

Invasion of the exotic freshwater mussel *Limnoperna fortunei* (Dunker, 1857) (Bivalvia: Mytilidae) in South America

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ABSTRACT

We traced the invasion and investigated the distribution of the Asian bivalve *Limnoperna fortunei* (Dunker, 1857) in South America. In addition, we comment on the problems caused by this invasive species. In 1991, *L. fortunei* was introduced into the Plata Basin (currently the only American continent drainage system invaded by this species) through Río de la Plata River. By the end of 1994 and during 1995 this species dispersed throughout the Argentine coast of the Río de la Plata River and was reported from the Uruguayan coast. In 1995 and 1996, it was first discovered in the Paraná River, in Santo Tomé (Salado del Norte River), and later up in Goya. In November, 1996, *L. fortunei* was reported in Cerrito Island, where the Paraguay River joins the Paraná River. In April 1997, it was collected in Paraguay River on Asunción Harbor, Paraguay. In 1999, it was detected in Brazil (Itapuã Beach, Municipality of Viamão, Rio Grande do Sul State). These recent records document the fast and ongoing expansion of the species geographic range, as well as its prompt adaptation to the different environments of the la Plata Basin.

Key words: South America; Neotropical Region; la Plata Basin; invasive species; distribution; biofouling.

INTRODUCTION

The la Plata Basin is one of the most important hydrographic systems in South America. It has a drainage area of approximately 3×10^6 km², and comprises 4 main sub-basins (Bonetto, 1994): (1) Uruguay River, (2) Paraná-Paraguay system, (3) Río de la Plata River, and (4) the Andean tributaries (figure 1).

A diverse, native molluscan fauna occurs along the Argentine shore of the Río de la Plata estuary (Darrigran, 1994), including 27 gastropod and 21 bivalve species. Only 4 of the bivalves are strictly freshwater and infaunal species: *Anodontites tenebricosus* (Lea, 1834), *Diplodon paranensis* (Lea, 1834), *Musculium argentinum* (d'Orbigny, 1835) and *Pisidium sterkiatum* Pilsbry, 1897. The only epifaunal species on the Argentine coast of Río de la Plata River is the estuarine *Mytella char-*

ruana (d'Orbigny, 1842). Until 1993, *M. charruana* was the only Mytilidae found in Río de la Plata River, in Punta Piedras, Argentina and Montevideo, Uruguay (Darrigran and Pastorino, 1995a).

In the 1970s, 2 asiatic freshwater bivalves, *Corbicula largillierti* (Philippi, 1844) and *C. fluminea* (Müller, 1774) (Corbiculidae), entered South America along the Argentine shores of Río de la Plata River (Ituarte, 1981).

In 1991 we detected, for the first time in South America, the presence of a mytilid, *Limnoperna fortunei* (Dunker, 1857), in the Río de la Plata River shore at Bagliardi Beach (Pastorino *et al.*, 1993). This is an euryhaline freshwater species, native to China and southeastern Asia (Morton, 1977), which resembles marine mussels (Mytilidae) in its morphology and biology.

Commerce between Argentina and the countries where *L. fortunei* is supposedly native takes place mainly by sea. Following Carlton (1992) and Carlton and Geller (1993), Darrigran and Pastorino (1995a) hypothesized that *L. fortunei* and other invading organisms may have arrived in ballast water of ships coming from southeastern Asia.

Other authors have indicated that *L. fortunei* was introduced in and recorded from Hong Kong in 1966 (Morton, 1975, 1996) and Japan in 1991 (Kimura, 1994). In the Americas, *L. fortunei* is known to have invaded only Río de la Plata Basin. Morton (1973) suggested that the morpho-functional features of this species allow for rapid expansion of its distribution range, in similar fashion to the invasive abilities of the zebra mussel, *Dreissena polymorpha* (Pallas, 1771), in the Northern Hemisphere. The species exhibits 2 features that may contribute to its abilities as an invader: (1) it is the only relevant mollusk in the freshwater littoral having a byssus, and (2) has no known native competitors for physical space. As a result of the high rates of invasion, as we further discuss below, *L. fortunei* causes serious biofouling of municipal drinking water and industrial water systems. As we demonstrate below, populations of *Limnoperna fortunei* are not only rapidly increasing in density in sev-

eral localities but are also quickly expanding geographically, mostly in northward direction.

Since 1991, when it was first found at Bagliardi Beach, until the end of 1993, the species was found only in mixohaline (e.g., Punta Piedras and Punta Indio) and euryhaline environments (e.g., Magdalena Beach, Atalaya Beach, Punta Blanca, La Balandra Beach). At that time, the species had not been collected farther north than the freshwater environment of Punta Lara Beach, and was apparently absent from all other countries and rivers comprising the la Plata Basin (Darrigran and Pastorino, 1993).

