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Diet seasonality and resource partitioning by large catfishes in the Madeira River, Brazil

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ABSTRACT

Large catfishes form a diverse group with complex life histories, different habitat requirements and home range sizes, which may be related to several ecological aspects. Being among the main top predators in Amazonian river channels, they play a critical role in trophic dynamics, making their conservation particularly significant. However, our ecological understanding of this group remains limited. We evaluated the trophic seasonality and interspecific relationships among large pimelodid catfishes with different life histories and habitat uses in the Madeira River, in the Brazilian Amazon. The dataset was compiled through collaboration with local communities and commercial fishermen at 15 fishing sites, with samplings conducted between April 2009 and September 2011. A total of 225 stomachs contained food items that were identified at the taxonomic level of family. The diet was described for eight species, of which diet seasonality was tested for four, while diet dissimilarity and overlap were estimated for seven regarding only the low-water season. The large pimelodids fed upon many fish families. Most *Brachyplatystoma* species did not exhibit seasonal shifts in prey consumption. Diet overlap was higher among congeneric and channel-restricted species, particularly *Brachyplatystoma platynemum*, *B. rousseauxii,* and *B. vaillantii*. Despite the diet overlap, some degree of trophic niche partitioning was observed, even among channel-restricted *Brachyplatystoma* species*,* mainly when comparing *B. filamentosum* to the other congeneric species.

KEYWORDS: top predators, trophic ecology, feeding behavior, Amazon fish, Siluriformes

Sazonalidade da dieta e partilha de recursos por grandes bagres no Rio Madeira, Brasil

RESUMO

Grandes bagres constituem um grupo diversificado com histórias de vida complexas, diferentes requisitos de habitat e tamanhos de área de vida relacionados a vários aspectos ecológicos. Como figuram entre os principais predadores de topo em canais fluviais amazônicos, eles têm um papel crítico na dinâmica trófica, portanto sua conservação é particularmente relevante. Entretanto, nosso conhecimento ecológico deste grupo permanece restrito. Nós avaliamos a sazonalidade trófica e as relações interespecíficas de grandes bagres pimelodídeos com diferentes histórias de vida e uso de habitat que habitam o Rio Madeira, na Amazônia brasileira. O conjunto de dados foi construído em colaboração com a população local e pescadores comerciais em 15 localidades de pesca entre abril 2009 e setembro 2011. Um total de 225 estômagos contiveram itens alimentares, que foram identificados em nível taxonômico de família. A dieta foi descrita para oito espécies, das quais a sazonalidade da dieta foi testada para quatro e a similaridade e sobreposição da dieta para sete, apenas em relação à estação de águas baixas. Os grandes pimelodídeos alimentaram-se de muitas famílias de peixes. A maioria das espécies de *Brachyplatystoma* não apresentou mudanças sazonais no consumo de presas. A sobreposição da dieta foi maior entre espécies congenéricas e restritas ao canal do rio, sendo particularmente alta entre *Brachyplatystoma platynemum*, *B. rousseauxii* e *B. vaillantii*. Apesar da sobreposição nas dietas, observamos algum grau de partição de nicho trófico, mesmo entre espécies de *Brachyplatystoma* restritas ao canal, principalmente quando se compara *B. filamentosum* com suas congenéricas.

PALAVRAS-CHAVE: predadores de topo, ecologia trófica, comportamento alimentar, peixes Amazônicos, Siluriformes

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INTRODUCTION

Phylogenetically related species occupying similar habitats and with similar morphological attributes are more likely to compete for a shared resource (Webb *et al.* 2002). However, in nature, resource partitioning is more common due to slight differences in food consumption driven by ecological adaptations (Huang *et al.* 2021) and environmental heterogeneity, which provides a wider range of resource opportunities (van der Sleen and Rams 2023). By consuming slightly different forms of resources, using the same resource in different microhabitats or periods of the day, or employing diverse feeding tactics, species can reduce resource overlap, thereby making coexistence easier (Huang *et al.* 2021; van der Sleen and Rams 2023).

Home range size and habitat seasonality can also play a relevant role in diversifying resource use and mediating species interactions and trophic specialization (Huang *et al.* 2021; van der Sleen and Rams 2023). For example, specialization may be more likely in large-bodied organisms with large home range when habitat and resource availability fluctuate minimally over time (Huang *et al.* 2021). In the Neotropics, the seasonal oscillation of the level of large rivers and flooding of marginal habitats strongly regulates habitat availability and heterogeneity, as well as species phenology and movement, which, in turn, influences food availability for fish (Goulding *et al.* 1988). Flooding affects trophic guilds differently, increasing food for most (e.g., herbivores, omnivores and frugivores), but reducing it for piscivores due to prey dispersion (Goulding *et al.* 1988; McMeans *et al.* 2019). Conversely, during the low-water period, higher fish densities lead to increased food availability for piscivorous species (Flood *et al.* 2023). Habitat use and prey availability have been pointed out as key variables for species coexistence (Mérona and Rankin-de-Mérona 2004; Correa and Winemiller 2014; Mortillaro *et al.* 2015; van der Sleen and Rams 2023).

Large catfishes (> 1 meter in length) figure among the main natural fish predators in riverine environments (alongside river dolphins and crocodilians), inhabiting predominantly large river channels, but also occupying floodplain habitats (Barthem and Goulding 1997). Goliath catfishes of the genus *Brachyplatystoma* (Pimelodidae) primarily occupy the main channel of large rivers and undertake longitudinal movements along the rivers for growth and reproduction (Duponchelle *et al.* 2016; Barthem *et al.* 2017; Hauser *et al.* 2018; Hauser *et al.* 2019). Other pimelodid species belonging to the genera *Pseudoplatystoma*, *Pinirampus*, and *Zungaro* are known to use a diversity of connected habitats, moving seasonally from the river channels to floodplain habitats (Barthem and Goulding 1997; Loubens and Panfili 2000; Fabré and Barthem 2005; Barbarino-Duque 2005; Santos *et al.* 2006; Pereira *et al.* 2023). These species undertake both downstream and upstream short-medium migrations (*sensu* Duponchelle *et al.* 2021), as well as lateral migrations for reproduction and feeding (Loubens and Panfili 2000; Santos *et al.* 2006; Alves *et al.* 2007; Ziober *et al.* 2012; Avigliano *et al.* 2023). Movements for feeding purpose seem to be synchronized with fish schools that gather and change habitats during the same periods (Goulding 1980).

Over this complex spatial-temporal movements, habitat segregation has been suggested as one of the main factors responsible for differences in foraging strategies and prey consumption by this group of fish (Barbarino-Duque and Winemiller 2003). The most obvious habitat differences include species restricted to the main river channel and species which move seasonally from the main river channel to the floodplain and small tributaries (Barbarino-Duque and Winemiller 2003).

During the low-water season large catfish species are forced to retreat to the river channel, where they are more likely to co-occur (Goulding 1979). In that season, the density of prey increases while habitat heterogeneity decreases (Lowe-McConnell 1987) possibly leading to higher trophic overlap and competition (Barbarino-Duque and Winemiller 2003). As potential prey fish exhibit a high diversity of migratory behaviors and habitat use throughout the annual flooding cycle of river-floodplain systems, it is reasonable to expect seasonal variations in the diets of large pimelodid catfishes. However, species with large home range and habitat specialization, such as the river-channel catfishes, frequently feed on the most available prey in the habitat (Riotte-Lambert and Matthiopoulos 2020; Huang *et al.* 2021), which could suppress the seasonal effect of hydrological variation that affects most floodplain fish assemblages (Bogotá-Gregory *et al.* 2023).

In this context, in this study we examined the diet and feeding ecology of the most abundant large pimelodid catfishes captured in the Madeira River, in the southwestern Brazilian Amazon, between 2009 and 2011. We describe the diet and test hypotheses to address the following questions: (1) Do the diets of *Brachyplatystoma* species, as habitat specialists with large home ranges, exhibit seasonal variation?; and (2) How do habitat use and congeneric traits relate to the trophic segregation of large catfish species, enabling their co-occurrence in the Madeira River? It was expected that catfish species restricted to the main river channel, such as *Brachyplatystoma* spp., exhibit low or no seasonal variation in their diet. During the low-water season, when large catfishes are forced to retreat into the river channel and are more likely to co-occur, we expected a higher degree of dietary overlap among congeneric species compared to non-congeneric ones. Regarding habitat use, main channel-restricted species were expected to show higher trophic overlap, segregating from other large river-floodplain catfish species.

MATERIAL AND METHODS

Study area

The Madeira River is formed by the confluence of the Beni and Mamoré rivers and is the largest tributary of the Amazon River in terms of drainage area, discharge, and sediment transport (Goulding 1981; Goulding *et al.* 2003; Junk *et al.* 2011; Latrubesse *et al.* 2017). Before dam construction, the Madeira River basin could be geographically divided into two distinct regions in relation to its main rapids and waterfalls (Jirau, Teotônio, and Santo Antônio waterfalls, which are now submerged by the reservoirs of the Jirau and Santo Antonio hydroelectric power plants; Cella-Ribeiro *et al.* 2017). Upstream of the waterfalls, the water is highly turbid for most of the year, with its tributaries flowing through deep (8-20 m), narrow, incised channels with very limited floodplain, reflecting its non-meandering morphology. Downstream of the waterfalls, the river widens, has a lower flow speed and larger floodplains with meandering tributaries towards the confluence with the Amazon River (Leite *et al.* 2011; Torrente-Vilara *et al.* 2011).

