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ORIGINAL PAPER

Rapid spread of an invasive snail in South America: the giant African snail, *Achatina fulica*, in Brasil

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Abstract Beginning around 1800, but primarily since the early and mid-twentieth century, the giant African snail, *Achatina* (*Lissachatina*) *fulica* Bowdich, 1822, has been introduced throughout the tropics and subtropics and has been considered the most important snail pest in these regions. In Brasil, specimens probably brought from Indonesia were introduced into the state of Paraná in the 1980s for commercial purposes (''escargot'' farming) that were not successful. *Achatina fulica* is now widespread in at least 23 out of 26 Brasilian states and the Federal District, including the Amazonian region and natural reserves. Among the reasons for the species' rapid invasion are its high reproductive capacity and the tendency for people to release the snails into the wild. *Achatina fulica* occurs in dense populations in urban areas where it is a pest in ornamental gardens, vegetable gardens, and small-scale agriculture. Also of concern is the damage caused to the environment, and potential competition with native terrestrial mollusks. It can also act as an intermediate host of *Angiostrongylus cantonensis*, a nematode that can cause meningoencephalitis in people, and it may be a potential host of *A. costaricensis*, which causes abdominal angiostrongylosis, a zoonosis that occurs from the southern United States to northern Argentina. Management and control measures for *A. fulica* are under way in Brasil through a national plan implemented by the Brasilian government.

Keywords *Achatina fulica* · Brasil · Control · Dispersal · Giant African snail · Mollusca

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Introduction

The giant African snail, *Achatina* (*Lissachatina*) *fulica* Bowdich, 1822, has been considered the most widely introduced and invasive land snail

species in the world, and the most important land snail pest (Mead 1979; Karnatak et al. 1998; Raut and Barker 2002). Its spread, the problems it causes, and the control measures that have been implemented against it have been reviewed most extensively by Mead (1961, 1979) and Raut and Barker (2002). Its introduction to the islands of the Pacific and the subsequent ill-conceived introduction of putative biological control agents have been reviewed by Cowie (1992, 2000, 2001) and Civeyrel and Simberloff (1996).

The chronology of the spread of *A. fulica* around the world has been most recently summarized by Raut and Barker (2002). Starting in its native East Africa, it reached Madagascar by about 1800, thence spreading gradually eastward, reaching the Seychelles and Réunion during the nineteenth century, Sri Lanka by 1900, most of south-east Asia, Japan, and the western Pacific islands of Guam, the Marianas, and Palau in the 1920s and 1930s, and New Guinea by the 1940s (Cowie 2000). Much of this later spread was related to Japanese activities in the years leading up to and during World War II. It was introduced to Hawaii in 1936 and subsequently to many other Pacific islands through the 1970s to 1990s (Cowie 2000). In the Pacific, incipient populations appear to have been eradicated in Fiji and Wake (Raut and Barker 2002), Tuvalu (Anonymous 1996a, b), and Kosrae (Anonymous 1998, 2000), and as of 2006 it has not become established on these islands. It was introduced to the mainland United States (Florida) from Hawaii in 1966, but was contained and eventually eradicated after huge expenditure over a number of years. It continues to be frequently intercepted entering the United States by quarantine officials (Robinson 1999). By 1984, *A. fulica* was established on the Caribbean island of Guadeloupe, by 1988 on Martinique, and subsequently on Barbados and Saint Lucia (Raut and Barker 2002). It was first introduced to Brasil in the 1980s, although Raut and Barker (2002) and Smith (2005) gave 1996–1997 as the date of introduction.

Reasons for the widespread introduction of *A. fulica* are numerous (Cowie and Robinson 2003). Often it has been deliberately introduced as a human, and in some cases animal, food resource, but it has also been introduced as a pet, and for both ornamental and medicinal purposes. It may also be transported inadvertently associated with agricultural, horticultural, and other commercial products and the containers they are shipped in. Accidental transport with military equipment may also be important (Mead 1961).

