

Aquatic Invasions Records

On the presence, distribution and habitat of the alien freshwater snail *Ferrissia fragilis* (Tryon, 1863) (Gastropoda: Planorbidae) in the oceanic islands of the Azores

Pedro M. Raposeiro*, Ana C. Costa and António Frias Martins

CIBIO–Açores – Research Center for Biodiversity and Genetic Resources, Department of Biology, University of Azores, 9501-855 Ponta Delgada, Açores Portugal

E-mail: raposeiro@uac.pt (PMR), accosta@uac.pt (ACC), frias@uac.pt (AFM)

*Corresponding author

Received: 30 November 2011 / Accepted: 24 January 2011 / Published online: 10 February 2011

Abstract

The present work reports on the presence and distribution of an alien and invasive gastropod, *Ferrissia fragilis* (Tryon, 1863), in freshwater systems of the oceanic islands of the Azores archipelago. First registered in 2007, *F. fragilis* was found in S. Miguel, Santa Maria, and Graciosa. This study increases to 6 the number of freshwater species of mollusks occurring in the Azores. Remarks are added on the possible impact of invasive species in island freshwater systems.

Key words: *Ferrissia fragilis*, invasive species, oceanic islands, freshwater

Introduction

The geographic position of oceanic islands strongly limits dispersal and colonization of freshwater systems, resulting in a “disharmonic” fauna, characterized by low levels of diversity and high abundance of insect orders when compared to continental systems. Oceanic islands are potentially highly vulnerable to invasive species due to the low levels of diversity (and therefore competitors) and the resulting availability of ecological niches (Covich 2009).

Freshwater biotas and ecosystems are being profoundly reshaped by ongoing human mediated transoceanic biotic exchange (Benson 1999). Members of the ancyliid gastropod genus *Ferrissia* Walker, 1903 are found worldwide in freshwater ecosystems but have received relatively little systematic attention in recent decades. *Ferrissia* freshwater limpets have been identified from several European and Asian countries under different names: *Pettancyclus petterdi* (Johnston, 1879), *P. australicus* (Tate, 1880), *Ferrissia wautieri* (Mirolli, 1960), *Ferrissia clessiniana* (Jickelli, 1882) (Raposeiro et al. 2007; Son 2007). However, Walther et al. (2006), Walther (2008) and (Walther et al. 2010)

using molecular taxonomical methods have revealed that these taxa are in fact the North American species: *Ferrissia fragilis* (Tryon, 1863).

Ferrissia fragilis has a near-cosmopolitan distribution in temperate and tropical freshwater pond ecosystems, owing to its small body size, hermaphroditism and ability to live in stagnant water (Walther et al. 2006). First records in Europe were from artificial habitats - aquaria and botanical gardens in Germany (Boettger 1949) and England (Brown 1977).

The early studies of the malacofauna of the Azores clearly stated the absence of freshwater mollusks (Morelet 1860). The first fresh-water species, *Physa teneriffae* Mousson [= *Physella acuta* (Draparnaud)], was recorded by the Azorean malacologist F. Arruda Furtado (1881) and soon after Jules de Guerne (1887) described *Pisidium dabney* [= *Pisidium casertanum* (Poli)] from Faial. E. Fisher-Piette (1946) added *Ancylus striatus* Q. and G., but its presence in the Azores was never confirmed. Backhuys (1975), in his revision of the land and fresh-water malacofauna of the Azores, added *Helisoma trivolvis* (Say), *Galba truncatula* (Müller) and *Radix peregra* (Müller). *F. fragilis* was recorded for the first time from S. Miguel,

Santa Maria, and Graciosa by Raposeiro et al. (2007); the present contribution analyses its distribution and habitat in Azorean waters, and discusses the impact of the alien species in these freshwater ecosystems.

Materials and methods

Study area and sampling procedure

Located between 36°-39° North, and 24°-31° West, the Azores is an atlantic oceanic archipelago comprising nine islands (Figure 1). Being 1,300 km from the nearest continental coast (Cabo da Roca, Portugal), and 1,900 km from the American Continent, it is the most remote Macaronesian archipelago.

Collections were made during the biological freshwater monitoring program of surface waters during 2005-2007 (Gonçalves et al. 2007, 2008), during Graciosa (Azevedo et al. 2005) and Pico Expedition (Gonçalves et al. 2006) and other campaigns in all islands. The sampling covered several types of freshwater habitats in the Azorean archipelago. Samples were collected with a hand net (mesh size: 500 µm) along the surface waters of ponds, lakes, streams, reservoirs and animal drinking troughs. All collected material was fixed in 70% ethanol and deposited in the mollusks collection of the Department of Biology of the University of the Azores (DB_FW_AZ_0004).