Data collection was carried out along a transect spanning approximately 600 km over the Mamoré - Madeira River basin, including three urban fish markets as well as 12 riverine communities with fisheries landings located on the banks of the river (Figure 1), as described in Doria *et al.* (2012) and Sant'Anna *et al.* (2020). The most upstream site was Guajará-Mirim, on the lower Mamoré River, and the most downriver site was in the municipality of Humaitá, in the middle Madeira River (Doria *et al.* 2012). Data collection occurred between April 2009 and September 2011, covering both the low-water (usually from May to October) and high-water periods (usually from November to April), before reservoir flooding by the dams, which started in September 2011.

Study species and data collection

Eight large catfish species figured among the most landed species in the surveyed fish markets (Doria and Lima 2016) and were considered for stomach sampling: *Brachyplatystoma platynemum* (Boulenger 1898), *B. filamentosum* (Lichtenstein 1919), *B. rousseauxii* (Castelnau 1855), *B. vaillantii* (Valenciennes 1840), *Pinirampus pirinampu* (Spix and Agassiz 1829), *Pseudoplatystoma punctifer* (Castelnau1855), *P. tigrinum* (Valenciennes 1840), and *Zungaro zungaro* (Humboldt 1821). Data collection was conducted as part of the Fisheries Monitoring and the Fish Ecology and Biology Monitoring programs, associated with the environmental studies of the Santo Antonio and Jirau Hydroelectric power plants (Doria *et al.* 2010; Doria and Lima 2016; Hauser *et al.* 2018). Stomachs were obtained weekly from fishes captured by commercial fisheries and landed at the 15 fishing sites across the study area, preserved (see below) and sent monthly to the Laboratory of Ichthyology and Fisheries at the Federal University of Rondônia (LIP/UNIR) in Porto Velho, Rondônia, Brazil. At each site, a local trained collector or a technician from LIP/UNIR recorded the standard length (mm), total weight (g), fishing date and locality during fish landings. Stomachs containing food items were collected from a subsample of the landed target species, identified by species and preserved in a 4% formaldehyde solution, and later transferred to a 70% alcohol solution in the laboratory. The fishing techniques used by fishermen included longlines, bottom longlines, harpoons, gillnets, cast nets, and drift gillnets (Doria and Lima 2016). The main habitat targeted by fisheries and the source of the samples was the main channel of the Madeira River, primarily in the rapids' sections (see details in Doria and Lima 2016; Sant'Anna *et al.* 2020).

Stomachs were examined under a stereomicroscope, and prey items were identified to the most detailed taxonomic level possible by taxonomy experts, using specialized literature and reference collections at UNIR (see Queiroz *et al.* 2013a,b,c). For each stomach containing food items, the relative volume of each food item was visually estimated relative to the total stomach content, considering the total volume of the items as 100% (Goulding *et al.* 1988). Because fishing with longlines and bottom longlines involves the use of bait that usually is commonly captured fishes (e.g., Curimatidae, Prochilodontidae, Anostomidae species), prey items were carefully validated. Fish prey showing minimal digestion and perforations caused by hooks (i.e., used as bait) were excluded from the relative volume estimate. Captures using other methods, such as nets or harpoons, typically did not involve bait, and are the most representative fisheries techniques except for *Zungaro zungaro* (Goulding 1979; Doria *et al.* 2012; Sant'Anna *et al.* 2020). Empty stomachs were not completely reported by our local collaborators, and it was not possible to assess the frequency of empty stomachs among the species and seasons of the year.

Data analysis

Of the 315 stomachs containing food items obtained during the sampling period, only those containing prey items identified at least to the level of order were included in the analysis. Analyses were performed by grouping the data at the level of order and at the level of family, except for the

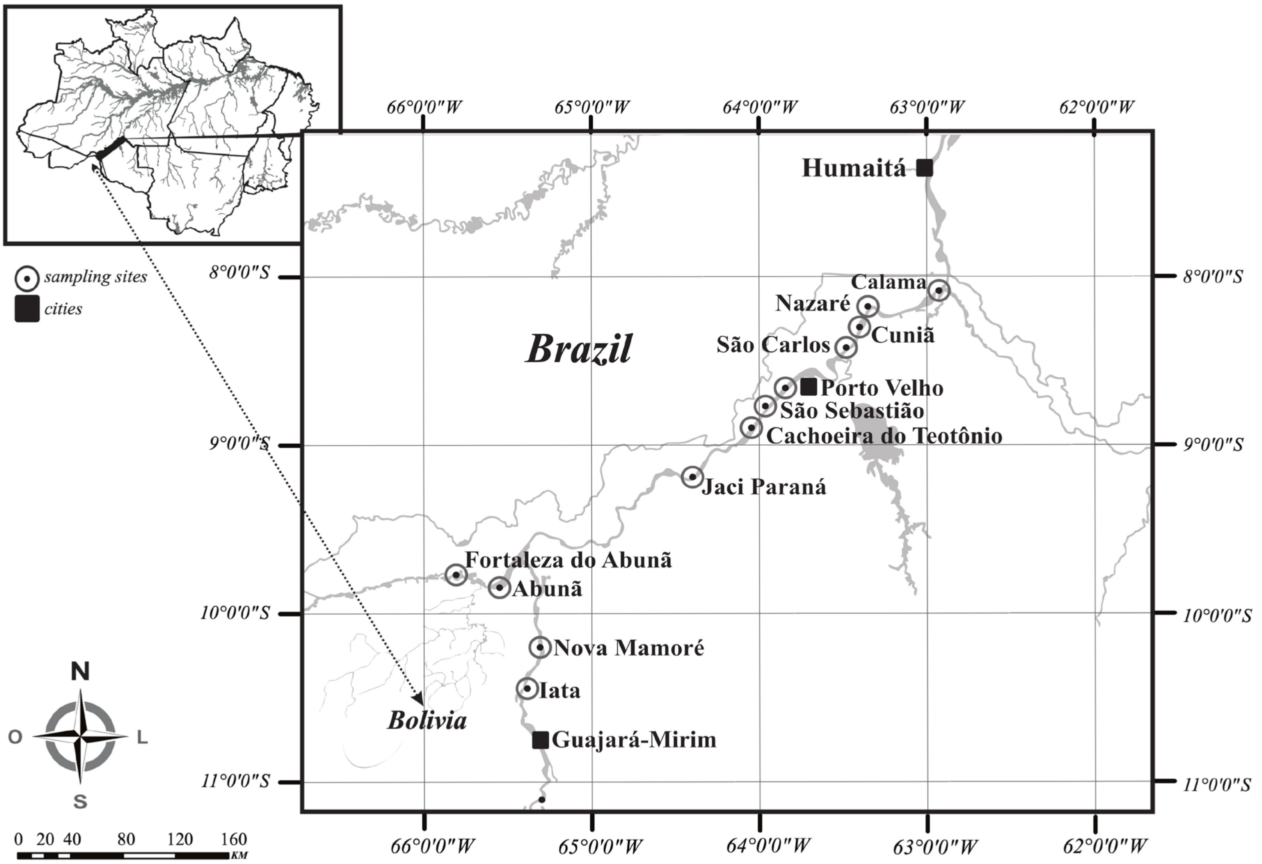

Figure 1. Location of the 15 commercial fishery landing localities (circles) and three urban fish markets (squares) that conform the study area along the Madeira and Mamoré rivers in Rondônia state (Brazil).

analysis of diet overlap, in which grouping at order level would overestimate niche overlap.

Diet description was based on all data available for each species, pooling samples from the high and low water seasons. However, due to variations in sample size among species and seasons (samples were about two times higher during low water, Table S1), we selected two distinct data sets to address the research questions posed in this study (Table 1). For *Zungaro zungaro* only the diet description is presented due to the low sample size. Details on the number of stomachs analyzed, seasonal distribution, fish size and weight, and habitat preferences per species are provided in the Supplementary Material (Tables S1 and S2).

Diet seasonality - We tested diet change between seasons (high water x low water) using multivariate permutation analysis of variance (PERMANOVA; Anderson 2001) separately for each of the four *Brachyplatystoma* species. Diet composition was based on individual values of the relative volume of food items identified to the level of family. Month of capture was categorized as low water (May – October) or high water (November – April). Values were transformed by log (x+1) before constructing a Bray-Curtis dissimilarity matrix. To identify the food items contributing most to dietary differences, we employed the percentage similarity method (SIMPER, Clarke 1993) with 999 randomizations. A PERMANOVA test was also applied to verify sampling year effect, which indicated no significance for any species (results not shown).

Diet segregation during the low-water season - To assess diet dissimilarity, we transformed the individual relative volume values of food items by log (x+1). Next, we created a Bray-Curtis dissimilarity matrix of diet composition and applied a PERMANOVA combined with pairwise tests and Bonferroni correction (Armstrong 2014). To visualize the diet dissimilarity among the species a cluster analysis based on the UPGMA method was applied, based on the sum of relative volumes of each food item per species.

The dietary overlap was then calculated according to Pianka (1974), using the equation $O_{ij} = (\Sigma p_{ij} \times p_{ik} / \sqrt{\Sigma p_{ij}\text{^}2\ \Sigma p_{ik}\text{^}2})$, where O_{jk} is Pianka's index of species *j* and *k*, p_{ij} is the relative

Table 1. Analytical design to address the two main research questions on the trophic ecology of large catfishes from the Madeira River between 2009 and 2011. The numbers represent the total stomachs analyzed for each species and seasonal period.

