

Communication

Not peer-reviewed version

Occurrence of Freshwater Stingrays in the Uatumã River Basin, Amazon Region: A Field Study

[Maria Fernanda da Silva Gomes](#) , [Paulo Henrique Rocha Aride](#) , Maiko Willas Soares Ribeiro ,
Cristiane Cunha Guimarães , Tiago Cabral Nóbrega , [Rayana Melo Paixão](#) , Adriene Nuzia de Almeida Santos
, [Adriano Teixeira de Oliveira](#) *

Posted Date: 5 April 2024

doi: 10.20944/preprints202404.0432.v1

Keywords: Biodiversity; Geographic distribution; Potamotrigoníneos



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Communication

Occurrence of Freshwater Stingrays in the Uatumã River Basin, Amazon Region: A Field Study

Maria Fernanda S. Gomes ¹, Paulo Henrique R. Aride ², Maiko Willas S. Ribeiro ¹, Cristiane C. Guimarães ¹, Tiago C. Nóbrega ¹, Rayana M. Paixão ¹, Adriene Núzia A. Santos ¹ and Adriano Teixeira de Oliveira ^{2,*}

¹ Federal University of Amazonas – UFAM, Manaus, Amazonas, Brazil; gomesfernanda0807@gmail.com (M.F.S.G.); maikowillas@hotmail.com (M.W.S.R.); cristiane_c_guimaraes@hotmail.com (C.C.G.); tiago.cnobrega@gmail.com (T.C.N.); rayana.ifam@gmail.com (R.M.P.); almeida.adriene@gmail.com (A.N.A.S.)

² Federal Institute of Education, Science and Technology of Amazonas – IFAM, Manaus, Amazonas, Brazil; aride@ifam.edu.br

* Correspondence: adriano.oliveira@ifam.edu.br

Abstract: The Amazon region has the most incredible diversity of freshwater stingrays; however, there are still places where information about this group is scarce. The present work aims to record the occurrence of freshwater stingrays in the Uatumã river basin, Amazonas, Brazil. For this, collections were carried out in three municipalities bathed by the Uatumã River, Presidente Figueiredo, Itapiranga and São Sebastião do Uatumã. The rays were collected through fishing using a hand net and, after capture, were identified through the pattern of the dorsal and ventral color of the disc, the absence or presence of the labial groove and the organization of the row of spines on the tail, too were also measured, weighed and sexed. In total, 69 specimens of Potamotrygonines were captured, 59 of which were from the genus *Potamotrygon* and ten individuals from the genus *Paratrygon*. The present study provides preliminary information on the characteristics of freshwater stingray species that may occur in the Uatumã River. Furthermore, new research is necessary to improve the identification of specimens to determine the diversity and elucidate aspects related to the biology of elasmobranchs in the Uatumã River Basin, Brazil.

Keywords: biodiversity; geographic distribution; Potamotrigoníneos

Key Contribution: Add knowledge to characterize the freshwater stingray population in the Uatumã River, Amazon region, Brazil, contributing to increasing knowledge regarding the geographic distribution of freshwater stingrays.

1. Introduction

Stingrays of the subfamily Potamotrygoninae are the only taxon within the subclass of Elasmobranchii adapted to survive and reproduce exclusively in freshwater environments. They are endemic to the rivers of South America and are found in almost all countries, except for rivers in Chile, where Brazil stands out for having more incredible wealth [1]. Currently, the group is composed of 45 species divided into four genera: the genus *Paratrygon* (Duméril, 1865), which is considered a species complex, with ten species, *Plesiotrygon* (Rosa, Castelo, Thorson, 1987) and *Heliotrygon* (De Carvalho & Lovejoy, 2011) with two species each and *Potamotrygon* (Garman, 1877) which is the most diverse genus with 31 valid species [2,3].

Some species present high phenotypic plasticity and wide distribution in the Amazon basin and can be found in all types of water (black, clear, white and intermediate types), such as *Potamotrygon motoro* (Müller & Henle, 1841) and *Potamotrygon orbignyi* (Castelnau, 1855), other species have specialized physiological mechanisms to interact with the environment where they live, and therefore

have a geographical distribution limited to water courses, such as the species *Potamotrygon wallacei* (Carvalho, Rosa and Araújo, 2016), which is endemic to the Rio Negro basin, and *Potamotrygon leopoldi* (Castex & Castello, 1970) native to the Xingu river [4–8].

Stingrays can be found in different types of habitats and substrates, with their occurrence recorded in both lentic and lotic habitats, as well as rocky, sandy, muddy or leaf litter bottoms [9,10]. However, despite the wide variety of habitats, stingrays have a predilection for certain areas, the species *Paratrygon aiereba* has a predilection for areas with sandy substrates, on the other hand, *Potamotrygon motoro* can live in intermediate areas between igapós and beaches, with muddy bottoms [11].

