

## SHORT COMMUNICATION

# Non-native golden dorado, *Salminus brasiliensis* (Characiformes: Bryconidae): A threat to biodiversity in the Preguiças River, Northeastern Brazil

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**ABSTRACT.** The emergence of non-native species as a threat to local biodiversity is a pressing concern that warrants immediate attention. Our study reports the first record of the non-native fish golden dorado, *Salminus brasiliensis*, for the Preguiças River Basin, Maranhão State, Northeastern Brazil, near the Parque Nacional dos Lençóis Maranhenses (PNLM). This discovery occurred when a single adult, measuring 77 cm in total length, was captured by artisanal fishers using gillnets in January 2024. This finding underscores the importance of ongoing monitoring efforts focused on the ichthyofauna of the Preguiças River Basin: the tributaries of the lower portion of the basin are located within and at the border of the PNLM area. Such monitoring initiatives are essential for comprehending the distribution range of *S. brasiliensis* and evaluating its potential impacts on local native freshwater species.

**KEYWORDS.** Bioinvasion, exotic species, freshwater biodiversity crisis, sport fishing.

Maintaining biodiversity in natural ecosystems is essential for their full functionality and the preservation of vital ecosystem services (Rajaonarimalala et al. 2024). However, the introduction of exotic species poses significant risks to these functions and the benefits ecosystems provide to human societies (Singh 2024). These impacts are particularly severe in protected areas, where biological invasions have been shown to negatively affect global biodiversity (Carneiro et al. 2024). The increasingly frequent introduction of non-native species, whether accidental or intentional, represents one of the most significant global alterations driven by human activity in recent centuries (Gozlan 2008). Gozlan et al. (2024) recently detailed the consequences of non-native species on trophic dynamics, ecosystem health, water chemistry, and human health, emphasizing the necessity of adopting an integrated approach that involves multiple stakeholders, such as health workers, aquatic animal health professionals, and environmental health experts, as a tool to identify the benefits and mitigate the risks associated with non-native species.

The introduction of exotic species is one of the human activities that has been leading to the freshwater biodiversity crisis (Dudgeon et al. 2006, Harrison et al. 2018, Albert et al. 2020, Otoni et al. 2023). Non-native species not only threaten native biodiversity but also jeopardize essential ecosystem services such as water purification, nutrient cycling, and food provision, all critical to sustaining human livelihoods (Rajaonarimalala et al. 2024). By altering habitat structures, disrupting trophic dynamics, and degrading water quality, invasive species can reduce ecosystem's ability to support local economies, particularly fisheries (Pejchar and Mooney 2009). These disruptions are especially problematic in protected areas, where they undermine conservation goals and the benefits these ecosystems provide to surrounding communities (Pyšek et al. 2020).

Protected areas, including national parks, play a crucial role in global biodiversity conservation. However, the Parque Nacional dos Lençóis Maranhenses (PNLM) faces threats from biological invasions, with some invasive alien species already established within its boundaries. This situa-

tion underscores the urgent need for proactive measures to control, reduce, and mitigate the impacts of non-native species (Silva et al. 2024). In the PNLM region, various groups of animals have been introduced, including the gecko *Hemidactylus mabouia* (Moreau de Jonnès, 1818) (Miranda et al. 2012), the wild boar *Sus scrofa* Linnaeus, 1758 (Salvador et al. 2019), the domestic dog *Canis lupus familiaris* Linnaeus, 1758 (Lessa et al. 2016), and some fish species such as, Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758), Mozambique tilapia *Oreochromis mossambicus* (Peters, 1852), peacock bass *Cichla monoculus* Spix & Agassiz, 1831 (Monroe et al. 2023), and *Cichla kelberi* Kullander & Ferreira, 2006 (Brito et al. 2020). These species cause several impacts on native species, including increased competition for resources, nest predation, heightened predation pressure, pathogen introduction, native species extinction, and biotic homogenization (Olden and Rooney 2006, Gozlan et al. 2024).