Question	Analyses	Species	Period	
			Low water	High water
1- Seasonal changes in diet	PERMANOVA by species with individual data	*Brachyplatystoma filamentosum*	20	11
		Brachyplatystoma platynemum	9	11
		Brachyplatystoma rousseauxii	27	25
		Brachyplatystoma vaillantii	72	8
			Low water	
2- Trophic segregation	1. Diet dissimilarity among species - PERMANOVA with individual data; 2. Trophic Niche breadth - PERMDISP with individual data; 3. Niche overlap - t-test for Pianka`s index comparing channel restricted species to others; t-test comparing congeneric and non-congeneric species	*Brachyplatystoma filamentosum**	20	
		*Brachyplatystoma platynemum**	8	
		*Brachyplatystoma rousseauxii**	27	
		*Brachyplatystoma vaillantii**	72	
		*Pseudoplatystoma punctifer***	13	
		*Pseudoplatystoma tigrinum***	6	
		*Pinirampus pirinampu***	6	

*River channel-restricted species; ** River-floodplain species

volume of food item i in the overall food items of species j, p_{ik} is the proportion of food item i in the total food items of species k, and n is the total number of food items. We estimated the consumption of each food type by the sum of the relative volume of that item for each species, and the results were consistent when using the average of relative volume (results not shown). Dietary overlap values range from 0 (no overlap) to 1 (full overlap), with values greater than 0.6 considered high, values from 0.4 to 0.6 considered intermediate, and values below 0.4 considered low (modified from Grossman 1986). To test if congeneric species had higher trophic overlap compared to non-congeneric species a t-test with Welch's correction was conducted using Pianka`s overlap values for each group. To test if channel-restricted species segregate from river-floodplain species, another t-test with Welsh correction was conducted by comparing Pianka`s overlap values among *Brachyplatystoma* species to the overlap values between *Brachyplatystoma* and other (non-congeneric) species.

The niche breadth was estimated using PERMDISP with a Bray-Curtis dissimilarity matrix of diet composition (Anderson 2006). Dietary niche breadth was measured as the average distance of each individual to the group's centroid in a Principal Coordinate Analysis (PCoA) (Correa and Winemiller 2014).

All statistical analyses were performed in the R programming environment (R Core Team 2023), with a significance level of $p < 0.05$. Statistical analyses were conducted using the *adonis2* (PERMANOVA), *betadisper* (PERMDISP), and *simper* (SIMPER) from the vegan package; *hclust* (Cluster) function from the stats package, and *pairwise.perm.manova* (post-hoc test) from the RVAideMemoire package. We used the *niche.overlap* function from the spaa package for niche overlap analyses.

RESULTS

Minimum and maximum standard length suggest that most fish were subadults or adults (Table S1). From 315 valid samples, 267 stomachs had prey identified at order level and 225 had items identification at family level. Since the overall results comparing family and order level of prey identification did not differ significantly, here we present only the results based on the family-level identification of prey. Gymnotiformes was the most affected group when family level identification is considered, underestimating the relevance of this group in the diet of large catfishes, mainly *B. platynemum* (Table S3 and S4). Results based on order-level identification are available in the Supplementary Material (Tables S5-S7; Figure S1).

The diet based on the 225 stomachs containing food items identified to family level suggested that the large pimelodid catfishes predominantly consumed fish, with the occasional consumption of macroinvertebrates. Overall, 23 fish families were identified among the prey, with pimelodids representing the main prey consumed by the congeners *B. platynemum, B. rousseauxii,* and *B. vaillantii*. Pimelodidae and Doradidae were equally consumed by *B. filamentosum* (Figure 2a). *Pinirampus pirinampu* fed mainly on Triportheidae, *P. punctifer* consumed small Heptapteridae catfishes and Prochilodontidae equally, *P. tigrinum* strongly preyed upon Prochilodontidae, and *Z. zungaro* fed on Curimatidae and Prochilodontidae (Figure 2b; see Supplementary Material, Tables S3 and S4 for detailed prey identities).

Diet seasonality

Among the *Brachyplatystoma* species, the diet significantly varied seasonally only for *B. filamentosum*, which fed

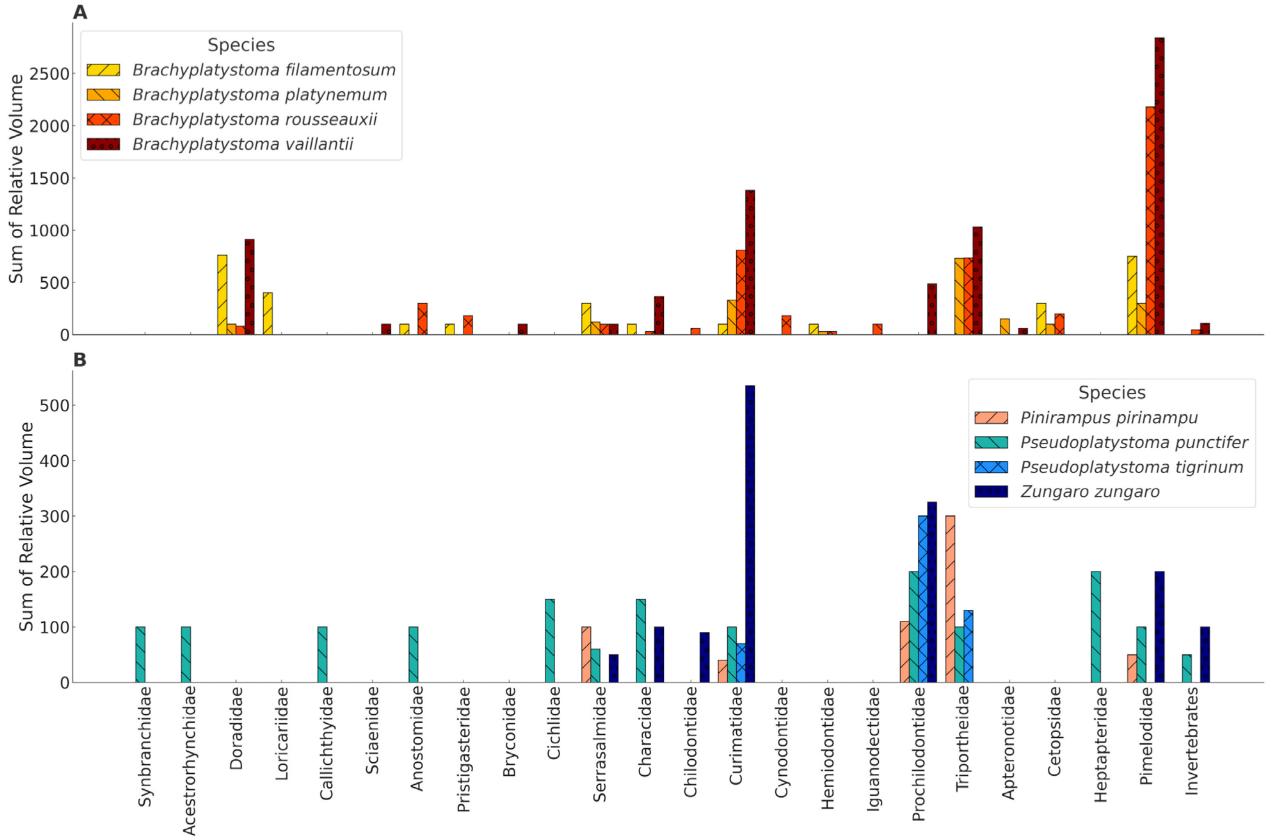

Figure 2. Sum of relative volumes of prey taxonomically identified to the family level for each study species of large catfish sampled along the Madeira River (Rondônia state, Brazil) from 2009 to 2011. Invertebrates were grouped due to their low representativeness. Species were split into two graphics for better visualization. **A** – *Brachyplatystoma* species; **B** – Other large catfish species.

predominantly on Pimelodidae (long-whiskered catfishes) and Serrasalmidae (*pacus* and *piranhas*) during the high-water season and shifted to Doradidae (thorny catfishes), Loricariidae (suckermouth catfishes), and several families of Characiformes during the low-water season (Table 2; Table S3).

Trophic segregation during low water

The diets of seven large catfishes analyzed for trophic segregation differed significantly during the low water season (PERMANOVA, F = 2.563; df = 6; 146; p = 0.001; Table 3, above the diagonal; Figure 3). The diet of *B. filamentosum* differed significantly from that of *B. rousseauxii* by the consumption of other siluriforms, including Loricariidae (mostly the deep channel dwelling *Planiloricaria* cf. *cryptodon*) and a large proportion of Doradidae and Cetopsidae. *Brachyplatystoma rousseauxii* preyed mainly on Characiformes, especially Curimatidae and Triportheidae. Furthermore, the diets of *B. filamentosum* differed from *Pinirampus pirinampu*, which consumed a larger proportion of Triportheidae (Table 3, above the diagonal; Figure 3). *Brachyplatystoma filamentosum* and *B. rousseauxii* differed significantly from *Pseudoplatystoma tigrinum*, which mainly consumed Prochilodontidae and *Macrobrachium* shrimps (Supplementary Material, Table S8).

