Diversity of Loricariidae (Actinopterygii: Siluriformes) assemblages in two Conservation Areas of the Middle Xingu River, Brazilian Amazon, and their suitability for sustainable ornamental fisheries

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The Xingu River has one of the most diverse fish faunas in the Amazon region. Loricariidae stands out as the most diverse family in the basin, comprising more than 60 species distributed over 26 genera. Species of Loricariidae are some of the most economically valued in the ornamental market worldwide. The loss of fishing environments in Altamira region due to dam impacts is driving a shift of ornamental fishing to areas upstream, among which are included the Xingu River and Iriri River Extractive Reserve Areas. Thus, the objective of this work was to inventory fish species with ornamental potential in these extractive reserves to serve as a baseline to help guide the future management of ornamental fishing in those areas. Thirty-two species of Loricariidae were collected in these reserves through either free diving or diving with compressed air. The composition of species varied according to the sampling method and area. The majority of species found in the reserves are also found in the impacted areas of Belo Monte near Altamira. The study areas showed high diversity of fish species in rapids environments, suggesting that this area could serve as an additional source of income for the residents of these reserves.

Keywords: Conservation units, Fish diversity, Ornamental fishery, Sustainable management.

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O rio Xingu possui umas das mais diversas ictiofaunas da região Amazônica. Loricariidae destaca-se como a família mais diversa nessa bacia, compreendendo mais de 60 espécies distribuídas em 26 gêneros. As espécies de Loricariidae estão entre as mais valorizadas economicamente no mercado ornamental mundial. A perda de ambientes de pesca na região de Altamira devido aos impactos das barragens está provocando uma mudança da pesca ornamental para áreas a montante, entre as quais estão incluídas as áreas das Reservas Extrativistas do Rio Xingu e do Rio Iriri. Assim, o objetivo deste trabalho foi o de inventariar espécies de peixes com potencial ornamental nestas reservas extrativistas para servir de linha de base para ajudar a orientar o gerenciamento futuro da pesca ornamental nestas áreas. Trinta e duas espécies de Loricariidae foram coletadas nestas reservas através de mergulho livre ou mergulho com ar comprimido. A composição das espécies variou de acordo com o método de amostragem e a área de conservação. A maioria das espécies encontradas nas reservas também são encontradas nas áreas impactadas de Belo Monte, perto de Altamira. As áreas de estudo mostraram grande diversidade de espécies de peixes em ambientes rápidos, sugerindo que esta área poderia servir como uma fonte adicional de renda para os residentes destas reservas.

Palavras-chave: Diversidade de peixes, Manejo sustentável, Pesca ornamental, Unidades de Conservação.

INTRODUCTION

The Xingu River is notable for being the fourth biggest tributary in the Amazon Basin (Goulding et al., 2003) and having the most extensive network of rapids in the world (Sawakuchi et al., 2015). The richness of Xingu fishes is among the highest in the Amazon region, comprising approximately 502 species in the entire basin (Dagosta, de Pinna, 2019); 50 of which are endemic to the Xingu (Zuanon, 1999; Sabaj-Pérez, 2015).

Among the Xingu's fishes, Loricariidae is one of the most diverse families, accounting for 60 species belonging to 26 genera (Camargo et al., 2012; Camargo et al., 2013), inhabiting the myriad rocky rapids, channels, islands, and different substrate matrices. Some Loricariidae species in the region are among the most important in the ornamental fish market; according to Araújo (2016), it is the group that attracts the most commercial interest in the region, being an important source of income for local fishermen.

Due to combinations of overharvesting for the ornamental fish trade and habitat destruction, some species of Loricariidae have become threatened (Batista et al., 2004; Roman, 2011). A complete understanding of the conservation status of many of the discussed species, though, is hindered by the fact that many species and/or phenotypically and genetically distinct populations have still not been described taxonomically and are poorly understood both biologically and ecologically. As a result, it has not been possible to establish guidelines for managing these economic resources (Torres et al., 2008).

The ornamental fish fishery in the Xingu River basin began in the late 1980s, when unemployed dredge miners started to use their diving equipment to capture fish

associated to the bottom (Barthem, 2001). The ornamental fisheries on the Xingu River is focused mainly on Loricariidae, supported by the high species richness of this family on the basin (more than 60 species) and great demand for this family in the international aquarium market (Prang, 2007; Ramos *et. al.*, 2015; Araújo *et al.*, 2017). Prior to the implementation of the Belo Monte Hydroelectric Power Plant (HPP), the Xingu River Basin ornamental Loricariidae fishery extended from the mouth of Xingu River, at Porto de Moz, upstream to São Félix do Xingu in the middle Xingu River, in addition to the lower stretch of the Iriri River. Historically, the highest concentration of ornamental fishing was in the region of the Volta Grande do Xingu, near the city of Altamira. According to several studies as well as fishermen observations, loricariid diversity in the Xingu region has already been impacted by the completion and operation of the Belo Monte HPP. Many environments, including rapids, deeper channels, and floodplain habitats are being lost, and previously clean substrates required by loricariids are being covered in silt and sediment (Sabaj-Pérez, 2015; Sawakuchi *et al.*, 2015; Lees *et al.*, 2016).