A recent case of concern involves the introduction of the golden dorado *Salminus brasiliensis* (Cuvier, 1816) which, although native to the La Plata, Madeira and Jacuí River basins (Fricke et al. 2024) has been increasingly observed in non-native regions. This large predatory fish, known for its extensive migratory behavior and ability to reach considerable sizes, poses significant ecological risks when introduced beyond its natural range (Hahn et al. 2011). With a potential size of up to 1 meter in length and 34 kg in total weight (Froese and Pauly 2024), it preys on a diverse range of fish species (Pereira et al. 2017). Given its popularity in commercial and sport fishing, deliberate introductions have occurred in various Brazilian drainage systems (Gubiani et al. 2010, Vitule et al. 2014, Ribeiro et al. 2017). Therefore, based on one adult, we report here the first occurrence of *Salminus brasiliensis* in the Preguiças River, whose lower tributaries occur within the PNLM area and on its border. We also explore potential introduction pathways and their impacts on aquatic communities.

The Preguiças River basin is located in the northeast of the state of Maranhão, in Northeastern Brazil (Fig. 1). Spanning 159.89 km, the river is characterized by marked spatial heterogeneity, primarily influenced by gradients of salinity, temperature, and turbidity (Cruz et al. 2023). The climate of the region is sub-humid with annual rainfall totals ranging from 1,456 to 1,656 mm. The mean annual temperature is relatively high, reaching 27 °C, while the maximum mean temperature ranges from 31 to 33 °C. Rainfall distribution is not homogeneous, with two distinct seasons: a rainy season, occurring from January to June, and a dry season, from July to December. The region is an ecotonal zone, featuring

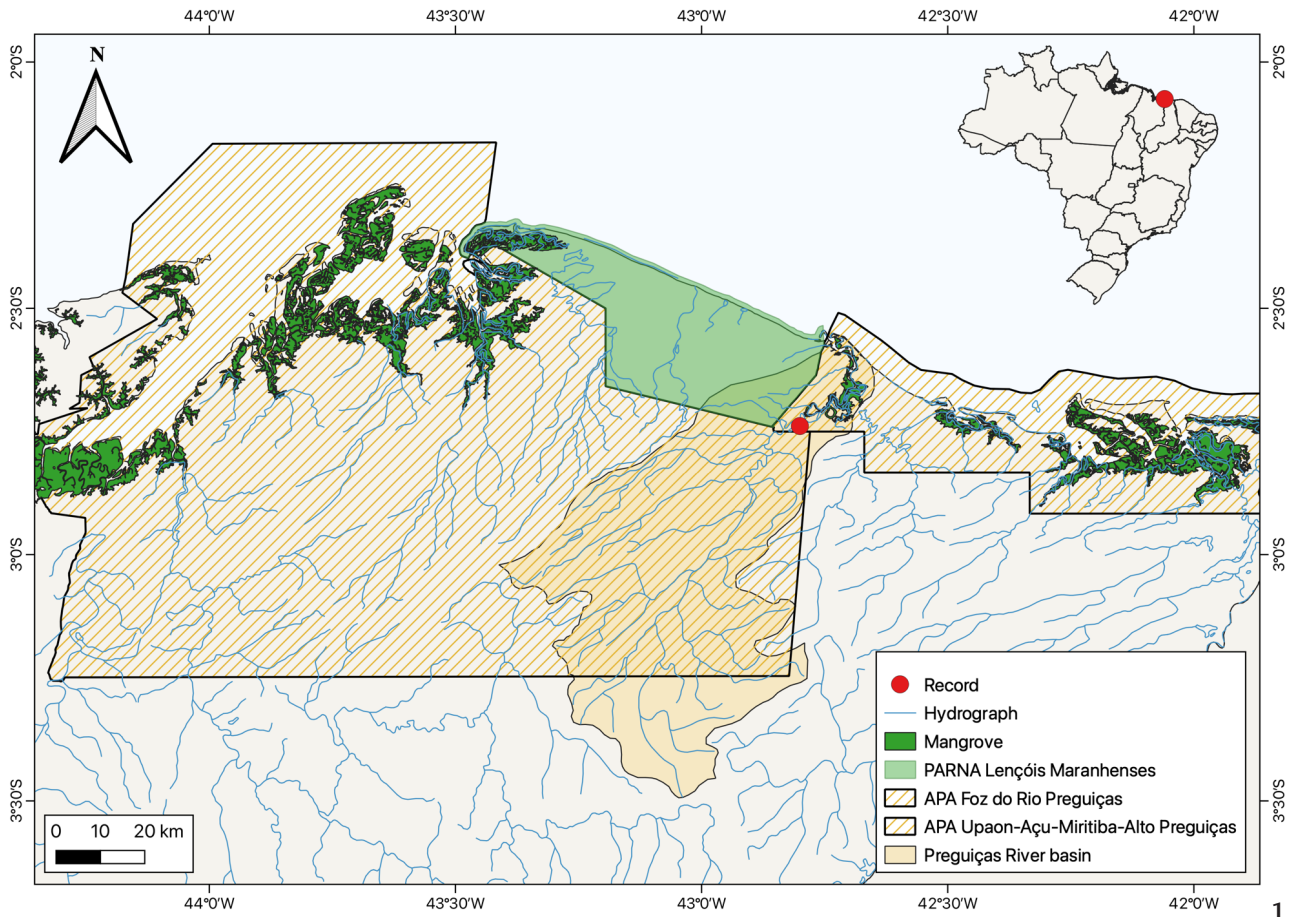
floristic composition typical of the Amazon, Cerrado, and Caatinga biomes. During the Quaternary period, one of the largest coastal dune fields in South America was formed, attracting thousands of tourists annually to the Lençóis Maranhenses National Park (Santos and Santos 2015).

