BIOTA
AMAZÔNIA
OPEN JOURNAL SYSTEM

ARTIGO

Impact of the invasion from Nile tilapia on natives Cichlidae species in tributary of Amazonas River, Brazil

Luana Silva Bittencourt[1], Uédio Robds Leite Silva[2], Luis Maurício Abdon Silva[3], Marcos Tavares Dias[4]

1. Bióloga. Mestrado em Biodiversidade Tropical (Universidade Federal do Amapá). E-mail: luanasilva.b@gmail.com
2. Geógrafo. Mestrado em Desenvolvimento Regional (Universidade Federal do Amapá). Coordenador do Programa de Gerenciamento Costeiro do Estado do Amapá, Instituto de Pesquisas Científicas e Tecnológicas do Amapá - IEPA. E-mail: uedio.leite@gmail.com
3. Biólogo. Doutorado em Biodiversidade Tropical (Universidade Federal do Amapá). Centro de Pesquisas Aquáticas, Instituto de Pesquisas Científicas e Tecnológicas do Amapá - IEPA. E-mail: luis.abdon13@gmail.com
4. Biólogo. Doutorado em Aquicultura de Águas Continentais (CAUNESP-UNESP). Pesquisador da EMBRAPA-AP. Docente orientador do Programa de Pós-graduação em Biodiversidade Tropical (UNIFAP) e Programa de Pós-graduação em Biodiversidade e Biotecnologia (PPG BIONORTE). E-mail: marcos.tavares@embrapa.br

ABSTRACT: This study investigated for the first time impact caused by the invasion of *Oreochromis niloticus* on populations of native Cichlidae species from Igarapé Fortaleza hydrographic basin, a tributary of the Amazonas River in Amapá State, Northern Brazil. As a consequence of escapes and/or intentional releases of *O. niloticus* from fish farms, there have been the invasion and successful establishment of this exotic fish species in this natural ecosystem, especially in areas of refuge, feeding and reproduction of the native cichlids species. The factors that contributed for this invasion and establishment are discussed here. The invasion of *O. niloticus* is pressuring the populations of native cichlids which are in a low populational density, as 72.7% of the biomass of cichlids (native and nonnative) is composed of *O. niloticus*. Consequently, the value of CPUE (2.489 kg.h^{-1})) for this invasive tilapia is much higher than the value of CPUE (0.641 kg.h^{-1}) for all the 16 species of native cichlids together. The results indicate the need for a management plan designed to control this invasive tilapia and thus avoid the extinction of native species of cichlids. Furthermore, results may also be useful for critical decision making of Brazilian governmental institutions regarding the approval of the introduction of any nonnative fish species in any other region from the country.

Keywords: Amazonia, exotic fish, *Oreochromis niloticus*, growth.

Impacto da invasão da tilápia-do-nilo sobre espécies de Cichlidae nativos em tributário do Rio Amazonas, Brasil

RESUMO: Este estudo providenciou a primeira investigação sobre impacto causado pela invasão da *Oreochromis niloticus* sobre a população de Cichlidae nativos da bacia hidrográfica Igarapé Fortaleza, um tributário do Rio Amazonas no estado do Amapá, no Norte do Brasil. Como uma consequência de escapes e/ou liberações intencionais de *O. niloticus* de pisciculturas, houve a invasão e estabelecimento dessa espécie de peixe exótico no ecossistema natural, especialmente em área de refugio, alimentação e reprodução das espécies de ciclídeos nativos. Os fatores que contribuíram para essa invasão e estabelecimento foram aqui discutidos. A invasão de *O. niloticus* está causando pressão sobre as populações de ciclídeos nativos, os quais encontram-se em baixa densidade populacional, pois 72,7% da biomassa dos ciclídeos (nativos e não nativos) está constituída por *O. niloticus*. Consequentemente, a CPUE (2,489 kg.h^{-1}) para essa tilápia invasora é muito superior aos valores da CPUE (0,641 kg.h^{-1}) de todas as 16 espécies de ciclídeos nativos juntas. Os resultados indicam uma necessidade de plano de manejo para controle desse peixe invasor, evitando assim a extinção de espécies de ciclídeos nativos. Além disso, serão úteis também para a tomada de decisão crítica de instituições governamentais (estadual e federal) quanto à aprovação da introdução de peixes não nativos na Amazônia ou qualquer outra região do país.

Palavras-chave: Amazônia, peixe exótico, *Oreochromis niloticus*, crescimento.

1. Introduction

Biological invasions are numerous in freshwaters around the world. The increasing accidental or deliberated introduction of nonnative species is currently a major worldwide concern (POULIN et al., 2011; GOSLAN 2012; RIBEIRO; LEUDA, 2012). Globalization of the modern systems of transport ensures that such rates of biological invasion occur and remain high (GOZLAN et al., 2010; POULIN et al., 2011). Aquaculture has been pointed out as one of the major means of introduction of exotic fish species that cause environmental (MCCRARY et al., 2007; GALLI et al., 2007; GOZLAN et al., 2012) and economic impacts (MCCRARY et al., 2007; POULIN et al., 2011). These introductions are one of the biggest causes of the extinction of native fish species. When the invasive species alters the trophic chains it mischaracterizes the ecological niches and/or reduces the natural fisheries stocks, imposing high economic costs to society (MCCRARY et al., 2007; GALLI et al., 2007; POULIN et al., 2011; RIBEIRO; LEUDA, 2012). The invasion of nonnative fish represents yet another major threat to the native ichthyofauna, the spread of new diseases and parasites in native populations (ARTHUR et al., 2010; POULIN et al., 2011; GOSLAN, 2012).

