ZOOLOGIA 34: e22181
ISSN 1984-4689 (online)
zoologia.pensoft.net

RESEARCH ARTICLE

# Variation in the distribution of *Corbicula* species (Mollusca: Bivalvia: Corbiculidae) after 25 years of its introduction in the Río de la Plata, Argentina

**Yamila Reshaid[1], Luciana Cao[1], Francisco Brea[1], María Ortiz Blanche[1], Santiago Torres[2], Gustavo Darrigran[1]**

[1]*División Zoología Invertebrados, Museo de La Plata (FCNyM-UNLP), Paseo del Bosque 1900, La Plata, Buenos Aires, Argentina.*
[2]*Unidad Académica San Julián, Universidad de la Patagónica Austral, Colón y Sargento Cabral, Puerto San Julián, Santa Cruz, Argentina.*
*Corresponding author: Gustavo Darrigran* (invasion@fcnym.unlp.edu.ar)

*http://zoobank.org/4617DD09-6265-48BB-83D1-2DBC0AF18AB9*

ABSTRACT. In 1981, *Corbicula fluminea* (Müller, 1774) and *C. largillierti* (Philippi, 1844) were recorded at the Río de la Plata River. During the 1980's, *C. largillierti* was found on a continuous fringe in the shore of that river, while *C. fluminea* was only found North of Buenos Aires' harbor. Ten years later, *C. fluminea* spread to Punta Indio, while *C. largillierti* remained restricted to tributary streams. The density and size frequency distribution of both species were compared with previous data from samples performed in the same area in 1985–1989. The aim of this research was to determine whether the densities of both species decreased; whether *C. fluminea* is still more abundant than *C. largillierti*; and whether the size frequency distributions indicate different population structures from those observed in the end of the 1980's. Nine localities from the river shore were sampled, and each individual was identified and measured. The size of *C. fluminea* varied between 2 and 39 mm, showing the highest frequency of individuals between 20 and 25 mm; furthermore the density decreased 90% in 2015/2016. No specimens of *C. largillierti* were found. In conclusion, the populations of *Corbicula* inhabiting the Río de la Plata River are retracting.

KEY WORDS. Bivalves, freshwater, invasion, invertebrates, mussel.

## INTRODUCTION

The Asiatic clam, *Corbicula fluminea* (Müller, 1774) naturally inhabits freshwater bodies from Southeast Asia, Africa, India, Pacific Islands and Australia (McMahon 1983, 2000). This species arrived in North America in 1920 (McMahon 2000) causing important environmental and economic problems, which resulted from its ability to reproduce quickly, and its capacity to adapt to different ecological conditions (Britton and Morton 1979, McMahon 1983). The first report of the presence of *C. fluminea* in Europe was in 1981, based on findings on the shores of the Dordogne River in France and the Tajo River in Portugal (Mouthon 1981).

In South America, two species of *Corbicula* Megerle, 1811, *C. fluminea* and *C. largillierti* (Philippi, 1844), arrived in the Río de la Plata River in the 1970's, according to Ituarte (1981), who mentioned the presence of *Corbicula* sp. for the first time in South America. Likewise, *C. fluminea* was introduced in Rio Grande do Sul (30°11'S, 51°16'W), Brazil (Mansur and Pares Garces 1988) in the late 1970's. Veitenheimer-Mendes and Olazarry (1983) provided new records from the Uruguay River (34°02'S, 58°15'W), Uruguay (Colonia Department) and in the Río de la Plata River (34°27'S, 57°15'W), Uruguay (San José Department).

