

## A review of zoonotic pathogens in Tilapia

### Uma revisão sobre patógenos zoonóticos de Tilápia

DOI:10.34117/bjdv8n11-340

Recebimento dos originais: 28/10/2022

Aceitação para publicação: 29/11/2022

#### **Alessandro Vinicius da Silva Rolim**

Master's candidate in Single Health at Universidade Santo Amaro

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,  
São Paulo - SP, CEP: 04829-300

E-mail: j-alessandro@estudante.unisa.br

#### **Amanda Barbosa Santana**

Biological Sciences Undergraduate

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,  
São Paulo - SP, CEP: 04829-300

E-mail: abarbosa1z@estudante.unisa.br

#### **Marcelo Eustáquio Pina**

Graduating in Biological Sciences

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,  
São Paulo - SP, CEP: 04829-300

E-mail: marceloeustaquio@estudante.unisa.br

#### **Sara Zanelato de Paula**

Biological Sciences Undergraduate

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,  
São Paulo - SP, CEP: 04829-300

E-mail: s.zanelato@estudante.unisa.br

#### **Herbert Sousa Soares**

Post-Graduation in Single Health at Universidade Santo Amaro

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,  
São Paulo - SP, CEP: 04829-300

E-mail: hesoares@prof.unisa.br

#### **Arlei Marcili**

Post-Graduation in Single Health at Universidade Santo Amaro

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,  
São Paulo - SP, CEP: 04829-300

E-mail: amarcili@prof.unisa.br

**Guilherme José da Costa Silva**

Post-Graduation in Single Health at Universidade Santo Amaro

Institution: Universidade Santo Amaro

Address: Rua Professor Eneas de Siqueira Neto, 340, Jardim das Imbuías,

São Paulo - SP, CEP: 04829-300

E-mail: gjsilva@prof.unisa.br

**ABSTRACT**

*Oreochromis niloticus*, or Nile tilapia, is widely consumed. This fish can cause several direct ecological imbalances in addition to transporting several pathogens. Pathogens in tilapia are responsible for several deaths in natural environments and commercial aquaculture, and hence, constitute an economic, social, and sanitary threat. This study gathered information from the literature and identified 18 species of pathogens with zoonotic potential found in tilapia, in addition to mapping the distribution of these fishes in Brazilian natural environments. We found that the most common pathogens involved were bacteria, protozoa, fungi and helminths (Trematoda and Nematoda). In Brazil, we also identified that the introduction of *O. niloticus* has grown in recent decades, and *O. niloticus* have been found mainly in the eastern region of the country, overlaying the region with the highest fish population density in Brazil. This work serves as an alert and a guide for planning public health policies to mitigate the possible consequences of the uncontrolled introduction of tilapia in the national territory.

**Keywords:** tilapia, parasites, pathogens, zoonoses, *oreochromis niloticus*.

**RESUMO**

*Oreochromis niloticus*, ou tilápia do Nilo, é amplamente consumido. Esse peixe pode causar diversos desequilíbrios ecológicos diretos além de transportar diversos patógenos. Patógenos em tilápias são responsáveis por várias mortes em ambientes naturais e na aquicultura comercial e, portanto, constituem uma ameaça econômica, social e sanitária. Este estudo reuniu informações da literatura e identificou 18 espécies de patógenos com potencial zoonótico encontrados em tilápias, além de mapear a distribuição desses peixes nos ambientes naturais brasileiros. Descobrimos que os patógenos mais comuns envolvidos foram bactérias, protozoários, fungos e helmintos (Trematoda e Nematoda). No Brasil, também identificamos que a introdução de *O. niloticus* tem crescido nas últimas décadas, sendo que *O. niloticus* tem sido encontrado principalmente na região leste do país, sobrepondo-se à região de maior densidade populacional humana do Brasil. Este trabalho serve como alerta e guia para o planejamento de políticas públicas de saúde para mitigar as possíveis consequências da introdução descontrolada da tilápia no território nacional.