Achatina fulica has been considered a major agricultural and garden pest (Raut and Barker 2002). It is also a vector of the rat lungworm, *Angiostrongylus cantonensis* (Chen, 1935), which causes eosinophylic meningoencephalitis in humans (Alicata 1991; Prociv et al. 2000). Although the agricultural impacts of *A. fulica* are frequently referred to, it is probably as a general nuisance that it impacts people most severely (Civeyrel and Simberloff 1996). Populations of introduced *A. fulica* may reach enormous densities, to the extent that they crawl up the walls of houses in great numbers, make walking on sidewalks difficult without treading on them, and there have even been reports of cars skidding on massed crushed snails on roads (Mead 1961).

Often, soon after the initial introduction or after a lag phase of a few years, numbers of *A. fulica* increase dramatically, and it is at this point that control measures are frequently considered. Eradication of the introduction in Florida in the 1960s involved massive use of molluscicides, hand collecting, and extensive public awareness measures (Mead 1979). In the islands of the Pacific and Indian Oceans, the use of biological control has been widely considered, notably introduction of a number of predatory snails and a predatory flatworm that have generally failed to control *A. fulica* (Cowie 2001) but that appear to have caused the extinction or decline of locally endemic island species of land snails (Cowie 1992; Hadfield et al. 1993; Coote and Loève 2003). On some of these islands, *A. fulica* has declined, for reasons unknown but not related to the introduction of the putative biocontrol agents (Cowie 1992, 2001).

In this paper we document for the first time in the international scientific literature the introduction, rapid spread, and now ubiquitous distribution of *A. fulica* in Brasil approximately 20 years since the initial introduction. We also outline the control measures that have been implemented by the Brasilian health and environmental agencies.

Brasil is a large country and a recent estimate (Pimentel et al. 2001) of the economic losses to Brasilian crops caused by introduced pests totaled US$42.6 billion; environmental costs associated with introduced species were estimated at US$6.7 billion. Costs to human health caused by introduced species are more difficult to estimate, but *A. fulica* has the potential to cause serious problems in all three of these arenas.

Introduction of *Achatina fulica* to Brasil

The introduction of *A. fulica* to Brasil occurred in 1988 at an agricultural fair in the state of Paraná (Teles and Fontes 2002), southern Brasil, where specimens, probably brought from Indonesia, were sold. The enormous potential benefits and profits to be generated by cultivation and commercial development of the species were announced widely in the national media. However, according to Brasilian law, introduction of alien species for cultivation must be done only with the approval of the relevant environmental agency, which at that time was the Instituto Brasileiro de Desenvolvimento Florestal (IBDF), now the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA, the Brasilian Environment Institute). This approval was apparently not obtained for the import of *A. fulica*.

A range of marketing efforts were initiated in order to distribute information widely about how to rear the species. Interested people quickly organized into cooperatives of producers. Each producer had to purchase a kit that included a certain number of snails and an amount of snail food, and then sell the snails produced to the supplier and organizer of the cooperative. Thereafter, what happened reflected a lack of economic forethought and a lack of prior assessment of the food consumption habits of Brasilians. Some cooperatives included more than 100 participants but could not sell their products. Most production was in home-made backyard facilities that did not have the necessary licenses from the federal animal sanitation inspection agency (Defensoria de Vigilância Animal – MAPA). Many operations did not have the specialized freezers necessary for correct processing of the meat. Additionally, Brasilians do not habitually eat terrestrial snails (''escargot''), and even those who are accustomed to eating the true ''escargot'' (*Helix pomatia* Linnaeus, 1758) would not pay high prices for a substitute of uncertain origin.

The result was thousands of frustrated people with millions of animals in backyard facilities requiring enormous maintenance. Inevitably, most of them gave up rearing the snails and, unaware of the potential negative consequences, released them by putting them in the garbage, discarding them on waste land and the edges of highways, or throwing them into rivers. The disastrous result was widespread infestation of urban areas and large areas surrounding cities. Garbage dumps became entirely infested, and although *A. fulica* is a land snail, it spread extensively throughout areas along rivers and streams, either in floating mats of vegetation (Thiengo and Cowie, personal observation) or simply by surviving long enough in the water to float downstream.

