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LIMNOPERNA FORTUNEI (DUNKER, 1857), THE GOLDEN MUSSEL AND CURRENT GEOGRAPHIC DISTRIBUTION IN BRAZIL

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Danilo Henrique Monteiro Marangoni[1], Paulo Santos Assis[2], Pedro Machado Pelli[3], Afonso Pelli[4].

ABSTRACT

The introduction of alien species into multiple aquatic ecosystems is considered one of the main reasons for global biodiversity loss. A common example of the insertion of exotic species is the movement of species promoted by ship's ballast water discharges, which is considered responsible for the introduction of Limnoperna fortunei (Dunker, 1857), the Golden Mussel, in South America. The study of the golden mussel is relevant to propose control measures, aiming at reducing environmental, social and economic impacts. Considering the current scenario, the objective of this article was to review the characteristics of the golden mussel and to evaluate the geographic distribution in the Hydrographic Basins of Brazil. A survey of publications in the databases of publications from 2002 to 2023 in English, Spanish, and Portuguese was carried out through the CAPES Portal, Scielo, and Google Scholar. Scientific documents that demonstrated an alternative for controlling the species were selected. The documents gathered were evaluated for their contribution. The golden mussel is a bivalve aquatic mollusk, with two symmetrical valves fitted dorsally. They are organisms that have gills, inhalant and exhaling siphon, foot and byssus. Brazil has twelve hydrographic basins, and in seven of them the presence of the animal has already been recorded. The authors present a systematic review and new map for the expansion of the golden mussel in Brazil.

Keywords: Exotic Species, Biodiversity, Environmental Management, Invading Mollusks.

[1] Master in Environmental Science and Technology
Federal University of Triângulo Mineiro
Institute of Biological and Natural Sciences
E-mail: danilom.henrique@hotmail.com
[2] Full Professor
Doutor em Metalurgia na Rheinisch-Westfälische Technische Hochschule/Aachen
Federal University of Ouro Preto
LATTES: http://lattes.cnpq.br/7360474381329605
E-mail: assis@ufop.edu.br
[3] Graduating in Medicine
University of Ribeirão Preto
LATTES: http://lattes.cnpq.br/1960116562246739
ORCID: https://orcid.org/0009-0008-1848-3529
E-mail: pedrompelli@gmail.com
[4] Full Professor, PhD in Aquaculture
Federal University of Triângulo Mineiro
Institute of Biological and Natural Sciences
LATTES: https://lattes.cnpq.br/3020343973167468
ORCID: https://orcid.org/0000-0001-8279-2221
E-mail: afonsopelli@gmail.com

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INTRODUCTION

The introduction of alien species into multiple aquatic ecosystems is considered one of the main reasons for global biodiversity loss1,2. This phenomenon is characterized as biological invasion, which is considered a real problem by the scientific community because it causes significant impacts on the environment3.

There are discussions about the real definition of invasive species4 define these species as beings that acquire a competitive advantage over others, without natural obstacles that would prevent their proliferation, being able to disperse and establish themselves easily in other environments.

Lopes and Villac created a concept of exotic and invasive species that is used in decision-making on this issue5. The exotic species is the one recorded outside its original distribution area. The native species refers to the species that lives in its region of origin; and the cryptogenic species has a biogeographically unknown or uncertain origin, with no clear evidence of whether it is native or exotic.

As for the definitions for categories of exotic species, according to Lopes and Villac, they would be:

a) Contained species: defined when exotic species are found in artificial, controlled environments, totally or partially isolated from the natural environment;
b) Species detected: species detected in a natural environment. However, without a subsequent increase in its abundance or when it was an isolated record (without subsequent information on its species);
c) Established species: species detected recurrently, with a complete cycle in nature and signs of population increase over time, but without presenting apparent ecological or socioeconomic impacts;
d) Invasive species: one that has abundance or geographic dispersion that interferes with the ability of other species to survive, or when they cause socioeconomic, environmental, or human health impacts.