**Palavras-chave:** tilapia, parasitas, patógenos, zoonoses, *oreochromis niloticus*.

**1 INTRODUCTION**

According to the Food and Agriculture of the United Nations (FAO), Nile tilapia (*Oreochromis niloticus*, Linnaeus, 1758) is the most cultivated fish and the third most consumed fish on the planet. This fish can be found in over 100 countries (FAO, 2020)

in fresh and brackish water. In 2018, more than 4.4 million tons of *O. niloticus* were produced, accounting for 8.3% of all fish produced on the planet (FAO, 2019). In Brazil, *O. niloticus* was introduced in 1971 (FAO, 2020). In 2020, national production reached 400.000 tons (Peixe-BR, 2020). Tilapia productivity success is because of biological properties of the species, as well as several projects of the genetically-improved farmed tilapia (GIFT). GIFT improves the productivity and acclimatation of the fish so that they can be cultivated in different environments, improving the yield of fish farms (Dey, 2000; Mondal & Dalui, 2020).

Tilapia occupy lacustrine regions, and they often an environmental problem in the regions they are introduced (Charvet et al. 2021; Doria et al. 2021; Thresher et al. 2020). Biological properties, such as omnivorous feeding habits, year-round reproduction, parental care of the offspring, and high tolerance to environmental factors favor the dominance of the species in introduced environments (Mjoun et al. 2010). The population control of the species faces several technical challenges when introduced, in addition to a significant ecological/social dilemma. Although tilapia promote ecological imbalances by competing with the local fauna, they have also become the main source of fish and an important source of protein for human populations, reducing fishing pressures on native species (Thresher et al. 2020).

However, it must be noted that the introduction of exotic fauna can also introduce a series of pathogens that directly affect native species. Among the most common diseases affecting the cultivation of tilapia and causing high mortality. Bacteria, fungi, and protozoa have been found to be the most common pathogens (FAO, 2020). There are also records of large losses caused by helminth infections (Akoll et al. 2012), with multiple pathogen infections often occurring in individuals (Abdel-Latif et al. 2020). In Brazil, tilapia die-offs because of reservoir outbreaks have been widely reported (Delphino et al. 2019).

In addition to the environmental and economic impact of fish pathogens, there are also risks of transmission to humans by different modes, thus configuring zoonotic agents in some cases (Boylan, 2011; Chai et al. 2005; Jorge Costa Eiras et al. 2018; Gauthier, 2015; McCarthy & Moore, 2000; Wodajo, 2020; Zhu et al. 2019). Tilapia have prominent spines on their dorsal fins that can injure workers' skin in the fishing industry, which leads to transmission of pathogens via inoculation. There is also the possibility of transmission by sharing water and consuming contaminated fish, the latter being intensified by the

growing habit of consuming raw or undercooked fish (Delphino et al. 2019; Gauthier, 2015; Mohanty & Sahoo, 2007; Wodajo, 2020).

In view of the increasing consumption of *O. niloticus* in Brazil and the lack of a review of the risks of emerging zoonoses from these fish, this study sought to gather information about all possible zoonotic agents in the literature and in collection databases already reported in tilapia. It correlated the potential risks of infection by these agents because of the occurrence of tilapia in natural environments, thus serving as an alert and guide for planning public health policies.

## 2 MATERIAL AND METHODS

The investigation in present study is a bibliometric research and was carried out in exploratory and descriptive form with a qualitative approach to zoonotic diseases in tilapia (Wallin, 2005) The data set was structured from the analysis of articles accessed through the database available on the Web of Science (WoS), PubMed and Google Scholar platforms from 2000 to 2022. In these databases, searches were carried out to find indexed articles.

The search terms Pathogens, Zoonotics, *Tilapia nilotica*, *Oreochromis nilotica*, freshwater fish that could be expressed in the title, abstract and/or keywords were used. The terms were applied in several combinations, using the Boolean operators E and OR in order to be found in the singular, plural and its variant forms. After obtaining the list of published articles, which reported the terms of the research, a search was carried out in books and search of articles cited in the selected publications according to the search

Through a massive bibliographic survey, we sought to identify all pathogens with zoonotic potential already present in *Oreochromis niloticus*. In our searches, we preferred articles and review books in English and secondarily in Portuguese. We also sought to identify the causes and primary means of infection, and where the *Tilapia*-pathogen interaction was detected. Through analysis of biological collection databases, collection points in a natural environment were surveyed where tilapia were collected in a Brazilian natural environment, and therefore were introduced. We searched collection data in the SpeciesLink digital catalogs that gather information from Brazilian and international collections. We used both *Oreochromis niloticus* and its synonym (*Tilapia nilotica*) in the search engine. In this review, we adopted the World Health Organization's concept of

zoonosis, which is defined as an infectious disease that passes from a non-human animal to man.

