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Heterotilapia buttikoferi (Hubrecht, 1881) (Perciformes: Cichlidae), an introduced exotic fish in the upper Paraná river basin

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Abstract
Aquatic biodiversity loss can be attributed in part by the presence of invasive species that increase the risk of extinction of native species through competition, predation, transmission of parasites and disease, hybridization and introgression. This study reports the first record of *Heterotilapia buttikoferi* in the upper Paraná River basin, Brazil. Additionally, the effects of establishment of this invasive species and the lack of an effective political and environmental management in Brazil that hinder exotic species' eradication are herein discussed.

Key words
Alien fish; invasive species; Pseudocrenilabrinae; Tilapiini.

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Introduction

The loss of biodiversity throughout freshwater ecosystems is linked to various factors including siltation, eutrophication, pollution, presence of hydroeletric plants and dams, flood control, over-exploitation of resources, and exotic species (Reis 2013, Britton and Gozlan 2013, Orsi and Britton 2014, Valiente-Banuet et al. 2015). Among these threats, the impacts of invasive species are particularly alarming, especially in degraded environments, such as near hydroelectric plants, that benefit the establishment of populations of invasive species (Simberloff et al. 2013, Pelicice et al. 2014, Kalous et al. 2015, Thomaz et al. 2015, Daga et al. 2015, Pagad et al. 2015).

By competing with native species, feeding on them, transmitting parasites, degrading their habitats, and even by hybridizing and introgressing genes with them, invasive species are ranked as the third worst threat. The number of fish species introduced to the Neotropical region has grown exponentially in the last decades mainly as a result of accidental escapes of captive individuals or translocation with the aim to increase artisanal fishers' income or to improve fisheries (Britton and Orsi 2012, Magalhães and Jacobi 2013, Thomaz et al. 2015). Invasive species negatively affect at least 30% the native species (Speziale et al. 2012). In this regards, it is important to understand the process of biological invasion in order to define what stage a newly discovered invasion is at. All invasive species go through sequential stages to overcome environmental resistance towards becoming established in the

Figure 1. Uberabinha River at low water flow in the locality of hydroelectric plant, where *Heterotilapia buttikoferi* were collected.

natural environment. These stages are: (1) introduction, when they first arrive in a new environment; (2) establishment, when a viable population is generated; and (3) invasion, when the rate of dispersal is high and proceeds rapidly generating a negative impact on populations of native species (Moyle and Light 1996). Only after a species has reached the final stage is it considered an invasive organism (Colautti and MacIsaac 2004).

Among the most widely introduced fish species in the world are those that belong to the cichlid tribe Tilapiini, which is native from Africa and Asia and includes more than 70 species. Due to the biological characteristics, and high level of adaptive plasticity, the tilapiinis are particularly attractive for aquaculture. They are currently the second most cultivated taxon in the world and introduced to 150 countries (Canonico et al. 2005, Cressey 2009, Abdelhadi 2011, Luque et al. 2013). In Brazil, tilapia production began in the 1950s with *Coptodon rendalli* (Boulenger, 1897) and currently represents over 40% of the aquaculture production in South American. Tilapia are now introduced to all major Brazilian basins (Ostrensky et al. 2007). There are currently at least further 2 invasive tilapia species in Brazil: *Oreochromis mossambicus* (Peters, 1852) and *Oreochromis niloticus* (Linnaeus, 1758), and also at least 4 morphotypes of *O. niloticus* known to the aquaculture and fishing trade: Tilapia Chitralada of Thailand, GenoMar Supreme Tilapia, Fishgen (Oliveira et al. 2007), and the St Peter (Kubitza 2011). All of these species have invaded natural environments or are in the process of invasion (Azevedo-Santos et al. 2011, Daga et al. 2015). It is likely that records of other members of Tilapiini in Brazil can have been underestimated or species misidentified since the identification keys are not easily available.

The present study aims to record a new occurrence of the exotic fish species *Heterotilapia buttikoferi* (Hubrecht, 1881) in the upper Paraná river basin and discusses the main impacts of its introduction in that habitat.

Methods

Specimens were collected on 10 September 2014 with a license from Instituto Estadual de Florestas de Minas Gerais (License IEF079/2014). Three individuals, 2 adult males and a non-sexed juvenile, of *H. buttikoferi* were captured in the Uberabinha River (Fig. 1), a tributary to the Araguari drainage, Paranaíba river basin, in the section of reduced-flow of a small hydroelectric plant, Uberlândia municipality, Minas Gerais (18°40′43.64″ S, 048°30′19.99″ W; Fig. 2). The specimens were collected using gill and mesh cast nets. The specimens were fixed in formaldehyde diluted to 10% and preserved in 70% ethanol. All specimens were deposited at ichthyology collection of the Museu de Zoologia, Universidade Federal de Viçosa, Brazil (catalog number MZUFV 4437).