The spread and current distribution of *A. fulica* in Brasil

Information on the expanding distribution of *Achatina fulica* in Brasil since its initial introduction was obtained from data associated with specimens collected by the authors and by the staff of the IBAMA and from samples received for identification by the Departamento de Malacologia of the Instituto Oswaldo Cruz/FIOCRUZ and the Setor de Malacologia of the Museu Nacional do Rio de Janeiro at the Universidade Federal do Rio de Janeiro.

Achatina fulica has been recorded from 23 of 26 states in Brasil, plus the Federal District (Brasilia). Although the list is probably incomplete, of a total of 5,561 municipalities (the major administrative subdivisions of the states) throughout Brasil, *A. fulica* has been recorded in 439 (Fig. 1). Details of the infested municipalities are given by Thiengo et al. (in prep.).

Samples from eight states representing the five major regions of Brasil (South, Southeast, North, Northeast, Midwest) have been deposited as vouchers in the Malacological Collection of the Museu Nacional da Universidade do Rio de

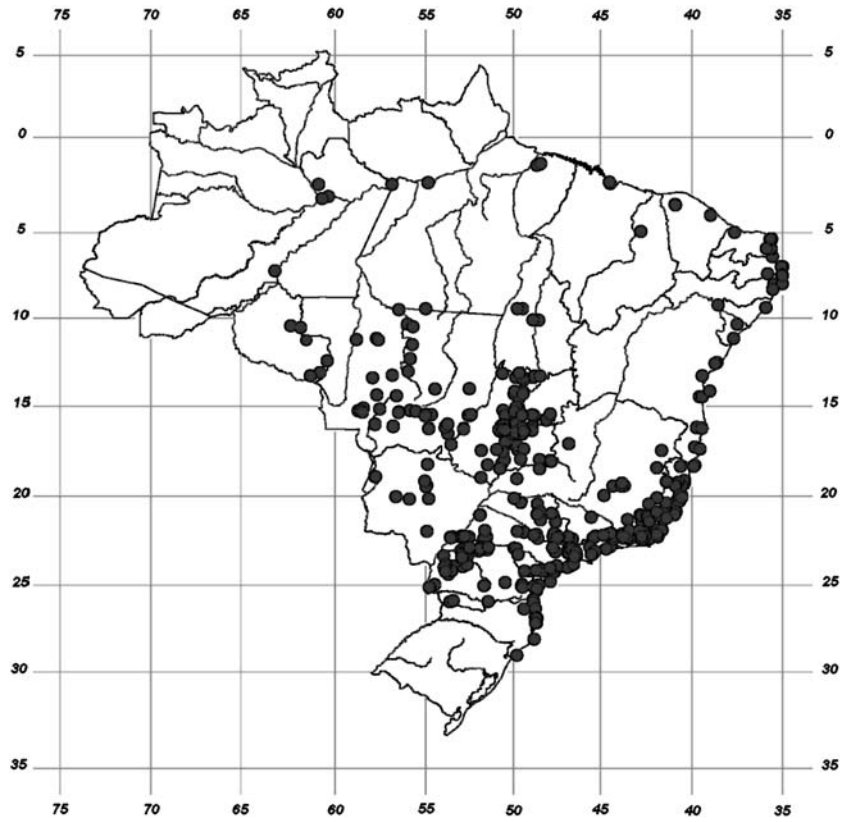

Fig. 1 Distribution of *Achatina fulica* in Brasil, as of June 2006. Each dot represents an infested municipality; some dots overlap

Janeiro (MNRJ), as follows (MNRJ catalogue numbers): Angra dos Reis, 10340; Belford Roxo, 10361; Bragança Paulista, 10365; Carpina, 10587; Chapada dos Guimarães, 10366; Duque de Caxias, 10359; Itaperuna, 10350; Guaraqueçaba, 10588; Lagarto, 10589; Magé, 10388; Manaus 10590; Maranguape, 10346; Maricá, 10352; Niterói, 10362; Nobres, 10339; Nova Friburgo, 10347; Nova Iguaçu, 10371; Paracambi, 10356; Rio das Ostras, 10349; Rio de Janeiro, 10345, 10348, 10353, 10354, 10355, 10358, 10363; Saquarema; Silva Jardim, 10357; Várzea Grande, 10343; Vitória, 10344.