For an exotic organism to succeed in invading an ecosystem, it needs to overcome geographical barriers, tolerate physicochemical variations in the location, and still nourish itself efficiently. The absence or restraint of predators and parasites will naturally interfere with the eventual success of the invader1,6.

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Mollusks make up an important group in our daily lives. They are used as food in various parts of the world (Fig. 01), constituting a noble source of protein of animal origin7.

Figure 1. Specimens of shells of bivalve mollusks used in human food, in Brazil and in other countries, such as Italy, France and Spain.

Source: authorship.

They occupy different niches, including marine, freshwater and terrestrial. They can have different ways of obtaining resources, and can be predators, herbivores, scrapers, filter feeders or scavengers. These characteristics are related to the adaptive success of the group, composing one of the largest groups of invertebrates, right after the Hexapoda7-9.

Due to the plasticity of this group, the number of species described so far is around 240,000, including living and fossil species7,10-12.

In addition to their importance in human and animal food, they play important roles in ecosystems. In addition, they are used in clothing, curative medicine, environmental studies (such as biomonitoring, bioindicators, and toxicological), biogeographical, behavioral, phylogenetic, and molecular studies8-10,13-18. Several species are used as ornamentals in various regions of Brazil and the world (Figure 02).

On the other hand, there are species that cause negative impacts, such as *Limnoperma fortunei* and *Biomphalaria spp*., considered a serious public health problem, responsible for the infection of 230 to 250 million people worldwide7,8,13.

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Figure 2. Specimen of *Physa acuta* Drapramurd, 1805, in an ornamental aquarium in the City of Uberaba, in the Triângulo Mineiro in Minas Gerais, in 2023.

Source: kindly provided by Profa. Dr. Ana Carolina Borella Marfil Anhê.

Limnoperma fortunei has a high tolerance to various environments associated with human activities, thus constituting a threat to aquatic ecosystems19-21.

A common example is the movement of species promoted by ballast water discharges, which is considered responsible for the insertion of the golden mussel in South America1,22,23. The species, originally from rivers and streams in China and Southeast Asia, was first identified in 1991 along the banks of the Río de la Plata in Argentina6,24.

Ballast is a material used to give weight and maintain the stability of ships. In the first models of cargo ships, solid ballast such as stones, sand or metals was used. Currently, vessels use water as ballast, which has facilitated the work of loading and unloading, being more economical and efficient than solid ballast25.

The ballast water exchange process promoted by vessels in ports is carried out when a ship is unloading or loading. Its tanks receive ballast water to maintain their stability, and during their loading, the water from the port of origin is discharged into the sea25.

Regional dispersion occurs in several ways; such as the movement of small boats, during the removal and transport of sand from an already invaded environment; during the transport of fingerlings to supply aquaculture enterprises or through the transport of water26.

To propose control and prevention measures, it is necessary to study the place where the animal is established, as each region has its own characteristics. For industrial plants that use *fresh* water, physical treatment is indicated. For fish farming in cages, the

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treatment method will be diversified according to other species that are involved in the process.

Prevention or rapid detection of intrusions is economically feasible compared to post-invasion management; but this requires detailed knowledge of the routes of introduction and environmental tolerance27,28. One of the alternatives is to model the distribution potential of the species under study based on its ecological niche to predict the spread of invasive species29.

Thinking about this scenario, the present article aimed to carry out a bibliographic review on the characteristics of the golden mussel to evaluate the geographic distribution of the animal in the Hydrographic Basins of Brazil.

METHODOLOGY

To carry out the evaluation of the golden mussel among the Brazilian river basins, a survey of publications was carried out in the databases for publications from 2002 to 2023, in English, Spanish and Portuguese, through the CAPES Portal, Scielo and Google Scholar.

Documents that demonstrated an alternative control of the golden mussel or that were related to morphology, historicity, biogeographic surveys, dispersion and physiology were selected. The eligibility evaluation process consisted of two phases: documentary screening with reading of the title and abstract, and confirmation phase in which the full article was read.

