DISTRIBUTION OF THE GOLDEN MUSSEL *LIMNOPERNA FORTUNEI* (DUNKER, 1857), (BIVALVIA: MYTLIDAE) AFTER 10 YEARS INVADING AMERICA

GUSTAVO DARRIGRAN[1] & GUIDO PASTORINO[2]

Abstract *The Golden Mussel* Limnoperna fortunei *invaded the South American continent about 10 years ago, and in this paper we present a summary of the changes observed since its arrival. The Golden mussel and the asian freshwater clam* Corbicula fluminea *(Müller) are the two most successful bivalve invaders in the Rio de la Plata system.* L. fortunei *is now found in the principal rivers of South America: Rio de la Plata, Paraná, Paraguay and Uruguay in Argentina. In addition it was recently found in the other countries of the Rio de la Plata drainage basin: Paraguay, Uruguay and Brazil. Both species are having impacts on the native fauna and on human utilisation of the river systems, especially industry.*

Key words Limnoperna fortunei, *Bivalves, South America, Mytilidae, Invaders*

INTRODUCTION

In Argentina, two hydrographical regions are differentiated (Bonetto 1994). The most studied, and with the richest freshwater biodiversity, is the Rio de la Plata drainage basin. By contrast, the Chilean-Patagonian subregion of the Atlantic slope has scarcely been studied and from the little data available has lower freshwater biodiversity and it currently has desertification problems. The area occupied by these two hydrographical regions has been examined as part of the Millenium project on Projected Status of Biodiversity 1998-2018, which found that approximately 55% of the territory in a critical and endangered condition, and 15% of the territory is threatened (National Geographic Society 1999).

The first data on freshwater molluscs from Argentina probably come from Alcide d´Orbigny's Voyage dans l'Amerique Meridionale (1834-1847), but there are limited data on systematics, distribution and lifecycles of this important ecological group in Argentina. Moreover, the information available on non-native mollusc species in this region is scarce and poorly documented, with the exception of those species of recent introduction with a high impact on the environment (e.g. *Limnoperna fortunei*) (see Table 1 for details of these recent introductions).

Eno (1998) defined non-native or alien, introduced, exotic species as those species distributed directly or indirectly by human activity, in an intentional or a non-intentional way, in an area outside the natural range of dispersion in a historical time. In this paper we consider that an invasive species is an alien species, which colonises natural or semi-natural ecosystems becoming an agent of change, and threatening native biodiversity (Lowe 1997). We examine the case of invasive bivalve species in the southern part of the Neotropical region and the consequent impact of this invasive species on natural ecosystems and human activities.

There are three freshwater invasive bivalves which have impacted greatly on the American continent: *C. fluminea, L. fortunei* and the Zebra mussel *Dreissena polymorpha* (Fig. 1, A-C). The latter species is causing most problems in North America, but as yet is still absent in the Neotropical region. *Limnoperna fortunei* invaded Hong Kong in 1965 (Morton 1977) and Japan (Kimura 1994) and Taiwan (Ricciardi 1998) in the 90s (Fig. 3). Darrigran & Pastorino (1995) described the non-intentional introduction of this species

[1] Facultad Ciencias Naturales y Museo (UNLP), Paseo del Bosque s/n , 1900 La Plata, Buenos Aures, Argentina.

[2] Museo Argentino de Ciencias Naturales, Av. Angel Gallardo 470, 3er piso Lab 57, C1405DJR Buenos Aires, Argentina.