Elasmobranchs are predators in almost all environments where they live and play an essential role in the energy flow between trophic levels [12]. Regarding reproductive aspects, in Amazonian elasmobranchs, the seasonal hydrological cycle of river floods and droughts influences reproduction [13], but, in general, they have similar biological characteristics to marine elasmobranchs, such as low fecundity, slow growth, great longevity, complex reproduction patterns and late sexual maturation, these aspects result in low rates of population renewal and greater vulnerability to overfishing and environmental changes [14–16]. Furthermore, constant accidents and injuries involving stingray stingers have driven the practice of negative fishing, which consists of capturing animals for mutilation purposes, by removing the tail, or sacrificing it [17].

In recent years, there have been significant advances in studies of freshwater stingrays, including studies on contaminants [18], and determination of stingray meat using low-cost analytical tools [19]. Still, despite these studies, most *Potamotrygonines* are listed as data deficient on the IUCN List of Threatened Species due to a lack of information on population rates and geographic dispersion [20]. This lack of information occurs because these are regions of difficult access and complexity, where the transport of people and cargo is mainly carried out via waterways [21] and among these locations is the Uatumã river basin, Amazonas, Brazil.

The Uatumã River is part of the complex hydrographic network of the Amazon basin that covers an area of 6,112,00 Km², equivalent to 57% of the Brazilian territory [22]. The Uatumã River is a tributary of the Amazon River, and its total area is around 70,600 Km²; its sources are located in the Precambrian shield of the Guianas, from where it transports black, acidic waters with a low amount of sediment and nutrients [22]. Uatumã is a case of how managing natural resources can significantly impact the ecosystem, as the Balbina Hydroelectric Plant (BHP) was installed on this river between 1983 and 1987, which flooded an area of more than 3000 km² of forests [23]. Of the Uatumã basin area, around 18,862 Km² represents the contribution basin of the HPP [22]. Due to the scarcity of information on the presence of elasmobranchs in the Uatumã River, the present work aims to record the occurrence of freshwater stingrays in the Uatumã River basin to expand knowledge about their geographic distribution.

2. Materials and Methods

The research was carried out upon release from the Biodiversity Authorization and Information System (SISBIO) following Normative Instruction Ordinance ICMBio nº748/2022. Number: 76127-4 and by the Ethics Committee on the Use of Animals of the Federal Institute of Education, Science and Technology of Amazonas (2019/010.02.0905). The study is being developed following the regulations of the ethical principles in animal experimentation considered by the National Animal Control Council Animal Experimentation – CONCEA.

The collections took place in the Uatumã river basin, the northeastern region of the State of Amazonas, Brazil, with points in the municipalities of Presidente Figueiredo (PF), Itapiranga (ITA) and São Sebastião do Uatumã (SSU) (Figure 1). The collections followed the direction of the river that goes from north to south, starting in Presidente Figueiredo, then Itapiranga, and finally, São Sebastião do Uatumã, which was the closest collection point to the mouth of the Uatumã River, on the Amazon River. In Presidente Figueiredo, collections took place in an area that was impacted by the construction of the Balbina Hydroelectric Plant.

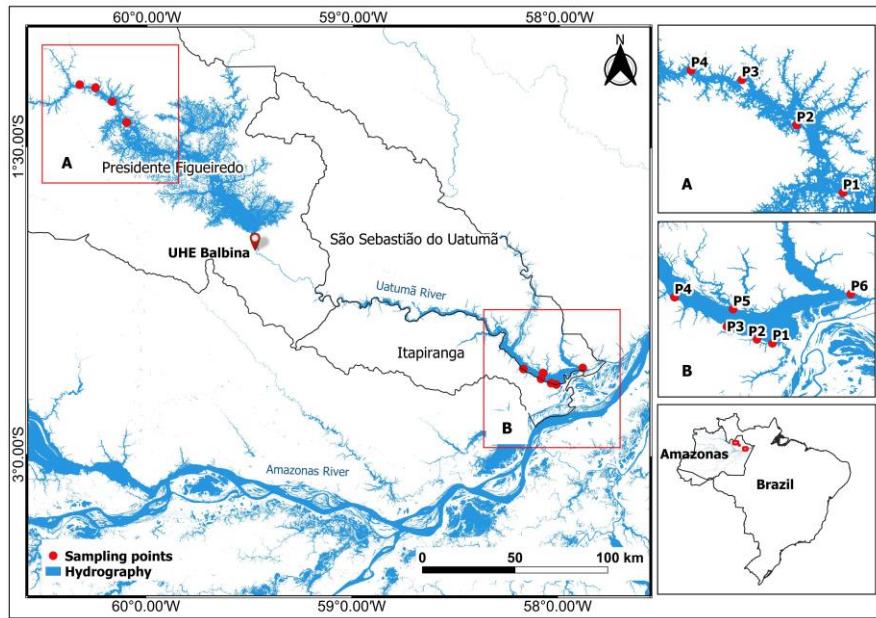


Figure 1. Geographic location of the Uatumã River with an indication of sampling points in the municipalities of Presidente Figueiredo, Itapiranga, and São Sebastião do Uatumã, a northeastern region of Amazonas, Brazil.

The capture of stingrays occurred through fishing at night using a hand net. After capture, to avoid possible accidents with stingers, the rays were anesthetized through immersion baths in plastic pockets with eugenol ($200 \mu\text{L.L}^{-1}$) and then mechanical containment of the stinger was performed using forceps, and subsequently, procedures were carried out to obtain biometric data, the disc width – DW and total length – TL were measured using a measuring tape (Figure 2) and the weight was checked using a portable scale.



