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Ecological Features of Large Neotropical Reservoirs and Its Relation to Health of Cage Reared Fish

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1. Introduction

Environmental Brazilian legislation allow the implementation of cage culture fish farm enterprises in large public reservoirs (Ayroza et. al., 2006), aiming a qualitative and quantitative increase of inland aquaculture, regarding concerns with environmental, economic and social sustainability (Costa-Pierce, 2002; Valente, 2000). Fish farming is an important activity for animal protein production, and if well planned, is benefic to the economic development of the country. However, it is necessary continuous assistance of appropriate expertise and scientific support in order to organize and improve fishery and aquaculture (Agostinho et al., 2007). Due to low productivity of inland native fish stocks, Brazilian government aquaculture programs initially focused on change artisanal fisher to fish farmers, assuming that this could improve their economic situation. This is a mistaken philosophy, since the extrativist way of life contradicts the planned life of a modern aquaculturist. This is especially applicable for Brazilian Southeastern region, where this activity is basically maintained by intensive culture of tilapia (Furlaneto et al., 2006) by capitalized stakeholders. Food and Agriculture Organization of the United Nations [FAO] (2010) and Rojas & Wadsworth (2007) highlight that aquaculture annual growth rate surpasses other zootechnical activities. Currently, annual fish yield in Brazil, by means of aquaculture and extractive fishing, has accomplished a 1,240,000 metric tons/year baseline, of which approximately 10% are related to tilapias (*Ministério da Pesca* [MPA], 2010), predominantly *Oreochromis niloticus* and derived hibrids Lovshin, 1982). Within this context, Brazil has been showing vigorous growth (over 25% per year) in this decade, however this growth is still modest considering the prodigious potential of water resources and suitable weather that Brazil offers (Godinho, 2007; MPA, 2010). It is evident that Brazilian aquaculture production is behind its potential comparing to Chinese fish yield, that produces approximately 47.5 millions of metric tons/year (FAO, 2010). Fitzsimmons (2006) highlights Brazil as a prominent country that could compete with China as biggest fish producer in the world. The Paraná River is the second largest catchment in South America, with 3,780 km of extension, and is the main River of La Plata

River basin originating at the confluence of Paranaíba and Grande Rivers and has a watershed area of 2,800,000 km², which consists chiefly of sedimentary and volcanic rocks. The Paraná River stretches are divided into an upper course, from its source to Itaipu reservoir; a middle course along Paraguay-Argentina border; and a lower course from Paraguay River confluence to La Plata River estuary. The Upper Paraná River basin, with an extension of 809 km and area 820,000 km², has about 250 km without impoundments, resulting in a deeply altered hydrological and limnological regime (Stevaux, 1994). Currently, Brazilian inland net cage aquaculture is integrated to these large reservoirs. Within this context, in the last five decades it is noticed that Brazilian large Rivers have been impounded to build dams and power-plants, aiming hidroelectricity as a priority (Tundisi, 1993; Zocchi, 2002), to meet the increasing demand for energy in the country. This way of producing hidroelectricity energy represents 14.8% of all Brazilian energy matrix (Ministério das Minas e Energia [MME], 2006), with São Paulo state responsible for over 22% of this type of energy. These impoundments were built as a cascade system in large rivers (Grande, Tietê, Paranapanema and Paraná Rivers) (Agência Nacional de Energia Elétrica [ANEEL], 2009; Agostinho et al., 2007). Under an ecological perspective and environmental legislation, a good water quality and aquatic ecosystem integrity are fundamental to allocate the multiple uses of these large reservoirs, especially to effective organization by policy makers for aquaculture and fishing activities. In limnological terms, the determination of trophic state index (TSI) *sensu* Carlson (1977), based upon phosphorus and *a* chlorophyll contents to a specific water body, is a satisfactory and practical tool as environmental indicator, considering different human interventions that induce artificial eutrophication process. Various studies in hydrographic sub-basins of Tietê and Paranapanema Rivers show that this index usually varies. As an example, the index varies between oligotrophic to mesotrophic state for upper and middle Paranapanema stretches (Nogueira et al. 2006), and also between oligotrophic to eutrophic for Tietê River (Barbosa et al. 1999; Moretto et al., 2008; Tundisi & Straškraba, 1999). These variations are mainly due to anthropogenic actions, such as occupation of lands for agriculture, livestock, increasing urbanization due to growth of human population, and emissions of organic wastes (Tundisi, 2005). Brazilian native ichthyofauna of large rivers has been subjected to negative impacts, such as these impoundments (Agostinho et al., 2007), introduction of non-native species (Brandão et al., 2009; Latini & Petrere, 2004; Orsi & Agostinho, 1999; Santos & Formagio, 2000; Souto et al., 2011), environmental contamination, loss of riparian vegetation, sedimentation, and erosion (Agostinho et al., 2007). Currently, a new form of impact in Brazil is the increasing development of fish farming in floating cages (Ramos et al., 2008). In cage systems, the input of organic matter and nutrients is done by artificial feeds, and output is done through the removal of fish produced, similar to what occurs in fish ponds (Beveridge, 2004). However, Beveridge (2004); Munday et al. (1992); Persson (1988); and Pillay (2004) report that in fish cage farming systems up to 30% of feed is lost into the aquatic environment, in the form of unconsumed feed and wastes. These feed losses can cause problems related to eutrophication (Beveridge, 1984) and/or be used as a food resource by local biota (Beveridge, 2004; Håkanson, 2005; Ramos et al., 2008; Vita et al., 2004), resulting in ecological changes around these systems (Beveridge, 2004; Håkanson, 2005; Ramos et al., 2008). Besides these impacts, several authors as Agostinho et al. (2007); Beveridge (1984, 1996 e 2004); Dempster et al. (2002); Håkanson (2005); Karakassis et al.

(2000, 2002 e 2005); Machias et al. (2004, 2005 e 2006); Pitta et al. (2005); Ramos et al. (2008); Yucel-Gier et al. (2007); and Zanatta et al. (2010) discuss the problems of this activity in coastal and inland waters. These authors cite impacts upon water quality and sediment which have implications on the structure of benthic communities, plankton and fish, and furthermore, the inherent scapes of caged fish. Thus, it is evident the necessity of developing new technologies aiming the enhancement of fish yield, associated to decrease of environmental impacts caused by this zootechnical activity. This is a big challenge for Brazilian aquaculture that needs to guarantee its economic and social sustainability with preservation of water resources and multiple uses of public reservoirs.