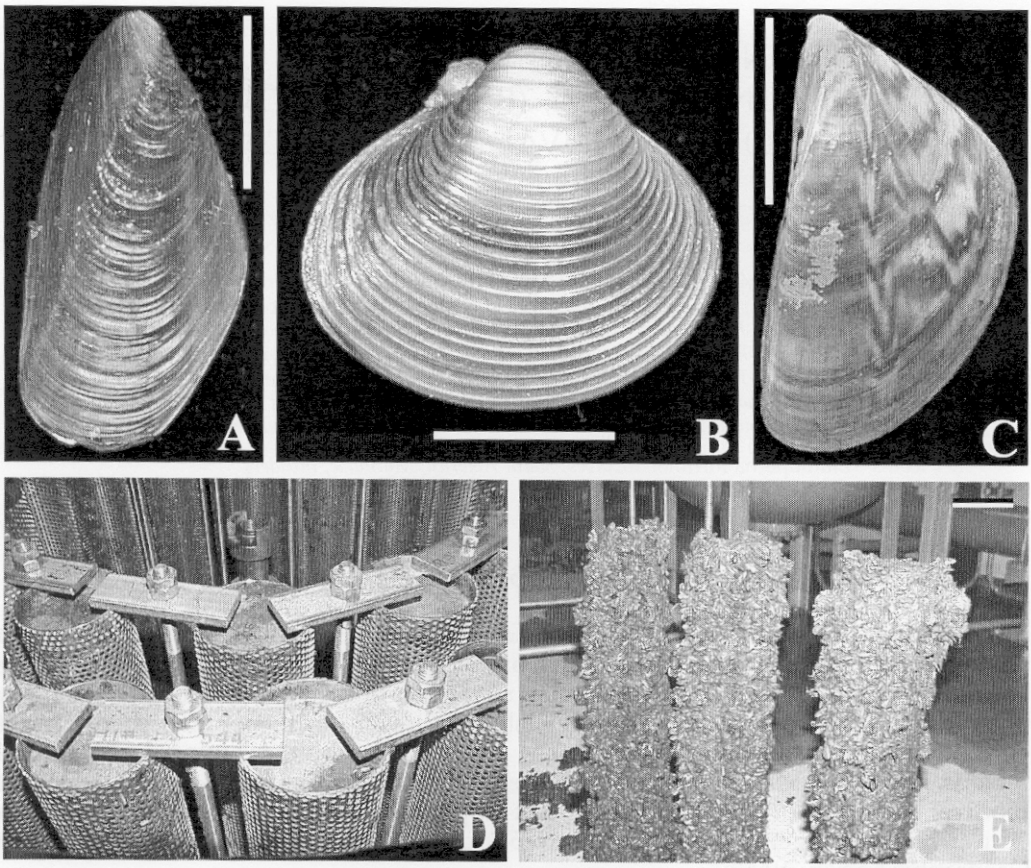

Fig. 1 Freshwater invader bivalves in the American continent. **A** *Limnoperna fortunei* **B** *Corbicula fluminea* **C** *Dreissena polymorpha* Scale bars = 1 cm. **D–E** Filters from Yacyreta dam. **D** Clean **E** Infested with *L. fortunei* Scale bar=10 cm.

into South America in 1991, as the result of ballast water discharge by large ships. Although there are many mechanisms for non-intentional introduction of species, discharge of vessel ballast water in foreign waters is recognised as the most common causes of introduction of invasive species. According to the National Research Council (1996), the ballast water represents a major transport vector for aquatic invaders and it has been estimated that more than 3,000 aquatic species can be in transit in ballast waters world-wide per day.

In the last three decades, three species of freshwater bivalves from southeast Asia have reached the Neotropical region. These species are now found on the Argentine coast of the Río de la Plata estuary: two species from the Family Corbiculidae (Asiatic clam *Corbicula fluminea* (Müller) (Ituarte 1981), and *C. largillierti* (Philippi), and one Mytilidae: the golden mussel *Limnoperna fortunei* (Dunker) (Pastorino *et al.* 1993). One of these species *Corbicula largillierti* has not become established in the river systems (Darrigran 1992). However, *C. fluminea* and *L. fortunei* have become established and these have many characteristics of invader species (see Morton 1996; McMahon 2000): namely rapid growth, early maturity and high fecundity rate and adaptability to different environments, including extensive capacities for natural and anthropomorphic dispersal (Darrigran 2000).

TABLE 1
Non-native freshwater molluscs introduced to Argentina

	First Citation	Distribution	Origin	Way of Introduction
Gastropoda				
Physidae				
Physella cubensis (Pfeiffer)	Miquel, 1985	Plata Basin	?	Aquarism
P. venustula (Gould)	Miquel, 1985	Patagonian rivers Atlantic slope	Europe ?	Aquarism
Lymnaeidae				
Pseudosuccinea columnella Say	Hylton Scott, 1953	Paraná; Uruguay rivers	Philadelphia	?
Thiaridae				
Melanoides tuberculata (Muller)	Peso & Quintana, 1999	Paraná (Yacyretá reservoir)	South Asia	Aquarism
Bivalvia				
Corbiculidae				
Corbicula fluminea (Müller)	Ituarte, 1981	Plata Basin	Southeast Asia	Human feeding or ballast water
C. largillierti (Philippi)	Ituarte, 1981	Plata Basin	Southeast Asia	Human feeding or ballast water
Mytilidae				
Limnoperna fortunei (Dunker)	Pastorino *et al.*, 1993	Plata Basin	Southeast Asia	Ballast water

