain ecosystems, with reduced variability and lower standard deviation. (Table S16). The minimums and averages values of SEAc found in the AM were the highest, with the SEAc in the AM being four times greater than in the PA, twice as big as in the AR, and 1.4 times bigger than in the PR. Additionally, the median SEAc in the AM was about twice as big as in the other wetlands (Fig 6 and, Table S17).

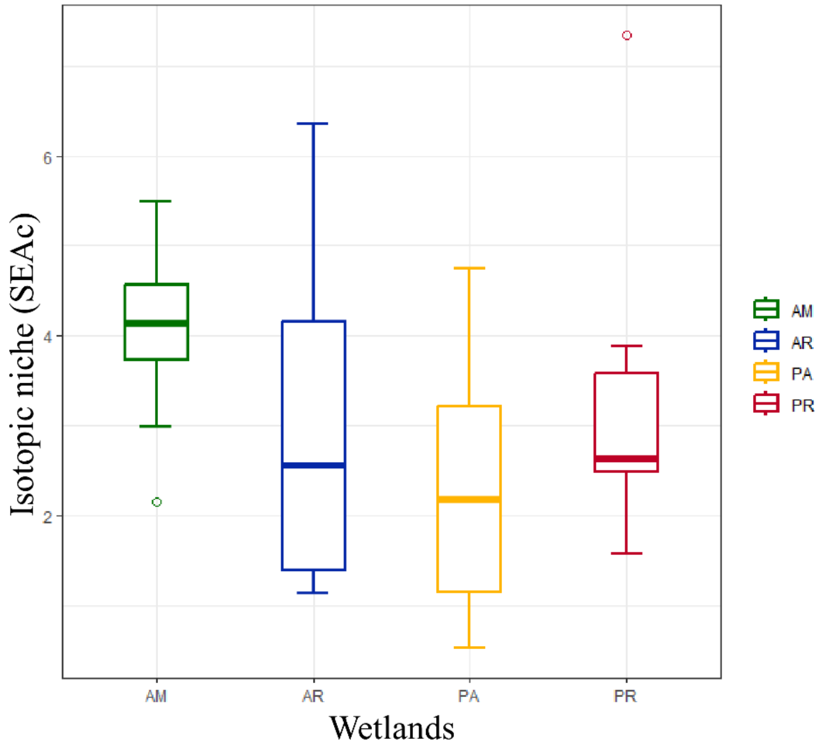


Fig 6. Boxplot of SEAc values for the piscivorous guild in the four wetlands. The upper and lower lines indicate the 97.5 and 2.5% percentiles, respectively. The bottom and top edges of the boxes represent the 75 and 25% percentiles, respectively, while the central line indicates the 50% percentile. AM: Amazon river floodplain; AR: Araguaia river floodplain; PA: Pantanal floodplain; PR: Paraná river floodplain.

The increase in ahuman land use was inversely associated with the assimilation of allochthonous energy sources and FCL, and directly associated with the isotopic niche area (Fig 7 and 9). The effect scale of human land use on FCL was 100 m, and 5000 m for allochthonous assimilation and isotopic niche (Fig 7 and, Table S18). On the other hand, the TSI of lagoons was positively associated with phytoplankton assimilation but not with periphyton (Fig 8). We did not find association between environmental size and FLC ($Y = 1.44 - 1.48^{-0.9} X$; $p = 0.38$).

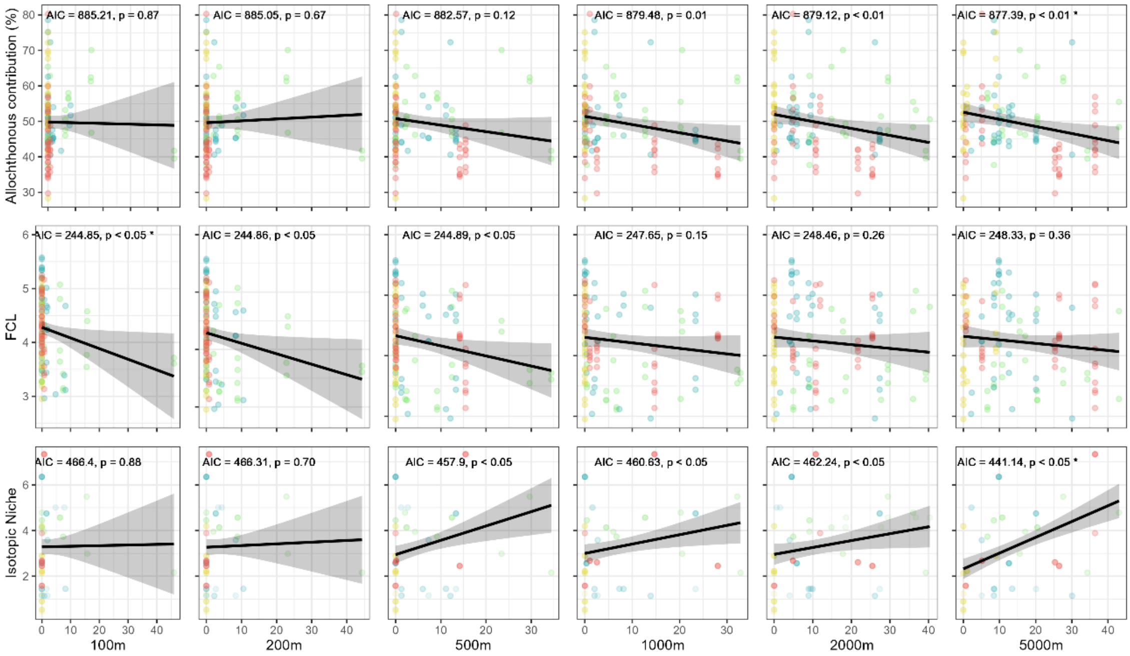


Fig 7. Generalized linear models between the (%) contribution allochthonous basal energy source, food chain length (FCL) and isotopic niche (SEAc) and human land use in different buffers (100 m, 200 m, 500 m, 1000 m, 2000 m, and 5000 m). * = Scale of effect, defined by the lowest AIC value.

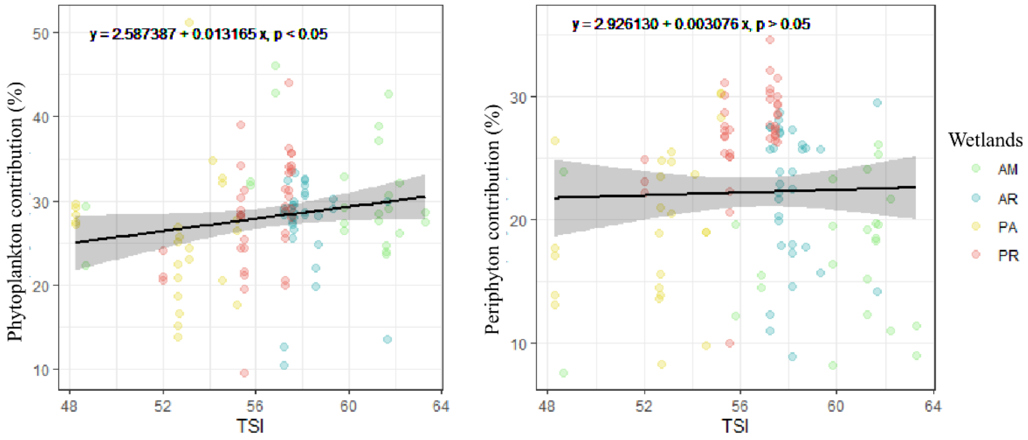


Figure 08. Generalized linear models between the contribution (%) of phytoplankton and periphyton and the trophic state index (%). AM: Amazon River floodplain; AR: Araguaia River floodplain; PA: Pantanal floodplain; PR: Paraná River floodplain.

We found, through the SEM, that the FCL exhibited a significantly inverse relationship with both scales (local and landscape) of human activities. The FCL was indirectly impacted by human activities at the landscape level, as evidenced by a significant negative correlation between anthropogenic land use at this scale and the proportion of allochthonous sources, which in turn was associated with FCL. The niche area exhibited a significant relationship only with human land use at the landscape scale (Fig 9 and, Table S19).

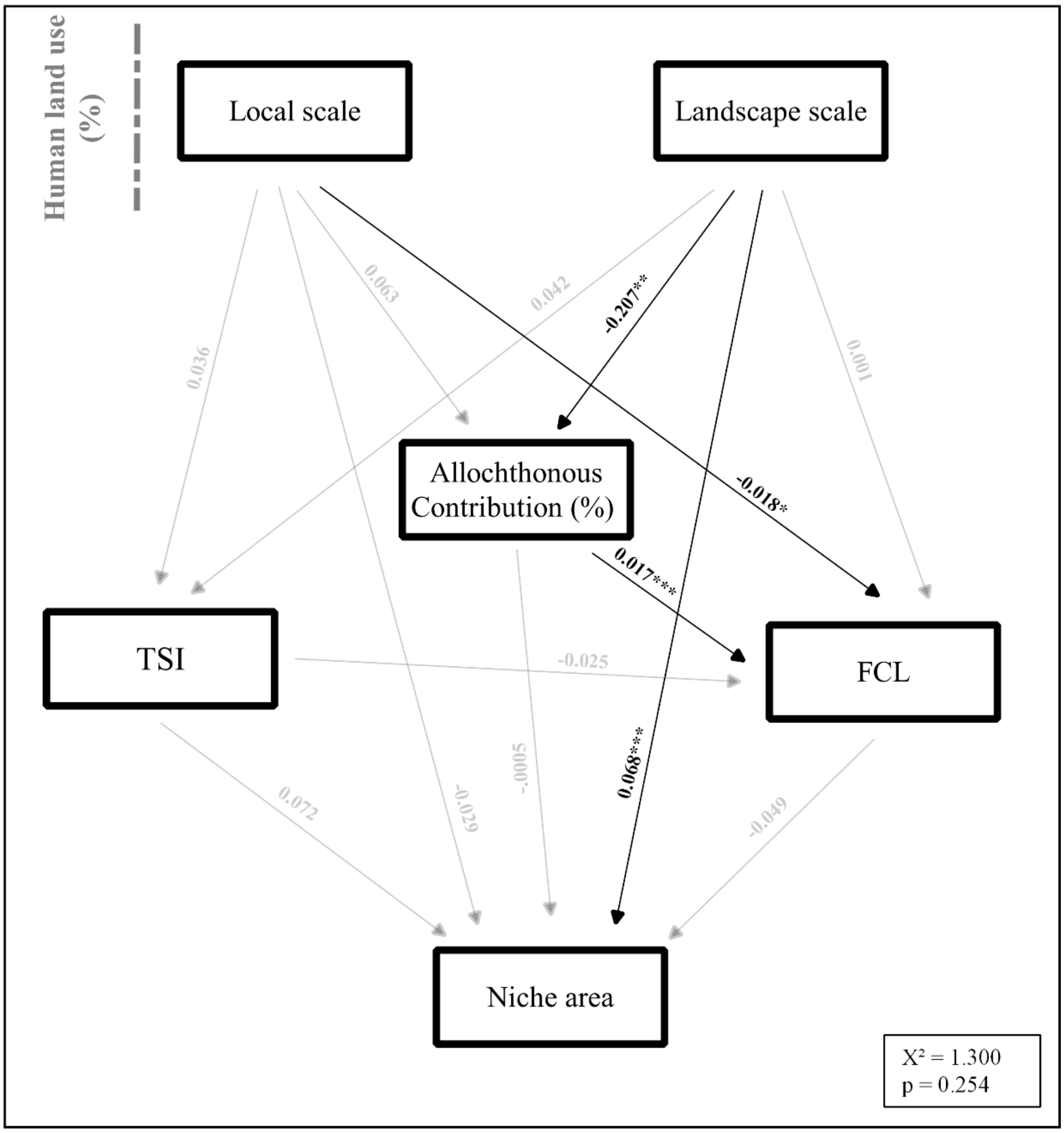


Figure 09. Structural Equation Model (SEM). Arrows indicate each regression; black arrows represent significant regressions, and gray arrows indicate non-significant regressions. The number above each arrow indicates the regression estimate; negative values represent negative interactions, and positive values represent positive interactions. * = p < 0.05, ** = p < 0.01, and *** = p < 0.0001. The lower right box indicates the model statistics, X^2 = chi-square. Local Scale = 100m scale, Landscape Scale = 5000m scale, Riparian Veg (%) = contribution of C_3 riparian vegetation to consumers, TSI = Trophic State Index, and Niche Area = SEAc.

4. Discussion

Our initial hypothesis, suggesting a negative relationship between the escalation of human activities at the landscape level and the assimilation of allochthonous carbon, FCL, and niche area, was corroborated by our findings. However, the hypothesis that TSI would demonstrate a positive association with autochthonous carbon assimilation, FCL, and niche area was only partially confirmed. The final hypothesis, suggesting a positive relationship between FLC and environmental size, was rejected. Interestingly, FCL and niche area were found to be related to land use, indicating the impact of land use on animal populations occupying intermediate trophic levels within the food web. This impact may stem from the reduction in biodiversity caused by land use changes (Freitas et al., 2018), subsequently influencing higher trophic levels of the food web. These results also underscore the significant dependence of wetlands on surrounding environments.

4.1. Landscape-Scale Human Pressures Drive Trophic Structure Changes

The impact of landscape-scale human land use on allochthonous carbon assimilation, particularly from C_3 riparian vegetation, underscores the floodplain's dependency on flooded vegetation during periods of high-water levels (Junk et al., 1989; Lobón-Cerviá, 2015), particularly at the landscape-scale (Freitas et al., 2018; Pereira et al., 2023b). These findings align with previous studies (e.g., Wang et al., 2014; Correia & Winemiller, 2018; Felden et al., 2021; Wang et al., 2022) that illustrate dynamics consistent with the Flood Pulse Concept (Junk et al., 1989). Additionally, the association between increased human land cover and decreased allochthonous assimilation leading to an uptick in autochthonous carbon sources poses a serious risk to floodplain consumers. This shift may not adequately support fish assemblages in environments evolutionarily adapted to rely on allochthonous carbon sources, especially in wetlands (Freitas et al., 2018; Oczkowski et al., 2009; Effert-Fanta et al., 2022; Wang et al., 2022).

