



## From Africa to Brazil: detection of African *Oreochromis niloticus* parasites in Brazilian fish farms

Da África para o Brasil: detecção de parasitos africanos de *Oreochromis niloticus* em pisciculturas brasileiras

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**Abstract: Aim:** To evaluate the introduction of *Oreochromis niloticus* gill parasites in the Paranapanema River basin, northern Paraná, southern Brazil, as well as to inventory its occurrences in Brazilian fish farms and discuss the risks of transmission to native fauna. **Methods:** The gills of 632 fish specimens from four fish farms in the Paranapanema Basin were analyzed. The parasites were collected, processed and identified according to specific procedure. Literature review was carried out to compile records of occurrence of gill parasites species in other Brazilian river basins. **Results:** A total of seven (7) species of parasites were recorded, five (5) of the genus *Cichlidogyrus*, one (1) of *Scutogyrus* (Ancyrocephalidae, Monogenoidea) and one (1) of *Lamproglena*, *Lamproglena monodi* (Copepoda, Lernaeidae). All native from Africa. Some of these species have been reported in fish farms located in five other Brazilian watersheds. However, in this study a greater number of African gill parasite species was recorded in fish farms in northern Paraná (seven species), in the Paranapanema Basin, with *Cichlidogyrus rognoni* reported only for this basin. **Conclusions:** The results confirm the introduction of these African parasites along with their host, *O. niloticus*, and the establishment of these species in Brazilian waters, since many specimens belonging to the species identified herein presented breeding activity for at least one period of the year. Although, only *L. monodi* has been recorded parasitizing Brazilian native species, data reported for other countries demonstrates the imminent risk of transmission of these *O. niloticus* parasites to native cichlids.

**Keywords:** freshwater; non-native species; invasion; Neotropical; Nile tilapia.

**Resumo: Objetivo:** Avaliar a introdução de parasitos branquiais de *Oreochromis niloticus* na bacia do rio Paranapanema, norte do Paraná, sul do Brasil, assim como inventariar suas ocorrências em pisciculturas brasileiras e discutir os riscos de transmissão para a fauna nativa. **Métodos:** As brânquias de 632 espécimes de peixes de quatro estações de piscicultura na bacia do rio Paranapanema foram analisadas. Os parasitos foram coletados, processados e identificados de acordo com procedimento específico. A revisão da literatura foi realizada para compilar registros de ocorrência de espécies parasitas branquiais em outras bacias hidrográficas brasileiras. **Resultados:** Um total de sete (7) espécies de parasitos foi registrado, sendo cinco (5) do gênero *Cichlidogyrus*, uma (1) de *Scutogyrus* (Ancyrocephalidae, Monogenoidea) e uma (1) de *Lamproglena*, *Lamproglena monodi* (Copepoda, Lernaeidae), todas nativas da África. Algumas dessas espécies foram registradas em pisciculturas localizadas em outras cinco bacias hidrográficas brasileiras. No entanto, neste estudo, um número maior de espécies parasitas africanas foi registrado em pisciculturas no norte do Paraná (sete espécies), na bacia do rio Paranapanema, sendo *Cichlidogyrus rognoni* relatada apenas para essa bacia.



**Conclusões:** Os resultados confirmam a introdução destes parasitos africanos juntamente com o hospedeiro *O. niloticus* e o estabelecimento dessas espécies em águas brasileiras, uma vez que muitos espécimes pertencentes às espécies aqui identificadas apresentaram atividade reprodutiva por pelo menos um período do ano. Embora apenas *L. monodi* tenha sido registrada parasitando espécies nativas brasileiras, dados relatados para outros países demonstram o risco iminente de transmissão desses parasitos de *O. niloticus* para ciclídeos nativos.

**Palavras-chave:** água doce; espécies não nativas; invasão; Neotropical; tilápia do Nilo.

## 1. Introduction

Fish translocation has been carried out by human activities for a long time and for various purposes. Translocation is mainly intentional, with aquaculture, improvement of wild populations (fish stocking), fishing, biological control, and aquarium dumping as the main introduction vectors worldwide (Leprieur et al., 2008; Gozlan et al., 2010). Several negative effects caused by the introduction and subsequent invasion of fish species may occur, such as predation, habitat degradation, increased competition for resources, hybridization and disease transmission (Gozlan et al., 2010; Cucherousset & Olden, 2011). Thus, invasive fish can affect a wide variety of native organisms, both directly and indirectly, at levels ranging from the genome to the ecosystem (Cucherousset & Olden, 2011).