In 1979, Ituarte (1981) mentioned the genus *Corbicula* for the first time in the Río de la Plata River shore and described that *Corbicula* spp. occupied a continuous fringe along its margins, from headwaters (34°29'S, 58°13'W) to Magdalena's beach (35°1.813'S, 57°30.317'W), being absent from its tributary streams. That distribution pertained *C. largillierti*, while *C. fluminea* was only found at the north of the Buenos Aires harbor (34°29'S, 58°13'W) (Ituarte 1981, 1985). During 1982, *C. fluminea* settled in Atalaya, near the southern limit of the species in the river's shore (Ituarte 1985). In 1985, speciemens of *Corbicula* were found for the first time in tributary streams of Río de la Plata River (Darrigran 1992a). At the end of the 1980's, almost a decade after the first record, the distribution of the genus changed (Fig. 1): *C. fluminea* inhabited a continuous fringe on the shore, from the headwaters to Punta Indio, where it was sporadically found; whereas *C. largillierti* was only found from La Balandra to Magdalena (Darrigran 1992b).

*Corbicula fluminea* reached high densities when compared to the native bivalves, approximately 1,200 ind./m$^2$ in the Río de la Plata River (Darrigran 1991), or between 4,000 and 5,000 ind./m$^2$ in Río Grande do Sul, Brazil (Santos et al. 2012). Despite this, there were only a few reports of the species' economic impact in South America during 1998, at a hydroelectric power station located in Rio Grande do Sul (macrofouling in heat exchangers) (Santos et al. 2012), contrasting with the impact that species of *Corbicula* cause in North America (see McMahon 1983, 2000).

The aim of the present work was to ascertain the distribution of *Corbicula* in the Argentinian shore of the Río de la Plata River. The following hypotheses were tested: 1) the densities of both species have decreased; 2) *C. fluminea* is found in higher frequencies than *C. largillierti*; 3) the size frequency distributions indicate different population structures than those found in the end of the 1980's.

## MATERIAL AND METHODS

Samples were taken from nine localities along the Argentinian shore of Río de la Plata River, between June 2015 and June 2016, during low tides (Table 1, Fig. 1). In each locality, a sampling area was delimited and the clams were manually collected. Depending on the type of environment, the area was delimited by a cylindrical sampler of 0.05 m$^2$, which was pushed into the sediment up to 0.10 m depth; or by a square of 1 m$^2$. From each site, 2 to 4 samples were taken (Table 1). The sediment was sieved through a mesh of 1mm of pore diameter in the field and the specimens were separated. In the laboratory, each individual was identified and measured (maximum length) using a digital caliper, following Darrigran and Maroñas (1989). In the present work, size frequency distributions in the Argentinian shore of the Río de la Plata River were compared between the late 1980's (Darrigran and Maroñas 1989) and this study. Density (D = number of individuals/m$^2$) and size frequency distribution were plotted and analyzed for both species. Frequency percentages were calculated by: F = m.100/M, where m is the number of samples with presence of specimens, and M is the total number of samples collected. Due to the lack of the assumptions of the Student t test, a non-parametric statistical analysis of Mann-Whitney U test was performed to compare the densities values obtained between 1985-1989 for the same localities (Darrigran 1991, 1992b).

## RESULTS

*Corbicula fluminea* was present in seven sampling sites (Table 1). Its mean population density varied between 0 and 52.23 ind/m$^2$. Figure 2 shows the variation between the density values. The frequency value obtained for *C. fluminea* was 52%. No live specimens of *C. largillierti* were found during the sampling.

Table 1. Sampling localities. Geographical coordinates, sample date, number of samples (n), Presence (+), Absence (–) of *C. fluminea* and substrate type.

| Locality | Geographical coordinate | Date | n | Presence/ Absence | Substrate Type |
|---|---|---|---|---|---|
| Anchorena | 34°29'S, 58°13'W | 10 Dec 2015 | 3 | – | "Tosca" (tight sandy silt) and stone |
| Quilmes | 34°42'S, 58°13'W | 20 Jun 2016 | 3 | + | Sand, stone |
| Punta Lara | 34°45'S, 57°59'W | 6 Jun 2016 | 2 | + | Sand |
| Bagliardi | 34°52'S, 57°48'W | 26 Oct 2015 | 3 | + | Sand-lime, stone |
| La Balandra | 34°55'S, 57°43'W | 17 Jun 2015 | 4 | + | Sand, stone |
| Punta Blanca | 31°56'S, 57°40'W | 28 Sep 2015 | 3 | + | Sand, rush |
| Atalaya | 35°08'S, 57°31'W | 22 Jul 2015 | 4 | + | Sand |
| Magdalena | 35°10'S, 57°30'W | 22 Jul 2015 | 3 | + | Sand |
| Punta Indio | 35°16'S, 57°13'W | 7 Nov 2015 | 2 | – | Sand, stone, rush |

