THE OCCURRENCE OF THE ASIAN CLAM *Corbicula fluminea* IN THE LOWER AMAZON BASIN

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ABSTRACT - This paper records for the first time the presence of *Corbicula fluminea* (Philipi, 1844) in the Brazilian Amazon Basin. This exotic bivalve was found in localities on the Amazonas, Pará and Tocantins rivers. Density and population size structure were measured in some localities. Mean density is between 6.66 and 7.3 individuals m^{-2}. Population size structure and the dates of the first records suggest that the introductions may have occurred between 1997 and 1998. The introductions may have been mediated by ocean-going vessels visiting the ports of Manaus and Belém. The potential impact of the invasion on native freshwater bivalves is discussed along with the need for monitoring and prevention of further introductions of non-indigenous bivalves in Brazil.

Key-words: *Corbicula fluminea*, exotic species, distribution, Amazon.

A ocorrência do bivalve asiatico *Corbicula fluminea* na bacia amazônica inferior

RESUMO - No passado recente, três espécies de moluscos bivalves exóticos têm invadido as águas continentais da América do Sul. O presente trabalho registra pela primeira vez a presença de *Corbicula fluminea* (Philipi, 1844) na bacia amazônica brasileira. Este bivalve exótico foi encontrado em localidades nos rios Amazonas, Pará e Tocantins. A densidade e a estrutura em tamanho da população foram medidas em alguns locais. A densidade média é entre 6.66 e 7.3 indivíduos m^{-2}. A estrutura da população e as datas dos primeiros registros sugerem que os moluscos foram introduzidos entre 1997 e 1998. As introduções talvez tenham sido causadas por navios visitando os portos de Manaus e Belém. O impacto potencial da invasão sobre os moluscos bivalves nativos é discutido bem como a necessidade de monitoramento e a prevenção de outras introduções de moluscos não-indígenos no Brasil.

Palavras-chave: *Corbicula fluminea*, espécie exótica, distribuição, Amazônia.

INTRODUCTION

Three exotic species of freshwater bivalve, all from Southeast Asia, have been introduced into South American inland waters in the recent past (Darrigran, 1997a). *Limnoperna fortunei* (Dunker, 1857) was first reported in South America from the Río de la Plata, Argentina in 1991 (Pastorino *et al.*, 1993; Darrigran and Pastorino, 1995). *Corbicula largillierti* (Philippi, 1844) was first recorded in South America in 1982 on the eastern shore (Uruguay) of the Río de la Plata (Ituarte, 1994). *Corbicula fluminea* was found for the first time in South American rivers in 1978 (Veitenheimer-Mendes, 1981) and was believed to have been introduced to the Guaíba and Jacuí river basins in southern Brazil (Figure 1A) sometime around the beginning of the 1970s (Veitenheimer-Mendes, 1981). *C. fluminea* was first collected from the Río de la Plata (Figure 1B) in 1979 (Ituarte, 1981). *C. fluminea* is now common along the littoral regions of the Río de la Plata estuary and has also been reported

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from two of its most important tributaries, the Parana and Uruguay river basins (Figure 1C and 1D) (Ituarte, 1994). *C. fluminea* was recently recorded from Patagonia (Figure 1E) (Cazzaniga, 1997). In northern South America, *C. fluminea* was reported for the first time in Venezuela from the San Juan and Caripe rivers (Martínez, 1987) (Figure 1F).

All three species are considered invasive because, apart from being exotic, they are characterized by early sexual maturity, high reproductive potential and a remarkable ability to adapt to the environments they colonize (Darrigran, 1997b). Such characteristics allow exotic bivalves to disperse quickly in great numbers (Darrigran and Pastorino, 1995). Their entry into South America most probably occurred via trading ships from Southeast Asia (Ituarte, 1981; Darrigran and Pastorino, 1995).

In Argentina, concern has been growing over the effects of these non-indigenous bivalves on industrial and domestic water intake pipes and other structures (Darrigran and Pastorino, 1995; Darrigran, 1997b). In North America, *C. fluminea* has been spreading throughout rivers since 1924, having been imported as a food item by Chinese immigrants (McMahon, 1982). There it is responsible for bio-fouling of water intakes, pumps, and industrial and power plant cooling systems (Isom, 1986).