The especially severe impact of Belo Monte on habitats from which ornamental fishes were collected in the Altamira region is forcing the ornamental fisheries to relocate upstream. According to de Francesco, Carneiro (2015), fisheries areas have already been displaced to further upstream from the main dam, causing territorial conflicts among fishermen. This situation, as well as an increase in local demand, are pushing fishermen into some Sustainable Use Conservation Areas (CA), specifically those upstream of the area affected by Belo Monte. Studies performed in two extractive reserves (RESEX in Portuguese) of the Xingu and Iriri Rivers have reported that residents and officials in these regions are concerned about the increased extractive pressure inside the reserves, specially by non-residents (ICMBio, 2010, 2012). The collection and commerce of natural goods on Sustainable Use Conservation Areas can be allowed, since management plans have been settled between the residents and the official regulatory agencies (Brasil, 2011). These plans are proven to be a good way to preserve a given area, as the local residents control who can or cannot harvest in the reserve. A mandatory step to begin the management plan discussions is to have a list of the species of the area. As such, the objective of this study was to inventory species of Loricariidae in the Xingu and Iriri River RESEXes. Although not a major study goal, we also explored potential influences of methods of collection and differences among Loricariidae composition on the two protected areas. This study thus establishes a baseline for further studies of the sustainable extraction of ornamental fishes in the in the Xingu and Iriri River RESEXes.

MATERIAL AND METHODS

Sampling sites. This research was undertaken in two Sustainable Use Conservation Areas (CA), both located in the Terra do Meio region, an area consisting of various protected areas between the Xingu and Iriri Rivers in the state of Pará, Brazil (**Fig. 1**). This region exhibits enormous environmental and social diversity and holds significant importance with respect to cultural heritage due to the presence of extractive, river-dependent, and indigenous populations (ICMBio, 2012).

Located in Pará, in the north of the Xingu River Basin, the Iriri River RESEX was established by Brazilian Federal Decree on June 5, 2006. It consists of roughly 398,000

hectares and has 285 residents, according to 2009 census (ICMBio, 2010).

The Xingu River RESEX is also located in Pará and was created by Brazilian Federal Decree on June 5, 2008. It has an area of approximately 303,841 hectares and 298 residents as of August 2011 (ICMBio, 2012).

The Iriri and the Xingu rivers drain the Brazilian Shield and are considered clear water rivers with rocky bottom and similar water parameters: pH 6.5-7.2, conductivity 20 μS, visibility varying from 0 (rainy season) to 3 m (dry season). The Iriri River at most parts is shallower than the Xingu River, leading to warmer temperatures (up to average 34°C compared to 32°C of Xingu in dry season).