The absence of a relationship between FCL and environmental size or autochthonous primary production, contrary to what theoretical models propose as key determinants, may be due to prior research being focused on enclosed ecosystems, such as lakes and islands. (Post et al., 2000; Post & Takimoto, 2007; Takimoto et al., 2012; Takimoto & Post, 2013). The only relationship found between FCL and human land use and allochthonous energy sources may be due to wetlands' high dependence on surrounding environments (Junk et al., 1989; Correia & Winemiller, 2018). This is supported by the indirect influence of landscape-scale human land use on FCL, mediated by its relationship with allochthonous assimilation. The greater direct impact of local-scale human land use on FCL may reflect the adverse effects of land use on organism abundance at intermediate levels of the food web (Freitas et al., 2018; Bomfim et al., 2023).

The reduction in FCL can be attributed to the decrease in environmental functional diversity (Wilkinson et al., 2021), which is caused by fewer trophic links (Post et al., 2000). This phenomenon is likely exacerbated by intensified human activities around aquatic habitats. Consequently, human activities encroaching into wetlands play a crucial role in determining FCL, influencing functional diversity (Wilkinson et al., 2021; Lo et al., 2020; Moi et al., 2023), community dynamics, ecosystem functioning (Post et al., 2000), and ultimately, the provision of ecosystem services. Thus, the assimilation of allochthonous vegetation emerges as the primary determinant of FCL, alongside land use pressures from local to landscape scales. Furthermore, the reduction in this energy pathway's availability may result in decreased resilience and stability of ecosystems (Wilkinson et al., 2021). Therefore, human activities along the margins of these environments renders them more susceptible to environmental degradation.

Consequently, the conservation of natural vegetation buffers is essential for maintaining the resilience of energy pathways and, consequently, the health of aquatic environments.

On the other hand, the expansion of niche areas associated with the increased human activities, as documented in previous studies (de Carvalho et al., 2017; Wang et al., 2021a), may be attributed to the introduction of new anthropic energy sources (Wang et al., 2021b). The incorporation of these sources results in an increased range of δ13C sources accessible for uptake by consumers (Wang et al., 2021a; Pereira et al., 2023a), consequently influencing the niche area of apex consumers. The reduction in FCL with an increase in human land uses indicates that the growth in niche area is not a consequence of trophic level insertions. Furthermore, there is a diminishing trend in fish richness and abundance with escalating human land uses (Freitas et al., 2018; Britton et al., 2019), particularly at the landscape-scale (ranging from 1000 to 5000 m; Lobón-Cerviá, 2015; Freitas et al., 2018; Pereira et al., 2023b), which corresponds to the scale of effect of human land use observed under the niche area herein. Thus, we believe that the increase of niche area is not due to the increase in fish richness but rather due to the introduction of human energy sources.

This phenomenon is exemplified by the observed wider trophic niche area of crocodiles in the Araguaia floodplain (downstream from our collection points), environments affected by fragmentation due to agricultural and pasture impacts (Pereira et al., 2023a). Thus, the utilization of both natural and human energy sources can result in a wider trophic niche, providing support for consumers in fragmented environments (Pereira et al., 2023a). This suggests that at the trophic guild level, the increase in new energy sources may contribute to the sustenance of fish communities or resilient species (Pereira et al., 2023a), while individual species may face collapse due to habitat fragmentation (Layman et al., 2007; Champagne et al., 2022). Such collapse is attributed to a decrease in their natural energy sources (Champagne et al., 2022). These findings pose serious risks to the biota, as energy sources from urban centers, pasture, and agriculture are typically associated with environmental pollution (Britton et al., 2019).

Moreover, it is crucial to emphasize that in the PR, despite the high percentage of human land use, the presence of non-native fish species in these environments (Agostinho & Júlio, 2002) may have influenced the niche area. This influence arises from niche segregation observed between native and non-native species in this environment (Alves et al., 2017a; Alves et al., 2020). Additionally, despite the absence of a relationship between the niche and the TSI, the relatively lower variation in niche areas in the AM, an environment characterized by the greatest abiotic heterogeneity and nutrient concentration, may suggest that abiotic composition is a crucial driver for niche areas, as they have a complex relationship with the isotopic signatures of energy sources (Alves et al., 2017b). Furthermore, the smaller niche area was observed in the PA, an environment with lower nutrient and chlorophyll-a concentrations and higher water transparency. Consequently, we posit that the availability of nutrients may play a significant and complex role in driving the niche area of the piscivore trophic guild.

4.2.Considerations to Protect Floodplain Trophic Structure

The strong dependence of floodplain trophic structure on landscape-scale human land use, coupled with extensive human land use expansion into wetlands, jeopardizes the primary energetic pathway supporting floodplain consumers, particularly in the AM, where the highest percentages of human land use were observed across all analyzed scales. This situation is further exacerbated by earlier research that demonstrates a notable increase in cropland within the floodplain downstream from our AM sampling sites between 1970 and 2008. (Renó et al., 2011). Similarly, both the PR and AR show an increase in human land use, primarily at the landscape scale, as previously demonstrated in these wetlands (Urbano et al., unpublished data; Pereira et al., 2023a). In contrast, the PA exhibits higher conservation levels, with just 1.24 ± 3.15% of human land use in the 5000 m buffer zone. Despite the high conservation level in our study area in the PA, our findings underscore the urgency of reevaluating the Brazilian Forest Act (Brasil, 2012), not only to prevent the impact of human pressures in this floodplain but also to mitigate the high human pressures surrounding the other wetlands.

Our results contradict the predictions outlined in the 4th article of the Brazilian Forest Act (Brasil, 2012) regarding the buffers of riparian vegetation, as human activities were observed in buffers of 100 and 200 m in the AM, AR, and PR, areas theoretically protected from human pressures. Furthermore, the significant influence of landscape-scale human land use on trophic structure suggests that the current Brazilian law is insufficient to protect the trophic structure of wetlands. This highlights the importance of considering floodplain ecosystems' unique characteristics, where buffers should be defined from the maximum water level of the flood season (Grasel et al., 2019).

The minimum widths required to protect floodplain trophic structure should include at least a buffer of 1000 m of Native vegetation protection, the scale with the most significant effect between niche area, allochthonous energy source and FCL. However, for more effective floodplain protection, the establishment of a Protected Area (PA) within a 5000 m buffer is ideal, as it represents the most effective scale for maintaining floodplain trophic structure, in conjunction with the 1000 m native vegetation protection buffer. Relying on a single scale of riparian protection is inadequate to encompass all riverine functions, especially in environments with complex hydrological dynamics such as floodplains (Junk et al., 1989). Furthermore, these landscape-scale protections are crucial for biodiversity conservation in wetlands (Fereira et al., 2018). Additionally, implementing monitoring plans for land use within PA is essential to ensure their effectiveness, utilizing tools such as satellite imagery. There are some Brazilian Protected Environmental Areas (APA), such as PR EPA and AR EPA, which aim to “guarantee the protection of biota” (Brazil, 1997, 1998). However, despite the recovery of vegetation cover observed in EPA PR in recent decades (Schmitz et al., 2023), we observed a high percentage of human land use in EPA PR, in contrast to EPA AR. Thus, along with the change in land use, the trophic structure of the apex fish also changes, making the efficiency of this EPA questionable. This may be the result of the low contribution of C_3 riparian vegetation observed in the PR, contrasting with other wetlands, especially in AR, which exhibit a high percentage of natural cover within their EPA. The restoration of riparian vegetation to a previous state may be challenging, particularly because the Native vegetation protection law is more prone to the expansion of agribusiness (Matzger et al., 2010). Therefore, revisions to the Brazilian Forest Act need to be developed in close collaboration between the agricultural sector and the scientific community. Economic incentives, such as interest reduction on bank loans and territorial taxes, and environmental certification for landholders who conserve riparian vegetation properly, may be viable alternatives, as suggested by other studies advocating for increased riparian areas (e.g., Luke et al., 2019; Dala-Corte et al., 2020).

In addition to human land uses, other human pressures in these environments may jeopardize the primary energy source in wetlands, such as the Hidrovia Paraguay-Paraná (HPP) project in Pantanal (Wantzen et al., 2024) (including our PA study area), the high number of dams in the Paraná basin (Agostinho et al., 2008) (upstream PR collect points), and the growth of consolidated and projected dams in the Tocantins-Araguaia and Amazon basins (Pelicice et al., 2021). The HPP aims to deepen the river channel, leading to a drastic reduction in the flood pulse (Wantzen et al., 2024), similar to the observed effects of dam regulation in PR upstream from our collection points (Agostinho et al., 2007). The absence of the flood pulse results in a decline in allochthonous energy sources (Junk et al., 1989), an event associated with a reduction in fish assemblages (Wang et al., 2014; Lobón-Cerviá et al., 2015). Therefore, regulating hydrological levels by hydropower dams to simulate natural hydrological dynamics can serve as a useful tool for maintaining fish biomass, abundance, and richness in environments impacted by such activities (Baumgartner et al., 2018; Oliveira et al., 2020; Lopes et al., 2020), an important consideration for future dam implementations.

5. Conclusion

This study highlights the importance of conserving riparian vegetation in wetlands, as it represents the primary energy source sustaining apex consumers in these environments. Moreover, given the association of FCL with natural land cover, the decrease observed with the expansion of human activities along aquatic margins implies a potential loss of trophic levels in these ecosystems. Conversely, the larger isotopic niche size in environments with a higher percentage of human land use around water bodies suggests the incorporation of new energy sources from human activities. However, despite the observed growth in niche areas, the FCL was not greater in these environments. Therefore, the conservation of riparian vegetation buffers around water bodies emerges as a crucial tool for the conservation of aquatic communities and, consequently, the maintenance of their resilience.

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7. Author contributions

V.A.U.: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Validation; Visualization; Roles/Writing - original draft; and Writing - review & editing. G.H.Z.A.: Conceptualization; Data curation; Investigation; Methodology; Validation; Supervision; Visualization; Roles/Writing - original draft; and Writing - review & editing. E.B: Conceptualization; Methodology; Funding acquisition; Project administration; Resources; Supervision; Roles/Writing - original draft; and Writing - review & editing.

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Supplementary material

Human land use drives to trophic structure change of apex fish in Neotropical wetlands

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Table SI. Sampling environment, lagoon: lagoons name, TSI: trophic state index; Trophic category: Ult: ultraoligotrophico; Oli: oligotrophic; Mes: mesotrophic; Eu: eutrophic; Hyp: hypereutrophic e Sup: supereutrophic.

Wetland	Lagoon	Code	Altitude	TSI	Trophic category	Lagoon size (m^2)	Coordinate
Paraná	L. Garças	PR 15	239	55.35	Mes	123300	S 22º 43' 470″ W 053º 13' 040″
	R. Pau Véio	PR 16	240	52.01	Oli	93600	S 22º 44' 868″ W 053º 15' 338″
	L. Guaraná	PR 7	226	57.51	Eut	54900	S 22º 43' 263″ W 053º 18' 176″
	L. Fechada	PR 8	232	57.4	Eut	120600	S 22º 40' 669″ W 053º 16' 618″
	L. Patos	PR 1	229	55.52	Mes	985500	S 22º 49' 490″ W 053º 33' 176″
	L. Ventura	PR 2	229	57.24	Eut	1350900	S 22º 51' 389″ W 053º 35' 902″
Pantanal	L Tuiuiu	PA 2	95	54.55	Mes	1563419	S 18° 48' 30.2" W 057° 39' 20.4"
	L Baía Bugre	PA 7	95	53.12	Mes	1407600	S 19° 30' 43.3" W 057° 23' 27.3"
	L R Miranda I	PA 8	87	54.12	Mes	111600	S 19° 25' 38.2" W 057° 18' 58.4"
	L R Miranda II	PA 9	94	55.17	Mes	34200	S 19° 25' 07.7" W 057° 18' 49.0"
	L Capivara	PA 12	85	52.67	Oli	54900	S 19° 24' 16.6" W 057° 18' 03.5"
	L Figueira	PA 13	90	52.71	Oli	12600	S 19° 24' 24.0" W 057° 18' 49.3"
	L Albuquerque	PA 15	92	52.62	Oli	34200	S 19° 24' 01.5" W 057° 21' 49.6"
	L Piuva	PA 16	95	48.26	Oli	27900	S 19° 26' 52.7" W 057° 23' 09.9"
Araguaia	L Crixas I	AR 1	215	57.56	Eut	394200	S 13º 21' 33.1″ W 050º 36' 42.9″
	L Crixas II	AR 2	210	58.13	Sup	123300	S 13º 21' 42.8″ W 050º 36' 26.9″
	L Japones I	AR 5	221	57.38	Eut	43200	S 13º 25' 15.0″ W 050º 38' 02.4″
	L Japones II	AR 6	218	57.7	Eut	72900	S 13º 25' 23.6″ W 050º 38' 57.4″
	L Montaria I	AR 7	216	59.31	Hyp	48600	S 13º 24' 07.9″ W 050º 43' 10.2″
	L R Montaria II	AR 8	217	57.22	Eut	54000	S 13º 23' 43.1″ W 050º 42' 17.3″

	L Piranha	AR 10	209	57.22	Eut	54000	S 13º 02' 53.5″ W 050º 37' 32.2″
	L Piratinga	AR 12	207	58.68	Sup	433900	S 13º 03' 58.9″ W 050º 34' 57.6″
	L Do Brito	AR 13	217	57.63	Eut	540900	S 13º 10' 35.2″ W 050º 34' 55.4″
	L Comprido II	AR 15	207	58.56	Sup	624600	S 12º 51' 02.2″ W 050º 34' 26.1″
	L Goiaba	AR 16	206	61.64	Hyp	90000	S 12º 50' 54.1″ W 050º 32' 04.7″
Amazonia	L Piranha	AM 3	22	55.77	Eut	807300	S 03° 16' 59.5" W 060° 39' 51.5"
	L Lagoa	AM 5	16	56.84	Eut	409500	S 03° 12' 57.3" W 060° 42' 32.2"
	L Grande	AM 6	11	61.27	Hyp	20397600	S 03° 22' 51.3" W 060° 35' 03.0"
	L Poço Curuça	AM 7	13	61.72	Hyp	380700	S 03° 22' 42.4" W 060° 34' 07.5"
	L Cadete	AM 8	18	61.61	Hyp	1570500	S 03° 23' 54.9" W 060° 33' 15.7"
	L Grande II	AM 10	11	62.21	Hyp	44688600	S 03° 22' 04.7" W 060° 16' 54.5"
	L Castanho	AM 12	23	63.31	Hyp	44501400	S 03° 24' 00.0" W 060° 13' 35.9"
	L Poraquequara II	AM 14	4	48.66	Ult	3908700	S 03° 00' 31.2" W 059° 49' 32.0"
	L Poraquequara III	AM 15	10	59.82	Hyp	58500	S 03° 02' 59.1" W 059° 49' 06.0"

Table II. Consumer trophic guilde for each floodplain.