The trophic overlap (Table 3, below the diagonal) was significantly higher among the congeneric species pairs (*Brachyplatystoma* spp. and *Pseudoplatystoma* spp.), while most of the other pairwise comparisons showed low to moderate levels of overlap (t = 3.311, df = 11.125, p-value <0.01; mean Pianka`s overlap: congeneric = 0.656; non-congeneric = 0.331; Figure 3). Trophic overlap was also significantly higher among the channel-restricted species than between those and

Table 2. PERMANOVA results for seasonal variations (high vs. low water) in the diet composition of Brachyplatystoma species from the Madeira River, based on the relative volume of consumed prey items for the period of 2009 and 2011. Separate tests were conducted for each species, with statistically significant results highlighted in bold.

Species	DF	F	P
Brachyplatystoma filamentosum	30	2.555	**0.03**
Brachyplatystoma platynemun	19	1.787	0.13
Brachyplatystoma rousseauxii	51	0.959	0.38
Brachyplatystoma vaillantii	79	1.505	0.32

the river-floodplain species (t = 3.302, df = 8.466, p-value < 0.01; mean Pianka`s overlap: main channel-restricted = 0.66; main channel-restricted x river-floodplain= 0.313; Table 3; Figure 4). Despite the contrasting diet composition and trophic overlap, all species exhibited similar dietary niche breadths (PERMDISP, F= 0.816; df=6; 146; p > 0.1).

DISCUSSION

Our study revealed three relevant aspects of the trophic ecology of large Pimelodidae catfishes in the Madeira River: 1 - most species with habitat use restricted to the main river channel did not exhibit seasonal shifts in prey consumption; 2 - diet overlap during the low water season was higher only among congeneric and channel-restricted species, particularly among *B. platynemum*, *B. rousseauxii,* and *B. vaillantii*; and 3 - there is evidence of trophic niche partitioning among the co-occurring species. This partitioning is particularly evident between *B. filamentosum* and its congeneric species.

The studied species did not exhibit trophic specialization in the form of predation on any specific prey family, suggesting that prey selection is driven by local and momentary availability (Barthem and Goulding 1997) and possibly mediated by differences in feeding tactics or foraging meso-habitat use. Seasonal variation in prey abundance, driven

Table 3. Results of diet dissimilarity and trophic overlap among seven catfish species from the Madeira River for the period between 2009 and 2011. Pairwise comparisons (PERMANOVA) for diet dissimilarity among large catfish species (Bonferroni-adjusted p-values) are presented above the diagonal, while Pianka's index of diet overlap is shown below the diagonal. Statistically significant p-values (PERMANOVA) and high trophic overlap values (Pianka's index) are highlighted in bold.

	B. filamentosum	*B. platynemum*	*B. rousseauxii*	*B. vaillantii*	*P. pirinampu*	*P. punctifer*	*P. tigrinum*
Brachyplatystoma filamentosum	-	1.000	**0.042**	0.063	**0.042**	0.231	**0.021**
Brachyplatystoma platynemum	0.450	-	1.000	1.000	1.000	1.000	0.504
Brachyplatystoma rousseauxii	0.414	**0.776**	-	1.000	1.000	0.189	**0.021**
Brachyplatystoma vaillantii	0.531	**0.852**	**0.933**	-	0.399	0.357	0.084
Pinirampus pirinampu	0.064	0.488	0.433	0.451	-	1.000	1.000
Pseudoplatystoma punctifer	0.198	0.400	0.407	0.529	0.523	-	1.000
Pseudoplatystoma tigrinum	0.024	0.276	0.183	0.336	**0.656**	**0.637**	-

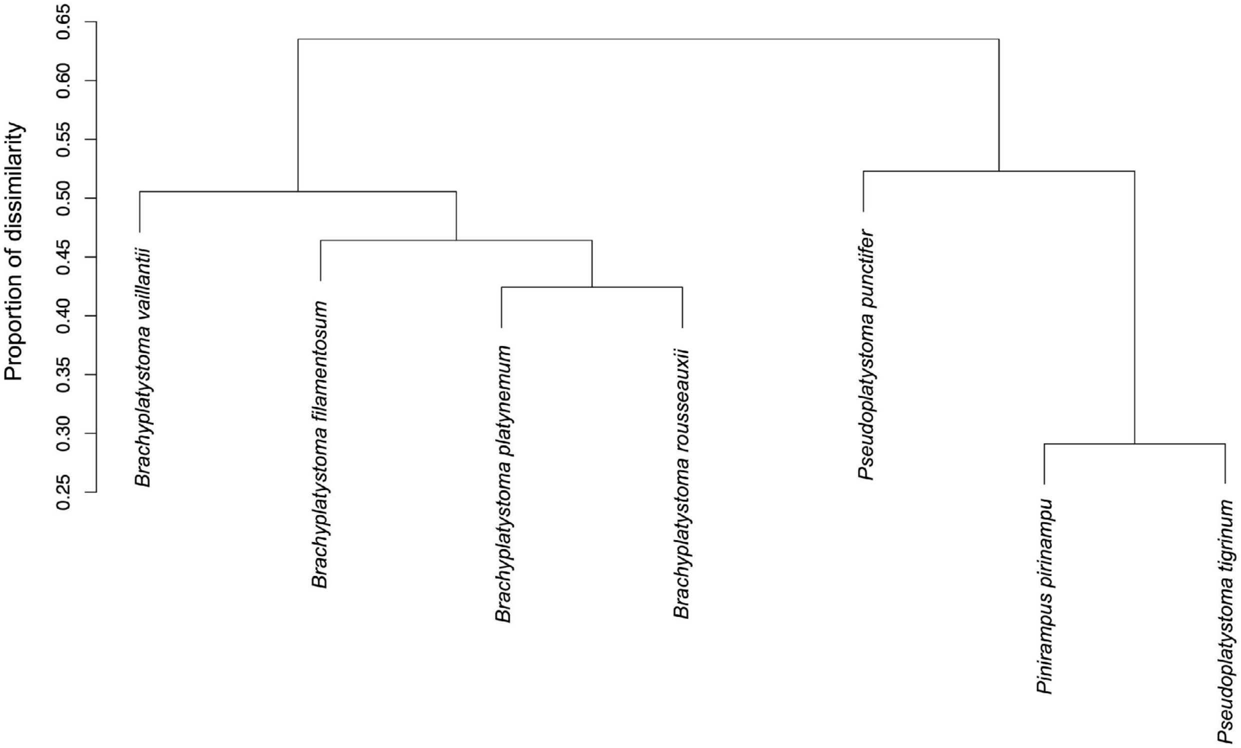

Figure 3. Cluster dendrogram of diet dissimilarity among seven large catfish species during the low-water season in the Madeira River (Rondônia state, Brazil) from 2009 to 2011. The prey items consumed by each species are represented by the sum of the relative volumes of items consumed by all individuals sampled for each species.

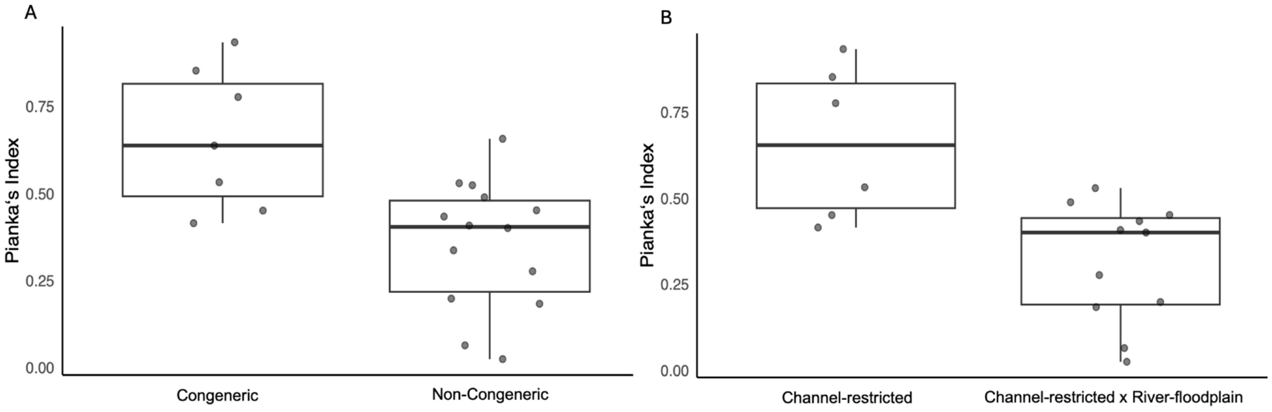

Figure 4. Pianka's trophic overlap between groups of large catfishes from the Madeira River (Rondônia state, Brazil) based on congeneric relatedness and habitat use. **A** –congeneric vs. non-congeneric species; **B** – Pianka`s values among channel-restricted species vs. Pianka`s values among channel-restricted and river-floodplain species. The bold line indicates the mean, the box the standard deviation, the bar the range and the circles are individual values. The groups were compared with t-tests (with Welch's correction).

by fish movements between rivers and floodplains, is a key factor shaping predator-prey relationships in tropical rivers (Lowe-McConell 1987). Species movements, both longitudinal within the river channel and lateral to and from the floodplains, are strongly influenced by water level fluctuations, resulting in varying fish assemblages (Lowe-McConnell 1987; Röpke *et al.* 2016; Duarte *et al.* 2022; Bogotá-Gregory *et al.* 2023).