Figure 2. Measurement of biometric parameters in *Paratrygon* spp. collected in the Uatumã river basin, northeastern Amazonas, Brazil. (a) measurement of total length; (b) measurement of disc width.

From the values recorded for the disc width – DW, the developmental stage of the captured stingrays was determined; for the *Potamotrygon motoro* stingray, the recommendations of Araújo [24] were followed; for *Potamotrygon scobina* and *Potamotrygon orbignyi*, the recommendations of Acosta-Santos et al. [25] and Lasso et al. [26], respectively, for specimens of the genus *Paratrygon*, data from the species *Paratrygon aiereba* described by Araújo [27] were used.

For identification, the key proposed by Rosa and Carvalho [28] was used, verifying five characteristics: 1) Disc shape; 2) Pattern of the ventral color of the disc; 3) Dorsal color pattern of the

disc; 4) Absence or presence of the labial groove; 5) distribution pattern of spines on the tail. In addition, sexing was also carried out based on observation of the presence or absence of claspers.

3. Results

3.1. Diversity and Biometric

In total, 69 specimens of Potamotrygonines were captured, 59 of which were from the genus *Potamotrygon* and ten individuals from the genus *Paratrygon*. Of the 59 individuals of the genus *Potamotrygon*, 43 were of the species *P. orbignyi*, 13 *P. motoro* and 3 *P. scobina* (Figure 3).

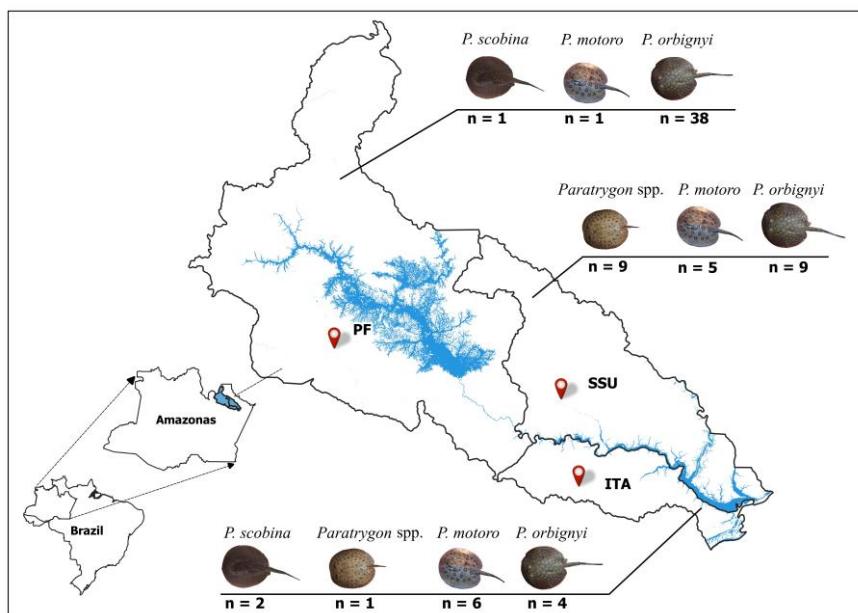


Figure 3. Indication of stingrays captured in the municipalities of Presidente Figueiredo (PF), São Sebastião do Uatumã (SSU) and Itapiranga (ITA), in the Uatumã river basin, northeastern region of Amazonas, Brazil.

Data for biometric parameter values and developmental stages are found in Table 1. All neonatal individuals were captured during the high water season of the Uatumã River in May. This fact may be related to the influence of the hydrological period of Amazon rivers on the reproduction of stingrays [13]. It is essential to highlight that, in this collection, only neonatal individuals were captured, and no individuals were found in other stages of development. This, in addition to being related to reproduction, may also be related to the increase in the volume of water, the periodic expansion of the stingrays' habitat, and the reduction of transparency, which causes low visibility and makes capture difficult [29,30]. All other specimens captured at different stages of development (juveniles, subadults and adults) were collected during the Uatumã River's dry period between September and November. At this time of year, the volume of water is smaller, the habitat is reduced, and there is an increase in transparency, making capturing these individuals easier [4,17]. In the neonate of *P. motoro* Captured at point ITA, the total length was not determined, as it was captured without the tail, demonstrating the presence of negative fishing.

Table 1. Values of biometric parameters of stingrays captured in the Uatumã river basin, northeastern Amazonas region, Brazil.