2. Situation of the aquaculture in cage farms in Brazilian Southeastern reservoirs: An overview

The effects of cage aquaculture enterprises in Brazilian inland waters upon the biota and water quality have not been satisfactory elucidated yet, thus these effects still require studies aiming a full comprehension to better ordinate these activities. However, despite divergent opinions of some sectors of Brazilian society, the Brazilian government has been sponsoring studies focusing on taking advantage of the potential for aquaculture of large public reservoirs (Ayroza et al., 2006). Thus, Brazilian government has been selecting, delimitating, and controlling areas to install Aquaculture Parks in different reservoirs, based upon premises that promote sustainable development, enhancement of Brazilian fish yield, social inclusion, and food safety. Effective success of production in aquaculture founds in limnological studies and environmental carrying capacity, regarding concerns with water quality and maintenance of water resources (Costa-Pierce, 2002; Tundisi, 2005), as well as its interference upon aquatic biota, through escapes of non-native species, and pathogen dispersion (Agostinho et al., 2007; Orsi & Agostinho, 1999). According to Dillon & Rigler (1975) and Beveridge (2004), the modeling of environmental carrying capacity is done based upon two fundamental equations, which define phosphorus emission to aquatic ecosystem without inducing eutrophication, and how much P is emitted per product unit. The lack of suitable information to define application values of this modeling has been repeatedly emphasized as the highest difficulty to appraise environmental impacts caused by aquaculture (Pillay, 2004). In Brazil, cage fish farming systems has gained impulse in the mid-90's, especially in Brazilian Southeastern (Medeiros, 2002; Ono, 1998; Rojas & Wadsworth, 2007). Nowadays, this activity is in accelerated expansion in Brazilian reservoirs, and at least 40 freshwater fish species are used in Brazil, considering all kinds of pisciculture (Godinho, 2007). However, despite this rich fish diversity, the most used species for inland aquaculture in Brazil is the non-native Nile tilapia (*O. niloticus*) due to its favorable zootechnical features (Castagnolli et al., 2000; David et al, 2006; Rojas & Wadsworth, 2007). The Middle Paranapanema River area has about 800 net-cages designated to Tilapia culture along its reservoirs and ponds. It is estimated in 200 kg of fish/m³/cycle in small net-cages (up to 6m³); and 100 kg of fish/m³/cycle in net-cages of great capacity (over 10m³) (Furlaneto et al., 2006). In this sense, three issues are eminent within this approach: 1) artificial eutrophication, which is interconnected with environmental carrying capacity; 2) dispersion of parasites and pathogens and; 3) escapes, relating to depletion of fish biodiversity *lato sensu* by ecological processes of competition and predation. Below, it is followed the results of our main researches aiming to identify and quantify the ecological interferences of tilapia farming.
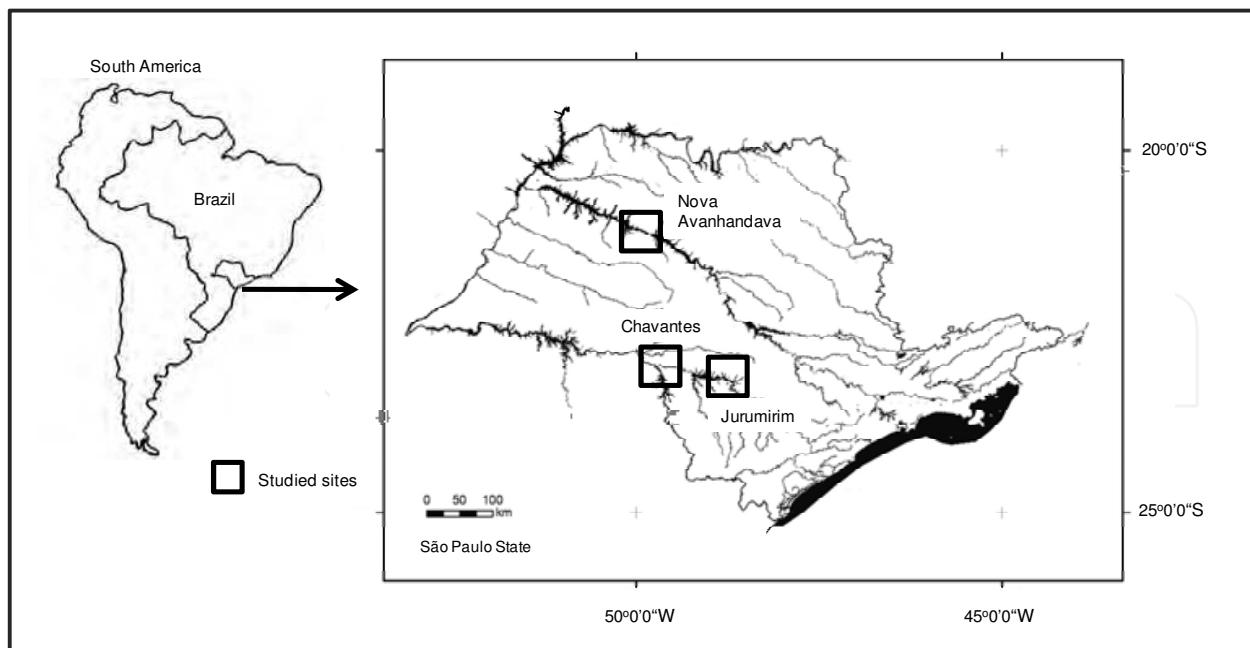
Fig. 1. Reservoirs studied in the Upper Paraná River Basin, São Paulo State, Brazil.

2.1 Limnological conditions and trophic state index

A comparative approach was used to evaluate the impact of three cage farms upon limnological conditions of the stretches were the cages are installed. These farms are located in three different reservoirs in the upper Paraná River Basin, São Paulo state, Brazil (fig. 1). The farms are small and medium-sized enterprises (ranging from 30 to 200 cages with 6 m^3 each), mainly for the culture of Nile tilapia (*O. niloticus*) using an intensive model, with high densities and fed with pelleted compound feed. An example of such farms is shown in fig. 2. Monthly surveys were performed in the farms in different years from 2003 to 2009, sampling limnological data and water samples inside the Farm Sites (referred as FS) and in similar Control areas sited upstream (CT). Differences among farm sites and control areas were regarded as effect of the nutrient loads from the farms. Limnological sampling included Secchi depth (Z_{DS}), water temperature, pH, dissolved oxygen (DO), electric conductivity (K_{25}) measured *in situ* using a water quality multiprobe Horiba model U-22; water samples were collected for nutrients (total Nitrogen - TN and total Phosphorus – TP following Valderrama, 1981; Strickland & Parsons, 1968), total suspended solids (Teixeira et al., 1978) and chlorophyll *a* (CHL, Golterman et al., 1978) analyses. TSI was determined based on CHL and TP by formulae 1 and 2, combined using formulae 3 (Carlson, 1996, as cited in Lin, 2001). The first reservoir studied by our research group was Nova Avanhandava, which is the fifth of a cascade of reservoirs on the Middle Tietê River, sampled from 2003 to 2004 (Paes, 2006). It is a run-of-river plant, that has been operated since 1982, located at 358 m above sea level, with surface area of 210 km², total water volume of 2,720 x 10^6 m³, mean discharge rate of 688 m³/s, maximum depth 30 m, level oscillation of less than 1 m throughout the year, and water residence time of 46 days (Torloni et al., 1993; Rodgher et al., 2002). The second reservoir was Jurumirim, where the surveys were done from 2004 to 2005; it is a storage plant at Upper Paranapanema River, operated since 1962, located at 568 m above sea level, total area 484 km², total volume of 7,900 x 10^6 m³ mean discharge rate of 210

m^3 s^{-1}, mean depth 12.9 m, residence time 334 days (Henry et al., 2006) and significant level oscillation of 2.2 m along the year.

$$TSI (CHL) = 9.81*\ln(CHL)+30.60 \qquad (1)$$

$$TSI (TP) = 14.42*\ln(TP)+4.15 \qquad (2)$$

$$TSI = (TSI (CHL)+ TSI (TP))/2 \qquad (3)$$

Fig. 2. Cage farm at Chavantes reservoir, Middle Paranapanema River Basin, São Paulo State, Brazil.

Lastly, it was studied Chavantes reservoir, that is also a storage plant in Paranapanema River, operating since 1970 in its middle stretch at 474 m above sea level. This reservoir area is 400 km^2, total volume of 8,800 x 10^6 m^3, maximum depth 80 m, residence time 281 days, mean outflow 322 m^3 s^{-1}, and seasonal water level oscillation is more than 3 m (Nogueira et al., 2006). The three reservoirs are in a region with annual precipitation above 1,500 mm, and with a rainy season from September to February and dry season from March to August. Limnological characterization of the three sites studied are shown in Table 1.