Success in the establishment of a fish species introduced in a new environment may vary among different species, as it depends on several biotic and abiotic factors PAVLOV et al., 2006; RIBEIRO; LEUDA, 2012). Therefore, perception of the ecological impacts caused to the native ichthyofauna by this introduction may take years, sometimes even decades (ARTHUR et al., 2010), as these impacts are not easily demonstrated or perceived (GOSLAN, 2012).

Nile tilapia *O. niloticus*, an African cichlid was spread around the world, including Brazil, with different purposes (CANONICO et al., 2005). However, the introduction of this tilapia has compromised the native ichthyofauna in Mexico, Australia, United States, Philippines, Madagascar (CANONICO et al., 2005) and Panama (ROCHE et al., 2010), causing serious environmental problems. In Lakes Victoria and Kyogo (Africa), *O. niloticus* dominated the environment, greatly reducing the native populations of *Oreochromis esculentus* and *Oreochromis variabilis* (BWANIKA et al., 2006) .The invasion of tilapias of the genus *Oreochromis* in over half the lakes of Nicaragua led to the reduction of 80% of the native cichlids due to environmental competition (MCCRARY et al., 2007). In Panama, the introduction of *O. niloticus* led to the extinction of two species of endemic cichlids (ROCHE et al., 2010), due to several factors, for example, diseases and loss of habitat.

In Brazil, specimens of *O. niloticus* were initially introduced in 1971 as part of a federal governmental program against hunger from Northeast area. Currently, even though the country has one of the richest diversity of native ichthyofauna in the world (NOVAES; CARVALHO, 2011), the Nile tilapia is paradoxically still the main zootechnical model for the national aquaculture (PANTOJA et al., 2012). Consequently, this species of tilapia has spread into several lakes, dams, reservoirs (MINTE-VERA; PETRERE-JR, 2000; NOVAES; CARVALHO, 2011; ATTAYDE; BRASIL; MENESCAL, 2011) and also into the basins of Rivers Tietê (NOVAES; CARVALHO, 2011) and Paraná (BRITTON; ORSI, 2012). In public reservoirs, the dominance of the Nile tilapia has drastically altered the composition of the native fish populations, jeopardizing the local artisanal fishing (NOVAES; CARVALHO, 2011; ATTAYDE; BRASIL; MENESCAL, 2011). Therefore, in the several natural ecosystems of the country where there has been the invasion of Nile tilapia, but the impacts this introduction on the native ichthyofauna must be investigated.

In the state of Amapá, eastern Amazon region (Northern Brazil), specimens of *O. niloticus* were introduced in 1994 in some fish farms from Macapá municipality (TAVARES-DIAS, 2011). Among 2000 and 2001, there were reports of intentional and accidental escapes of this fish into a major tributary of the Amazonas River, the Igarapé Fortaleza basin, especially due to an overflowing of the culture ponds caused by heavy rains. In this area, the aquacultures are usually established within or near natural bodies of water (GAMA, 2008; TAVARES-DIAS, 2011). Currently, was reported that *O. niloticus,* invasive of the Igarapé Fortaleza basin have infection by *Ichthyophthirius multifiliis*, *Trichodina centrostrigeata*, *Paratrichodina africana*, *Trichodina nobilis* and *Cichlidogyrus tilapiae*. This fish has not acquired any parasite species common to the native ichthyofauna of this Amazonian ecosystem, due its rusticity and the presence of native parasites with relative specificity, but without ability to complete its life cycle in this invasive host. However, *T. nobilis, a trichodinid* of *O. niloticus* was transmitted to *Aequidens tetramerus*, a native cichlid of this basin (BITTENCOURT et al., 2014). Therefore, is necessary to evaluate if the establishment of *O. niloticus* was successful in this Amazonian environment invaded and if there is some impact of this invader tilapia on native fish. Thus, this study investigated the effects of the invasion of the *O. niloticus* on the abundance of native Cichlidae populations from the Igarapé Fortaleza basin, a tributary of the Amazonas River system in Amapá State.

2. Material and Methods

Study area

The Igarapé Fortaleza hydrographic basin, located in municipality of Macapá and Santana, in State of Amapá (Northern Brazil) is composed by the main channel of this tributary of the Amazonas River and by the floodplain areas (Figure 1). This single ecosystem is made up mainly by the Amazonas River and the main channel of the Igarapé Fortaleza basin. The Amazonas River – floodplain systems are fluvial silted systems drained by freshwater and influenced by the high rainfall rates of the Amazonia and by the tides of the Amazonas River (TAKYAMA et al., 2004; BITTENCOURT et al., 2014).