Results

In the Azores, *Ferrissia fragilis* was recorded in S. Miguel, Santa Maria, and Graciosa. First observed in São Miguel in Sete Cidades Lake (25°46'41"N/37°52'10"W in January, 2004) and was later found in Furnas Lake (25°19'58"N/37°45'59"W in March, 2004). *F. fragilis* was also collected in the same year in a rivulet in Santa Maria (25°07'09"N/36°57'43"W in March, 2004) and in a wet zone in Graciosa (39°02'35"N/28°01'38"W in August, 2004). In the lakes, it was found most commonly on submerged leaves of macrophytes (e.g. the introduced invasive *Egeria densa* in Sete Cidades) in the onshore shallow zone (depth 0.2-0.3 m); it was also seen on submerged stones covered by periphyton or on plant detritus deposited on the bottom. In streams, *F. fragilis* was found attached to submerged stones, more frequently in pools or in zones where there is a predominant low flow.

Description: shell thin, light amber to greenish-brown, with elliptical, laterally flattened dorso-ventral outline, covered with marked growth rings; apex on the posterior third, slightly dislocated to the right side (Figure 2A); height from base to apex about twice its width. Length and width measurements were made in the case of ten specimens, using a square grid calibrated at 0.1mm. Specimens were on average 1.6 mm length (max: 1.9 mm; min: 1.0 mm) and 1.0 mm width (max: 1.1 mm; min: 0.7 mm). Animal completely covered by the shell; head-foot whitish to light-brown, tentacles moderately long and thin, eyes black, conspicuous, sessile, located at the posterior base of the tentacles; visceral mass brown, irregularly mottled with darker spots (Figure 2B).

Discussion

The record of *Ferrissia fragilis* in the Azores corresponds to the only register of the species in the oceanic islands of Macaronesian region. As matter of fact, this species is not reported in the last updated checklist published for the region (Izquierdo et al. 2001; Bank et al. 2002; Arechavaleta et al. 2005). The record of *F. fragilis* increases to 6 the number of species occurring in the archipelago, distributed across 2 classes and 4 families (Table I). Apparently, all the gastropods found in Azorean freshwater systems are introduced (Backhuys 1975; Frias Martins 1991).

Molecular work by Walther (2008) has revealed that all the Azorean specimens, as well as the European *F. clessiniana*, are in fact a single North American species, *F. fragilis*. This finding highlights the importance of the Azores as a possible stepping-stone for colonization and dispersal of species across the Atlantic, possibly mediated by nearctic birds or insects. Birds like American Black Duck (*Anas rubripes*), Common Snipe (*Gallinago gallinago*), Mallard (*Anas platyrhynchos*), Moorhen (*Gallinula chloropus*) and, Teal (*Anas crecca*) are possible vectors in bringing *F. fragilis* to the Azores archipelago because they live in freshwater systems, breed locally, and migrate from America passing through the Atlantic islands on their way to Europe. Once arriving, the key for successful establishment of populations might be the capacity for self-fertilization of this hermaphroditic gastropod.

Figure 1. Location of Azores archipelago and islands (in dark) where *Ferrissia fragilis* is present.