Limnological features of Tietê River basin are quite different from Paranapanema River basin (table 1). Ph values are higher in Tietê, reaching 9.6, while Paranapanema values were close to neutrality. Conductivity was three fold higher in Tietê, and CHL were almost ten fold higher. TP values were slightly higher at Tietê, and TN was two times higher in Nova Avanhandava than in Jurumirim, and five fold higher than Chavantes. OD mean values

Reservoirs	Nova Avanhandava[1]		Jurumirim[2]		Chavantes[3]	
Parameters/Sites	FS	CT	FS	CT	FS	CT
Temperature (°C)	20.3-31.3 (26.3±3.3)	20.0-31.2 (26.2±3.5)	18.9-27.4 (23.6±3.0)	18.4-28.2 (23.2±3.0)	19.3-27.4 (23.4±2.5)	19.6-28.7 (23.8±2.5)
pH	5.8-8.9 (8.0±0.7)	7.2-9.6 (8.2±0.8)	6.0-8.3 (6.8±0.6)	6.0-8.2 (6.7±0.8)	6.0-7.6 (7.0±0.4)	6.6-7.8 (7.1±0.3)
Dissolved Oxygen (mg/L)	6.4-9.9 (8.5±1.1)	7.0-10.0 (8.7±1.0))	6.5-8.9 (8.0±0.8)	6.8-9.0 (8.0±0.7)	6.5-11.4 (8.1±1.3)	2.2-11.5 (8.2±1.7)
Conductivity (µS/cm)	143.7-208.0 (184.8±18.5)	148.0-207.0 (183.9±19.0)	50.0-83.0 (59.3±9.4)	50.0-86.0 (59.8±9.1)	36.8-60.0 (40.5±6.0)	36.0-60.0 (40.3±6.2)
Secchi depth (m)	0.7-2.7 (1.4±0.6)	0.8-2.5 (1.3±0.5)	0.6-1.5 (0.9±0.2)	0.4-1.5 (1.0±0.3)	1.5-5.0 (3.1±0.7)	1.5-5.0 (3.1±0.8)
Chlorophyll a (µg/L)	2.2-30.5 (17.7±9.3)	5.1-30.1 (18.0±8.7)	0.5-8.0 (3.3±2.8)	0.9-3.8 (2.4±0.8)	0.9-2.3 (1.5±0.5)	0.7-5.4 (1.9±1.3)
Total dissolved solids (mg/L)	0.0-11.1 (3.8±2.8)	0.5-4.0 (2.7±1.1)	0.1-5.0 (2.0±1.5)	0.1-4.4 (1.3±1.4)	-	-
Total P (µg/L)	7.7-23.7 (14.1±3,7)	5.9-21.3 (12.7±4.3)	3.4-9.8 (7.0±2.0)	4.9-15.0 (8.2±3.6)	4.9-23.5 (11.1±5.2)	3.1-23.1 (9.7±4.1)
Total N (µg/L)	763.7-1950.2 (1282.6± 283.9)	871.0-1973.4 (1213.2± 342.5)	600.0-825.0 (669.4±72.0)	520.0-780.0 (621.3±83.5)	108.2-404.6 (244.9±74.0)	120.0-376.9 (236.0±78.7)

Table 1. Limnological characterization of surface waters of the three reservoirs studied in the Paranapanema and Tietê Rivers, Upper Paraná Watershed. Modified from [1]Paes (2006), [2]Zanatta (2007) and [3]David et al. (2011).

were above 6 mg/L in all sites, considered adequate for tilapia culture, and average Z_{DS} reached 3.1 m at Chavantes, while in the other sites were about 1 m. A concerning issue about the improvement of cage aquaculture in Upper and Middle Paranapanema reservoirs is that winter temperatures were far below 23°C (fig. 3) and in a less degree for Nova Avanhandava, assumed as a lower limit for efficient tilapia grow-out commercial systems (Shelton & Popma, 2006; Suresh, 2002). This fact can hinder aquaculture sustainability and profitability in this watershed, and suitable native species would be desirable. Paes (2006) studied a medium-sized farm, with 80 fish cages of six m³ volume, in Nova Avanhandava reservoir and concluded that the limnological variables measured showed no statistically significant differences between FS and CT (Table 1). Some of the variables were considered high, especially electrical conductivity and total nitrogen, indicating risks of water quality deterioration, a typical feature of Tietê River Watershed (Barbosa et al., 1999). The Trophic state index (TSI) was mesotrophic for both areas (fig. 4A). These conditions can be seriously aggravated by nutrient loads from cage farming activities, which can induce autopollution and loss of water quality for aquaculture purposes. Alves & Baccarin (2006) found similar values for these limnological variables, in a cage farm that uses more than 2 tons of feed per day to produce 1,500 to 1,800 kg of fish per cage per cycle. Water quality depletion is object of concerns in this basin because of widespread blooms of cyanobacteria (Fracácio et al., 2002, Tundisi, 2005). In Jurumirim reservoir, Zanatta (2007) studied a small farm with only 30 cages of six m³ volume, and no significant differences between FS and CT was found for all limnological parameters measured. The very limited scale of farming operations probably prevented impacts on water quality in this large reservoir. Thus, only natural
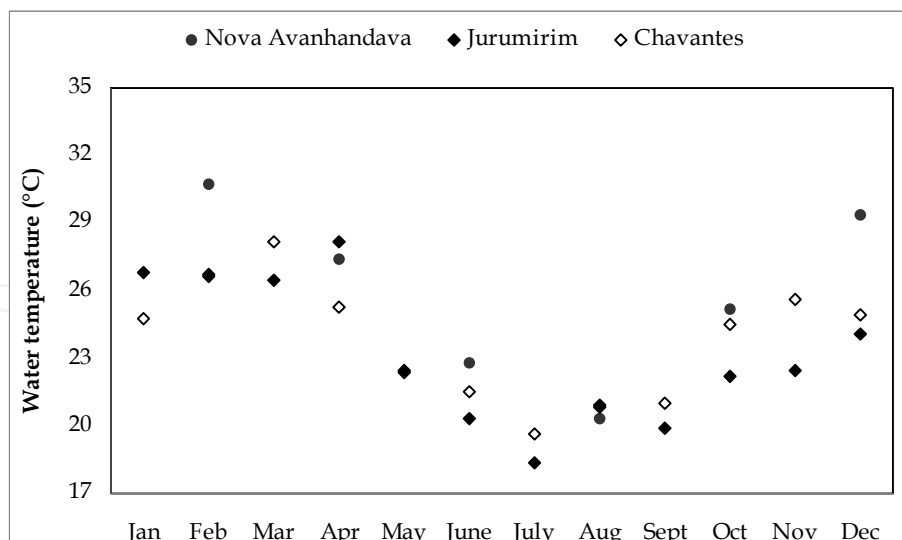
Fig. 3. Seasonal variation of water surface temperature in the studied sites.

and seasonal differences were reported. Jurumirim reservoir was oligotrophic in both areas throughout the year, except for FS (mesotrophic in August), (fig. 4B).

David et al. (2011) using data from a cage farm in Chavantes reservoir with 200 cages, found significant seasonal variation for all limnological parameters measured, but no significant differences among areas at monthly scale. In this same study, comparison of mean values (pooled data per year) of phosphorus in the water between FS and CT indicates that fish farming may be related to hipernutrification of FS in the euphotic layer ($\Delta TP=1.65mg/m^3$, $p<0.05$), although no significant increase in chlorophyll *a* was detected. However, in the euphotic layer other limnological variables measured showed no significant differences between areas, even though depletion of dissolved oxygen in the bottom layer in FS was verified. Most of the year, oligotrophic conditions were also found in Chavantes, but switched to mesotrophic in January for CT, and in December/January for FS (fig. 4C). Simulations on the carrying capacity, due to availability of more detailed data on hydrodynamics and field farming practices in Chavantes reservoir, was also performed by 18 David et al. (2011). Data used for carrying capacity modelling were: Feed Conversion Rate (FCR): 1.5; feed total phosphorus content: 1.5%; whole fish phosphorus content: 0.9% (Dantas & Athayde, 2007), resulting on of 13.5 kg P/ton of fish produced. It is worth emphasizing that phosphorus loads can be greatly influenced by FCR (fig. 5), which itself is related to the welfare of fish and their physiological condition. In addition to unprofitability, the cultivation of tilapia at temperatures below the optimal nutrient emissions increases, which brings higher risks of eutrophication. Hydrological data of FS used in modelling were: original total phosphorus water content of 10.85 mg/m^3, maximum allowable TP water content of 30.0 mg/m^3, and sedimentation rate of 0.083 (Larsen & Mercier, 1976). Retention time used was 1 day for precautionary purposes, according to estimates of Persson et al. (1994) and direct ADCP measurements was less than 1 day, with measured water current velocity from 0.1 to 0.3 m/s.

