FISH ASSEMBLAGE OF THE SANTO ANASTÁCIO RESERVOIR (CEARÁ STATE, BRAZIL)*

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ABSTRACT

Located on the campus of the Federal University of Ceará, the Santo Anastácio reservoir is a hypereutrophic ecosystem which has been the object of ecological research over the last four decades. The present study describes the current fish assemblage of the reservoir and discusses variations observed since 1977. Fish were sampled monthly between October 2009 and March 2010 using gillnets and seine nets in three zones. The fishes were identified, measured (standard length; cm) and weighed (g) to evaluate aspects of structure (richness, diversity, biomass and size) and spatial distribution of the icthyofauna in the reservoir. The fish assemblage in the reservoir was found to have changed considerably over time. Several fish species reported in earlier studies, such as *Leporinus friderici*, *Eigenmannia virescens*, *Serrasalmus brandtii* and *Betta* sp., were not registered in our samples from 2009 and 2010. The predominance of species tolerant to hypoxic and eutrophic ecosystems, such as *Oreochromis niloticus*, *Poecilia vivipara, Poecilia reticulata* and *Hoplosternum littorale*, as well as the scarcity of *Prochilodus brevis* and *Hypostomus pusarum*, illustrate the influence of environmental conditions and the introduction of exotic species on fish richness. The icthyofauna of the Santo Anastácio reservoir consisted of relatively few species. The sampled zones did not vary significantly with regard to community structure. Despite the small number of species, the resevoir's population of *O. niloticus* is exploited by local subsistence fishermen.

Keywords: Ichthyofauna; lentic ecosystems; hypereutrophic; semi-arid

ASSEMBLÉIA DE PEIXES NO AÇUDE SANTO ANASTÁCIO (CEARÁ, BRASIL)

RESUMO

O açude Santo Anastácio, localizado no campus da Universidade Federal do Ceará, é um ecossistema hipereutrófico e tem sido alvo de pesquisas ecológicas nas últimas quatro décadas. Este estudo compilou dados da ictiofauna, analisando a variação da assembléia desde 1977. Em três zonas do açude foram realizadas coletas mensais, entre outubro de 2009 a março de 2010, utilizando-se de redes de espera e redes de arrasto (picaré). Os peixes foram identificados, medidos (comprimento padrão; cm) e pesados (g), para avaliar aspetos da estrutura (riqueza, diversidade, biomassa e tamanho) e distribuição espacial no reservatório. O açude apresentou mudanças na composição íctica no tempo avaliado. Espécies como *Leporinus friderici*, *Eigenmannia virescens*, *Serrasalmus brandtii* e *Betta* sp., registradas em estudos anteriores, não foram capturadas nas coletas realizadas entre 2009 e 2010. A dominância de espécies de peixes com adaptações a situações de hipóxia e maior eutrofização, como *Oreochromis niloticus*, *Poecilia vivipara*, *Poecilia reticulata* e *Hoplosternum littorale*, além da baixa abundância de *Prochilodus brevis* e *Hypostomus pusarum*, sugerem a influência das condições do ambiente e da introdução de espécies exóticas na riqueza local. Observou-se que a ictiofauna do açude Santo Anastácio apresentou um baixo número de espécies e os aspectos relacionados à estrutura da comunidade não variaram significativamente entre as zonas amostradas. Entretanto, a população de *O. nilocticus* sustenta a pesca artesanal dos moradores de seu entorno.

Palavras chave: Ictiofauna; ecossistema lêntico; hipereutrofizado; semi-árido

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INTRODUCTION

Long-term studies evaluating temporal fluctuations in the physical, chemical and biological variables of tropical lentic ecosystems are scarce. In addition, information on a given taxonomic group may be fragmented or collected with different methodologies, making comparisons difficult. Among the exceptions, fishing productivity data from the Gargalheiras reservoir in Rio Grande do Norte, Northeastern Brazil, collected over three decades by the National Department for Drought Relief (DNOCS), make it possible to evaluate the temporal variation in the assemblage of native and exotic fish species of this location (ATTAYDE *et al*., 2011). Likewise, due to its location inside the campus of the Federal University of Ceará, the Santo Anastácio reservoir has been the object of a number of fish ecological studies, resulting in comprehensive records of occurrence of the main fish taxa, covering the last three decades (OLIVEIRA and GURGEL, 1977; FAUSTO-FILHO, 1988).

The Santo Anastácio reservoir is part of the Maranguapinho watershed, in the coastal region of Fortaleza. The system has suffered extensive anthropogenic silting over the past 40 years and may be described as hypereutrophic in view of the high levels of organic phosphorus registered (57-130 mg m^{-3}) (OLIVEIRA and GURGEL, 1977). The reservoir is subject to increasing eutrophication mainly due to the input of domestic wastewater and garbage discharged into the ecosystem by residents along the margins of the waterway (ARAÚJO, 2003).

Located near the sea, the Maranguapinho watershed was subject to marine regressions nearly ten thousand years ago, probably affecting the structure of the local fish communities. The watershed was later influenced by ecosystems further inland and, more recently, has been greatly impacted by extensive and continual real estate developments (NILIN *et al*., 2007).