Through a non-parametric statistical analysis Mann-Whitney U test (U = 1097, p = 0.000039), significant differences were found when comparing the densities obtained during this study with those previously registered for the same localities (Darrigran 1992b).

Figure 3 compares the size distribution values published by Darrigran and Maroñas (1989) with those from this work (2015/2016). The size frequency for *C. fluminea* varied between 2 and 39 mm, showing the highest frequency of individuals between 20 and 25 mm in Magdalena's beach.

## DISCUSSION

The comparison between the density values of the species of *Corbicula* obtained during this study and those recorded 25 years ago in the same samples sites, leads to the conclusion that these species are retracting from the shores of Río de la Plata River'. While in the 80's *C. fluminea* and *C largillierti* showed frequency values of 75% and 37% respectively, the frequency value obtained for *C. fluminea* in this study was 52%, and no individuals of *C. largillierti* were found alive. Significant differences between densities recorded in 2015-2016 with those registered in 1990 for the same localities allow us to state that the density of the species has decreased by about 90%.

The decreasing density (e.g. *C. fluminea*) or the displacement of a species from an environment (e.g. *C. largillierti*), are frequent phenomena and their causes are very difficult to ascertain. Similar examples are the mass mortality of the native species *Amarilladesma mactroides* (Reeve, 1854) in South America (Fiori and Cazzaniga 1999) or the invasive species, *Limnoperna fortunei* (Dunker, 1857), in Embalse Río Tercero 32°13'S, 64°26'W), Argentina (Mariñelarena et al. 2016). Also, the reduction and displacement of the species of *Corbicula* in the Argentinian shore of Río de la Plata River could be associated