Localit y	Species	Developme nt stage	Sex	n	DW (cm)	TL (cm)	Weight (g)
PF	<i>P. orbignyi</i>	Young	M	1	19.0 ± 2.69	33 ± 2.79	384 ± 101.9
			F	8	20.0 ± 2.27	34 ± 3.69	420 ± 139.7
				1			
				5			
		Adult	M	2	24.0 ± 0.0	38.5 ± 0.70	625.0 ± 7.07
			F	3	24.0 ± 0.0	42.0 ± 1.52	683.0 ± 110.1
	<i>P. motoro</i>	Young	M	1	21.0	32.0	570.0
	<i>P. scobina</i>	Adult	M	1	23.0	44.0	470.0
	<i>P. orbignyi</i>	Neonate	F	1	7.5	13.0	270.0
		Young	F	3	24.7 ± 3.5	45.5 ± 3.5	660.0 ± 266.3
ITA	<i>P. motoro</i>	Young	M	1	8.0	-	310.0
			M	1	24	43	530
			F	3	21.7 ± 3.05	41 ± 9.64	433.5 ± 179.2
		Adult	M	1	41.5	51.0	570.0
		Neonate	F	1	11.0	21.5	590.0
	<i>P. scobina</i>	Adult	M	1	24.8	47.0	480.0
			M	1	45.0	57.0	3,100.0
	<i>Paratrygon</i> spp.	Subadult	M	1			
	<i>P. orbignyi</i>	Young	F	2	20.0 ± 4.2	37.0 ± 4.2	310.0 ± 169.7
SSU	<i>P. motoro</i>	Young	M	2		47.3 ± 6.07	
			M	3	23 ± 1.0	53.05 ±	436.6 ± 49.3
			F	3	31 ± 2.82	13.4	1,075 ± 233.3
	<i>Paratrygon</i> spp.	Young	M	2	23 ± 1.41	40.75 ±	
			F	6	23.21 ± 1.54	12.3	435 ± 35.35
		Subadult	F	1	33.0	45 ± 8.83	425 ± 103.2

n: Number of samples, **DW:** Disc width, **TL:** Total length.

3.2. Diagnosis of *Potamotrygon orbignyi* (Castelnau, 1855) Captured in the Uatumã River Basin

The most common freshwater stingray in the Uatumã river basin was *P. orbignyi*, with the highest incidence in the portion located in the Presidente Figueiredo municipality. This portion of the Uatumã River was impacted by the construction of the Balbina hydroelectric plant, and the flooded vegetation is still decomposing, compromising water quality in the region [31]. The occurrence of *P. orbignyi* in the hydrographic areas impacted by hydroelectric plants was also recorded for the Parnaíba, Tocantins and Araguaia river basins, highlighting the high adaptability of *P. orbignyi* [32,33].

A total of 38 specimens of *P. orbignyi* were captured at the site. Although this species presents high polychromatism in the dorsal region of the disc [33], all individuals presented the same

reticulated pattern (Figure 4a,b). This fact may have occurred due to the construction of the hydroelectric plant, which intensified the impact of population fragmentation within and between tributaries, resulting in the reduction of genetic diversity and the loss of color variability [32]. The captured species presented the typical pattern of spines on the tail, organized in a row, with a well-developed labial groove, and the majority presented a rounded spot in the ventral region of variable size and color (black and dark gray) in the portion located between and below the slits.

Other factors that may explain the abundance of *P. orbignyi* are the effect of the transformation of the river, a lotic environment into a lentic climate, as well as the increase in the flooded area, which consequently increased the biomass of invertebrates, such as insects, which favors the diet of the *P. orbignyi*. *P. orbignyi*, which is predominantly insectivorous [33–35].

In other stretches of the Uatumã River, the occurrence of *P. orbignyi* was lower. Still, in addition to presenting the reticulated dorsal color pattern (Figure 4a,b), species with other patterns and a brownish background were also found (Figure 4c) and a black background (Figure 4d).



Figure 4. Specimens of *P. orbignyi* were collected in the Uatumã River, northeastern Amazonas, Brazil. (a), (b) *P. orbignyi* with a reticulated color pattern; (c) *P. orbignyi* with a brownish background; (d) *P. orbignyi* with a black background.

3.3. Diagnosis of *Potamotrygon motoro* (Müller & Henle, 1841) Captured in the Uatumã River Basin

The *P. motoro* stingray occurred at all points analyzed in this study, but unlike *P. orbignyi*, *P. motoro* showed a higher incidence in the area outside the influence of the Balbina hydroelectric plant, with only one specimen captured in this region. The specimen presented a variation in the color pattern not found at other points in this study, with small, bicolored ocelli with a yellow center and black outer ring arranged on a dark brown background and without the presence of ocelli on the tail (Figure 5b).

In total, four different patterns were found in the color of *P. motoro* in the Uatumã River, the pattern present in stingrays a and b (Figure 5a,b) is the most widespread and comprehensive in the Amazon basin region [36].

Patterns a and c were found both at the point in ITA and the point in SSU. Pattern a is formed by large, tricolor eyespots with a yellow and orange background and a black outer ring arranged on a brown background, while pattern c is formed by yellowish ocelli arranged on a light brown background (Figure 5a,c). The pattern of stingray d (Figure 5d) is less common for this species, being found in more restricted areas. Only one specimen with this pattern was collected at the point in ITA, to date, this pattern has only been recorded in three regions, two in Peru and one in Brazil on the Tarauacá River in the state of Acre [36]. All captured specimens had a circular disc, poorly developed labial furrow and a single row of spines on the tail.

