SC/69B/SM/06

Sub-committees/working group name: SM

Range-wide decline in Amazonian river dolphin abundance: are we seeing a mirror of Asian river dolphins' fate?

Mariana Paschoalini Frias, Fernando Trujillo, Maria Jimena Valderrama, Miriam Marmontel, Fabiola La Rosa-Camino, Oscar Quispe Hure, Cedric Gilleman

INTERNATIONAL WHALING COMMISSION

Range-wide decline in Amazonian river dolphin abundance: are we seeing a mirror of Asian river dolphins' fate?

Mariana Paschoalini Frias*[1,2], Fernando Trujillo[2,3], Maria Jimena Valderrama[2,3], Miriam Marmontel[2,4], Fabiola La Rosa-Camino[2,5], Oscar Quispe Hure[2,5], Cedric Gilleman[2,6]

1. World Wide Fund for Nature, Brasília - Brazil
2. South American River Dolphins Initiative
3. Omacha Foundation, Bogotá - Colombia
4. Mamirauá Institute for Sustainable Development, Tefé – Brazil
5. World Wide Fund for Nature, Lima – Peru
6. Solinia, Iquitos, Peru

Abstract

Freshwater cetaceans are a small and endangered group of dolphins distributed in 14 countries in Asia and northern South America river basins. All species are classified by the IUCN as endangered and most of them face deep population declines (mainly in Asia). In South America basin-wide data on population trend of *Inia geoffrensis* (boto) and *Sotalia fluviatilis* (tucuxi) is unlike to be assessed due to their wider range. However, small scale studies have indicated population declines for both species in the Mamirauá Reserve and suggest declining to the upper Amazon River (the Amazon Trapezium). In this study we provide data on trends in abundance for two new sites: the Meta River in the Orinoco basin, and the Tapajós River in the Southern Amazon basin, adding basin-wide approach to the population status for these two species. Additionally, we provide new systematic data collected in the Amazonian Trapezium confirming the indications of population declined evidenced in previous years. 52% and 30% decline was perceived to boto and tucuxi respectively in the Amazonian Trapezium over a period of 30 years. In the Tapajós River, the population decline was estimated near 11% and 34% for boto and tucuxi, respectively over a period of eight years. In the opposite way, the population of boto in the Meta River, Orinoco basin, showed signs of population stability (possible increase 18%) over a period of 16 years. This paper is still preliminary, and no model was applied considering the generation-time either population availability analysis. This is a work in progress that may provide in the mid-term understanding on how severe the declines for the assessed areas and supports effective management actions targeting to reverse the curve.

Short introduction

Freshwater cetaceans are a small and endangered group of dolphins distributed in 14 countries in Asia and northern South America river basins (Trujillo et al. 2010, Smith & Smith 1998). In South America, two species (with one subspecies) have been recognized by the Society for Marine Mammalogy's Taxonomy Committee (CT-SMM 2023): 1. the boto, *Inia geoffrensis,* and the subspecies *Inia geoffrensis boliviensis* and 2. the tucuxi *Sotalia fluviatilis*. They are distributed throughout the wider Amazon-Orinoco region except for the tucuxi, not found in the Orinoco basin. In the past decade, two new species belonging to the genus *Inia* have been described, but not yet validated due to genetic and morphological inconsistencies, in addition to the low geographic representation of the samples collected: bufeo - *Inia boliviensis* (currently considered a subspecies category) and Araguaian-boto - *Inia araguaiaensis* (Banguera-Hinestroza et al. 2002, Hrbek et al. 2014, Gravena et al. 2015, Emin- Lima et al. 2022).

Data on abundance assessment of freshwater dolphins in South America have significantly increased over the past 20 years. However, population trend data is still scarce in the literature, and no range-wide estimate for species is available, mainly due to difficulties in generating long time-series. Surveys have been conducted since 1979 in many areas within the species range in

Bolivia, Brazil, Colombia, Ecuador, Peru, and Venezuela (Trujllo et al. 2010, Gómez-Salazar et al. 2012a). For the most part, these studies reported encounter rates, instead of abundance estimates. Among these, few studies assessed the population numbers and only for relatively small areas. These estimates varied from a few dozen to a few thousand individuals, depending on the size of the survey area, season, and river features (e.g., Vidal et al. 1997, Martin & da Silva 2004, Gómez-Salazar et al. 2012b, Pavanato et al. 2016, 2019, Aliaga-Rossel & Duran 2020, Paschoalini et al. 2020).