Records of the fish communities in the Maranguapinho watershed from the late 1970s (OLIVEIRA and GURGEL, 1977) up to 2010 (FAUSTO-FILHO, 1988; and the present study) show considerable variation in composition and richness over time. Not surprisingly, natural or anthropic disturbances and processes of competitive exclusion have resulted in different states of equilibrium, with a handful of species predominating in terms of abundance and biomass (CHORUS and SCHLANG, 1993; KOMÁRKOVÁ and TAVERA, 2003; O'CONNELL *et al*., 2004; VIEIRA *et al*., 2004; CANONICO *et al*., 2005; CARVALHO, 2009). According to WHITTAKER (1975), a balanced community is one in which species occupy different niches, thereby reducing competition. Segregation by niche may be attained in the absence of disturbances and with minimum diversity in the ecosystem due to competitive exclusion. On the other hand, ecosystems submitted to extensive and continual disturbances, such as the Santo Anastácio reservoir, can attain stability with minimal variations in biomass and assemblage abundances. The objective of the present study was to characterize the fish assemblage of the Santo Anastácio reservoir (Fortaleza, Ceará, Brazil) as recorded over the last 36 years, and relate it to environmental and anthropic factors.

MATERIAL AND METHODS

The Santo Anastácio reservoir is located at 3°44'25"S and 38°34'30"W – 3°44'49"S and 38°34'01"W. It is included in the Maranguapinho watershed which covers 86.8 km^2 of coastal territory (FAUSTO-FILHO, 1988), corresponding to 28.7% of the municipality of Fortaleza (Ceará, Brazil). The region was strictly rural in the early twentieth century, but is presently (2010) highly urbanized (ARAÚJO, 2003; NILIN *et al*., 2007). The fish were sampled from three zones (1, 2 and 3) along the longitudinal gradient of the reservoir (Figure 1).

Currently, the lake has a perimeter of 2,858 m, a volume of 316,760 m^3, an average depth of 2.29 m and a maximum depth of 4.97 m (ARAÚJO, 2003). When the reservoir was built 75 years ago, it was designed for a maximum capacity of 508,000 m^3 but, as shown by ARAÚJO (2003), due to silting and pollution the capacity is now reduced to 372,000 m^3. Thus, the Santo Anastácio reservoir may be described as a small body of water with low average depth, daily wastewater inflow, high aquatic macrophyte density and marginal vegetation characteristic of the coastal areas of Northeastern Brazil. In addition, there is no salinity fluctuation due to the adjacent sea or nearby estuarine areas (ARAÚJO, 2003).

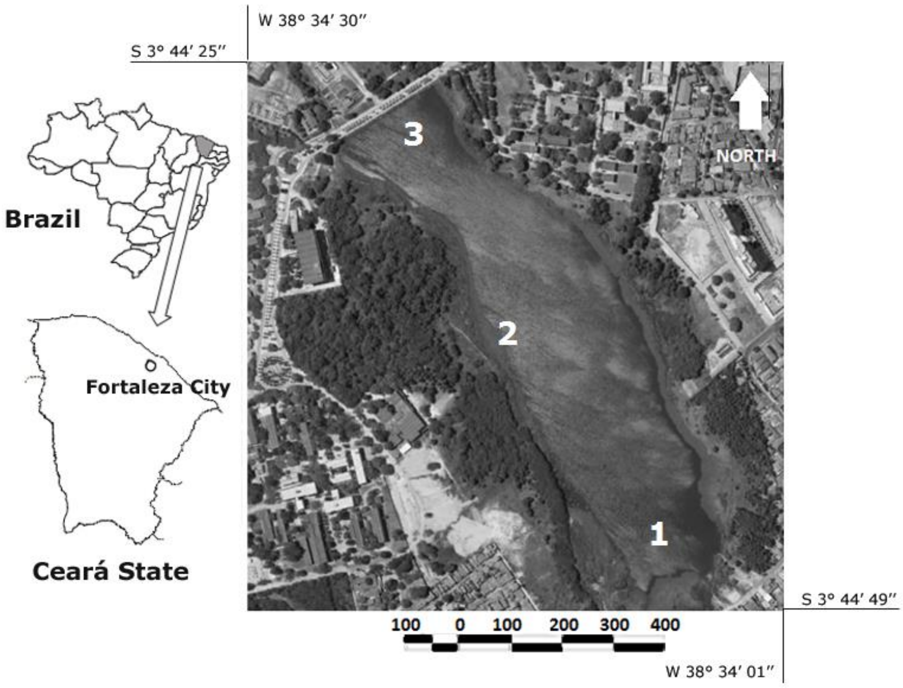

Figure 1. Geographical location and aerial view of the Santo Anastácio reservoir showing the sampling zones (1, 2, 3) (scale in meters) (GOOGLE EARTH**,** <http://earth.google.com/>).

Fish samplings were made once a month, alternately in each zone, between October 2009 and March 2010. The fish fauna was sampled using a set of seven gillnets with graded mesh sizes (25, 30, 40, 50 and 60 mm, between opposite knots) measuring 20 m by 1.5 m, totaling 212.45 m² per sampling zone. To cover both the limnetic area and the lakeside, the nets were deployed perpendicularly to the shoreline for approximately three hours (from 8 a.m. to 11 a.m.) on each occasion. A seine net measuring 1.3 m x 1.45 m (mesh size: 5 mm, between opposite knots) was used to sample the fish fauna by the lakeside in areas with abundance of aquatic macrophytes. Six samplings occurred in areas dominated by *Eichhornia crassipes* and *Panicum repens* (three in each), with a capture effort of 11.34 m² per sampling zone to evaluate the spatial distribution of the fish composition, abundance and biomass. For safety reasons, in accordance with the recommendations of the University's department of health surveillance, samplings were conducted only in the morning.

The fish were captured under a license issued by the Water Management Company (COGERH/Companhia de Gestão dos Recursos Hídricos) as part of a program to monitor water quality and fish mortality in reservoirs in Ceará. All sampled fish were stored in ice boxes after being identified on site using lists and taxonomic keys (REIS *et al*., 2003; CASTRO and VARI, 2004; BRITSKI *et al*., 2007; OYAKAWA and MATTOX, 2009). The fish were counted, measured (standard length in cm) and weighed (total weight in g), then donated to local communities and at least one specimen of each species was deposited in the fish collection of the Federal University of Rio Grande do Norte (UFRN).

