Neotropical Biology and Conservation
9(2):115-119, may-august 2014
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SHORT COMMUNICATION

Aquarium trade as a potential disseminator of non-native invertebrates in Northeastern Brazil

Comércio de aquarismo como potencial dispersor de invertebrados não-nativos no Nordeste do Brasil

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Abstract

Aquarium trade is one of the most important pathways of biological invasion. Much attention has been given to target introduced species, but little is discussed on the associated bycatch ones. The aim of this paper is to analyze the risk of invasion by non-commercial invertebrates using aquarium stores as a model. Monthly visits to eight stores in Aracaju (Sergipe State) were performed from April to September 2011. Inspections were carried out and questionnaires were applied to owners and employees of the establishments. Two non-native species were identified, *Melanoides tuberculatus* (Gastropoda: Thiaridae) and *Lernaea cyprinacea* (Crustacea, Copepoda). Sixty-two specimens of *M. tuberculatus* were found among the aquatic plants in one of the stores, while *L. cyprinacea* was collected in four establishments parasitizing *Carassius auratus*, *Hypostomus* sp., *Poecilia latipinna*, *Poecilia sphenops*, *Poecilia reticulata* and *Xiphophorus hellerii*. The interviews that have been done with owners and employees revealed that none of the stores has submitted fishes and plants to quarantine, and the disposal of wastewater is directly into the sewer system. It is necessary to adopt preventive measures such as a quarantine period for fishes and the creation of a warning about the dangers of biological invasions or aquarium dumping for aquarium hobbyists to mitigate the risk of invasion.

Keywords: bioinvasion, *Lernaea cyprinacea*, *Melanoides tuberculatus*.

Resumo

O comércio de peixes ornamentais figura entre os principais mecanismos de invasões biológicas. Muita atenção é dada às espécies-alvo introduzidas, porém, pouco se discute sobre a fauna acompanhante das introduções. O objetivo do presente estudo foi analisar o risco de invasão de invertebrados não-comerciais utilizando lojas de aquário como modelo. Visitas mensais a oito lojas na cidade de Aracaju ocorreram de abril a setembro de 2011. Nos estabelecimentos, foram realizadas inspeções e aplicações de questionários aos lojistas. Foram detectadas duas espécies não-nativas, *Melanoides tuberculatus* (Gastropoda: Thiaridae) e *Lernaea cyprinacea* (Crustacea, Copepoda). Sessenta e dois espécimes de *M. tuberculatus* foram coletados em meio às plantas em uma das lojas, enquanto *L. cyprinacea* foi registrada em quatro estabelecimentos parasitando *Carassius auratus*, *Hypostomus* sp., *Poecilia latipinna, Poecilia sphenops*, *Poecilia reticulata* e *Xiphophorus hellerii.* As entrevistas revelaram que nenhuma das lojas submete peixes e plantas adquiridos à quarentena, sendo o descarte da água dos aquários feito diretamente na rede de esgoto. São sugeridas medidas preventivas, tais como período de quarentena para peixes e orientação sobre os perigos das invasões biológicas ou soltura de espécimes no ambiente natural, visando à mitigação dos riscos de invasão.

Palavras-chave: bioinvasão, *Lernaea cyprinacea*, *Melanoides tuberculatus*.

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The ornamental fish industry moves more than U$15 billion per year worldwide (Projeto Piaba, 2001), and over 60% of this amount comes from exporting fishes from developing countries like Brazil, Colombia, Indonesia, and Malaysia, which represents more than U$ 400 million of sold fishes (Projeto Piaba, 2001; Cardoso and Igarashi, 2009). Other ornamental aquatic organisms such as plants and invertebrates are associated with the aquarium trade (Courtenay Jr., 1999; Duggan, 2010).