The Preguiças River basin is home to some endemic fish species from the Maranhão-Piauí ecoregion (Brito et al. 2019, 2020), with 48 recorded freshwater fish species (Koerber et al. 2022, 2023). Despite that, only a small portion of the basin is protected by the PNLM, which, though federally protected, continues to suffer from human impacts (Amaral et al. 2019). Moreover, the main course of the Preguiças River and its headwaters, located within the Upaon-Açu/Miritiba/Alto Preguiças Environment Protection Area, as well as the lower course within the Foz do Rio Preguiças Environment Protection Area, are subject to environmental pressures. These include deforestation, mining, agriculture, real estate speculation, tourism, and the introduction of non-native species, all of which pose significant threats to the basin's ecological integrity (Monroe et al. 2023, Santana et al. 2023).

In January 2024, an artisanal fisherman captured a single specimen of *Salminus brasiliensis* using a gillnet measuring 1.8 m in height and 17 m in length, with a mesh size of 40 mm between opposite knots. The gillnet was deployed parallel to the riverbank and left fishing for two hours in the evening (17:00–19:00 h). Unfortunately, due to the circumstances of the artisanal fishing activities, it was not possible to preserve the specimen after collection. Identification was carried out based on distinct morphological characters outlined by Sleg and Albert (2017) for the genus, and Lima and Britski (2007) and Lima (2022) for the species, including eye diameter, head size, caudal peduncle length, scale counts along the lateral line, as well as above and below the lateral line, and color pattern.

It was not possible to determine the total weight because the individual was eviscerated. Therefore, we used the equation  $WT = 0.0086 \times TL^{3.06}$  provided by Massaro et al. (2020) to estimate the total weight. Where WT is the total weight and TL is the total length. The life stage of the specimen was estimated based on the length at first sexual maturity where the size of first sexual maturation is 45 cm for males and 44 cm for females (Barzotto and Mateus 2017).

The specimen, measured 77 cm in total length with an estimated total weight of 5095.2 g (Fig. 2). It was collected in the main course of the Preguiças River, near the Boa Vista neighborhood, within the boundaries of the APA Foz do Rio Preguiças. The region is close to the mouth of the Preguiças River and is influenced by the tide, but it is characterized



Figures 1–2. Locality where the adult of *Salminus brasiliensis* was captured by artisanal fishermen in the main channel of the Preguiças River, state of Maranhão, Northeastern Brazil. (2) Specimen of golden dorado, *Salminus brasiliensis*, 77 cm in total length, collected in the main channel of the Preguiças River.

predominantly by freshwater conditions and aquatic macrophyte vegetation.