The samples were evaluated with regard to assemblage (taxa), richness (number of species), relative abundance (number of individuals per species) and individual weight (biomass in grams). Based on the observed abundance and biomass, the catch per unit of fishing effort (CPUE) was calculated and expressed as the total number of individuals (CPUEn) (ind $100m^{-2}$ $hour^{-1}$)

or biomass in grams (CPUEb) (g 100 m^{-2} $hour^{-1}$) for samples collected by gillnet, and the total number of individuals (CPUEn) (ind m^{-2}) or biomass in grams (CPUEb) (g m^{-2}) for samples collected by seine net. This standardization allowed to compare the species with regard to the number of individuals captured.

The specific richness (number of species), abundance (CPUEn), weight (CPUEb) and standard length (cm) of the fish species in the assemblage were evaluated. Diversity and equitability were compared spatially between the three sampling zones, respectively, with Shannon-Wiener and Pielou's index (MAGURRAN, 1989) using the statistical software PAST (HAMMER *et al.*, 2001). The fish composition and abundance data for the three zones were analyzed using BRAY and CURTIS (1957) coefficients and the UPGMA method (SNEATH and SOKAL, 1973). Subsequently, dendrograms were constructed with the software PAST.

Finally, our findings for the Santo Anastácio reservoir were compared to those of OLIVEIRA and GURGEL (1977) and FAUSTO-FILHO (1988) with regard to fish assemblage composition and richness. These comparisons are restricted to the fish species registered in each study, since each author covered different seasons and sampling times and employed different techniques and gears.

RESULTS

A total of 2,674 specimens were collected from the limnetic area and lakeside of the reservoir. The fish belonged to nine species, representing seven families and four orders (Table 1).

Table 1. Taxonomic classification, number of individuals (N), standard length (SL) (cm) and weight (W) (g) of specimens collected in the limnetic area (l) and in macrophyte stands (**e** = *Eichhornia crassipes*/p = *Panicum repens*) of the Santo Anastácio reservoir (Fortaleza, Brazil), between October 2009 and March 2010. SD = standard deviation.

Taxon	**Nl**	**SLl (SD)**	**Wl (SD)**	**Ne**	**SLe (SD)**	**We (SD)**	**Np**	**SLp (SD)**	**Wp (SD)**
Characiformes									
Characidae									
Astyanax bimaculatus (Linnaeus, 1758)	52	7.37 (0.7)	17.60 (6.16)	-	-	-	-	-	-
Erythrinidae									
Hoplias malabaricus (Bloch, 1794)	8	24.20 (4.3)	248.30 (107)	-	-	-	-	-	-
Prochilodontidae									
Prochilodus brevis (Steindachner, 1875)	8	21.10 (3.03)	241.50 (109.60)	-	-	-	-	-	-
Siluriformes									
Callichthyidae									
Hoplosternum littorale (Hancock, 1828)	49	15.80 (1.40)	160.60 (35.40)	-	-	-	-	-	-
Loricariidae									
Hypostomus pusarum (Starks, 1913)	22	13.6 (2.50)	87.10 (48.40)	2	3.10 (1.40)	0.80 (0.80)	6	1.90 (0.70)	0.14 (0.14)
Cyprinodontiformes									
Poeciliidae									
Poecilia vivipara Bloch and Schneider, 1801	-	-	-	747	1.80 (0.30)	0.16 (0.13)	738	1.70 (0.30)	0.15 (0.37)
Poecilia reticulata Peters, 1859	-	-	-	192	1.50 (0.10)	0.06 (0.02)	168	1.50 (0.10)	0.05 (0.02)
Perciformes									
Cichlidae									
Cichlasoma bimaculatum (Linnaeus, 1758)	104	7.41 (1.00)	21.50 (9.10)	-	-	-	-	-	-
Oreochromis niloticus (Linnaeus, 1758)	287	12.70 (2.32)	86.50 (37.10)	190	2.70 (2.80)	6.30 (19.90)	100	1.70 (0.80)	0.31 (0.68)

In the reservoir as a whole, the most representative order with regard to the number of individuals was Cyprinodontiformes (69.0%), followed by Perciformes (25.5%), Siluriformes (2.9%) and Characiformes (2.6%). With regard to biomass (g), the most representative order was Perciformes (65.0%), followed by Siluriformes (23.0%), Characiformes (11.0%) and Cyprinodontiformes (1.0%). Thus, the family Poeciliidae accounted for the greatest number of individuals while the family Cichlidae represented the largest biomass sampled (Table 1).

In relation to the total number of specimens collected, 530 (20%) were captured by gillnet while 2,143 (80%) were captured by seine net. The average weight was 863.10 g (99% of total weight) and 7.97 g (1%), respectively. In the samples obtained by gillnet in limnetic areas, the smallest and largest average size and weight were observed for *A. bimaculatus* (7.37 ± 0.7 cm; 17.6 ± 6.16 g) and *H. malabaricus* (24.2 ± 4.3 cm; 248.3 ± 107 g). *Poecilia vivipara* was predominant in macrophyte stands, while *Oreochromis niloticus* was the most representative species in terms of biomass, mainly due to the capture of specimens weighing over 40 g. In areas with *E. crassipes* stands, *P. reticulata* had the smallest average size and weight (1.50 ± 0.10 cm; 0.06 ± 0.02 g), *H. pusarum* had the largest average size (3.10 ± 1.40 cm) and *O. niloticus* the greatest average weight (6.3 ± 19.90 g). Likewise, in *P. repens* stands, *P. reticulata* had the smallest average size and weight (1.50 ± 0.10 cm; 0.05 ± 0.02 g), *H. pusarum* had the largest size (1.90 ± 0.70 cm), while *O. niloticus* displayed the largest weight (0.31 ± 0.68 g) (Table 1).