Despite the interval since it was first introduced, surprisingly little is known about the effects of *C. fluminea* on the native North American bivalve fauna (Strayer, 1999). *C. fluminea* appears to co-exist with native species both in South America (Duarte and Diefenbach, 1994; Mansur and Garces, 1988; Mansur *et al.*, 1991) and North America (Kraemer, 1979; Miller and Payne, 1993). This paper presents the first records of *C. fluminea* in the Brazilian Amazon and discusses the need for monitoring of the native freshwater bivalve fauna and the prevention of further introductions of exotic bivalve species to Brazil.

MATERIAL AND METHODS

Casual observations of the presence of *C. fluminea* were made at several sites on rivers of the lower Amazon basin. At the Cametá site, a quantitative survey of their density was carried out in two 100 m x 100 m areas which, in a previous survey (Beasley, 2001), had been found to contain three species of native bivalve but that had showed no evidence of *C. fluminea*. Random coordinates were chosen at which a sample of sediment from the river bottom was collected using a metal box that samples aproximately 0.06 m^2 of sediment. The sediment was sieved using a 1 mm^2 mesh size and the bivalves that were removed were counted and measured. Mean density (no. individuals m^{-2}) was estimated from the data.

Shells that were collected at the Alenquer and Cametá sites were measured for anterior-posterior length using a Vernier calipers and length frequency distributions were constructed. The ages of specimens were approximated using age at length data from another South American population (Cataldo and Boltovskoy; 1998).

RESULTS

Figure 1 shows the Alenquer (G), Cametá (I), Caixuanã (H) and Melgaço (J) sites in the Brazilian Amazon where *C. fluminea* was recently recorded. Empty shells of *C. fluminea* were discovered during casual observations of the sandy and sandy-muddy margins of the Surubiú River, a branch of the Amazonas River, in the Municipality of Alenquer, State of Pará, Brazil during October 1998. The shells were very abundant, practically carpeting the river margins. At the time of collection it was not possible to carry out a program of sampling to determine if live specimens were present. Local fishermen say that the larger native bivalves (shell diameter circa 10 cm) at the Alenquer site disappeared and only *C. fluminea* is now found there. Although this has yet to be verified through an objective sampling program, recent casual observations by one of us (WBF) in 1999, suggest that *C. fluminea* may now be the only bivalve present at the Alenquer site.

In January 1999, a single live specimen of *C. fluminea* was found buried in the sandy-muddy sediment of the margin of a small island in the Tocantins River (Municipality of Cametá, State of Pará, Brazil). In August 1999,

large numbers of live individuals, together with native bivalves, were found buried in sediment at different water depths (0.1 m to 3 m) at several beaches at the Cametá site. In June 2000 the mean density estimated for *C. fluminea* at the two surveyed areas in the Cametá site was 6.66 and 7.3 individuals m^{-2}. On the Pará River, *C. fluminea* was found together with native bivalve species at Caixuanã in November 1999 and at Melgaço in June 2000. No density or population structure data are available yet for the latter sites, however it appears that, at these sites, native bivalves are still abundant. At the Cametá site, native bivalve shells form an important economic resource, being used in button manufacture (Beasley, 2001). *C. fluminea* was not found during surveys of freshwater bivalves at sites on the Xingú, Tapajós, Guamá and Irituia rivers, all in the State of Pará.