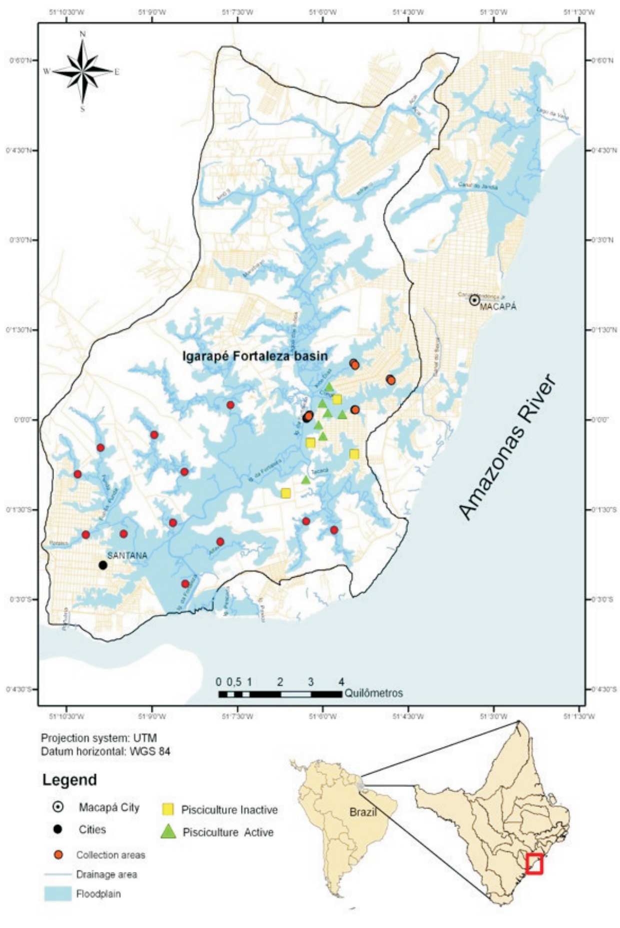

Figure 1. Sites of the invasion from *Oreochromis niloticus* in Igarapé Fortaleza basin, eastern Amazon (Brazil).

The main channel of the Igarapé Fortaleza basin carries rich organic matter that is brought by the tides of the Amazonas River and carried to the floodplain, which are protected environments. These areas are of difficult access to large predators and thus they make up an environment favorable to the development of different species of small and medium fish. Several species of native fish are known to the basin and some are endemic. Some species are important for the artisanal subsistence fishing in the region, while others have potential for aquarist (GAMA; HALBOTH, 2004; BITTENCOURT et al., 2014), especially the species of Cichlidae. During the rainy season (from December to May), waters rich in nutrients – due to the quick decomposition of grass and animals remains or the forest's layer of humus- spread over the floodplain. This leads to a great growth of vegetation and biomass of invertebrates (insects, crustacean zooplankton and mollusks) which are used as food by fish (TAKYAMA et al., 2004). Thus fish biomass increases quickly during the flood season, largely due to the fast growth of young forms during the year. These favorable conditions lead most fish to reproduce at the beginning of the rainy season, the main period of feeding, growth and accumulation of energy reserves needed to face the short supply of food during the dry season (from June to November). Therefore, fish are born in a season when there is plenty of food and when the fast growth of vegetation also offers refuge against predators (GAMA; HALBOTH, 2004).

Fish collection and analysis procedures

From December 2009 to June 2011, efforts were made in order to capture specimens of native Cichlidae and exotic *O. niloticus* in the main channel of the Igarapé Fortaleza and in the floodplain. For capturing fish, cast nets with 30 and 40 mm mesh were used during the day and gillnets with a mesh of 20, 25 and 30 mm were used during the night (ICMBio authorization: 23276-1). The nets were exposed during 8 hours/day, from dawn or dusk. Fish were transported on ice to the Laboratory of Aquaculture and Fishery of Embrapa Amapá, in Macapá, State of Amapá (Brazil). All collection sites were georeferenced and plotted for making a map with the occurrence of fish.

Productivity and biomass of collected fish were estimated through the catch per unit effort/CPUE (GULLAND, 1969), taking into account the number of fish caught by every eight hours of effort.

Body weight (g) and total length (cm) of collected fish were measured and used to calculate the weight-length relationship and the relative condition factor (Kn). The relative condition factor (Kn) was determined according to Le-Cren (1951) to native cichlids species and *O. niloticus*, and values of each species (main channel and floodplain areas) were compared using test *t* ($p<0.05$). To calculate the weight-length relationship in *O. niloticus*, it was used the equation $W_t=aL^b$, where W_t is the total weight in grams and *L* the total length in cm and a and b are constants. These constants were estimated by linear regression of the transformed equation: W=log a + b x log L. The level of significance *r* and the value of *b* (LE-CREN, 1951) were estimated by test *t* ($p>0.05$). Weight and length values of fish species from both environments were compared by test *t* ($p>0.05$).

4. Results

Figure 1 shows the sites of invasion from *O. niloticus* and active and inactive fish farms with culture of Nile tilapia in Igarapé Fortaleza basin. In this area, there were eight active fish farms and two fish farms which ended their activity some years ago. 218 specimens of Nile tilapia and 358 specimens of sixteen species of native Cichlidae were captured. In the floodplain, the number of native species of Cichlidae was low when compared to the specimens captured in the main channel of Igarapé Fortaleza basin (Table 1).