Floodplain	Species	Trophic guilde	Reference
PR	*Acestrorhynchus lacustris* (Lütken, 1875)	Piscivore	Almeida et al. (1997)
	Auchenipterus osteomystax (Miranda Ribeiro, 1918)	Carnivore	Hahn et al. (2004)
	Cichla kelberi (Bloch & Schneider, 1801)	Piscivore	Espínola et al. (2010)
	Hoplias argentinensis (Rosso, Mabragaña, González-Castro, Bogan, Cardoso, Mabragaña, Delpiani & Díaz de Astarloa, 2018)	Piscivore	Hahn et al. (2004)
	Hemisorubim platyrhynchos (Valenciennes, 1840)	Piscivore	Hahn et al. (2004)
	Hoplias mbigua Azpelicueta, Benítez, Aichino & Mendez, 2015	Carnivore	Reis (2003)
	Hoplias sp2	Piscivore	Hahn et al. (2004)
	Parauchenipterus galeatus (Linnaeus, 1766)	Carnivore	Hahn et al. (2004)
	Pseudoplatystoma corruscans (Spix & Agassiz, 1829)	Piscivore	Hahn et al. (2004)

	Salminus brasiliensis (Cuvier, 1816)	Piscivore	Hahn et al. (2004)
	Serrasalmus maculatus Kner, 1858	Piscivore	Almeida et al. (1997)
	Serrasalmus marginatus Valenciennes, 1837	Piscivore	Almeida et al. (1997)
PA	*Acestrorhynchus pantaneiro* Menezes, 1992	Piscivore	De Resende (2000)
	Hoplias sp7	Carnivore	Reis (2003)
	Pseudoplatistoma corruscans (Spix & Agassiz, 1829)	Piscivore	Luz-Agostinho et al. (2006)
	Pseudoplatystoma reticulatum Eigenmann & Eigenmann, 1889	Carnivore	Barthem & Goulding (1997)
	Pygocentrus nattereri Kner, 1858	Piscivore	Novakowski et al. (2008)
	Serrasalmus maculatus Kner, 1858	Piscivore	Almeida et al. (1997)
	Serrassalmus maginatus Valenciennes, 1837	Piscivore	Almeida et al. (1997)
AR	*Acestrorhynchus heterolepis* (Cope, 1878)	Piscivore	Dourado et al. (2015)
	Acestrorhynchus microlepis (Jardine, 1841)	Piscivore	Sumido et al. (2008)
	Boulengerella cuvieri (Spix & Agassiz, 1829)	Piscivore	Montaña et al. (2008)
	Cichla kelberi (Bloch & Schneider, 1801)	Piscivore	Espínola et al. (2010)
	Cynodon gibbus (Agassiz, 1829)	Piscivore	Froese et al. (2023)
	Hoplias malabaricus (Bloch, 1794)	Piscivore	Carvalho et al. (2002)
	Plagioscion squamosissimus (Heckel, 1840)	Piscivore	González (2002)
	Pseudoplatystoma fasciatum (Linnaeus, 1766)	Piscivore	Rejas (2018)
	Pygocentrus nattereri Kner, 1858	Piscivore	Novakowski et al. (2008)
	Rhaphiodon vulpinus Spix & Agassiz, 1829	Piscivore	Novakowski et al. (2008)
	Serrasalmus eigenmanni Norman, 1929	Piscivore	González (2002)
	Serrasalmus maculatus Kner, 1858	Piscivore	Almeida et al. (1997)
	Serrasalmus rhombeus (Linnaeus, 1766)	Piscivore	González (2002)
AM	*Acestrorhynchus falcirostris* (Cuvier, *1819)*	Piscivore	Hawlitschek et al. (2013)
	Cichla monoculus Agassiz, 1831	Piscivore	Luz-Agostinho et al. (2006)
	Hoplias malabaricus (Bloch, 1794)	Piscivore	Carvalho et al. (2002)
s	*Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)*	Piscivore	Hahn et al. (2004)
	Hoplias aff malabaricus (Bloch, 1794)	Carnivore	Reis (2003)
	Osteoglossum bicirrhosum (Cuvier, 1829)	Carnivore	Costa & Freitas (2013)
	Pellona flavipinnis (Valenciennes, 1836)	Carnivore/Piscivore	Moreira-Hara et al. (2009)

	Pseudoplatystoma sp.	Piscivore	Hahn et al. (2004)
	Pygocentrus nattereri Kner, 1858	Piscivore	Rejas (2018)

Table S2. PERMANOVA analysis results. * represent analysis without significant interaction between groups in the Adonis pairwise test. # represent analysis with significant interaction in the adonis pairwise test.

		df	R^2	F	p
AM					
	Periphyton	2	0.72	3.84	0.07
	Phytoplankton	8	0.58	4.76	0.001*
	C3 Vegetation	8	0.15	0.57	0.86
AR					
	Periphyton	7	0.82	5.20	0.004*
	Phytoplankton	10	0.10	0.53	0.89
	C3 Vegetation	10	0.77	11.35	0.001*
PA					
	Periphyton	6	0.87	7.83	0.001*
	Phytoplankton	7	0.81	14.08	0.001*
	C3 Vegetation	7	0.40	2.95	0.02*
PR					
	Periphyton	5	0.93	16.64	0.001*
	Phytoplankton	5	0.81	16.62	0.001#
	C3 Vegetation	5	0.58	4.36	0.004*

Table S3. GLM results between consumer number per lagoon (predictor variable) and, TP, TA, SEA and SEAc (response variable).

Response variable	Estimative	Intercept	Error	t-value	p
TP	0.0002	1.44	0.0009	0.271	0.787
TA	0.037	1.21	0.004	9.109	< 0.01
SEA	0.008	0.91	0.003	2.40	0.018
SEAc	0.003	1.13	0.003	0.952	0.343

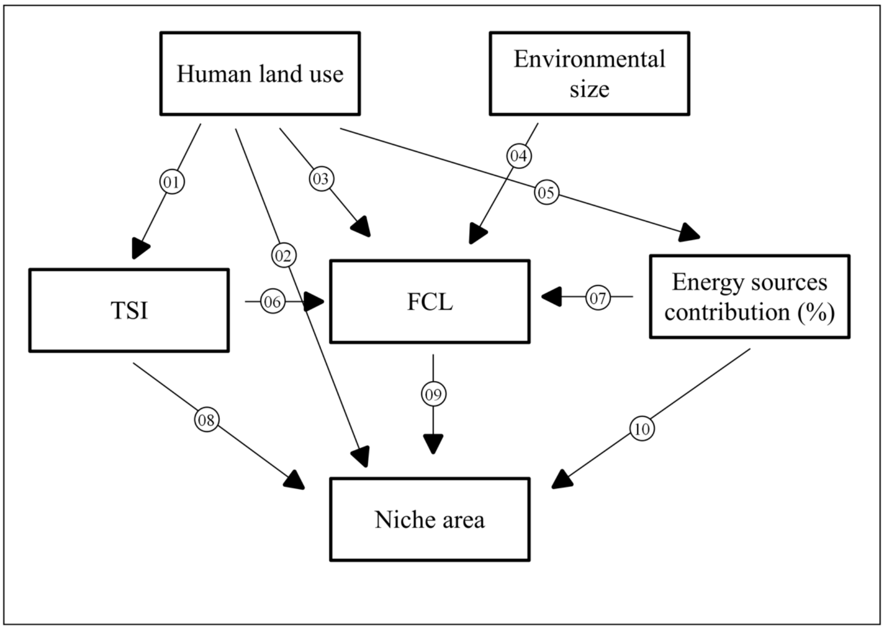

Figure S1. Prior model for construction and analysis of the SEM model.

Table S4. Support theory for each relationship in the a priori SEM model established in Figure 01.

Arrow	Rationale	Reference
01	Aquatic environments whose river basin has a high percentage of human land use have high input rates of nitrogen and phosphorus compounds originating from pastures, agriculture or urban centers, which influence the trophic state of the environment.	Britton et al. (2019), Zheng et al. (2022)
02	The isotopic niche area for aquatic consumers can be greater in environments impacted by human land uses, such as agriculture and pasture, due to the new energy sources.	Pereira et al. (2023)
03	The aquatic consumers under human impacts change their trophic position, due change in the energy sources available.	Cabana & Rasmussen (1996), Carvalho et al. (2015)
04	The FCL is directly influecied by the environmental size.	Post (2000), Post & Takimoto (2008)
05	The proportion of energy sources contribution may be impacted by the type of land use (as natural or human land cover) and the percentage of different types of land use.	Felden et al. (2021), Champagne et al. (2022)
06	Autochthonous primary production is one of the main factors that impact FCL.	Post (2000), Post & Takimoto (2008)
07	The proportion of contributions from different energy sources has a direct relationship with FCL because the shortest food chain is supported mainly by one energy source.	Wang et al. (2016), Zheng et al. (2018)
08	The availability of nutrients is one of the factor determinants of the isotopic niche area.	Wang et al. (2021)
09	The FCL is positively associated with the isotopic niche metrics.	Wang et al. (2021)
10	The greater isotopic niche area is supported by many different energy sources.	Pereira et al. (2023)

Table S5. Results of pairwise PERMIDISP test to the abiotic variables in each floodplain (AM, AR, PA e PR), * p < 0,05, ** p < 0,01 and, *** p < 0,001.

	AM	AR	PA	PR
AM		***	***	*
AR	***			**
PA	***			**
PR	***	***	**	

Table S6. Centroid distance of the abiotic variables in each floodplain (AM, AR, PA and PR).

Floodplain	AM	AR	PA	PR
Centroid distance	1406,3	176,3	103,6	630,9

Table S7. Results to pairwise PERMANOVA test to abiotic variables to each floodplain (AM, AR, PA e PR), * $p < 0,05$ and ** $p < 0,01$.

	AM	AR	PA	PR
AM		*	*	
AR	*		**	
PA	*	**		
PR				

Table S8. Average and standard deviation of the abiotic variables. Secchi: Secchi disk (m), Turb.: turbidity (NTU), DO: dissolved oxygen (mg L^{-1}), Cond.: conductivity (**µ**s cm^{-1}), Chl: Chlorophyll a (**µ**g L^{-1}), TN: total nitrogen (mg L^{-1}), NO_3^-: nitrate ion (mg L^{-1}), NH_4^+: ammonium ion (**µ**g L^{-1}), TP: total phosphorus (**µ**g L^{-1}), PO_4^{3-}: phosphate ion (**µ**g L^{-1}).

	Kruskal-Wallis	AM	AR	PA	PR
Secchi	$X^2_3 = 19.14$ e $p < 0.01$	0.41 ± 0.35^{a}	0.49 ± 0.15^{a}	2.04 ± 0.43^{b}	0.69 ± 0.54^{a}
Turb	$X^2_3 = 15.75$ e $p < 0.01$	78.01 ± 75.85^{a}	32.74 ± 21.67^{a}	4.03 ± 1.95^{b}	38.22 ± 42.71^{ab}
DO	$X^2_3 = 9.32$ e $p < 0.05$	6.26 ± 1.08^{ab}	5.93 ± 1.88^{ab}	4.32 ± 0.55^{a}	6.90 ± 0.81^{b}
pH	$X^2_3 = 18.05$ e $p < 0.01$	6.31 ± 3.10^{a}	6.90 ± 0.28^{a}	7.62 ± 0.25^{b}	6.77 ± 0.42^{a}
Cond	$X^2_3 = 10.85$ e $p < 0.05$	75.76 ± 64.49^{abc}	38.08 ± 8.02^{ab}	86.15 ± 43.98^{b}	36.97 ± 17.84^{ac}
Chl	$X^2_3 = 18.95$ e $p < 0.01$	49.01 ± 39.67^{a}	19.55 ± 10.94^{a}	2.82 ± 1.58^{b}	8.77 ± 3.90^{ab}
TN	$X^2_3 = 11.37$ e $p < 0.01$	2597.9 ± 1705.44^{a}	1243.37 ± 235.07^{ab}	862.42 ± 113.14^{b}	1386.22 ± 818.35^{ab}
NO_3^-	$X^2_3 = 4.47$ e $p = 0.21$	46.47 ± 79.32^{a}	30.18 ± 10.01^{a}	34.02 ± 60.64^{a}	36.38 ± 57.72^{a}
NH_4^+	$X^2_3 = 18.03$ e $p < 0.01$	44.41 ± 78.45^{a}	19.91 ± 16.43^{a}	1.1 ± 1.56^{b}	38.4 ± 33.35^{a}
TP	$X^2_3 = 16.05$ e $p < 0.01$	113.27 ± 50.75^{a}	86.5 ± 29.51^{a}	38.4 ± 9.05^{b}	59.32 ± 38.76^{ab}
PO_4^{3-}	$X^2_3 = 2.44$ e $p = 0.48$	15.45 ± 8.19^{a}	12.68 ± 4.68^{a}	21.21 ± 12.69^{a}	16.68 ± 10.82^{a}

Tabela S9. Porcentagem e categorias de uso da terra nas APA do AR e PR.