Case Study: *Limnoperna fortunei* (Dunker, 1857)

Since *Limnoperna fortunei* became established as an invasive species within the South American continent in 1998, the Argentine National Coastguard (Prefectura Naval Argentina) has established regulations to control the discharge of ballast water from vessels that enter the Rio de La Plata Basin. In future the adoption of a worldwide convention on Ballast Water Movement by the United Nations International Maritime Organization (IMO) should provide additional support for these regulations reducing the likelihood of unintentional transportion of non-native species.

Limnoperna fortunei produces an environmental impact similar in scale to that of *D. polymorpha* in North America, in contrast to *Corbicula fluminea* which shows the lowest impact, both in human and natural environments..

The following two features make it an invasive species:

1. *High biotic potential* In 1991, when it was first detected its density was 4-5 individuals per m^2 (Darrigran & Pastorino 1995; Darrigran 2000). By 1995 in the same environment, its density had increased to approximately 150,000 individuals per m^2 (Darrigran *et al.* 1998). It is the only epifaunal species of freshwater bivalve living in South America to achieve this high density.
2. *Great capacity to colonise* In 1991 this bivalve was introduced along the Río de la Plata (Pastorino *et al.* 1993). By November 1999, *L. fortunei* was detected in Rio Grande do Sul, Brazil (Mansur *et al.* 1999). In 2001, it was been found at four localities examined in the Río Uruguay and the ecological reserve of the Pantanal also in Brazil (A. Takeda, pers. com.). This shows that the species has colonised a length of 1,100 km in the La