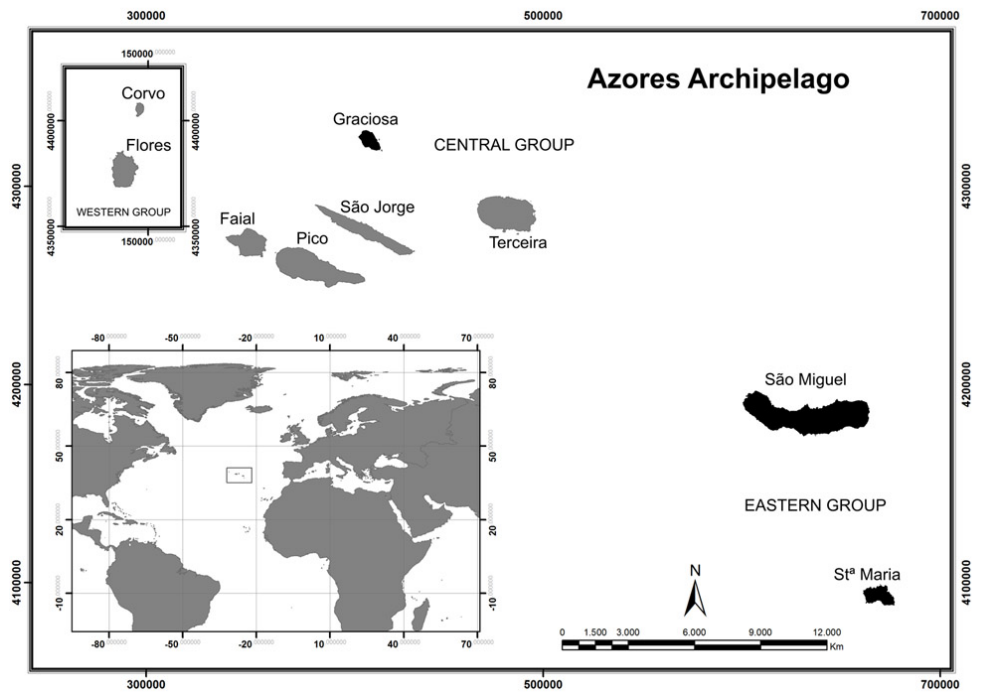


Figure 2. *Ferrissia fragilis* A) Shell; B) Living animal. Photograph by António Frias Martins.

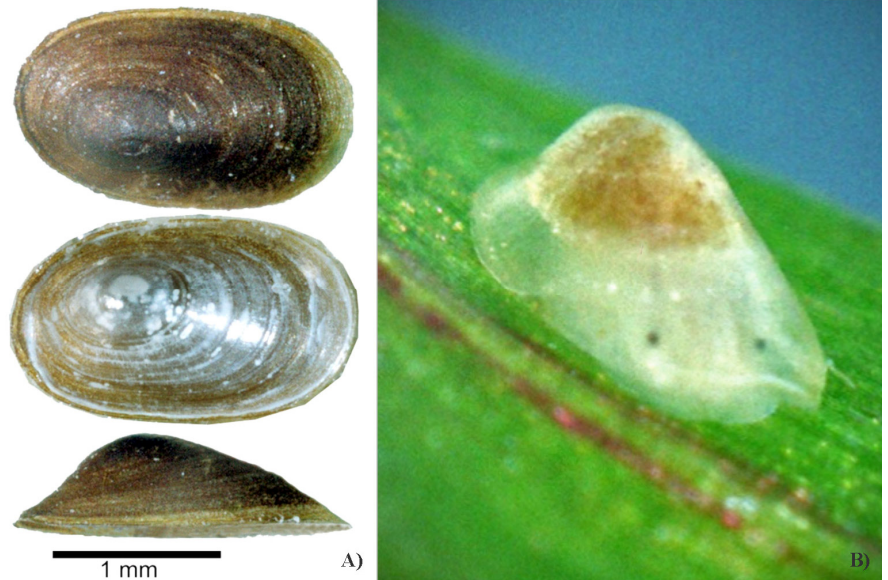


Table 1. Checklist of Azorean freshwater mollusks (COR – Corvo; FLO – Flores; FAI – Faial; PIC – Pico; GRA – Graciosa; SJO – São Jorge; TER – Terceira; SMG – São Miguel; STM – Santa Maria) based on Cunha et al. (2010).

	COR	FLO	FAI	PIC	GRA	SJO	TER	SMG	STM
Classe Bivalvia									
Sphaeriidae									
<i>Pisidium casertanum</i> (Poli, 1791)		FLO	FAI	PIC			TER	SMG	STM
Classe Gastropoda									
Lymnaeidae									
<i>Galba truncatula</i> (Müller, 1774)								SMG	STM
<i>Lymnaea peregra</i> (Müller, 1774)								SMG	
Physidae									
<i>Physella acuta</i> (Draparnaud, 1805)						SJO	TER	SMG	
Planorbidae									
<i>Helisoma trivolvis</i> (Say, 1817)							TER		
<i>Ferrissia fragilis</i> Turton, 1863					GRA			SMG	STM

In Sete Cidades and Furnas lakes, *F. fragilis* occurs simultaneously with two other alien invasive species: the crayfish – *Procambarus clarkii* (Girard, 1852) (Correia and Costa 1994), and the plant - *Egeria densa* Planch. Both species are present in Lagoa das Sete Cidades, but only the crayfish is covered by Portuguese law (Dec. Lei 565/99). *Egeria densa*, also known as Brazilian elodea, in contrast to the crayfish, is not mentioned as introduced, potentially harmful or an invasive species under national law. However, the conspicuous presence and growth of this plant has provided evidence for public awareness of the eutrophic state of the lake. As a consequence, the local government has shown environmental concern by taking measures such as mechanical harvesting, in order to mitigate its impact on the eutrophication of the lake (Costa 2005). *F. fragilis* is likely to become an element of crayfish diet providing another source of animal protein for the crayfish, and both will benefit from the habitat provided by *E. densa*. The extent of trophic relations among these three non-native species in Sete Cidades lake remains to be established but their co-existence underlines the degraded state of this lake. Another possible pathway for arrival of *F. fragilis* to the Azores is through the aquarium industry, as reported by Frias Martins (1991), in Terceira island for *Helisoma trivolvis*. In Graciosa, *F. fragilis* was present in a small pond, 35 by 15 m, very turbid, with a strong dominance of Euglenophyta, namely *Phacus longicauda* and *Trachelomonas bacillifera* (Azevedo et al. 2005),

