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Golden invasion: Update on records golden mussel in the Amazon region

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Abstract

This study updates the distribution of the invasive bivalve *Limnoperna fortunei* in the Brazilian Amazon. It was found that the species exceeded predictions from previous models, after only two years since the first record. Agglomerations of the golden mussel were observed in various natural and artificial substrates in all municipalities along the Tocantins River, expanding to the Pará River and Marajó Island. There is no evidence of golden mussel invasion in the state capital (Belém). However, considering the dispersal rate and the diversity of habitats occupied by the invasive mollusk, continuous monitoring is urgently needed as a fundamental strategy for risk management and biodiversity conservation.

Keywords: Amazon region, invasive species, bivalve mollusc, mussels.

Resumo - Invasão dourada: Atualização dos registros de mexilhão-dourado na região Amazônica

Este estudo atualiza a distribuição do invasor *Limnoperna fortunei* na Amazônia Brazileira. Constatamos que a espécie superou previsões de modelos anteriores, após apenas dois anos do primeiro registro. Verificamos aglomerados do mexilhão-dourado em diversos substratos naturais e artificiais em todos os municípios banhados pelo Rio Tocantins, expandindo-se para o Rio Pará e a Ilha de Marajó. Mesmo que ausente na capital do estado (Belém), considerando a taxa de dispersão e a diversidade de habitats ocupados pelo molusco invasor, reforçamos a urgência do monitoramento contínuo como estratégia fundamental para a gestão de riscos e conservação da biodiversidade.

Palavras-chave: Região amazônica, espécie invasora, molusco bivalve, mexilhões.

Resumen - Invasión dorada: Actualización sobre los registros del mejillón dorado en la región amazónica

Este estudio actualiza la distribución del bivalvo invasor *Limnoperna fortunei* en la Amazonia brasileña. Se observó que la especie superó las predicciones de modelos previos, tras solo dos años desde su primer

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registro. Se observaron aglomeraciones del mejillón dorado en diversos sustratos naturales y artificiales en todos los municipios a lo largo del río Tocantins, expandiéndose hasta el río Pará y la isla de Marajó. No hay evidencia de invasión del mejillón dorado en la capital del estado (Belém). Sin embargo, considerando la tasa de dispersión y la diversidad de hábitats que ocupa el molusco invasor, se requiere urgentemente un monitoreo continuo como estrategia fundamental para la gestión de riesgos y la conservación de la biodiversidad.

Palabras clave: Región amazónica, especies invasoras, molusco bivalvo, mejillones.

Invasive alien species are organisms introduced into new environments that, upon adapting, reproduce and proliferate uncontrollably. This process can destabilize ecological processes, generating negative impacts on native biodiversity, habitats, and ecosystem integrity (Darrigan, 1997; Lopes, 2009; Teixeira et al., 2010; Latini et al., 2016; Lopes-Lima et al., 2025). The increase in bioinvasions is associated with global changes and the globalization of trade (Zanella, 2015). Human activities such as shipping, water diversion, and aquaculture are the primary vectors for the introduction of invasive species into aquatic environments, resulting in significant ecological alterations (Matthews, 2005; MMA, 2006; Santos & Lamonica, 2008; Zanella, 2015).

In Brazil, the invasion of non-native species is considered one of the most substantial threats to ecosystems, especially in aquatic environments (MMA, 2006; Lopes, 2009; Latini et al., 2016). In this context, the presence of non-native species in Brazilian inland waters is well-documented, with an estimated total of 163 organisms, including fish, crustaceans, macrophytes, amphibians, mollusks, among others. In the context of biological invasions, freshwater bivalve mollusks stand out for their high invasive potential, primarily due to their successful colonization of new environments (Lopes-Lima et al., 2025). Regarding bivalve mollusks, three species of Asian clams stand out, *Corbicula fluminalis* (O.F.Müller, 1774), *Corbicula fluminea* (O.F.Müller, 1774), and *Corbicula largillierti* (R.A.Philippi, 1844) (Latini et al., 2016) and the golden mussel *Limnoperna fortunei* (Dunker, 1857) (Chagas et al., 2025b; Honda, Miyahira & Passos, 2025).