The native distribution of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) (Cichliformes, Cichlidae), is from North and East Africa, throughout the coastal rivers of Israel, the Nile River basin and several African lakes (Trewavas, 1983). It is widely distributed throughout several tropical and subtropical countries, due to aquaculture introduction (Eschmeyer et al., 2017; Froese & Pauly, 2017).

In Brazil, the introduction of *O. niloticus* first ensued in the 1970s in the Brazilian Northeast, as the National Department of Drought Works (Departamento Nacional de Obras Contra a Seca - DNOCS) sought to populate dams during programs developed to fight hunger (Castagnolli, 1996). Since this event, the species has become intensely farmed in fish farms and 'fish and pay' establishments in several States and is currently farmed in practically the entire country (Borghetti & Teixeira da Silva, 2008; Boscardin, 2008).

Although the introduction of *O. niloticus* was initiated with the aim of promoting the creation of developing economies, this species has caused serious environmental problems and threats to the native fish fauna in several countries, including the United States, Mexico, Australia, the Philippines, Madagascar, and Brazil, due to its high invasive

potential (Froese & Pauly, 2017; Cassemiro et al., 2018). The introduction of this species is of concern due to its ability to alter the invaded environment (Cassemiro et al., 2018), threatening native fish fauna by preying on fish in early development stages (i.e., eggs and larvae) and competing for space and food (Martin et al., 2010; Sanches et al., 2012). In the Americas, this species has promoted competitive displacement and alterations of reservoir water quality and phytoplankton communities (Figueredo & Giani, 2005; Martin et al., 2010).

In Lakes Victoria and Kyoga, after its invasion, *O. niloticus* has predominated and drastically reduced the native *Oreochromis esculentus* (Graham, 1928) and *Oreochromis variabilis* (Boulenger, 1906) populations (Ogutu-Ohwayo, 1990; Maithya et al., 2012). The invasion of African tilapia (*Oreochromis* spp.) in Nicaragua lakes has also led to decreased native cichlid biomass and richness (McCrary et al., 2007).

As well as representing a direct biological risk for native fish fauna, *O. niloticus* invasion may also lead to the presence of other organisms, like parasitic species non-natives (Jiménez-García et al., 2001; Azevedo et al., 2012; Bittencourt et al., 2014a; Zago et al., 2014; Šimková et al., 2019). Co-introductions include parasitic species, and are a rarely documented risk, particularly in Brazil (Azevedo et al., 2012; Bittencourt et al., 2014a; Zago et al., 2014), as, most of the time, parasite introductions by hosts are neglected. Diseases caused by ectoparasites are variable, and may cause destruction of scales, abundant secretion of mucus, hyperplasia and necrosis of cells (Eiras, 1994). In some cases, fungi and bacteria invade the lesions, which can cause more serious consequences than those due to the parasitosis itself, in both farmed and wild fish (Eiras, 1994). Non-native parasite species alter natural parasite-host interactions, which may lead to anemia, low coefficient of condition (Yamamoto et al., 1984), and increase mortality among native host species (Prenter et al., 2004; Goedknegt et al., 2016).

In this context, we aimed to evaluate the introduction of *O. niloticus* gill parasites in earthen

ponds and net cages in the Paranapanema River basin, southern Brazil, and compare this event with other Brazilian fish farms. In addition, we discuss the risks of transmission to native fish fauna.

## 2. Material and Methods

A total of 632 of juveniles and adults of *O. niloticus* specimens sexually reverted (males) donated by four fish farms in the northern Paraná State, Paranapanema Basin, were examined, from two net cages (22°47'22.36"S, 51°17'46.53"W and 22°41'09.10"S, 51°17'49.88"W) and two earthen ponds (23°16'25.82"S, 51°26'23.70"W and 23°16'57.59"S, 51°25'30.81"W). Of the 632 individuals, 156 specimens were obtained from earthen ponds and 476 from net cages. Samplings were carried out seasonally, from April 2010 to February 2011. Each specimen collected were dead and cooled. The gills of each specimen were removed and examined closely under stereomicroscope magnification. The parasites were collected and processed adequately according to Eiras et al. (2000). Each monogenoidean was identified according to the descriptions reported by Paperna (1964), Paperna & Thurston (1969), Ergens & Yurkimenko (1987), Douëllou (1993), Pariselle

& Euzet (1995), Pariselle et al. (2003) and the determination key proposed by Pariselle & Euzet (2009). Copepods were identified based on the redescrptions of Ibraheem & Izawa (2000) and Azevedo et al. (2012).