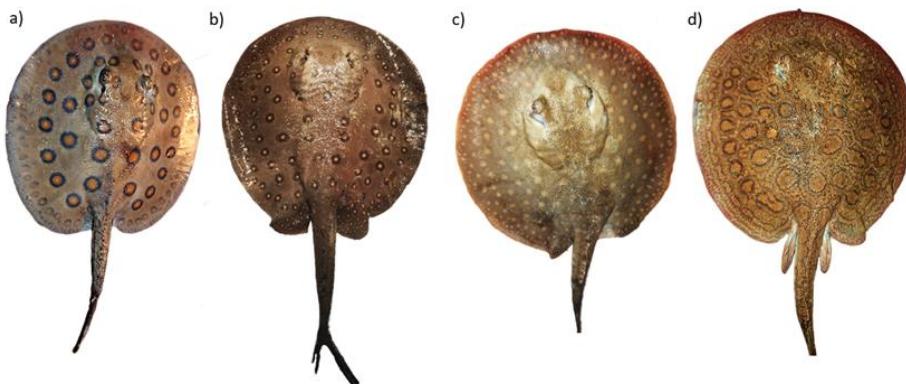


Figure 5. Specimens of *Potamotrygon motoro* collected in the Uatumã river basin, northeastern Amazonas, Brazil. (a) *P. motoro* with tricolor ocelli captured in ITA and SSU; (b) *P. motoro* with bicolor ocelli captured in PF; (c) *P. motoro* with yellow ocelli captured in ITA and SSU; (d) *P. motoro* with a less common pattern for the species, collected at the point in ITA.

3.4. Diagnosis of *Potamotrygon scobina* (Garman, 1913) Captured in the Uatumã River Basin

P. scobina was the species found least frequently; its occurrence was recorded at two collection points, PF and ITA (Figure 2), with two specimens at the ITA point and one at the PF point. The specimens from the ITA point presented a brownish disc with numerous clustered light spots distributed throughout the disc and tail with a single row of spines (Figure 6a).

The PF specimen had a brownish disc with small, light eyespots and a tail with spines arranged irregularly at the base and organized in a single row on the rest of the tail, in addition to spots spread throughout the tail (Figure 6b).



Figure 6. Specimens of *Potamotrygon scobina* collected in the Uatumã river basin, northeastern Amazonas, Brazil. (a) Specimen collected in ITA; (b) Specimen collected in PF.

All captured individuals had a subcircular disc with a more prominent central portion, a robust tail up to the base of the stinger and thin from that point onwards, a poorly developed labial groove, a poorly exposed pelvic fin and a light ventral region, showing a white color.

3.5. Diagnosis of *Paratrygon* spp. (Dumeril, 1865) Captured in the Uatumã River Basin

Until recently, the genus *Paratrygon* was believed to be the only monotypic genus in the family Potamotrygonidae, with only the species *Paratrygon aiereba* [2].

Although *P. aiereba* is one of the first species of freshwater stingrays described, there is still no extensive and specific literature about it [3]. The discussion about gender diversity had already been addressed by Rosa [37], Rosa et al. [10] and Carvalho et al. [5], but the species was only dismembered

by Loboda [2] after carrying out a taxonomic and morphological review of the genus, which resulted in eight more species.

However, although it is currently known that *Paratrygon aiereba* is a complex species, the characteristics of the species are not yet well elucidated, which is why in the present work, individuals of *Paratrygon* are referred to only by the generic epithet.

In the Uatumã River, three color patterns were found for *Paratrygon*, with patterns b and c (Figure 7b,c) being the most similar and predominant. For pattern a (Figure 7a), only one specimen was found at point SSU. In Figure 7, stingray d is the standard stingray c at another stage of development, with stingray c being a young individual and stingray d a subadult.



Figure 7. Specimens of the genus *Paratrygon* captured in the Uatumã river basin, northeastern Amazonas, Brazil. (a) Specimen captured at the SSU point; (b) Copy collected in ITA and SSU; (c) Young specimen collected in ITA and SSU; (d) Subadult specimen collected in ITA and SSU.

All captured specimens presented the characteristics already described in the literature, absence of labial groove, slightly concave shaped disc, long, thin tail without the presence of spines in young individuals and subadult individuals, a short, robust tail with long spines and organized irregularly throughout the tail.

All captured individuals of *Paratrygon* spp. they were captured in areas with a sandy substrate, corroborating what Oliveira described [11] about the preference of these stingrays for beaches. This preference may be related to the absence of *Paratrygon* spp., at the point in PF.

5. Conclusions

In general, the present work adds knowledge for the characterization of the stingray population in the Uatumã River region and the Amazon region, contributing to the increase in the collection of knowledge related to the geographic distribution of freshwater elasmobranchs.

Although only four species were collected, the high degree of polychromatism found in the color pattern of the rays was notable since the color is related to adaptation processes related to the characteristics of the species, such as eating habits, hunting and escaping from threats [38]. Furthermore, the high rate of young individuals collected reflects the capture method used in this study.

The study provides preliminary information on the characteristics of freshwater stingray species that may occur in the Uatumã River. Furthermore, new research is necessary to improve the identification of specimens to determine the diversity and elucidate aspects related to the biology of elasmobranchs present in the Uatumã River Basin.