The golden mussel belongs to the family Mytilidae and is its only member to inhabit freshwater. *L. fortunei* is native to the Pearl River basin in Southeast Asia; its introduction to South America was recorded in 1991 in the Río de La Plata, likely originating from the ballast water of Asian ships (Pastorino et al., 1993). Subsequently, *L. fortunei* dispersed naturally through the river, primarily via water currents (Zhan et al., 2012).

In Brazil, the first record of *L. fortunei* occurred in the late 1990s, in the Guaíba Lake basin, in the state of Rio Grande do Sul (Mansur, Richinitti & Santos, 1999) and currently, it has already been recorded in seven hydrographic basins (Miyahira et al., 2024; Chagas et al., 2025b; Honda, Miyahira & Passos, 2025). Among the major concerns regarding the golden mussel invasion was its arrival in the Amazon region (Barbosa et al., 2018; Miyahira et al., 2024). In this context, Barbosa et al. (2018) performed simulations indicating that the golden mussel invasion in the Amazon region was not predicted until the 2030s, with consolidation expected in the 2050s. However, as is now known, the first record of the golden mussel in the Amazon region occurred in the Tocantins River in October 2023 (Chagas et al., 2025a), considerably sooner than expected. Based on this, it appears that the understanding of the factors favoring golden mussel dispersal used in models is either ambiguous or insufficient (Boltovskoy et al., 2022).

The biological and ecological characteristics of the golden mussel enable its success as an invader where settlement occurs (Darrigran et al., 2003). These include a short life cycle (2 to 3 years), early sexual maturity (5-10 mm), rapid growth (reaching 21 mm in the first year), accelerated dispersal, sessile behavior, dense colonization, and physiological tolerance (Boltovskoy et al., 2022).

Following the first record of *L. fortunei* in the Amazon region, numerous reports have emerged. Recently, Chagas et al. (2025b) presented qualiquantiative data on the species' invasion in the Amazon and indicated that it is already found in several municipalities along the Tocantins River. In this context, the present study aims to update the occurrence status of *L. fortunei* in the Amazon region.

The mapping of *L. fortunei* records in the Amazon region was carried out using four approaches: (1) a survey of scientific literature; (2) reports from professionals linked to municipal and state agencies, researchers, and the local population living along the Tocantins River; (3) searches on digital media; and (4) scientific expeditions.

The scientific literature survey was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to standardize data collection (Moher et al., 2015; Salameh et al., 2020). For the literature search, the *Portal de Periódicos da CAPES* was used as the database, as it is a secondary data

source that includes numerous other electronic databases in its domain (e.g., Web of Science, SCOPUS, SciELO, Redalyc, etc.), thus maximizing the likelihood of finding relevant studies.

The search was conducted in December 2024. To filter the articles, we used the search string: ("Limnoperna fortunei" OR "mexilhão-dourado" OR "golden mussel" OR "mejillón dorado") AND (Amaz* OR "Amazon basin"). The scientific name was used as it is consistently included in species-specific studies; however, common names in English, Portuguese, and Spanish were also included. Associated with the species terms, we included the region of interest, limiting the search to the Amazon region or the Amazon basin. An asterisk (*) was used as a wildcard to include words derived from each search term.

Reports from professionals working in municipal and state agencies, as well as reports from researchers and the local population, were extremely important for the mapping, mainly due to the vast extent of the Tocantins River. This survey was carried out between November and December 2025.

Regarding the consultation of digital media (e.g., news reports on television channels and publications on social networks), only records that were photographed or filmed in situ were considered. In addition, a consultation was made with the responsible party to confirm the occurrence of the species in the respective location. This retrospective survey was carried out between the period of the first record of the species (August 2023) and December 10, 2025.