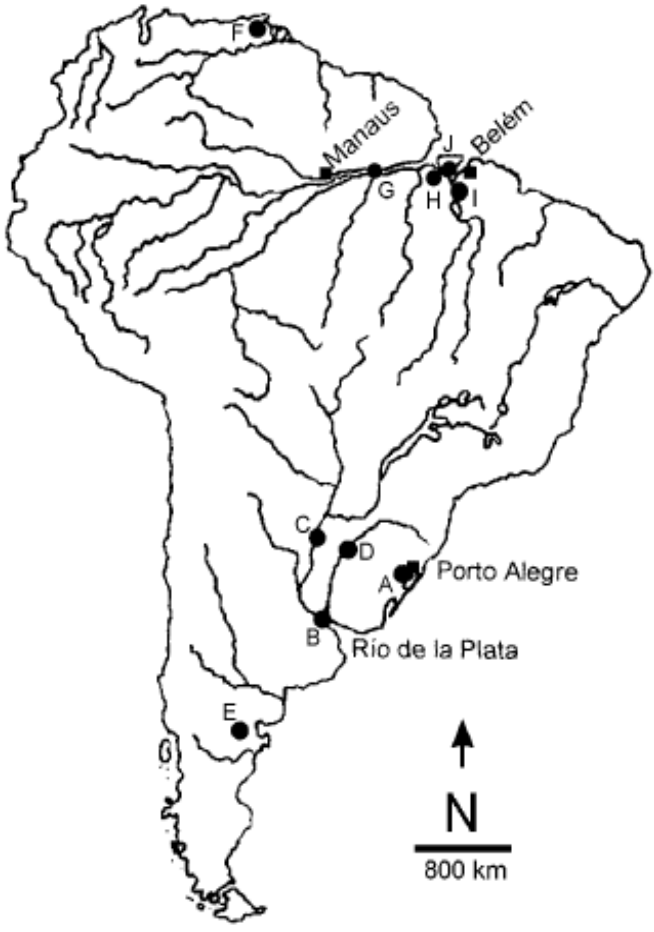

Figure 1. Published (A-F) and new records (G-J) of the occurrence of *C. fluminea* in South America. A. Guaíba & Jacuí rivers, Brazil (Veitenheimer-Mendes, 1981); B. Río de la Plata, Argentina (Ituarte, 1981); C. Parana river, Argentina (Ituarte,1994); D. Uruguay river, Uruguay (Ituarte, 1994); E. Patagonia (Cazzaniga, 1997); F. Caripe & San Juan rivers, Venezuela (Martínez, 1987); G. Alenquer, Surubiú (Amazonas) river, (1998); H. Caixuanã, Pará river, (1999); I. Cametá, Tocantins river (1999); J. Melgaço, Pará river (2000).

Figure 2 shows that the Asian clam size frequency distributions at Alenquer and Cametá are strikingly different. The Alenquer site (Figure 2a) is composed of mainly small shells ranging from 8 to 20.3 mm in length with a modal size class of 12.1-13 mm. *C. fluminea* from the Cametá site (Figure 2b) are larger in size (16.9-26.7) with a modal size class of 22.1-23 mm.

The approximate age distribution of each sample shows that most of the individuals from the Alenquer sample (88%) are less than one year of age whereas the remainder (12%) is made up of one-year-old individuals. The sample from Cametá is almost evenly divided into individuals aged at least one year (55%) and individuals aged at least two years (45%). Based on these age estimates and the dates of first records, the introduction of *C. fluminea* into the lower Amazon Basin may have taken place as recently as 1997 or 1998.

DISCUSSION

Exotic species are those brought outside their original ranges by human activities (Strayer, 1999). The means of dispersal of exotic bivalve species has probably been via ships from Asian countries visiting South American ports (Darrigran and Pastorino, 1995; Darrigran, 1997b). The lower Amazon Basin is largely navigable by ocean-going vessels involved in international trade. Manaus is a busy inland port having a large industrial sector whereas Bélem is the entry point for ships navigating the lower Amazon Basin. One of the most likely scenarios is that juveniles and adults of *Corbicula* are released into the river with the ballast water being pumped out prior to or during cargo loading. *C. fluminea* is originally from Southeast Asia but since the species is well established in other countries, it is possible that ships coming from North America, Argentina or even Porto Alegre in southern Brazil, may have brought *C. fluminea* to the Brazilian Amazon Basin.

Control measures to prevent further introductions must therefore be imposed on all shipping entering Brazilian ports. This is important to prevent bio-fouling of industrial and domestic water intake installations which already causes a great deal of problems in North America (Isom, 1986) and Argentina (Darrigran, 1997b). Methods of control and removal of *C. fluminea* are varied and include filters, electric discharge, chlorine treatment, poisons, electromagnetism, high temperature and ultrasound. However, these methods often incur high cost and some leave toxic residues (Darrigran, 1997a). Chemical treatment using chlorine in combination with a filtering system may be the type of control method appropriate for ballast water.