Author Contributions: Conceptualization, Maria Gomes and Adriano Oliveira.; methodology, Maria Gomes, Maiko Ribeiro, Cristiane Guimarães and Tiago Nóbrega; formal analysis, Maria Gomes, Rayana Paixão, Cristiane Guimarães and Adriene Santos.; data curation, Maria Gomes, Adriene Santos, Maiko Ribeiro, Tiago Nóbrega and Adriano Oliveira; writing, Maria Gomes, Paulo Aride and Rayana Paixão; writing – review and editing, Adriano Oliveira; supervision, Paulo Aride and Adriano Oliveira.; acquisition of financing, Adriano Oliveira.

Funding: This research was funded by the Amazonas State Research Support Foundation - FAPESAM, through the Biodiversa program, notice: 007 of 2021.

Institutional Review Board Statement: The study was conducted following the Declaration of Helsinki and approved by the Ethics Committee on the Use of Animals of the Federal Institute of Education, Science and Technology of Amazonas (2019/010.02.0905).

Data Availability Statement: Available upon request from the corresponding author of this article.

Acknowledgments: The authors would like to thank the Postgraduate Program in Animal Science and Fisheries Resources (PPGCARP/UFAM) and the Center for the Study of Invertebrates and Vertebrates of the Amazon (NEIVA/IFAM).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fontenelle, J.P.; Carvalho, M.R. Systematic revision of the *Potamotrygon scobina* Garman, 1913 species-complex (Chondrichthyes: Myliobatiformes: Potamotrygonidae), with the description of three new freshwater stingray species from Brazil and comments on their distribution and biogeography. *Zootaxa* **2017**, *4310*, 1-63.
2. Loboda, T.S. Revisão taxonômica e morfológica do gênero *Paratrygon* Duméril (1865) (Chondrichthyes: Myliobatiformes: Potamotrygonidae). Tese de Doutorado, Universidade de São Paulo, São Paulo, Brazil, 2016.
3. Loboda, T.S.; Lasso, C.A.; Rosa, R.S.; Carvalho, M. R. Two new species of freshwater stingrays of the genus *Paratrygon* (Chondrichthyes: Potamotrygonidae) from the Orinoco basin, with comments on the taxonomy of *Paratrygon aiereba*. *Neotrop Ichthyol.* **2021**, *19*, 1-80. DOI: <https://doi.org/10.1590/1982-0224-2020-0083>.
4. Duncan, W.P. Ecofisiología das raias de água doce (Potamotrygonidae): mecanismos de interação organismo-ambiente. In *XV. Rayas de agua dulce (Potamotrygonidae) de Suramérica. Parte II: Colombia, Brasil, Perú, Bolivia, Paraguay, Uruguay y Argentina*, 1 ed; Lasso, C.A.; Morales-Betancourt, M.A.; Garrote-Neto, D.; Carvalho, M.R. Eds. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá, Colombia, 2016, pp. 45-64.
5. Carvalho, M.R.; Lovejoy, N.N.; Rosa, R.S. Family Potamotrygonidae (river stingrays). In *Check List of the Freshwater Fishes of South and Central América*. Reis R E, Kullander SO, Ferraris J. Eds. Edipucrs, Porto Alegre, 2003, pp. 22-29.
6. Araújo, M.L.G.; Charvet-Almeida, P.; Almeida, M.P.; Pereira, H. Freshwater stingrays (Potamotrygonidae): status, conservation and management challenges. *Information document AC 20 2004*, 1-6.
7. Carvalho, M.R. Description of two extraordinary new species of freshwater stingrays of the genus *Potamotrygon* endemic to the Rio Tapajós basin, Brazil (Chondrichthyes: Potamotrygonidae), with notes on other Tapajós stingrays. *Zootaxa* **2016**, *4167*, 1-63. DOI: [10.11646/zootaxa.4167.1.1](https://doi.org/10.11646/zootaxa.4167.1.1)
8. Carvalho, M.R.; Rosa, R.S.; Araújo, M.L.G. A new species of Neotropical freshwater stingray (Chondrichthyes: Potamotrygonidae) from the Rio Negro, Amazonas, Brazil: the smallest species of *Potamotrygon*. *Zootaxa* **2016**, *4107*, 566- 586. DOI: [10.11646/zootaxa.4107.4.5](https://doi.org/10.11646/zootaxa.4107.4.5)
9. Almeida, M.P.; Barthem, R.B.; Viana, A.S.; Charvet-Almeida, P. Factors affecting the distribution and abundance of freshwater stingrays (Chondrichthyes: Potamotrygonidae) at Marajó Island, mouth of the Amazon River. *Pan-American Journal of Aquatic Sciences* **2009**, *4*, 1-11.
10. Rosa, R.S.; Charvet-Almeida, P.; Quijada, C.C.D. Biology of the South American potamotrygonid stingrays. In *Sharks and their relatives II: biodiversity, adaptative physiology and conservation*; Carrier, J.C.; Musick, J.A.; Heithaus, M.R. Eds. 2010, pp. 241-281. DOI: [10.1201/9781420080483-10](https://doi.org/10.1201/9781420080483-10)
11. Oliveira, A.T.; Araujo, M.L.G.; Lemos, J.R.G.; Santos, M.Q.C.; Pantoja-Lima, J.; Aride, P.H.R.; Tavares-Dias, M.; Marcon, J.L. Ecophysiological interactions and water related physicochemical parameters among freshwater stingrays. *Brazilian Journal of Biology* **2017**, *77*, 616-621. DOI: [10.1590/1519-6984.01816](https://doi.org/10.1590/1519-6984.01816)
12. Shibuya, A.; Zuanon, J.; Carvalho, M. R. Alimentação e comportamento predatório em raias Potamotrygonidae. In *XV. Rayas de agua dulce (Potamotrygonidae) de Suramérica. Parte II: Colombia, Brasil, Perú, Bolivia, Paraguay, Uruguay y Argentina*, 1 ed; Lasso, C.A.; Morales-Betancourt, M.A.; Garrote-Neto, D.; Carvalho, M.R. Eds. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá, Colombia, 2016, pp. 67-81.
13. Charvet-Almeida, P.; Araújo, M.L.G.; Almeida, M.P. Reproductive Aspects of Freshwater Stingrays (Chondrichthyes: Potamotrygonidae) in the Brazilian Amazon Basin. *J. Northw. Atl. Fish. Sci.* **2005**, *35*, 165-171. DOI: [http://dx.doi.org/10.2960/J.v35.m502](https://doi.org/10.2960/J.v35.m502).
14. Carrier, J. C.; Pratt, H. L.; Castro, J. I. Reproductive biology of elasmobranchs, In: *Biology of sharks and their relatives*, 1 ed.; Carrier, J.C.; Musick, J.A.; Heithaus, M.R. Eds. CRC Press, Boca Raton, 2004; pp. 269-286.