A large literature review was carried out in order to compile records of occurrence of parasitic gill species in other Brazilian river basins, during January to May 2018. Only data published in scientific journals were considered. The research was conducted on the Web of Science, Scopus, Scielo and Google Scholar platforms, using the term 'Brazil' and combinations of the following terms: 'Monogenea', 'Monogenoidea', 'Ancyrocephalidae', 'Dactylogyridae', '*Cichlidogyrus*', '*Scutogyrus*', '*Lamproglena*', '*Oreochromis*', 'Nile tilapia'.

## 3. Results and Discussion

The literature review resulted in the compilation of nine studies on the occurrence of gill parasites in Brazilian river basins (Table 1). The following monogenoidean species were identified in fish farms in the Paranapanema River basin: *Cichlidogyrus rognoni* Pariselle, Bilong Bilong & Euzet, 2003, *C. sclerosus* Paperna & Thurston, 1969, *C. thurstonae* Ergens, 1981, *C. halli* (Price & Kirk, 1967),

**Table 1.** *Oreochromis niloticus* gill parasites species of African origin detected in different Brazilian river basins.

Species	Geographical distribution in Brazil	References
Platyhelminthes		
Monogenoidea		
<i>Cichlidogyrus halli</i>	Grande River basin (MG/SP) Paranapanema River basin (SP/PR) Itajaí River basin (SC)	Zago et al. (2014) Britto & Silva-Souza (2017), Present study Jerônimo et al. (2011)
<i>Cichlidogyrus rognoni</i>	Paranapanema River basin (SP/PR)	Britto & Silva-Souza (2017), Present study
<i>Cichlidogyrus sclerosus</i>	Paranapanema River basin (SP/PR)  Itajaí River basin (SC) Uruguay River basin (SC)	Lizama et al. (2007), Britto & Silva-Souza (2017), Present study  Ghiraldelli et al. (2006a), Jerônimo et al. (2011) Martins et al. (2014)
<i>Cichlidogyrus thurstonae</i>	Grande River basin (MG/SP) Paranapanema River basin (SP/PR) Itajaí River basin (SC) Uruguay River basin (SC)	Zago et al. (2014) Britto & Silva-Souza (2017), Present study Jerônimo et al. (2011) Martins et al. (2014)
<i>Cichlidogyrus tilapiae</i>	Amazon River basin (AP) Paranapanema River basin (SP/PR) Uruguay River basin (SC)	Pantoja et al. (2012), Bittencourt et al. (2014a) Britto & Silva-Souza (2017), Present study Martins et al. (2014)
<i>Scutogyrus longicornis</i>	Grande River basin (MG/SP) Paranapanema River basin (SP/PR); Itajaí River basin (SC) Uruguay River basin (SC)	Zago et al. (2014) Britto & Silva-Souza (2017), Present study Jerônimo et al. (2011) Martins et al. (2014)
Crustacea		
Copepoda		
<i>Lamproglena monodi</i>	Paraíba do Sul River basin (RJ) Paranapanema River basin (SP/PR)	Azevedo et al. (2012) Present study

MG: state of Minas Gerais; SP: state of São Paulo; PR: state of Paraná; SC: state of Santa Catarina; AP: state of Amapá.

*C. tilapiae* Paperna, 1960, and *Scutogyrus longicornis* (Paperna & Thurston, 1969), all originating from Africa (Table 1). These six monogenoidean species recorded herein in *O. niloticus* gills were found in an earthen pond from another fish farm in northern Paraná (Britto & Silva-Souza, 2017). Five *Cichlidogyrus* species, comprising *C. sclerosus* and four unidentified species, were recorded infesting *O. niloticus* gills in specimens raised in ponds in the state of São Paulo, also in the Paranapanema River basin (Lizama et al., 2007). Four *Cichlidogyrus* species were recorded in net cages, two of which unidentified, in addition to *S. longicornis*, in the Água Vermelha Reservoir, Grande River basin, located in the state of São Paulo (Zago et al., 2014). Nile tilapia reared in net cages in the Guarapiranga Reservoir, also in the state of São Paulo, were infested by *Cichlidogyrus* sp.