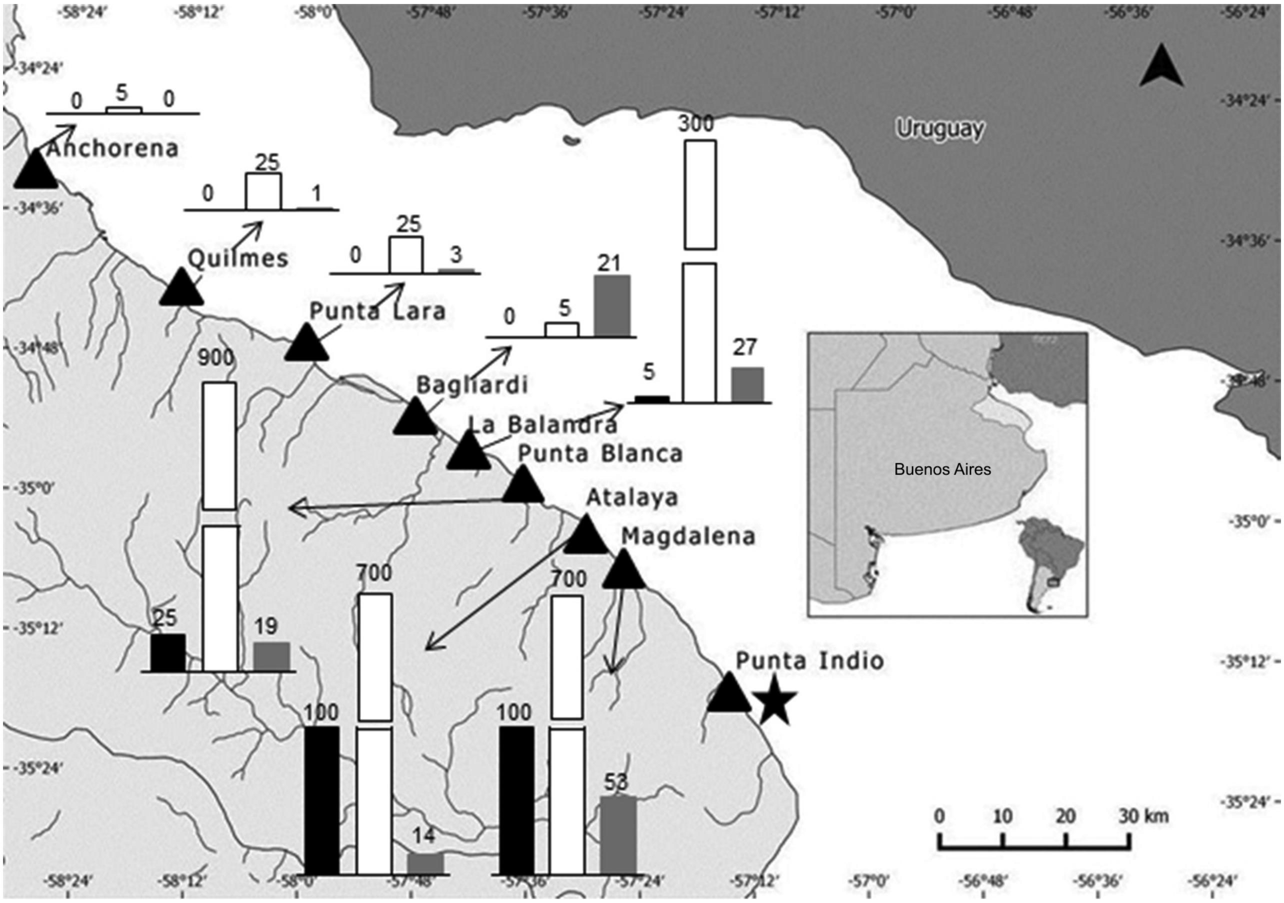


Figure 1. Sampling localities and comparison of densities means, data from Darrigran (1992b) vs. data from present study. Black bars: *C. largillierti* in 80's; White bars: *C. fluminea* in 80's; Grey bars: *C. fluminea* 2015/2016. (★) Sporadic presence of *C. fluminea* in 80's.

with the tourist activities there. However, tourism in the area has not changed much since the introduction of the species. Tourism and related outdoor recreation involve the frequent congregation of people, vehicles and vessels from geographically diverse areas. These are considered major pathways for the spread of non-native species (Anderson et al. 2015). For this reason, the tourism-related activities in the Argentinian shore of Río de la Plata River are more likely to spread non-native species like *C. fluminea* and *C. largillierti*, than they are to control their populations. Apparently, *C. largillierti* is being displaced to tributary streams, where it lives in sympatry with *C. fluminea*. It is, however, found in lower densities than *C. fluminea*. This preference *C. largillierti* has for streams and other lotic environments, was detected by Reyna et al. (2013), in the Suquía River basin, Argentina (31°32'S, 64°10'W). Also, it should be noted that there are environmental differences between the Río de la Plata and the tributary streams. Cortelezzi et al. (2015) described the Argentinian pampean region streams as having: low slope (<1%), slow speed of flow, high turbidity, abundant organic matter, and elevated content of suspended solids. Their streambed consists of fine sediments (primarily silt and clay) and few stones or pebbles. Along their course dense macrophyte stands and periphyton growth are observed. According to Darrigran (1999) there are large areas of the Río de la Plata shore with different types of substrate: "soft" substrate: sand beach, stones and aquatic vegetation, "hard" substrate: "caliche" beach. *C. fluminea* is found in soft sediments and stones. In addition, the margins of the Rio de la Plata are influenced by an unstable and unpredictable hydrological regimen due to the action of daily tides of unequal levels. Also, the wind causes significant disturbances in the daily tides (Darrigran 2002a).