This rapid spread throughout almost the entire country followed a pattern similar to the initial spread in the state of Paraná, that is, distribution for commercial purposes followed by the release of the snails into the wild when people gave up the enterprise. The states with the highest numbers of infested municipalities are located in the southeast and in central western Brasil, that is, in the states of Goiás (75 municipalities), São Paulo (69), Paraná (66), Rio de Janeiro (57), Mato Grosso (38), Espírito Santo (23) and Minas Gerais (20). The lesser numbers of infested municipalities in other states may reflect in part the lack of targeted surveys as well as a real lower level of infestation.

As an example illustrating the spread of *A. fulica* in more detail, Figs. 2–5 show its rapid spread in the state of Rio de Janeiro. In June 2002 only eight municipalities had reported its occurrence (Fig. 2). Five months later it had been detected in another eight municipalities (Fig. 3). By January 2005 it had spread to 39 (Fig. 4) and in June 2006 it was recorded in 57 out of 92 municipalities (62%) (Fig. 5). Similarly, in the states of Goiás and Espírito Santo, where surveys specifically searching for *A. fulica* have been undertaken, it has been detected in 31% and 30% of the municipalities, respectively. It is reasonable, therefore, to expect that if such targeted surveys as those undertaken in these states were to be undertaken in other areas, *A. fulica* would be detected more widely than has so far been reported.

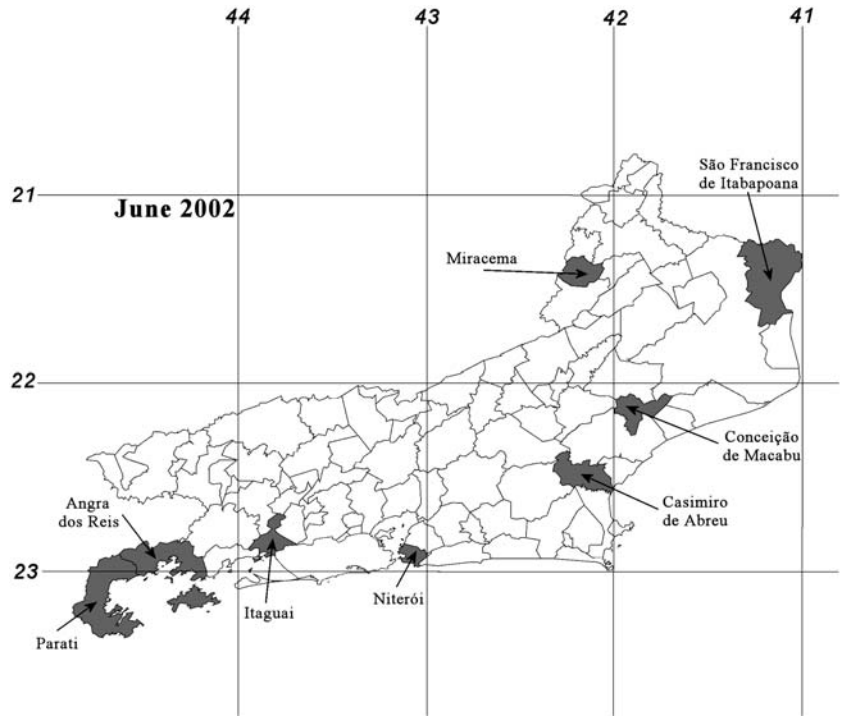

Fig. 2 Distribution of *Achatina fulica* in the state of Rio de Janeiro in June 2002, with infested municipalities shaded