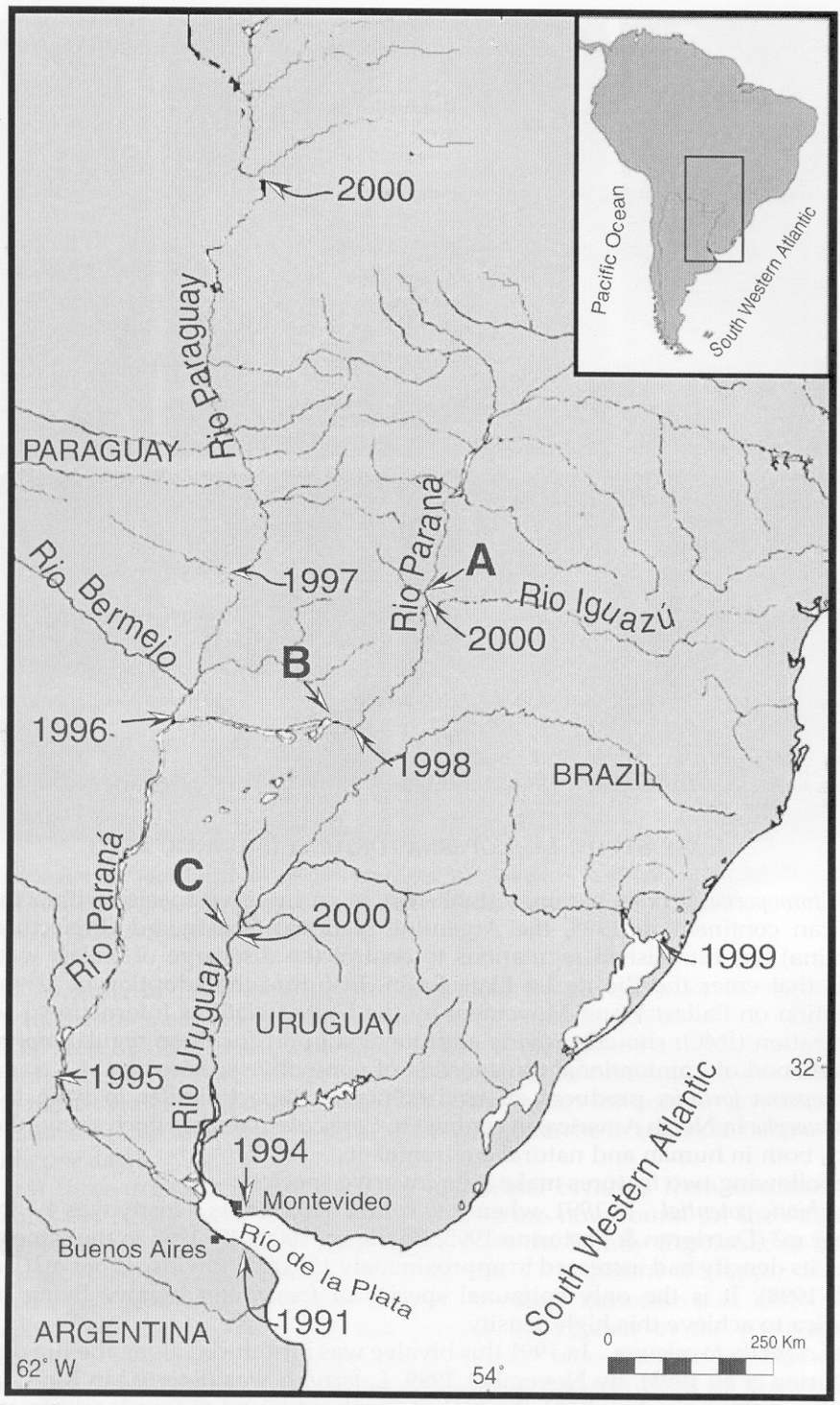

Fig. 2 Distribution of *Limnoperna fortunei* (Dunker, 1857). Years point out places and dates when they were recorded for the first time. **A** Itaipú dam. **B** Yacyretá dam. **C** Salto Grande dam (modified from Darrigran *et al.* 2000).

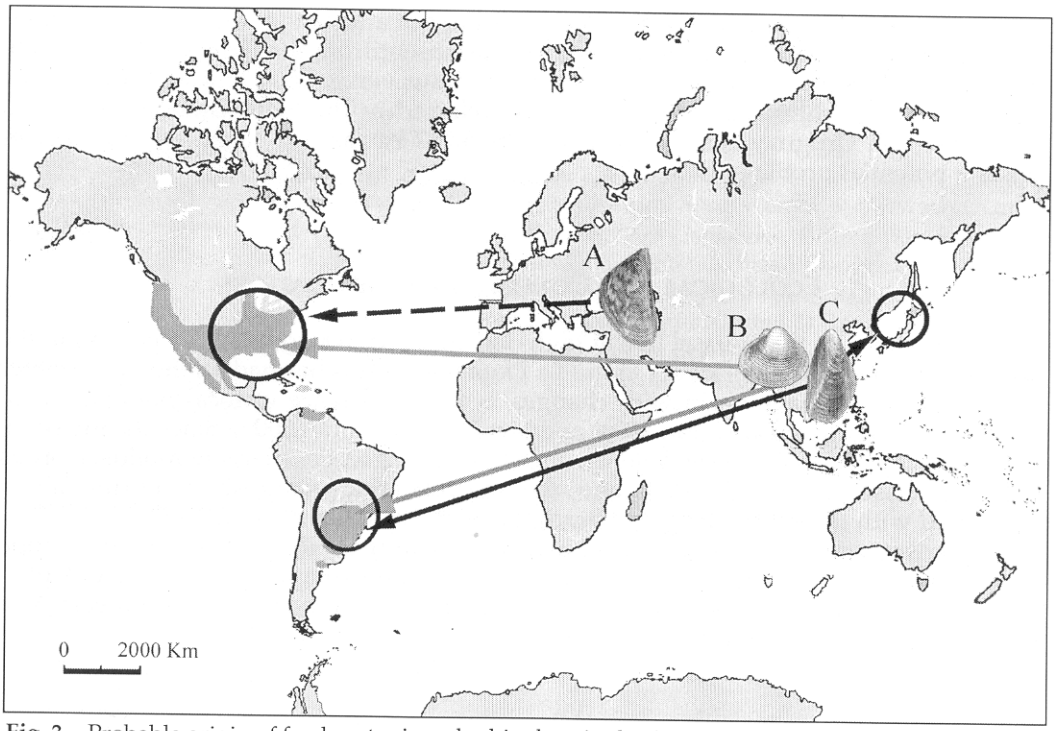

Fig. 3 Probable origin of freshwater invader bivalves in the American continent. **A** *Dreissena polymorpha* (black dashed line) **B** *Corbicula fluminea* (grey line) **C** *Limnoperna fortunei* (black line). The size is not relative.