Data collection and analysis. The collection and use of animals complied with Brazilian animal welfare laws, guidelines and policies as approved by SISBIO License #52313-1. Fishes were collected in 2016 over two different periods: the rainy season
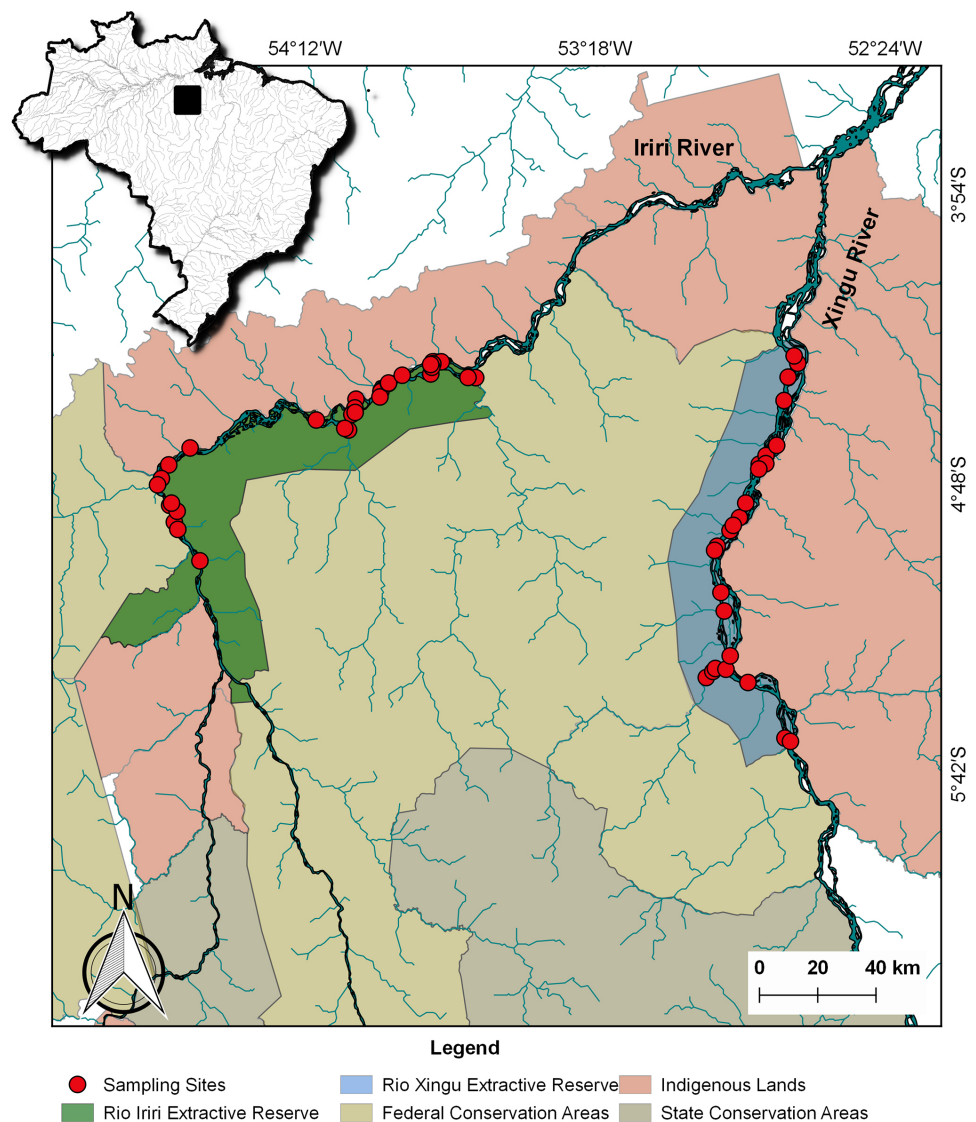

FIGURE 1 | Map of the collection areas in the Xingu and Iriri River Extractive Reserves.

(January and February), and the dry season (August and September). The collections alternated between the reserves and lasted 17 days each; as such, there were two expeditions to each RESEX. Field collections were focused on the family Loricariidae, given its relevance to the fishermen of this region due to the high prices of these fishes on the ornamental market.

The first collections took place in the rainy season. In every locality, two local fishermen collected ornamental fishes, using cast nets and compressed–air diving equipment. A total of 39 points were sampled in the Iriri RESEX and 40 in the Xingu RESEX in the rainy season. In the dry season, fishes were collected by free diving, with only cast nets and "vaquetas" (a wooden stick instrument, produced by the fishermen). Collections were performed by local fishermen who were at liberty to choose their collection points, thereby prioritizing local ecological knowledge. In the dry season, 14 and 23 points were sampled in the Iriri and Xingu River RESEXes, respectively.

Although collection methods differed between seasons, all dives were conducted in environments with rocky substrates and were standardized by time. Most dives lasted about one hour.

In the rainy season, collected fishes were packed in plastic bags, separated by sample, tagged, and afterward euthanised with clove oil and fixed in a 10% formaldehyde solution. In the dry season, most fishes were sorted and identified while still in the field, then released afterward. Some specimens were sacrificed and processed as in the rainy season. All voucher specimens are deposited at Laboratório de Ictiologia de Altamira (LIA) fish collection of the Federal University of Pará, Altamira Campus.

In the laboratory, fishes were identified to the lowest taxonomic level possible. Identifications were based on specific literature sources; whenever necessary, specialists for each group were consulted. The L–number code (a parataxonomical system coined by German magazine Deutsche Aquarien- und Terrarien-Zeitschrift - DATZ) was utilized to refer to undescribed morphospecies in some cases. Afterward, samples were separated into groups (for species and sample point), transferred to 70% alcohol, and catalogued.

In order to evaluate the specificity and fidelity of each species for each RESEX, an indicator value (IndVal) was calculated (Dufrêne, Legendre, 1997), with values varying from 0 to 100, where numbers closest to 100 meaning more specificity and fidelity to each variable.

