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The small foreigner: new laws will promote the introduction of non-native zooplankton in Brazilian aquatic environments

O pequeno forasteiro: novas leis favorecerão a introdução de espécies não-nativas de zooplâncton em ambientes aquáticos brasileiros

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Abstract: Non-native species of zooplankton have been introduced in Brazilian continental aquatic environments for a variety of reasons (e.g., non-native fish stocking, aquaculture), but many pathways of zooplankton introductions remain unknown. Recently, the governor of the State of Amazonas passed Law No. 79/2016, which allows for aquaculture operations using non-native fish in that state. This change in policy will likely result in the species introduction or propagule pressure of non-native zooplankton such as: *Mesocyclops ogunnus* Onabamiro, 1957; *Kellicottia bostoniensis* (Rousselet, 1908); *Daphnia lumholtzi* Sars, 1885; *Lernaea cyprinacea* (Linnaeus, 1758); *Lamproglena monodi* Capart, 1944. Of further concern is federal law No. 5989/09, which proposes the use of non-native fish in Brazilian aquaculture nationwide. We believe that both laws will intensify the introduction of non-native zooplankton. Once established in aquatic environments, non-native species of zooplankton could result in negative impacts (e.g., a loss of ecosystem services, food web alterations). Therefore, Brazilian authorities should incentivize the use of local native species rather than pass laws that threaten the environment.

Keywords: biological invasions; propagule pressure; Neotropical; freshwater; environmental policy.

Resumo: Espécies não-nativas de zooplâncton foram introduzidas em ambientes aquáticos continentais Brasileiros por uma variedade de razões (e.g., estocagem de peixes não nativos, aquicultura), mas muitas vias de introdução de zooplâncton permanecem desconhecidas. Recentemente, o governador do Estado do Amazonas aprovou a Lei nº 79/2016, que permite operações de aquicultura utilizando peixes não-nativos nesse estado. Esta mudança de política provavelmente resultará na introdução de espécies ou pressão de propágulos de zooplâncton não-nativos, tais como: *Mesocyclops ogunnus* Onabamiro, 1957*; Kellicottia bostoniensis* (Rousselet, 1908); *Daphnia lumholtzi* Sars, 1885; *Lernaea cyprinacea* (Linnaeus, 1758); *Lamproglena monodi* Capart, 1944. Outro motivo de preocupação é a lei federal, N ° 5989/09, que propõe o uso de peixes não-nativos na aquicultura brasileira em todo o país. Acreditamos que ambas as leis favorecerão a introdução de zooplâncton não-nativos. Uma vez estabelecido em ambientes aquáticos, zooplâncton não-nativos podem resultar em impactos negativos (e.g., uma perda nos serviços ecossistêmicos, alterações na cadeia alimentar). Portanto, as autoridades brasileiras deveriam incentivar o uso de espécies locais nativas em vez de aprovar leis que ameacem o meio ambiente.

Palavras-chave: invasões biológicas; pressão de propágulo; Neotropical; água doce; política ambiental.

In Brazil, non-native zooplankton species were introduced in continental aquatic environments for different reasons (see Table 1), mainly associated with fish (Gabrielli & Orsi, 2000; Silva & Roche, 2017). For instance, *Mesocyclops ogunnus* Onabamiro, 1957, has already been introduced through the cultivation of tilapia in the Amazon basin: however, in this region this species seems

Table 1. Examples of non-native zooplankton species introduced into Brazilian freshwater environments and their possible paths.

