Project Report to

Society for Marine Mammalogy Conservation Fund

Counting to protect: population estimation of a highly threatened subpopulation of river dolphin (genus *Inia*) in the Tocantins, the most impacted river by dams and land use changes in Brazil

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Project Summary: The Tocantins River, part of the Brazilian Araguaia-Tocantins river basin, travels through 2,400 km of cerrado (Brazilian savanna), Amazon, and transition zones before it flows into the Atlantic Ocean in the north part of the country. One of the most important Brazilian rivers for water supply, irrigation, transportation, and hydropower potential, the Tocantins is also one of the most threatened, due to extensive habitat degradation, human occupation, sewage, mining, cattle ranching, agriculture, industry and urban development, road and hydroelectric dam construction. It is there that one of the most recently discovered cetacean taxa, the Araguaian boto (*Inia araguaiaensis* Hrbek et al. 2014), occurs. The species has not yet been recognized by the Society for Marine Mammalogy, but it is accepted and classified as Endangered by the Brazilian environmental authority.

For over a month in mid-2022 a team of researchers traveled over 2,000 km of the Tocantins River, from Abaetetuba (Pará state), close to its mouth in the Atlantic Ocean, to Minaçu (Goiás state), near its headwaters, including the reservoirs of seven hydroelectric dams that sever the river in eight stretches. Data was collected, using a distance sampling protocol in two stretches: up to the large Tucuruí Dam the survey was conducted on regional double-decker boat that accomodated the full team of seven observers; observations in all the other sections between dams were conducted by two observers only, onboard five different local, speed boats, due to geomorphological limitations. Data was recorded in a one-way independence approach. We used a mixed protocol of strip (parallel to the margin) and line transects (across the river channel). For each observation we recorded species, group size, presence of calves, radial distance from sighting and the vessel, radial angle, distance from dolphin groups to the margin, habitat type, associated margin, presence of human activities, weather and visibility conditions.

A total of 1,609 km was surveyed, resulting in 85 recorded sightings of Araguaian boto (*Inia araguaiaensis*) and 36 tucuxis (*Sotalia* sp). No calves were sighted; density estimates were derived for each surveyed segment, several with a value of 0. These data suggest that the population is small and potentially experiencing local extirpation in certain stretches. The high density of individuals recorded near the Tocantins-Araguaia confluence underscores the ecological significance of maintaining the Araguaia River as a Free-Flowing River. The considerable number of anthropogenic disturbances documented reflect the intense human pressure along the Tocantins River basin. The progressive degradation of fluvial habitats caused by the cascade development of hydroelectric dams may lead to reproductive isolation of the target taxon and habitat loss, especially in the upper Tocantins.

Based on the data, we estimate the total population of Araguaian boto in the Tocantins River not to exceed 1,000 individuals (including those located downstream of the Tucuruí dam). When

considering Upstream Tucuruí Dam (i.e. "pure" *Inia araguaiaensis* with no influence of the hybrid zone downstream) the number could be less than 800.

Even though not yet recognized as a valid species by the Society for Marine Mammalogy and therefore not assessed by IUCN, the Araguaian boto deserves special attention given its limited distribution, estimated low numbers and the shear volume of threats affecting them. We addressed some of these data deficiencies, by estimating density of Araguaian boto along the whole Tocantins River main stem, and collecting accessory data along the expedition, and making a case for the implementation of a full assessment of the taxon.

Amount Requested from SMM: US $ 24,981.00, requested advance of 90% total, or $ 22,482.90

Methods

We conducted an Araguaia boto population estimation expedition along the Tocantins River (Brazilian states of Pará, Maranhão, Tocantins, Goiás) between 07 July and 13 August 2022 (Fig. 1).

The team included (at different times) seven observers, four experienced (Miriam Marmontel, André Coelho, Cristiane Moraes, Alcebíades Martins) and three (Eduarda, Rafael Meneses and a Guianan colleague, Indranee Roopsind) in training. Adriano Gambarini, photographer had a conflicting committment so reporter Tiffany Higgins replaced him temporarily .We had land support from two drivers and a rental car; one large regional boat (for the first part of the trip on the main river up to the Tucuruí Hydroelectrical Dam UHE) and five different speed boats with respective pilots (to transit between hydroelectric dam lakes, and cross rapids).