After evaluating whether the composition of the species varied based on the collection method, a Permutational Multivariate Analysis of Variance (PERMANOVA) was performed (Anderson, 2001), using a significance threshold of $p = 0.05$. An independent sample t–test was used to test for differences in the richness of the collected species by location and different collection methods utilized. To test for differences in species composition on the two reserves, a permutational multivariate dispersion test (PERMDISP) and a PERMANOVA were performed (Anderson, 2001), using a significance threshold of $p = 0.05$. In order to graphically visualize the differences in species composition, Principal Component Analysis (PCA) was employed (Legendre, Legendre, 2012); a Hellinger transformation was overlaid using a Decostand function, in order to remove the arch effect in biotic communities (Legendre, Gallagher, 2001). All analyses were performed in the program R, using the packages Indcspecies (IndVal), Vegan with Adonis and Bray Curtis method (PERMANOVA), Betadisper (PERMDISP), and RDA (composition PCA) functions (R Core Team, 2016).

RESULTS

In total, 6,059 individual fishes were collected, of which 3,232 were preserved and deposited in the LIA fish collection. The remaining fishes were returned alive to where they were collected as described above. The collected samples were assigned to 32 species or morphotypes of Loricariidae (Tab. 1).

TABLE 1 | List of registered species and number of collected specimens in the Xingu and Iriri River RESEXes.

Species/morphospecies	Voucher	Iriri River RESEX		Xingu River RESEX		Total
		Rainy season	Dry season	Rainy season	Dry season	
Ancistomus feldbergae (de Oliveira, Rapp Py-Daniel, Zuanon & Rocha, 2012)	LIA 6226	174	116		4	294
Ancistrus cf. *ranunculus* Muller, Rapp Py-Daniel & Zuanon, 1994 (L255)	LIA 3780			174	9	183
Ancistrus ranunculus Muller, Rapp Py-Daniel & Zuanon, 1994	LIA 3541	34	1			35
Ancistrus sp.1	LIA 3810			2		2
Ancistrus sp.2	LIA 6186	25		1	1	27
Ancistrus sp.3	LIA 3468	34	5	13	4	56
Ancistrus sp.4	LIA 3494	8				8
Ancistrus sp.5	LIA 6019				3	3
Ancistrus sp.6	LIA 3996			2		2
Aphanotorulus aff. *emarginatus* (Valenciennes, 1840)	LIA 3470	15		1	2	18
Baryancistrus aff. *niveatus* (Castelnau, 1855)	LIA 3562	45		15	3	63
Baryancistrus chrysolomus Rapp Py-Daniel, Zuanon & Ribeiro de Oliveira, 2011	LIA 3881	1		17	24	42
Baryancistrus xanthellus Rapp Py-Daniel, Zuanon & Ribeiro de Oliveira, 2011	LIA 3483	385	1087	33	522	2027
Farlowella amazonum (Günther, 1864)	LIA 6007	1	2		4	7
Hopliancistrus wolverine de Oliveira, Zuanon, Rapp Py-Daniel, Birindelli, & Sousa, 2021	LIA 3870	6	7	8	8	29
Hopliancistrus xikrin de Oliveira, Zuanon, Rapp Py-Daniel, Birindelli & Sousa, 2021	LIA 3495	4		1		5
Hypostomus gr. *cochliodon* Kner, 1854	LIA 6159				1	1
Hypostomus gr. *plecostomus* (Linnaeus, 1758)	LIA 3676	7	1	4		12
Leporacanthicus heterodon Isbrücker & Nijssen, 1989	LIA 3591	3	22		8	33
Panaque armbrusteri Lujan, Hidalgo & Stewart, 2010	LIA 6000	1	1		1	3
Parancistrus aurantiacus (Castelnau, 1855)	LIA 3515	205	61	235	103	604
Peckoltia sabaji Armbruster, 2003	LIA 3887	11		8	29	48
Peckoltia vittata (Steindachner, 1881)	LIA 3905	10		4	7	21
Pseudacanthicus pirarara Chamon & Sousa, 2016	LIA 3613	9	16	2	2	29
Pseudancistrus asurini Silva, Roxo & Oliveira, 2015	LIA 3612	21	30	35	60	146
Rineloricaria sp.	LIA 2555		1			1
Scobinancistrus aureatus Burgess, 1994	LIA 3627	6	19		22	47
Scobinancistrus pariolispos Isbrücker & Nijssen, 1989	LIA 3646	10	5	10	27	52
Scobinancistrus sp. L253	LIA 6040	8	7	1	22	38
Spatuloricaria tuira Fichberg, Oyakawa & de Pinna, 2014	LIA 3696	4	26	3	68	101
Spectracanthicus punctatissimus (Steindachner, 1881)	LIA 3476	377	166	86	395	1024
Spectracanthicus zuanoni Chamon & Rapp Py-Daniel, 2014	LIA 3505	191	86	280	541	1098
Overall Total		**1595**	**1659**	**935**	**1870**	**6059**

Out of the total, 24 species were found in both RESEXes, whereas only 3 and 5 were exclusive to the Iriri and Xingu River RESEXes, respectively (Fig. 2).