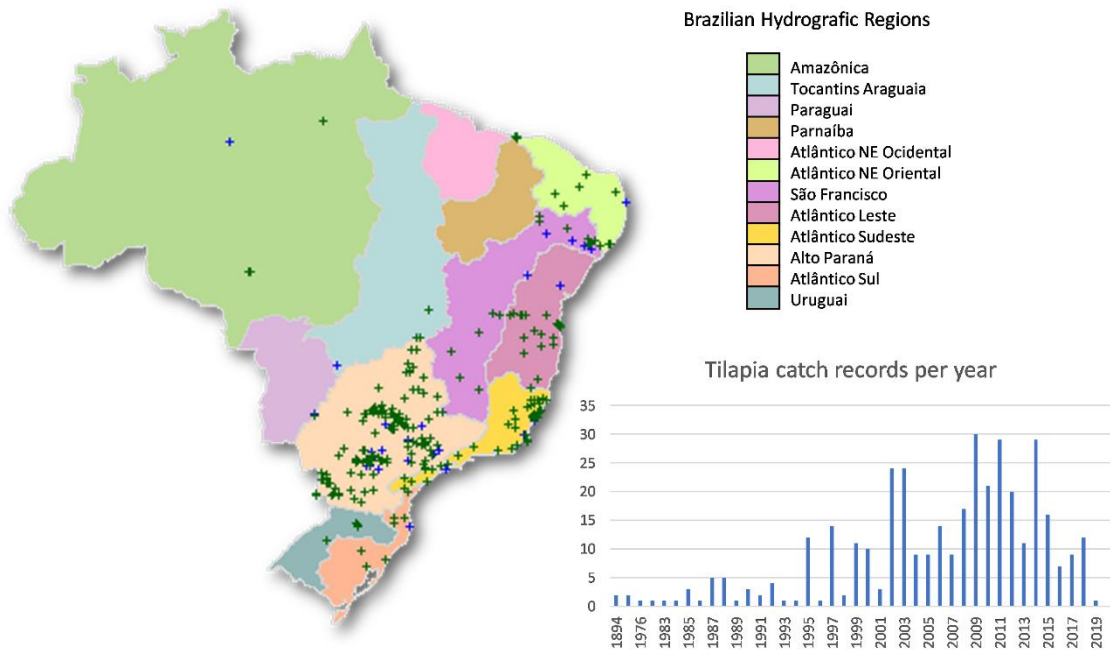
### 3 RESULTS

From the bibliographical survey, 18 pathogens were identified: five bacteria, one fungi, two protozoa, eight trematodes and two nematodes. These pathogens, as well as their most likely modes of transmission, are shown in Table 1. Data from biological collections show that *O. niloticus* has been widely introduced in Brazilian territory but has an unequal distribution. The number of records increased since 1994, which marks the first record of the species deposited in biological collections in Specieslink (Figure 1).

Table 1: Zoonotic species found in Tilapia (*Oreochromis niloticus*).

Parasite identification	Host local catalogated	Contagion method	Reference
<b>Bacteria</b>			
<i>Edwardsiella tarda</i>	All continents	Inoculation and food	(Mohanty & Sahoo, 2007)
<i>Klebsiella pneumoniae</i>	Thailand	Unknown, maybe by water	(Khosravani et al. 2017)
<i>Plesiomonas shigelloides</i>	Brazil	Food	(Delphino et al. 2019)
<i>Streptococcus agalactiae</i>	Brazil, Iraq, USA, Honduras	Food	(Evans et al. 2008)
<i>Streptococcus iniae</i>	Canada	Unknown	(Gauthier, 2015)
<b>Fungus</b>			
<i>Candida albicans</i>	Thailand, Egypt	Food	(Eissa et al. 2013; Khosravani et al. 2017)
<b>Protozoan</b>			
<i>Cryptosporidium parvum</i>	Egypt, Papua New Guinea		(Ammar & Arafa, 2013; Koinari et al. 2013)
<i>Giardia duodenalis</i>	Egypt	Food	(Ghoneim et al. 2012)
<b>Trematoda</b>			
<i>Centrocestus formosanus</i>	All continents	Food	(Chai & Jung, 2019)
<i>Haplorchis pumilio</i>	Thailand, China	Food	(Chai et al. 2005; Zhu et al. 2019)
<b><i>Haplorchis taichui</i></b>	China	Food	(Zhu et al. 2019)
<i>Heterophyes heterophyes</i>	Egypt	Food	(Chai & Jung, 2019)
<i>Metagonimus</i> sp.	China	Food	(Li et al. 2013)
<i>Procerovum varium</i>	China	Food	(Li et al. 2013)
<i>Prohemistomum vivax</i>	Egypt	Food	(Chai & Jung, 2019)
<i>Pygidiopsis genata</i>	Egypt	Food	(Chai & Jung, 2019)
<b>Nematoda</b>			
<i>Gnatostoma</i> sp.	Mexico	Food	(León-Règagnon et al. 2005)
<i>Prohemistomum</i> sp.	Egypt	Food	(Hassan, E.A., Soliman, M.F.M., Ghobashy, 2012)