Species	Geographical origin	Locality of introduction	Reasons of introduction	References
Ceriodaphnia dubia Richard, 1894	Europe	Belgo-Mineira Lagoon (Doce River Basin) and Machado Mineiro Reservoir (Pardo River Basin)	Unknown	Eskinazi-Sant'Anna et al. (2005); Santos-Wisniewski et al. (2011)
		Furnas, Billings and Taiaçupeba Reservoirs (Paraná River Basin)	Ecotoxicological tests	Abreu et al. (2010); Rocha et al. (2011)
Daphnia lumholtzi (Sars, 1885)	Australia, southwestern Asia and Africa	Três Irmãos Reservoir (Paraná River Basin)	Fish stocking	Zanata et al. (2003)
Kellicottia bostoniensis (Rousselet, 1908)	North America	Itapecerica River (São Francisco River Basin)	Unknown	Ferraz et al. (2009)
		Lake Dom Helvécio (Doce River Basin)	Unknown	Maia-Barbosa et al. (2008)
		Lakes Carioca, Águas Claras and Jacaré (Doce River Basin)	Fish stocking	Peixoto et al. (2010)
		Paiva Castro, Billings, Águas Claras, Taiaçupeba, Jundiaí, Guarapiranga Reservoirs (Paraná River Basin)	Unknown	Lucinda et al. (2004)
		Furnas and Lagoa do Nado Reservoirs (Paraná River Basin)	Ballast water	Edmondson (1959); Reid & Pinto-Coelho, (1994) apud Bezerra-Neto et al. (2004)
		Furnas Reservoir (Paraná River Basin)	Unknown	Landa et al. (2002)
		Xirica, São João and Saraiva Lagoons (Paraná River Basin)	Unknown	Bomfim et al. (2015)
Lernaea cyprinacea (Linnaeus, 1758)	Europe, Asia, Africa and North America	Santo Antônio stream (Paraíba do Sul River Basin)	Aquaculture	Magalhães (2006)
		São Francisco River (São Francisco River Basin)	Unknown	Demaree Junior (1967); Santos & Brasil-Sato (2004)
		Paranapanema, Taquari and Tabagi Rivers (Paraná River Basin)	Aquaculture	Gabrielli & Orsi (2000); Acosta et al. (2013)
Mesocyclops ogunnus Onabamiro, 1957	Africa and Asia	Furnas Reservoir (Paraná River Basin)	Fish stocking	Van de Velde (1984); Reid & Pinto-Coelho (1994)
		Guaraná and Pato Lakes (Paraná River Basin)	Unknown	Lansac-Tôha et al. (2002)
		Barra Bonita, Bariri, Ibitinga, Promissão, Nova Avanhandava, Três Irmãos and Juruminin Reservoirs (Paraná River Basin)	Fish stocking	Van de Velde (1984); Matsumura-Tundisi & Silva (2002)
		Lake Dom Helvécio (Doce River Basin)	Unknown	Maia-Barbosa et al. (2008)
		Lake Dom Helvécio (Doce River Basin)	Fish stocking	Peixoto et al. (2010)
		Três Lagoas	Fish stocking	Van de Velde (1984); Cardôso et al. (2013)
		Jamari River (Amazon River Basin)	Aquaculture	Van de Velde (1984); Silva & Roche (2017)
Lamproglena monodi Capart, 1944,	Africa	Guandu River (Paraíba do Sul River Basin)	Aquaculture or fish stocking	Azevedo et al. (2012)

so far to be restricted to the Jamari River (Silva & Roche, 2017; Figure 1). Another example is the *Kellicottia bostoniensis* (Rousselet, 1908) which was introduced in lakes of the Middle River Doce, in Minas Gerais State (Peixoto et al., 2010). Copepods of the family Lernaeidae [e.g., *Lernaea cyprinacea* (Linnaeus, 1758)] were also introduced in Brazilian environments together with fish (e.g., Gabrielli & Orsi, 2000; Azevedo et al., 2012).

The governor of the State of Amazonas passed Law No. 79/2016, which, among other things, allows aquaculture of non-native fishes in that state (Tofoli et al., 2016; Padial et al., 2017). In addition, there is also a federal Project Law No. 5989/09, which intends to allow aquaculture of non-native fishes (including carps and tilapias) in reservoirs of Brazil (Azevedo-Santos et al., 2011; Vitule et al., 2012; Pelicice et al., 2014). This change in policy will result in introductions of non-native fishes (Azevedo-Santos et al., 2011; Pelicice et al., 2014; Padial et al., 2017); however, we note that another consequence of these laws will be the increased introductions or a greater propagule pressure of non-native zooplankton species such as *M. ogunnus*, *K. bostoniensis*, *Daphnia lumholtzi* Sars, 1885, *L. cyprinacea* and *Lamproglena monodi* Capart, 1944 and several others. Adults and eggs of these species can by transported with small non-native fish (e.g., Peixoto et al., 2010) that will be stocked in cages or similar structures in rivers and/or reservoirs. In addition, zooplankton (Cladocera and Rotifera) can reproduce asexually (e.g., Allan, 1976), meaning that they could establish a population with just a single individual.