Population sizes of freshwater dolphin species in the Amazon vary regarding the areas of their distribution (Paschoalini et al. 2021), mainly due to the geomorphological features of the river systems as well as their productivity. This variation is also influenced by the level of human-induced modifications in the environment (Campbell et al. 2022). The time-series sampling in such regions (remote and logistically-challenging) to monitor population trends will then be larger or smaller depending on resources available and area accessibility. Williams et al. (2016) and da Silva et al. (2018) provided the first models of population trends of freshwater dolphins in South America, pointing out to declines into two regions: the Upper Amazon River and the Mamirauá Reserve, respectively. Recently, Guizada-Duran et al. (2024 preprint) added the Mamoré River basin, in the Bolivian Amazon, as a third site that might indicate population declines.

For greater clarity on the status of population decline of freshwater dolphin species in South America, at species level, representative regional dataset is critical. Additionally, a basin-wide approach from the perspective of human pressures in the entire hydrographic region is needed to understand the drivers leading the species to population decrease. Given this context, this paper brings raw and preliminary results of population trend for both boto and tucuxi, using systematic time-series sampling in three different regions of their range: Amazonian Trapezium, Tapajós and Meta rivers.

Material and Methods

Data for density and abundance estimation of freshwater dolphin species in South America has been collected since 2006 (Gómez-Salazar et al. 2012, Frias 2019), using standardized field protocols and methodology following distance sampling modified for species-specific criteria (Buckland et al. 2001, 2015, as in Frias 2019). Over the last 20-years, systematic sampling over three hydrographic regions were carried out enabling the investigation about trends in populations of boto and tucuxi.

River expeditions were carried out in the Amazonian Trapezium, Tapajós River, and Meta River, at three distinct hydrographic regions as shown in table 1 and figure 1. The Amazonian Trapezium is a geometrically shaped territory located at the triple border of Brazil, Colombia and Peru. It marks the site of the first major confluence of the Amazon River where it received the white waters from the Andes region in Peru and Ecuador (Portocarrerro-Aya et al. 2016). The Tapajós River basin is the fifth largest basin that discharges into the Amazon River and covers 7% of the total Amazon basin (Goulding et al. 2003), showing crystal clear waters coming from the Brazilian central shield. Finally, Meta River is one of the largest tributaries of the Orinoco River and has its source on the eastern side of the Andes, contributing around 10% of water and nearly 50% of the total sediment load to the Orinoco River (Arrieta-Castro et al. 2020).

Sampling efforts were spaced chronologically over an average interval of five years, including at least three standardized samples covering the same area (river extension). All sampling events were conducted during transitional water periods, either during rising or receding water levels, when most parts of the habitat types are available for the dolphins' use (Gómez-Salazar et al. 2012b); the distribution of the animals throughout the areas is assumed as random. The exception was the sampling event carried out in Tapajós River in 2022 during the high-water season. Density and abundance reported in the results for population trend purpose were calculated only for the overlapped stretches among samples, identified in table 1 as (*), also used for plotting trend graphs. In the case of the the Amazon River in the Amazonian Trapezium, we chose to restrict the analyzes to the region covered by previous studies already published (Williams et al. 2016), in order to provide basis for discussing the identified trend.

Table 1. Overall summary effort of expeditions in Amazon River – Amazonian Trapezium, Tapajós and Meta rivers.

Study	Sampling year	Effort (km)	Study site
Vidal et al. (1997)	1993	120*	Upper Amazon River
Williams et al. (2016)	2002	120	
Williams et al. (2016)	2007	120	Triple border between Brazil, Colombia and Peru (Amazonian Trapezium)
Present study	2020	874	
Present study	2021	403	
Present study	2022	557	
Pavanato et al. (2016)	2014	577*	Tapajós River Southern Amazon River basin, Brazil (lower and Middle section)
Present study	2019	940	
Present study	2022	704	
Gómez-Salazar et al (2012)	2006	462*	Meta River Colombia/Venezuela border, Orinoco river basin (lower section)
Present study	2012	585	
Present study	2018	630	
Present study	2022	469	

Using a combination of transects running parallel (200 m strip-width transect) and cross-channel (line transect) in a zigzag pattern at an average speed of 10 km/h, we surveyed the six different habitat types formed throughout the mosaic of the river ecosystem (main river, tributary river, lake, channel, island, and confluence) by visual boat-based platform (Gómez-Salazar et al. 2012a). A double-counting platform (bow and stern) was adopted, and the observations at each platform were assumed to be independent, considering a "one-way" configuration (i.e., the observers at the stern platform were unaware of detections made by those at the bow) to enable corrections of missed sightings and calculation of detection probability on the trackline (g(0)) using distance Sampling capture–recapture methods (Thomas et al. 2010). For each sighting event observers reported the species, group size, presence of calves, radial distance, radial bearing, bearing side depending on the closest shore, and distance from shore (range finder measured) either from dolphin sighted and in relation to the observer position, as well as habitat type.