The objectives of this paper are to investigate the invasion of *L. fortunei* in South America, to provide an update of its distribution in the Neotropical Region, and to emphasize the importance of this invasive bivalve in biofouling processes in the la Plata Basin.

MATERIALS AND METHODS

Collections were made along the Río de la Plata River shore at low tides. In the Paraná River, samples were collected with a 319 cm² "Tamura" dredge (Marchese and Ezcurra de Drago, 1992). Periphytic populations were sampled by hand. In the mouth of Paraguay River, "macrofouling" samplers (Stupak *et al.*, 1996) were used. Environmental parameters taken into account were: temperature, pH, and conductivity. The study localities are shown in figure 1. Specimens from the Malacological Collection of La Plata Museum, Argentina, (MLP) were examined. Sampling for larvae was made using a mesh of 25 µm in Uruguay River (towns of Colón and Concepción del Uruguay), at 3 stations in the Carcarañá River, and Correntoso River.

RESULTS AND DISCUSSION

Limnoperna fortunei was first found in South America in 1991 at Bagliardi Beach (Argentina) with densities of 5 individuals·m⁻² (Pastorino *et al.*, 1993). In 1992, the maximum density recorded was about 3×10⁴ individuals·m⁻². In 1993, in the same locality, the maximum density recorded was 8×10⁴ individuals·m⁻². In 1998, densities of about 15×10⁴ individuals·m⁻² were commonly recorded, values equivalent to those for mytilid densities at the seashore in Mar del Plata, Argentina (Penchaszadeh, 1973).

In 1994 and 1995, *L. fortunei* was found in the water intakes of the town of Bernal (MLP 5204) and Retiro, and on Buenos Aires Harbor (MLP 5205). Scarabino and Verde (1994) reported the species from the town of Colonia del Sacramento, Uruguay (MLP 5202). All these localities are on the Río de la Plata estuary. During 1996, the species expanded to the town of Goya (29°10'S, 59°16'W), in Corrientes Province (Di Persia and Bonetto, 1997) and nearby lotic bodies, and was collected in the middle Paraná River, near the city of Santa Fé, where the river has a very wide alluvial plain (25 km in width; Drago, 1990).

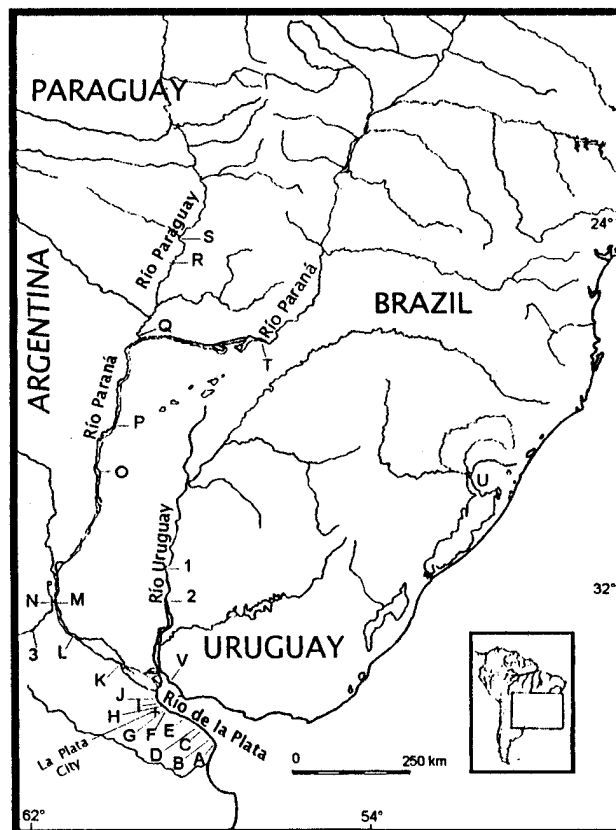


Figure 1. Studied localities on the la Plata Basin. A, Punta Piedras; B, Punta Indio; C, Magdalena beach; D, Atalaya Beach; E, Punta Blanca; F, La Balandra Beach; G, Bagliardi Beach; H, Punta Lara Beach; I, Bernal Beach; J, Buenos Aires Harbor; K, Atucha I Nuclear Power Plant; L, City of Rosario; M, Town of Santo Tomé; N, City of Santa Fé; O, Esquina; P, Goya; Q, Cerrito Island; R, Town of Formosa; S, Asunción Harbor; T, Posadas Harbor; U, Praia de Itapuá (Rio Grande do Sul State, Brazil); V, Town of Colonia del Sacramento; 1, Town of Colón; 2, Town of Concepción del Uruguay; 3, Carcarañá River.