Many species of Characiformes, including *Triportheus* spp., *Mylossoma* spp., *Prochilodus nigricans*, *Psectrogaster* spp., and *Potamorhina* spp*.,* which were the most consumed prey, abound in the river channel and form large schools that undertake annual migrations in both directions. These migrations are typically upstream for feeding and dispersal during flooding and return to the main river channel (or seek refuge in deep and permanent floodplain lakes) during low water periods (Lowe-McConnell 1987). Additionally, the evolution of long-distance migration in some of the studied catfish species exposes them to varying prey abundances across their home ranges, preventing fine-tuned specialization and favoring consumption of broadly and predictably available prey (Huang *et al.* 2021). As a result, main-channel species showed niche breadths similar to those using broader habitats, such as *P. pirinampu, P. punctifer,* and *P. tigrinum*, which was somewhat surprising.

Seasonal and spatial variability might explain why the same species are classified differently across regions, ranging from piscivorous to carnivorous, and why their diet composition differs in a non-specialized manner (see references in Supplementary Material, Table S9). For example, remarkably different diets have been described for *Brachyplatystoma* spp. across river basins. In the lower Amazon River, Barthem and Goulding (1997) found Characiformes as the main prey of these large catfishes. In the Apure-Arauca rivers, Barbarino-Duque and Winemiller (2003) recorded a high consumption of Gymnotiformes, while in the Madeira River, we observed predominant consumption of Siluriformes, mainly Pimelodidae and Doradidae, and several families of Characiformes.

The large dietary variation observed among all studied species in the Madeira River supports our findings on diet overlap, suggesting that resource partitioning likely occurs due to differences in foraging tactics and meso-habitat use. Nevertheless, higher values of dietary overlap were found among channel-restricted species. All *Brachyplatystoma* species are bottom feeders (Goulding 1980; Barthem and Goulding 1997; García *et al.* 2009), but *B. filamentosum* appears to exhibit some specialization in consuming Loricariidae, particularly *Planiloricaria* cf. *cryptodon*, a deep-water species usually captured only using bottom trawl-nets (Cella-Ribeiro 2010). In contrast, the other three *Brachyplatystoma* species predominantly consumed Pimelodidae (*Pimelodina flavipinnis* and *Pimelodus blochii*) and Triportheidae (*Triportheus* spp.), which are highly abundant along riverbank areas and in the shallow water column (Duarte *et al.* 2010).

Our results suggest that species co-occurrence likely influences the trophic ecology of *Brachyplatystoma* in the Madeira River basin. For instance, although the migratory behavior of *B. filamentosum* is poorly known, if individuals of this species have a smaller home range compared to their congeneric species, it could indicate a different ecological strategy. Goulding (1979) and Barthem *et al.* (1991) suggest that *B. filamentosum* may exhibit migratory patterns similar to *B. platynemum*, which is restricted to the Madeira River (Hauser *et al.* 2019). In this case, resource competition may have driven *B. filamentosum* to adapt its diet by exploiting more specific habitats.

Conversely, the broader home ranges of longer-distance migratory *Brachyplatystoma* species might have constrained dietary specialization, as these species are exposed to more variable prey availability across wide spatial scales. Contemporary niche differentiation would be expected if past competition shaped their trophic behavior (Cavender-Bares *et al.* 2009). Barbarino-Duque and Winemiller (2003) suggested that, despite high trophic overlap among adults and subadults of *B. rousseauxii, B. vaillantii*, and *B. platynemum,* competition among these species in the Apure-Arauca rivers might have been mitigated by their consumption of similar prey from different micro and meso-habitats. A similar pattern may occur in the Madeira River, as the proportion of shared prey families varies among the congeners. However, the higher diet overlap observed in this study, combined with the reduced growth rates of *B. rousseauxii* during the low water season in the Madeira River (Hauser *et al.* 2018) - despite high prey availability - supports the hypothesis of interspecific competition. It is worth mentioning that Barthem and Goulding (1997) reported moderate to low diet overlap for juvenile individuals of *Brachyplatystoma* species in the lower Amazon River, suggesting that asymmetric spatial competition may have driven the evolution of complex life cycles, particularly for *B. rousseauxii* and *B. vaillantii*. Our findings also suggest that subadults and adults of *Brachyplatystoma* species may experience a higher degree of interspecific competition. Further studies examining species co-occurrence at smaller spatial scales, alongside growth and body condition across life stages, could clarify these competitive dynamics.

Pseudoplatystoma punctifer, *P. tigrinum,* and *P. pirinampu* also seem to exploit the water column and shallow riverbank areas, mainly preying on Prochilodontidae and Curimatidae. These large catfishes likely have greater ability to exploit the water column and use structurally complex shallow habitats compared to other large Pimelodidae species (Goulding 1980; Barthem and Goulding 1997). Different studies (Supplementary Material, Table S9) found that small Characiformes were the main prey of *Pseudoplatystoma* spp. and *P. pirinampu*. These types of prey are highly abundant across diverse habitats of the Amazon river-floodplain systems (Lowe-McConnell 1987), where prey migrations may reduce competitive interactions among those species (van der Sleen and Rams 2023).

Some studies have highlighted that effective conservation of large catfishes requires not only fisheries management but also protection of prey species. Based on Barthem and Goulding's (1997) findings, Angelini *et al.* (2006) proposed that the conservation of stocks of *B. rousseauxii*, *B. vaillantii*, *B. filamentosum*, *P. tigrinum*, and *P. fasciatum (= P. punctifer)* depends on the protection and management of key Characiformes prey species, such as those in the families Triportheidae, Curimatidae, and Prochilodontidae. Our results support this hypothesis, as these prey groups were predominantly consumed during the high-water period, a time when fish prey density is relatively low for piscivorous predators, especially in large river channels. However, in the Madeira River, adults and subadults of *Brachyplatystoma* species consumed a large amount of Siluriformes year-round. Thus, protecting main prey groups is essential but challenging at the scale of the Amazon basin.

Studies on the ecology of large Amazonian catfishes remain relatively scarce and geographically limited, especially given the vast home ranges of some species. The huge scale of the Amazon basin, coupled with the high diversity of catfishes and their prey, as well as the variety of habitats they occupy, presents challenges in collecting sufficient data to test hypotheses about prey preferences, dietary specialization, and trophic competition. Commercial fisheries remain the primary source of specimens and data for large catfishes across the Amazon basin. However, reliance on fisheries-derived samples can introduce inherent biases due to the seasonal and selective nature of fishing practices. For example, fisheries in the Madeira River exploit predominantly the main river channel, which strongly limited the number of samples for river-floodplain species during the high-water period in the study. Also, fisheries practices often result in specimens with viscera removed or in advanced stages of digestion or decomposition, making prey identification difficult, along with uncertainties about the precise location and habitat of capture of the large catfishes. These difficulties likely influenced our study by limiting the sample size for some species.

Understanding the relationship of top predators with their prey and how it may shape habitat use, home-range, and movements over the life cycle of large migratory catfishes allows inferring possible evolutionary impacts of anthropic disturbances (Riotte-Lambert and Matthiopoulos 2020). A decade after the construction of two large hydropower plants on the Madeira River, changes in migratory behavior and reductions in the home ranges of *B. rousseauxii* have already been detected (Hauser *et al.* 2024), though the full impact of disrupted migration routes remains unclear. Documented post-damming declines in catfish and prey abundance (Sant'Anna *et al.* 2020; Santos *et al.* 2018; Arantes *et al.* 2022) further underscore the urgency of basin-wide conservation.

Despite limitations, some consistent patterns of the trophic ecology of the studied species across different regions suggest a robust ecological understanding for these species. The relevance of bottom-dwelling preys and short- to medium-sized migratory prey species highlights the importance of habitat diversity and connectivity in sustaining prey-predator interaction. Seasonal movements of prey between floodplains and river channels are essential to support top predator populations in the Madeira River and throughout the Amazon basin. Therefore, conserving floodplain habitats linked to the home range of those large migratory catfishes and their connectivity to the main river is essential for maintaining these ecological processes and the integrity of aquatic food webs.

CONCLUSIONS

Overall, the catfish species examined did not show predation on a specific prey family. Except for *B. filamentosum*, channel-restricted species did not change diet seasonally. The trophic partitioning is strong among species, even during the low-water season, and diet overlap was high only among congeneric species that were restricted to the main river channel. Among the *Brachyplatystoma* species, the lowest overlap was observed when comparing *B. filamentosum* to its congeneric species, suggesting the more specialized foraging strategy.