The annual growth of aquariums around the world is estimated in 11% (Ribeiro, 2008). The popularization of this hobby could be related both to the films featuring fishes as protagonists (e.g. Finding Nemo) and the advances in technology to create equipments that facilitated the maintenance of these pets in captivity (Courtenay Jr., 1999). Electronic commerce, which allows consumers to easily purchase pets online, boosted this kind of trade (Magalhães and Jacobi, 2010).

The large number of invertebrate species that have been traded in aquarium business greatly increases the risk of invasion in terms of the colonization pressure (Magalhães and Costa, 2007). Discard of live animals in the natural environment and the lack of criteria in the handling of plants and animals (Courtenay Jr., 1999, Magalhães and Jacobi, 2010, 2013) make the aquarium trade one of the most important pathways of invasion (Magalhães *et al*., 2009). Non-native species provide ecological and economic damage worldwide usually by competing with native species, thus limiting or reducing their population (Pimentel *et al*., 2005; França *et al*., 2007). Much attention has been given to target introduced species, but little is discussed on the associated bycatch ones (Duggan, 2010). Thus, this study aims to analyze the risk of invasion by non-native invertebrates in aquarium stores.

Monthly visits to the eight major aquarium stores in Aracaju (10°54'36"S, 37° 04'12"W), Sergipe State, Brazil, occurred from April to September 2011. Inspections were conducted in fish and plant tanks, looking for potential non-native species. When detected, the specimens were removed from the tanks and transported to the laboratory where they were counted and identified with the aid of identification keys (Thompson, 1984; Kabata, 1985; Simone, 2006). During the visits, a questionnaire was applied to owners and employees, asking about procedures adopted after the acquisition of fishes, parasite detection, disposal of aquariums wastewater, and the knowledge about biological invasions.

Two non-commercial species were identified with risk of invasion: the Malaysian trumpet snail *Melanoides tuberculatus* (Müller 1774) (Gastropoda: Thiaridae), native of East Africa and Asia (Pointier, 1999), and the anchor worm *Lernaea cyprinacea* (Linnaeus 1758) (Crustacea, Copepoda), native of Eastern Europe and Asia (Kabata, 1985). In one of the stores, 62 specimens of *M. tuberculatus* were observed in the tanks of plants ('Araguaia' *Hygrophila* sp., pygmy chain sword *Helanthium tenellum* (Mart. ex Schult. and Schult. f.) Britton, duck potato *Sagittaria* sp., waterweeds *Elodea* sp., and eelgrass *Vallisneria* sp.). Possibly *M. tuberculatus* is transported by the plants from where they grow to the stores.

Melanoides tuberculatus (Figure 1) has the ability to reproduce through parthenogenesis, a form of reproduction that has the potential to produce a large number of offspring in a short period of time (Jesus *et al*., 2007), and a single individual could be responsible for the whole colonization. In the case of an infestation, the snail will probably be discarded via sanitary sewer or in natural water bodies (Santos *et al*., 2007), or even along with the disposal of ornamental plants.

Melanoides tuberculatus has already been reported in drainages next to the study places (Souto *et al*., 2011), and its presence in the lower Sergipe River may not have been recorded yet due to lack of samples. The high plasticity to environmental conditions and low mortality rate even allow its colonization in disturbed environments such as urban areas with high pollution rate (França *et al*., 2007, Jesus *et al*., 2007). Besides the competition with native species, as *Biomphalaria* spp. and *Pomacea* spp. (Jesus and Manso,

Figure 1. Specimen of *Melanoides tuberculatus* collected in one of the aquarium stores in Aracaju, Sergipe State, Northeastern Brazil. Bar: 5 mm.
Figura 1 - Espécime de *Melanoides tuberculatus* coletado em uma das lojas de aquário em Aracaju, Sergipe, nordeste do Brasil. Barra: 5 mm.