The greatest CPUEn values among species collected by gillnet was observed for *O. niloticus*, followed by *C. bimaculatum*, *A. bimaculatus*, *H. littorale*, *H. pusarum*, *H. malabaricus* and *P. brevis* (the latter two species with equal values) (Figure 2a). The greatest CPUEb value was observed for *O. niloticus*, followed by *H. littorale*, *C. bimaculatum*, *H. pusarum, P. brevis* and *A. bimaculatus* (Figure 2b).

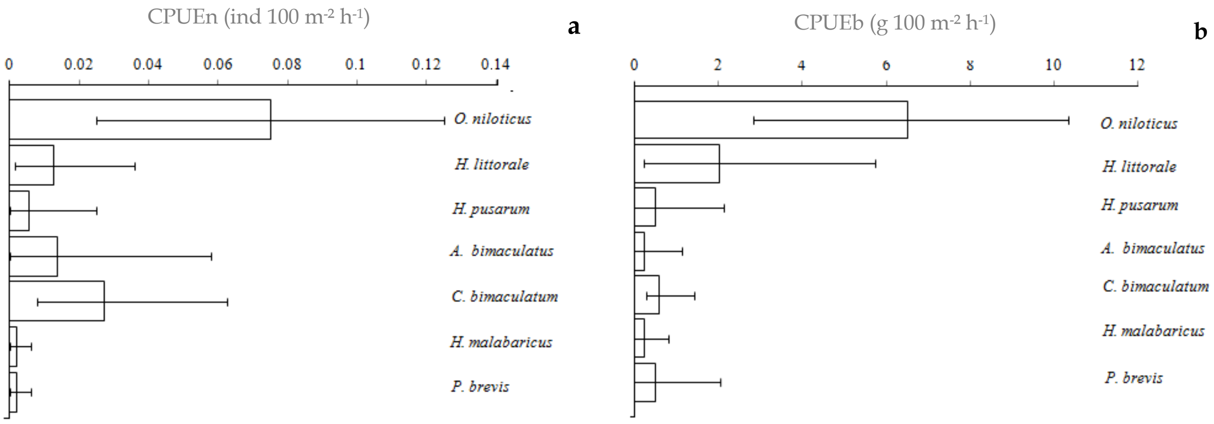

Figure 2. CPUEn (a) and CPUEb (b) values of fish species sampled by gillnet in the Santo Anastácio reservoir (Fortaleza, Brazil) between October 2009 and March 2010. Bars represent mean values; lines indicate standard deviation values.

Approximately the same number of individuals were sampled by seine net from locations dominated by the macrophytes *E. crassipes* (53%) and *P. repens* (47%). In locations dominated by *E. crassipes*, four species were observed, the CPUEn and CPUEb values of which are shown in Figure 3.

Among the species sampled by seine net, the greatest biomass was observed for *O. niloticus*, mostly due to the capture of specimens above 40 g. In locations dominated by *P. repens*, five species were observed, the CPUEn and CPUEb values of which are shown in Figure 4. Here, *P. vivipara* was the dominant species in both number and biomass.

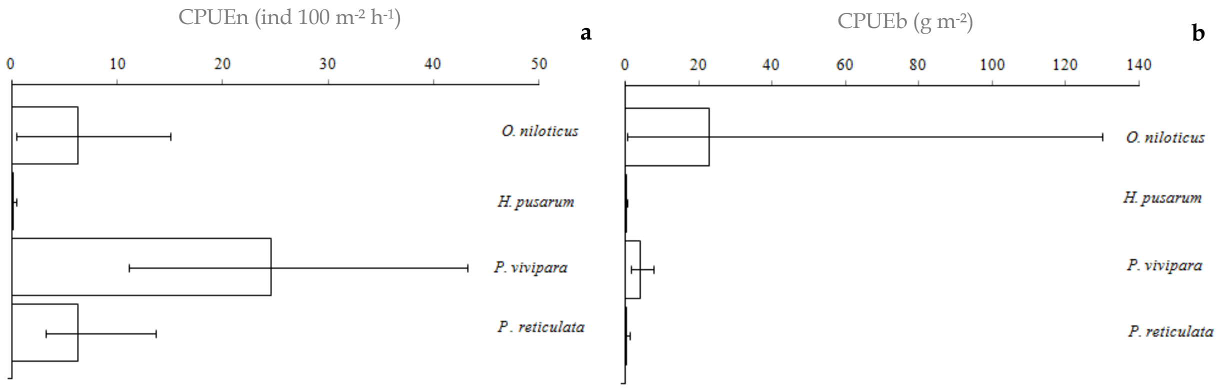

Figure 3. CPUEn (a) and CPUEb (b) values of fish species sampled by seine net in locations dominated by *E. crassipes* along the lakeside of the Santo Anastácio reservoir (Fortaleza, Brazil). Bars represent mean values; lines indicate standard deviation values.