Finally, four scientific expeditions were carried out based on the limits of the *L. fortunei* records in the Tocantins River indicated by Chagas et al. (2025b). All expeditions were carried out between December 5 and 29, 2025, with logistical and institutional support from the *Centro Nacional de Pesquisa e Conservação da Biodiversidade Marinha do Norte – CEPNOR/ICMBio*.

The result of the systematic review of the scientific literature on studies of the golden mussel in the Amazon region indicates only three suitable studies. These studies make important contributions to understanding the golden mussel, Chagas et al. (2025a) recorded the first occurrence of the species in the Amazon region, Honda, Miyahira and Passos (2025) indicated that the introduction of the exotic species into the Tocantins River stems from aquaculture, and Chagas et al. (2025b) presented the first qualitative and quantitative data on the invasion of the region.

Based on the literature review conducted, as well as the other methodologies used, we verified that since the publication by Chagas et al. (2025b) the golden mussel has actively dispersed to other municipalities, encompassing all municipalities bathed by the Tocantins River (Figure 1). Furthermore, the introduction of the species into the Pará River is noteworthy, including municipalities on Marajó Island, such as Curralinho and, more recently, Muaná. The degree of dispersal of *L. fortunei* in the Amazon region is within the range estimated in the literature, which indicates that the golden mussel has an average dispersal of 240 km/year in continental water ecosystems (Darrigran & Drago, 2000).

During the expedition, we carried out sampling beyond the limits of mussel records indicated by Chagas et al. (2025b). Thus, observations were made at 62 strategic points starting from Tabatinga Island, in Abaetetuba. We chose to extend the sampling points to the state capital, the municipality of Belém, due to its proximity to the municipalities where the invasive mollusk is already present. Thus, we highlight that mussels were found at all points up to the limit of Sirituba Beach, in the municipality of Barcarena. However, at the port of Arapari, also in Barcarena, bathed by the Acará River, where numerous trips between Barcarena and Belém occur daily, no mussels were found. Even so, we chose to continue observations to Mosqueiro Island (Figure 2), a district of the capital Belém, and we note that no mussels were found at any of the strategic points in the municipality. Based on this study, we indicate that the limits of occurrence of *L. fortunei* in the Amazon region are: to the North, the municipalities of Muaná and Barcarena, and to the West, the municipalities of Curralinho and Oeiras do Pará.