indicating strong water pollution by nutrients. Also, in Santa Maria it was found in a small rivulet enriched with nutrients (Inova 2006). The presence of non-native and invasive species in organic polluted and degraded aquatic systems has long been observed and it has been recently proved that such polluted habitats can favour invasive species (Crooks et al. 2010).

Oceanic islands have a reduced, but unique diversity due to the different levels of separation caused by various factors for example, distance to mainland, island age and origin, all of which strongly limit the dispersal, colonization and evolution of the organisms therein. Insular systems are potentially highly vulnerable to invasive species due to the low levels of diversity (and therefore competitors) and the resulting availability of ecological niches. The establishment and consequences of introduced species has been object of discussion in a lot of studies (e.g. Ricciardi 2003; Gilbert and Parker 2010), but we are still not able to predict either the outcome of the introduction of any particular species, for example *F. fragilaris*, or the impact of invasions in general to historically highly vulnerable insular systems such as the Azores.

Acknowledgements

Part of this study was financed by Fundação para a Ciência e Tecnologia (FCT - SFRH/BD/28798/2006). We thank two reviewers for useful comments on the earlier version of this paper.

References

- Arechavaleta M, Zurita N, Marrero JC, Martín JL (2005) Lista preliminar de especies silvestres de Cabo Verde (hongos, plantas y animales terrestres), Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias, 155 pp
- Azevedo JMN, Gonçalves V, Raposeiro P, Couto AI, Costa AC (2005) Contribuição para o conhecimento Biológico das águas interiores da Graciosa. Relatórios e Comunicações do Departamento de Biologia da Universidade dos Açores. XI Expedição Científica do Departamento de Biologia / Graciosa 2004 32, pp 143–149
- Backhuys W (1975) Zoogeography and Taxonomy of the Land and Freshwater Molluscs of the Azores, Backhuys and Meesters, Amsterdam, 350 pp
- Bank R, Groh K, Ripken TEJ (2002) Clecom-Project: Catalogue and bibliography of the non-marine Mollusca of Macaronesia. In: Falkner M, Groh K (eds). Speight, M.C.D. Collectanea Malacologica, Festschrift für Gerhard Falkner Conchbooks, Hackenheim, pp 89–235
- Benson AJ (1999) Documenting over a century of aquatic introductions in the U.S. In: Claudi R, Leach JH (eds), Nonindigenous Freshwater Organisms: Vectors, Biology and Impact. Lewis Press, Washington, D.C., pp 1–31
- Boettger CR (1949) Die Einschleppung einer nordamerikanischen Süßwasserschnecke der Gattung *Ferrissia* nach Deutschland. *Archiv für Molluskenkunde* 78: 187
- Brown DS (1977) *Ferrissia* - a genus of freshwater limpet new for Britain. *Conchologists' Newsletter* 62: 23–24
- Correia P, Costa AC (1994) Introduction of the red swamp crayfish *Procambarus clarkii* (Crustacea, Decapoda) in São Miguel, Azores, Portugal. *Arquipélago - Life and Marine Sciences* 12A: 67–73
- Costa AC (2005) Invasive species in São Miguel island (Azores) inland waters. INWAT: Biological invasions in inland waters. Abstracts of International Workshop, May 5-7, 2005, Firenze, Italy
- Covich AP (2009) Freshwater ecology. In: Gillespie RG, Clague DA (eds), *Encyclopedia of islands*. University of California Press, Berkeley, pp 343–347
- Crooks J, Chang A, Ruiz G (2010) Aquatic pollution increases the relative success of invasive species. *Biological Invasions* 13: 165–176, <http://dx.doi.org/10.1007/s10530-010-9799-3> 1-12
- Cunha R, Rodrigues P, Frias Martins AM (2010) List of molluscs (Mollusca). In: Borges PAV, Costa A, Cunha R, Gabriel R, Gonçalves V, Frias Martins AM, Melo I, Parente M, Raposeiro P, Rodrigues P, Santos RS, Silva L, Vieira V (eds), A list of the terrestrial and marine biota from the Azores. *Principia, Cascais*, pp 165–178