Maximum allowable fish production in the area was estimated to be 1666 tons/year, while the theoretical fish production that would result on the observed increase of TP was 144 tons/year while total tilapia production of approximately 55 tons/year. These results
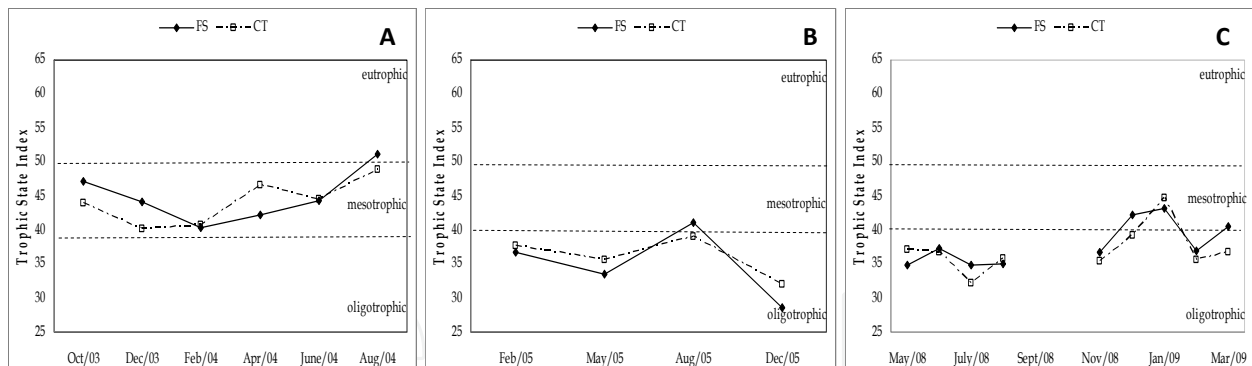
Fig. 4. Seasonal variation of Trophic State Index (TSI) for FS and CT for Nova Avanhandava (A), Jurumirim (B) and Chavantes (C) reservoirs.
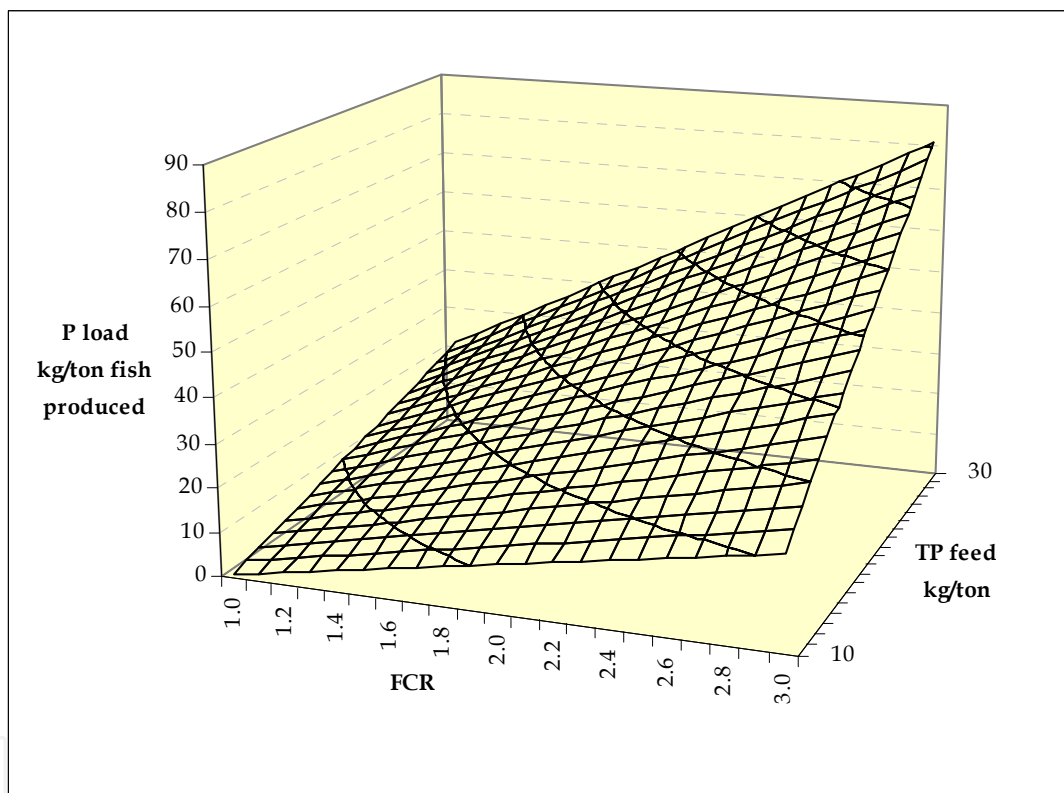

Fig. 5. Effect of FCR and feed composition on Phosphorus loads by fish cage culture

indicate that fish production at FS is compatible with the local carrying capacity for the assimilation and recycling of nutrients derived from aquaculture.

Regarding water quality, conditions may be considered adequate, with no signals of surpassing eutrophication thresholds. Dillon & Rigler mass balance model overestimated the fish production needed to cause the observed FS increase, indicating that specific models are needed for the management of aquaculture in the ecosystems studied here.

2.2 Main fish parasites in cage farms

The interest in fish parasites has increased in recent decades due to economic implications, particularly for intensive fish farms. The high rates of parasitic infestations or infections can