Once introduced, *C. fluminea* may spread rapidly because of its capacity for direct development, where young are released directly from the adult without a parasitic life stage, and its ability to survive conditions which native bivalves cannot tolerate. From its initial introduction into North America around 1924, *C. fluminea* has spread to and established itself in at least 33 states (Counts, 1986). Its rapid dispersal has been attributed to a combination of human activities and inherent powers of dispersal (McMahon, 1982). *C. fluminea* has enormous potential to inhabit sandy sediment rivers and streams since it can carry out both pedal- (deposit-) and filter-feeding, which together are very efficient in extracting organic matter from the sediment (Hakenkamp and Palmer, 1999). Densities of *C. fluminea* in southern Brazil can reach up to 5000 individuals per m^2 of sediment (Mansur and Garces, 1988) and some populations appear to be on the rise (Duarte and Diefenbach, 1994).

Intensive sampling of native bivalves at the Cametá site did not reveal any *Corbicula* during 1998 (Beasley, 2001), however, in less than a year the bivalve could be easily found at the same locality. The density of *C. fluminea* in the Tocantins is much lower than that recorded in southern Brazil, however, the sites are being monitored for any changes in density. The difference in the size frequency distributions at the Alenquer and Cametá sites may be due to the episode of Asian clam mortality at the former site which may have ocurred early in the establishment of the population, hence the smaller shell size. *C. fluminea* may have been introduced into the Amazon Basin only