Plata Basin between 1991 and the present (Fig. 2). This species must be able to adapt to changing conditions and it's fecundity permits a fast expansion over a large geographic distribution.

The problems caused both to natural and human environments (macrofouling) by *L. fortunei* in South America, are similar to those described for *Dreissena polymorpha* in the Northern Hemisphere (Nalepa & Schoelesser 1993). This is a new economic and environmental problem for South America. Until the beginning of the 1990s, macrofouling in the Neotropical region was only found in marine and mixohaline waters (Darrigran & Ezcurra de Drago 2000). Since the introduction of *L. fortunei*, this kind of fouling has also developed in freshwater environments. Among the problems caused, the following stand out:

1. light reduction of pipelines;
2. pipe obstruction;
3. reduction in the flux velocity in pipes due to the loss through friction (turbulent fluxes);
4. accumulation of empty valves and pollution of water ways by massive mortality;
5. filter occlusion (Fig. 1, D-E)
6. increase in the corrosion of surfaces due to settlements.

This invasive species has a great impact on the human environment especially through the problems caused within energy power plants. In 1997 *Limnoperna fortunei* was recorded at Yacyretá Dam (Joint Argentine and Paraguay construction, 27°29'S; 56°44'W). In the world's largest dam, Itaipú (Joint Brazil and Paraguay construction, 25°25'S; 54°25'W) it was recorded in 2001 at a density of 4 to 5 individuals per m^2 and in only 12

months this density grew to 14,000 individuals per m^2 causing the problems listed above (O. Zanella, pers. com.). *Limnoperna fortunei* was absent from the Uruguay River (probably due to the lack of commercial transport), however in 2000 it was found in low densities, and within a few months it was collected in the Salto Grande dam (Joint Argentine and Uruguay construction, 31°17'S; 57°57'W), and as such, now the species poses a potential problem there.

ECOLOGICAL AND CONSERVATION IMPLICATIONS

The populations of this mussel live at high densities (100,000 individuals per m^2) in the available hard substrate of rivers in the La Plata Basin. This has had an impact on other species in the drainage basin with changes in the abundance of local populations of gastropods (Martín & Darrigran 1994) and bivalves (Darrigran 2000). Since the invasion, fishes like *Leporinus obtusidens* Valenciennes have changed their largely molluscivorous diet (Penchaszadeh *et al.* 2000) and the macrobenthic composition of the fauna associated with the byssus threads (Darrigran *et al.* 1998) has also changed.

The consequences of this successful invasion mean that North America and Europe should now consider that any vessel coming from South American waters is a potential agent of infection for *L. fortunei* where, in the past, only vessels from south-east Asia were potential sources of this invasive species.

ACKNOWLEDGEMENTS

We are grateful to Dr. Alice Takeda (Brazil) and Ing. Olivo Zanella (Argentina) for information on early records of *L. fortunei*. This project was partly support by grants BID 1201 OC/AR PICT 01-03453 from the Agencia Nacional de Promoción Científica y Tecnológica, Facultad Ciencias Naturales y Museo, Universidad Nacional de La Plata and Fundación Antorchas all from Argentina. Both authors belong to the Carrera del Investigador, CONICET, Argentina.

REFERENCES

BONETTO A.A. 1994 Austral rivers of South America. *In* (R. Margalef ed.) *Limnology Now: A Paradigm of Planetary Problems* pp. 425-472 Elsevier Science, The Netherlands.

DARRIGRAN G. 1992 Variación temporal y espacial de la distribución de las especies del género *Corbicula* Megerle, 1811 (Bivalvia, Corbiculidae) en el estuario del Río de la Plata, República Argentina *Neotropica* **38**: 59-63.

DARRIGRAN G. 2000 Invasive freshwater bivalves of the Neotropical region *Dreissena* **11**: 7-13.

DARRIGRAN G. & PASTORINO G. 1995 The recent introduction of a freshwater asiatic bivalve, *Limnoperna fortunei* (Mytilidae) into South America *The Veliger* **38**: 171-175.