For juveniles and adults of *O. niloticus* from the main channel and the floodplain of Igarapé Fortaleza basin, the growth was negative allometric (Figure 2), indicating an increase in body mass greater than in size. Furthermore, the relative condition factor (Kn) for *O. niloticus* from both environments was similar and did not differ from the standard Kn= 1.0 ($p>0.05$) indicating good body conditions for this population in the new invaded environment. Similar results of Kn were also found for native cichlids species from both environments investigated (Table 1).

Table 1. Biometric parameters in species of Cichlidae (natives and nonnative) captured in two sites of the Igarapé Fortaleza basin, eastern Amazon (Brazil. Values express mean ± standard deviation. Different letters on the same line indicate differences by test t ($p<0.05$).

	Main channel				Floodplain areas			
Fish species	N	Weight (g)	Length (cm)	Kn	N	Weight (g)	Length (cm)	Kn
Oreochromis niloticus	37	275.2 ± 51.5a	23.2 ± 1.7a	0.99 ± 0.02a	181	115.4 ± 77.5b	17.2 ± 4.9b	1.00 ± 0.02a
Geophagus bransiliensis	1	76.0 ± 0.0	14.5 ± 0.0	-	-	-	-	-
Astronotus ocellatus	13	212.0 ± 65.0a	20.1 ± 2.6a	1.00 ± 0.02	4	236.35 ±104.5a	21.5 ± 4.8a	-
Pterophyllum scalare	7	11.1 ± 3.8	8.5 ± 1.1	-	-	-	-	-
Heros efasciatus	3	64.6 ± 43.9	12.1 ± 4.1	-	-	-	-	-
Chaetobranchus flavescens	14	94.4 ± 62.6	17.0 ± 4.4	0.99 ± 0.03	-	-	-	-
Chaetobranchopsis orbicularis	31	105.2 ± 43.9	16.6 ± 3.0	0.99 ± 0.06	-	-	-	-
Cichlassoma amazonarum	6	34.6 ± 7.0a	10.7 ± 1.0b	-	54	49.2 ± 19.6a	12.8 ± 2.2a	1.00 ± 0.09
Aequidens tetramerus	33	57.1 ± 18.2b	13.5 ± 1.6b	1.00 ± 0.05a	59	69.0 ± 27.5a	14.5 ± 2.2a	1.00 ± 0.03a
Aequidens sp.	4	71.0 ± 24.4	13.9 ± 1.5	-	3	37.7 ± 5.7	11.7 ± 0.7	-
Mesonauta sp.	2	34.0 ± 0.0	12.0 ± 0.5	-	29	54.6 ± 31.6	12.6 ± 2.2	1.00 ± 0.06
Mesonauta acora	7	22.0 ± 7.3b	10.0 ± 1.4b	-	30	62.1 ± 18.7a	13.6 ± 1.5a	1.00 ± 0.02
Laetacara curviceps	17	55.4 ± 24.3a	13.6 ± 2.0a	1.00 ± 0.04	3	18.5 ± 4.0b	9.1 ± 1.2b	-
Satanoperca jurupari	20	41.3 ± 32.8	12.0 ± 4.0	0.99 ± 0.11	-	-	-	-
Hypselecara temporalis	1	56.0 ± 0.0	13.2 ± 0.0	-	-	-	-	-
Mesonauta guyanae	9	19.3 ± 7.7	9.5 ± 2.1	-	-	-	-	-
Cichlassoma bimaculatum	8	59.0 ± 21.1	14.1 ± 2.9	-	-	-	-	-

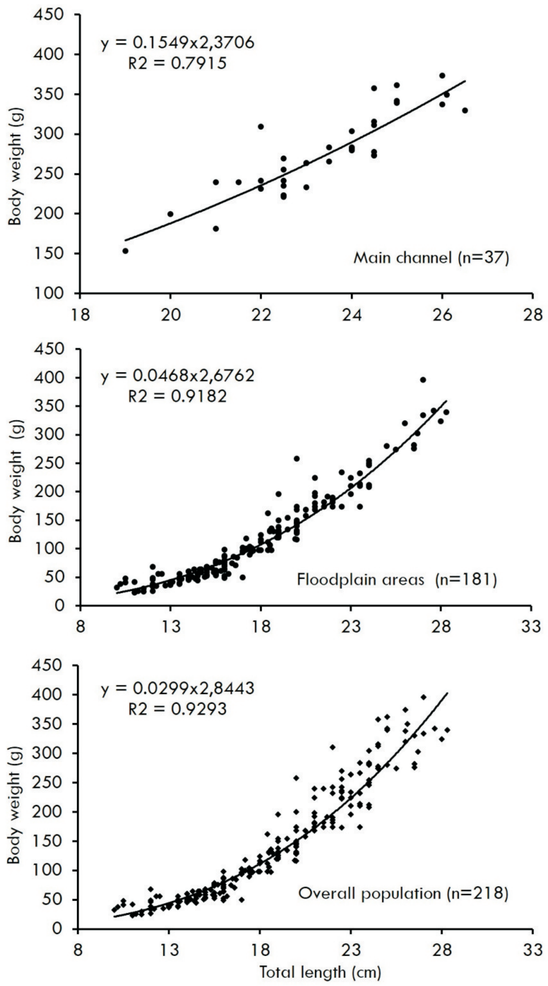

Figure 2. Weight-length relationship for *O. niloticus* captured in two sites of the Igarapé Fortaleza basin, eastern Amazon (Brazil).