When comparing the two sampling methods, eleven species presented significant IndVal values for free diving (by apnea) while two species for air compressed diving (Tab. 2).

When taking into account drainage in the RESEXes, *A. feldbergae, P. pirarara, A. ranunculus,* and *Ancistrus* sp.4 were more representative of the Iriri River RESEX, reaching IndVal values of 85.3, 48.2, 30.7 and 30.7, respectively. On the other hand, the species that best represented the Xingu River RESEX were *Ancistrus* cf. *ranunculus* L255, *P. sabaji,* and *B. chrysolomus,* with values of up to 64.8, 40.9, and 33.1, respectively (Tab. 3).

In relation to the richness of the species, there were significant differences between the samples, both based on free diving (x = 8.48) and diving with compressed air (x = 5.71). On average, there was more variation when comparing the richness of three species using the free diving method (t = 5.88, df = 113, p < 0.01). However, species richness didn't vary significantly between the reserves (t = 1.311, df = 113, p = 0.09).

The composition of species changed depending on the method of capture (R^2 = 0.09; p < 0.01) (Fig. 3). *Ancistrus* sp.5, *Hypostomus* gr. *cochliodon, Rineloricaria* sp. were only collected by free diving, whereas the *Ancistrus* sp.1, *Ancistrus* sp.4, *Ancistrus* sp.6, and *Hopliancistrus xikrin* were only collected using compressed–air diving equipment.
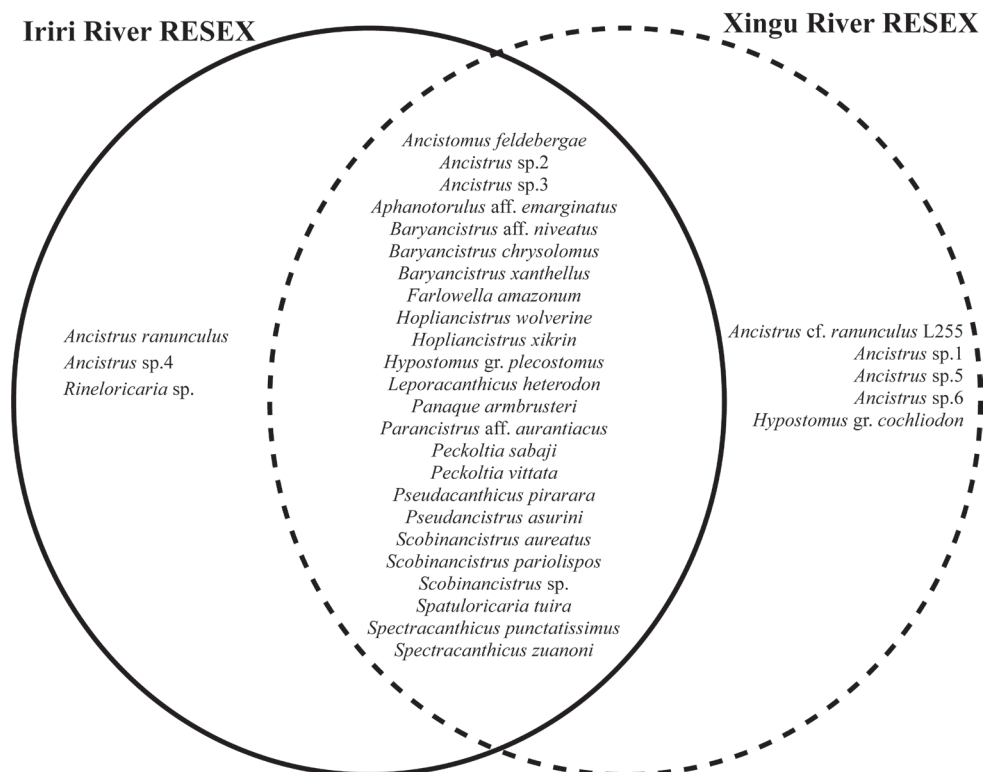

FIGURE 2 | Venn diagram showing the compositions of the Loricariidae species found in both extractive reserves.