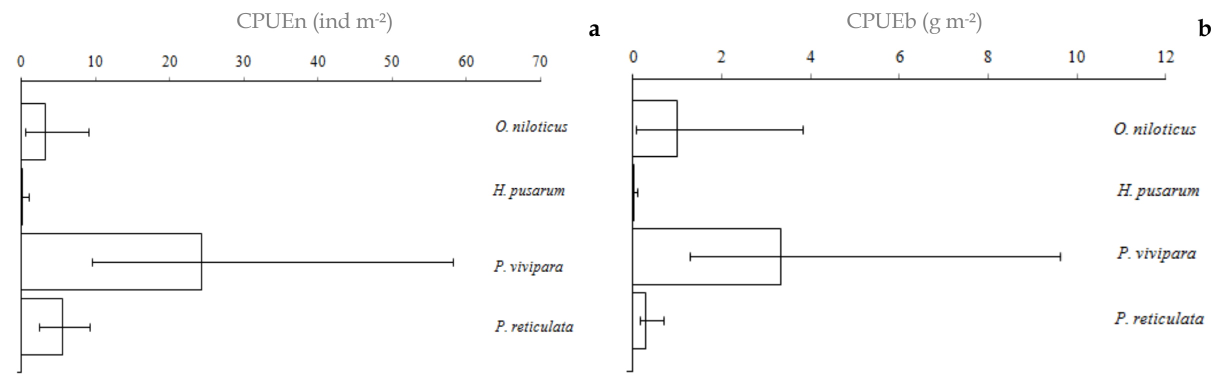

Figure 4. CPUEn (a) and CPUEb (b) values of fish species sampled by seine net in locations dominated by *P. repens* along the lakeside of the Santo Anastácio reservoir (Fortaleza, Brazil). Bars represent mean values; lines indicate standard deviation values.

The three limnetic zones displayed little variation in diversity and equitability, although values were somewhat higher in Zone 3. In macrophyte stands, the greatest diversity (species richness) was observed in Zone 1, while the values were similar for Zone 2 and Zone 3 (Figure 5).

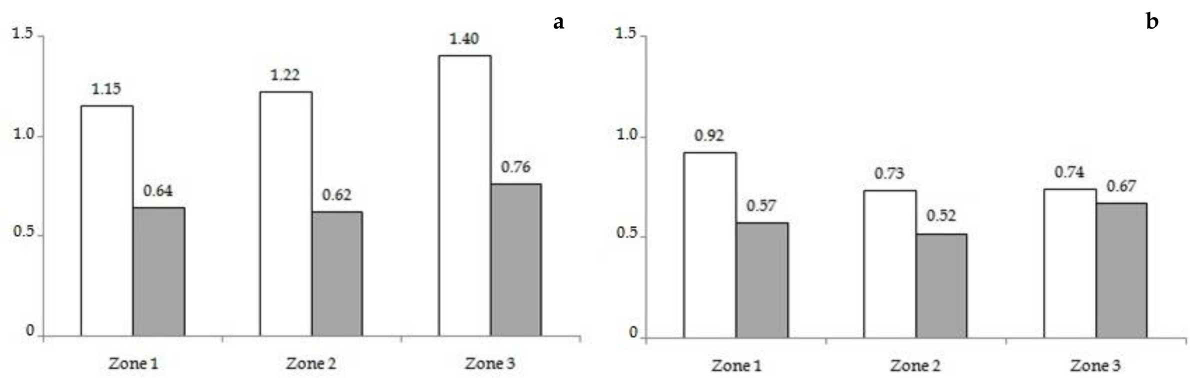

Figure 5. Diversity Index (white bars) and Equitability (gray bars) for three sampling zones in the Santo Anastácio reservoir along the lakeside (a) and in limnetic areas (b).

The abundance of fishes captured by gillnet generated a group with greater similarity between the limnetic areas in Zone 2 and Zone 3. The abundance of fishes captured by seine net generated a group with greater similarity between the lakeside areas in Zone 1 and Zone 3 (Figure 6).