In the Argentinian shore of the Río de la Plata River, the size of *C. fluminea* varied between 2 and 39 mm. The highest frequency of individuals between 20 and 25 mm was found in Magdalena's beach, which is also the locality with the highest density of individuals in the present work (Fig. 2). The sizes observed in Punta Blanca by Darrigran and Maroñas (1989) varied between 1 and 36 mm, with 2 mm individuals being more

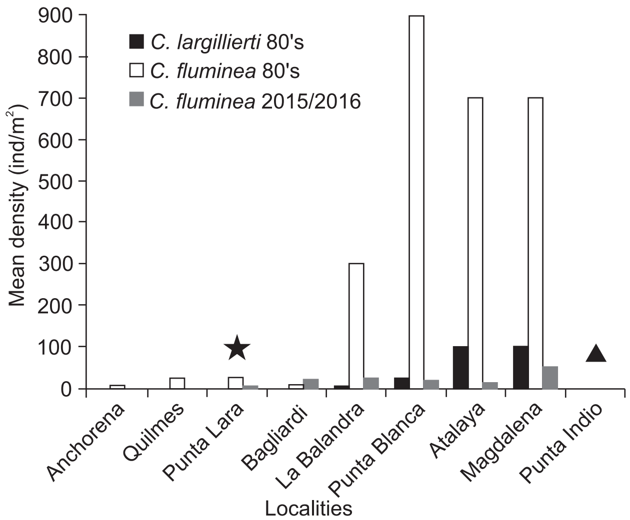


Figure 2. *Corbicula* spp. mean density at sampled localities and previous density values for the same localities (Darrigran 1992b). (★) Presence of *C. largillierti* in 80’s; (▲) sporadic presence of *C. fluminea* in 80’s.

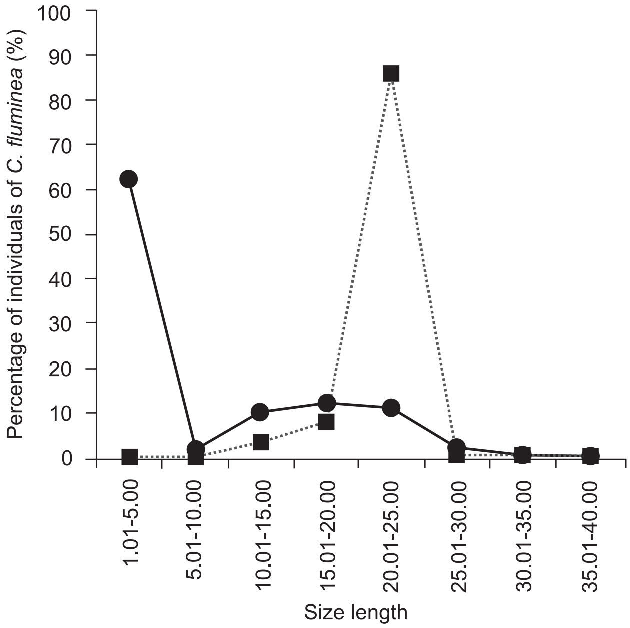


Figure 3. Comparison of the size distribution between the values of Darrigran and Maroñas (1989) (●) and 2015/2016 (■).

abundant (about the 42% of the specimens). The population of *C. fluminea* in the late 1980’s was increasing, right after its introduction into Río de la Plata River, but now, 25 years later, the population is in lower densities and individuals are on average smaller (less than 20 mm length), indicating that the population is shrinking.

It is possible that a decrease in population density could be caused by environmental changes such as extreme variations in the water level (Paschoal et al. 2015). However, such changes are temporal and the population usually recovers when conditions are reversed. Two changes have been observed in the *Corbicula* populations of the Río de la Plata River’s shore: 1) the frequency and density of individuals have decreased and 2) *C. largillierti* has been displaced.