Non-native zooplankton present unique challenges that complicate their management. For example, the detection of microscopic zooplankton may take longer than other macroscopic non-native organisms (e.g., fish, molluscs), because of the necessity of microscope. In addition, the study of zooplankton communities requires high-frequency time series sampling, which often is not possible due to budgetary or logistic constraints. Finally, correct taxonomic identification of invertebrates often requires specialists. Even with specialists, unfamiliar microscopic organisms can lead to erroneous or doubtful identifications (e.g., Matsumura-Tundisi & Silva, 2002), and make it difficult to detect the introduction of organisms.

It is usually more difficult to control or eradicate an introduced non-native species once they are established (Lodge et al., 2006) and

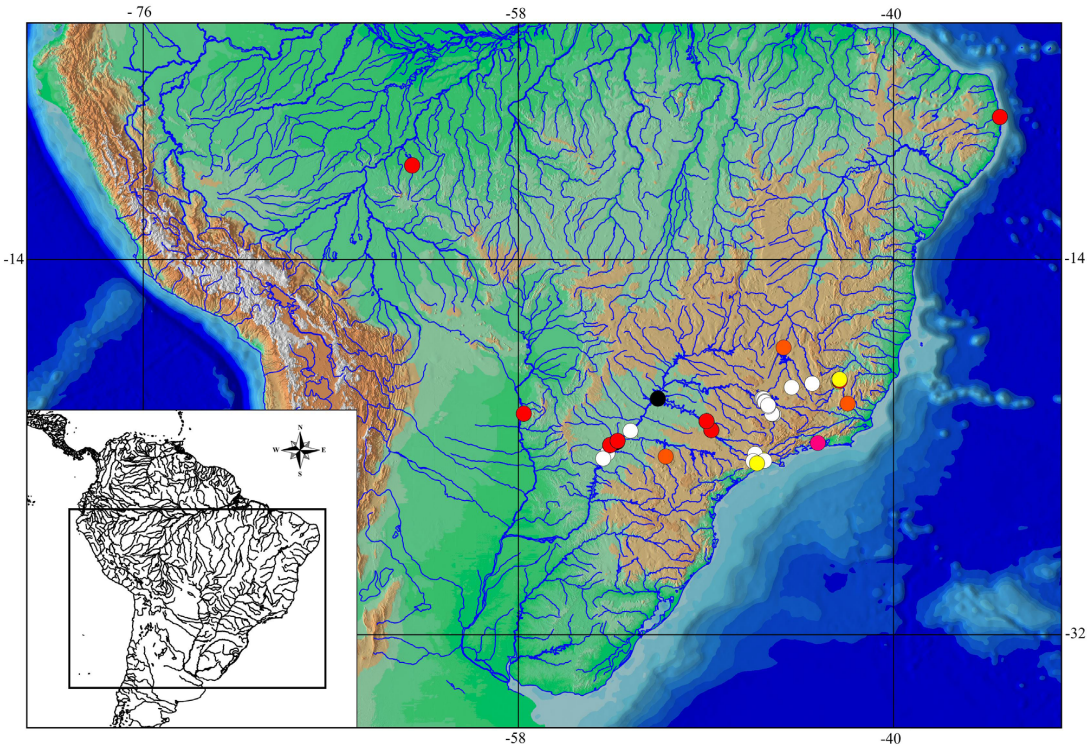

Figure 1. Examples of non-native zooplankton introduced in different Brazilian environments: *Ceriodaphnia dubia*, yellow circle; *Daphnia lumholtzi*, black circle; *Kellicottia bostoniensis*, white circle; *Lamproglena monodi*, pink circle; *Lernaea cyprinacea*, orange circle; *Mesocyclops ogunnus*, red circle (Sampling sites; see Table 1).

zooplankton can pose a high risk of adverse socio-ecological impacts (e.g., Foster & Sprules, 2009). For instance, the establishment of the non-native cladoceran *Bythotrephes longimanus* into Lake Mendota (U.S.A.) directly influenced the food web through a trophic cascade, caused a decline in water clarity and accelerated the effects of cultural eutrophication (Walsh et al., 2016). Thus, the best solution is to prevent new events of introduction (Azevedo-Santos et al., 2015). Once established, damages may be irreversible and expensive. In this context, Brazilian politicians and authorities should incentivize the use of local native fish species rather than pass laws that threaten the environment and the natural resources of the future generations (Lima Junior et al., 2012). In addition, political decisions must be made on the basis of scientific evidence to avoid unsustainable development (Azevedo-Santos et al., 2017). In conclusion, we make a call the development of protocols that will minimize the introduction of non-native zooplankton (and other organisms) due to aquaculture operations in aquatic environments.

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