Density and abundance were estimated for each of the habitat types per species and rivers, for all the sampling events. Details of statistical procedures on distance sampling (detection function and curves, and variances can be viewed in Frias (2019) and Paschoalini et al. (2021). Overall abundances in each river for each species were obtained by the sum of the estimated abundances (Di x Ai) in each habitat type (i) through the equation provided below. For the estimation of the water surface area (km^2), we used open-source satellite images (ESA – European Space Agency) of the exact or closest available sampling period (containing images from Landsat and Copernicus sensors).

$$N = \sum_{i-1}^{n} \mathrm{D}i\mathrm{A}i, \text{ for } i = 1, \ldots, n$$

Data processing was performed using the R programing language and population estimation, and variances, assessed through available Distance Sampling packages SDS (Miller 2019), MRDS (Lake et al. 2017) with coding adaptations. For population trend graphs we used a simple linear regression code and the following plot packages: Shiny (Chang et al. 2017) and ggplo2 (Wickhan 2009). Given that the abundance parameter can be influenced by the size of the surveyed area, which may vary among satellite images calculated for each period, we chose to present trends in density in the graph instead of abundance.

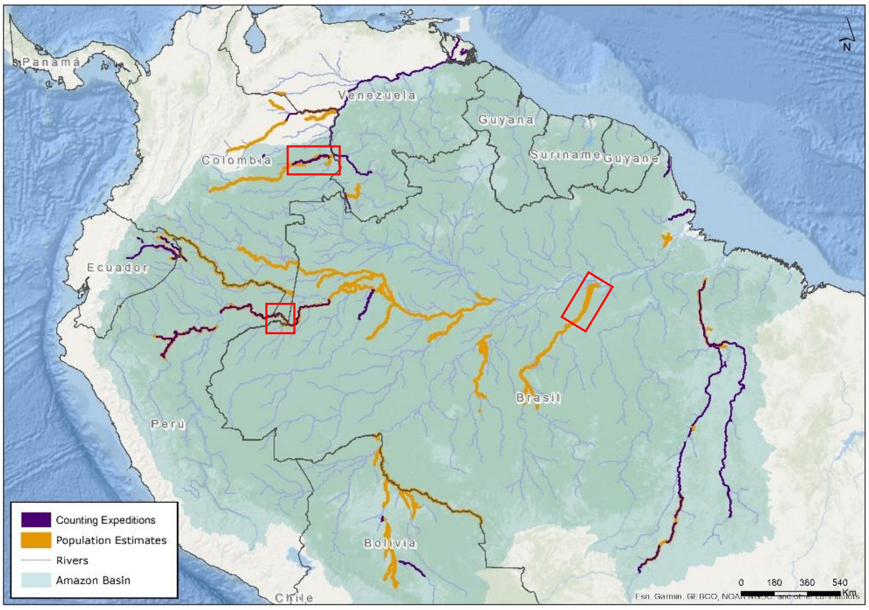

Figure 1. Spatial representation of river expeditions in South America over the past 20 years, highlighting in red polygons the three areas used to assess population trend in this paper. Source: SARDI river dolphins Dashboard (available in here).

Results

Of the three hydrographic regions assessed, two suggest signs of a decline in population abundance, which are the Upper Amazon River in the Amazonian Trapezium and the lower/middle Tapajós River. Both species in these sites show reduction in density and abundance through the time series. In the case of Amazonian Trapezium, the estimated reduction over a period of 30 years represents nearly 52% of the population of boto and 30% of tucuxi. In the case of Tapajós River, the decline for boto is subtle (11%) and for tucuxi the decline exceeds 34% over a period of eight years. The results for this specific area, however, deserve caution due to the difference in the hydrological season of the last sampling effort (more information is presented in the discussion session).