	Natural				Antrópico					
	Florestal	Savana	Campo	Apicum	Pastagem	Mosaico	Urbano	Não vegeta	Silvicultura	Agricultura
AR	20.31	41.73	25.18	0.14	10.15	1.91	0.004	0.45		0.11
PR	11.75		29.71		34.52	9.09	0.14	0.02	0.024	14.73

Table S10. Kruskal – Wallis test results between the human land use percentage between the different buffers and wetlands. The significant difference between pairs of lines and columns is represented by: *** = p < 0,0001, ** = p < 0,001 and, * = p < 0,05.

	AM 100	AM 200	AM 500	AM 1000	AM 2000	AM 5000	AR 100	AR 200	AR 500	AR 1000	AR 2000	AR 5000	PA 100	PA 200	PA 500	PA 1000	PA 2000	PA 5000	PR 100	PR 200	PR 500	PR 1000	PR 2000	PR 5000
AM 100													*	*	*	*	*							
AM 200													**	**	**	**	**	*	*	*				
AM 500							*	*					**	**	**	**	**	*	*	*				
AM 1000							**	**					***	***	***	***	***	**	**	**				
AM 2000							**	**					***	***	***	***	***	**	**	**	*			
AM 5000							**	**					***	***	***	***	***	**	***	***	*			
AR 100											*	**											*	**
AR 200											*	**											*	**
AR 500													*	*	*	*	*		*	*				
AR 1000													**	**	**	**	**		*	*				
AR 2000													**	**	**	**	**	**	**	**				
AR 5000													***	***	***	***	***	**	**	**				
PA 100																							**	***
PA 200																							**	***
PA 500																							**	***
PA 1000																						**		***
PA 2000																							**	***
PA 5000																							*	***
PR 100																							*	**
PR 200																							*	**
PR 500																								
PR 1000																								
PR 2000																								
PR 5000																								

Table S11. Mean and standard deviation of the $\delta^{13}C$ and $\delta^{15}N$ of the energy sources in each lagoon. * represent the mean and standard deviation of the floodplain and, $^{\#}$ represent the value unique of the floodplain.

Floodplain	Lagoon	Riparian vegetation C_3			Riparian vegetation C_4			Phytoplankton			Periphyton		
		n	$\delta^{13}C$	$\delta^{15}N$	n	$\delta^{13}C$	$\delta^{15}N$	n	$\delta^{13}C$	$\delta^{15}N$	n	$\delta^{13}C$	$\delta^{15}N$
AM	P 03	4	-30.86 ± 1.07	3.45 ± 1.71	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-31.37 ± 1.88	5.69 ± 2.15	6*	-25.35 ± 1.95	5.29 ± 0.78
	P 05	3	-30.82 ± 1.08	4.68 ± 2.14	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-33.21 ± 0.66	5.33 ± 0.85	6*	-25.35 ± 1.95	5.29 ± 0.78
	P 06	4	-30.19 ± 0.27	4.13 ± 1.99	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-30.53 ± 1.58	4.13 ± 0.36	6*	-25.35 ± 1.95	5.29 ± 0.78
	P 07	3	-30.57 ± 0.42	3.54 ± 0.96	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-31.08 ± 0.11	2.00 ± 2.00	2	-27.19 ± 1.09	4.51 ± 0.38
	P 08	4	-29.88 ± 0.26	3.32 ± 1.10	6*	-12.12 ± 0.34	6.57 ± 1.28	3	-27.60 ± 1.41	5.29 ± 0.76	2	-25.56 ± 0.29	5.30 ± 0.54
	P 10	2	-30.18 ± 0.92	2.22 ± 3.89	6*	-12.12 ± 0.34	6.57 ± 1.28	5	-28.30 ± 1.72	2.51 ± 1.73	6*	-25.35 ± 1.95	5.29 ± 0.78
	P 12	4	-30.14 ± 1.80	2.73 ± 1.05	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-29.70 ± 1.55	4.46 ± 0.43	6*	-25.35 ± 1.95	5.29 ± 0.78
	P 14	5	-30.98 ± 1.32	3.63 ± 0.71	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-29.30 ± 0.53	3.77 ± 1.27	6*	-25.35 ± 1.95	5.29 ± 0.78
	P 15	6	-30.45 ± 0.59	4.03 ± 0.64	6*	-12.12 ± 0.34	6.57 ± 1.28	4	-29.79 ± 0.24	5.83 ± 1.09	2	-23.31 ± 2.12	6.06 ± 0.81
AR	P 01	9	-29.71 ± 0.68	4.52 ± 1.57	$1^{\#}$	-12.56	9.92	5	-30.97 ± 0.43	5.41 ± 0.73	2	-30.88 ± 0.04	6.07 ± 0.56
	P 02	1	-32.36	3.13	$1^{\#}$	-12.56	9.92	3	-31.30 ± 0.97	4.05 ± 0.57	1	-28.05	5.15
	P 05	5	-29.93 ± 2.12	6.23 ± 2.68	$1^{\#}$	-12.56	9.92	4	-32.01 ± 0.17	4.99 ± 0.69	2	-25.93 ± 2.86	6.21 ± 0.36
	P 06	5	-29.95 ± 0.92	4.78 ± 1.45	$1^{\#}$	-12.56	9.92	4	-28.75 ± 0.79	5.85 ± 0.91	2	-22.02 ± 1.59	5.76 ± 2.07
	P 07	5	-30.58 ± 1.15	4.47 ± 3.00	$1^{\#}$	-12.56	9.92	4	-27.90 ± 0.13	3.71 ± 0.14	17*	-27.27 ± 2.73	6.20 ± 1.50
	P 08	5	-30.34 ± 0.62	4.93 ± 0.75	$1^{\#}$	-12.56	9.92	4	-30.05 ± 0.31	5.07 ± 0.29	2	-27.71 ± 0.11	6.32 ± 0.28
	P 10	5	-30.21 ± 0.95	4.21 ± 4.16	$1^{\#}$	-12.56	9.92	4	-33.58 ± 0.26	8.17 ± 1.38	2	-29.27 ± 0.33	9.44 ± 0.47
	P 12	5	-30.87 ± 1.07	4.13 ± 2.99	$1^{\#}$	-12.56	9.92	4	-28.82 ± 0.17	4.59 ± 0.42	17*	-27.27 ± 2.73	6.20 ± 1.50
	P 13	5	-29.84 ± 0.97	4.60 ± 1.12	$1^{\#}$	-12.56	9.92	4	-29.70 ± 3.18	5.43 ± 1.59	2	-27.18 ± 0.40	5.29 ± 0.08
	P 15	4	-29.29 ± 0.90	3.35 ± 0.58	$1^{\#}$	-12.56	9.92	4	-29.69 ± 0.25	5.06 ± 0.07	2	-28.45 ± 3.07	4.61 ± 1.15
	P 16	5	-29.78 ± 1.63	5.42 ± 3.38	$1^{\#}$	-12.56	9.92	4	-27.14 ± 0.16	6.28 ± 0.11	2	-26.34 ± 0.61	6.41 ± 0.70
PA	P 02	6	-29.84 ± 0.76	2.28 ± 0.62	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-34.09 ± 0.47	6.01 ± 0.86	2	-21.01 ± 0.74	6.48 ± 0.34
	P 07	5	-28.80 ± 1.67	7.33 ± 0.95	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-34.68 ± 0.57	3.88 ± 0.28	2	-29.48 ± 1.49	6.62 ± 0.68

	P 08	5	-29.21 ± 1.00	5.88 ± 2.76	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-32.58 ± 1.69	4.17 ± 0.75	2	-26.34 ± 0.61	6.36 ± 0.09
	P 09	3	-30.14 ± 0.53	6.80 ± 1.63	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-25.32 ± 0.27	6.26 ± 0.21	2	-27.50 ± 0.85	5.97 ± 0.59
	P 12	5	-30.56 ± 1.76	1.09 ± 1.50	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-32.89 ± 0.59	4.15 ± 0.33	2	-31.63 ± 0.06	4.65 ± 0.30
	P 13	5	-29.80 ± 0.77	2.29 ± 1.29	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-30.24 ± 2.43	4.10 ± 0.67	2	-31.00 ± 0.47	5.94 ± 0.62
	P 15	5	-30.60 ± 1.08	0.70 ± 2.37	3*	-12.33 ± 0.27	3.55 ± 1.12	3	-26.82 ± 4.89	3.47 ± 0.33	2	-16.00 ± 7.31	3.73 ± 1.21
	P 16	4	-26.83 ± 7.99	2.96 ± 1.95	3*	-12.33 ± 0.27	3.55 ± 1.12	4	-26.90 ± 0.58	4.96 ± 1.48	1	-23.42	5.39
PR	P 01	4	-30.26 ± 0.75	2.04 ± 1.61	$1^{\#}$	-12.82	6.2	5	-26.95 ± 1.90	2.18 ± 3.20	2	-27.53 ± 0.64	2.61 ± 0.29
	P 02	3	-29.15 ± 0.73	2.69 ± 1.11	$1^{\#}$	-12.82	6.2	4	-32.20 ± 0.38	5.09 ± 0.18	2	-31.78 ± 0.16	4.11 ± 0.86
	P 07	3	-29.19 ± 1.40	4.28 ± 1.07	$1^{\#}$	-12.82	6.2	4	-27.65 ± 0.17	2.67 ± 0.12	2	-28.55 ± 0.09	3.50 ± 0.52
	P 08	4	-28.93 ± 0.95	6.01 ± 1.35	$1^{\#}$	-12.82	6.2	4	-28.92 ± 0.11	2.27 ± 0.33	2	-28.25 ± 0.51	4.74 ± 0.56
	P 15	5	-29.24 ± 1.39	7.90 ± 3.20	$1^{\#}$	-12.82	6.2	4	-30.23 ± 0.16	6.77 ± 1.15	2	-27.22 ± 0.17	7.02 ± 0.76
	P 16	3	-30.73 ± 1.07	5.03 ± 0.44	$1^{\#}$	-12.82	6.2	4	-35.44 ± 0.32	5.22 ± 1.28	2	-30.85 ± 0.99	6.34 ± 0.91

Table S12. Mean and standard deviation of the $\delta^{13}C$ and $\delta^{15}N$ of the consumers in each lagoon.

Floodplain	Lagoon	Consumer	n	$\delta^{13}C$	$\delta^{15}N$
AM	P 03	*A. falcirostris*	3	-32.77 ± 1.81	9.40 ± 0.22
		C. monoculus	1	-32.75 ±	10.76
	P 05	*A. falcirostris*	4	-31.89 ± 1.09	10.44 ± 0.92
		H. malabaricus	4	-32.67 ± 0.43	10.95 ± 0.53
	P 06	*C. monoculus*	1	-32.97	10.57
		O. bicirrhosum	1	-27.56	9.65
		P. flavipinnis	2	-36.02 ± 0.68	10.21 ± 0.57
		P. nattereri	5	-29.61 ± 1.712	9.54 ± 0.41
	P 07	*C. monoculus*	2	-27.22 ± 4.59	10.95 ± 0.55
		H. aff. malabaricus	2	-28.49 ± 2.62	9.74 ± 0.25
		P. nattereri	5	-29.39 ± 1.21	10.17 ± 0.46
	P 08	*C. monoculus*	4	-33.87 ± 1.16	9.98 ± 0.26
		H. aff. malabaricus	6	-28.04 ± 1.63	9.00 ± 0.29
		P. nattereri	4	-28.96 ± 1.45	9.11 ± 0.43
	P 10	*H. aff. malabaricus*	8	-30.11 ± 1.60	9.28 ± 0.51
		H. unitaeniatus	7	-26.78 ± 2.19	9.95 ± 0.58
	P 12	*H. aff. malabaricus*	8	-31.76 ± 1.31	8.52 ± 0.85
		H. unitaeniatus	11	-30.02 ± 2.29	9.54 ± 0.57
	P 14	*A. falcirostris*	10	-33.01 ± 0.85	11.94 ± 0.55
		H. aff. malabaricus	2	-30.21 ± 3.53	12.43 ± 0.14
	P 15	*A. falcirostris*	3	-33.13 ± 0.40	9.11 ± 0.95
		C. monoculus	2	-34.71 ± 1.62	9.48 ± 0.14
		H. aff. malabaricus	3	-30.63 ± 0.81	9.22 ± 0.29
		P. nattereri	1	-33.02	10.19
AR	P 01	*P. nattereri*	6	-29.30 ± 1.12	10.54 ± 0.53
		S. rhombeus	1	-29.23	10.71
		A. heteroleps	1	-31.82	10.65
		A. microlepis	1	-27.74	12.08
		C. dorsalis	1	-28.85	10.59
		C. gibbus	2	29.11 ± 0.13	11.50 ± 0.12
	P 02	*P. nattereri*	8	-28.45 ± 1.13	10.63 ± 0.26
		A. heteroleps	1	-32.97	9.97
		C. immaculata	1	-32.3	11.38
		H. cf. microlepis	1	-33.59	7.7
		R. vulpinus	1	-30.90	10.38
		S. eigenmanni	1	-28.67	10.49
		S. maculatus	1	-28.92	12.66
	P 05	*H. malabaricus*	6	-28.80 ± 2.43	9.07 ± 0.76
	P 06	*P. nattereri*	4	-27.43 ± 0.48	9.83 ± 0.59
	P 07	*P. nattereri*	1	-27.89	9.85
		C. dorsalis	1	-29.96	8.73
		S. rhombeus	2	-27.52 ± 0.07	10.92 ± 0.87