The total length indicates that the specimen was an adult. The eye diameter measured 1.7 cm, the head length

was 13.8 cm, and the caudal peduncle length was 6.0 cm. The head length is contained 5.6 times in the total length, and the caudal peduncle height is contained 12.8 times. The eye diameter is contained 8.0 times in the head length. The



lateral line contained 97 scales. Transverse line above the lateral line with 14 and below the lateral line with eight series of scales. The specimen exhibited a golden coloration with reddish reflections and a dark spot on the caudal peduncle extending to the tip of the median caudal rays; pigments concentrated in the central region of the scales forming longitudinally dotted dark stripes; and yellowish fins. These features mentioned above fit the description of the species proposed by Lima and Britski (2007) and Lima (2022).

This addition brings the total of documented exotic fish species in the Preguiças River basin to five, including *S. brasiliensis*, *C. monoculus*, *O. niloticus*, *O. mossambicus* (see Monroe et al. 2023), and *C. kelberi* (see Brito et al. 2020). The presence of these species highlights the pressing need for effective management strategies to prevent, control, or mitigate the spread of exotic species within this ecosystem.

*Salminus brasiliensis*, popularly known as dorado, dourado, golden dourado, or golden dorado, is a large fish native to the La Plata, Madeira and Jacuí River basin (Fricke et al. 2024). It is piscivorous and feeds on a variety of fish species such as characids, loricarids, serrasalmids, cichlids and gymnotids (Pereira et al. 2017). The digestive tract likely has anatomical features that enable the intake and storage of large prey for subsequent digestion and nutrient absorption (Alves et al. 2021). This species inhabits riverine systems, and during the reproductive period, particularly during periods of peak flooding, it undertakes upstream spawning migrations, covering distances of more than 400 km (Hahn et al. 2011). Thus, *S. brasiliensis* poses a significant threat to the local biodiversity where it is introduced due to these characteristics that facilitate its establishment and expansion, and it can easily spread throughout the Preguiças River basin.

Deliberate releases are the main pathways for introducing vertebrate species (Hulme et al. 2008), while aquaculture, sport fishing, aquarium trade, and biological control are the primary causes of introductions of non-native fish species in the Neotropical region (Bueno et al. 2021). Sport fishing and escapes from fish farms are considered to be the main introduction pathways in protected areas (Carneiro et al. 2024). The occurrence and expansion of non-native fish species in the region of the PNLM have been facilitated by fish farming and recreational sport fishing (Monroe et al. 2023). In the Preguiças River basin, *S. brasiliensis* has been observed outside its natural range, likely due to deliberate releases aimed at promoting recreational fishing. *Salminus* species are widely recognized as one of the primary targets of amateur fishing within their native distribution area and

have been introduced into various drainage systems across Brazil for catch-and-release practices (Gubiane et al. 2010, Vitule et al. 2014). For example, in the Iguaçu River basin, this species is deliberately being introduced to sustain recreational fishing activities, utilizing catch and release practices, and clandestinely restocking through workshops involving children and adolescents, thereby endorsing a completely misguided initiative (Ribeiro et al. 2017).

Fish farming serves as a primary driver for the introduction of non-native fish into freshwater ecosystems with escapes from fish farming facilities posing a significant threat to the biodiversity of native fish species (Ortega et al. 2015, Zaniboni-Filho et al. 2018). In Brazilian freshwater aquaculture, as well as the Preguiças River basin, fish are commonly cultivated in production ponds situated along river margins, making them vulnerable to flooding during periods of heavy rainfall which, can lead to escapes through effluent water discharge, pond drainage, and notably, through ruptures or overflow events triggered by flooding, all serving as primary pathways for introducing exotic species into natural water bodies (Orsi and Agostinho 1999, Casimiro et al. 2018). *Salminus brasiliensis* stands out for its significant potential in aquaculture, being highly valued due to its resilience to handling, acceptance of artificial diets, and adaptability to intensive farming systems. Furthermore, its aggressive nature makes it a sought-after species in pay-to-fish enterprises, where it is prized for sport fishing (Flora et al. 2010).