15. Lameiras, J.L.V.; Costa, O.T.F.; Dos-Santos, M.C.; Duncan, W.L.P. Arraias de água doce (Chondrichthyes – Potamotrygonidae): biologia, veneno e acidentes. *Scientia Amazonia* **2013**, *2*, 11-27.
16. Lucifora, L.O.; Balboni, L.; Scarabotti, P.A.; Alonso, F.A.; Sabadin, D.E.; Solari, A.; Vargas, F.; Barbini, S. A.; Mabragaña, E.; Díaz, J.M.A. Decline or stability of obligate freshwater elasmobranchs following high fishing pressure. *Biological Conservation* **2017**, *210*, 293-298. DOI: <https://doi.org/10.1016/j.biocon.2017.04.028>
17. Oliveira, A.T.; Lima, E.C.; Santos, S.M.; Araujo, R.L.; Pantoja-Lima, J.; Aride, P.H.R. Relação entre as populações naturais de arraias de água doce (Myliobatiformes: Potamotrygonidae) e pescadores no baixo Rio Juruá, estado do Amazonas, Brasil. *Biota Amazônica* **2015**, *5*, 108-111
18. Oliveira, A.T.; Rodrigues, P.A.; Ramos-Filho, A.M.; Gomes, M.F.S.; Liebl, A.R.S.; Pinho, J.V.; Aride, P.H.R.; Conte-Junior, C.A. Levels of total mercury and health risk assessment of consuming freshwater stingrays (Chondrichthyes: Potamotrygoninae) of the Brazilian Amazon. *International Journal of Environmental Research and Public Health* **2023**, *20*, 69-90. DOI: <https://doi.org/10.3390/ijerph20216990>
19. Andrade, J.C.; Oliveira, A.T.; Amazonas, M.G.F.M.; Galvan, D.; Tessaro, L.; Conte-Junior, C.A. Fingerprinting based on spectral reflectance and chemometrics - An analytical approach aimed at combating the illegal trade of stingray meat in the Amazon. *Food Chemistry* **2023**, *436*, 137-637. DOI: <https://doi.org/10.1016/j.foodchem.2023.137637>
20. Shibuya, A. A review of the ecological role of the Neotropical freshwater stingrays (Chondrichthyes: Potamotrygoninae). *Food Webs* **2022**, *32*. DOI: <https://doi.org/10.1016/j.fooweb.2022.e00244>
21. Jézéquel, C.; Tedesco, P.A.; Bigorne, R.; Berdorff, T.O. Um banco de dados de espécies de peixes de água doce da Bacia Amazônica. *Sci Data* **2020**, *7*. DOI: <https://doi.org/10.1038/s41597-020-0436-4>
22. Baldisseri, D.H. As transformações espaciais e os impactos ambientais na bacia do rio Uatumã–AM, Brasil. In Proceedings of X Encontro de Geógrafos da América Latina, Universidade de São Paulo, Brasil, 20 a 26 de março de 2005.
23. Assahira, C.; Piedade, M.T.F.; Trumbore, S.E.; Wittmann, F.; Cintra, B.B.L.; Batista, E.S.; Resende, A.F.; Schongart, J. Tree mortality of a flood-adapted species in response of hydrographic changes caused by an Amazonian River dam. *Forest Ecology and Management* **2017**, *396*, 113-123. DOI: <https://doi.org/10.1016/j.foreco.2017.04.016>
24. Araújo, M.L.G. Plano de Monitoramento de arraias de água Doce. Convênio IBMA-AM/ACEPOAM. 1999, pp. 31.
25. Acosta-Santos, A.; Agudelo, E.; Duque, S.R. Diversidad de rayas de agua dulce en el río Amazonas Colombiano: Resultados Preliminares. In *XV. Rayas de agua dulce (Potamotrygonidae) de Suramérica. Parte II: Colombia, Brasil, Perú, Bolivia, Paraguay, Uruguay y Argentina*, 1 ed; Lasso, C.A.; Morales-Betancourt, M.A.; Garrote-Neto, D.; Carvalho, M.R. Eds. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá, Colombia, 2016, pp. 361 -373.
26. Lasso, C.A.; Rosa, R.S.; Sánchez-Duarte, P.; Morales-Betancourt, M.A.; Agudelo-Córdoba E. Eds. In *IX. Rayas de agua dulce (Potamotrygonidae) de Suramérica. Parte I. Colombia, Venezuela, Ecuador, Perú, Brasil, Guyana, Surinam y Guayana Francesa: diversidad, bioecología, uso y conservación*. Instituto de Investigación de los Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá, Colombia, 2013, pp. 368.
27. Araújo, M.L.G. Dinâmica de população e conservação de *Paratrygon aiereba* (Chondrichthyes-Potamotrygonidae) no médio Rio Negro, Amazonas. Tese de Doutorado, Universidade Federal do Amazonas, Manaus, Brazil, 2011.
28. Rosa, R.S.; Carvalho, M.R. Claves para identificación de las rayas de agua Dulce (Potamotrygonidae). In *XV. Rayas de agua dulce (Potamotrygonidae) de Suramérica. Parte II: Colombia, Brasil, Perú, Bolivia, Paraguay, Uruguay y Argentina*, 1 ed; Lasso, C.A.; Morales-Betancourt, M.A.; Garrote-Neto, D.; Carvalho, M.R. Eds. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá, Colombia, 2016, pp. 105-126.
29. Araújo, M.L.G. Biología Reproductiva e pesca de *Potamotrygon* sp. (ChondrichthyesPotamotrygonidae) no médio Rio Negro, Amazonas. Dissertação de Mestrado, Instituto Nacional de Pesquisa da Amazônia, Manaus, Brasil, 1998.
30. Duncan, W.P.; Fernandes, M. N. Physicochemical characterization of the white, black, and clearwater rivers of the Amazon Basin and its implications on the distribution of freshwater stingrays (Chondrichthyes, Potamotrygonidae). *Pan-American Journal of Aquatic Sciences* **2011**, *5*, 1-11.
31. Fearnside, P.M. Hidrelétrica de Balbina. In *Hidrelétricas na Amazônia: Impactos Ambientais e Sociais na Tomada de Decisões sobre Grandes Obras*, 1 ed.; Cohn-Haft, M. Eds. Editora do INPA, Manaus, 2015; pp. 297.
32. Palmeira-Nunes, A.R.O.; Ferreira, L.A.C.; Medeiros, A.M.; Santos, M.E.M.; Nunes, J.L.S.; Rincon, G. Distribuição da raia de água doce *Potamotrygon orbignyi* e impactos de hidrelétricas em suas populações na região amazônica. In *Padrões e processos biogeográficos na Amazônia*, 1 ed.; Siqueira, G.M.; Silva, R.A.; Guedes-Filho, O. Eds. Editora da Universidade Federal do Maranhão, São Luís, 2022; pp. 62-91.
33. Rincon-Filho, G. Aspectos taxonômicos, alimentação e reprodução da raia de água doce *Potamotrygon orbignyi* (Castelnau) (Elasmobranchii: Potamotrygonidae) no Rio Paraná Tocantins. Tese de Doutorado, Universidade Estadual Paulista. Rio Claro, Brasil, 2006.