2010), *M. tuberculatus* can act as a vector of trematode parasites, which can affect wildlife and humans (Abilio and Watanabe, 1998), becoming a risk to the native aquatic biota and it can be a danger to the public health. There are reports of infected *M. tuberculatus* in several drainages in Brazil (Bogéa *et al*., 2005; Paula-Andrade *et al*, 2012; Pinto and Melo, 2013), however, the environmental impact of the parasite remains unknown (Pinto and Melo, 2013).

Lernaea cyprinacea is a species that has no host specificity (Eiras *et al*., 2010), which increases the risk of infestation in the tanks. This species was recorded in four establishments parasitizing the goldfish *Carassius auratus* (Linnaeus 1758) (n = 54), the suckermouth catfish *Hypostomus* sp. (n = 1), the mollies *Poecilia latipinna* (Lesueur 1821) (n = 11) and *P. sphenops* Valenciennes 1846 (n = 5), the guppy *P. reticulata* Peters 1859 (n = 7), and the swordtail *Xiphophorus hellerii* Heckel, 1848 (n = 9) (Table 1). Most infected fishes presented one to two parasites, but an extreme case was reported in *P. reticulata* with 44 (Figure 2A).

The impressive record of parasitism in *C. auratus* (Table 1; Figure 2B) is related to infestation in a single lot purchased by one of the stores. This is a worrying fact because it means that the supplier is the principal focus of infestation, featuring a lack of quality control of fish sold. Occasionally, besides the adult forms of parasites, aquariums may carry free larvae forms (nauplii), which could infest other tanks if the water circulation system is common between them. Fishes parasitized by *L. cyprinacea* could present nutritional deficits and other infections caused by fungi and bacterium (Luque, 2004).

The presence of ovigerous females of *L. cyprinacea* (Figures 2C; D) represents the possibility of reproduction within the aquarium. The reproductive cycle of the species may differ depending on the water temperature. Tropical environments with higher temperatures, as in the region of the present study (Araújo *et al*., 2010), may have increased reproductive rates up to six times when compared to the temperate environments (Shields and Tidd, 1968). The release of infected fish and the disposal of infected aquarium water in sewage can contribute to the contamination of the natural waters.

Although *L. cyprinacea* have been usually recorded as a parasitizing fish, it can also occur in amphibians (Kupferberg *et al.*, 2009). Tadpoles of native species like the cururu toad *Rhinella jimi* (Stevaux 2002) and the butter frog *Leptodactylus latrans* (Steffen 1815) (Morato *et al*., 2011), if affected by the parasite, could further exacerbate the damage to other native fauna.

The results obtained from the questionnaires (Table 2) revealed that none

Table 1. List of species and number of parasitized fishes by *Lernaea cyprinacea*; number of parasites found in each fish; and number of stores with contaminated samples in Aracaju, Sergipe State, Northeastern Brazil.
Tabela 1- Relação das espécies e número de peixes parasitados por *Lernaea cyprinacea*, número de parasitas encontrados em cada peixe e número de lojas com ocorrência, em Aracaju, Sergipe, nordeste do Brasil.

Species	Parasitized fishes				Stores
	1 to 2	3 to 5	More than 5	Total	
Carassius auratus	35	19	0	54	1
Poecilia latipinna	11	0	0	11	3
Xiphophorus hellerii	9	0	0	9	1
Poecilia reticulata	2	3	2	7	1
Poecilia sphenops	5	0	0	5	1
Hypostomus sp.	1	0	0	1	1