	P 08	*P. nattereri*	6	-26.55 ± 1.42	9.78 ± 0.45
		S. rhombeus	8	-27.05 ± 0.85	10.15 ± 0.33
	P 10	*P. nattereri*	1	-26.52	9.89
		S. rhombeus	1	-27.92	10.82
	P 12	*P. nattereri*	2	-26.96 ± 0.035	10.50 ± 0.65
		S. rhombeus	1	-27.82	10.34
	P 13	*P. fasciatum*	2	-28.88 ± 0.39	9.59 ± 0.078
		P. nattereri	3	-27.57 ± 2.61	10.23 ± 0.41
		P. squamosissimus	1	-29.67	11.55
		C. dorsalis	1	-29.08	10.41
		S. maculatus	1	-28.07	11.56
	P 15	*P. nattereri*	10	-25.75 ± 0.66	8.46 ± 0.53
		S. rhombeus	1	-27.70	8.70
	P 16	*P. nattereri*	5	-26.02 ± 0.749	9.28 ± 0.18
		C. kelberi	1	-26.73	8.43
PA	P 02	*S. maculatus*	1	-29.75	10.32
		A. pantaneiro	2	-31.65 ± 0.59	10.13 ± 0.10
		S. maginatus	2	-30.69 ± 0.25	10.45 ± 0.04
	P 07	*A. pantaneiro*	2	-26.03 ± 2.92	8.79 ± 0.31
		P. reticulatum	1	-29.02	9.25
		S. maculatus	2	-25.23 ± 1.38	8.21 ± 0.34
	P 08	*A. pantaneiro*	4	-28.71 ± 0.85	9.51 ± 0.38
	P 09	*A. pantaneiro*	1	-27.93	8.95
		P. nattereri	2	-27.10 ± 0.52	9.62 ± 1.07
		S. maculatus	5	-25.92 ± 1.04	9.41 ± 0.47
	P 12	*A. pantaneiro*	1	-24.80	9.45
		P. nattereri	1	-26.49	9.20
		S. maculatus	5	-25.80 ± 0.91	9.14 ± 0.24
		S. maginatus	3	-26.19 ± 0.47	9.89 ± 0.21
	P 13	*P. nattereri*	3	-26.04 ± 2.32	8.99 ± 0.43
	P 15	*A. pantaneiro*	6	-29.61 ± 1.34	9.91 ± 0.51
		Hoplias sp7	2	-28.24 ± 0.50	8.96 ± 0.50
		P. corruscans	1	-27.73	9.38
		P. nattereri	3	-28.18 ± 0.56	9.01 ± 0.15
	P 16	*A. pantaneiro*	1	-28.53	9.30
		P. corruscans	1	-27.88	9.24
		P. nattereri	2	-26.28 ± 0.23	9.31 ± 0.16
		S. maculatus	1	-24.55	8.74
		S. maginatus	1	-27.25	10.15
PR	P 01	*A. lacustres*	10	-32.51 ± 0.44	11.29 ± 0.32
		H. argentinensi	5	-30.71 ± 0.75	10.34 ± 0.63
		H. mbigua	4	-30.30 ± 0.46	10.72 ± 0.45
		Hoplias sp2	19	-29.66 ± 0.82	10.53 ± 0.57
		P. corruscans	1	-29.68	10.79

	S. maculatus	6	-28.67 ± 0.66	10.75 ± 0.36
	S. maginatus	8	-30.53 ± 1.20	11.14 ± 0.64
P 02	*A. lacustres*	11	-31.36 ± 1.21	10.49 ± 0.27
	H. argentinensi	6	-30.35 ± 0.59	10.75 ± 0.29
	H. mbigua	1	-31.14	10.56
	P. corruscans	6	-30.84 ± 0.67	10.72 ± 0.14
	S. brasilisiensis	1	-28.25	12.19
	S. maculatus	4	-28.35 ± 0.74	11.46 ± 0.04
	S. maginatus	13	-29.80 ± 1.09	11.01 ± 0.70
P 07	*A. lacustres*	10	-27.97 ± 1.06	11.52 ± 0.49
	H. argentinensi	3	-26.51 ± 2.04	11.05 ± 0.48
	H. mbigua	10	-27.14 ± 0.48	10.95 ± 0.44
	H. platyrh	1	-27.19	11.75
	Hoplias sp2	14	-25.40 ± 2.04	10.99 ± 0.34
	P. corruscans	2	-27.85 ± 0.10	11.47 ± 0.07
	S. maginatus	1	-27.54	11.59
P 08	*A. lacustres*	12	-28.60 ± 1.14	10.91 ± 0.22
	H. argentinensi	5	-26.85 ± 0.93	10.54 ± 0.47
	H. mbigua	6	-27.25 ± 1.78	10.45 ± 0.73
	Hoplias sp2	3	-26.26 ± 0.66	10.26 ± 0.49
	S. maculatus	4	-26.03 ± 0.13	11.19 ± 0.42
	S. margina	4	-28.08 ± 0.214	10.44 ± 0.63
P 15	*A. lacustres*	7	-29.23 ± 0.83	13.49 ± 0.48
	A. osteomy	1	-25.52	13.06
	C. kelberi	10	-26.93 ± 2.60	11.70 ± 1.06
	H. argentinensi	6	-26.48 ± 1.67	11.75 ± 0.99
	H. mbigua	8	-27.75 ± 1.38	12.51 ± 0.89
	Hoplias sp2	3	-26.70 ± 2.30	11.18 ± 0.41
	P. corruscans	2	-28.25 ± 0.19	12.76 ± 0.21
	P. galeatus	2	-28.03 ± 2.34	14.09 ± 0.35
P 16	*A. lacustres*	12	-27.69 ± 1.03	13.84 ± 1.06
	H. mbigua	9	-26.50 ± 1.14	13.38 ± 0.70
	Hoplias sp2	1	-26.69	11.65
	S. maginatus	3	-27.10	11.63

Table S13. Trophic position and alpha value to each species of consumer in each lagoon.

	Lagoon	Consumers	Lower TP	High TP	Median TP	Mode TP	Lower Alpha	High Alpha	Median Alpha	Mode Alpha
AM	P 10	*H. unitaeniatus*	2.19	7.59	4.33	4.21	0.12	1.00	0.74	0.96
		H. aff. malabaricus	2.00	7.38	3.92	3.96	0.01	0.94	0.48	0.36
	P 12	*H. unitaeniatus*	3.31	4.37	3.77	3.70	0.05	0.99	0.52	0.75
		H. aff. malabaricus	2.96	4.25	3.55	3.52	0.00	0.95	0.45	0.10
	P 14	*A. falcirostris*	3.89	4.87	4.40	4.41	0.00	0.85	0.17	0.02

		H. aff. malabaricus	2.00	7.09	4.58	4.60	0.01	0.96	0.48	0.19
	P 15	*A. falcirostris*	2.02	4.39	3.27	3.27	0.00	0.94	0.45	0.14
		C. monoculus	2.00	6.27	3.42	3.40	0.00	0.94	0.47	0.34
		H. aff. malabaricus	2.26	3.87	3.26	3.33	0.00	0.94	0.44	0.13
		P. nattereri	2.01	9.31	4.77	3.55	0.00	0.94	0.48	0.28
	P 03	*A. falcirostris*	2.14	4.30	3.29	3.29	0.08	1.00	0.63	0.96
		C. monoculus	2.02	9.17	4.74	3.74	0.06	1.00	0.53	0.87
	P 05	*A. falcirostris*	2.62	4.66	3.61	3.59	0.15	1.00	0.79	0.91
		H. malabaricus	2.79	4.48	3.72	3.70	0.18	1.00	0.85	0.98
	P 06	*C. monoculus*	2.00	9.26	4.81	3.94	0.03	0.98	0.52	0.75
		O. bicirrhosum	2.00	9.39	5.07	3.68	0.05	1.00	0.50	0.26
		P. flavipinnis	2.01	7.10	3.85	3.76	0.06	1.00	0.53	0.80
		P. nattereri	2.80	4.38	3.65	3.66	0.00	0.94	0.48	0.26
	P 07	*C. monoculus*	2.00	7.72	3.86	3.72	0.07	1.00	0.56	0.78
		H. aff. malabaricus	2.00	6.90	3.48	3.35	0.08	1.00	0.62	0.87
		P. nattereri	2.60	4.45	3.53	3.51	0.18	1.00	0.80	0.91
	P 08	*C. monoculus*	2.30	4.50	3.42	3.42	0.00	0.95	0.48	0.27
		H. aff. malabaricus	2.26	4.15	3.11	3.10	0.09	1.00	0.68	0.93
		P. nattereri	2.33	4.12	3.15	3.14	0.07	1.00	0.64	0.91
AR	P 01	*P. nattereri*	3.32	4.13	3.72	3.71	0.00	0.85	0.31	0.13
		S. rhombeus	2.00	9.17	4.71	3.75	0.01	0.96	0.49	0.38
		A. heteroleps	2.01	9.24	4.60	3.68	0.04	0.99	0.48	0.17
		A. microlepis	2.30	9.66	5.38	4.18	0.06	1.00	0.52	0.88
		C. dorsalis	2.03	9.29	4.98	3.69	0.05	1.00	0.52	0.71
		C. gibbus	2.59	6.86	4.03	3.96	0.10	1.00	0.64	0.85
	P 02	*A. heteroleps*	2.01	9.42	5.35	4.68	0.00	0.91	0.34	0.08
		C. immaculata	2.01	9.44	5.34	3.79	0.00	0.91	0.34	0.04
		H. cf. microlepis	2.02	9.41	5.20	3.14	0.00	0.91	0.34	0.04
		P. nattereri	2.32	6.94	4.19	3.92	0.17	1.00	0.80	0.94
		R. vulpinus	2.00	9.43	5.40	3.74	0.09	1.00	0.66	0.94
		S. eigenmanni	2.00	9.45	5.55	4.02	0.10	1.00	0.67	0.91
		S. maculatus	2.00	9.46	5.58	4.89	0.10	1.00	0.67	0.97
	P 07	*C. dorsalis*	2.01	9.14	4.46	3.28	0.06	1.00	0.56	0.87
	P 10	*P. nattereri*	2.05	9.43	4.96	3.06	0.00	0.94	0.45	0.21
		S. rhombeus	2.01	9.46	5.20	3.44	0.00	0.94	0.44	0.12
	P 12	*P. nattereri*	2.67	9.64	4.83	3.81	0.08	1.00	0.63	0.92
		S. rhombeus	2.01	9.38	5.02	3.84	0.05	1.00	0.53	0.82
	P 13	*P. squamosissimus*	2.00	9.25	4.68	3.91	0.00	0.95	0.47	0.19
		P. fasciatum	2.05	5.94	3.44	3.39	0.00	0.93	0.41	0.15
		P. nattereri	2.23	4.73	3.63	3.60	0.00	0.94	0.47	0.25
		S. maculatus	2.02	9.23	5.01	3.98	0.00	0.95	0.48	0.14
		C. dorsalis	2.00	9.25	4.57	3.60	0.05	1.00	0.52	0.84
	P 15	*P. nattereri*	2.26	3.95	3.12	3.10	0.00	0.73	0.40	0.48
		S. rhombeus	2.01	9.28	4.68	3.08	0.06	1.00	0.56	0.85
	P 16	*P. nattereri*	2.50	3.99	2.96	2.93	0.13	1.00	0.81	0.98
		C. kelberi	2.01	9.23	4.79	2.85	0.00	0.95	0.47	0.17
	P 05	*H. malabaricus*	2.14	3.86	3.04	3.04	0.00	0.83	0.28	0.07
	P 06	*P. nattereri*	2.61	4.33	3.39	3.36	0.12	1.00	0.71	0.96