cause considerable mortality in several species of farmed fish and its treatment in some cases is very difficult, while in others, there are no currently effective treatments. The economic losses caused by parasites can often be verified in an indirect way, either by reducing the rates of assimilation and growth of infected animals, or by decreasing the value of marketable final product (Eiras, 1993). Many organisms have been associated with fish diseases. Although parasites can occur in natural environments, these organisms become more abundant in conditions of intensive cultivation and depending on the conditions of culture, they can have a deleterious effect to fishes. In eutrophic environments this situation could worsen due to the presence of many intermediate host species, favouring the life cycle of many parasites (Pillay, 2004). Our studies performed with *O. niloticus* in cage farms have shown that the main parasites affecting fish health in intensive cage systems are monogenoids, *Trichodina* spp., *Ichthyophthirius multifiliis* and *Henneguya* sp. Monogeneans (fig. 6A) are ectoparasites responsible for the most important parasitic disease of fish farming in Brazil (Martins, 1998). They are characterized by the presence of a fixation structure generally located in the back of the body, called haptor, which contain hooks, bars and anchors, in different numbers and sizes according to the species and its function is the fixation of parasite in the hosts (Gerasev, 1990). The adult parasites are elongated, oval or round and measure one to 75 millimeters. The most important monogeneans in fish farms belong to the families Gyrodactylidae and Dactylogyridae. Gyrodactilids are viviparous species and they are mostly parasites of the body surface of fish. Dactylogirids are oviparous and are found in the gills, but can also become placed in the nasal cavities and, more rarely, other parts of the body (Kubtiza & Kubtiza, 1999). The studies performed with *O. niloticus* from fish farms from Chavantes reservoir showed that the dactylogyrids *Cichlidogyrus halli* (fig. 6B-C) and *Scutogyrus longicornis* were the most abundant monogeneans found in the gills of this fish species. Dactylogyrid monogeneans are hermaphrodites and have direct life cycle, which facilitates the parasitic re-infestation. Generally in monogeneans the eggs (dactylogyrids) or larvae (gyrodactylids) leave the uterus by the genital pore, attach to the host and develops in the same host (Cheng, 1986). According to Eiras (1993), pathogenesis caused by monogeneans varies with the species and the fixation site. Monogeneans which parasitize the gills frequently cause cell hyperplasia and mucus hypersecretion. The lesions are much more serious as the parasites are most abundant, which can reach high densities. When attached to the tegument, necrosis of cells, destruction of scales and mucus hypersecretion can be observed. In cases of high intensity of infection, monogeneans can cause mortalities especially in small fish (Noga, 1996), which has been recorded for numerous fish species (Cone et al., 1983; Ergens, 1983; Lester & Adams, 1974; Mackenzie, 1970). Considering the seriousness of this disease and also the difficulty of eradicating this disease in fish after installed, it is suggested that all new fish bought undergo to quarantine and prophylactic baths using commercial formalin diluted 1:4,000 for an hour or sodium chloride in 1 to 3% from 30 minutes to 3 hours (Pavanelli et al., 1999). Another important group of organisms that can affect fish health, especially those in breeding system, includes the protozoans of the phylum Ciliophora, highlighting, *Trichodina* spp. (fig. 6D) and *I. multifiliis* (fig. 6E). Apparently, these ciliates live as ectocomensal in the tegument and gills of the fish without causing major damage, except in cases of heavy infestations, which is particularly evident in species that multiply rapidly by successive binary divisions, especially in environments with excess of organic material and low amounts of dissolved oxygen in water (Eiras, 1993). The rearing of *O. niloticus* in cage farms in Chavantes reservoir have high infection rates by *Trichodina* spp. (fig. 6D), in some cases and periods,

the prevalence is 100%. Trichodinids are ciliated protozoa commonly found in both freshwater and saltwater, and show no host specificity, which favors their widespread distribution. Their morphology is characteristic, with a circular shape and the presence of an adhesive disc with a series of denticles that help fix the parasites in the host. They are usually considered ectoparasites of skin and gills of the host and can rapidly proliferate in the presence of decaying material (Heckmann, 1996). The life cycle of *Trichodina* spp. occurs by binary fission, in which the parasite divides and fixes in the host's skin (Cheng, 1986). Its pathogenesis is related to the rotatory movements of these ciliates on the gills and tegument of the host, leading to an abrasive action of the skeletal structures and denticles present in the adhesive disk, which damage the epithelial cells. Trichodinidiasis signs include loss of appetite, lethargy, excessive mucus production in the gill epithelium and skin, erythema, and sometimes bleeding skin (Heckmann, 1996). This is more evident in cases of intense parasitism, which is observed when environmental conditions favour the reproduction of the parasite and weakens the host, which happens when there is a decline in water quality. These parasites are easily transmitted through infected fish, water, plants or utensils used on fish farms. The treatment can be accomplished by bath with malachite green 2-3 g/10 m³, when the fish are not used for consumption, or a bath for two hours in commercial formalin 1:4.000-6.000 (Pavanelli et al., 1999). *Ichthyophthirius multifiliis* (fig. 6E) however, has not been frequently found in *O. niloticus* from Chavantes reservoir. It causes a disease commonly known as freshwater white spot disease. This protozoa is a ciliate parasite, ovoid, measuring 100-1000 μm, the cytoplasm is granular and contains numerous vacuoles and contractile structures. These protozoans are characterized by the presence of a horseshoe-shaped macronucleus and a micronucleus barely visible (Cheng, 1986). Although often cited as ectoparasites, it is located under the epidermis, presenting the appearance of small white spots on skin and gills of fish (Eiras, 1993). The life cycle of *I. multifiliis* is completed in 3-4 days at 25.5 °C, but can also occur in up to 5 weeks at 18 °C and in lower temperatures the parasite will remain dormant. The adult parasite called trophont reach the maturity, leaves the host as tomont forms and fixes in the substrate of fish cage forming a cyst. Inside it, multiple cell divisions form many tomites which are the infective forms to new fishes when the cyst breaks (Ewing & Kocani, 1987). Probably this protozoan is responsible for major economic losses in fish farms in the world. Young fish are usually more susceptible, and high infestations are usually associated with sudden drops in temperature in the water fish farm (Eiras, 1993). In Brazil, *I. multifiliis* was already reported infecting *Colossoma macropomum*; *Prochilodus cearensis*, *Cichla ocellaris*, *Piaractus mesopotamicus*; *Leporinus macrocephalus*; tambacu hybrid (*P. mesopotamicus* x *C. macropomum*); *Tilapia rendalli*; *O.niloticus* and *Cyprinus carpio* (Békési, 2002; Tavares-Dias et al., 2001).

The most appropriate way to avoid freshwater white spot disease is maintaining good water quality, adequate food, and avoiding stress, caused mainly by changes in temperature. In this case, fish are more sensitive to attack by parasites. It should be considered that freshwater white spot disease is difficult to treat, especially in large cages. Treatment should be done in special cages for therapeutic baths. One product that can be used is sodium chloride 0.3%, where the fish stay sunk for about 24 hours. More concentrated doses, 5% for example, may be used in severe cases, with the fish remaining in the solution for 30 minutes (Pavanelli et al., 1999). Myxozoa includes parasites frequently found in marine fish and freshwater. Currently the phylum Myxozoa includes the classes Myxosporea and Malacosporea, and almost all fish parasites belong to Myxosporea (Eiras et al., 2006). The life
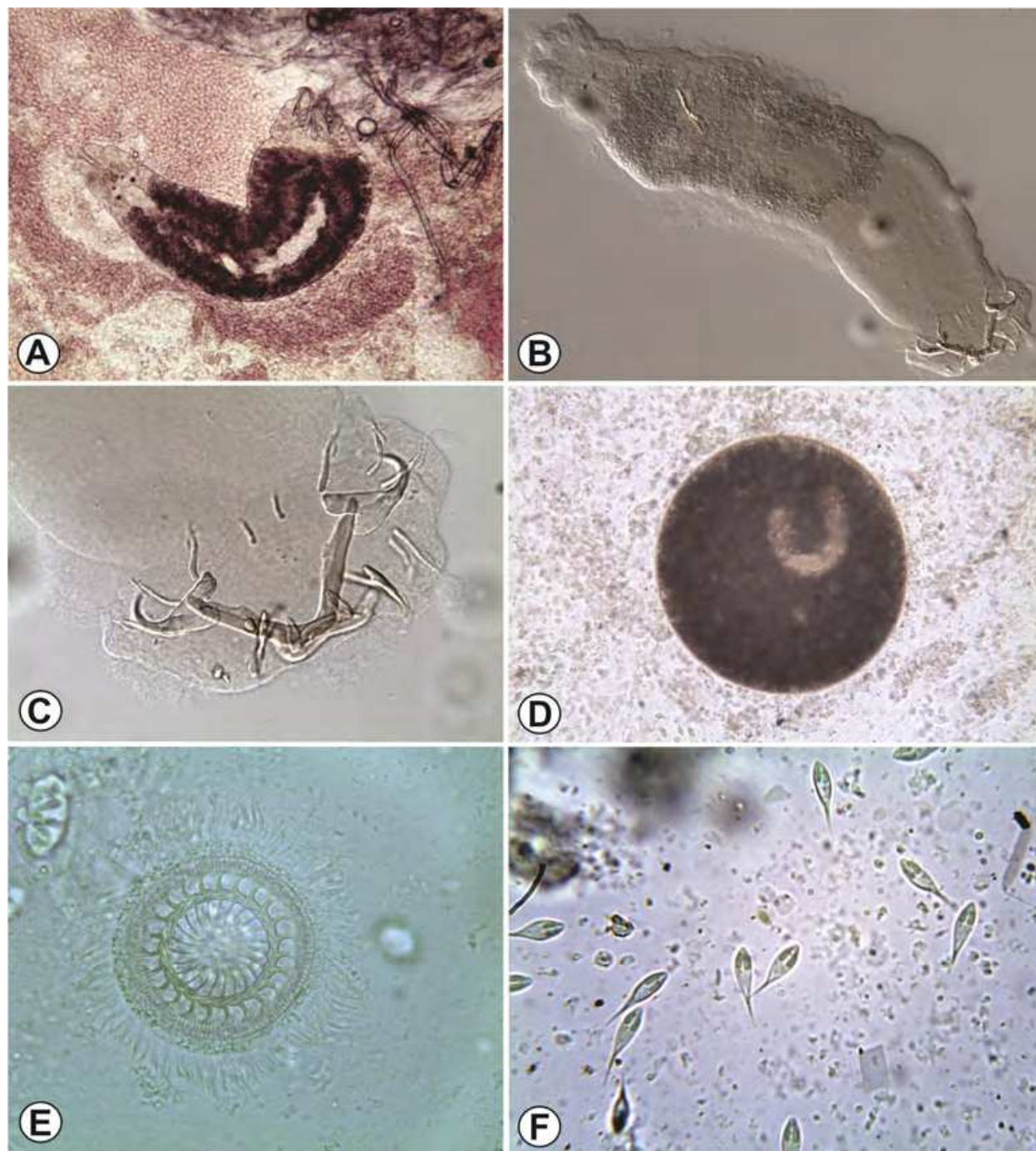
Fig. 6. A) Monogenoid in the gill of *Oreochromis niloticus* (10x); B) *Cichlidogyrus halli*
specimen (10x); C) detail of the haptor and sclerotized structures of *Cichlidogyrus halli* (40x);
D) *Ichthyophthirius multifiliis* specimen (40x); E) *Trichodina* sp. specimen (40x); F) *Henneguya*
sp. spores in fish tegument (100x).