To elaborate the search strategy, search terms were defined and added using the Boolean logical operator "AND". The data found in the literature review were reported. The mapping was composed of four stages:

1. Identification of watersheds contaminated with the golden mussel.
2. Screening is carried out on the documents and checking if the date that the water body was infested with the pest is mentioned. If it was not mentioned, the year of publication of the reference was used in the map.
3. Verification of the quality of the documents selected in the second stage.
4. Arrangement of data on the map.

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RESULTS AND DISCUSSION

In the Americas, the Mytilidae Family has native marine and estuarine forms, with the exception of *Limnoperna fortunei* (Dunker, 1857), the golden mussel, which is the only specimen of the group found in fresh waters30,31. The shell of the Bivalve is composed of three layers32:

- Internal, called nacreada, which is in contact with the soft parts of the animal (mantle), white and purple in color;
- Medium, called prismatic or ostracic layer; and
- External (Figure 3), called organic or periostracon, thin, smooth and shiny, ranging from dark brown to yellow, consisting mainly of organic material.

In the inner part of the mussel (Figure 4), in the mantle, there are two cavities, where the foot, the visceral mass and the gills meet. At the base of the foot, byssus filaments are produced, formed by collagen fibers, from a producing region composed of canaliculi. The golden mussel has byssus threads, similar to a marine mussel, but it does not support high salinity33.

The golden mussel is a bivalve aquatic mollusk, classified as such because it has a single shell formed by two symmetrical valves fitted dorsally. They are organisms that have gills, inhalant and exhaling siphons, mouth, stomach, adductor muscles and ligaments, foot and byssus21.

Figure 3. Adult and juvenile specimen of the golden mussel, *Limnoperna fortunei* (Dunker, 1857), kept in aquariums, with partially controlled environmental conditions, at the Nico Nieser Ecology & Evolution Laboratory, UFTM, in Uberaba/MG. Matrices collected in the Rio Grande, near the Volta Grande Hydroelectric Power Plant, in the Municipality of Água Comprida/MG.

Source: authorship.

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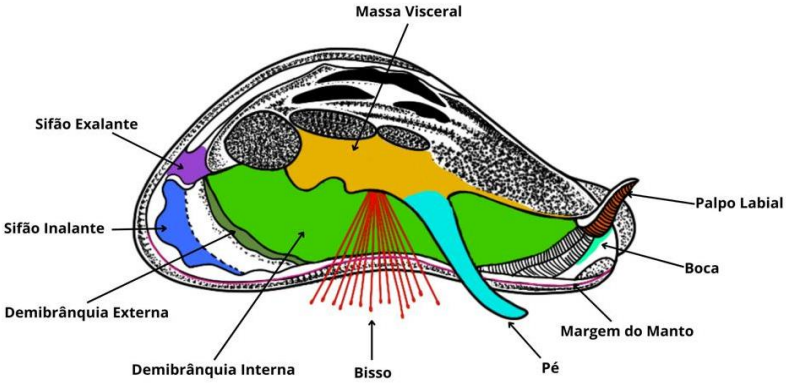
The dorsal hinge is a structure derived from the periostrate, through which the shells interact with each other. The adductor muscles, of unequal size, are responsible for closing the valves, while the hinge ligaments (internal and external) open the valves34,35.

For the study of impacts caused by the golden mussel, it is essential to understand its filtration mechanisms and particle selection. In filter bivalves, water enters through the inhalant siphon and the feces exits through the exhaling siphon, as with other bivalves36.

Particle selection occurs in the mantle, visceral mass, foot, gills, and labial palps. The golden mussel conducts the filtered particles in acceptance streams, which go to the mouth of the bivalve to be ingested, and rejection streams, which go to the exhaling siphon to be expelled37. The golden mussel feeds on other animals, such as rotifera, nematoda, cladocera, copepoda, ostracoda, the golden mussel itself, and phytoplankton19,37,38.

The riparian currents in the mantle (including the siphon), visceral mass and foot are rejections and move the particles to accumulate in the posterior region of the visceral mass, leaving the mantle cavity free of undesirable particles. Soon after, the particles are directed to the internal demibrachea, ventral or dorsal, towards the food grooves39.