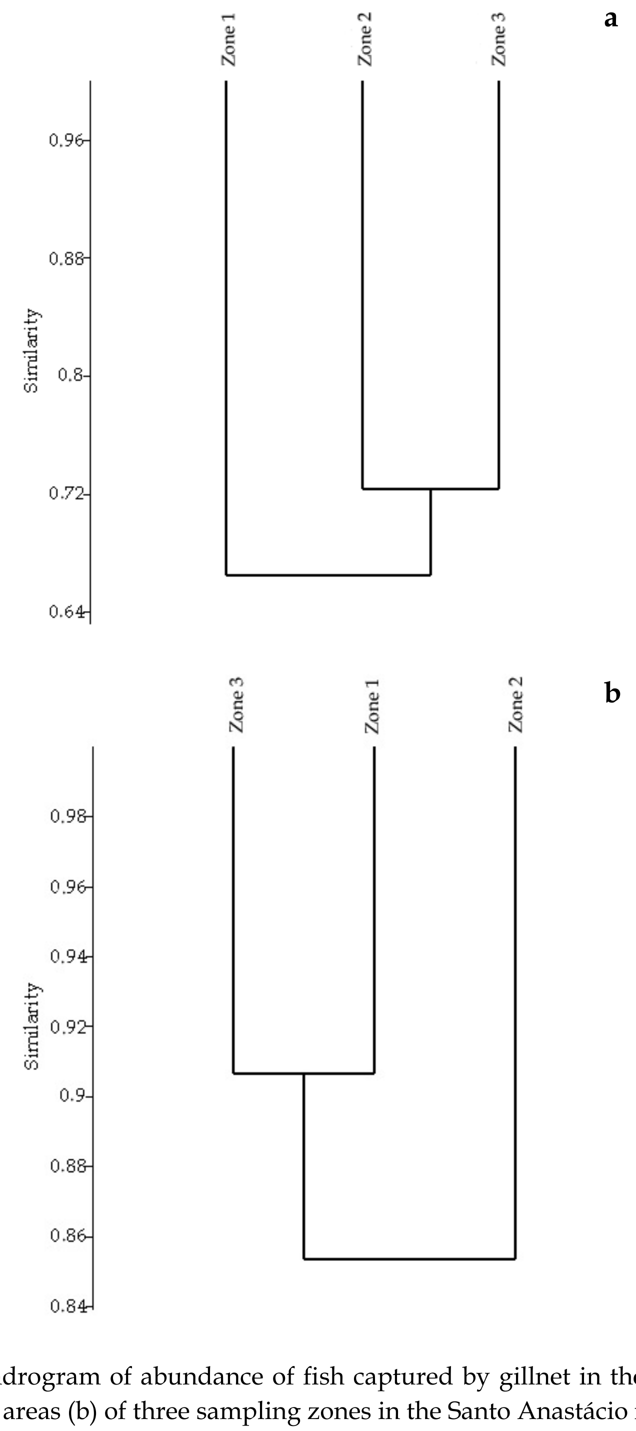

Figure 6. Similarity dendrogram of abundance of fish captured by gillnet in the limnetic areas (a) and by seine net in the lakeside areas (b) of three sampling zones in the Santo Anastácio reservoir.

Three of the nine species described in this study (*P. reticulata*, *O. niloticus* and *H. littorale*) were introduced from other ecosystems; the remainder are considered native (ROSA *et al*., 2003). Some species described in earlier surveys of the Santo Anastácio reservoir, including *Leporinus* *friderici*, *Eigenmannia virescens* and *Serrasalmus brandtii*, were not observed in our samples. In contrast, some species not described earlier, such as *Hoplosternum littorale* and *Prochilodus brevis*, were registered for the first time in the present study. The species *O. niloticus* was first registered in the Santo Anastácio reservoir by FAUSTO-FILHO (1988) (Table 2).

Table 2. Fish assemblage in the Santo Anastácio reservoir (Fortaleza, Brazil) from 1977 to 2010, based on samples collected between October 2009 and March 2010 (current study) and on surveys published by OLIVEIRA and GURGEL (1977) and FAUSTO-FILHO (1988).

Species	OLIVEIRA and GURGEL (1977)	FAUSTO-FILHO (1988)	Current study with the voucher number
Synbranchus marmoratus		X	
Leporinus friderici	X	X	
Hoplerythrinus sp.	X	X	
Hoplias malabaricus	X	X	UFRN 1848
Astyanax bimaculatus	X	X	UFRN 1849
Serrasalmus brandtii		X	
Prochilodus brevis			UFRN 1850
Hoplosternum littorale			UFRN 1851
Hypostomus pusarum	X		UFRN 1852
Plecostomus plecostomus		X	
Plecostomus sp.		X	
Poecilia vivipara	X	X	UFRN 1853
Poecilia reticulata	X		UFRN 1854
Eigenmannia virescens	X		
Cichlasoma bimaculatum	X	X	UFRN 1855
Oreochromis niloticus		X	UFRN 1856
Betta sp.	X	X	
Total number of species	**10**	**12**	**9**

DISCUSSION

The Santo Anastácio reservoir is a small and shallow body of water with a daily flow of effluents and an almost constant volume throughout the year (ARAÚJO, 2003, NILIN *et al.*, 2007). These features, in addition to a continuous discharge of domestic wasterwater, reflect a considerable input of nutrients, classifying the ecosystem as hypereutrophic (ARAÚJO, 2003). Over the last three decades, increasing eutrophication, low water quality, variations in the availability of food resources and the introduction of exotic fish species have led to evident changes in fish assemblage and richness. More specifically, the increase in primary productivity associated with hypereutrophication, favors the survival of planktivorous fishes which compete for zooplankton and upturn the sediment in search for food, thereby moving nutrients from the bottom into the water column (ATTAYDE *et al.*, 1996; ATTAYDE *et al.*, 2007). Not surprisingly, most of the individuals collected in the Santo Anastácio reservoir in 2009/2010 (*O. niloticus*, *P. vivipara* and *P. reticulata*) feed on plankton and detritus (DUSSAULT and KRAMER, 1981; LAZZARO *et al.*, 2003; MESERVE *et al.*, 2003; ABELHA *et al.*, 2005; MAGURRAN, 2005; OSO *et al.*, 2006). The characteristics of the reservoir and the current fish assemblage indicate an ecosystem tending towards a bottom-up community (McQUEEN *et al.*, 1986, McQUEEN, 1998; MESERVE *et al.*, 2003) in which *O. niloticus* is predominant in terms of biomass (500:1) compared to other species (except the detritivore *H. littorale*) as a result of its omnivorous habits and the abundance of algae and detritus (DRENNER *et al.*, 1996; STARLING *et al.*, 2002, DIEHL, 2003; LAZZARO *et al*., 2003; ATTAYDE *et al.,* 2007). However, the decline of piscivorous fishes caused by trophic changes in ecosystems dominated by planktivorous species may be illustrated by the disappearance from the Santo Anastácio reservoir of the species *S. brandtii* which was last registered by FAUSTO-FILHO (1988).

The fish fauna of the Santo Anastácio reservoir was dominated by small species (<20 cm), with the exception of *H. malabaricus* and *P. brevis*, which are considered intermediate (between 20 and 40 cm) (ABILHÔA and BASTOS, 2005). The morphological and biometrical features of individuals depend on the environmental conditions under which they live (CIONEK *et al*., 2009). In fact, the individuals of *O. niloticus* collected in the Santo Anastácio reservoir presented evident consequences of hypereutrophic conditions, such as small size and low average weight, and some specimens displayed anomalies, including spots and body deformations (Jorge Iván Sánchez Botero, *personal observation*).