The trip included the following cities and hydroelectrical dams (UHE): Abaetetuba (PA) – Cametá (PA) – São José de Ituquara (PA) – Nazaré dos Patos (PA) - Tucuruí (PA) – São João do Tocantins - (TO) – Imperatriz (MA) – Itaguatins (TO) – Estreito UHE (MA) – Babaçulândia (TO) – Palmeirante (TO) – Lajeado UHE - Porto Nacional (TO) – Ipueiras (TO) – Peixe UHE (TO) – São Salvador UHE (TO) - Cana Brava UHE (GO) - Serra da Mesa (GO). In Porto Nacional we recovered a male dolphin carcass collected by a fisherman collaborator, obtaining the skeleton and information.

We waited 11-18 July to get a permit to cross the Tucuruí UHE locks, without success. Due to the delay, five collaborators had to leave within a few days of each other after we left Tucuruí, so from Peixe UHE (Usina Hidrelétrica – Hydroelectric Dam) on only André Coelho and Miriam Marmontel remained observing, this time using a voice recorder to register data. Otherwise, we practiced the usual protocol of population estimation adapted for river dolphin situations, as described below.

Data was collected, using a distance sampling protocol similar to Pavanato et al. (2016) and Paschoalini et al. (2020) in two stretches: 1) From Abaetetuba (Belém) to Tucuruí and 2) From Tucuruí to Goiânia. In stretch one the survey was conducted using a regional double-decker boat where seven observers rotated every hour between two observation platforms on the bow (Platform 1) and stern (Platform 2) of the boat. In stretch 2 we used smaller boats about 10 m long, due to geomorphology of the river that hampers navigation of larger boats. The observers set on the star and port actively looked for dolphins in from 10° of the opposite side to 90° of their own side, a third person was in charge of data recording. This overlap in search field reduces the probability of losing animals in the vicinity of the trackline. The use of two independent platforms enables to estimate the detection probability of river dolphins. Data was

recorded in a one-way independence approach, i.e. observers on the stern platform were be unaware of the sightings from the bow, enabling the calculation of the detection probability (g(0)). After finishing a cycle in one platform every researcher rested for at least two hours before beginning a new one.

We used a mixed protocol of strip (parallel to the margin) and line transects (across the river channel); transects were 2.5 km long and line transects were performed after four straight strip transects. During strip transects we tried to navigate at 100 m from the margin according to navigation conditions (e.g. rocks, depth, and banks). Observers searched for dolphins by naked eye, and used angle boards to measure sighting angles in relation to the trackline. For each observation we recorded species, group size, presence of calves, radial distance from sighting and the vessel, radial angle, distance from dolphin groups to the margin, habitat type, associated margin, presence of human activities (e.g. fisheries, large harbours, communities, etc), weather and visibility conditions.

Because of the difficulty of retrieving all the information from collaborators that live in different cities, transcribing all the (voice-)recorded information for part of the trip into excel sheets, making corrections to transects and GPS locations, and compiling all the information into one sole format, the analysis period was prolonged.

Data analysis

We conducted analysis using the R packages Distance and MRDS. Transects were analysed separately - line transects (cross-channel) and strip (parallel to margin). Density estimates were calculated for each habitat type by stratification, since river dolphin density varies with habitat type (Pavanato et al., 2016; Paschoalini et al., 2020). Like Paschoalini et al. (2020) we also stratified the study area according to the dams along the Tocantins course, given that dams cause deep shifts in habitat shape and dynamics. Density estimates for line transects followed distance sampling methods. Truncation distances were assessed by means of exploratory analysis.