Estimated parameters and respective CVs for both regions are listed in tables 2 and 3 per species, and graphs showing the trend line are presented in figures 2 and 3, also per species and region.

Table 2. Time-series estimated density and abundance of boto (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) in the Amazon River basin, Amazonian Trapezium. Number inside parentheses represents the CV (Coefficient of Variation).

Study	boto *Inia geoffrensis*		Tucuxi *Sotalia fluviatilis*	
	D	N	D	N
Vidal et al. (1997) - 1993	1.85 (0.14)	472	1.53 (0.15)	389
Williams et al. (2016) - 2002	0.79 (0.28)	209	2.17 (0.24)	573
Williams et al. (2016) - 2007	1.25 (0.58)	330	1.9 (0.79)	502
Present study - 2020	1.29 (0.79)	341	1.1 (0.47)	243
Present study – 2021	0.67 (0.30)	188	1.8 (0.48)	406
Present study - 2022	0.88 (0.51)	322	1.07 (0.28)	403

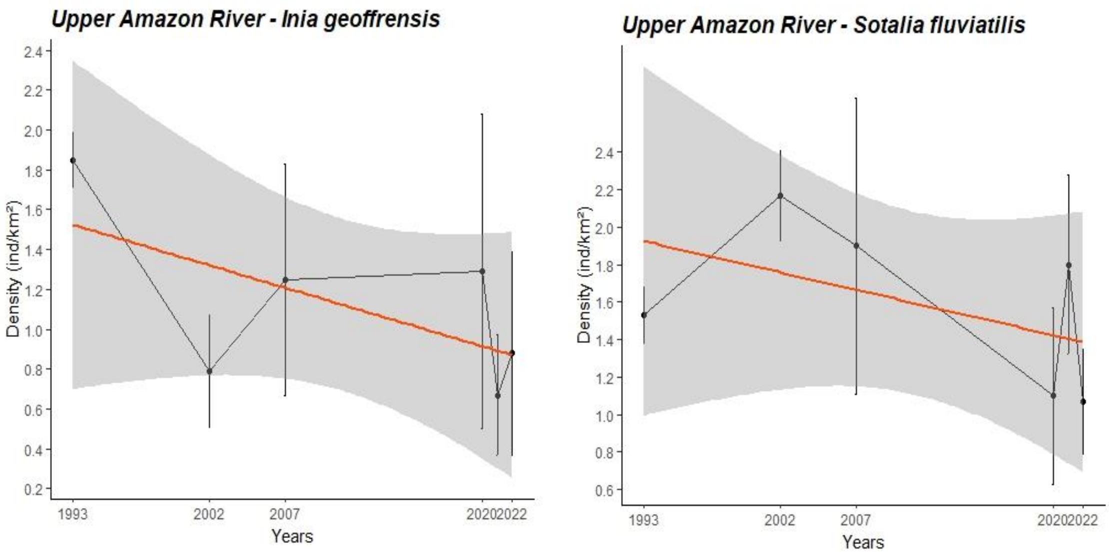

Figure 2. Population trend graph of freshwater dolphin' species in the upper Amazon River 1993 to 2022, Amazon Trapezium. The red line shows declining trend in density parameter for both species; grey shadow area represents the error band assuming values of the coefficient of variation (CV) for each sampling event.

Table 3. Time-series estimated density and abundance of boto (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) in Tapajós River basin (lower and middle reaches). Number inside parentheses represents the CV (Coefficient of Variation).

Study	boto *Inia geoffrensis*		Tucuxi *Sotalia fluviatilis*	
	D	N	D	N
Pavanato et al. (2016)	0.47 (0.39)	1814	1.24 (0.38)	3371
Present study - 2019	0.43 (0.44)	1572	0.58 (0.43)	1577
Present study - 2022	0.21 (1.98)	1604	0.40 (2.03)	1088