Figure 1: Temporal and spatial distribution of Tilapia sampling in natural environments in Brazil. Font: Specieslink network, 09-Ago-2021.



## 4 DISCUSSIONS

### 4.1 TILAPIA ZOONOTIC BACTERIA

The main zoonotic agents from tilapia belong to the group of bacteria, with cases reported in almost all continents (Table 1). The modes of transmission vary, such as direct contact with contaminated water or fish, consumption of meat, or inoculation through wounds (Delphino et al. 2019; Gauthier, 2015; Lehane & Rawlln, 2000; Mohanty & Sahoo, 2007; Wodajo, 2020). Infection in humans differs significantly in terms of virulence and pathogenicity. Species such as *Klebsiella pneumoniae* cause pneumonia, liver abscess, bloodstream infection, and urinary tract infections (Arnaud et al. 2015; Chang et al. 2015; Wang et al. 2018). There are also cases of death reported because of antibiotic-resistant bacteria (Wang et al. 2018). This bacterium has been identified in asymptomatic tilapia and is believed to be more related to the aquatic environment than to the fish (Khosravani et al. 2017). However, other species pose significant risks to aquaculture, in addition to a high zoonotic potential. *Edwardsiella tarda* causes edwardsiellosis, putrefactive disease, and septicemia. It is the cause of mortality in various populations and species of fish worldwide (Mohanty & Sahoo, 2007), including tilapia from Brazil (Muratori et al. 2001). Although it is widely distributed, its pathogenicity to humans is limited, promoting gastroenteritis, which can, in extreme situations, become systemic and lethal (Leung et al. 2012; Schlenker & Surawicz, 2009).

Like *E. tarda*, *Streptococcus* species are recorded in different parts of the planet and are often found in warm water environments (Gauthier, 2015). Bacteriosis contracted from fish is usually more aggressive in children and immunocompromised individuals (Boylan, 2011; Gauthier, 2015; Leira et al. 2017).

#### 4.2 TILAPIA ZOO NOTIC PROTISTS

Apicomplexa *Cryptosporidium parvum* is a pathogen with a broad host range that infects amphibians, reptiles, and fish from hot water, usually acquired by ingestion (Graczyk et al. 1996). *C. parvum* is the most common zoonotic species in the genus and has been reported in Brazil (Meireles, 2010). This protozoan completes its life cycle in a single host. It tends to infect children and immunocompromised people with greater severity, leading to severe diarrhea ranging from asymptomatic to fulminant (Chalmers & Davies, 2010; Vanathy et al., 2017). The transmission is by eating raw or undercooked fish or through contact with infected fish (Golomazou & Karanis, 2020). In fish, it can cause epithelial inflammation and even necrosis of affected tissues, resulting in animal apathy, morbidity, and reduced weight gain (Koinari et al. 2013). In tilapia, this parasite has already been identified in lakes in Papua New Guinea (Koinari et al. 2013) and Egypt (Ammar & Arafa, 2013). The flagellate protozoan *Giardia duodenalis* (syn *G. intestinalis* and *G. lamblia*) is very common in developing countries and contracted by water. In humans, this parasite usually reaches the digestive tract, causing Giardiasis, which has a series of symptoms such as nausea, abdominal pain, diarrhea, and failure to thrive (Vesy & Peterson, 1999). In Egypt, *G. duodenalis* has been detected in tilapia and has a high prevalence in free-living fish. These fish were moderately contaminated, indicating that they not only serve as a mechanical vector (Ghoneim et al. 2012) but also act as host species.