Results

The specimens were identified with identification keys and diagnostic characters from Hubrecht (1881), Boulenger (1899), Lévêque (1992), Dunz (2012), and Dunz and Schliewen (2013). The identification was confirmed

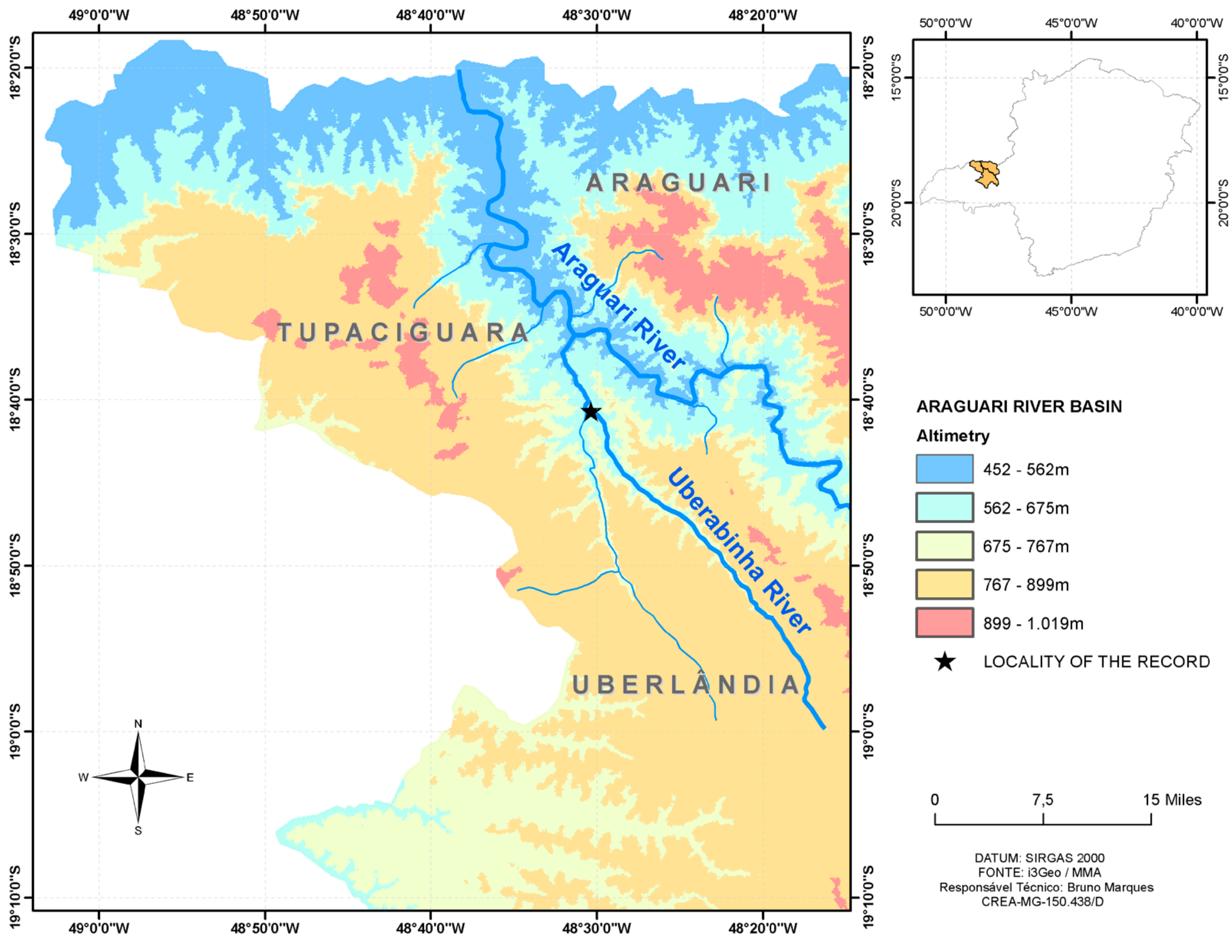

Figure 2. Locality of the specimens recorded of *Heterotilapia buttikoferi* from Uberabinha River, upper Paraná River basin.