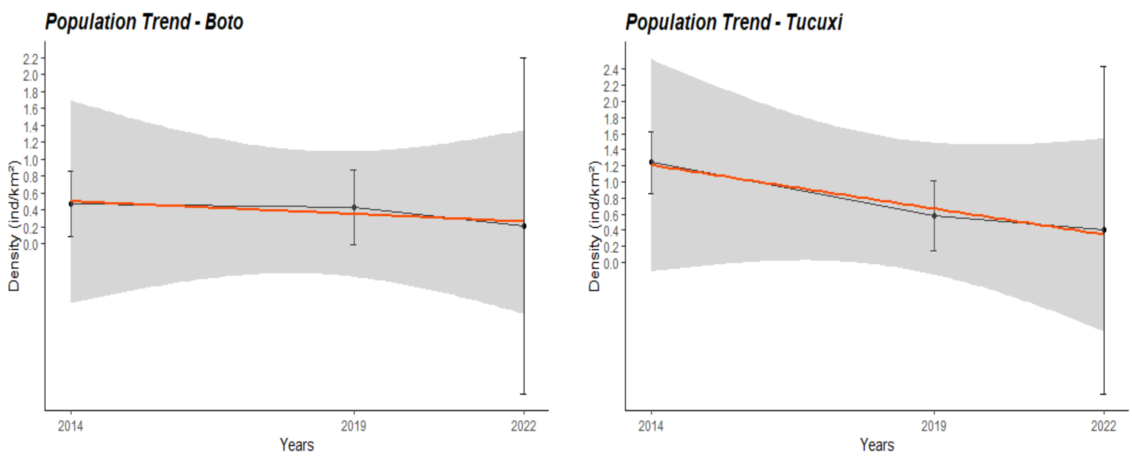

Figure 3. Population trend graph of freshwater dolphin species in the lower and middle reaches of the Tapajós River. The red line shows declining trend in density parameter for both species; grey shadow represents the error band assuming values of the coefficient of variation (CV) for each sampling event.

The only population exhibiting stability or possible population increase is that found in the Meta River, in the Orinoco River basin (Table 4, Figure 4). For this population numbers increased 18% over the last 16 years, little more than 1% per year, then assumed as stable.

Table 4. Time-series estimated density and abundance of boto in Meta River (*Inia geoffrensis*), Orinoco River basin. Number inside parentheses represents the CV (Coefficient of Variation).

Study	*Inia geoffrensis*	
	D	N
Gómez-Salazar et al. (2012) - 2006	0.82 (0.85)	1,016
Present study – 2012	1.04 (0.56)	972
Present study – 2018	1.49 (0.95)	1397
Present study – 2022	2.27 (0.96)	1201

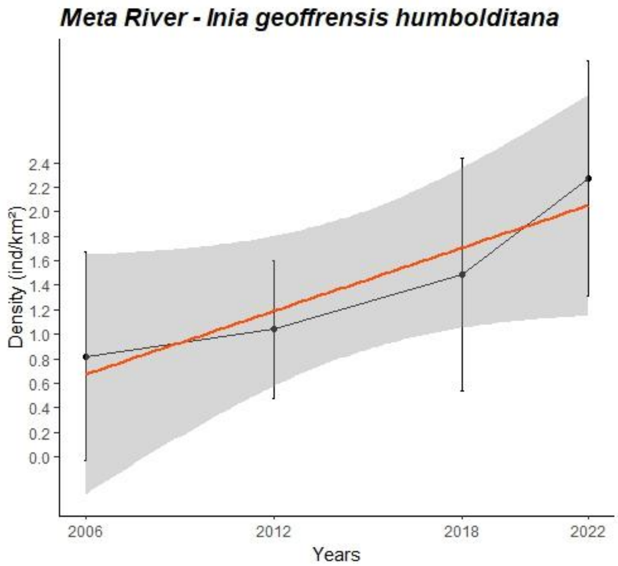

Figure 4. Population trend graph of freshwater dolphin species in the lower reaches of the Meta River. The red line shows an increase trend in density parameter; the grey shadow represents the error band assuming values of the coefficient of variation (CV) for each sampling event.

Discussion

Assessing the population decline of river dolphins is hard chalanging due to the complexity of sampling the ecosystems inhabited by these species, in addition to the wide range and various levels of threat that different populations are submitted throughout South America. This is why a comprehensive range-wide assessment has not yet been conducted. Sampling and analytical reservation have been previously discussed by William et al. (2016), the first authors to indicate declines in freshwater dolphin populations in the Amazonian Trapezium. Since then, data have been collected in the same area of the upper Amazon River, accumulating a time-series monitoring system spanning nearly 30 years. The findings presented here support the conclusion of Williams et al. (2016) that boto and tucuxi face populations decline in this region. The Amazonian Trapezium hosts numerous villages, indigenous territories, urban centers (e.g., Tabatinga and Leticia), with intense boat traffic, and great pressure to supply local and regional fishing markets (Portocarrero-Aya et al. 2016). The cumulative effects of these diverse human activities in the area undoubtedly contribute to declines in freshwater biodiversity, and consequently, to dolphin species.