While fishing for species of Nile tilapia *O. niloticus* and native cichlids, only seven species that occur in the main channel were also captured in the f**loodplain**, with a predominance of tilapias. However, the biomass of *O. niloticus* was higher than the biomass of native cichlids in these two environments (Table 2), indicating a higher abundance of this nonnative fish. Among all seventeen species of native and nonnative fish that were captured, *O. niloticus* accounted for 72.7%, representing a CPUE of 2.489 $kg.h^{-1}$ (in a total of 88 h), higher than the CPUE of only 0.641 $kg.h^{-1}$ (in a total of 128h) for species of native cichlids.

4. Discussion

In 1994, *O. niloticus* were introduced in some fish farms from State of Amapá, due to their easy natural reproduction, which quickly populated cultivation ponds (GAMA, 2008; TAVARES-DIAS, 2011; PANTOJA et al., 2012). As most of these fish farms are or have been within or near the Igarapé Fortaleza basin, there were accidental escapes (GAMA, 2008; TAVARES-DIAS, 2011) and also intentional releases into the natural environment. Consequently, a population of this fish species started to grow in this environment probably around 2002, since studies conducted between years 2000-2001 did not record the occurrence of *O. niloticus* (GAMA; HALBOTH, 2004). The ecological impacts of this invasion on the native ichthyofauna are hard to prove because they may be indirect such as cases of transmission of pathogenic agents (GOSLAN, 2012) or direct as it is happening with the native species of Cichlidae from this study. However, the intensity of negative impacts depends upon biotic and abiotic factors, since under specific conditions there can be coexistence between native and introduced species (RIBEIRO; LEUDA, 2012; BITTENCOURT et al., 2014).

Table 2. Productivity in number and biomass of Cichlidae species (natives and nonnative) captured in two sites of the Igarapé Fortaleza basin, eastern Amazon (Brazil). CPUE: Catch per Unit Effort.

	Main channel					Floodplain areas				
Fish species	N	Relative Frequency (%)	Biomass (g)	CPUE ($g.h^{-1}$)	CPUE ($N.h^{-1}$)	N	Relative Frequency (%)	Biomass (g)	CPUE ($g.h^{-1}$)	CPUE ($N.h^{-1}$)
Oreochromis niloticus	37	44.6	10.184	1.273.0	4.60	181	75.0	208.825	2.61	5.60
Geophagus bransiliens	01	0.3	76.0	9.5	0.12	-	-	-		-
Astronotus ocellatus	13	12.1	2.756	114.8	0.54	4	0.4	945.4	59.1	0.12
Pterophyllum scalare	7	0.3	78.0	9.8	0.87	-	-	-	-	-
Heros efasciatus	3	0.8	194.0	24.3	0.37	-	-	-	-	-
Chaetobranchus flavescens	14	5.8	1.322	33.1	0.35	-	-	-	-	-
Chaetobranchopsis orbicularis	31	14.3	3.263	68.0	0.48	-	-	-	-	-
Cichlassoma amazonarum	6	0.9	208.0	13.0	0.37	54	5.3	14.776	46.2	1.68
Aequidens tetramerus	33	8.2	1.886	78.6	1.37	59	14.6	40.741	84.9	1.84
Aequidens sp.	4	1.2	284.0	35.5	0.50	3	0.4	1.132	14.2	0.09
Mesonauta sp.	2	0.3	68.0	8.5	0.25	29	3.2	8.916	12.4	0.90
Mesonauta acora	7	0.7	154.0	19.3	0.87	30	0.7	1.802	11.2	0.93
Laetacara curviceps	17	4.1	942.0	117.8	2.12	3	0.4	55.6	13.9	0.09
Satanoperca jurupari	20	3.3	744.0	13.3	0.36	-	-	-	-	-
Hypselecara temporalis	1	0.2	56.0	7.0	0.12	-	-	-	-	-
Mesonauta guyanae	9	0.8	174.0	10.9	0.56	-	-	-	-	-
Cichlassoma bimaculatum	8	2.1	472.0	59.0	1.00	-	-	-	-	-
Total	213	100	22.861	-	-	363	100	278.249	-	-

The dispersion of *O. niloticus* in Nicaragua (MCCRARY et al., 2007), Mexico, Australia, United States, Philippines and Madagascar (CANONICO et al., 2005) began with the invasion of this newcomer specie that quickly adapted to the new environmental conditions.

Then, this invasive species started its reproduction and the formation of a new population, drastically increasing its abundance due to a lack of natural predators, competitors and diseases in these new invaded ecosystems (PAVLOV; MIKHEEV; DGEBUADZE, 2006). Similarly, in Igarapé Fortaleza basin, after about 12 years of *O. niloticus* invasion, this fish successfully formed a population of individuals in good body conditions as indicated by relative condition factor (Kn), which was similar to that of *O. niloticus* from fish farms from this same region of Amazonia (PANTOJA et al., 2012). The effective use of the food resources available in this natural ecosystem of the Amazon estuary was one of the factors that contributed to the successful colonization of *O. niloticus*. However, Kn of native cichlids species was not affected, because this parameter was not a good indicator of stress caused by invasion of *O. niloticus*.