Brasil is currently experiencing the explosive phase of the invasion. Dense populations of *A. fulica*, generally with many large individuals, occur in urban areas, mainly in ornamental and vegetable gardens. The nuisance they cause leads people to seek assistance from local

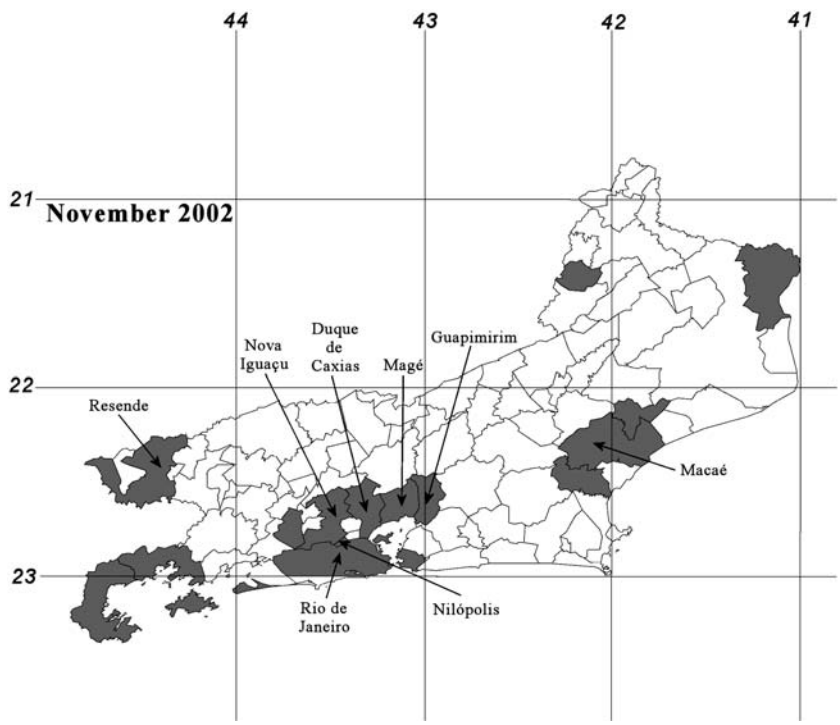

Fig. 3 Distribution of *Achatina fulica* in the state of Rio de Janeiro in November 2002, with infested municipalities shaded and those infested since June 2002 labeled