Figure 4. Internal anatomy of *Limnoperna fortunei* (Dunker, 1857), the golden mussel.



Source: Kindly drawn by Beatriz G. Lopes, from various sources.

Prevention actions are important to contain the dispersion of the golden mussel to the watersheds that have not yet been contaminated. They should involve different actors in society and be implemented prior to the detection of the invasive species, with the purpose of alerting to the main vectors of dispersion, which are mostly due to human activities40.

The population control of the golden mussel is mainly focused on industrial facilities, and can be planned through two approaches. These can be through proactive treatment; in which molluscicides dosages are applied to control the settlement of larvae, through intermittent, continuous or semi-continuous applications. This approach is adopted from the

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beginning of the larval release period into plankton. Treatment can also be reactive, in which the target is adult individuals. It can be applied at the end of a breeding season or periodically. Both approaches require monitoring to monitor the population fluctuations of larvae and adults41,42.

Currently, on the South American continent, in addition to Argentina, the golden mussel has infested countries such as Uruguay, Paraguay, Bolivia and Brazil. The geographic distribution of the golden mussel in Brazil has been evaluated through several records of its presence in the environments43.

The most widely used methods for detecting the presence of the golden mussel were the observation of the presence of adults through the inspection of submerged blocks, carried out manually or with the use of dredges, by inspecting rock exposures along the coast and in the riverbed and/or reservoir, in addition to being collected also in lakes and marginal lagoons44.

Brazil has twelve hydrographic basins, and in seven of them (Uruguay, South Atlantic, Paraná, Paraguay, São Francisco, Southeast Atlantic and Eastern Northeast Atlantic) the presence of the animal has already been recorded (Figure 5)[28,45].

Other methods are also used for the identification of the golden mussel in the environment. The most common after the visual identification of the adult animal is the collection of plankton and consequent identification of the different stages of development of the mussel, but recently the use of the environmental DNA technique has revolutionized studies46.

Between 2016 and 2020, three new records of the golden mussel were identified in the 60 available publications, this record was published in 2019 and refers to 10 specimens of the golden mussel collected in October 2010 in the bay-estuary complex of the Santos, São Vicente and Bertioga channels45.

In the State of São Paulo, the presence of the golden mussel is reported in hydroelectric plants that use water from the Paraná River, such as in the Ilha Solteira, Porto Primavera and Jupiá Hydroelectric Power Plants (HPPs), and in the Paranapa-nema Hydroelectric Power Plant, in the Rosana HPP47.

Dispersing along the Paraná/Tietê waterway system, the golden mussel expanded northwards, reaching the states of Minas Gerais and Goiás, where its presence was recorded in 2004 in the Paranaíba River48.