The Nile tilapia is a fish with great food plasticity, since depending on the phase of its lifecycle, natural populations feed on zooplankton, phytoplankton, detritus, sediments or insect larvae (BWANIKA et al., 2006; BWANIKA; MURIE; CHAPMAN 2007; ATTAYDE; BRASIL; MENESCAL, 2011). This plasticity and its omnivorous feeding habits favored the occupation and growth of this invasive fish in the basin of Igarapé Fortaleza. This factor allowed its development and the acquisition of high caloric content (BWANIKA et al., 2006; BWANIKA; MURIE; CHAPMAN, 2007), ensuring its success during the establishment in the new environment which is rich in items from its diet due to the anthropogenic eutrophication and the transport of organic material leached by the tides of the Amazonas River (TAKIYAMA; SILVA, 2004).

Novaes and Carvalho (2011) stated that the eutrophication and the high primary production were also factors that contributed to the establishment of ***O. niloticus*** in Brazilian reservoirs. The floodplain, due to their high primary production, allows the feeding of several species of the native ichthyofauna in the early stages of their development (GAMA; HALBOTH, 2004), especially species of native Cichlidae. Therefore, these areas are also used for breeding and refuge by the population of this invasive tilapia in the basin of Igarapé Fortaleza.

Some other factors that strongly contribute to the success of *O. niloticus* invasion are its flexibility in growth rate and size of sexual maturation according to environmental conditions, as well as its high adaptability to harsh environmental conditions (ATTAYDE; BRASIL; MENESCAL, 2011). In Lake Nabugabo, Uganda, the size of this tilapia ranged from 3.7 to 5.2 cm and the positive allometric growth (b=3.117) was influenced by factors dependent on the populational density. In this environment, after its establishment, there was strong pressure on the fishing of this introduced species (BWANIKA; MURIE; CHAPMAN, 2007). However, in Lake Coatetelco, Mexico, for fish with sizes ranging from 8.9 to 16.5 cm, allometric growth was negative (b=2.469), caused by the capture of younger individuals (GÓMEZ-MÁRQUEZ et al., 2008). In the Igarapé Fortaleza basin, for captured *O. niloticus* the growth was negative allometric (b= 2.844), because in this new environment this nonnative species needs a rapid increase in body mass in order to quickly reach the reproductive stage and guarantee the naturalization made up of an abundant population of individuals with a stable reproductive capacity.

Therefore, since the individuals captured ranged from 10.0 to 28.3 cm in length, the establishment was successful because the environment allowed the completion of the lifecycle of this fish. In addition, the *O. niloticus* population does not suffer any kind of pressure from local fishing which has no interest in this invasive tilapia. In contrast, the introduction of tilapias of the genus *Oreochromis* compromised the market of native fish in Nicaragua (MCCRARY et al., 2007). Therefore, all these factors contributed positively to the invasion of *O. niloticus* in the region of this study and to its high populational density, which will continue to increase if there is no interference in the biomass of this invasive fish that is now a natural population.

There has always been concern with the impacts that the invasion of *O. niloticus* may cause through their establishment in natural ecosystems. This invasion may alter the structure of the native cichlids communities while competing for food, preying on their eggs and larvae, maintaining a strong territorial behavior, multiple spawning, parental care and occupying almost all habitats for spawning, compromising the spawning of other species (PETERSON et al., 2004; CANONICO et al., 2005; BWANIKA et al., 2006; ATTAYDE; BRASIL; MENESCAL, 2011) and the food chain of the invaded ecosystem (MARTIN; VALENTINE;VALENTINE, 2010; ATTAYDE; BRASIL; MENESCAL, 2011).

In lakes from Nicaragua, the invasion of *Oreochromis* spp. led to a reduction of 80% of native cichlid species due to environmental competition (MCCRARY et al., 2007). Roche et al. (2010) reported that in lakes from the Panama Canal, after the invasion of *O. niloticus*, from three endemic species of cichlids, only one can still be found in the region nowadays. In Brazil, studies reported a drastic reduction in the artisanal fishing of native fish in the Billings Reservoir (MINTE-VERA; PETRERE JR, 2000) and in the Barra Bonita Reservoir (NOVAES; CARVALHO, 2011) in São Paulo and also in the Gargalheiras Reservoir in Rio Grande do Norte (ATTAYDE; BRASIL; MENESCAL, 2011) due to the dominance of *O. niloticus* in these environments. The invasion of *O. niloticus* in the Igarapé Fortaleza basin is also putting on pressure on the species of native Cichlidae, especially in the floodplain that are the main place for spawning, refuge and feeding of this native fish which currently show a low populational density.

Thus, in the floodplain areas, the biomass of this invasive tilapia was ten times higher than in the main channel, so that 72.2% of the total biomass of all captured cichlids (native and nonnative) was represented by *O. niloticus*. Consequently, there was a smaller abundance in the population of native cichlids because while the CPUE for this invasive tilapia was 2.489 $kg.h^{-1}$, for the species of native cichlids it was of only 0.641 $kg.h^{-1}$.