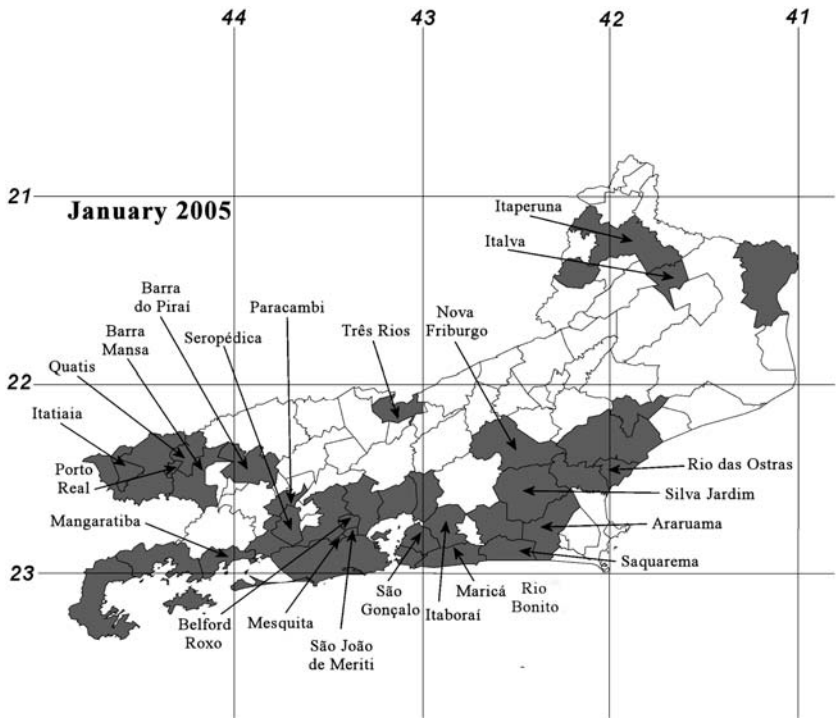

Fig. 4 Distribution of *Achatina fulica* in the state of Rio de Janeiro in January 2005, with infested municipalities shaded and those infested since November 2002 labeled

public health institutions, so that detection of infestations in urban areas is more likely than in rural areas. In addition, in urban areas there are many modified environments, including waste land, that are readily invaded by *A. fulica* because the vegetation and accumulated

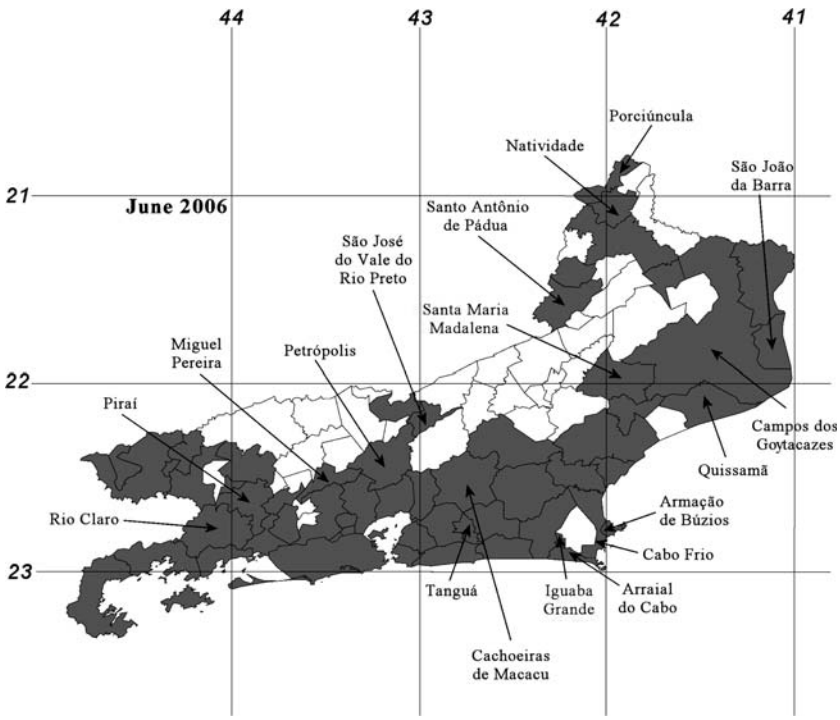

Fig. 5 Distribution of *Achatina fulica* in the state of Rio de Janeiro in June 2006, with infested municipalities shaded and those infested since January 2005 labeled

garbage provide food, shelter and suitable places for oviposition.

In rural regions *A. fulica* is present especially in vegetable gardens, small-scale plantations, or in abandoned agricultural areas, where the snails attack many crops to differing degrees. Table 1 lists those crops most seriously affected. Other crops that have been reported as sustaining damage are listed by Thiengo et al. (in prep.).