Limnoperna fortunei was first collected in Paraná River at Vuelta del Este, Zárate, on the Paraná de Las Palmas River (MLP 5206), and at Paso Burghi, city of Rosario, on the lower Paraná River (MLP 5207) toward the end of 1995 (figure 1). The species settles on all kinds of substrates across the entire floodplain. It was found in the main channel, on the left bank at town of Paraná and associated alluvial plain, in San Javier and Correntoso (MLP 5287) rivers, near the city of Santa Fe. It was also found on the right bank of the lower Salado del Norte River (MLP 5285), in the town of Santo Tomé (31°40'S, 60°45'W).

Limnoperna fortunei was part of the epifauna present on Solanaceas and *Paspalum* sp. (MLP 5286) in all habitats observed, but was not found on the sandy, moving bars (Drago, 1997) in the main channel. Perhaps due to the unfavorable sandy substrate, the central part of the

main channel provides habitat to only a few benthic species (Marchese and Ezcurra de Drago, 1992). In the Correntoso River (a secondary channel of the middle Paraná River), *L. fortunei* colonized the silty clay beds at all locations sampled.

The euryhaline attributes of *L. fortunei* probably facilitates its rapid spread. The mean salinity at the main channel of the Paraná River is 0.05 ‰, and in Correntoso River it ranges between 0.064–0.345 ‰. In Salado del Norte River, which mixes with the waters of the Paraná River, salinity varies from 0.5 to 4 ‰ (Ezcurra de Drago, personal observation). Mean pH is 7.4 in the Paraná main channel and 7.2 in secondary courses (Marchese and Ezcurra de Drago, 1992), while in Salado del Norte River pH reaches 8.7.

In 1996, this species was collected on "fouling" samplers in Cerrito Island (27°20'S, 58°43'W), near the confluence of the Paraguay and Paraná rivers (MLP 5340). In April 1997, it was collected on Asunción Harbor (25°17'21"S, 57°38'08"W), in the Paraguay River, in Paraguay (figure 1). It was also collected during the last months of 1998, at Posadas Harbor, on the upper Paraná River. In November 1999, *L. fortunei* was detected in Brazil on Itapuã Beach, Municipality of Vianão, Rio Grande do Sul State (MLP 5550). No larvae, juveniles or adults have been found at any of the localities examined in Uruguay River (Colón, Concepción del Uruguay) or Carcaraña River (Carcaraña and la Ribera).

The biofouling problems caused by *L. fortunei* in South America are similar to those described for *Dreissena polymorpha*, the zebra mussel, in the Northern Hemisphere (Darrigran, 1995).

The principal problems caused by zebra mussel invasion, settlement, and maturity, into water distribution systems (Nalepa and Schloesser, 1993) are listed below (the problems which have already been detected in Argentina resulting from invasion by *L. fortunei* are marked with (X)).

- (X) Reduction of pipe diameter
- (X) Blockage of the pipeline
- Decreased water velocity caused by friction (turbulent flows).
- (X) Accumulation of empty shells
- Contamination of water pipelines by mass mortality
- (X) Filter occlusion

These problems have occurred in the intakes of water treatment plants in the city of La Plata; water treatment plants along the Corrientes River (MLP 5365), and also in industrial and power-generating plants. They cause an increase in the operational costs of these facilities due to reduced pump efficiency, increased tube corrosion (caused by proliferation of bacteria and fungi), and increased frequency of shutdowns for cleaning and filter changes.

Absence of relevant records in the numerous benthic studies conducted prior to 1991 (Darrigran, 1991, 1994; Marchese and Ezcurra de Drago, 1992) indicate that colonization by *L. fortunei* is a recent event. By late 1996

and early 1997, the first cases of fouling by *L. fortunei* in nearby industries were reported in the Paraná River (e.g., Atucha I Nuclear Power Plant and San Nicolás de Los Arroyos Electric Plant (MLP 5300), Buenos Aires Province).

Based on the facts above described, it appears that the geographic range of *L. fortunei* is in continuous expansion in South America, and that the species is apparently adapting to different environments along its invasion routes. Between 1991–1999 this species invaded 4 countries (Argentina, Uruguay, Paraguay, and Brazil); 3 of the Río de la Plata Basin main rivers (la Plata, Paraná, and Paraguay). It traveled upstream at a speed of about 240 km·year⁻¹. Throughout its distribution range, *L. fortunei* inhabits a wide variety of environments: from euryhaline waters in the La Plata estuary to strictly freshwater habitats along the Paraguay and Paraná rivers.