The introduction of exotic species can change the dynamics of the local fish fauna structure and, in some cases, contribute to the extinction of native species and loss of biodiversity (VITULE, 2009). Although stocking with exotic species may be justified from the socioeconomic point of view, in small lentic ecosystems a sudden shift towards the predominance of planktivorous species can negatively impact the fish fauna structure and the environment (ATTAYDE *et al*., 2011). *Oreochromis niloticus*, one of the species introduced into the Santo Anastácio reservoir, is abundant, widely distributed and socioeconomically important in northeastern Brazil (PANOSSO *et al*., 2007; ATTAYDE *et al*., 2011). Nevertheless, the lack of control and surveillance of the introduction of exotic species poses a potential threat to commercially important native species (WELCOMME, 1988; CANONICO *et al*., 2005; VITULE, 2009; ATTAYDE *et al*., 2011). The success of the colonization of northeast Brazilian lentic ecosystems by *O. niloticus* is associated with several factors, including the species' omnivorous habits, tolerance of adverse physico-chemical conditions (pollution, high temperatures and low levels of dissolved oxygen), high reproductive potential, adjustment of size at sexual maturation to environmental conditions, parental care and intermittent spawning behavior (LOWE-MCCONNELL, 1999; BEVERIDGE and BAIRD, 2000; DUPONCHELLE *et al*., 2000). These hypereutrophic conditions in the Santo Anastácio reservoir for at least two decades favored the establishment, proliferation and predominance of *O. niloticus* in the ecosystem. The species was registered by FAUSTO-FILHO (1988) and identified as the most important subsistence fishing resource, and it represented the greatest biomass in the experimental fisheries conducted for this study. However, it should be pointed out that *O. niloticus* was not mentioned in the fish fauna survey published by OLIVEIRA and GURGEL (1977), suggesting the species had not yet been introduced or that the introduction was recent and the population was still relatively small.

The species *P. reticulata* and *H. littorale*, which are likewise believed to have been introduced from other ecosystems (ROSA *et al*., 2003; OLIVEIRA and BENNEMAN, 2005; LANGEANI *et al*., 2009), were abundant as well as representative in terms of biomass. Thus, omnivorous habits, rapid growth, adaptability, tolerance to changes in temperature and salinity (GOMES-JÚNIOR and MONTEIRO, 2008) and considerable resistance to the effects of anthropogenic pollution (OLIVEIRA and BENNEMAN, 2005; VIEIRA and SHIBATTA, 2007) likely contributed to the successful colonization and distribution of *P. reticulata* in the reservoir. *Poecilia vivipara* was very abundant in shallow areas by the lakeside in part due to its reproductive efficiency (ARANHA and CARAMASCHI, 1999).

Registered in the Santo Anastácio reservoir for the first time in 2010, *H. littorale* accounted for a significant proportion of the collected biomass. However, considering the unavailability of appropriate identification keys in 1988, FAUSTO-FILHO (1988) may have misidentified the species as *Plecostomus* sp. On the other hand, the abundance of *H. littorale*, a detritivorous species characteristic of lentic environments, may be explained by its ability to extract dissolved oxygen from the surface of the water (MATOS *et al.,* 1993; JUCÁ-CHAGAS and BOCCARDO, 2006) and by its negligible importance to local fishermen.

The total CPUEn and CPUEb values from gillnet samplings in limnetic areas were relatively high (on the average, 0.14 ind m^{-2} h^{-1} and 10.9 g m^{-2} h^{-1}, respectively) when compared to other Brazilian lentic ecosystems, such as the flood plains in Paraná (1.66 g m^{-2} h^{-1}) (AGOSTINHO *et al.*, 2007) and the coastal lagoons in northern Rio de Janeiro (0.014 ind m^{-2} h^{-1}) (SÁNCHEZ-BOTERO *et al.*, 2008). This finding may be explained by the predominance of *O. niloticus*, the abundance and biomass of which represented, respectively, 54% and 60% in all samplings. The abundance and biomass values in the macrophyte stands (on the average, 33.25 ind m^{-2} and 24.16 g m^{-2} for fishes associated with *E. crassipes*, and 29.78 ind m^{-2} and 6.61 g m^{-2} for fishes associated with *P. repens*) differed from the values reported in studies covering other Brazilian lentic ecosystems, such as the lakes of the Amazonian floodplain (13.3 g m^{-2}) (SÁNCHEZ-BOTERO *et al.*, 2003) and the coastal lagoons in Rio de Janeiro (6.01 g m^{-2}) (SÁNCHEZ-BOTERO *et al.*, 2008). In *P. repens* stands, *P. vivipara* was highly predominant, with CPUEn and CPUEb values more than twice the values of all the other species combined. In *E. crassipes* stands, larger individuals of *O. niloticus* were observed, generating greater CPUEb values, due to the better oxygen conditions offered by this type of stand (JEDICKE *et al.*, 1989; SÁNCHEZ-BOTERO *et al.*, 2001). The large proportion of juveniles and small fish species associated with this macrophyte in the Santo Anastácio reservoir suggests it serves as a refuge and nursery.

The low diversity values observed were associated with low equitability, indicating a possible process of competitive exclusion (TOWNSEND *et al.*, 2010). In fact, due to its high biological plasticity and resistance to hypereutrophic conditions, the dominant species *O. niloticus* has been much favored in the competition against other species (ATTAYDE *et al.*, 2007).

The abscence of differences in composition and richness along the longitudinal axis of the reservoir (from the limnetic area to the lakeside) is probably due to the small size of the reservoir and the proximity and hydrodynamic homogeneity of the three sampling zones (ARAÚJO, 2003).