cycle of mixosporeans occurs in two hosts: a vertebrate (fish) and invertebrates (oligochaete).
The spore is released when infected fish dies and decomposes, or through contaminated
faeces of a predator fish that have eaten infected fish. The oligochaetes are infected when they
ingest the sporoplasms that fix to the intestinal wall using polar filaments; these proliferate
and remain incubated for 3 months. After this period the Actinospore are released to infect

the fish in the water column and deposit the sporoplasm within the epidermis which will migrate to the organs and gills (Stevens et al., 2001). The main genera of Myxozoa infecting fishes are *Myxobolus* and *Henneguya* (fig. 6F). In Brazil there are only reports on the occurrence of *Henneguya* sp. infecting *O. niloticus* (Ranzani-Paiva et al., 2005). Histopathological analysis of the gills of fish infected *Henneguya* sp. reveal the presence of severe bleeding and inflammatory foci in the gill epithelium, where the cysts are located. Lesions such as compression of capillaries causing edema in superficial lamellae more frequently in primary and secondary lamellae occasionally can be observed. In later stages, cysts dilate the respiratory lamellae decreasing respiratory efficiency of infected fish (Martins et al., 1999). The treatment of this disease has been carried out using 10 ml of formalin/m^3, which has been quite effective (Martins et al., 1999). Other studies have been conducted evaluating the oral administration of chemotherapeutics (quinine, salinomycin) that had significant effect on the treatment of infections in the gills of fish mixosporeans (Dohle et al., 2002). However, studies on the treatment of infections *Henneguya* spp. are still scarce. Our studies with *O. niloticus* in Chavantes reservoir have also demonstrated that the occurrence of parasites in cage farms is associated with environmental variables. Therefore, we have observed a higher prevalence, abundance and intensity of infection of parasites in the summer. No difference was noted in the parasitism levels among different fish tanks, considering the groups established by the zootechnical methods in fish farm. Depending on the parasite species, fish size also influences the parasitism. For example, a negative correlation was observed between monogenoids and fish size and a positive correlation between *Trichodina* sp. and fish size. This is important because demonstrates that some parasites are more important in the initial breeding phase while others are problems in the final stages. In conclusion, we can note that despite the wide distribution and incidence of parasites in fish rearing, there are few studies on the prevalence, pathogenesis, and potential biological cycle of transmission of these parasites in Brazilian cage fish farms. It is important to consider that in cage farming there must be a balance between the health of the host, the proliferation of pathogens and conditions of the aquatic environment. Thus, poor water quality, reduction of dissolved oxygen, changes in temperature, high fish density, inadequate management or unbalanced nutrition are factors able to induce stress to the animals, predisposing them to various types of infections, including parasites. Water offers an extremely favorable environment for the proliferation of these agents and the parasites are responsible for major losses in fish farms worldwide, with more relevance in the neotropics, due to the climatic characteristics of these regions (Martins, 1998; Thatcher, 1994).

2.3 Impacts on the resident ichthyofauna and fish feeding ecology

Brazilian freshwater fish fauna has been managing to adjust to continuous environmental impacts, such as damming and deforestation, due to its great diversity of species, with different tactics of life cycle (Agostinho et al., 2007). Currently, a new expanding form of impact is fish farming in floating cages. However, knowledge of the impacts from this activity on the ichthyofauna is still precarious. This activity provides food resources and shelter to resident fish fauna, attracting a large number of fish (Brandão, 2010; Nobile, 2010; Paes, 2006; Zanatta, 2007, 2011), which is also observed for marine fish farms (Boyra et al., 2004; Machias et al., 2004, 2005, 2006). This attraction is due to availability of food resources, such as feed losses, fish scales, and fish faeces. According to Beveridge (2004) and Pillay (2004), these losses can reach 30% of all feed used in aquaculture enterprises. Thus, the