TABLE 2 I Indicator value (IndVal) of the species for different sampling methods.

Species	Sampling method	IndVal	Mean	SD	p
Baryancistrus xanthellus	Free diving	90.4	17.62	3.28	0.0002
Spatuloricaria tuira	Free diving	80.8	0.86	2.34	0.0002
Pseudancistrus asurini	Free diving	73.7	1.26	1.97	0.0002
Scobinancistrus aureatus	Free diving	59.5	0.40	1.36	0.0002
Scobinancistrus pariolispos	Free diving	52.1	0.45	1.15	0.0036
Scobinancistrus sp. L253	Free diving	51.0	0.33	1.12	0.0016
Leporacanthicus heterodon	Free diving	50.8	0.28	1.41	0.0008
Pseudacanthicus pirarara	Free diving	45.8	0.25	0.77	0.0124
Peckoltia sabaji	Free diving	45.4	0.41	1.44	0.0064
Hopliancistrus wolverine	Free diving	43.3	0.25	0.66	0.0278
Farlowella amazonum	Free diving	35.4	0.06	0.27	0.0116
Baryancistrus aff. *niveatus*	Air Compressor	60.9	0.54	1.06	0.0004
Ancistrus cf. *ranunculus* L255	Air Compressor	50.4	1.59	4.05	0.0124

TABLE 3 I Indicator values (IndVal) of the species, taking into account drainage in the Xingu and Iriri River RESEXes.

Species	RESEX	IndVal	Mean	SD	p
Ancistomus feldbergae	Iriri	85.3	2.55	5.29	0.0002
Pseudacanthicus pirarara	Iriri	48.2	0.25	0.77	0.0010
Ancistrus ranunculus	Iriri	30.7	0.30	1.94	0.0234
Ancistrus sp.4	Iriri	30.7	0.06	0.34	0.0190
Ancistrus cf. *ranunculus* L255	Xingu	64.8	1.59	4.05	0.0002
Peckoltia sabaji	Xingu	40.9	0.41	1.44	0.0267
Baryancistrus chrysolomus	Xingu	33.1	0.36	2.35	0.0380
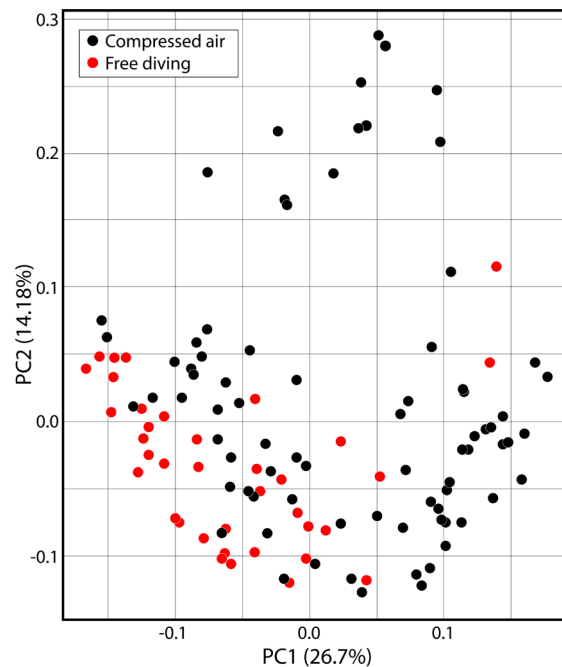
FIGURE 3 I Principal component analysis (PCA) for composition of ornamental fish species based on the method of capture (Hellinger transformation), considering the two extractive reserves.
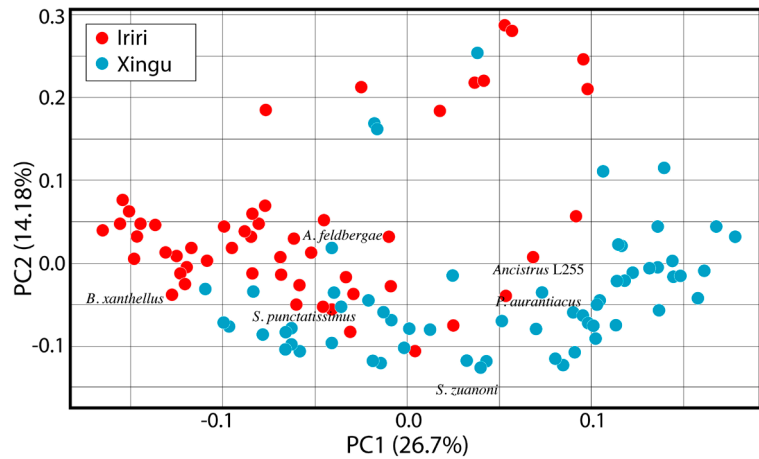
FIGURE 4 | Principal Component Analysis (PCA) of fish composition in the drainages of both the Xingu and Iriri River RESEXes (Hellinger transformation). Only species names that made greatest contributions to compositional differences are shown.