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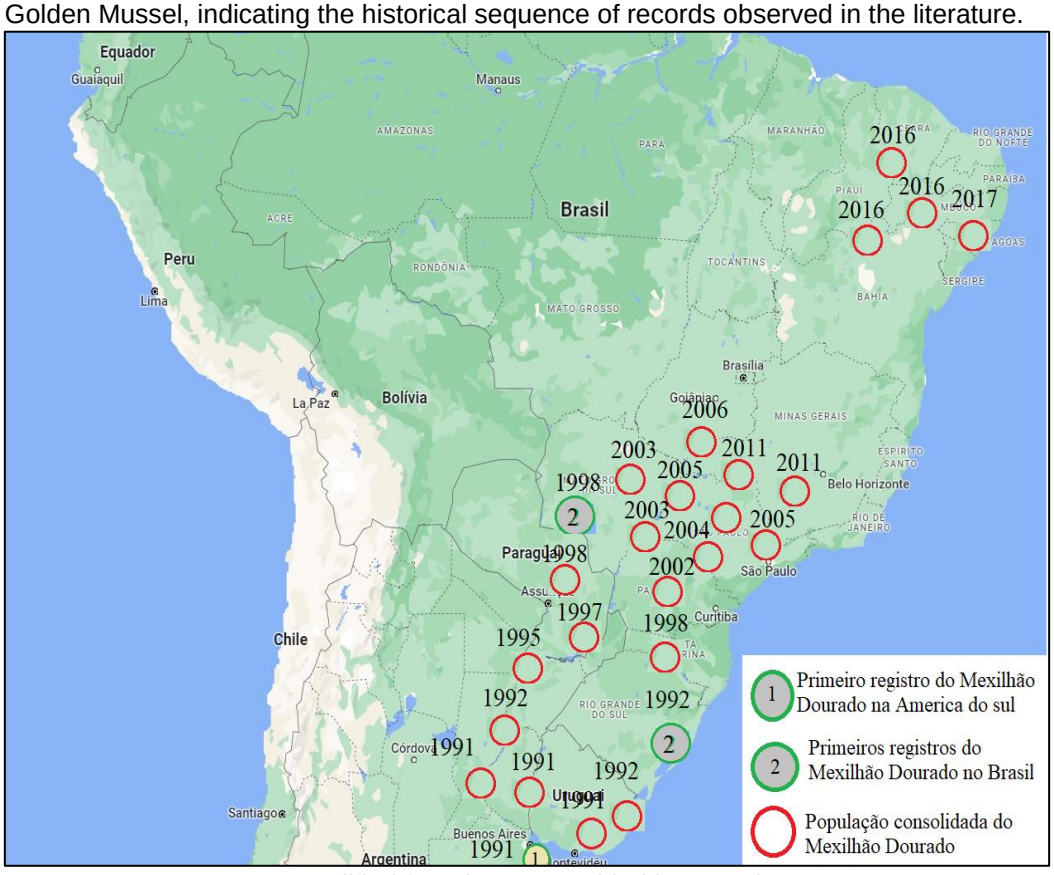
In the Upper Paraguay in 2004, the presence of the golden mussel had already been detected along the entire length of this river, from its mouth in Pylar (Paraguay) to the Apa River, which is at the end of the basin studied, proving that the dispersion of the species is facilitated by the integration between water bodies of different systems49.

The golden mussel was recorded in the Rio Grande in 2011, in the reservoir of Volta Grande SP/MG, although the Rio Grande does not have characteristics of a navigable waterway for commercial vessels, due to the presence of cascade dams, the presence of the species was recorded in a large part of the Rio Grande, in the reservoirs of Porto Colômbia, Mascarenhas de Morais and Marimbondo. This fact can be explained by other dispersion vectors present in these rivers, such as fishing boats, fish farming, and the use of sand taken from infested sites48.

Figure 5. Map of the history of the invasion, in Brazil and South America, of *Limnoperna fortunei* (Dunker, 1857), the Golden Mussel, indicating the historical sequence of records observed in the literature.



Source: modified from image provided by Google, 2023.

The São Francisco River, is one of the most important hydrographic basins in the country, supplies more than 500 municipalities, from its source, in Serra da Canastra, in Minas Gerais, to the Atlantic Ocean, running through the states of Bahia, Pernambuco,

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Alagoas and Sergipe. Major engineering works have been and are being carried out in its course, the most important being the hydroelectric plants and the transposition works50.

Records of the occurrence of the golden mussel in the São Francisco basin accelerate its dispersion through transposition waters, given its impressive adaptability and successful larval reproductive cycles51.

Specimens of mussels were found in the water capitation and transposition systems in the Sertão Canal, in 2021, in the metal structures of the pumping pumping station on the banks of the lake of the Apolônio Sales HPP and on the bridge over the Canal50.

CONCLUSION

It is believed that the golden mussel, due to its biotic characteristics, has a tendency to distribute throughout South America, occupying the most diverse aquatic environments. The current patterns observed indicate that the golden mussel should be distributed throughout all hydrographic basins, in the most voluminous stretches and main channels, without eventually occupying the springs or first-order environments.

To date, there is no effective mechanism to control the golden mussel. Perhaps in small spaces it may be possible to manage management and live with the situation. After its introduction, little or almost nothing has been done, not only in Brazil, but all over the world.

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