34. Charvet-Almeida, P.; Araújo, M.L.G.; Rosa, R.; Rincon, G. Neotropical Freshwater Stingrays: diversity and conservation status. *Shark News*. IUCN Specialist Group. 2002.
35. Gama, C.S.; Rosa R.S. Uso de recursos e dieta das raias de água doce (Chondrichthyes, Potamotrygonidae) da Reserva Biológica do Parazinho, AP. *Biota Amazônia* **2015**, 5, 90-98. DOI: <http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v5n1p90-98>
36. Loboda, T.S. Revisão taxonômica e morfológica de *Potamotrygon motoro* (Muller & Henle, 1841) na bacia Amazônica (Chondrichthyes: Myliobatiformes: Potamotrygonidae). Tese de Doutorado, Universidade de São Paulo, São Paulo, Brazil, 2010.
37. Rosa, R.S. *Paratrygon aiereba* (Muller & Henle, 1841): the senior synonym of the freshwater stingray *Disceus thayeri* Garman, 1913 (Chondrichthyes: Potamotrygonidae). *Revista Brasileira de Zoologia* **1991**, 7, 425-437
38. Ortolani, A.; Caro, T.M. The adaptive significance of colour patterns in carnivores: phylogenetic tests of classic hypotheses. In *Carnivore behavior, ecology and evolution*; Gittleman, J.L. Eds. 1996, pp. 132-188.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.