The introduction of exotic species results in a series of ecological impacts on the aquatic ecosystem (Pyšek et al. 2020). The introduction alien fish species has been related to fish community disassembly, local extinction, decrease of the richness and relative abundance of native species and changes in the trophic chain of native species (Pompeu and Godinho 2001, Pinto-Coelho et al. 2008, Pelicice et al. 2015). The introduction of predatory fish alters the structure of the aquatic community and triggers cascading impacts on aquatic habitats, due to increased predation at lower trophic levels (Gallardo et al. 2016). *Salminus brasiliensis* is a voracious predator that consumes other piscivorous fish as a mechanism for its success and maintenance in the aquatic ecosystem (Pereira et al. 2015). Additionally, in the region, there is the presence of *C. monoculus* (Monroe et al. 2023) and *C. kelberi* (Brito et al. 2020), which are aggressive predators that also consumes native predatory fish to ensure its establishment in the new environment and reduce competition for food resources. These non-native predators can also prey on juveniles of native species that have high commercial value. In the Doce and Paraíba do Sul River

basins, the introduction of piscivorous fish has led to the population decline of catfish species from the genus *Steindachneridion* driving them to extinction in local markets (Alves et al. 2007). Consequently, these alien species exert intense predation pressure on native communities, affecting both subsistence and commercial fisheries.

The ichthyofauna of the Preguiças River basin is composed of 48 species, with 11% being endemic to the Maranhão-Piauí ecoregion (Brito et al. 2019, 2020). The endemic species are mainly small characids, curimatids, cyprinodontids, cichlids, and pimelodids, which can serve as potential prey for the non-native predator *S. brasiliensis*. Additionally, these small fish are key food resources for native piscivorous fish species, making the establishing of *S. brasiliensis* particularly concerning, as its presence may disrupt the balance of the local food web and threaten native fish population. This situation is further exacerbated by the limited knowledge of the local ichthyofauna. The scarcity of taxonomic and ecological understanding could hinder efforts to assess the full impact of this non-native predator, with potential losses occurring before these species are thoroughly studied.

Temporal analyses have already detected an increase in non-native species and a reduction in the occurrence of native species associated with the establishment of *O. niloticus*, *O. mossambicus*, *C. monoculus*, and *C. kelberi* in the Preguiças River basin (Brito et al. 2020, Monroe et al. 2023). However, the local characteristics of the region where the specimen was captured—such as the proximity to the estuarine zone and the influence of tidal fluctuations—may limit the downstream distribution of *S. brasiliensis*, thereby reducing the area it can potentially inhabit. While salinity does not act as a barrier to the spread of tilapia (Franco et al. 2024), which can be found in estuarine-marine conditions, it may constrain the distribution of *S. brasiliensis* in such areas.

Preventing introductions is the primary management strategy to minimize the subsequent adverse effects of introducing exotic species and the associated costs of potential remediation and mitigation programs (Gozlan et al. 2010). Legislation plays a crucial role in educating and assisting in the management and control of invasions by non-native fish species (Geller et al. 2021). However, decision-makers have increasingly encouraged sport fishing with non-native species, disregarding the environmental, social, and economic damages caused by these decisions (Ota et al. 2019). Changing human behavior through educational opportunities is more effective, as well-informed society will naturally avoid harmful activities that may lead to the introduction of exotic

species (Azevedo-Santos et al. 2015). Gozlan et al. (2024) proposes adopting a One-Health approach to help conserve native ecosystems, protect public health, and promote global food security because this approach is an innovative way to link positive and negative animal, environmental, and human health impacts that arise from introductions of non-native species into an ecosystem.

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