contribution of allochthonous energy in aquatic ecosystems can cause changes in the food chain, especially upon plankton community, benthic community, and fish fauna, interfering with the dynamics of the aquatic ecosystem. Our studies in the Paraná River basin (Middle Tietê River and Upper/Middle Paranapanema River) reported impacts on the ichthyofauna (Nobile, 2010; Paes, 2006; Zanatta, 2007, 2011) from this activity, such as changes in population structure of fish fauna (Ramos et al., 2008), changes in diet (Brandão, 2010; Ramos et al., 2008, 2009), and changes in bromatological composition of some fish species (Queiroz, 2010). A research made by Paes (2006) in 2003 and 2004 at Nova Avanhandava reservoir, evaluated some impacts of fish farms upon ichthyofauna. While in FS was recorded 18 species, a greater number of fish species (N=20) was recorded in CT. However, a greater number of individuals was captured in FS (n=684) than in CT (n=518). For species, the Shannon-Wiener diversity index H' (Krebs, 1999) showed no significant differences between these two sites (p> 0.05). For Simpson dominance 1/D (Krebs, 1999), similar values were recorded for FS (1/D = 5701) and CT (1/D = 5555). Even though this difference was small, the dominant species in the FS was *Metynnis maculatus*, an omnivorous species with tendency to herbivory, while in CT the dominant species was *Plagioscion squamosissimus*, a strict carnivore species. A study conducted by Ramos et al. (2008) aimed to compare the diet of the species *M. maculatus*, *Astyanax altiparanae* and *P. squamosissimus* between FS and CT. The results show that the omnivorous species *M. maculatus* changed its diet in FS. This species used a new alimentary source with high availability and low energy cost, and its diet consists almost exclusively of feed from fish farming (85%). Such a change in diet led to a change in population structure of this species, showing higher values of weight and length in FS (p <0.05). Similar results were found at Jurumirim by Zanatta (2007). A greater number of species (N=24) was captured in CT than in FS (N=21), and a greater number of individuals were captured in CT (n=1,601) than in FS (n=1,470). There was no significant differences for H ' (p> 0.05) between the two sites, and Pielou evenness E (Krebs, 1999) values were similar for FS (E = 0.73) and CT (E = 0.76). At Chavantes reservoir, Nobile (2010) showed differences only between the abundance of individuals in both sites, recording the 78% of the capture (n=3096) in FS. Furthermore, it was recorded introduction of the non-native fish *Ictalurus punctatus* by aquaculture activities, whose impacts upon native fish fauna of Brazilian reservoirs are still unknown (Zanatta et al., 2010). There was also the capture of *O. niloticus* juveniles, which we believe that they are recruited from reproductive processes occurring in the reservoir rather than escaped, due to its great abundance, and size smaller than juveniles stocked in the cages (fig. 7). If these recruits are born from adult scaped fish from fish farms, than efficiency of the sexual reversion process in use is not enough to avoid breeding in this aquatic ecosystem, which may lead to disruptions of ecological interactions with native fish assemblages. In Chavantes reservoir, Brandão (2010) and Ramos (2009) observed that the most abundant species showed differences in diet composition between the FS and CT. Remains of feed was major component of the diet of *Pimelodus maculatus* (98%) and *A. altiparanae* (99%) in FS. For CT, the diet of *P. maculatus* was composed of detritus (27%), aquatic insects (22%), vegetables (21%) and molluscs (21%); and *A. altiparanae* by terrestrial insects (61%) and vegetables (30%). Another species analyzed was *Apareiodon affinis*, which diet was composed of detritus (80%) and feed remains (20%) in FS, and only by detritus in CT. Moreover, two carnivorous species were analyzed (*Galeocharax knerii* and *P. squamosissimus*), and there was no differences in their diet between the sites studied. Comparative analysis of weight and length show that omnivorous species grows faster at FS due to use of remains of feed as main food source. In addition,

Fig. 7. *Oreochromis niloticus* juveniles captured around FS at Chavantes reservoir.

Queiroz (2010) observed change in bromatological composition of muscle tissue of *P. maculatus*.

Significant differences for total lipids and gross protein were observed between fish caught around FS and CT (p <0.05). It is evident that this type of fish farm attracts native ichthyofauna in these reservoirs. Attractiveness is directly related to availability of food resources, especially remains of feed. These are similar to the findings for marine aquaculture in coastal ecosystems, which also found the effect of attractiveness of these systems (Boyra et al., 2004; Dempster et al., 2002; Håkanson, 2005). The results presented allow the conclusion that remains of feed are used by omnivorous species with large feeding plasticity, which certainly justifies its dominance in sites used for cage aquaculture. Furthermore, the changes in the diet of these species have direct effects on their population structure, and the effects upon fish fauna still need to be clarified. Håkanson (2005) and Ramos et al. (2008) report that such changes in the diet of abundant species in aquatic ecosystems may affect the food chain in long term, and the effects upon ichthyofauna are still unknown. We conclude that where fish farms in cages are deployed, there is a change upon the population structure of fish communities, due to attractiveness and changes in the diet of omnivorous species in nearby sites, which may interfere in the local ecological dynamics, especially in the food web, altering ecological relationships between the components of local biota.

3. Conclusion

The results showed that cage aquaculture fish production in oligotrophic ecosystems, as Jurumirim and Chavantes reservoirs (Paranapanema River) is compatible with environmental carrying capacity, and wild fishes play a relevant role recycling nutrients derived from aquaculture. The main constraint to cultivation of tilapia in these reservoirs is the low temperatures during the winter months, with recent records of mass mortality of fish due to parasite infestation in this season. These aquaculture enterprises are an important source of dispersion of non-native fish species, as *O. niloticus* and *I. punctatus*. In Tietê river (Nova Avanhandava reservoir), the situation is more complex because of low

water quality due to high nutrient loadings of sewage and agriculture runoff, related to the presence of cyanobacteria blooms, causing severe consequences for the environmental and economic sustainability of aquaculture. After some years operating cage farms in middle and lower Tietê River, events of fish mass mortality associated with eutrophication motivated fish farmers to move to sites with better water quality. It is also pertinent to note that fish farming in cages still need the development of scientific and technological knowledge, which besides basic technical support, could also allow the improvement of this activity. The lack of expertise and the inappropriate implementation of best management practices can lead to failure of these enterprises, making them economically unviable in the short and medium term. Measures for the effective planning for farming public waters require further discussion and guidance at governmental levels, in order to reach a truly sustainable aquaculture, in all its socioeconomic and environmental interfaces.

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5. References

Agência Nacional de Energia Elétrica - Aneel. 2009. Banco de Informações de geração. In: *ANEEL, Brasília, DF, Brasil*. Available from (http://www.aneel.gov.br)

Agostinho, A.A.; Gomes, L.C. & Pelicice, F.M. (2007). *Ecologia e Manejo de Recursos Pesqueiros em Reservatórios do Brasil*, EDUEM, ISBN 978-857-6280-95-8, Maringá, Brazil

Alves, R.C.P. & Baccarin, A.E. (2005). Efeito da produção de peixes em tanques-rede sobre a sedimentação de material em suspensão e de nutrientes no córrego da Arribada (UHE Nova Avanhandava, baixo rio Tietê, SP), In: *Ecologia de reservatórios: impactos potenciais, ações de manejo e sistemas em cascata*, Nogueira, M.G.; Henry, R. & Jorcin, A. (Eds.), 329-347, RiMa, ISBN 85-7656-092-5, São Carlos, Brasil

Ayrosa, D.M.M.R.; Furlaneto, F.P.B. & Ayrosa, L.M.S. (2006). Regularização dos projetos de tanques-rede em águas públicas continentais de domínio da União no Estado de São Paulo. *Boletim técnico do Instituto de Pesca*, No.36, (December 2006), pp.1-32, ISSN 0103-1767

Barbosa, F.A.R.; Padisák, J.; Espíndola, E.L.G.; Borics, G. & Rocha, O. (1999). *The cascading reservoir continuum concept and its application to the river Tietê-Basin, São Paulo State, Brazil*, In: *Theoretical reservoirs ecology and its applications*, J.G. Tundisi & M. Straskraba (Eds.), 425-437, International Institute of Ecology, ISBN 8587418025, São Carlos, Brazil

Békési, L.; Székel, C. & Molnár, K. (2002). Atuais Conhecimentos Sobre Myxosporea (Myxozoa), Parasitas de Peixes. Um Estágio Alternativo dos Parasitas no Brasil. *Brazilian Journal of Veterinary Research and Animal Science*, Vol.39, No.5, (July 2002), pp. 271-276, ISSN 1413-9596

Beveridge, M.C.M. (1984). *Cage and pen fish farming: carrying capacity models and environmental impact*, FAO, ISBN 92-5-102163-5, Rome, Italy

Beveridge, M.C.M. (1996). *Cage Aquaculture* (2ª edition), Fishing News Book, ISBN 0-85238-235-9, Oxford, United Kingdon

Beveridge, M.C.M. (2004). *Cage Aquaculture* (3ª edition), Blackwell Publishing, ISBN 978-140-5108-42-3, Oxford, United Kingdon

Boyra, A.; Sanchez-Jerez, P.; Tuya, F.; Espino, F. & Haroun, R. (2004). Attraction of Wild Coastal Fishes to an Atlantic Subtropical Cage Fish Farms, Gran Canária, Canary Islands. *Environmental Biology of Fishes*, Vol.70, (November 2003), pp. 393-401, ISSN 1573-5133

Brandão, H. (2010). Biologia Populacional com Ênfase na Dieta das Principais Espécies de Peixes Agregados a um Sistema de Piscicultura em Tanques-Rede na Pepresa de Chavantes (Médio Rio Paranapanema, SP/PR). In: *Pesquisas de teses e dissertações - Instituto de Biociências, Universidade Estadual Paulista, Botucatu*. Available from (http://www.ibb.unesp.br/posgrad/teses/zoologia_do_2010_heleno_brandao.pdf)

Brandão, H.; Vidotto-Magnoni, A.P.; Ramos, I.P. & Carvalho, E. D. (2009). Assessment of the ichthyofauna in stretches under the influence of Salto Grande Reservoir (Middle Paranapanema River, SP/PR, Brazil). *Acta Limnologica Brasiliensia*, Vol.21, No.4, (Novembro 2009), pp. 451-463, ISSN 0102-6712

Carlson, R.E. (1977). A Trophic State Index for Lakes. *Limnology and Oceanography*, Vol.22, No.2, (March 1977), pp. 361-369.