with the help of Dr Sven Kullander (Department of Vertebrate Zoology, Swedish Museum of Natural History, Stockholm). *Heterotilapia* includes 2 species, *H. buttikoferi* and *H. cessiana* (Thys van den Audenaerde, 1968), that can be distinguished from other members of Tilapiini by the pharyngeal molariform teeth, an exclusive feature of these species (Thys van den Audenaerde, 1968). The specimens were distinguished from the congener based on the presence of bicuspid and tricuspid external mandibular teeth (vs presence of external bicuspid teeth of the mandible; Fig. 3); 5–6 series of scales in the preopercular region (vs 3–4 series of scales in this region); and 4½–6 series of scales between the first spine of the dorsal fin and the lateral line (vs 4–4½ scales in that region, Fig. 4). The body color pattern consists of vertical bars, in which the darker bars are wider than lightener-spaces background (vs darker vertical bars narrower than the light interspaces background; Fig. 5). Additionally, other characteristics were helpful in identifying the species: the presence of 13–15 spines and 14–16 soft rays in the dorsal fin; 3 spines and 10 or 11 soft rays in the anal fin; lower pharyngeal bone almost as long as wide with anterior lamella shorter than the toothed area; expanded median pharyngeal teeth when compared to lateral ones (Fig. 6).

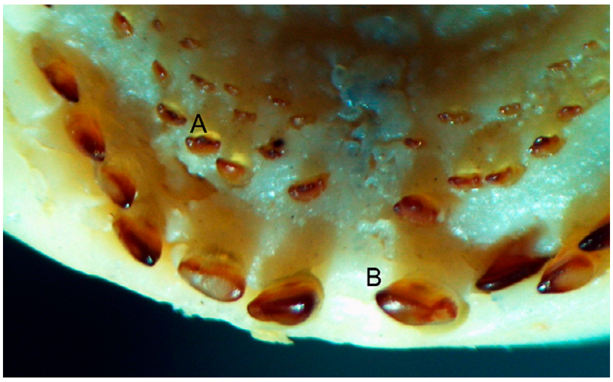

Figure 3. Teeth of the Jaw. **A.** Outer jaw teeth tricuspid. **B.** Outer jaw teeth bicuspid.

Discussion

The occurrence of *Heterotilapia buttikoferi* in the Uberabinha River is the first record of this species from the upper Paraná river basin, and in fact, from Brazilian territory. The Uberabinha basin currently suffers of many anthropogenic impacts such as water contamination by domestic and industrial effluents, habitat loss due to the presence of hydroelectric plants and dams, and alien species introduction (Langeani et al. 2007). Particularly, the construction of dams provides a main pathway by which alien fishes are introduced in the Neotropical freshwater

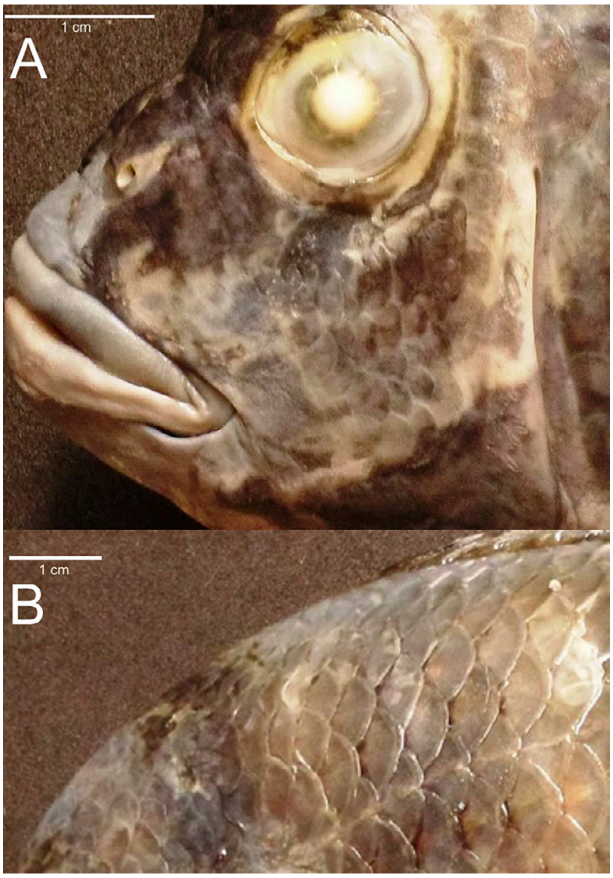

Figure 4. Series of scales of a specimen of *Heterotilapia buttikoferi* (200 mm SL). **A.** On the cheek. **B.** Between dorsal-fin origin and lateral line.

ecosystems, especially the Tilapiini, which represent one of the predominant groups in such environmental (Ortega et al. 2015). In the Uberabinha River these impacts have resulted in more homogeneous habitats, which benefit generalist and opportunistic species. Non-native species represent about 20% of the ichthyofauna of the Uberabinha River, but this may still be underestimated (Sampaio et al. 2012).