Achatina fulica also occurs in forest regions, especially in the forest edges (up to 500 m in from the edge) and in regenerating forest. It has been reported in Unidades de Conservacão (Units of Conservation), including, in 2004, the Reserva Biológica de Poço das Antas (REBIO), state of Rio de Janeiro. This reserve has full protection; human activities are restricted to scientific research authorized by IBAMA; and it contains the largest remaining natural population of the endangered golden lion tamarin, *Leontopithecus rosalia* (Linnaeus, 1766). Other reserves in which *A. fulica* has been detected include the Parque Nacional da Chapada dos Guimarães, state of Mato Grosso, in 2004 (Thiengo, unpublished), and Ilha Grande, state of Rio de Janeiro, in 2001 (Santos et al. 2002). The occurrence of *A. fulica* in such areas may have ecological impacts that threaten the local fauna but these impacts have not been evaluated. In the state of Paraná, *A. fulica* has been observed in preservation areas in the Guaraqueçaba municipality, mostly in islands (Ilha Rasa, Ilha das Peças and Superagui), in great numbers, which demands an urgent and effective plan of eradication to prevent its establishment and dispersal into more remote, wild areas (Fischer and Colley 2004, 2005). It has been reported in other environmental preservation areas in Paraná (Instituto Horus 2006): Parque Nacional Saint Hilaire/Lange in the Guaratuba municipality and Vila Fátima, Ponta do Lanço and Almeida in Guaraqueçaba municipality.

Table 1 Vegetable and ornamental garden plants most seriously attacked by *A. fulica* in Brasil

Family	Species	Common name
Acanthacea	*Hemigraphis colorata*	Hera-roxa
	Jacobinia coccinea	–
Araceae	*Xanthosoma maffafa*	Boa
Asteraceae	*Chicorium intybus*	Wild chicory
	Lactuca sativa	Lettuce
Cactaceae	*Carica papaya*	Papaya
Compositae	*Spilanthes acmella*	–
Commelinaceae	*Ipomoea batatas*	Sweet potato
Cruciferae	*Brassica oleracea* var. *acephala*	Collard greens
	Brassica oleracea var. *italica*	Broccoli
	Brassica oleracea var. *capitata*	Cabbage
	Raphanus sativus	Radish
Cucurbitacea	*Cucurbita* spp.	Pumpkin
	Dioscorea bulbifera	Yams
Euphorbiaceae	*Lycopersicum esculentum*	Tomato
	Manihot esculenta	Cassava
Lamiaceae	*Malpighia* spp.	–
Malpighiaceae	*Hybiscus* spp.	–
Moraceae	*Musa* spp.	Banana
Musaceae	*Ipomopsis* spp.	–
Orchidacea	*Arachis hipogaea*	Peanut
Papilionaceae	*Phaseolus vulgaris*	Bean
Rutaceae	*Paulinia cupana*	Guaraná
Sapotaceae	*Capsicum annuum*	Bell pepper
Umbelliferae	*Boehmeria nivea*	–

Data from Paiva (2001) and the Coordenadoria de Defesa Sanitária Vegetal, Secretaria de Agricultura, Abastecimento, Pesca e Desenvolvimento do Estado do Rio de Janeiro, Brasil

What has been done to control the invasion?

In 2001 the Sociedade Brasileiro de Malacologia (Brasilian Malacological Society) presented recommendations for the control of *A. fulica* to the Ministério da Agricultura e do Abastecimento (MAPA). In 2003, IBAMA and MAPA published documents (IBAMA 006/03 – January 17; MAPA 003/03 – January 20) in which cultivation and marketing of *A. fulica* was considered inadvisable. In 2003 the municipality of Atibaia, São Paulo state, enacted a law (Law no. 3377) that forbids rearing, purchase or selling of *A. fulica*. A similar law was passed in 2004 applying to the entire state of São Paulo (Law no. 11,756). And in 2005 IBAMA issued Instrução Normativa no. 73, which forbids rearing of and commerce in *A. fulica* in Brasil (which will eventually lead to a formal law). Also in 2005 the Ministério do Meio Ambiente organized in Brasília the ''First National Symposium on Exotic and Invasive Species'', at which the situation regarding *A. fulica* in Brasil was discussed (Thiengo et al. 2006).

A national plan for management and control of *A. fulica* was created by IBAMA and actions

under this plan have been implemented since the beginning of 2004. The control method adopted is physical control: collection and destruction of snails and eggs from infested sites, through organized campaigns involving technical staff from local IBAMA and health service offices, local people, students, and teachers. After collection, the snails are crushed using road rolling machinery, put into 2 m depth ditches, covered with kaolin, and then covered with earth.