In southern Brazil, five species have also been reported in ponds in different fish farms in the state of Santa Catarina, in the Itajaí River basin (Ghiraldelli et al., 2006a; Jerônimo et al., 2011) and in the Uruguay River basin (Martins et al., 2014). On the other hand, only *C. tilapiae* was recorded in the state of Amapá, northern Brazil, in four fish farms (Pantoja et al., 2012). Thus, the high number of African parasitic gill species recorded in northern Paraná fish farms, in the Paranapanema Basin, is noteworthy, with *C. rognoni* being found only in this basin to date.

In Africa, Ancyrocephalidae (Monogenoidea) is the family with most representatives of gill parasites infesting *Oreochromis* Günther, 1889, *Coptodon* Gervais, 1853 (= *Tilapia* Smith, 1840), and *Sarotherodon* Rüppell, 1852. *Oreochromis niloticus* gill parasites are distributed in two genera: *Cichlidogyrus* Paperna, 1960 and *Scutogyrus* Pariselle & Euzet, 1995 (Pariselle, 1995; Pariselle & Euzet, 2009). *Cichlidogyrus sclerosus*, present in three Brazilian hydrographic basins (Table 1), was introduced in Colombia (Kritsky & Thatcher, 1974) and in Mexico (Kritsky et al., 1994). On the other hand, *C. tilapiae*, also reported in three Brazilian basins, including the Amazon Basin, was registered in Cuba by Prieto et al. (1985). These records demonstrate that this group of African parasites presents a wide distribution in the Neotropical region, where they presented tolerance and adjustment to the new environment.

The six species of Monogenoidea recorded displayed breeding activity for at least one period of the year in fish farming activities also carried out in northern Paraná (Britto & Silva-Souza,

2017). In the present study, although they were not quantified, individuals from the same species of egg-containing gill parasites were found in all evaluated fish farms. These results allow us to consider that these African species are established and adjusted to the environments where their hosts are being reared and, therefore, propagule pressure of the recorded parasites has been potentiated.

*Lamproglena monodi* Capart, 1944 (Copepoda Lernaecidae), also from Africa, was registered in one of the fish farms containing earthen ponds (Table 1). *Lamproglena* von Nordmann, 1832 comprises 41 freshwater fish parasite species (Piasecki, 2008) distributed throughout Africa (Douëllou & Erlwanger, 1994; Ibraheem & Izawa, 2000; Hassan et al., 2013; Marzouk et al., 2013; Sinaré et al., 2016), Asia (Kumari et al., 1989; Yambot & Lopez, 1997) and Europe (Galli et al., 2001). In Brazil, *Lamproglena* sp. has been reported since the year 2000 in the states of São Paulo, Rio de Janeiro and Santa Catarina (Alves et al., 2000; Azevedo et al., 2006; Ghiraldelli et al., 2006a; Ghiraldelli et al., 2006b; Lizama et al., 2007; Martins et al., 2010). According to Douëllou & Erlwanger (1994), *Lamproglena monodi*, a gill parasite of several species of cichlids, has *Coptodon rendalli* (Boulenger, 1897) as one of its preferred hosts. However, in Brazil, *L. monodi* has been recorded in freshwater environments as both a parasite of *O. niloticus* and *C. rendalli* (Azevedo et al., 2010; Azevedo et al., 2012; Tavares-Dias et al., 2015). Such records confirm that *O. niloticus* has brought along partly or all of its native parasites when introduced in Brazil (Britto & Silva-Souza, 2017).

The lack of data on fish farmed during the last 15 years does not allow for conclusions regarding *L. monodi* introduction in Brazil (Martins et al., 2010). However, this crustacean was found as a parasite in Amazonian cichlid populations introduced in the Guandu River, in the state of Rio de Janeiro, namely *Astronotus ocellatus* (Agassiz, 1831) and *Cichla ocellaris* Bloch & Schneider, 1801 (Azevedo et al., 2010) (Table 1). According to Tavares-Dias et al. (2015), *L. monodi* is distributed throughout the Paraná, Uruguay and Atlantic Ocean River systems.