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SUPPLEMENTARY MATERIAL

Röpke *et al*. Diet seasonality and resource partitioning by large catfishes in the Madeira River, Brazil

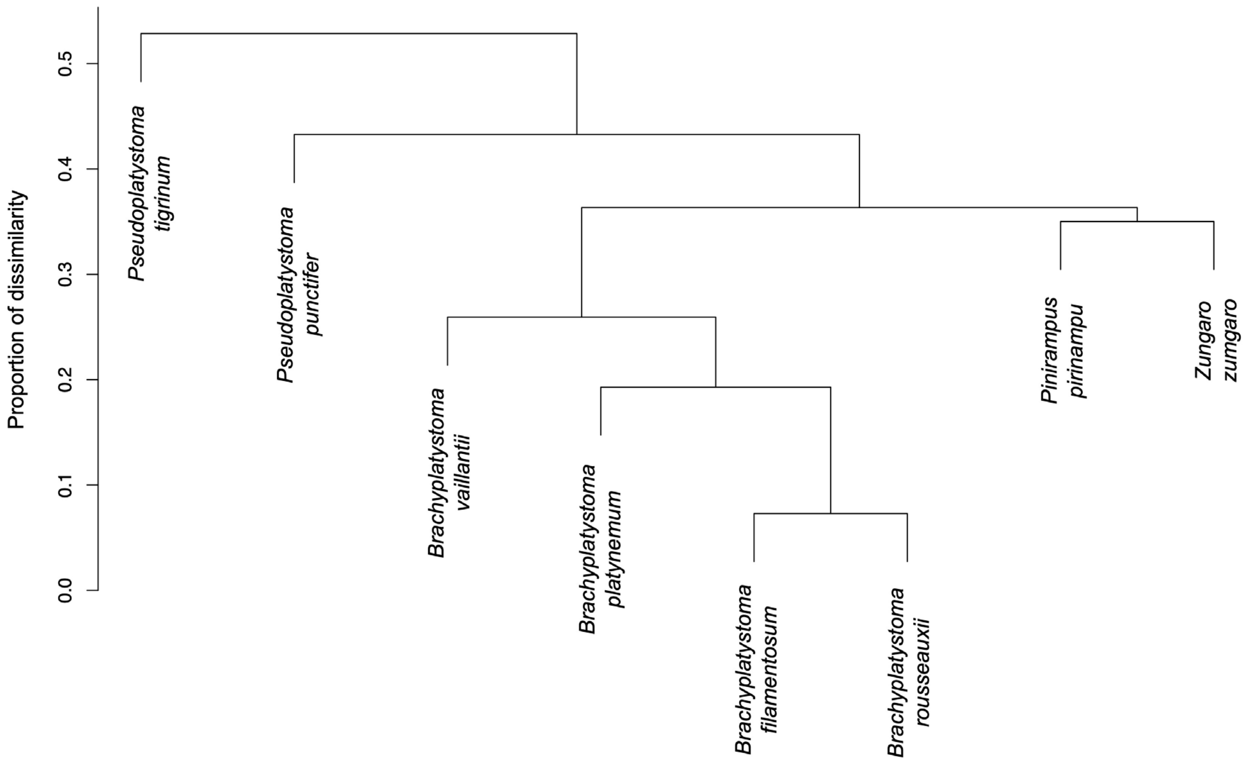

Figure S1. Cluster dendrogram of diet dissimilarity among eight large catfish species in the Madeira River (Rondônia, Brazil) between 2009 and 2011. Cluster based on order level of items identification during low water season. The cluster was generated based on the average method from the Bray-Curtis metric. The items consumed by each species were considered as the sum of the items consumed by all individuals sampled for each species.

Table S1. Information on habitat use, the number of stomachs containing food items identified at least to family level (N), and the minimum and maximum values of standard length (SL, in cm) and total weight (TW, in g) for eight large catfish species per season (high water and low water period). The fish were sampled in the Madeira River (Rondônia, Brazil) between 2009 and 2011.

Species	Habitat	High water			Low water			Total		
		N	SL (Min-Max)	TW (Min-Max)	N	SL (Min-Max)	TW (Min-Max)	N	SL (Min-Max)	TW (Min-Max)
Brachyplatystoma filamentosum	Channel-restricted	11	63-123	4500-30000	20	64-119	3220-24000	31	63-123	3220-30000
Brachyplatystoma platynemum	Channel-restricted	11	54-84	1500-8000	9	51-64	1000-3000	20	51-84	1000-8000
Brachyplatystoma rousseauxii	Channel-restricted	25	67.5-105	880-18000	27	50-101.5	1540-28000	52	50-105	880-28000
Brachyplatystoma vaillantii	Channel-restricted	8	33-59	500-3500	72	25-47	250-4000	80	25-59	250-4000
Pinirampus pirinampu	River-floodplain	-	-	-	6	39-44.2	630-1309	6	39-44.2	630-1309
Pseudoplatystoma punctifer	River-floodplain	3	-	-	13	44-85	1000-6000	16	44-85	1000-6000
Pseudoplatystoma tigrinum	River-floodplain	-	-	-	6	77-88	6000-8000	6	77-88	6000-8000
Zungaro zungaro	Channel-restricted	11	-	-	3	137	-	14	137	-

Table S2. Number of stomachs per species and season with content identified at least to the order level. The data refer to eight large catfish species sampled in the Madeira River (Rondônia, Brazil) between 2009 and 2011.

Species	**High water**	**Low water**	**Total**
Brachyplatystoma filamentosum	16	23	39
Brachyplatystoma platynemum	14	15	29
Brachyplatystoma rousseauxii	25	29	54
Brachyplatystoma vaillantii	9	87	96
Pinirampus pirinampu		8	8
Pseudoplatystoma punctifer	3	16	19
Pseudoplatystoma tigrinum		7	7
Zungaro zungaro	11	4	15
Total	**78**	**189**	**267**

Table S3. Sum of relative volumes of prey taxonomically identified at family level in the stomachs of eight large catfish species sampled in the Madeira River (Rondônia, Brazil) between 2009 and 2011 in the high and low water season. Insect orders and families were pooled due to low representativeness. Values are based on 225 stomachs.

Prey family	***Brachyplatystoma filamentosum***		***Brachyplatystoma platynemum***		***Brachyplatystoma rousseauxii***		***Brachyplatystoma vaillantii***		***Pinirampus pirinampu***		***Pseudoplatystoma punctifer***		***Pseudoplatystoma tigrinum***		***Zungaro zungaro***	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Synbranchidae	0	0	0	0	0	0	0	0	–	0	0	100	–	0	0	0
Acestrorhynchidae	0	0	0	0	0	0	0	0	–	0	0	100	–	0	0	0
Doradidae	100	660	0	100	0	80	100	810	–	0	0	0	–	0	0	0
Loricariidae	0	400	0	0	0	0	0	0	–	0	0	0	–	0	0	0
Callichthyidae	0	0	0	0	0	0	0	0	–	0	0	100	–	0	0	0
Sciaenidae	0	0	0	0	0	0	0	100	–	0	0	0	–	0	0	0
Anostomidae	0	100	0	0	300	0	0	0	–	0	0	100	–	0	0	0
Pristigasteridae	100	0	0	0	180	0	0	0	–	0	0	0	–	0	0	0
Bryconidae	0	0	0	0	0	0	0	100	–	0	0	0	–	0	0	0
Cichlidae	0	0	0	0	0	0	0	0	–	0	100	50	–	0	0	0
Serrasalmidae	300	0	120	0	100	0	100	0	–	100	0	60	–	0	50	0
Characidae	0	100	0	0	0	30	0	365	–	0	0	150	–	0	100	0
Chilodontidae	0	0	0	0	0	60	0	0	–	0	0	0	–	0	90	0
Curimatidae	0	100	100	230	357	450	0	1380	–	40	0	100	–	70	535	0
Cynodontidae	0	0	0	0	180	0	0	0	–	0	0	0	–	0	0	0
Hemiodontidae	0	100	0	30	30	0	0	0	–	0	0	0	–	0	0	0
Iguanodectidae	0	0	0	0	0	100	0	0	–	0	0	0	–	0	0	0
Prochilodontidae	0	0	0	0	0	0	0	485	–	110	0	200	–	300	325	0
Triportheidae	0	0	580	150	293	440	210	820	–	300	0	100	–	130	0	0
Apteronotidae	0	0	0	150	0	0	0	60	–	0	0	0	–	0	0	0
Cetopsidae	100	200	100	0	0	200	0	0	–	0	0	0	–	0	0	0
Heptapteridae	0	0	0	0	0	0	0	0	–	0	200	0	–	0	0	0
Pimelodidae	450	300	100	200	900	1280	390	2450	–	50	0	100	–	0	0	200
Macrobrachium spp.	0	0	0	0	45	0	0	5	–	0	0	50	–	0	0	0
Trichodactylus sp.	0	0	0	0	0	0	0	3	–	0	0	0	–	0	0	100
Megaloptera	0	0	0	0	0	0	0	100	–	0	0	0	–	0	0	0

Table S4. Sum of relative volumes of food items (prey) identified to the lowest taxonomic level in 315 stomachs of eight large catfish species sampled in the Madeira River (Rondônia, Brazil) during the high and low water season between April 2009 and September 2011.