In Parnamirim, state of Rio Grande do Norte, after five months of efforts, approximately 4000 kg of snails were collected and destroyed, resulting in a significant reduction in the numbers of snails found in the urban part of the municipality (Faraco, unpublished). In addition to that in Parnamirim, similar programs have been implemented in Manaus, state of Amazonas, six municipalities in the state of São Paulo, two in the state of Rio de Janeiro, and two in the state of Mato Grosso.

Discussion

Although there has been no study of the impact of the introduction of *A. fulica* on the natural environment in Brasil, it is possible that the native snail fauna is threatened. Brasil has many large native snail species (e.g., *Megalobulimulus* spp., *Orthalicus* spp., *Thaumastus* spp.) that superficially resemble *A. fulica*. These species may be vulnerable to competition with *A. fulica*, especially because they lay clutches of few eggs (Jurberg et al. 1988; Salgado, unpublished), whereas *A. fulica* lays clutches of up to 400 eggs with an annual production of up to 1200 eggs (Raut and Barker 2002). It is also important that efforts to control *A. fulica*, for instance using pesticides or physical/mechanical methods, do not affect these native species. Furthermore, efforts elsewhere to control *A. fulica* using alien predators as biological control agents have led, most notably in the islands of the Pacific, to the decline and in some cases extinction of native snail species, without controlling *A. fulica* (Civeyrel and Simberloff 1996; Cowie 2001); such methods would be ill-advised in Brasil.

Regarding the agricultural impacts of the invasion of *A. fulica*, considerable economic losses have been sustained, primarily in small-scale agriculture (farms of less than 10 planted hectares) where losses of up to 30% have been reported (Faraco, unpublished). Most of these small-scale farmers still use traditional techniques of cultivation and lack experience in how to deal with this kind of novel problem.

The indiscriminate use of molluscicides containing metaldehyde is also a concern. For instance in Vale do Ribeira, state of São Paulo, a major infestation of *A. fulica* caused losses in the production of bananas, the main agricultural product of the area. Farmers in this area, unaware of the environmental problems associated with the use of molluscicides, used poison baits in the banana crops. As a result, in addition to *A. fulica*, the local animals that still remained in the area (including insectivorous bats, skunks, lizards, and small rodents), many of them possibly important as natural control agents of agricultural pests, were also killed (Faraco, unpublished). There is also the possibility of illegal use of other pesticides that may have harmful effects on non-target organisms and human health.

Achatina fulica is a public health concern since it is a vector of the nematode *Angiostrongylus cantonensis* (Chen, 1935), which causes eosinophillic meningoencephalitis in humans, notable cases having been reported in some Asian countries and Pacific islands (Alicata 1991; Prociv et al. 2000). It is also a potential host of *Angiostrongylus costaricensis* Morera and Céspedes 1971, which causes abdominal angiostrongylosis, a zoonosis that occurs from the southern United States to northern Argentina. In Brasil, most cases of this infection are concentrated in the southern states and many species of terrestrial molluscs have been identified as vectors (Graeff-Teixeira et al. 1993). According to Carvalho et al. (2003) and Thiengo (2004), *A. fulica* may be a risk in the transmission of *Angiostrongylus costaricensis* in Brasil, especially in urban areas, because of the lack of specificity of the parasite for its intermediate hosts, the large numbers of snails available as vectors and the high likelihood of contact with people and subsequent transmission, and the snail's rapid dispersal.

The invasion of *Achatina fulica* in Brasil is a major problem, mainly in urban areas but also increasingly in important natural areas. Brasil is

currently experiencing the explosive phase of the invasion. Although *A. fulica* has not been considered a potentially serious large-scale agricultural pest, it is a concern in small-scale agriculture. It is also a public health concern as well as being a major public nuisance. Because of its now wide distribution and the great size of Brasil, it is impossible to eradicate *A. fulica*. However, local control remains possible, although it will entail great financial and labor costs.

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