	P 07	*P. nattereri*	2.02	9.29	4.65	3.73	0.00	0.95	0.53	0.73
		S. rhombeus	2.32	7.98	4.24	4.09	0.12	1.00	0.72	0.86
	P 08	*P. nattereri*	3.16	3.82	3.48	3.47	0.06	1.00	0.54	0.85
		S. rhombeus	3.23	8.86	3.61	3.56	0.05	1.00	0.58	0.96
PA	P 12	*A. pantaneiro*	2.01	9.42	5.20	4.07	0.00	0.94	0.47	0.16
		P. nattereri	2.01	9.42	5.14	4.04	0.02	0.97	0.47	0.13
		S. maculatus	3.44	5.00	4.20	4.21	0.00	0.85	0.18	0.03
		S. maginatus	3.43	5.41	4.28	4.30	0.00	0.90	0.27	0.03
	P 13	*P. nattereri*	2.83	4.80	3.78	3.73	0.00	0.94	0.47	0.15
	P 15	*A. pantaneiro*	3.33	5.38	4.37	4.38	0.00	0.87	0.26	0.08
		Hoplias sp7	2.01	7.31	4.13	3.97	0.00	0.91	0.41	0.29
		P. corruscans	2.00	9.30	5.04	4.27	0.00	0.94	0.47	0.20
		P. nattereri	3.07	5.55	4.07	3.95	0.00	0.90	0.42	0.23
	P 16	*A. pantaneiro*	2.00	9.20	4.68	3.48	0.06	1.00	0.52	0.80
		P. corruscans	2.00	9.20	4.55	3.56	0.03	0.97	0.51	0.84
		P. nattereri	2.00	6.11	3.57	3.50	0.09	1.00	0.68	0.96
		S. maculatus	2.00	9.40	4.98	3.30	0.06	1.00	0.53	0.83
		S. maginatus	2.02	9.25	4.74	3.78	0.03	0.97	0.52	0.86
	P 02	*A. pantaneiro*	2.04	6.60	3.76	3.73	0.13	1.00	0.57	0.58
		S. maculatus	2.00	9.31	4.98	3.95	0.01	0.94	0.45	0.17
		S. maginatus	2.05	6.10	4.01	4.00	0.01	0.86	0.40	0.37
	P 07	*A. pantaneiro*	2.00	7.75	3.67	3.51	0.00	0.90	0.38	0.11
		P. reticulatum	2.02	9.35	4.87	3.68	0.03	0.96	0.50	0.55
		S. maculatus	2.00	7.71	3.54	3.35	0.00	0.87	0.32	0.15
	P 08	*A. pantaneiro*	2.25	4.28	3.28	3.27	0.00	0.82	0.21	0.03
	P 09	*A. pantaneiro*	2.01	9.27	4.47	2.75	0.04	0.98	0.50	0.45
		P. nattereri	2.00	6.96	3.19	2.98	0.06	0.99	0.53	0.64
		S. maculatus	2.38	3.50	2.95	2.95	0.08	1.00	0.64	0.85
PR	P 01	*A. lacustres*	3.42	4.71	3.92	3.83	0.12	1.00	0.79	0.98
		H. argenti	3.21	4.60	3.80	3.78	0.20	1.00	0.65	0.69
		H. mbigua	3.15	4.92	3.97	3.97	0.13	0.95	0.58	0.62
		Hoplias sp2	2.64	4.80	4.01	4.04	0.00	0.67	0.34	0.34
		P. corruscans	2.00	9.24	4.90	4.11	0.04	0.98	0.50	0.58
		S. maculatus	3.16	4.99	4.12	4.11	0.00	0.64	0.26	0.21
		S. marginata	3.21	5.70	4.07	4.02	0.17	1.00	0.61	0.66
	P 15	*A. lacustres*	2.72	4.61	3.82	3.88	0.08	1.00	0.58	0.77
		A. osteomy	2.01	9.44	5.17	3.71	0.02	0.96	0.49	0.55
		C. kelberi	2.32	4.73	3.43	3.42	0.00	0.82	0.26	0.09
		H. argenti	2.07	4.66	3.39	3.34	0.00	0.87	0.26	0.04
		H. mbigua	2.38	4.88	3.56	3.53	0.00	0.84	0.30	0.11
		Hoplias sp2	2.08	4.23	3.14	3.13	0.01	0.94	0.46	0.18
		P. corruscans	2.00	7.09	3.87	3.67	0.00	0.93	0.42	0.15
		P. galeatu	2.04	7.73	4.12	4.02	0.02	0.97	0.48	0.23
	P 16	*A. lacustres*	4.30	5.57	4.92	4.89	0.00	0.50	0.08	0.01
		H. mbigua	4.17	5.47	4.82	4.80	0.00	0.77	0.10	0.01
		Hoplias sp2	2.00	9.42	5.19	4.16	0.00	0.94	0.48	0.13
		S. marginata	2.10	9.45	5.20	4.12	0.00	0.94	0.47	0.13
	P 02	*A. lacustres*	2.70	5.66	4.41	4.43	0.00	0.92	0.21	0.03

	H. argenti	3.05	5.51	4.48	4.49	0.00	0.80	0.14	0.02
	H. mbigua	2.01	9.28	4.98	4.42	0.00	0.94	0.46	0.26
	P. corruscans	3.66	5.26	4.49	4.50	0.00	0.82	0.15	0.02
	S. brasilisiensis	2.00	9.28	5.25	5.00	0.00	0.94	0.46	0.12
	S. maculatus	3.83	5.46	4.66	4.69	0.00	0.88	0.35	0.33
	S. marginata	3.49	5.51	4.57	4.59	0.00	0.68	0.14	0.03
P 07	*A. lacustres*	2.90	5.28	4.28	4.35	0.00	0.83	0.41	0.42
	H. argenti	2.70	5.92	4.36	4.38	0.08	1.00	0.62	0.89
	H. mbigua	3.61	4.85	4.30	4.34	0.11	1.00	0.65	0.75
	H. platyrh	2.06	9.30	5.01	4.60	0.06	0.99	0.54	0.69
	Hoplias sp2	3.49	4.90	4.33	4.37	0.09	1.00	0.66	0.96
	P. corruscans	2.01	6.43	4.32	4.35	0.01	0.92	0.48	0.48
	S. marginata	2.00	9.23	4.94	4.32	0.03	0.98	0.53	0.88
P 08	*A. lacustres*	3.46	4.78	4.25	4.42	0.13	1.00	0.74	0.97
	H. argenti	3.14	4.53	3.93	4.05	0.06	0.96	0.58	0.73
	H. mbigua	3.22	4.69	4.07	4.16	0.10	1.00	0.67	0.85
	Hoplias sp2	2.54	5.01	3.81	3.85	0.05	0.96	0.55	0.64
	S. maculatus	3.29	4.74	4.13	4.17	0.07	0.89	0.52	0.69
	S. marginata	3.03	5.19	4.16	4.31	0.15	1.00	0.80	0.97

Table S14. Energy source contribution (%) to each species of consumers and, contribution average in each floodplain.

Floodplain	Lagoon	Consumer	C_3 Riparian Vegetation	C_4 Riparian Vegetation	Phytoplankton	Periphyton	Allochthonous	Autochthonous
AR	P 01	*P. nattereri*	32.0±19.2 (3.6-73.5)	10.7±4.8 (2.8-21.0)	29.5±18.0 (3.7-69.9)	28.1±17.9 (3.4-69.3)	43	57.6
		S. rhombeus	45.3±30.5 (2.0-89.5)	7.4±4.9 (1.1-19.7)	27.4±27.8 (1.4-85.9)	19.9±22.9 (1.4-83.0)	53	47.3
		A. heteroleps	43.3±31.7 (1.7-89.9)	5.9±4.0 (0.9-15.8)	28.6±29.1 (1.3-87.7)	22.2±25.6 (1.2-86.3)	49	50.8
		A. microlepis	41.7±29.1 (1.9-87.5)	9.5±6.4 (1.3-25.2)	27.1±26.6 (1.4-85.6)	21.7±23.4 (1.5-81.6)	51	48.8
		C. dorsalis	46.1±30.4 (1.9-88.9)	7.9±5.3 (1.1-20.6)	25.6±26.8 (14-85.9)	20.3±23.5 (1.2-83.3)	54	45.9
		C. gibbus	28.5±19.9 (2.8-74.8)	15.9±12.4 (2.1-49.7)	28.2±19.7 (2.6-73.5)	27.4±19.3 (2.5-73.1)	44	55.6
	P 02	*P. nattereri*	31.8±16.0 (4.9-64.6)	12.5±5.0 (31-0.22.8)	28.4±16.0 (4.0-63.5)	27.3±15.5 (4.1-61.4)	44	55.7
		A. heteroleps	46.8±33.5 (1.7-91.7)	6.0±4.2 (9-16.8)	32.6±32.3 (1.3-89.6)	14.6±20.2 (1.1-82.2)	53	47.2
		C. immaculata	44.3±28.6 (2.0-88.3)	6.6±4.3 (1.0-17.6)	31.8±27.4 (1.8-86.3)	17.3±19.1 (1.4-77.7)	51	49.1
		H. cf. microlepis	58.1±33.4 (1.6-93.5)	4.5±3.0 (0.6-12.2)	28.6±32.5 (1.0-90.6)	8.9±12.2 (0.8-35.8)	63	37.5
		R. vulpinus	42.7±29.8 (2.0-88.6)	6.9±4.5 (1.1-18.2)	32.4±28.8 (1.5-86.7)	18.0±20.5 (1.2-79.8)	50	50.4
		S. eigenmanni	38.3±29.5 (1.8-87.4)	8.3±5.8 (1.2-23.1)	30.9±28.5 (1.5-86.4)	22.5±24.7 (1.5-84.2)	47	53.4
		S. maculatus	36.4±28.2 (1.9-86.6)	8.9±6.4 (1.3-25.0)	30.7±26.8 (1.8-84.6)	23.9±24.3 (1.5-83.1)	45	54.6
	P 05	*H.malabaricus*	30.3±20.7 (2.6-73.7)	11.4±6.0 (2.0-24.6)	32.5±19.1 (3.3-69.7)	25.8±18.2 (2.7-68.9)	42	58.3
	P 06	*P. nattereri*	39.3±20.7 (4.3-77.5)	9.6±6.0 (1.7-24.1)	33.3±20.8 (3.1-76.2)	17.9±12.6 (2.5-49.8)	49	51.2
	P 07	*P. nattereri*	45.9±28.2 (2.2-87.9)	8.1±5.6 (1.2-21.7)	30.3±28.0 (1.6-86.2)	15.7±17.9 (1.3-75.6)	54	46
		C. dorsalis	55.4±27.5 (2.3-89.9)	6.5±4.4 (0.9-17.4)	24.3±26.3 (1.4-87.6)	13.9±16.6 (1.3-74.5)	62	38.2
		S. rhombeus	28.6±19.6 (2.8-73.5)	16.7±12.5 (2.0-49.7)	29.1±20.1 (2.7-75.7)	25.7±18.6 (2.4-69.8)	45	54.8
	P 08	*P. nattereri*	28.0±17.0 (3.3-65.1)	16.2±5.9 (4.6-27.7)	28.3±17.5 (3.3-66.3)	27.5±17.8 (3.0-68.5)	44	55.8
		S. rhombeus	28.2±15.4 (4.0-61.2)	15.8±4.8 (5.8-25.2)	28.6±15.4 (4.3-62.1)	27.5±16.5 (3.7-65.5)	44	56.1
	P 10	*P. nattereri*	64.5±13.2 (38.8-87.7)	14.1±8.0 (2.0-31.6)	10.4±8.4 (1.4-31.3)	11.0±8.8 (1.4-3.14)	79	21.4
		S. rhombeus	63.9±14.7 (30.9-88.4)	11.3±7.0 (1.6-27.3)	12.6±10.9 (1.3-39.9)	12.3±10.2 (1.4-36.4)	75	24.9
	P 12	*P. nattereri*	28.2±19.2 (2.8-72.4)	17.8±12.6 (2.4-49.3)	28.2±19.6 (2.8-74.2)	25.8±18.8 (2.5-70.9)	46	54
		S. rhombeus	48.7±27.3 (2.3-87.5)	8.6±5.8 (1.1-22.8)	24.8±25.4 (1.6-85.7)	17.8±19.9 (1.3-79.0)	57	42.6
	P 13	*P. squamosissimus*	38.8±29.6 (1.9-88.0)	7.2±5.1 (1.0-19.9)	30.0±27.5 (1.5-86.5)	23.9±25.0 (1.4-84.6)	46	53.9
		C. dorsalis	40.7±30.7 (1.7-88.0)	6.9±4.5 (1.1-18.1)	29.5±28.3 (1.5-85.8)	22.9±25.1 (1.4-85.2)	48	52.4
		P. fasciatum	30.0±20.7 (2.6-75.7)	15.1±12.5 (1.7-50.5)	28.0±20.0 (2.6-75.0)	27.0±19.7 (2.3-73.6)	45	55