Although the last expedition carried out in Tapajós River was conducted during high-water season, data collected are comparable to those of previous incursions due to the use of statistical bases that consider the coefficient of variation (CV) - that is: how much the estimate of the number of animals can vary downwards or upwards depending on environmental or seasonal conditions.

For both species, despite the high CVs, population decline is estimated at 11% and 34%, for boto and tucuxi. For both boto and tucuxi, the highest threshold of the confidence interval (95% CI) was considered to infer the possible rate of decline. Even adopting the maximum number of individuals within the 95% CI, a decline was observed. These data are preliminary and population models must be applied considering birth intervals, seasonal movements, anthropic removal rate, natural mortality rate, and other variables.

Estimated sharp declines of boto and tucuxi populations in Mamirauá Reserve, central Brazilian Amazon, suggest that these species might reach an irreversible curve towards extinction (> 7% decline rate per year), which means a complete and permanent loss within the next 50 years (da Silva et al. 2018, Martin & da Silva 2022). The Mamirauá Reserve is a protected area and even in one of the better protected parts of its range the population is dropping faster than any other region. Nevertheless, this region represents less than 1,8% of the entire species range and factors driving declines in this area are much associated with direct catching of boto and tucuxi in the piracatinga fishery and negative interactions with fishermen. The piracatinga fishery is not present at the Tapajós basin, and therefore not counted as direct threat to the species. In the Tapajós, possible declines may be associated to effects of mercury contamination on dolphins' physiology and reproduction, habitat changes due to expansion of hydro ways, fish stock depletion, and competition in negative interactions with fishermen (bycatch and direct killing).

In the opposite direction, the population of dolphins in the Meta River shows a growth trend, even though this is a river impacted by human actions. This river flows between Colombia and Venezuela and presents growing threats. These include overfishing, increased boat navigation and port construction, deforestation processes, and large-scale rice, soybean, and African palm cultivation (Mosquera et al., 2015a; Mosquera et al., 2015b). Likewise, climatological models show a tendency to reduce the flow during low water periods by 50% in the next 20 years as a result of increased droughts and agro-industrial water harvesting (Nogales Pimentel et al. 2021). During the last 5 years there has been hunting and consumption of dolphin meat, and stranded animals have had to be rescued because the river levels have dropped abruptly. This situation increased during the COVID 19 epidemic when people in the Orinoco region used dolphins blubber as medicine to mitigate the illness. Because not response from authorities stopped this some people started to eat dolphin meat. Therefore, the observed population stability may in the near future be impacted.

Final Considerations

Amazon and Orinoco River basins are logistically challenging for the establishment of a robust and precise method to estimate dolphin population parameters such as density and abundance. The efforts of standardize methodology and consistent monitoring provided the best results at the moment and was advised by the IWC in subsequential meetings as of great importance to inform decision-making. It is also one of the priorities of the Conservation Management Plan (CMP) for river dolphins signed by the governments of Brazil, Colombia, Ecuador and Peru.

Freshwater biodiversity worldwide has been decreasing at surprisingly fast rates. Asian river dolphins are clear examples of such declines, almost all considered critically endangered and on the path to extinction. Our results suggest a basin-wide decline of freshwater dolphin species in the Amazon basin. Although no declining rate has been assessed in any of the population trends estimates, and variances are high, the results should be discussed at appropriate importance for the species conservation. Such highly variable environment as river ecosystem poses limitation in sampling that may not reduce the importance of data gathered. The increase in human population in the Amazon and Orinoquia is significant in the last 20 years, as is the scale and impact of legal and illegal economic activities leading to increased deforestation, mercury contamination, overfishing and river fragmentation. All this will undoubtedly continue to negatively impact the conservation of these species, so it is essential to implement population assessments on a regular basis and with standardized methodologies.

This paper is preliminary, and no model was applied considering the generation-time or population availability analysis. This is a work in progress that may provide in the mid-term understanding on how severe the decline for the assessed areas is and supports effective management actions targeting to reverse the curve.

References

Aliaga-Rossel, E., & Duran, L. A. G. (2020). Four decades of research on distribution and abundance of the Bolivian river dolphin *Inia geoffrensis boliviensis*. *Endangered Species Research*, 42, 151-165.