Heterotilapia buttikoferi has also been introduced to various other regions of the world including Japan, Singapore, Thailand, and the United States, with its establishment confirmed in the first 2 countries (Nico et al. 2007, Mito and Uesugi 2004, Kwik et al. 2013, Fuller et al. 2015). In Brazil it is likely that the introduction of this species was an accidental escape, as usual for other tilapia species (Linde et al. 2008). The introduction of *H. buttikoferi* is worrying due to its biological characteristics such as high physiological plasticity and its ability in tolerate broad environmental variations, which are common features to other species of Tilapiini. These characteristics make *H. buttikoferi* a very dangerous exotic species, with potential for a massive invasion, even with the introduction of only a few individuals, is its possible establishment in the Alto Paraná basin (Ogutu-Ohwayo and Hecky 1991, Luque et al. 2013, Britton et al. 2015) (Fig. 7). Furthermore, based on the ecology of Tilapiini, the likely scenario is that *H. buttikoferi* will continue to expand its geographical distribution to other Brazilian river basins. Once established in the environment, non-native species become permanent and eradication is unlikely. Their effects on native populations are extremely difficult to quantify and evaluate (Pérez et al. 1997), but competition, predation, and physical and chemical attributes changes to the aquatic environment, can threaten and lead to extinction of wild populations of native species (Figueireido and Giani 2005, Canonico et al. 2005, Zambrano et al. 2006).

Moreover, some politic amendments can contribute to the dispersion of invasive species, especially the Law No. 11,959, of 29 June 2009, which naturalized exotic species such as tilapia.

Figure 5. Live specimen of *Heterotilapia buttikoferi* (200 mm SL) collected at Uberabinha River.

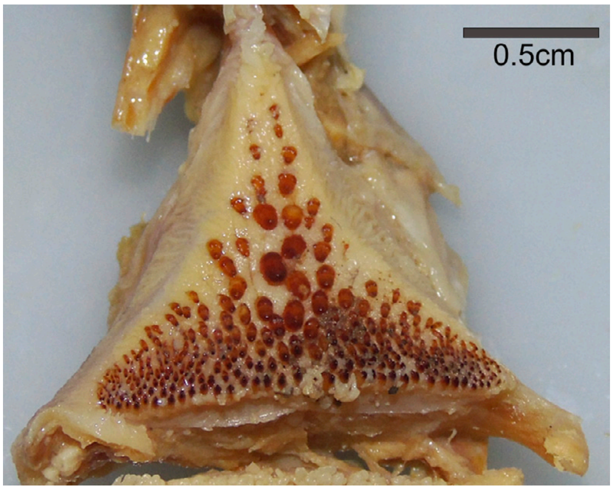

Figure 6. Dorsal view of lower pharyngeal jaw of *Heterotilapia buttikoferi* (200 mm SL).

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Authors' Contributions

WMSS collected the data, WMSS, FB, PG, JD and MLO wrote the text.

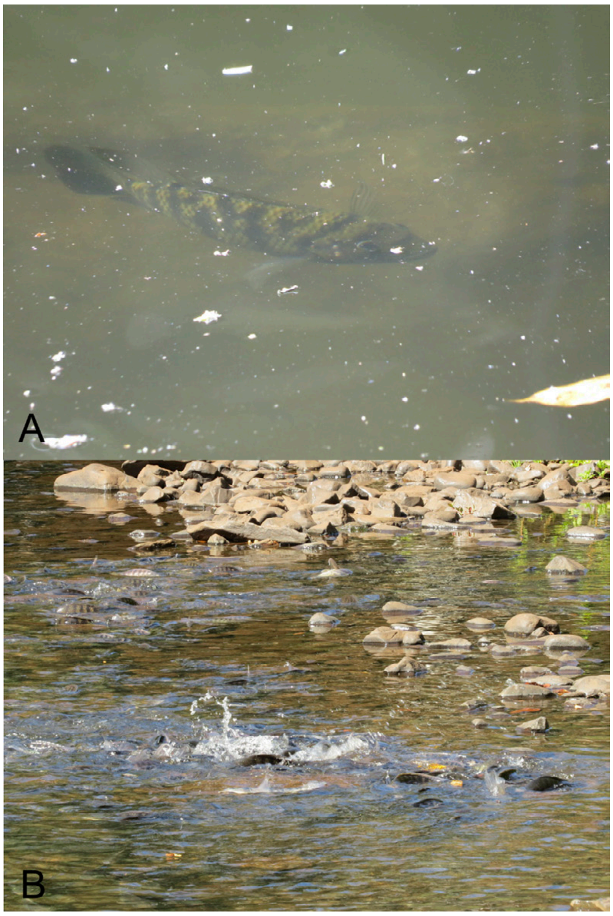

Figure 7. Photographs of *Heterotilapia buttikoferi* in the Uberabinha River. **A.** Individual in detail. **B.** Population.

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