In total, during the expedition, we found mussels associated with a wide variety of natural and artificial substrates, throughout the intertidal zone, with a predominance in the middle to lower intertidal zone. In the upper intertidal zone and the spray zone, the number of mussels decreased drastically or they were not present. This greater abundance of individuals in the lower zones is a result of the species' need to remain submerged. (Ferreira et al., 2024). Regarding natural substrates, mussels were found both on rock fragments and on rocky shores, branches, trunks, and tree roots. As for artificial substrates, mussels were found on artificiais rocks, bricks, lost/abandoned/discarded fishing gear (gillnets, cables, buoys, etc.), concrete structures, wooden structures, discarded household appliances (e.g., washing machines) in the river, rubber and electronic cables (coated in plastic), and metal spoons. It is noteworthy that no mussel associations were found on PET-type substrates, commonly used in bottling water, soft drinks, and related products, nor on plastic bags, glass, or metal.
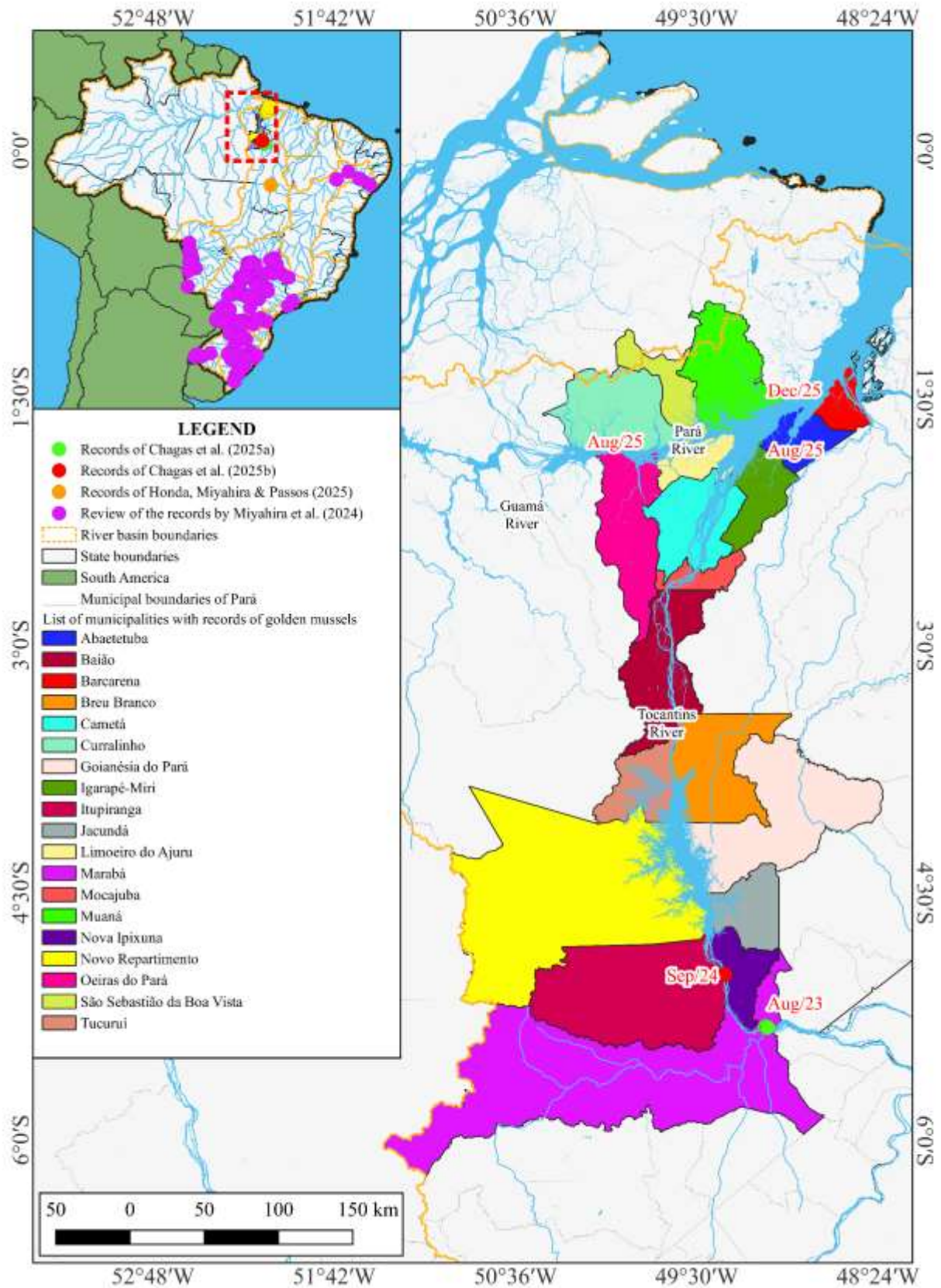
Figure 1. Updated map of the golden mussel's distribution in the Amazon region based a survey of scientific literature, reports from professionals linked to municipal and state agencies, researchers, and the local population living along the Tocantins River, searches on digital media, and scientific expeditions.

The types of substrates attached by mussels are similar to those described by Boltovskoy et al. (2022). According to the authors, as in the present study, the bottom of most water bodies colonized by *L. fortunei* is dominated by loose sediments (clay, silt), and therefore, the mussel cannot establish itself. However, the diversity of natural and artificial substrates allows for the growth of colonies.