		P. nattereri	30.4±20.6 (2.7-76.5)	14.3±9.5 (2.1-37.2)	26.6±18.7 (2.3-69.1)	28.7±20.5 (2.7-77.4)	45	55.3
		S. maculatus	36.2±28.9 (1.8-86.2)	8.1±5.7 (1.2-22.3)	28.6±26.9 (1.5-85.0)	27.1±26.5 (1.6-85.0)	44	55.7
	P 15	*P. nattereri*	37.1±23.6 (3.1-84.8)	14.6±11.9 (1.5-46.8)	22.1±17.8 (1.9-67.1)	26.1±20.1 (0.2-74.6)	52	48.2
		S. rhombeus	47.5±31.1 (1.9-89.7)	7.0±4.7 (1.1-18.7)	19.8±23.8 (1.2-84.1)	25.7±27.5 (1.4-87.1)	55	45.5
	P 16	*P. nattereri*	27.9±16.5 (3.6-63.4)	12.7±5.9 (2.6-25.6)	29.9±19.0 (3.1-72.1)	29.5±18.6 (3.0-70.8)	41	59.4
		C. kelberi	63.5±19.5 (5.0-89.9)	8.8±5.8 (1.2-22.6)	13.5±14.5 (1.2-67.3)	14.2±16.0 (1.3-76.0)	72	27.7
	Média		**40.77**	**11.17**	**26.37**	**21.70**	**51.94**	**48.07**
PA	P 02	*A. pantaneiro*	30.7±21.8 (2.7-80.3)	17.5±15.6 (1.8-61.5)	32.8±22.2 (2.7-78.3)	19.0±15.9 (2.0-62.8)	48	51.8
		S. maculatus	60.6±24.7 (4.1-90.5)	9.2±6.6 (1.2-25.8)	20.5±22.5 (1.3-80.2)	9.8±8.7 (1.1-30.4)	70	30.3
		S. maginatus	32.1±22.4 (2.4-81.2)	16.7±14.4 (1.7-58.2)	32.2±21.6 (2.7-77.8)	19.0±15.6 (2.1-61.7)	49	51.2
	P 07	*A. pantaneiro*	25.5±18.5 (2.6-70.0)	24.8±15.2 (3.2-61.9)	24.3±17.1 (2.6-65.4)	25.5±18.5 (2.4-70.4)	50	49.8
		P. reticulatum	15.4±21.1 (1.1-82.3)	12.9±9.1 (1.4-34.6)	51.2±28.2 (1.9-88.6)	20.5±25.5 (1.2-86.3)	28	71.7
		S. maculatus	25.0±18.0 (2.4-68.4)	27.3±14.8 (3.6 -61.6)	23.0±16.0 (2.8-63.6)	24.7±17.8 (2.6-67.8)	52	47.7
	P 08	*A. pantaneiro*	29.7±19.8 (2.8-73.9)	11.8±7.4 (2.1-28.7)	34.8±18.6 (3.8-71.6)	23.7±16.9 (2.5-66.2)	42	58.5
	P 09	*A. pantaneiro*	43.4±31.2 (1.6-89.0)	8.8±6.0 (1.2-23.6)	17.6±22.6 (1.1-84.6)	30.3±30.8 (1.3-89.1)	52	47.9
		P. nattereri	28.9±19.5 (2.8-72.9)	16.5±13.7 (2.0-56.6)	26.4±19.3 (2.2-73.3)	28.3±19.8 (2.8-73.5)	45	54.7
		S. maculatus	28.4±16.2 (3.4-62.1)	13.6±6.4 (3.1-26.8)	27.8±18.1 (3.4-70.8)	30.2±18.7 (3.4-71.5)	42	58
	P 12	*A. pantaneiro*	48.0±25.2 (3.0-86.4)	24.2±16.3 (2.3-61.2)	13.8±14.2 (1.3-59.9)	13.9±15.3 (1.2-65.5)	72	27.7
		P. nattereri	52.6±24.8 (3.7-88.0)	16.6±11.9 (1.7-46.8)	15.2±16.6 (1.4-69.6)	15.6±17.7 (1.4-73.0)	69	30.8
		S. maculatus	27.2±15.9 (3.8-62.4)	30.8±7.5 (13.9-44.5)	20.9±12.7 (2.9-50.2)	21.0±13.2 (3.2-51.6)	58	41.9
		S. maginatus	27.5±18.2 (3.5-69.0)	26.6±11.1 (4.9-48.7)	22.4±15.0 (2.5-56.8)	23.5±16.3 (3.0-63.8)	54	45.9
	P 13	*P. nattereri*	30.9±20.3 (3.1-74.9)	18.6±10.7 (3.1-44.5)	25.7±18.1 (2.7-68.3)	24.8±17.8 (2.5-66.6)	50	50.5
	P 15	*A. pantaneiro*	67.5±16.0 (24.1-89.5)	7.6±4.9 (1.1-19.7)	16.6±14.4 (1.4-57.5)	8.3±5.9 (1.2-22.9)	75	24.9
		Hoplias sp7	37.2±23.0 (3.3-81.8)	17.1±14.2 (1.9-57.8)	26.8±20.1 (2.3-74.1)	18.9±15.7 (1.9-62.0)	54	45.7
		P. corruscans	57.5±22.6 (4.6-88.6)	10.2±7.4 (1.3-29.2)	18.7±19.9 (1.4-79.1)	13.6±14.3 (1.4-61.7)	68	32.3
		P. nattereri	47.1±23.0 (4.4-84.8)	13.3±10.7 (1.8-41.3)	25.1±19.6 (2.0-72.3)	14.5±11.9 (1.8-47.3)	60	39.6
	P 16	*A. pantaneiro*	49.4±26.8 (2.3-88.5)	10.4±8.1 (1.3-31.9)	27.2±27.2 (1.5-86.2)	13.1±14.0 (1.3-59.8)	60	40.3
		P. corruscans	47.2±27.7 (2.1-88.1)	10.4±8.3 (1.1-32.6)	28.4±27.9 (1.4-86.9)	13.9±15.7 (1.3-70.4)	58	42.3
		P. nattereri	26.1±18.6 (2.5-70.0)	17.8±13.8 (2.0-54.1)	29.7±20.7 (2.3-77.2)	26.4±19.7 (2.4-73.9)	44	56.1
		S. maculatus	41.0±27.5 (2.1-85.8)	13.9±11.7 (1.4-46.2)	27.5±26.5 (1.6-84.5)	17.7±20.0 (1.4-80.1)	55	45.2

	Média		**36.17**	**16.15**	**26.73**	**20.96**	**52.32**	**47.69**
AM	P 03	*A. falcirostris*	36.8±24.9 (3.0-86.6)	11.6±10.9 (1.2-42.7)	31.9±23.6 (2.2-82.9)	19.6±17.1 (1.6-65.5)	48	51.5
		C. monoculus	49.2±30.4 (2.4-90.8)	6.3±4.3 (0.9-16.8)	32.3±29.2 (1.6-86.9)	12.2±14.0 (1.1-62.0)	56	44.5
	P 05	*A. falcirostris*	33.8±23.5 (2.7-83.1)	7.9±6.4 (1.2-23.4)	42.8±23.2 (3.7-82.8)	15.5±12.4 (1.8-48.4)	42	58.3
		H. malabaricus	32.1±23.6 (2.3-84.3)	7.4±6.2 (1.1-23.3)	46.1±24.3 (3.7-85.8)	14.5±12.3 (1.6-49.7)	40	60.6
	P 06	*C. monoculus*	44.6±32.5 (1.6-90.6)	6.0±4.1 (0.8-16.8)	37.1±31.8 (1.6-89.1)	12.3±16.0 (1.1-74.5)	51	49.4
		O. bicirrhosum	43.8±29.2 (1.9-88.4)	9.4±6.5 (1.3-25.6)	27.6±26.9 (1.6-85.6)	19.2±21.8 (1.3-81.8)	53	46.8
		P. flavipinnis	28.3±20.9 (2.5-78.6)	19.2±15.7 (1.9-61.3)	28.5±20.8 (2.5-77.2)	24.1±18.6 (2.2-69.9)	48	52.6
		P. nattereri	38.9±24.1 (3.0-83.7)	7.1±4.9 (1.1-19.2)	38.9±23.4 (3.1-82.0)	15.2±12.1 (1.7-47.5)	46	54.1
	P 07	*C. monoculus*	26.1±19.4 (2.2-72.8)	18.9±13.8 (2.3-54.4)	29.0±20.5 (2.7-75.2)	26.1±19.6 (2.6-73.6)	45	55.1
		H. aff. malabaricus	28.3±20.2 (2.7-75.2)	15.7±12.1 (2.2-48.4)	30.7±20.8 (2.9-76.8)	25.3±18.8 (2.5-70.6)	44	56
		P. nattereri	29.6±19.8 (2.7-74.7)	8.1±4.7 (1.5-18.9)	42.7±21.6 (4.6-81.8)	19.6±14.6 (2.1-56.8)	38	62.3
	P 08	*C. monoculus*	45.5±26.4 (3.7-90.5)	10.8±10.0 (1.2-38.2)	24.0±20.7 (1.7-77.1)	19.7±17.7 (1.5-68.6)	56	43.7
		H. aff. malabaricus	51.0±20.4 (7.3-84.1)	7.0±4.2 (1.4-16.7)	23.7±18.4 (2.1-70.7)	18.3±14.3 (2.0-56.8)	58	42
		P. nattereri	48.8±23.4 (4.9-85.9)	7.9±6.3 (1.2-24.9)	24.7±20.1 (1.9-75.8)	18.5±15.7 (1.8-62.1)	57	43.2
	P 10	*H. unitaeniatus*	34.2±18.8 (4.1-71.7)	12.0±6.2 (2.3-25.7)	32.1±19.8 (3.6-74.7)	21.7±15.3 (2.4-59.7)	46	53.8
		H. aff. malabaricus	57.8±21.2 (8.6-88.6)	5.0±3.2 (0.9-13.0)	26.2±20.6 (2.2-76.7)	11.0±8.7 (1.3-33.9)	63	37.2
	P 12	*H. unitaeniatus*	56.1±21.7 (8.7-88.5)	5.2±3.0 (1.0-12.3)	27.4±20.8 (2.1-76.1)	11.4±8.5 (1.3-32.6)	61	38.8
		H. aff. malabaricus	58.3±24.6 (5.5-91.8)	4.1±2.8 (0.7-11.0)	28.6±23.8 (1.6-83.2)	9.0±7.6 (1.0-27.5)	62	37.6
	P 14	*A. falcirostris*	66.6±20.9 (10.8-92.8)	3.5±2.4 (0.6-9.5)	22.3±20.5 (1.4-79.5)	7.6±6.1 (0.9-23.6)	70	29.9
		H. aff. malabaricus	30.0±21.3 (2.7-77.5)	16.8±14.2 (1.7-57.9)	29.3±21.2 (2.6-78.6)	23.9±18.7 (2.1-71.2)	47	53.2
	P 15	*A. falcirostris*	37.4±24.9 (3.0-85.8)	14.0±12.8 (1.3-49.4)	29.2±22.4 (2.2-81.0)	19.5±16.9 (1.6-64.8)	51	48.7
		C. monoculus	29.6±21.6 (2.5-79.5)	19.8±16.6 (1.9-63.8)	27.3±20.6 (2.5-76.1)	23.3±18.4 (2.2-69.1)	49	50.6
		H. aff. malabaricus	40.1±24.1 (3.4-84.7)	10.6±9.7 (1.4-37.6)	32.9±23.3 (2.6-81.0)	16.4±14.2 (1.7-56.9)	51	49.3
		P. nattereri	60.0±30.9 (2.0-92.9)	5.4±3.7 (0.8-14.9)	26.4±30.4 (1.0-89.3)	8.2±9.3 (0.8-27.1)	65	34.6
	Média		**42.73**	**10.86**	**31.08**	**16.69**	**53.59**	**47.78**
PR	P 01	*A. lacustres*	77.3±14.3 (37.3-94.4)	3.0±2.1 (0.5-8.5)	9.6±9.5 (0.9-35.8)	10.0±9.8 (1.0-35.7)	80	19.6
		H. argenti	50.6±23.7 (4.6-87.6)	6.0±4.5 (1.0-17.2)	21.2±18.2 (1.6-71.1)	22.3±19.0 (1.9-72.5)	57	43.5
		H. mbigua	42.7±23.5 (3.6-83.7)	7.6±6.0 (1.2-22.9)	24.3±19.5 (2.1-73.4)	25.4±20.3 (2.2-76.4)	50	49.7
		Hoplias sp2	49.5±11.9 (25.1-72.6)	3.8±2.1 (0.8-8.7)	21.6±11.2 (3.3-45.3)	25.1±12.4 (4.4-50.6)	53	46.7

	P. corruscans	35.4±25.3 (2.3-83.6)	8.3±5.6 (1.2-22.6)	31.2±24.4 (2.0-82.0)	25.1±22.6 (1.9-81.2)	44	56.3
	S. maculatus	40.2±4.2 (5.2-76.4)	7.2±17.4 (1.4-17.0)	25.4±18.4 (2.8-68.4)	27.3±21.6 (3.0-71.6)	47	52.7
	S. marginata	55.1±19.9 (9.6-86.5)	4.8±3.0 (0.8-12.2)	19.5±15.5 (2.0-60.9)	20.6±16.2 (2.0-62.8)	60	40.1
P 02	*A. lacustres*	28.4±15.8 (4.4-65.0)	5.6±2.9 (1.3-12.4)	31.4±16.4 (4.3-66.3)	34.6±17.4 (5.0-70.9)	34	66
	H. argenti	30.8±18.3 (4.1-72.2)	9.8±4.9 (2.1- 20.3)	28.7±16.8 (3.2-65.6)	30.6±17.7 (3.9-68.4)	41	59.3
	H. mbigua	41.5±30.4 (1.8-88.9)	7.7±5.4 (1.1-20.9)	20.5±23.1 (1.2-83.0)	30.3±28.4 (1.5-86.2)	49	50.8
	P. corruscans	29.8±18.4 (3.5-70.8)	8.7±4.8 (1.6-19.8)	29.4±17.8 (3.1-68.7)	32.1±18.4 (4.3-72.5)	39	61.5
	S. brasiliensis	40.7±28.3 (2.3-87.6)	11.6±8.9 (1.4-33.4)	20.0±21.4 (1.5-79.3)	27.7±25.7 (1.7-83.5)	52	47.7
	S. maculatus	31.4±19.5 (3.7-74.7)	16.3±8.1 (3.0-33.8)	25.6±16.6 (2.9-63.9)	26.6±16.7 (3.0-63.3)	48	52.2
	S. marginata	33.7±15.2 (7.3-66.0)	10.4±4.0 (3.0-18.5)	26.1±13.2 (4.2-54.0)	29.8±13.9 (5.8-59.1)	44	55.9
P 07	*A. lacustres*	26.8±14.8 (3.5-59.7)	7.6±3.7 (1.7-15.4)	34.2±17.4 (5.0-70.4)	31.5±16.6 (4.3-67.0)	34	65.7
	H. argenti	25.7±17.6 (2.5-67.4)	16.6±10.2 (2.6-40.7)	29.1±19.6 (3.1-75.1)	28.6±19.2 (3.2-72.5)	42	57.7
	H. mbigua	25.5±13.8 (4.2-56.1)	11.0±4.5 (2.9-20.2)	33.5±15.9 (6.7-67.5)	30.0±15.0 (5.3-62.2)	37	63.5
	H. platyrh	24.5±23.6 (1.5-80.8)	10.6±7.8 (1.4-30.1)	35.6±26.9 (2.0-84.6)	29.3±25.6 (2.0-84.1)	35	64.9
	Hoplias sp2	21.2±12.7 (3.1-50.2)	18.7±4.9 (8.7-27.8)	33.8±17.1 (5.5-68.2)	26.3±14.8 (3.6-58.8)	40	60.1
	P. corrusc	27.2±19.1 (2.5-71.8)	16.3±12.7 (1.9-50.7)	28.0±20.1 (2.7-75.5)	28.5±19.9 (2.7-74.1)	44	56.5
	S. margina	24.9±23.1 (1.8-79.2)	10.0±7.2 (1.3 -79.2)	35.6±26.6 (2.3-85.0)	29.4±25.1 (2.0-82.8)	35	65
P 08	*A. lacustres*	22.8±13.5 (2.8-52.4)	6.9±3.3 (1.5-13.8)	44.0±17.8 (9.5-79.5)	26.4±14.8 (3.5-58.5)	30	70.4
	H. argenti	24.2±16.1 (2.8-61.8)	15.6±7.0 (3.6-30.4)	33.3±18.9 (4.4-73.5)	26.9±17.2 (3.2-67.2)	40	60.2
	H. mbigua	23.7±16.4 (2.6-63.3)	12.9±6.1 (2.7-26.2)	36.3±19.9 (4.6-76.5)	27.2±17.8 (3.3-69.6)	37	63.5
	Hoplias sp2	24.5±17.0 (2.8-65.4)	17.6±9.4 (3.0-38.5)	30.6±19.5 (3.1-72.5)	27.4±18.6 (2.9-69.6)	42	58
	S. maculatus	24.0±16.1 (2.7-61.5)	17.9±8.3 (3.7-34.9)	31.3±18.5 (3.8-71.1)	26.8±17.2 (3.0-66.6)	42	58.1
	S. marginata	26.3±17.9 2.5-68.9)	12.1±7.2 (2.2-28.6)	34.0±20.5 (3.4-77.5)	27.6±18.4 (2.8-69.2)	38	61.6
P 15	*A. lacustres*	28.3±17.6 (3.4-67.2)	7.4±4.0 (1.4-16.7)	39.0±19.3 (5.2-76.4)	25.4±16.5 (3.2-64.8)	36	64.4
	A. osteomy	31.6±24.6 (2.0-81.2)	17.3±11.3 (2.2-43.4)	24.4±22.0 (1.9-77.2)	26.7±23.8 (2.0-80.9)	49	51.1
	C. kelberi	22.8±16.7 (2.4-62.6)	17.7±6.4 (5.1-30.3)	28.3±18.0 (3.2-66.0)	31.1±21.1 (3.1-76.6)	41	59.4
	H. argenti	24.1±16.0 (2.6-61.5)	17.7±6.6 (4.5-30.7)	28.1±16.8 (3.7-64.0)	30.1±19.0 (3.5-72.9)	42	58.2
	H. mbigua	26.5±16.6 (3.3-63.4)	10.6±4.7 (2.5-20.6)	34.2±17.7 (4.8-70.3)	28.7±17.5 (3.4-68.1)	37	62.9
	Hoplias sp2	27.7±20.0 (2.4-74.0)	14.4±10.5 (2.0-41.1)	30.4±20.3 (2.8-74.3)	27.6±20.2 (2.5-75.1)	42	58
	P. corruscans	27.5±19.6 (2.6-73.6)	16.4±13.0 (2.1-52.7)	28.9±19.8 (2.8-73.1)	27.2±19.8 (2.5-73.7)	44	56.1