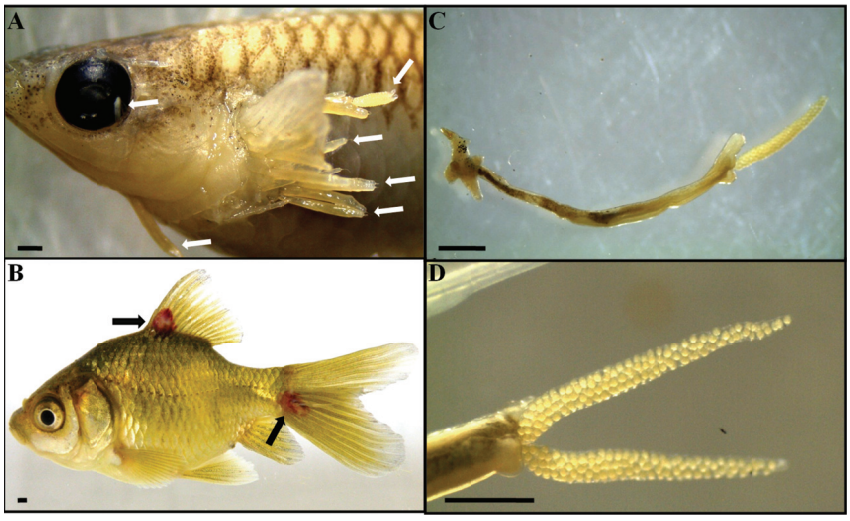

Figure 2. (A) Detail of the head of *Poecilia reticulata* parasitized by *Lernaea cyprinacea* (white arrows); (B) *Carassius auratus* with punctate hemorrhage in the region of attachment of *Lernaea cyprinacea* (black arrows); (C) reproductive female of *Lernaea cyprinacea*; (D) detail of the ovigerous sac of a reproductive female of *Lernaea cyprinacea*. Bar: 1 mm.
Figura 2 - (A) Detalhe da região da cabeça de *Poecilia reticulata* parasitada por *Lernaea cyprinacea* (setas brancas); (B) exemplar de *Carassius auratus* com hemorragia puntiforme na região de fixação (seta pretas) de *Lernaea cyprinacea*; (C) fêmea reprodutiva de *Lernaea cyprinacea*; (D) detalhe do saco ovígero de uma fêmea reprodutiva de *Lernaea cyprinacea*. Barra: 1 mm.

Table 2. Applied questionnaire to owners and managers of aquarium stores samples in Aracaju, Sergipe State, Northeastern Brazil.
Tabela 2. Questionário aplicado aos responsáveis pelas lojas de aquariofilia em Aracaju, Sergipe, nordeste do Brasil.

Questions	Answers
What's your procedure when you find parasitized fishes?	Replacement for a new lot: 2 (25%); Treatment in store: 6 (75%)
How do you dispose the aquarium water?	Directly in sewage: 7 (87.5%); After salinization: 1 (12.5%)
Have you received any kind of procedure orientation?	Yes: 0 No: 8 (100%)
What are the major bycath organisms found?	Anchor worm: 7 (87.5%); Trumpet snail: 6 (75%); Fungi: 5 (62.5%)
Do you have any kind of knowledge about biological invasions?	Yes: 0 No: 8 (100%)