The competition or impact of mussels on benthic organisms at the sampling sites during the expedition was not evaluated, but the gastropod *Vitta zebra* (Bruguière, 1792) was observed living and foraging on mussel colonies. Other bivalves, found in smaller numbers near the mussel beds, were *Cobicula* spp. and *Prisodon corrugatus* (Lamarck, 1819).
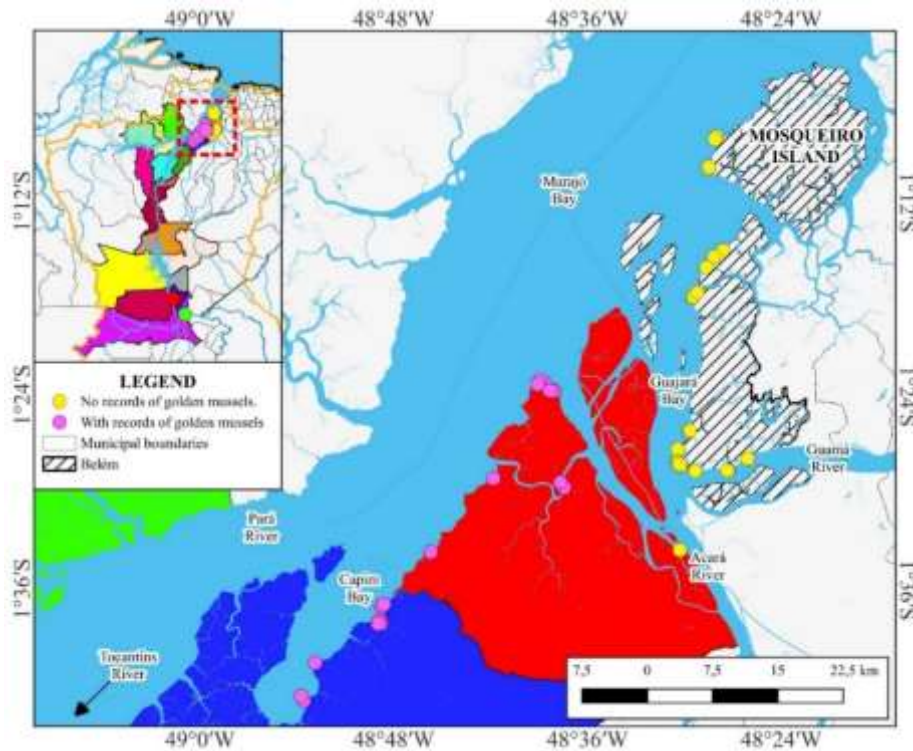

Figure 2. Observation points were established across three municipalities (Abaetetuba, Barcarena, and Belém) in order to record the occurrence of golden mussels and estimate their current distribution. For more details in the captions, see Figure 1.

Research on the golden mussel is growing abundantly worldwide, with Brazil being a particularly prominent área (Boltovskoy et al., 2022). Previously unpublished data from Chagas and colleagues will provide a national overview of mussel research, from its introduction to the present day.

The golden mussel can cause numerous socioeconomic and environmental impacts in invaded regions, compromising native biodiversity and infrastructure (Ayroza et al., 2021; Paula et al., 2021; Miyahira et al., 2024). Furthermore, because it is dispersed through multiple methods, *L. fortunei* has highly effective eradication methods (IBAMA, 2020; Santos & Souza, 2022), making continuous monitoring the primary control tool (Andrade, Razzolini & Baggio, 2021; Ribolli et al., 2021). Therefore, documenting new occurrences is crucial for risk management and modeling future infestations.

In this study, we present the current distribution of the golden mussel invasion in the Amazon region. Our results indicate that the species is already present in the Pará River, including in water bodies on Marajó Island. We highlight that the species is not yet present in the municipality of Belém. We recommend monitoring the invasion in municipalities neighboring those delimited in this study.

Acknowledgments

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