Tocantins River Survey 2022: Density Estimation and Conservation Implications

During the 2022 field expedition along the Tocantins River, a total of 1,609.2 km were surveyed, resulting in 121 recorded sightings, of which 85 were identified as Araguaian boto (*Inia araguaiaensis*) and 36 as tucuxis (*Sotalia sp*). Notably, no calves were observed during the monitoring period, raising concerns about reproductive activity and recruitment within the population.

A significant proportion of the sightings were classified as NW (new stern observations), indicating a low probability of detection ahead of the research vessel. This suggests potential limitations in survey efficiency and highlights the need for methodological refinement. Additionally, a high frequency of route deviation events was recorded (94), due to challenging navigation conditions in the sampling areas. These factors may have introduced bias into population estimates. Furthermore, a considerable number of anthropogenic disturbances were documented (741), reflecting the intense human pressure along the Tocantins River basin.

Although it was not yet possible to calculate the total surface area of the reservoirs or the other habitat areas between hydroelectric facilities, density estimates were derived for each surveyed segment. These data already provide critical insights into spatial distribution patterns and suggest that the population is small and potentially experiencing local extirpation in certain stretches.

Of particular concern is the progressive degradation of fluvial habitats caused by the cascade development of hydroelectric dams along the Tocantins River. This fragmentation has likely led to reproductive isolation and habitat loss, especially in the upper Tocantins, where the Serra da Mesa and Cana Brava reservoirs are located. It is imperative to diagnose whether functional extirpation of the species has occurred in these upstream impoundments.

To address these challenges, we recommend the implementation of fixed passive acoustic monitoring stations. These should be integrated into the Araguaia River Dolphin Conservation Network (REBOTO), in collaboration with the environmental secretariats of the states of Goiás and Tocantins, regions that encompass the largest known distribution of the species. REBOTO is a multi-sectoral initiative that includes governmental, academic, research, tourism, fisheries, and civil society stakeholders. Passive acoustic monitoring would reduce observational bias and enable robust assessments of population presence or absence, particularly in areas suspected of reproductive isolation.

Importantly, the highest density of individuals was recorded near the Tocantins-Araguaia confluence (Reservoir 2 of the Tucuruí dam until Imperatriz city). This finding underscores the ecological significance of maintaining the Araguaia River as a Free-Flowing River (FFR). The relatively less disturbed habitat in this region likely contributes to its role as a critical refuge for aquatic biodiversity, reinforcing the need for its long-term protection.

The observed patterns are consistent with the findings of the 2020 study *On the Brink of Isolation* (Paschoalini et al. 2020), which documented the ecological consequences of hydroelectric expansion in the Tocantins basin. Our results further validate the methodological approach employed in this study, demonstrating consistency across multiple sampling efforts.

Based on current data, it is estimated that the total population may not exceed 1,000 individuals, assuming inclusion of those located downstream of the Tucuruí dam. If considering Upstream Tucuruí Dam, which means pure *Inia araguaiaensis* with no influence of the hybrid zone

downstream, this number could be less than 800. This projection is deeply concerning given the cumulative threats identified, including habitat fragmentation, anthropogenic pressures, and potential reproductive isolation. Immediate conservation actions are essential to prevent further decline and ensure the persistence of these emblematic freshwater cetaceans.

Table 1. Overall effort conducted during the Tocantins River expedition in 2022 for density estimation of the Araguaia dolphin (*Inia araguaiaensis*) and the *Sotalia* sp.

Strata	**Line**				**Strip**			
	k	**L (km)**	**n**		**k**	**L (km)**	**n**	
			Sotalia sp	*Inia* spp			*Sotalia* sp	*Inia* spp
Downstream the Tucuruí Dam	88	64.41	12	6	261	167.16	24	19
Reservoir 1 the Tucuruí Dam	61	61.9	0	0	66	45.66	0	0
Reservoir 2 - Upstream to Imperatriz city	203	156.18	0	15	158	92.45	0	3
Imperatriz city to Estreito Dam	142	65.3	0	0	113	48.23	0	0
Estreito to Lajeado Dam	148	82.82	0	2	574	333.76	0	2
Lajeado to Peixe Angical Dam	64	36.43	0	3	377	212.72	0	11
Peixe Angical to São Salvador Dam	57	36.5	0	4	68	43.53	0	3
São Salvador to Cana Brava Dam	14	8.7	0	0	84	44.8	0	17
Cana Brava to Serra da Mesa Dam	16	7.3	0	0	53	36.53	0	0
Serra da Mesa Dam	23	13.7	0	0	79	51.1	0	0
	816	**533.24**	**12**	**30**	**1833**	**1075.94**	**24**	**55**