P 16	*P. galeatu*	27.2±19.6 (2.4-72.9)	17.7±13.6 (2.1-53.8)	28.3±20.1 (2.6-74.8)	26.8±19.6 (2.4-72.6)	45	55.1
	A. lacustres	26.6±13.3 (5.3-56.8)	26.2±4.9 (16.7-35.6)	24.1±10.9 (5.0-46.9)	23.1±12.2 (3.6-49.3)	53	47.2
	H. mbigua	25.3±14.0 (3.8-55.5)	31.6±5.8 (19.8-42.5)	21.0±11.1 (3.6-44.8)	22.2±12.8 (3.6-51.2)	57	43.2
	Hoplias sp2	36.5±29.0 (1.9-86.8)	18.1±13.2 (1.7-49.8)	20.6±20.9 (1.6-73.7)	24.9±25.6 (1.6-83.3)	55	45.5
Média		**31.61**	**13.80**	**27.94**	**26.66**	**45.41**	**54.60**

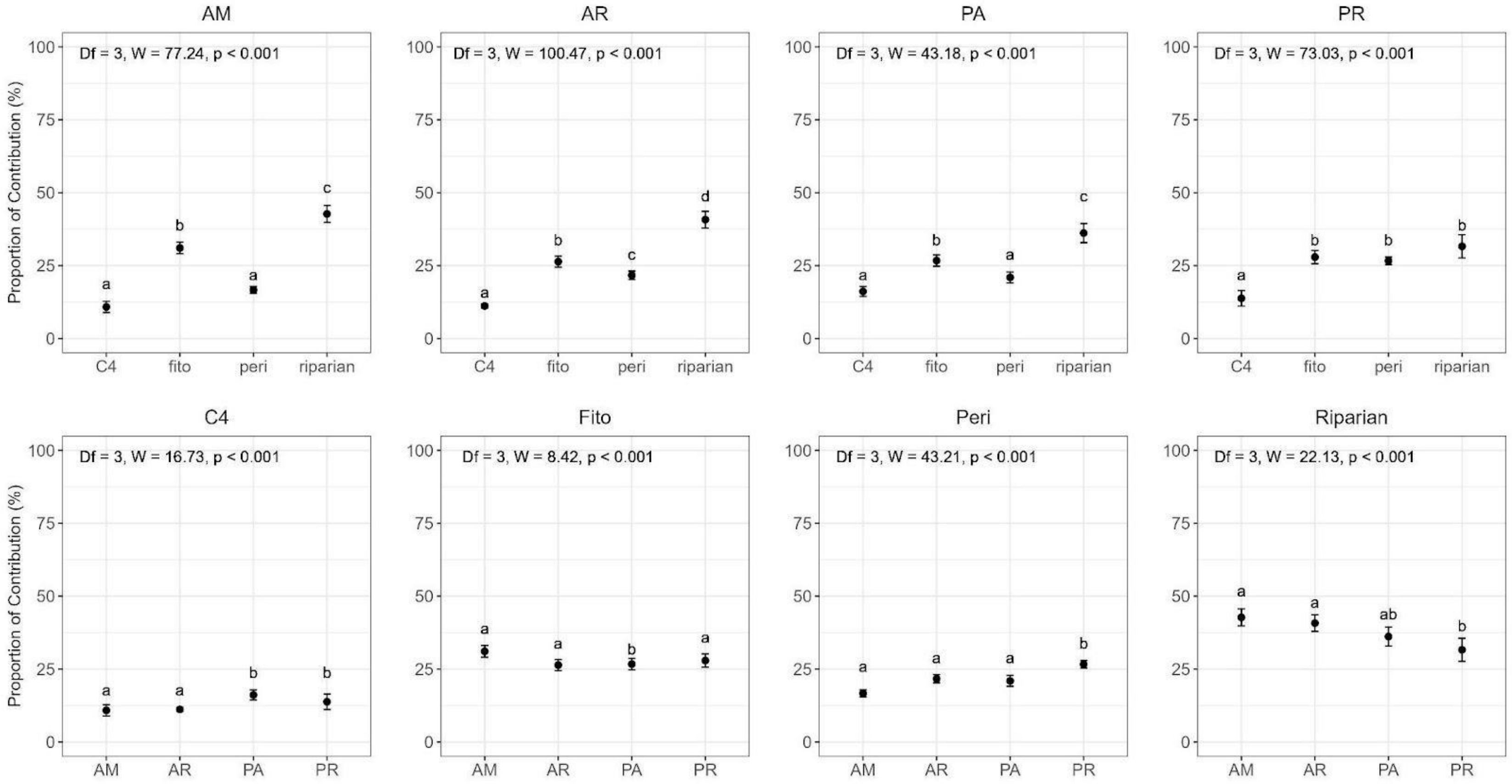

Figure S2. Kruskal-Wallis test result realized with contribution (%) in each lagoon, represented with mean end standard error.

Table S15. Kruskal – Wallis test result for allochthonous and autochthonous energy sources in each floodplain.

	AR W = 458.5. p = 0.365	AM W = 349.5. p = 0.20	PA W = 382. p = 0.01	PR W = 269.5. p < 0.01
Allochthonous	51.94^a	53.59^a	51.94^a	53.59^a
Autochthonous	48.07^a	47.78^a	48.07^b	47.78^b

Table S16. Niche analysis results, TA = niche total area, SEA = standard ellipse niche area, SEAc = corrected standard ellipse niche area.

Floodplain	Lagoon	TA	SEA	SEAc
AM	P 03	2.77	3.18	4.79
	P 05	2.16	1.85	2.15
	P 06	6.96	3.99	4.57
	P 07	7.38	3.88	4.45
	P 08	6.43	3.44	3.72
	P 10	9.42	3.67	3.95
	P 12	15.15	5.17	5.48
	P 14	6.35	2.70	2.98
	P 15	6.53	3.62	4.13
AR	P 01	4.68	2.32	2.57
	P 02	14.62	5.85	6.35
	P 05	5.15	4.00	5.01
	P 06	0.72	0.90	1.34
	P 07	1.84	2.37	3.57
	P 08	2.19	1.05	1.14
	P 10	5.00	3.00	3.50
	P 12	0.40	0.71	1.43
	P 13	6.05	4.07	4.75
	P 15	2.62	1.30	1.44
	P 16	1.16	0.90	1.14
PA	P 02	0.46	0.40	0.54
	P 07	3.68	3.13	4.19
	P 08	0.73	0.81	1.22
	P 09	2.92	1.83	2.12
	P 12	1.41	0.80	0.90
	P 13	0.11	0.22	0.44
	P 15	6.97	2.69	2.88
	P 16	2.05	1.78	2.21
PR	P 01	11.27	2.63	2.68
	P 02	6.95	1.53	1.57
	P 07	11.93	2.39	2.44
	P 08	9.61	2.53	2.60
	P 15	28.72	7.13	7.34
	P 16	2.77	3.18	4.79

Table S17. Position and dispersion values to SEAc for each floodplain.

Floodplain	Average	Median	Standard deviation	Minimum value	Maximum value	Amplitude

AM	4.03	4.14	0.99	2.16	5.49	3.33
AR	2.93	2.57	1.83	1.14	6.35	5.21
PA	2.36	2.18	1.52	0.54	4.75	4.21
PR	3.42	2.64	2.05	1.58	7.34	5.76

Table S18. Result of effect scale analysis to each floodplain. In bold, greater effect scale. Allochthonous: allochthonous contribution (C_3 and C_4 riparian contribution) (%) to the consumers.

	Buffer (m)	AIC	Intercept	Estimate	Standard Error	t-value	p-value
C^3 Riparian Vegetation contribution (%)	100	919.12	3.61	0.004475	0.004510	0.99	0.32
	200	917.77	3.60	0.006167	0.002564	1.49	0.14
	500	919.82	3.63	-0.001779	0.004122	-0.47	0.64
	1000	918.38	3.65	-0.003788	0.003039	-1.25	0.21
	2000	918.43	3.66	-0.003236	0.002675	-1.21	0.30
	5000	**913.26**	**3.71**	**-0.006169**	**0.002385**	**-2.59**	**0.01**
C_4 Riparian Vegetation contribution (%)	**100**	**732.7**	**2.53**	**-0.016019**	**0.006375**	**-2.51**	**0.01**
	200	738.6	2.55	-0.01608	0.00585	-2.75	< 0.01
	500	735.28	2.56	-0.010612	0.005329	-1.99	0.04
	1000	735.59	2.56	-0.007977	0.004322	-1.85	0.07
	2000	736.17	2.57	-0.006448	0.003829	-1.68	0.10
	5000	738.79	2.49	0.001060	0.003544	0.30	0.76
Allochthonous contribution (%)	100	885.21	3.91	-0.0004507	0.0028336	-0.16	0.87
	200	885.05	3.90	0.001128	0.002603	0.43	0.67
	500	882.57	3.90	-0.003675	0.002333	-1.57	0.12
	1000	878.48	3.93	-0.004787	0.001863	-2.57	0.01
	2000	879.12	3.94	-0.003974	0.001644	-2.42	< 0.01
	5000	**877.39**	**3.95**	**-0.004107**	**0.001482**	**-2.77**	**< 0.01**
FCL	**100**	**244.85**	**1.19**	**-0.006394**	**0.002820**	**-2.27**	**0.02**
	200	244.86	1.19	-0.005871	0.002590	-2.27	0.02
	500	244.89	1.20	-0.005328	0.002346	-2.27	0.02
	1000	247.65	1.19	-0.002792	0.001927	-1.45	0.15
	2000	248.46	1.19	-0.001927	0.001705	-1.13	0.26
	5000	248.33	1.20	-0.001855	0.001549	-1.20	0.23
Niche (SEAc)	100	466.4	1.19	0.001082	0.007733	0.14	0.89
	200	466.31	1.18	0.002666	0.007116	0.37	0.71
	500	457.9	1.07	0.01933	0.00614	3.15	< 0.01
	1000	460.63	1.09	0.013270	0.005103	2.60	0.01
	2000	462.24	1.07	0.010081	0.004641	2.17	0.03
	5000	**441.14**	**0.87**	**0.020476**	**0.003811**	**5.37**	< 0.001

Table S19. Structural equation model (SEM) analysis result. Positive estimate shows a positive relation, a negative estimate shows a negative relation. C_3 vegetation: C_3 riparian vegetation contribution (%) to the consumers: local land use: human land use percentage in the buffer of 100 m; Landscape land use: human land use in the buffer of 5000 m. TSI: trophic state index.

Regression	Estimate	Standard deviation	z-value	p-value
Allochthonous contribution (%)				
Local land use	0.063	0.139	0.45	0.65
Landscape land use	-0.207	0.075	-2.77	< 0.01

TSI				
Local land use	0.036	0.046	0.77	0.44
Landscape land use	0.042	0.025	1.70	0.09
FCL				
Local land use	-0.018	0.009	-2.07	0.04
Landscape land use	0.001	0.005	0.16	0.88
TSI	-0.025	0.018	-1.42	0.16
Allochthonous contribution (%)	0.017	0.006	2.83	< 0.01
Niche (SEAc)				
Local land use	-0.029	0.023	-1.28	0.20
Landscape land use	0.068	0.013	5.37	< 0.001
TSI	0.072	0.045	1.61	0.11
Allochthonous contribution (%)	-0.049	0.231	-0.21	0.83
FCL	-0.005	0.015	0.33	0.74

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