The PERMDISP showed that the variation in composition within the reserves does not differ (F = 0.002; p = 0.974). However, the PERMANOVA analysis showed that the species composition was significantly different between the reserves (F = 10.381; p < 0.001). *Spectracanthicus punctatissimus*, *B. xanthellus,* and *A. feldbergae* from the Iriri River RESEX and *Parancistrus aurantiacus*, *Ancistrus.* cf. *ranunculus* L255 and *S. zuanoni* from the Xingu River RESEX made the greatest contributions to compositional differences found between the two reserves (Fig. 4).

DISCUSSION

According to Herbert *et al.* (2010), freshwater biodiversity in protected areas in Brazil is still poorly understood, with very few studies addressing these areas. Until now, no research had been completed on the ichthyofauna of the Conservation Areas of Middle Xingu. Management plans for these CAs currently lack data on the diversity and richness of the ichthyofauna in rapids environments. However, they do contain statements from fishermen that ornamental fish species richness is high in the area, and that these species were regularly captured in these areas before the reserves were created (ICMBio, 2010, 2012).

In this study, 32 Loricariidae species were captured across the two reserves. This value represents approximately 60% of the total Loricariidae species already registered in the Xingu River Basin (Sabaj-Pérez, 2015). The majority of species found in both CAs are also found downstream in the Volta Grande area, which nowadays are experiencing severe alterations from the Belo Monte hydroelectric complex. Some species, however, are unique to the reserves, like *Ancistrus* cf. *ranunculus* L255, *Ancistrus* sp.2, *Ancistrus* sp.5, and *Ancistrus* sp.6. A study performed in the Madeira River indicated a diverse environment of 71 Loricariidae species (Torrente-Vilara *et al.*, 2013). Meanwhile, Anjos *et al.* (2008), identified Loricariidae as the second richest family, at 11 total species, in a compositional study of fishes in the upper Purus River, specifically in two tributaries, the Caeté and Macapá rivers, in the state of Acre, Brazil. Ferreira *et al.* (2011) came to

the same conclusion after recording 23 species in a survey of the Araguaia River, in Cantão State Park in Tocantins, near the border with Pará.

Of all the species in this study, 8 were registered for only one reserve or the other, with 3 for the Iriri River RESEX and 5 for the Xingu River RESEX. This fact highlights the importance of creating multiple conservation areas in sub-basins that are near each other, as not all species of a given region can be found in just one CA.

Few of the exclusive species have been taxonomically named yet, the majority of which might be new species without any scientific record. This precludes inferences on endemicity of these species to this region, but it does indicate the need to continue studying the area. However, given that the CAs are in different sub-basins, some of the species could, in fact, be exclusive to one reserve or the other. The Xingu River is known for its high rates of endemism (Sabaj-Pérez, 2015; Sawakuchi *et al.*, 2015; Winemiller *et al.*, 2016; Dagosta, de Pinna, 2019; Jézéquel *et al.,* 2020). For example, *Ancistrus* cf. *ranunculus* L255 was collected only in the Xingu River RESEX, thereby reinforcing the results from previous, unpublished research that showed that this species has a limited distribution in the Xingu River upstream from its confluence with the Iriri River.

Despite of the strong selectivity towards Loricariidae during all sampling sessions, the composition of the captured species varies depending on the method used. According to Carvalho Júnior *et al.* (2009), diving with an air compressor allows for the capture of species that live at greater depths, regardless of the time of year. In addition, this method provides more diving time, which could lead to a greater number of collected species. Meanwhile, free diving allows for capturing species in shallower environments; these are performed preferentially in dry periods (Mesquita, Isaac-Nahum, 2015).