In lakes Nicaragua, 54.0% of the biomass of captured cichlids is constituted mainly of *Oreochromis* sp. (MCCRARY et al., 2007). In a reservoir in the state of São Paulo, 81.5% of fishery is constituted by *O. niloticus* which presents a CPUE of 40.5 kg/fisherman (MINTE-VERA; PETRERE JR, 2000). Novaes and Carvalho (2011) reported that this same species of tilapia is also the most captured fish in the Barra Bonita Reservoir (State of São Paulo), representing 82.5% of the total biomass with a CPUE of 51.5 kg/day. Consequently this exotic tilapia represents the predominant fishery resource in the Brazilian reservoirs. Nevertheless, recently, the Brazilian Congress proposed a law to allow the rearing of nonnative fish in aquaculture cages in any hydroelectric reservoir of the country (PELICICE et al., 2013). These results denote one serious problem that may occur in the largest basins from South America with richest biodiversity, due to inadequate management by the government in regard to aquaculture and exotic species.

5. Conclusions

The invasion of the *O. niloticus* in the floodplains from Igarapé Fortaleza basin is compromising the abundance of native cichlids because this environment is the site of reproduction of these native fish. As this is the first report on the impacts of *O. niloticus* on the native ichthyofauna, additional studies are needed to monitor these populations of native cichlids and the importation of parasites. There is also imminent need for the implementation of a management plan aiming at the populational control of this invasive species in order to avoid future disastrous environmental consequences. However, the options for control and management of invasive fish are still restricted to traditional means such as eradication with products, mechanical removal, environmental education and legislation. Therefore, the introduction of Nile tilapia must then be carefully evaluated in regard to potential socio-economic benefits and to risks for native biodiversity.

6. Acknowledgments

The authors thank the National Council for Scientific and Technological Development (CNPq) for supporting this project (# 556827/2009-0). M. Tavares-Dias was supported by a Research fellowship from Conselho Nacional de Pesquisa e Desenvolvimento Tecnológico (CNPq, Brazil).

7. References

ARTHUR, R.I.; LOREZEN, K.; HOMEKINGKEO, P.A.; SIDAVONG, K. Assessing impacts of introduced aquaculture species on native fish communities: Nile tilapia and major carps in SE Asian freshwaters. **Aquaculture**, v. 299, p. 81-88, 2010.

ATTAYDE, J.L.; BRASIL, J.; MENESCAL, R.A. Impacts of introducing Nile tilapia on the fisheries of a tropical reservoir in North-Eastern Brazil. **Fisheries Management and Ecology**, v.18, p. 437-443, 2011.

BITTENCOURT, L.S; PINHEIRO, D.A.; CÁRDENAS, M.Q.; FERNANDES, B.M. M.; TAVARES-DIAS, M. Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* in tributary of Amazonas River (Brazil). **Brazilian Journal of Veterinary Parasitology**, v. 23, n. 1, p. 44-54, 2014.

BRITTON, J.R.; ORSI, M.L. Non-native fish in aquaculture and sport fishing in Brazil: economic benefits versus risks to fish diversity in the upper River Paraná Basin. **Reviews in Fish Biology and Fisheries**, doi: 10.1007/s11160-012-9254-x, 2012.

BWANIKA, G.N.; MURIE, D.J.; CHAPMAN, L.J. Comparative age and growth of Nile tilapia (*Oreochromis niloticus* L.) in lakes Nabugabo and Wamala, Uganda. **Hydrobiologia**, v. 589, p. 287-301, 2007.

BWANIKA, G.N.; CHAPMAN, L.J.; KIZITO, Y.; BALIRWA, J. Cascading effects of introduced Nile perch (*Lates niloticus*) on the foraging ecology of Nile tilapia (*Oreochromis niloticus*). **Ecology of Freshwater Fish**, v. 15, p. 470-481, 2006.

CANONICO, G.C.; ARTHINGTON, A.; MCCRARY, J.K; THIEME, M.L. The effects of introduced tilapias on native biodiversity. **Aquatic Conservation: Marine and Freshwater Ecosystems**, v.15, p. 463–483, 2005.

FRANCOVÁ, K; ONDRACKOVÁ, M.; POLACIK, M.; JURAJDA, P. Parasite fauna of native and non-native populations of *Neogobius melanostomus* (Pallas, 1814) (Gobiidea) in the longitudinal profile of the Danube River. **Journal of Applied Ichthyology**, v. 27, p. 879-886, 2011.

GALLI, P.; STRONA, G.; BENZONI, F.; CROSA, G.; STEFANI, F. Monogenoids from freshwater fish in Italy, with comments on alien species. **Comparative Parasitology**, v. 74, p. 264-272, 2007.

GAMA, C.S. A criação de tilápia no estado do Amapá como fonte de risco ambiental. **Acta Amazonica**, v. 38, p. 525-530, 2008.

GAMA, C.S.; HALBOTH, D.A. Ictiofauna das ressacas das bacias do Igarapé da Fortaleza e do Rio Curiaú. In: TAKIYAMA L.R.; SILVA A.Q. (Org.). **Diagnóstico de ressacas do estado do Amapá: bacias do Igarapé da Fortaleza e do Curiaú.** Macapá: Centro de Pesquisas Aquáticas do Instituto de Pesquisas Tecnológicas e Científicas do Estado do Amapá, 2004. p. 33-66.