The first change could be the expected outcome of a three-phase process of invasion (Darrigran and Damborenea 2009). According to this model, during the first invasion phase, a species establishes in the new environment and its population grows slowly. Then, in the second phase (“panic” phase), the invasive population grows quickly, exceeding the carrying capacity of the environment. In the last phase, the population stops growing exponentially and the density of individuals declines to a level that does not exceed the environment’s carrying capacity, reaching a state of “oscillatory equilibrium” around the level mentioned before (Darrigran and Guimarey 2011).

The influence of *C. fluminea* on benthic species was investigated by Ilarri et al. (2014). *C. fluminea* often plays the role of ecosystem engineer, generally causing physical disruptions in the ecosystems where the species is established, by changing the structure of the communities of benthic macroinvertebrates (Linares et al. 2017). It is possible that *C. fluminea* has displaced *C. largillierti* from the Argentinian shore of Río de la Plata River (Darrigran 2002b), since *C. largillierti* has not become established there (Darrigran 1992b, Ituarte 1994). Darrigran (1991) analyzed the temporal variation in the densities of both species in two areas of sympatry, in two localities of Río de la Plata River: Punta Blanca (34°56’S, 57°40’W) and Atalaya Beach (35°00’S, 57°33’W). In this result, *C. largillierti* was rare and was only found in restricted areas of the Río de la Plata River basin (Darrigran 2002b). The same can happen in the Suquía River basin. While *C. fluminea* is continually expanding geographically, *C. largillierti* is not (Reyna et al. 2013). About ten years after the ingression and dispersion of the two species of *Corbicula* to the Río de la Plata River area, other invasive species have arrived in Río de la Plata River. The population of *L. fortunei*, introduced in the early 1990’s, has increased exponentially in density (reaching a density of 150,000 ind/m$^2$), invading the new environment and causing the displacement of native and non-native species (Darrigran and Pastorino 1995, Pastorino et al. 1993). Probably the presence of this aggressive invasive species in the same environment as *C. fluminea* and *C. largillierti* is a factor that has altered the presence of both species. This is similar to the impact produced by *L. fortunei* on other benthic species (Darrigran et al. 1998, Darrigran and Ezcurra de Drago 2000, Darrigran 2002b, Darrigran and Damborenea 2011, Sylvester and Sardiña 2015).

## ACKNOWLEDGEMENTS

This work was partially financed by the Facultad de Ciencias Naturales y Museo-UNLP-(11/N795), Beca Entrenamiento de la CIC, Beca Interna Doctoral CONICET, Beca de Experiencia Laboral FCNyM (UNLP) and CONICET. LC, ST and GD are researchers of CONICET. We thank C. Damborenea for helping in the assorted tasks.

## LITERATURE CITED

Anderson LG, Rocliffe S, Haddaway NR, Dunn AM (2015) The Role of Tourism and Recreation in the Spread of Non-Native Species: a systematic review and meta-analysis. PLoS ONE 10: 1–15. https://doi.org/10.1371/journal.pone.0140833

Britton JC, Morton B (1979) *Corbicula* in North America: the evidence reviewed and evaluated. In: Britton JC (Ed.) Procedures of the First International Corbicula Symposium. Texas Christian University, Forth Worth, 21–31.

Cortelezzi A, Ocón C, López van Oosterom MV, Cepeda R, Rodrigues Capítulo A (2015) Nutrient enrichment effect on macroinvertebrates in a lowland stream of Argentina. Iheringia, Série Zoologia, 105: 228–234. https://doi.org/10.1590/1678-476620151052228234

Darrigran G (1991) Competencia entre dos especies de Pelecípodos invasores: *Corbicula fluminea* (Müller 1774) y *C. largillierti* (Philippi, 1844) en el litoral argentino del estuario del Río de la Plata. Biologia Acuática 15: 214215.