Arrieta-Castro, M., Donado-Rodríguez, A., Acuña, G. J., Canales, F. A., Teegavarapu, R. S., & Kaźmierczak, B. (2020). Analysis of streamflow variability and trends in the meta river, Colombia. *Water*, 12(5), 1451.

Banguera-Hinestroza, E., Cárdenas, H., Ruiz-García, M., Marmontel, M., Gaitán, E., Vázquez, R., & García-Vallejo, F. (2002). Molecular identification of evolutionarily significant units in the Amazon River dolphin Inia sp. (Cetacea: *Iniidae*). *Journal of Heredity*, 93(5), 312-322.
Buckland, S.T.; Anderson, D.R.; Burnham, K.P.; Laake, J.L.; Borchers, D.L.; Thomas, L. Introduction to Distance Sampling; *Oxford University Press*: New York, NY, USA, 2001.

Campbell, E., Alfaro-Shigueto, J., Aliaga-Rossel, E., Beasley, I., Briceño, Y., Caballero, S., ... & Godley, B. J. (2022). Challenges and priorities for river cetacean conservation. *Endangered Species Research*, 49, 13-42.

Chang W, Cheng J, Allaire J, Sievert C, Schloerke B, Xie Y, Allen J, McPherson J, Dipert A, Borges B (2024). *shiny: Web Application Framework for R*. R package version 1.8.1, https://github.com/rstudio/shiny, https://shiny.posit.co/

da Silva, V., Trujillo, F., Martin, A. R., Zerbini, A. N., Crespo, E. A., Aliaga Rossel, E., & Reeves, R. (2018). *Inia geoffrensis*, Amazon River Dolphin.

Emin-Lima, R., Machado, F. A., Siciliano, S., Gravena, W., Aliaga-Rossel, E., de Sousa e Silva, J., ... & de Oliveira, L. R. (2022). Morphological disparity in the skull of Amazon River dolphins of the genus Inia (Cetacea, *Iniidae*) is inconsistent with a single taxon. *Journal of Mammalogy*, 103(6), 1278-1289.

Frias, M.P. *Estimação dos parâmetros populacionais de densidade e abundância para os golfinhos de rio da América do Sul boto (Inia spp.) e tucuxi (Sotalia fluviatilis): Aperfeiçoamento do método e abordagens ecológicas* [Estimating Density and Population Size for South American River Dolphins Boto and Tucuxi: Improving Methods and Ecological Approaches]. Ph.D. Thesis, Universidade Federal de Juiz de Fora, Juiz de Fora, Brazil, 2019; 144p.

Gomez-Salazar, C., Coll, M., & Whitehead, H. (2012b). River dolphins as indicators of ecosystem degradation in large tropical rivers. *Ecological Indicators*, 23, 19-26.

Gomez-Salazar, C., Trujillo, F., Portocarrero-Aya, M., & Whitehead, H. (2012a). Population, density estimates, and conservation of river dolphins (*Inia* and *Sotalia*) in the Amazon and Orinoco river basins. *Marine Mammal Science*, 28(1), 124-153.

Goulding M, Barthem R, Ferreira E (2003) The Smithsonian atlas of the Amazon. Princeton Editorial Associates, Hong Kong

Gravena, W., Da Silva, V. M., Da Silva, M. N., Farias, I. P., & Hrbek, T. (2015). Living between rapids: genetic structure and hybridization in botos (Cetacea: *Iniidae*: Inia spp.) of the Madeira River, Brazil. *Biological Journal of the Linnean Society*, 114(4), 764-777.

Hrbek, T., da Silva, V. M. F., Dutra, N., Gravena, W., Martin, A. R., & Farias, I. P. (2014). A new species of river dolphin from Brazil or: how little do we know our biodiversity. *PLoS one*, 9(1), e83623.

Laake, J.; Borchers, D.; Thomas, L.; Miller, D.; Bishop, J. mrds: Mark-Recapture Distance Sampling. R Package Version 2.1.18. 2017. Available online: https://CRAN.R-project.org/package=mrds

Martin, A. R., & Da Silva, V. M. F. (2022). Amazon river dolphins *Inia geoffrensis* are on the path to extinction in the heart of their range. *Oryx*, 56(4), 587-591.

Martin, A.R.; da Silva, V.M.F.; Salmon, D. Riverine habitat preferences of botos (*Inia geoffrensis*) and tucuxis (*Sotalia fluviatilis*) in the central Amazon. Mar. Mammal Science. 2004, 20, 189–200.