This expansion is probably favored by the morpho-functional features of the species, and by the apparent absence of competitive interactions along the littoral of la Plata Basin. *Limnoperna fortunei* is the only relevant species using byssal epifaunal attachment among local freshwater species.

Although the distribution of *L. fortunei* is currently still limited to la Plata Basin, there are no apparent constraints that could prevent the invasion of other drainage systems. Moreover, this expansion may be favored by the increase in trade between Argentina, Uruguay, Paraguay and Brazil, as a consequence of the recently established MERCOSUR international economic consortium (Darrigran, 1995; Darrigran and Pastorino, 1995b). Additional dispersal of the species could also be favored by the international project HIDROVIA, which consists of a waterway connecting the main hydrographic systems of South America. The project comprises a complex fluvial network system that involves and interconnects Río de la Plata, Paraná, and Paraguay rivers, and includes plans for extensive basin dredging, harbor construction, and improvement of the harbors and highways. Connections among the main South American basins (e.g., Amazonas, Orinoco) are likely to be artificially established in the future. Up to now no effective control mechanisms have been proposed to prevent further spread of *L. fortunei*.

The impact of *L. fortunei* will not be restricted only to the economy, but will also affect the diversity of the native molluscan communities. Darrigran *et al.* (1998) showed that, since the introduction of *L. fortunei* at Bagliardi Beach, populations of 2 common gastropods have been displaced: *Chilina fluminea* (Maton, 1809) is no longer found, while *Gundlachia concentrica* (d'Orbigny, 1835) is becoming rare (figure 2).

In contrast, several benthic species, uncommon or absent before the occurrence of *L. fortunei*, are now present. These include Annelida Oligochaeta (8 species), Aphanoneura (1 species) and Hirudinea (8 species); plus assorted Crustacea and Insecta (Darrigran *et al.*, 1998). Additionally, we observed the epizoic colonization and smothering of native bivalves (e.g., *Anodontites trapessi-*

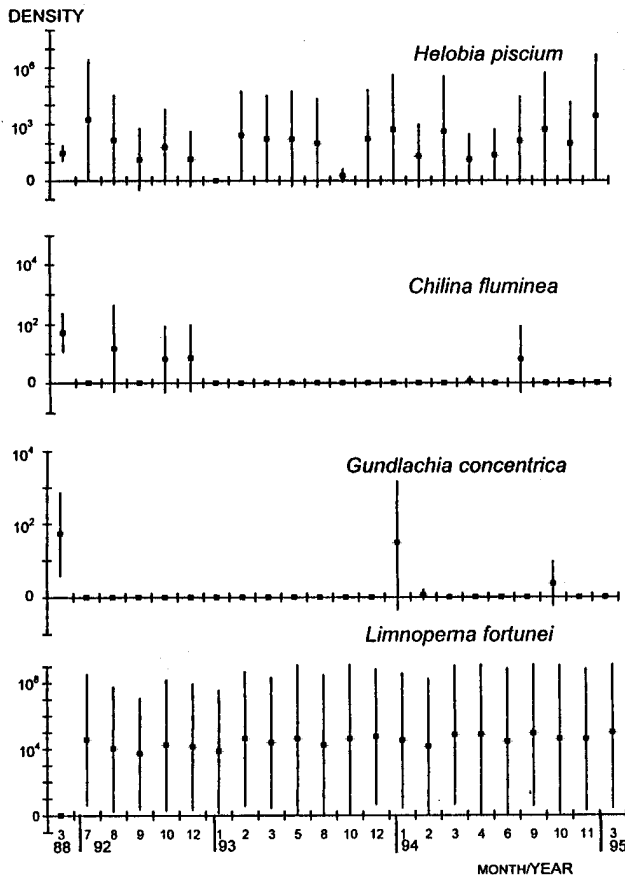


Figure 2. Temporal variation of density (individuals·m⁻², represented by mean and standard deviation) of some native mollusks associated with the byssus of *L. fortunei* in Bagliardi Beach (34°55'S, 57°49'W), Argentina.

alis (Lamarck, 1819) and *A. tenebricosus* (Lea, 1834) by *L. fortunei*, in a behavior similar to that shown by *Dreissena polymorpha* on unionids (Parker *et al.*, 1998).

Last but not least, further expansion of the natural range of *Limnoperna fortunei* and the possibility of invasion of parts of North America by this species should not be rejected. As Ricciardi (1998) observed, "Given that shipping traffic from both Asia and South America has already resulted in recent introduction of exotic bivalves to the USA, a future North American invasion by *L. fortunei* is highly probable."

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