- Fischer-Piette E (1946) Les caractères de la faune malacologique terrestre de Macaronésie. Contribution à l'étude du peuplement des Iles Atlantides. *Mémoires de la Société de Biogéographie* 8: 251–278
- Frias Martins AM (1991) Distribuição dos moluscos de água doce em São Miguel e na Terceira. *Açoreana* 7: 257–276
- Furtado FA (1881) A propósito da distribuição dos Molluscos terrestres nos Açores. *Era Nova* 1: 267–283
- Gilbert GS, Parker IM (2010) Rapid evolution in a plant-pathogen interaction and the consequences for introduced host species. *Evolutionary Applications* 3: 144–156, <http://dx.doi.org/10.1111/j.1752-4571.2009.00107.x>
- Gonçalves V, Raposeiro P, Costa AC, Marques H, Malhão V, Micael J, Cunha A (2007) Caracterização Ecológica das Massas de Água Interiores das ilhas de Pico, Faial, Flores e Corvo. Definição de ecótipos de Lagoas e Ribeiras, CCPA, Departamento de Biologia, Universidade dos Açores, Ponta Delgada, 131 pp
- Gonçalves V, Raposeiro P, Costa AC, Marques H, Malhão V, Micael J, Cunha A (2008) Caracterização Ecológica das Massas de Água Interiores das Ilhas de São Miguel e Santa Maria da Região Autónoma dos Açores, CCPA, Departamento de Biologia, Universidade dos Açores, Ponta Delgada, 117 pp
- Gonçalves V, Raposeiro P, Couto AI, Costa RM, Rocha F, Wattiez X, Camaerts D, Azevedo JMN (2006) Contribuição para a caracterização das águas interiores de superfície da ilha do Pico. Relatórios e Comunicações do Departamento de Biologia da Universidade dos Açores. XII Expedição Científica do Departamento de Biologia / Pico 2005 34, pp 93–103
- Guerne MJ (1887) Notes sur la faune des Açores. *Le Naturaliste* 9: 194–195
- Inova (2006) Monitorização da qualidade das águas superficiais e subterrâneas nas Ilhas de São Miguel e Santa Maria: caracterização físico-química e microbiológica. Relatório final, Instituto de Inovação Tecnológica dos Açores, Ponta Delgada (Portugal), 32 pp
- Izquierdo I, Martín JL, Zurita N, Arechavaleta M (2001) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres) 2001, Consejería de Política Territorial y Medio Ambiente Gobierno de Canarias, Islas Canarias, 437 pp
- Morelet A (1860) Notice sur L'Histoire Naturelle des Açores, J.B. Bailière et Fils, Paris, 214 pp
- Raposeiro P, Costa A, Martins AF (2007) Freshwater mollusks of the Azores: a reappraisal. *World Congress of Malacology - Antwerp, Belgium*, pp 175-176
- Ricciardi A (2003) Predicting the impacts of an introduced species from its invasion history: an empirical approach applied to zebra mussel invasions. *Freshwater Biology* 48: 972–981, <http://dx.doi.org/10.1046/j.1365-2427.2003.01071.x>
- Son MO (2007) North American freshwater limpet *Ferrissia fragilis* (Tryon, 1863) (Gastropoda: Planorbidae) - a cryptic invader in the Northern Black Sea Region. *Aquatic Invasions* 2: 55–58, <http://dx.doi.org/10.3391/ai.2007.2.1.6>
- Walther AC (2008) A systematic study of North American freshwater limpets (Gastropoda: Hygrophila: Ancyliidae), University of Michigan, Michigan, 122 pp
- Walther AC, Lee T, Burch JB, Foighil DO (2006) Confirmation that the North American ancyliid *Ferrissia fragilis* (Tryon, 1863) is a cryptic invader of European and East Asian freshwater ecosystems. *The Journal of Molluscan Studies* 72: 318–321, <http://dx.doi.org/10.1093/mollus/eyl009>
- Walther AC, Burch JB, Foighil DO (2010) Molecular phylogenetic revision of the freshwater limpet genus *Ferrissia* (Planorbidae: Ancyliinae) in North America Yields two species: *Ferrissia (Ferrissia) rivularis* and *Ferrissia (Kincaidilla) fragilis*. *Malacologica* 53: 25–45, <http://dx.doi.org/10.4002/040.053.0102>