Miller DL (2019). Distance: Distance Sampling Detection Function and Abundance Estimation. R package version 0.9.8, URL https://CRAN.R-project.org/package=Distance.

Mosquera-Guerra, F., Parra, C., Trujillo, F., Jiménez-Ortega, A. M. & H. Meluk. 2015[a]. Valoración estacional de las amenazas contra la conservación de *Inia geoffrensis* en la cuenca del río Meta, Colombia. *Therya*, 6 (2):371-388.

Mosquera-Guerra, F., Trujillo, F., Caicedo-Herrera, D. & S. Martínez. 2015b. Indicios de biomagnificación de Mercurio Total (Hg) en las especies del género *Inia* en los ríos Amazonas y Orinoco (Colombia). *Momentos de Ciencia* 12 (2): 145-149.

Nogales Pimentel, J., Rogéliz Prada, C. & T. Walschburger. 2021. Hydrological Modeling for Multifunctional Landscape Planning in the Orinoquia Region of Colombia. Front. Environ. Sci., 28. Sec. *Land Use Dynamics*. Volume 9. https://doi.org/10.3389/fenvs.2021.673215

Paschoalini, M., Almeida, R. M., Trujillo, F., Melo-Santos, G., Marmontel, M., Pavanato, H. J., ... & Zerbini, A. N. (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.

Paschoalini, M., Trujillo, F., Marmontel, M., Mosquera-Guerra, F., Paitach, R. L., Julião, H. P., ... & Zerbini, A. N. (2021). Density and abundance estimation of Amazonian river dolphins: understanding population size variability. *Journal of Marine Science and Engineering*, 9(11), 1184.

Pavanato, H.J.; Melo-Santos, G.; Lima, D.S.; Portocarrero-Aya, M.; Paschoalini, M.; Mosquera, F.; Trujillo, F.; Meneses, R.; Marmontel, M.; Maretti, C. Risks of dam construction for South American river dolphins: A case study of the Tapajós River. *Endanger. Species Reearchs* 2016, 31, 47–60.

Pavanato, H.J.; Salazar, C.G.; Lima, D.; Paschoalini, M.; Ristau, N.; Marmontel, M. Density, abundance and group size of river dolphins (Inia geoffrensis and Sotalia fluviatilis) in central Amazonia, Brazil. *J. Cetacean Res. Manag*. 2019, 20, 93–100.

Portocarrero-Aya, M., & Cowx, I. G. (2016). Conservation of freshwater biodiversity in key areas of the Colombian Amazon. Aquatic Conservation: *Marine and Freshwater Ecosystems*, 26(2), 350-363.

Smith, A. M., & Smith, B. D. (1998). Review of status and threats to river cetaceans and recommendations for their conservation. *Environmental Reviews*, 6(3-4), 189-206.

Thomas, L.; Buckland, S.T.; Rexstad, E.A.; Laake, J.L.; Strindberg, S.; Hedley, S.L.; Bishop, J.R.; Marques, T.A.; Burnham, K.P. Distance software: Design and analysis of distance sampling surveys for estimating population size. *J. Applied. Ecol*. 2010, 47, 5–14.

Thomas, L.; Buckland, S.T.; Rexstad, E.A.; Laake, J.L.; Strindberg, S.; Hedley, S.L.; Bishop, J.R.; Marques, T.A.; Burnham, K.P. Distance software: Design and analysis of distance sampling surveys for estimating population size. *J. Applied. Ecol*. 2010, 47, 5–14.

Trujillo, F., Crespo, E., Van Damme, P. A., & Usma, J. S. (2010). *The action plan for South American river dolphins 2010–2020*. WWF, Fundación Omacha, WDS, WDCS, Solamac, Bogota.

Vidal, O.; Barlow, J.; Hurtado, L.; Torre, J.; Cendon, P.; Ojeda, Z. Distribution and abundance of the Amazon river dolphin (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*) in the upper Amazon River. *Mar. Mammal Science*. 1997, 13, 427–445.

Wickham H (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. ISBN 978-3-319-24277-4, https://ggplot2.tidyverse.org.

Williams, R.; Moore, J.E.; Gomez-Salazar, C.; Trujillo, F.; Burt, L. Searching for trends in river dolphin abundance: Designing surveys for looming threats, and evidence for opposing trends of two species in the Colombian Amazon. *Biol. Conservation*. 2016, 195, 136–145.