Darrigran G (1992a) Nuevos datos acerca de la distribución de las especies del género *Corbicula* (Bivalvia, Sphaeriacea) en el área del Río de la Plata, República Argentina. Notas Museo La Plata 21: 143–148.

Darrigran G (1992b) Variación temporal y espacial de la distribución de *Corbicula* Mengerle, 1811 (Bivalvia, Corbiculidae), en el estuario del Rio de la Plata, República Argentina. Neotropica 38: 59–63.

Darrigran G (1999) Longitudinal distribution of molluscan communities in the Río de la Plata estuary as indicators of environmental conditions. Malacological Review 8: 1–12.

Darrigran G (2002a) Spatial and temporal changes of the malacofauna from a sandy shore in the Río de la Plata, Argentina. Malacological Review 31/32: 101–116.

Darrigran G (2002b) Potential impact of filter-feeding invaders on temperate inland freshwater environments. Biological Invasions 4: 145–156. https://doi.org/10.1023/A:1020521811416

Darrigran G, Damborenea MC (2009) Introdução a Biologia das Invasões o Mexilhão Dourado na América do Sul: biologia, dispersão, impacto, prevenção e controlo. CUBO Editora, São Carlos, 248 pp.

Darrigran G, Damborenea C (2011) Ecosystem engineering impacts of *Limnoperna fortunei* in South America, Zoological Science 28: 1–7. https://doi.org/10.2108/zsj.28.1

Darrigran G, Ezcurra de Drago I (2000) Invasion of *Limnoperna fortunei* (Dunker, 1857) (Bivalvia: Mytilidae) in America. Nautilus 2: 69–74.

Darrigran G, Guimarey P (2011) Bio Invasiones en el Sur del Cono Sur. Una aproximación de las invasiones de los moluscos acuáticos, 336-349. In: Santos SB dos, Pimenta AD, Fernandez MA, Thiengo SC (Orgs) Tópicos em Malacologia. Ecos do XIX Encontro Brasileiro de Malacologia, Rio de Janeiro, 468 pp.

Darrigran G, Maroñas M (1989) Crecimiento de las poblaciones naturales de *Corbicula fluminea* (Muller, 1774) y *C. largillierti* (Philippi, 1844) (Bivalvia: Sphaeriacea), en el litoral de Punta Blanca, en el estuario del Río de la Plata, República Argentina. Comunicaciones de la Sociedad Malacológica del Uruguay 7: 139157.

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 SM, Gullo B, Armendariz L (1998) Macroinvertebrates associated with *Limnoperna fortunei* (Dunker, 1857) (Pelecipoda, Mytilidae) in Río de la Plata, Argentina. Hydrobiologia 367: 223–230. https://doi.org/10.1023/A:1003-244603854

Fiori SM, Cazzaniga NJ (1999) Mass mortality of yellow clam *Mesodesma mactroides* (Bivalvia: Mactracea) in Monte Hermoso beach Argentina. Biological Conservation 89: 305–309. https://doi.org/10.1016/S0006-3207(98)00151-7

Ilarri MI, Souza AT, Antunes C, Guilhermino L, Sousa R (2014) Influence of the invasive Asian clam Corbicula fluminea (Bivalvia: Corbiculidae) on estuarine epibenthic assemblages. Estuarine, Coastal and Shelf Science 143: 12–19. https://doi.org/10.1016/j.ecss.2014.03.017

Ituarte CF (1981) Primera noticia de la introducción de pelecípodos asiáticos en el área Rioplatense (Mollusca, Corbiculidae). Neotropica 27: 79–82.

Ituarte CF (1985) Growth dynamics in a natural population of *Corbicula fluminea* (Bivalvia Sphaeriacea) at Punta Atalaya, Río de La Plata, Argentina. Studies of Neotropical Fauna Environment 4: 217–225. https://doi.org/10.1080/01650528509360693

Ituarte CF (1994) *Corbicula* y *Neocorbicula* (Bivalvia: Corbiculidae) in the Paraná, Uruguay and Río de la Plata Basins. The Nautilus 107: 12–135.