Inia araguaiaensis										
	Strata									
Density	Downstream Tucuruí	Reservoir 1 Tucuruí	Reservoir 2 - Upstream to Imperatriz city	Imperatriz city to Estreito Dam	Estreito to Lajeado Dam	Lajeado to Peixe Angical Dam	Peixe Angical to São Salvador Dam	São Salvador to Cana Brava Dam	Cana Brava to Serra da Mesa Dam	Serra da Mesa Dam
D	0,48	0	1,45	0	0,063	0,44	0,47	2,56	0	0

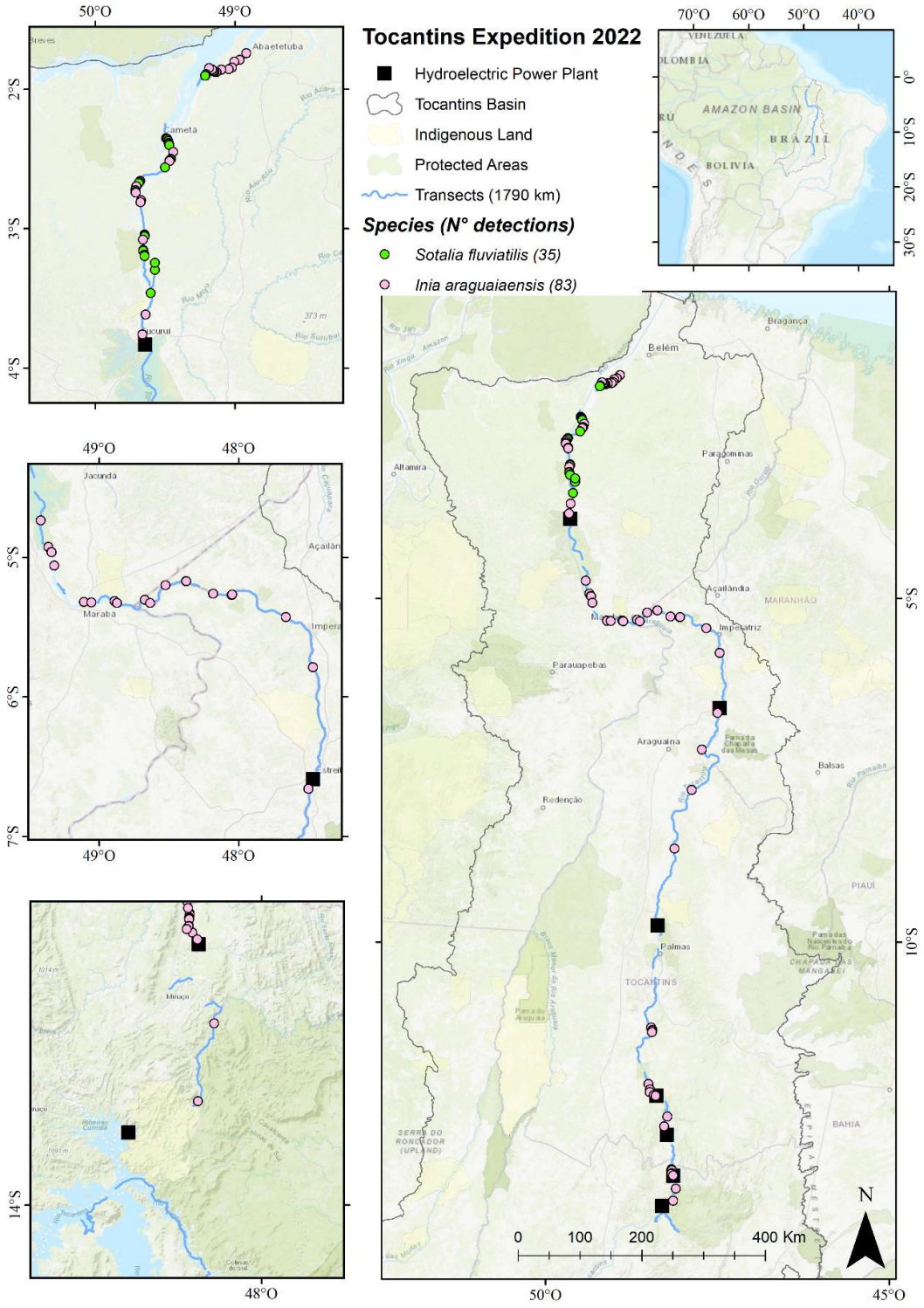

Figure 1. Map of the Tocantins River and from mouth to headwaters showing route traveled during population estimation expedition in 2022, and Amazon River and tucuxi dolphin sightings. Side panels provide details of stretches of the river: top panel – lower Tocantins, from Abaetetuba city to Tucuruí Dam; mid panel – mid Tocantins, from Tucuruí Lake to Estreito Dam; bottom panel – upper Tocantins, from Cana Brava Dam to Serra da Mesa Dam.

Additional information on efforts in the Tocantins-Araguaia Basin

Following the population estimation expedition, we were able to return to Tocantins River in mid-2023 for a follow-up trip to get more details on certain sites that had called our attention during the expedition. Miriam Marmontel and Hilda Chavez took a road trip along the Tocantins watershed 26 July – 28 August 2023. During that trip we received in donation another skeleton and tissue sample, a rib and tooth from another specimen of the Tocantins-Araguaia junction. We distributed approximately 100 copies do the booklet *The Araguaian boto* to schools, fishing colonies, tourism enterprises, and collaborators in the area.

At the end of this trip Miriam Marmontel joined Mariana Paschoalini, Cristiane Moraes and Pedro Fruet in the Peixe UHE to cross-bow sample Araguaia botos in that site: five tissue samples were obtained. A post-doc has been assigned to join the team and analyse those and dolphin samples from other watersheds in the Amazon.