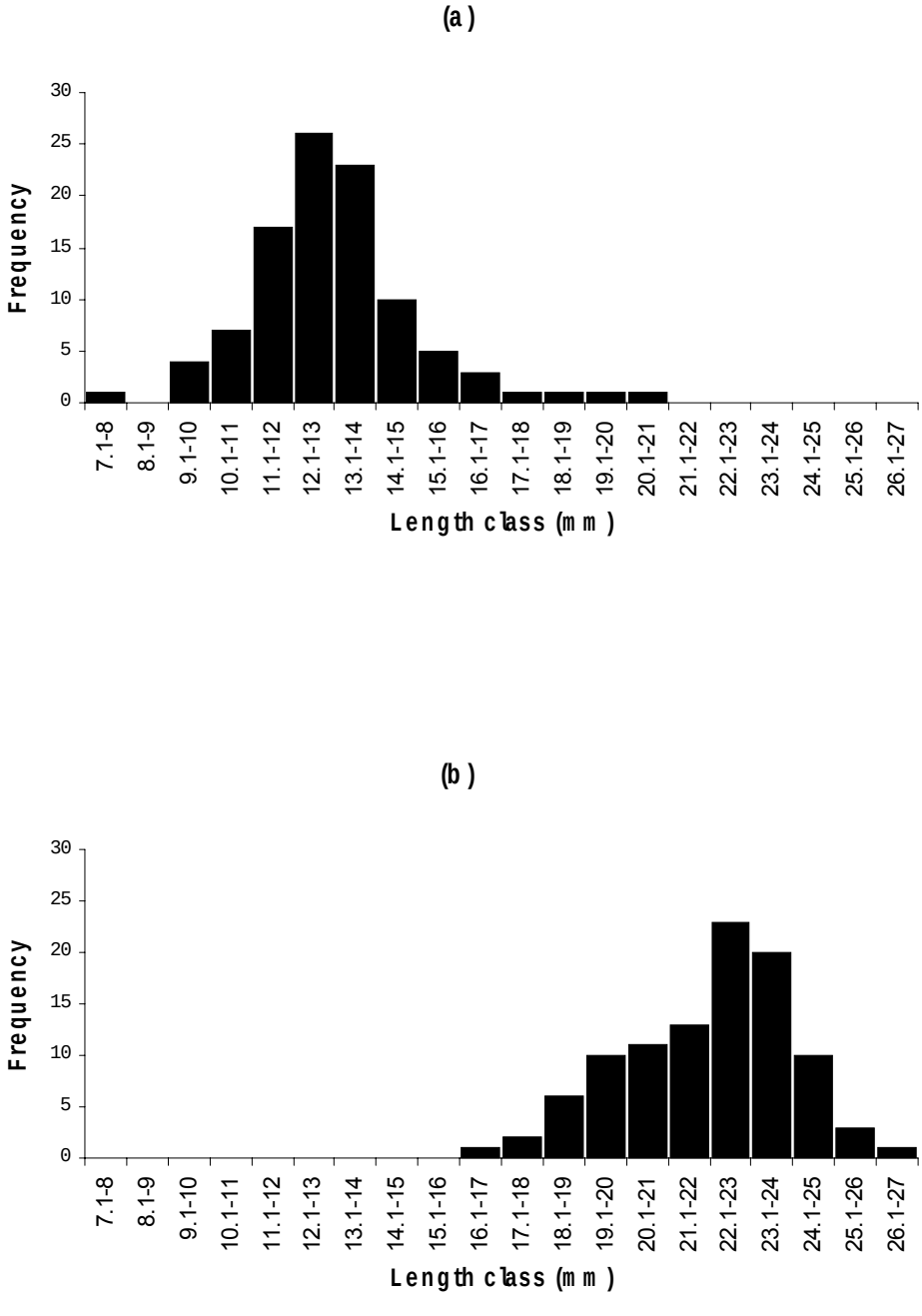

Figure 2. Anterior-posterior length frequency distributions of *C. fluminea* populations at (a) the Alenquer and (b) the Cametá sites in the lower Amazon basin. The number of individuals measured from each site was 100.

recently but if environmental conditions for growth and reproduction are optimal, it may spread rapidly throughout the region. However, there have been no recent reports of *Corbicula* spreading in Venezuela, a region with similar environmental conditions to the lower Amazon Basin, since it was first reported there (Martinez, 1987).

Although *Corbicula* has been found in diverse localities throughout South America, it is likely that the recent northern records represent independent introductions rather than any expansion in the species range through natural means of dispersal. In the south of the Argentina, *C. fluminea* is spreading into Patagonia (Cazzaniga, 1997) whereas in the south of Brazil it appears to be establishing itself among the native bivalve fauna (Mansur and Garces, 1988; Mansur *et al.*, 1991; Duarte and Diefenbach, 1994).

The effects of exotic species on molluscs in South American freshwater ecosystems may be going unnoticed because of the lack of information on the distribution and abundance of the native fauna itself (Bogan, 1993). The recent introductions of exotic bivalves to South America should give rise to concern since it may only be a matter of time before a seriously devastating invader such as the zebra mussel, *Dreissena polymorpha* (Pallas, 1781), if not already present, is introduced. There is evidence of biofouling of Hyriidae and Mycetopodidae by *L. fortunei* in southern Brazil (Mansur *et al.*, 1999) but the long-term effect on populations of native bivalves remains unclear.

Corbicula does not foul native bivalves in the same way that the zebra mussel (Ricciardi *et al.*, 1998) or *L. fortunei* (Mansur *et al.,* 1999) do but it has potential to compete with adult and juvenile bivalves for space and food. Similarly, *Corbicula* may compete with Sphaeridae and the native *Neocorbicula limosa* (Maton, 1809) (Veitenheimer-Mendes, 1981). Branchial incubation is common to *Corbicula* and *Neocorbicula* but the former incubates many more embryos which have a much shorter incubation period than is the case with *Neocorbicula* (Ituarte, 1994). Studies in southern Brazil show, however, that densities of *N. limosa* and *C. fluminea* are similar where both species occur together and it appears that *Corbicula* may coexist with *N. limosa* and other native bivalves (Duarte and Diefenbach, 1994; Mansur and Garces, 1988). Similarly, *C. fluminea* has been found to co-exist with the dense and diverse bivalve faunas of the Mississippi Basin (Miller and Payne, 1993).

Although our observations to date are mainly casual, it is clear that there is an urgent need to monitor South American freshwater bivalves so that the actual status of native bivalves and the presence and impact of introduced species can be determined. This is particularly important for the fauna in the Amazon basin, which is very poorly known. Priority should be given to completing this task given that the recent zebra mussel invasion in North America is predicted to accelerate the extinction rates of native freshwater bivalves there by 10-fold (Ricciardi *et al.*, 1998). A first step in preventing such a scenario in South America would be to implement control measures for the release of ballast waters of all visiting ships so as to prevent further introductions of non-indigenous molluscs (Darrigran, 1997a).

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