#### 4.3 TILAPIA ZOO NOTIC FUNGI

*Candida albicans* is a pathogenic and opportunistic fungus known to be one of the causative factors of fish kills (Eissa et al. 2013). In tilapia, it causes damage to epithelial tissues and can be severely affect the gills, leading the host to death caused by respiratory failure (Oda et al. 2016). This parasite is mainly found in warm-blooded hosts; however, it can take advantage of fish with low immunity to establish itself in environmental stress situations, mainly due to sewage input from large cities (Eissa et al. 2013). Commensal



strains of warm-blooded hosts usually cause infections with this fungus, and although the zoonotic potential of *C. albicans* is low, it cannot be ruled out (Oda et al. 2016). This fungus can also be contracted by consumption/contact with fish or contaminated water (McCullough et al. 1996). In humans, *C. albicans* can cause mucosal thickening in the oral and intestinal mucosae (Oda et al., 2016). It can also cause the diphtheria pseudomembranes, which is the formation of white or gray membranes, the most striking feature of this infection, in mucosal regions (McCullough et al. 1996).

#### 4.4 TILAPIA ZOONOTIC HELMINTHS

The roundworms (Nematoda) comprise animals that specialize in parasitism. Fish usually parasitize the digestive tract, muscles, and other viscera. Commonly, nematodes have a complex life cycle with intermediate hosts (usually crustaceans and fish), paratenic hosts (piscivorous animals), and definitive hosts (wild-blooded wild and domestic animals) (Jorge C Eiras & Pavanelli, 2020; Lima dos Santos & Howgate, 2011). Despite many zoonotic nematode species, only two were partially identified in tilapia, *Prohemistomum sp.*, and *Gnathostoma sp.* The latter was the cause of an emerging disease in Mexico (León-Règagnon et al. 2005). Humans are accidental hosts that develop broad symptomatic specter. These facts, in addition to the lack of studies on the diseases, has resulted in their negligence. It is known that the consumption of raw or uncooked fish is the main mode of transmission (Waikagul & Chamacho, 2007).

Belonging to the Phatyhelminthes phylum (Flatworms), the Trematoda class comprises three subclasses, with the Digenea subclass being the only one with a zoonotic potential. Trematoda species that cause human infections are divided into six groups according to their location of parasitism (blood, lungs, pharynx, pancreas, liver, and intestine) (Chai & Jung, 2017). This group of parasites was the most reported in tilapia, with 10 described species worldwide (Table 1). Several parasites were identified in the type locality of *O. niloticus* of specific regions, and others were found in tilapia throughout the tropical region (Chai et al. 2005, 2009; Chai & Jung, 2017, 2019; Li et al. 2013). These flatworms are tiny parasites, and their pathogenesis occurs mechanically or chemically through protein secretion and excretion. Symptoms in humans can range from muscle fatigue, mild gastrointestinal problems, epigastric pain, diarrhea, and anorexia. More severe cases can lead to death, mainly in the liver forms (Chai & Jung, 2017).

The biological cycle of a species depends on two intermediate hosts and one definitive host. Initially, the eggs hatch a miracidium in the snail's intestinal lumen, becoming the primary host (Chai et al. 2005). The parasite goes through two larval stages in the mollusk tissues, migrates to the aquatic environment, penetrates the fish skin, reaches the musculature, and encysts in the form of metacercariae. In this way, they can survive for 2.5 years on average until a warm-blooded animal consumes the fish, eventually humans. (Chai & Jung, 2019). Although the primary hosts of these worms are usually specific, the vast introduction of snail has led to an epidemic threat (Lu et al. 2018).

## **5 CONCLUSION**

In Brazil, tilapia records in the natural environment are not uniform and the populations have been increasing since 1994, and most collections took place in the basins further east of the country, especially in the upper Parana River basin. And, our data indicate a considerable proportion of occurrence of pathogens in tilapia in Brazil, which serves to direct and mobilize health surveillance and public health actions.

## **DECLARATION**

The authors have no relevant financial or non-financial interests to disclose.

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