We had a manuscript accepted for submission (Aquatic Mammals), compiling all available information (published or not) on the Araguaia boto, where we include all specimens available at this point – in the recent years we have been able to double the amount of skeletons collected. All our actions have been reported to SARDI and the Brazilian Action Plan on Amazonian Aquatic Mammals.

Attached please find a summary of funds spent during the expedition. A formal report shall be prepared by our Finance Department after the use of all the resources. I hereby present a a summary in English explaining how the funds were used. On 05/30/2022 we received $ 21,686.80 (equivalent to 90% of the award) which, at the exchange fee of 4,67 became R$ 101.277,36 (please see *Contrato de Câmbio* and *Ordem de Recebimento Exterior*). Please also find some pictures showing the species, the environment, and some of our activities.

We still have a balance of R$ 607,34, and the remaining 10% of the resource with the SMM – if at all available, to return to Tocantins and distribute more conservation education material and retrieve samples. I here present values in Reais.

Item	Amount invested (R$)	Percentage
Air, boat, land travel	17.570,62	17.45
Boat and car rental	47.937,78	47.62
Supplies (groceries, gas, office)	19.131,77	19.00
Per dia (lodging, meals)	16.029,85	15.92
Total	100.670,02	100

Literature cited

Paschoalini, M., Almeida, R.M., Trujillo, F., et al. 2020. On the brink of isolation: Population estimates of the Araguaian river dolphin in a human-impacted region in Brazil. *PLoS One 15*(4): e0231224. https://doi.org/10.1371/journal. pone.0231224

Pavanato, H.J., Melo-Santos, G., Lima, D.S., et al. 2016. Risks of dam construction for South American river dolphins: a case study of the Tapajós River. *Endangered Species Research 6*: 31:47–60.