The species *L. friderici* was reported in previous studies but was not identified in our sample (2009/2010), whereas the species *H. malabaricus* and *P. brevis* had become much less abundant. For the most part, the latter two species share the same habitat (lentic environments with mud bottoms), although *H. malabaricus* is a predator (CARVALHO *et al.*, 2002) while *P. brevis* feeds on detritus and performs long migrations in the mating season (CASTRO and VARI, 2004). The absence of *L. friderici* may be due to its migratory behavior since the species is adverse to permanent confinement (AGOSTINHO *et al.*, 2003; BENEDITO-CECILIO *et al.*, 2005; AGOSTINHO *et al.*, 2007). *Prochilodus brevis* was registered in the Santo Anastácio reservoir for the first time in 2010. Further studies are necessary to clarify the migration and mating behavior of this species within the watershed. Nevertheless, the presence in our sample and in previous surveys of *P. brevis and L. friderici*, a species known to migrate in the mating season (AGOSTINHO *et al.*, 2003; CASTRO and VARI, 2004), raises questions about the tolerance of this species with regard to environments restricting this type of behavior. In fact, in the vicinity of the Santo Anastácio reservoir, the Maranguapinho watershed features a number of barriers, both physical (dams and shallow straightened streams) and chemical (discharge of sewage and toxic substances) (NILIN *et al.*, 2007), limiting the migration of rheophilic species.

Although registered by OLIVEIRA and GURGEL (1977) and FAUSTO-FILHO (1988), the species *Betta* sp. was not observed in this study (2010), even in samples collected by the lakeside. There seems to be two possible explanations for its occurrence in the past: i) a rivulid species may have been misidentified as *Betta* sp. due to similarities in color, size and shape. Rivulids are short-lived and often appear temporarily in lakes and reservoirs following heavy rainfalls. The family is abundantly represented in the State of Ceará (COSTA *et al.*, 2001); ii) the species *Betta splendens* may have been introduced in the Santo Anastácio reservoir to help control mosquito larvae of the species *Aedes aegypti* (a vector of dengue fever) only to disappear over subsequent years. The species can tolerate very low levels of dissolved oxygen and temperatures up to 36ºC

(LOWE-MCCONNELL, 1999), suggesting its disappearance from the reservoir was likely due to biological interactions.

The absence of *E. virescens* registered by FAUSTO-FILHO (1988) may be related to its nocturnal habits, to its preference for deeper water and lower temperatures (18°C) (CRAMPTON, 1998; SCARABOTTI *et al.*, 2011).

Hoplerythrinus sp. was not observed in the samples collected for the present study. This species often rises to the surface in order to breathe air. Its ability to survive for a short period out of water and its nocturnal habitats (VAL, 1996) explains its occurrence in the Santo Anastácio reservoir. The observation suggests the need for making collections at different times of the day in order to sample the greatest possible number of species.

Two important food fishes introduced into the Santo Anastácio reservoir in the recent past, *Cyprinus carpio* and *Colossoma macropomum* (GURGEL, 1993), were not observed in this study, suggesting stocking efforts were unsuccessful. The absence of *C. macropomum* is possibly related to migratory behaviors in the mating season (ARAUJO-LIMA and RUFFINO, 2003) when the fish are trapped by earth embankments or low water levels, conditions not found in their native Amazon region. *Cyprinus carpio* may not have supported the local fishing pressure, or stocking may have been unsuccessful because reproduction was artificially induced, a process which can generate chromosomal abnormalities (MORAES *et al.*, 2004).

The native species *A. bimaculatus*, *C. bimaculatum*, *H. pusarum* and *H. malabaricus* (ROSA *et al.*, 2003) were reported in all fish fauna studies of the Santo Anastácio reservoir. These species are known for their extraordinary tolerance to frequent disturbances in lentic systems (OYAKAWA and MATTOX, 2009; SÁNCHEZ-BOTERO *et al.*, 2009), especially *A. bimaculatus*, an opportunistic species highly adaptable to alternative food sources (SAZIMA, 1986; SILVA *et al.*, 2010) and known to occur in eutrophic lentic ecosystems (ARCIFA *et al.*, 1991; SÁNCHEZ-BOTERO *et al.*, 2009).

The variation in the fish assemblage and richness observed in the Santo Anastácio reservoir over the past 33 years may be explained by at least three circumstances: i) species capable of resisting extreme variations in physico-chemical conditions caused by gradual eutrophication have become predominant in the assemblage; ii) competitive and versatile species have prevailed over species occupying restricted niches; iii) the introduction of successful colonizers from other ecosystems has caused a decline or the complete exclusion of less competitive species. Species negatively impacted by eutrophication tend to be replaced by hardier species tolerating harsher environmental conditions, as observed by MARINHO *et al.* (2006) for reservoirs in the semiarid hinterland of Paraíba (northeastern Brazil) and by other researchers of lentic ecosystems (VITULE *et al.*, 2009).

The predominance of species tolerant to hypoxic and eutrophic ecosystems, such as *O. niloticus*, *P. vivipara, P. reticulata* and *H. littorale*, as well as the scarcity of *P. brevis* and *H. pusarum*, illustrate the influence of anthropic factors on fish assemblage. Although the reservoir is habitat to few fish species, its population of *O. niloticus* is the object of subsistence fishing by local residents.

CONCLUSIONS

Over the last three decades, the richness of the fish fauna of the Santo Anastácio reservoir has been in decline, with substantial changes in assemblage as a result of increasing levels of eutrophication and colonization by exotic species tolerant of harsher environmental conditions, such as *O. niloticus*, *P. vivipara* and *P. reticulata*. The predominance of these species in neotropical ecosystems may be explained by aspects of their life history. In contrast, species recorded in the past but currently absent, or much less abundant, probably require environmental conditions for their physiological, reproductive or trophic activities which are no longer present in the Santo Anastácio reservoir. In conclusion, i) the fish fauna of the Santo Anastácio reservoir is presently characterized by a small number of species, ii) little variation was observed between the sampling zones with regard to community structure, and iii) the fish assemblage in the reservoir tends to change over time as a consequence of anthropic activities.

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