DARRIGRAN G., MARTIN S.M., GULLO B. & ARMENDARIZ L. 1998 Macroinvertebrate associated to *Limnoperna fortunei* (Dunker, 1857) (Bivalvia, Mytilidae) Río de La Plata, Argentina *Hydrobiologia* **367**: 223-230.

DARRIGRAN G. & EZCURRA DE DRAGO I. 2000 Distribución de *Limnoperna fortueni* (Dunker, 1857) (Mytilidae), en la Cuenca del Plata, Región Neotropical *Medio Ambiente* **13**: 75-79.

ENO N.C. 1998 The introduction to British waters of non-native marine molluscs and the implications to nature conservation interests *Journal of Conchology, Special Publication* **2**: 287-294.

Hylton Scott M. 1953 Sobre limnaeidae argentinos *Physis* **20**: 401- 408.

Ituarte C. 1981 Primera noticia acerca de la introducción de pelecípodos asiáticos en el área rioplatense (Mollusca: Corbiculidae) *Neotropica* **27**: 79-83.

Kimura T. 1994 Morphological identification of *Limnoperna fortunei* (Dunker) and *Limnoperna fortunei kikuchii* Habe *Chiribotan* **25**: 36-40.

Lowe S. 1997 *Draft IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion.* International Union for Conservation of Nature and Natural Resources. http://www.iucn.org/

Mansur M.C.D., Richinitti L.M.Z. & Santos C.P. DOS 1999 *Limnoperna fortunei* (Dunker, 1857) molusco bivalve invasor na Bacia do Guaíba, Rio Grande do Sul, Brasil *Biociências* **7**: 147-149.

Martin S.M. & Darigran G.A. 1994 *Limnoperna fortunei* (Dunker, 1857) en el Balneario Bagliardi, Río de la Plata. Alteración en la composición de la malacofauna litoral *Tankay* **1**: 161-166.

McMahon R.F. 2000 Invasive Characteristics of the freshwater bivalve *Corbicula fluminea. In* (Claudi R & Leach J. eds) *Nonindigenous freshwater organisms: vectors, biology and impacts* 315-343 Lewis Publishers, Boca Raton.

Miquel S. 1985 Presencia del género *Physella* Haldeman, 1842 en la República Argentina (Mollusca Pulmonata Physidae) *Neotropica* **31**: 38.

Morton B. 1977 The population dynamics of *Limnoperna fortunei* (Dunker, 1857) (Bivalvia: Mytilacea) in Plover Cove Reservoir, Hong Kong *Malacologia* **16**: 165-182.

Morton B. 1996 The aquatic nuisance species: a global perspective and review. *In* (D´itri F. ed) *Zebra Mussels and other Aquatic Species* 1-54 Ann Arbor Press, Ann Arbor.

Nalepa T. & Schloesser W. (eds.) 1993 *Zebra Mussels. Biology, impacts, and control.* Lewis Publishers. 508pp.

National Geographic Society 1999 Millennium in Maps Biodiversity. *Supplement to National Geographic* **195** (2).

National Research Council 1996 *Committe on Ships Ballast Operations Stemming the tide: controlling introductions of nonindigenous species by ships ballast water.* National Academy Press. Washington, D.C. pp141.

Pastorino G., Darrigran G., Martín S.M. & Lunaschi L. 1993 *Limnoperna fortunei* (Dunker, 1857) (Mytilidae), nuevo bivalvo invasor en aguas del Río de la Plata *Neotropica* **39**: 34.

Penchaszadeh P., Darrigran G., Angulo D., Averbuj A., Brignoccoli A., Brögger M., Dogliotti A. & Pírez N. 2000 Predation on the invasive freshwater mussel *Limnoperna fortunei* (Dunker, 1857)(Mytilidae) by the fish *Leporinus obtusidens* Valenciennes, 1846 (Anostomidae) in the Río de la Plata, Argentina *Journal of Shellfish Research* **19**: 229-231.

Peso J. & Quintana M. 1999 Otro molusco de origen asiático introducido en la Cuenca del Plata: *Melanoides tuberculata* en el embalse de Yacyretá, Argentina/Paraguay (Prosobranchia: Thiaridea). *IV Congreso Latinoamericano de Malacología* **31**. Coquimbo, Chile.

Ricciardi A. 1998 Global range expansion of the asian mussel *Limnoperna fortunei* (Mytilidae): Another fouling threat to freshwater systems *Biofouling* **13**: 97-106.