GÓMEZ-MÁRQUEZ, J.L.; PENA-MEÑDONZA, B.; SALGADO-UGARTE, I.H.; ARREDONDO-FIGUEROA, J.L. Age and growth of the tilapia, *Oreochromis niloticus* (Peciformes: Cichlidae) from a tropical shallow lake in Mexico. **Revista de Biologia Tropical**, v. 56, p. 875-884, 2008.

GOZLAN, R.E. Mapping conservation priorities in the Mediterranean: the issue of non-native freshwater fish introductions. **Fisheries Management and Ecology, v.** 19, p. 89-92, 2012.

GOZLAN, R.E; BRITTON, J.R.; COWX, I.; COPP, G.H. Current knowledge on non-native freshwater fish introductions. **Journal of Fish Biology**, v. 76, p. 751-786, 2010.

GULLAND, J.A. **Manual of methods for fish stock assessment. Part 1. Fish population analysis.** Rome: Food and Agriculture Organization of the United Nations, 1969. 154p.

LE-CREN, E.D. The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch (*Perca fluviatilis*). **Journal of Animal Ecology**, v. 20, p. 201-219, 1951.

MARTIN, C.W.; VALENTINE, M.M.; VALENTINE, J.F. Competitive interactions between invasive Nile tilapia and native fish: the potential for altered trophic exchange and modification of food webs. **Plos One**, *v.5,* doi:10.1371/journal. pone.0014395, 2010.

MCCRARY, J.K; MURPHY, B.R.; STAUFFER, J.R.JR.; HENDRIX, S.S. Tilapia (Teleostei: Cichlidae) status in Nicaraguan natural waters. **Environmental Biology of Fishes**, v. 80, p. 78-10, 2007.

MINTE-VERA, C.V.; PETRERE JR, M. Artisanal fisheries in urban reservoirs: A case study from Brazil (Billings Reservoir, São Paulo, Metropolitan Region). **Fisheries Management and Ecology, v.** 7, p. 537-549, 2000.

NOVAES, J.L.C.; CARVALHO, E.D. Artisanal fisheries in a Brazilian hypertrophic reservoir: Barra Bonita Reservoir, middle Tietê River. **Brazilian Journal of Biology**, v. 71, p. 821-832, 2011.

PANTOJA, W.M.F.; NEVES, L.R.; DIAS, M.K.R.; MARINHO, R.G.B.; MONTAGNER, D.; TAVARES-DIAS, M. Protozoan and metazoan parasites of Nile tilapia *Oreochromis niloticus* cultured in Brazil. **Revista Medicina Veterinaria Zootecnia Córdoba**, v. 17, p. 265-266, 2012.

PAVLOV, D.S.; MIKHEEV, V.N.; DGEBUADZE, Y.Y. Behavioral aspects of biological invasions of alien fish species. **The Journal of Ichthyology**, v. 46, p. 117-124, 2006.

PELICICE, F.M.; VITULE, J.R.S.; LIMA JUNIOR, D.P.; ORSI, M.L.; AGOSTINHO, A.A. A serious new threat to Brazilian freshwater ecosystems: the naturalization of nonnative fish by decree. **Conservation Letters**, doi: 10.1111/conl.12029, 2013.

PETERSON, M.S.; SLACK, W.T.; BROWN-PETERSON, N.J.; MCDONALD, J.L. Reproduction in nonnative environments: establishment of Nile tilapia, *Oreochromis niloticus*, in coastal Mississippi watersheds. **Copeia**, v.4, p. 842-849, *2004*.

POULIN, R.; PATERSON, R.A.; TOWNSEND, C.R.; TOMPKINS, D.M.; KELLY, W. Biological invasions and the dynamics of endemic diseases in freshwater ecosystems. **Freshwater Biology**, v. 56, p. 676-688, 2001.

RIBEIRO, F.; LEUNDA, P.M. Non-native fish impacts on Mediterranean freshwater ecosystems: current knowledge and research needs. **Fisheries Management and Ecology, v.** 19, p. 142-156, 2012.

ROCHE, D.G.; LEUNG, B.; MENDOZA-FRANCO, E.F; TORCHIN, M.E. Higher parasite richness, abundance and impact in native versus introduced cichlid fishes. **The International Journal for Parasitology**, v. 40, p. 1525-1530, 2010.

TAKIYAMA, L.R.; SILVA, A.Q.; COSTA, W.J.P.; NASCIMENTO, H.S. Qualidade das Águas das ressacas das bacias do Igarapé da Fortaleza e do Rio Curiaú. In: TAKIYAMA, L.R; SILVA, A.Q. (Ed.). **Diagnóstico das ressacas do Estado do Amapá: bacias do Igarapé da Fortaleza e Rio Curiaú, Macapá-AP.** Macapá: Centro de Pesquisas Aquáticas do Instituto de Pesquisas Tecnológicas e Científicas do Estado do Amapá, 2004. p. 81-104.

TAVARES-DIAS, M. **Piscicultura continental no estado do Amapá: diagnóstico e perspectivas.** Boletim de Pesquisa e Desenvolvimento, Embrapa Amapá, Macapá, 2011.