Linares MS, Callisto M, Marques JC (2017) Invasive bivalves increase benthic communities complexity in neotropical reservoirs. Ecological Indicators 75: 279–285. https://doi.org/10.1016/j.ecolind.2016.12.046

Mansur MCD, Pares Garces LMM (1988) Ocorrencia e densidade de *Corbicula fluminea* (Muller, 1774) e *Neocorbicula limosa* (Maton, 1811) no Estacao Ecologica do Taim e areas adjacentes. Rio Grande do Sul, Brasil. Iheringia, Série Zoologia, 68: 99–116.

Mariñelarena A, Mac Donagh ME, Donadelli J, Casco MA (2016) Un caso inusual de eutrofización en el Embalse Río Tercero: el posible rol de dos bioinvasores Biología Acuática 31: 10–18.

McMahon RF (1983) Ecology of an invasive pest bivalve *Corbicula*. In: Russell-Hunter WD (Ed.) The Mollusca Ecology. Academic Press, New York, 505–561. https://doi.org/10.1016/B978-0-12-751406-2.50019-2

McMahon RF (2000) Invasive Characteristics of the Freshwater Bivalve *Corbicula fluminea.* In: Claudi R, Leach JH (Eds) Nonindigenous Freshwater Organisms. Lewis Publishers, Boca Raton, 464 pp.

Mouthon J (1981) Sur la présence en Francia et en Portugal de *Corbicula* (Bivalvia Corbiculidae) originaire d'Asia. Basteria 45: 109–116.

Paschoal LRP, Andrade DP, Darrigran G (2015) How the fluctuations of water levels affect populations of invasive bivalve *Corbicula fluminea* (Müller, 1774) in a Neotropical reservoir? Brazilian Journal of Biology 75: 135–143. https://doi.org/10.1590/1519-6984.09113

Pastorino G, Darrigran G, Martín SM, Lunaschi L (1993) *Limnoperna fortunei* (Dunker, 1857) (Mytilidae), nuevo bivalvo invasor en aguas del Río de la Plata. Neotropica 39: 101–102.

Reyna PB, Morán AG, Tatián M (2013) Taxonomy, distribution and population structure of invasive Corbiculidae (Mollusca, Bivalvia) in the Suquía River basin, Córdoba, Argentina. Iheringia, Série Zoologia, 103:77–84. https://doi.org/10.1590/S0073-47212013000200001

Santos SB, Thiengo SC, Fernandez MA, Miyahira IC, Gonçalves ICB, Ximenes RF (2012) Espécies de moluscos límnicos invasores no Brasil. In: Mansur MCD et al. (Orgs). Moluscos Limnicos Invasores no Brasil: biologia, prevenção e controle. Redes Editoras, Porto Alegre, 418 pp.

Sylvester F, Sardiña P (2015) Relationships of *Limnoperna fortunei* with Benthic Animals. In: Bolltovskoy D (Ed.) *Limnoperna fortunei*. The ecology, distribution and control of a swiftly spreading invasive fouling mussel. Springer Series in Invasion Ecology, 191–210. https://doi.org/10.1007/978-3-319-13494-9_11

Veitenheimer Mendes IL, Olazarri J (1983) Primeros registros de *Corbicula* Megerle, 1811 (Bivalvia, Corbiculidae) para el Río Uruguay. Boletin de la Sociedad Zoológicadel Uruguay 1: 50–53.

Submitted: 25 October 2016
Received in revised form: 17 January 2017
Accepted: 17 February 2017
Editorial responsibility: Stephan Bullard

**Author Contributions:** YR LC FB MOB and ST conducted the samplings, analyzed the data and wrote the paper. GD designed the sampling proceedings in Rio de la Plata River shore, analyzed the data and corrected the manuscript.

**Competing Interests:** The authors have declared that no competing interests exist.