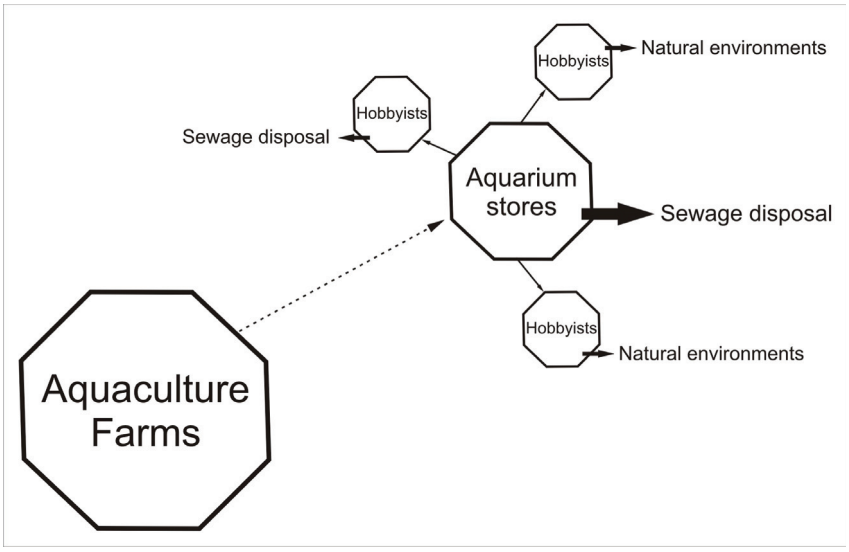

Figure 3. Stratified scatter plot showing the possible path of the aquatic invertebrates *Lernaea cyprinacea* and *Melanoides tuberculatus* from the aquarium stores until their introduction into the natural environment. Adapted from Lockwood *et al.* (2007).
Figura 3 - Gráfico de dispersão estratificada ilustrando o possível caminho dos invertebrados aquáticos *Lernaea cyprinacea* e *Melanoides tuberculatus* das lojas de aquários até sua introdução no ambiente natural. Adaptado de Lockwood *et al.* (2007).

of the visited stores submits purchased plants and fishes to quarantine. Once acquired, they are promptly placed in aquariums for sale. Employees of four stores, where a large amount of infected fishes were detected, attested that those fishes would be replaced for healthy individuals by the suppliers.

However, if the rates of parasitism in lots are low, employees first perform manual removal of the parasite and the application of methylene blue, which is recommended for the treatment of this parasitosis (França, 2007). However, the lack of quarantine done after this process is worrisome, because of the possible introduction of parasites in the environment if the procedure is ineffective.

All employees have affirmed to dispose the aquarium water directly into the sewer system. Only one establishment adopts the method of water salinization before disposal, aiming to eliminate the invertebrates. This procedure can be effective for the free forms of *L. cyprinacea* (Luque, 2004), but may not work against *M. tuberculatus*, which shows mechanisms of salt tolerance (Bolaji *et al.*, 2011). Regarding the presence of non-native organisms in the eight stores studied, seven presented *L. cyprinacea*, and five presented *M. tuberculatus*. The worrying factor is that none of the surveyed had knowledge about risks of bioinvasion; neither have they been alerted by a government agency such as the Secretaria de Meio Ambiente e Recursos Hídricos de Sergipe (Semarh) about those risks. The lack of knowledge about risks related to bioinvasion demonstrates the importance of management actions with wholesalers, retailers and consumers (e.g. aquarium hobbyists). The unawareness of the subject was also reported by sellers of Minas Gerais and Santa Catarina (Magalhães, 2006; Piazza *et al*., 2006). From the information obtained in this study, it was possible to apply the stratified dispersion model proposed by Lockwood *et al*. (2007), where aquaculture farms act as primary colonies of dispersion and the aquarium stores as satellite colonies, which expand the potential biological invaders to the hobbyists. Discharge of untreated water directly into the sewer system and the release of non-native organisms by aquarium hobbyists were identified as the most likely pathways of entry and spread in natural environment (Figure 3).

This work does not intend to harm the ornamental fish trade, but the presence of potential invasive species in stores is an alert to the possibility of dispersion into natural waters. Aquarium trade is not a well-managed segment in Brazil, especially when compared to other pet segments (Magalhães and Jacobi, 2013). It is necessary to adopt preventive measures such as a quarantine period for fishes and the creation of a warning about the dangers of biological invasions or aquarium dump-

ing for aquarium hobbyists. Added to this, other studies aiming to monitor drainages for the presence of the species mentioned in this manuscript are required.

Acknowledgments

To the Programa de Pós-Graduação em Ecologia e Conservação (PPEC/UFS) for the logistic support. To CAPES for the scholarship (DASA). To André L.B. Magalhães (PUC Minas) and the two anonymous referees for their valuable suggestions for the improvement of this manuscript. We also thank the owners and employees of the establishments visited for their assistance during the study.

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Submitted on January 30, 2014
Accepted on June 26, 2014