A lower number of gill parasites species was recorded infesting *O. niloticus* in fish farms located in the states of Minas Gerais, Rio de Janeiro, São Paulo, Santa Catarina and Amapá (Table 1). *Oreochromis niloticus* was introduced in 1994 in some fish farms in the municipality of Macapá,

in the state of Amapá, eastern Amazon region, in northern Brazil (Tavares-Dias, 2011). Between 2000 and 2001, several reports were made of *O. niloticus* escapes due to pond overflowing by heavy rains (Tavares-Dias, 2011). *Oreochromis niloticus*, an invasive species in the Igarapé Fortaleza basin, was infested with *Ichthyophthirius multifiliis* Fouquet, 1876, *Trichodina centrostrigeata* Basson, Van As & Paperna, 1983, *Paratrichodina africana* Kazubski & El-Tantawy, 1986, *Trichodina nobilis* Chen, 1963, and *Cichlidogyrus tilapiae*, with no common parasite species to the native Amazonian ecosystem fish fauna. On the other hand, *T. nobilis*, a trichodinid parasite of *O. niloticus*, was transmitted to the native basin cichlid, *Aequidens tetramerus* (Heckel, 1840) (Bittencourt et al., 2014a, b). However, nothing is known about Brazilian watershed native fish infestations by African monogenoidean parasites of *O. niloticus* gill. Nevertheless, in Mexico, after the introduction of *O. niloticus*, infestation of the native species *Vieja fenestrata* (Günther, 1860) (= *Cichlasoma fenestratum*) (Cichlidae) by *Scutogyrus longicornis* (= *Cichlidogyrus longicornis*) was observed (Jiménez-García et al., 2001). This monogenoidean species was detected in four Brazilian watersheds.

In Brazil, *O. niloticus* is the most farmed species and corresponds to 45.4% of the total fish production in the country, with the state of Paraná (southern region) as the largest producer, totaling 28.8% (Brasil, 2017). The species is farmed both in earthen ponds and in net cages located in reservoirs. Even if the species is only reared in earthen ponds, these constructions are usually built close to riverine areas subject to flooding, and fish escapes may occur during rainy periods (Casimiro et al., 2018).

In the summer of 2015/16, about 1.14 million fish belonging to 21 species and three hybrids escaped from fish farms to the Paranapanema River basin. Of this total, 96% comprised *O. niloticus* and *C. rendalli* specimens (Casimiro et al., 2018). It is important to note that *O. niloticus* specimens had already been recorded in the Capivara Reservoir (Paranapanema River) (Orsi & Britton, 2014). The presence of *O. niloticus* in the Grande and Uruguay river reservoirs and in the Amazonas River were reported, respectively, by Azevedo-Santos et al. (2011), Schork et al. (2013) and Bittencourt et al. (2014a). On the other hand, no records of *O. niloticus* in natural Itajaí River basin environments are available.

In this context, and according to the findings for fish farms in northern Paraná, in the Paranapanema River basin, as well as other Brazilian watersheds,

an imminent risk of transmission of *O. niloticus* parasites to cichlids, such as *Australoheros* Rican & Kullander, 2006, *Aequidens* Eigenmann & Bray, 1894, *Cichlasoma* Swainson, 1839, *Crenicichla* Heckel, 1840, *Geophagus* Heckel, 1840, and *Gymnogeophagus* Miranda Ribeiro, 1918, is noted (Langeani et al., 2007). The consequences of the association of these Africa parasites to native fish are still unclear, but there may be a risk of increased mortality as recorded for cichlids in Florida (Noga & Flowers, 1995). Ectoparasites may cause injuries of scales, secretion of mucus and necrosis of cells, which allow the entry of fungi and bacteria (Eiras, 1994). The pathogens caused by these parasites alter parasite-host interactions and reduce the native host population (Prenter et al., 2004; Goedknecht et al., 2016). Therefore, fish translocation by human intervention provides a window of opportunity for new interactions that threaten biodiversity.

It is important to note that the results presented and reported herein may not represent the actual distribution of parasitic species in Brazil, as these findings represent only the places where published studies took place. Due to the large size of the Brazilian territory, we detected the lack of information on the distribution of these parasites in several regions of the country, such as the northeast region where the first case of introduction of *O. niloticus* occurred. However, such records confirm that *O. niloticus* has introduced non-native parasites.

Thus, we suggest that, safety ponds should be installed in fish farms, to allow the water treatment prior to release in nearby springs. Fish farm inspection should be increased, and if escape events are proven, the National Environmental Policy that establishes the 'polluter pays' principle should be applied to the fish farmer. Non-native species are considered a form of environmental pollution and may be a serious impact on aquatic ecosystems (França et al., 2017; Casimiro et al., 2018). Therefore, the correct identification and survey of the distribution of non-native parasites are essential to maintain the integrity of Brazilian aquatic ecosystems. In addition, lay people, fish farmers and fishermen should be made aware of how to combat non-native species.

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