Contrary to what fishermen commonly argue, our study found a greater richness of species captured through free diving compared to compressed air dives. In this case, other factors might have impacted our results. For example, the free divers were residents of the area, meaning that they knew the region, whereas those who dived using compressed air were not from the reserves, but were knowledgeable, experienced fishermen who were selected due to their skills in diving with a compressor in another areas. In addition, the seasonal bias needs also to be accounted. Free diving was conducted mainly in the dry season and compressed air diving in the rainy season. Espírito-Santo *et al.* (2009) studied the Ducke Reserve, near the city of Manaus, Amazonas, and found that fish species richness and numbers of individuals captured were greater in the dry season, with a different composition and abundance observed depending on the season. Such results can also be found when considering river seasonality (Copatti *et al.*, 2009). The rapids portions of the Xingu River diminish during dry periods, thereby comparably affecting the habitats of the studied species. This might lead to a greater abundance and richness of species concentrated in a smaller area. That being said, Loricariidae species are dependent on the substrate, given that all their food sources are from the flora and fauna found in this habitat (Reis *et al.*, 2003; Lujan *et al.*, 2012). Collection conditions in the rainy season are worse: the transparency of the water is severely reduced and because the capture of loricariids while diving is mostly visual, collections are negatively affected during this period. However, the comparison of efficiency of each sampling method was not a major goal of this study design and we suggest that a proper comparison (with delimited number of sampling and replicates

by each method) should be the goal of a future study.

The reserves are located on different rivers, each one having a myriad of rapids and backwaters of their own, serving as geographical barriers that might limit migration and promote speciation. These geographical barriers, according to Silva *et al.* (2016), could be an important factor in determining the composition of the ichthyofauna. The Iriri River has a complex regional slope, in addition to the significant variations in water level across seasons (ICMBio, 2010). Furthermore, the Xingu River has morphological characteristics and a substrate composition that fundamentally affects its aquatic ecology and biodiversity (Sawakuchi *et al.*, 2015). These local structural characteristics work together with regional and historical factors in determining how fish species congregate, meaning that different habitats can lead to different combinations (Súarez, 2008).

Furthermore, this study identified several species that are classified as vulnerable by the Brazil Red Book of Threatened Species of Fauna, such as *S. aureatus* and *S. pariolispos* (ICMBio, 2018). The presence of these species in protected areas demonstrates the importance of conducting an inventory of ichthyofauna such as the one we conducted here. Information about diversity of an area is required to make qualified decisions about the management of natural areas (Silveira *et al.*, 2010). The detection of *Scobinancistrus aureatus* in the Iriri River RESEX is very interesting, as previous research had restricted its distribution to the middle and lower portions of the Xingu River (Camargo *et al.*, 2004), and the species had only been found between Cachoeira do Espelho and the rapids of Belo Monte (Camargo *et al.*, 2013). As such, this observation considerably increases the known distribution of this species and can contribute to new discussions about its conservation status.

Of the 32 Loricariidae species that were inventoried, 16 are already being sold in the ornamental market, with local market prices ranging from 0.20 to 100.00 Brazilian Reais per animal (Araújo, 2016), or 0.08 to 40.00 USD on 2015 currency. Nevertheless, few species fall in the higher part of this range (Gonçalves *et al.*, 2009; Camargo *et al.*, 2012). The environmental changes resulting from the Belo Monte Hydroelectric Plant have negatively affected many fishing areas that are important in the Volta Grande region and that sustained the ornamental fish market in Altamira and the region for decades. This loss of fishing areas near Altamira city is increasing the fishing pressures in protected areas upstream, with the RESEX regions being a new alternative for ornamental fisheries. However, these actions need to be closely monitored and a Management Plan must be created to regulate the use of the natural resources inside the reserves. The use of protected areas by non-resident fishermen can generate escalating conflicts and the reserve's residents are seeking regulations that protect their rights to the use of this resource. We recommend that fishing areas should be delimited with participation of local villagers and be rotated to avoid overfishing inside the reserves. Exploitation of fisheries resources in the reserve areas should be for the residents only.

The income of the residents of these reserves is based on forest products, like Brazil nuts, latex, and fish for human consumption, among other goods. These products have a strong seasonal availability. Brazil nut, for example, are harvested during the rainy season, whereas fishing for food is more common in the dry season. Ornamental fishing could be another option to complement the incomes of the families who live in the reserves. Nonetheless, additional biological and ecological research is necessary,

so that the life history and population dynamics of species within these CAs can be understood. This would allow these species to be managed sustainably, with as little an impact as possible on the fish population of the rapids of the region.

Protected areas have been a pillar of conservation throughout the world. However, their effectiveness and importance have not been adequately evaluated (Gaston *et al.*, 2008). Our results contribute to the understanding of the extent to which protected areas could be essential to maintaining the ichthyofauna of the Xingu region, thereby, reinforcing the importance of creating different protected areas throughout the basin. Such reserves could help preserve the regions distinctive ichthyofauna by maintaining the species in these environments. Inventories such as conducted by this study are needed to provide a baseline understanding of diverse natural resources and help guide the development, delimitation, and management of Conservation Areas to protect those resources.

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ETHICAL STATEMENT

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The authors no declare competing interests.

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