Prey	***Brachyplatystoma filamentosum***			***Brachyplatystoma platynemum***			***Brachyplatystoma rousseauxii***			***Brachyplatystoma vaillantii***			***Pinirampus pirinampu***			***Pseuplatystoma punctifer***			***Pseuplatystoma tigrinum***			***Zungaro zungaro***		
	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low
	41	16	25	32	14	18	60	29	31	125	9	116	10	-	10	21	4	17	7	-	7	15	11	4
Acestrorhynchus spp.																100		100						
Adontosternarchus balaenops				100		100																		
Amblydoras spp.										100		100												
Anadoras weddellii	100		100							430		430												
Ancistrus sp. sideral	100		100																					
Anodus spp.	100		100				30	30																
Anostomidae							200	200																
Aphyocharax sp.																50		50						
Apteronotus bonaparti				50		50																		
Astrodoras asterifrons										20		20												
Astyanax aff. *bimaculatus*										10		10												
Brycon spp.										100		100												
Bryconops alburnoides							100		100															
Caenotropus sp.							60		60													90	90	
Calophysus macropterus				90		90	100		100	200		200										100		100
Cetopsis candiru	100		100																					
Cetopsis coecutiens	200	100	100				200		200															
Cetopsis spp.				100	100																			
Characidae																						100	100	
Characiformes	250	250		180	180		100		100	437		437	100		100	340		340	180		180	100		100
Clupeiformes													100		100									
Coleoptera										23		23												
Crenicichla spp.																100	100							
Curimatella meyeri	100		100							100		100												
Curimatidae				60		60	90	90		170		170	40		40	100		100				150	150	
Doradidae	200		200	100		100				40	20	20												
Duopalatinum peruano	50	50																						
Escales n.i.										200		200												
Exallodontus aguanai	100		100																					
Gymnotyformes	20		20	400		400	140	100	40	300		300												
Hemiodontidae				30		30																		
Hoplosternum littorale																100		100						
Hypophthalmus marginatus							680		680															
Hypophthalmus spp.							400	100	300	20		20												
Leporinus spp.	100		100																					
Leptodoras juruensis	200	100	100																					
Macrobrachium spp.							45	45		5		5				50		50						
Megalonema spp.										135		135												
Megaloptera										100		100												
Moenkhausia spp.										55		55												
Myleinae	200	200											100		100									

Table S4. Continued

Prey	***Brachyplatystoma filamentosum***			***Brachyplatystoma platynemum***			***Brachyplatystoma rousseauxii***			***Brachyplatystoma vaillantii***			***Pinirampus pirinampu***			***Pseuplatystoma punctifer***			***Pseuplatystoma tigrinum***			***Zungaro zungaro***		
	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total	High	Low
	41	16	25	32	14	18	60	29	31	125	9	116	10	-	10	21	4	17	7	-	7	15	11	4
Mylossoma duriventre	100	100		120	120																	50	50	
Mylossoma spp.							100	100		100	100					60		60						
Nemadoras humeralis	100		100																					
Bones n.i.										130	30	100												
Fish n.i.	240		240	300	100	200	635	415	220	2870	100	2770	200		200	400	100	300	20		20			
Pellona castelnaeana							180	180																
Pellona spp.	100	100																						
Pimelodella spp.																200	200							
Pimelodidae	300	200	100				300	300		580		580												
Pimelodina flavipinnis	200	200		100	100		600	400	200				50		50									
Pimelodus blochii	100		100	110		110	100	100		1685	190	1495										100		100
Pimelodus spp.										120	100	20				100		100						
Planiloricaria cryptodon	300		300																					
Plasgioscion spp.										100		100												
Potamorhina spp.										100		100												
Potamorhina altamazonica										220		220												
Potamorhina latior							200	200											70		70	100	100	
Prochilodus nigricans										485		485	110		110				300		300	325	325	
Psectrogaster amazonica				70		70	100		100	200		200												
Psectrogaster rutiloides				100		100	320		320	390		390										285	285	
Psectrogaster spp.				100	100		30		30	200		200												
Psectrogastrer essequibensis							66.66	66.7																
Pseudanos trimaculatus																100		100						
Pterodoras granulosus	100		100							220	80	140												
Insects										10		10												
Rhaphiodon vulpinus							180	180																
Roeboides myersi							30		30															
Schizodon fasciatus							100	100																
Siluriformes	580	300	280	460	120	340	100		100	1145	70	1075				100		100						
Sternarchogiton sp.										60		60												
Symbranchus spp.																100		100						
Tetragonopterinae										100		100				100		100						
Tetragonopterus argenteus	100		100																					
Tetragonopterus spp.										200		200												
Trachydoras spp.	60		60				80		80	100		100												
Trichodactylus sp.										3		3										100		100
Trichoptera										7		7												
Triportheus spp.				680	580	100	273.3	33.3	240	640	110	530	100		100				130		130			
Triportheus angulatus				50		50	460	260	200	390	100	290	200		200									
Triportheus auritus																100		100						

Table S5. Results of PERMANOVA analysis for seasonal change in diet (high water x low water) based on prey identified at least to the order level for four species of large catfish in the Madeira River (Rondônia, Brazil) between 2009 and 2011. The statistic presented is derived from a separate test for each species. Statistically significant results are presented in bold.

Species	**DF**	**F**	**P**
Brachyplatystoma filamentosum	38	1.977	0.15
Brachyplatystoma platynemun	28	3.679	**0.05**
Brachyplatystoma rousseauxii	54	1.629	0.215
Brachyplatystoma vaillantii	95	5.212	0.705

Table S6. Results of pairwise comparison through PERMANOVA (DF = 188; R2 = 0.16; F = 4.977; p = 0.001) for diet dissimilarity (Bonferroni adjusted p-value) among eight species of large catfish sampled in the Madeira River (Rondônia, Brazil) from 2009 to 2011. Analysis based on prey identified at least to the order level. Significant p values are in bold.

	Brachyplatystoma filamentosum	*B. platynemum*	*B. rousseauxii*	*B. vaillantii*	*P. pirinampu*	*P. punctifer*
Brachyplatystoma platynemum	0.504	-	-	-	-	-
Brachyplatystoma rousseauxii	1.000	1.000	-	-	-	-
Brachyplatystoma vaillantii	0.392	1.000	1.00	-	-	-
Pinirampus pirinampu	**0.028**	0.252	0.364	0.168	-	-
Pseudoplatystoma punctifer	**0.028**	0.448	0.560	0.308	1.000	-
Pseudoplatystoma tigrinum	**0.028**	0.056	0.224	0.056	1.000	1.000
Zungaro zungaro	1.000	1.000	1.000	1.000	1.000	0.392

Table S7. Similarity Percentage - Simper pairwise contrast analysis for differences in diet composition during the low water period for species of large catfish sampled in the Madeira River (Rondônia, Brazil) between 2009 and 2011. Contrast analyses are presented only when the PERMANOVA indicated significant difference between species based on food items identified at order level. Ratio = ratio of the average dissimilarity to the standard deviation of the dissimilarity; Sd = standard deviation; Av.sp1 = average of relative volume for the first species; Av.sp2 = average of relative volume for the second species; cumsum = cumulative sum in explicability to difference in diet; p = significance level of difference for each item. Significant p-values are shown in bold.

Brachyplatystoma filamentosum X Pseudoplatystoma punctifer

Order	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Siluriformes	0.34220	0.22436	152.510	378.100	0.86500	0.474	**0.001**
Characiformes	0.31860	0.22908	139.090	0.80300	337.600	0.915	**0.001**
Synbranchiformes	0.03100	0.12043	0.25750	0.00000	0.28800	0.958	**0.024**
Cichliformes	0.01960	0.07596	0.25760	0.00000	0.24600	0.985	**0.025**
Gymnotiformes	0.01090	0.05117	0.21260	0.13200	0.00000	1.000	0.907

Brachyplatystoma filamentosum X Pinirampus pirinampu

Order	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Siluriformes	0.36730	0.20722	177.260	378.100	0.49100	0.464	**0.001**
Characiformes	0.35130	0.21206	165.640	0.80300	395.300	0.908	**0.001**
Clupeiformes	0.06200	0.16477	0.37640	0.00000	0.57700	0.987	**0.012**
Gymnotiformes	0.01070	0.05041	0.21200	0.13200	0.00000	1.000	0.853

Brachyplatystoma filamentosum X Pseudoplatystoma tigrinum

Order	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Characiformes	0.40840	0.18807	217.130	0.80300	458.400	0.494	**0.001**
Siluriformes	0.40730	0.18959	214.830	378.100	0.00000	0.987	**0.001**
Gymnotiformes	0.01100	0.05181	0.21250	0.13200	0.00000	1.000	0.839

Table S8. Similarity Percentage-Simper pairwise contrast analysis for differences in diet composition based on family level of prey identification during the low water period between species of large catfish sampled in the Madeira River from 2009 to 2011. Contrast analyses are presented only when the PERMANOVA indicated significant difference between species based on food items identified at family level. Ratio -refers to the ratio of the average dissimilarity to the standard deviation of the dissimilarity for a particular táxon; Sd - Standard deviation; Av.sp1 - average of relative volume for the first species; Av.sp2 - average of relative volume for the second species; cumsum - cumulative sum in explicability to difference in diet; p - significance level of difference for each item. Significant p values are shown in bold.

Brachyplatystoma filamentosum X Brachyplatystoma rousseauxii

Family	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Pimelodidae	0.23917	0.24704	0.96810	0.69230	221.390	0.266	0.056
Doradidae	0.17553	0.23447	0.74860	159.010	0.16280	0.461	**0.007**
Curimatidae	0.10736	0.19455	0.55180	0.23080	0.92370	0.581	0.840
Loricariidae	0.09798	0.19710	0.49710	0.92300	0.00000	0.690	**0.001**
Triportheidae	0.08335	0.18052	0.46170	0.00000	0.82130	0.782	0.837
Cetopsidae	0.07873	0.18159	0.43350	0.46150	0.34190	0.870	**0.004**
Characidae	0.03204	0.11285	0.28390	0.23080	0.12720	0.905	0.718
Anostomidae	0.02450	0.10731	0.22830	0.23080	0.00000	0.933	0.192
Hemiodontidae	0.02450	0.10731	0.22830	0.23080	0.00000	0.960	0.145
Iguanodectidae	0.01857	0.09479	0.19590	0.00000	0.17090	0.981	0.143
Chilodontidae	0.01750	0.08933	0.19590	0.00000	0.15230	1.000	0.138

Brachyplatystoma filamentosum x Pinirampus pirinampu

Family	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Triportheidae	0.25072	0.25181	0.99570	0.00000	230.760	0.256	**0.005**
Doradidae	0.15848	0.21995	0.72050	159.010	0.00000	0.418	0.181
Prochilodontidae	0.10782	0.15319	0.70380	0.00000	134.040	0.528	0.217
Pimelodidae	0.10539	0.17835	0.59090	0.69230	0.65530	0.636	0.992
Loricariidae	0.09136	0.18553	0.49240	0.92300	0.00000	0.729	**0.048**
Serrasalmidae	0.08357	0.18768	0.44530	0.00000	0.76920	0.814	**0.017**
Curimatidae	0.06772	0.13880	0.48790	0.23080	0.61890	0.883	0.903
Cetopsidae	0.04568	0.13898	0.32870	0.46150	0.00000	0.930	0.222
Anostomidae	0.02284	0.10091	0.22630	0.23080	0.00000	0.953	0.292
Characidae	0.02284	0.10091	0.22630	0.23080	0.00000	0.977	0.735
Hemiodontidae	0.02284	0.10091	0.22630	0.23080	0.00000	1.000	0.189

Brachyplatystoma filamentosum X Pseudoplatystoma tigrinum

Family	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Prochilodontidae	0.29985	0.21878	137.060	0.00000	286.730	0.302	0.001
Doradidae	0.17048	0.23554	0.72380	159.010	0.00000	0.474	0.118
Triportheidae	0.13016	0.19574	0.66500	0.00000	134.150	0.605	0.321
Loricariidae	0.09823	0.19876	0.49420	0.92300	0.00000	0.704	**0.036**
Curimatidae	0.09682	0.19403	0.49900	0.23080	0.71040	0.802	0.785
Pimelodidae	0.07367	0.17735	0.41540	0.69230	0.00000	0.876	0.995
Cetopsidae	0.04912	0.14895	0.32980	0.46150	0.00000	0.926	0.212
Anostomidae	0.02456	0.10817	0.22700	0.23080	0.00000	0.951	0.199
Characidae	0.02456	0.10817	0.22700	0.23080	0.00000	0.975	0.634
Hemiodontidae	0.02456	0.10817	0.22700	0.23080	0.00000	1.000	0.152

Brachyplatystoma rousseauxii X Pseudoplatystoma tigrinum

Family	average	sd	ratio	Av.sp1	Av.sp2	cumsum	p
Prochilodontidae	0.29307	0.21579	135.810	0.00000	286.730	0.316	**0.001**
Pimelodidae	0.23158	0.24504	0.94510	221.390	0.00000	0.566	0.240
Triportheidae	0.16525	0.21288	0.77620	0.82130	134.150	0.745	0.163
Curimatidae	0.13882	0.21015	0.66060	0.92370	0.71040	0.894	0.496
Cetopsidae	0.03638	0.12986	0.28020	0.34190	0.00000	0.934	0.225
Iguanodectidae	0.01819	0.09362	0.19430	0.17090	0.00000	0.953	0.116
Doradidae	0.01774	0.09134	0.19430	0.16280	0.00000	0.973	0.974
Chilodontidae	0.01713	0.08823	0.19420	0.15230	0.00000	0.991	0.117
Characidae	0.00825	0.04233	0.19500	0.12720	0.00000	1.000	0.868

Table S9. Most important food items consumed by seven species of large catfish according to the published literature.

Species	**Rivers**	**Main items consumed**	**Trophic category**	**Reference**
Brachyplatystoma filamentosum	Amazon, tributaries and estuary	*Semaprochilodus* sp. and Pimelodidae	Not determined	Barthem and Goulding 1997
Brachyplatystoma filamentosum	Amazon	Fish	Carnivorous	Santos *et al.* 2006
Brachyplatystoma filamentosum	Tocantins	Fish	Carnivorous	Santos *et al.*1984
Brachyplatystoma filamentosum	Machado	Curimatidae, Pimelodidae and Loricariidae	Not determined	Goulding 1980
Brachyplatystoma flavicans (=Brachyplatystoma rousseauxii)	Machado	Characiformes	Not determined	Goulding 1980
Brachyplatystoma flavicans (=Brachyplatystoma rousseauxii)	Amazon, tributaries and estuary	*Hemiodus* sp. and *Triportheus* sp.	Not determined	Barthem and Goulding 1997
Brachyplatystoma flavicans (=Brachyplatystoma rousseauxii)	Apure and Arauca	Gymnotiformes and fish remains	Piscivorous	Barbarino and Winemiller 2003
Brachyplatystoma flavicans (=Brachyplatystoma rousseauxii)	Madeira	Fish	Piscivorous	Goulding 1981
Brachyplatystoma flavicans (=Brachyplatystoma rousseauxii)	Tocantins	Fish	Carnivorous	Santos *et al.*1984
Brachyplatystoma rousseauxii	Ucayali, Marañón and Amazon	Curimatidae and Characidae	Piscivorous	García *et al.* 2009
Brachyplatystoma rousseauxii	Amazon	Fish	Piscivorous	Santos *et al.* 2006
Brachyplatystoma rousseauxii	Amazon estuary	Amuré (*Gobioides* sp.), sardinha (*Triportheus* sp.) and shrimp	Not determined	Fabré and Barthem 2005
Brachyplatystoma rousseauxii	Amazon	Sardinha (*Triportheus* sp.) and shrimp	Not determined	Fabré and Barthem 2005
Brachyplatystoma rousseauxii	Solimões	Sardinha (*Triportheus* sp.) and branquinha (Curimatidae)	Not determined	Fabré and Barthem 2005
Brachyplatystoma vaillantii	Amazon, tributaries and estuary	*Semaprochilodus* sp. and Doradidae	Not determined	Barthem and Goulding 1997
Brachyplatystoma vaillantii	Apure and Arauca	Fish remains	Piscivorous	Barbarino and Winemiller 2003
Brachyplatystoma vaillantii	Amazon	Fish and occasional invertebrates	Piscivorous	Santos *et al.* 2006
Brachyplatystoma vaillantii	Tocantins	Fish	Carnivorous	Santos *et al.* 1984
Brachyplatystoma vaillantii	Amazon estuarye	Amuré (*Gobioides* sp.), sardinha (*Triportheus* sp.) and shrimp	Not determined	Fabré and Barthem 2005
Brachyplatystoma vaillantii	Amazon	Sardinha (*Triportheus* sp.) and shrimp	Not determined	Fabré and Barthem 2005
Brachyplatystoma vaillantii	Solimões	Sardinha (*Triportheus* sp.) and branquinha (Curimatidae)	Not determined	Fabré and Barthem 2005
Goslinea platynema (=Brachyplatystoma platynemum)	Apure and Arauca	Gymnotiformes	Piscivorous	Barbarino and Winemiller 2003
Goslinea platynema (=Brachyplatystoma. platynemum)	Amazon	Fish and invertebrates	Carnivorous	Santos *et al.* 2006
Goslinea platynema (Brachyplatystoma platynemum)	Tocantins	Fish	Carnivorous	Santos *et al.* 1984
Pseudoplatystoma fasciatum (=Pseudoplatystoma punctifer)	Machado	Anostomidae, Loricariidae, crustaceans and Cichlidae	Not determined	Goulding 1980
Pseudoplatystoma fasciatum (=Pseudoplatystoma punctifer)	Amazon, tributaries and estuary	Curimatidae	Not determined	Barthem and Goulding, 1997
Pseudoplatystoma fasciatum (=Pseudoplatystoma punctifer)	Apure and Arauca	Fish remains, *M. duriventre* and *P. mariae*	Piscivorous	Barbarino and Winemiller 2003
Pseudoplatystoma fasciatum (=Pseudoplatystoma punctifer)	Amazon	Fish and csrustaceas	Carnivorous	Santos *et al.* 2006
Pseudoplatystoma fasciatum (=Pseudoplatystoma punctifer)	Tocantins	Fish	Carnivorous	Santos *et al*. 1984
Pinirampus pirinampu	Apure and Arauca	Fish remains	Piscivorous	Barbarino and Winemiller 2003
Pinirampus pirinampu	Mamoré	Fish	Piscivorous	Pouilly *et al.* 2004
Pinirampus pirinampu	Tocantins	Fish and Decapoda	Carnivorous non specialist	Mérona *et al.* 2001

Table S9. Continued

Species	Rivers	Main items consumed	Trophic category	Reference
Pinirampus pirinampu	Amazon	Fish and occasional invertebrates	Piscivorous	Santos *et al.* 2006
Pinirampus pirinampu	Tocantins	Fish	Carnivorous non specialist	Santos *et al.* 1984
Paulicea lutkeni (=Zungaro zungaro)	Madeira	Characiformes	Not determined	Goulding 1981
Paulinea lutkeni (=Zungaro zungaro)	Tocantins	Fish	Carnivorous	Santos *et al.* 1984
Zungaro zungaro	Amazon	Fish and Crustacean	Carnivorous	Santos *et al.* 2006

References citted only in the supplementary material

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