Castagnolli, N. (2000). Piscicultura intensiva e sustentável, In: *Aqüicultura no Brasil:* bases para um desenvolvimento sustentável, W.C. Valenti, (Ed.), 181-195, CNPq/Ministério da Ciência e Tecnologia, ISBN 85-87632-09-4, Brasília, Brasil

Cheng, T.C. (1986). *General Parasitology* (2ª edition), Academic Press, ISBN 978-012-1707-55-2, Orlando, United States

Cone, D.K.; Beverly-Burton, M.; Wiles, M. & MC Donald,T.E. (1983). The Taxonomy of *Gyrodactylus* (Monogenea) Parasitizing Certain Salmonid Fishes of North America, with Description of *G. nerkae* n. sp. *Canadian Journal of Zoology*, Vol.61, No.11, (January 1983), pp. 2587-2597, ISSN 1480-3283

Costa-Pierce, B.A. (2002). Sustainability of cage culture ecosystems for large scale resettlement from hydropower dams: an Indonesian case study, In: *Ecological aquaculture*: the evolution of the blue revolution, B.A. Costa-Pierce (Ed.), 286-313, Blackwell Science, ISBN 0632049618, Oxford, United Kingdon

Dantas, M.C. & Attayde, J.L. (2007). Nitrogen and phosphorus content of some temperate and tropical freshwater fish. *Journal of Fish Biology*, Vol.70, No.1, (January 2007), pp. 100–108, ISSN 0022-1112

David, G.S.; Carvalho, E.D.; Novaes, J.L.C.; Biondi, G.F. (2006). A tilápia do Tietê: desafios e contradições da pesca artesanal de tilápias nos reservatórios hipereutróficos do Médio Rio Tietê. *Panorama da Aqüicultura*, Vol.16, No.5, (September/October 2006), ISSN 1519-1141

David, G.S.; Carvalho, E.D.; Ramos, I.P.; Silva, R.J.; Ayroza, D.M.M.R.; Ayroza, L.M.S. & Lemos, D. (2011). Evaluation of mass balance models to predict impact of cage fish farming in large freshwater reservoirs, In: *Proceedings World Aquaculture WA 2011* (Conference Aquaculture for a changing World), pp. 322, abstracts, Natal, Brazil, June 2011

Dempster, T.; Sanchez-Jerez, P.; Bayle-Sempere, J.T.; Giménez-Casalduero, F. & Valle, C. (2002). Attraction of Wild Fish to Sea-Cage Fish Farms in the South-Western Mediterranean Sea: Spatial and Short-Term Temporal Variability. *Marine Ecology Progress Series*, Vol.242, (October 2002), pp. 237-252, ISSN 0171-8630

Dillon, P.J. & Rigler, F.H. (1975). A simple method for predicting the carrying capacity of lake for development, based on lake trophic status. *Jounal of Fisheries Research Board of Canada*, Vol.32, No.9, pp. 1519-1531, doi: 10.1139/f75-178

Dohle, A.; Schmahl, G.; Raether, W.; Schmidt, H. & Ritter, G. (2002). Effects of Orally Administered Chemotherapeutics (Quinine, Aalinomycin) Against *Henneguya* sp. Thelohán,1892 (Myxozoa: Myxobolidae), a Gill Parasite in the Tapir Fish *Gnasthonemus peterssii* Günther,1862 (Teleostei). *Parasitology Research*, Vol.88, No.9, (June 2002), pp. 861-867, ISSN 1432-1955

Eiras, J.C. (1993). *Elementos de Ictioparasitologia*. Fundação Engenheiro Antônio de Almeida, ISBN 972-9194-76-9, Porto, Portugal

Eiras, J.C.; Takemoto, R.M. & Pavanelli, G.C. (2006). *Métodos de estudo e técnicas laboratoriais em parasitologia de peixes*, EDUEM, ISBN 85-7628-032-9 Maringá, Brazil

Ergens, R. (1983). *Gyrodactylus* from Eurasian Freshwater Salmonidae and Thymallidae. *Folia Parasitologica*, Vol.30, No.1, (January 1983), pp. 15-26, ISSN 1803-6465

Ewing, M.S. & Kocan, K.M. (1987). *Ichthyophthirius multifilis* (Ciliophora) Exit from Gill Epithelium. *The Journal of Protozoology*, Vol.34, No.3, (August 1987), pp. 309-312, ISSN 0022-3921

Fitzsimmons, K. (2006). Prospect and potential for Global production, In: *Tilapia*: biology, culture and nutrition, C.E. Lim & C.D. Webster (Eds.), 51-72, Haworth Press, ISBN 9781560223184, New York, United State

Food And Agriculture Organization Of The United Nations - FAO. (2010). The State Of World Fisheries And Aquaculture, *FAO*, ISSN 1020-5489, Rome

Fracácio, R., Espíndola, E.L.G.; Rodgher, S.; Pereira, R.H.G.; Rocha, O. & Verani, N.F. (2002). Limnologia dos reservatórios em cascata do médio e baixo rio Tietê: uma análise espacial e temporal, In: *Recursos Hidroenergéticos*: usos, impactos e planejamento integrado, E.L.G. Espíndola; F.F. Mauad; V. Schalch; O. Rocha; N. Felicidade & A.C. Rietzler, 145-163, RiMa, ISBN 8586552259, São Carlos, Brazil

Furlaneto, F.P.B.; Ayrosa, D.M.M.R. & Ayroza, L.M.S. (2006). Custo e rentabilidade da produção de tilápia (*Oreochromis* spp.) em tanque-rede no médio Paranapanema, Estado de São Paulo, safra 2004/05. *Informações Econômicas*, Vol.36, No.3, (March 2006) pp. 63-69, ISSN 0100-4909

Gerasev, P.I. (1990). Principles for Revision of the Genus *Dactylogyrus* (Monogenea). *Journal of Ichthyology*, Vol.30, No.5, (January 1990), pp. 110-119, ISSN 0032-9452

Godinho, H.P. (2007). Estratégias reprodutivas de peixes aplicadas à aqüicultura: bases para o desenvolvimento de tecnologias de produção. *Revista Brasileira de Reprodução Animal*, Vol.31, No.3, (July 2007), pp. 351-360. (http://www.cbra.org.br).

Golterman, H.L.; Clymo, R.S. & Ohnstad, M.A.M. (1978). *Methods for physical and chemical analysis of freshwater*, Blackwell (IBP Handbook, 8), ISBN 0632994592, 9780632994595, Oxford, United Kingdon

Håkanson, L. (2005). Changes to Lake Ecosystem Structure Resulting from Fish Cage Farm Emissions. *Lakes & Reservoirs: Research and Management*, Vol.10, (February 2005), pp. 71-80, ISSN 1440-1770

Heckmann, R. (1996). Protozoan Parasites of Fish, Part II. *Aquaculture Magazine*, Vol. 21, pp. 56-59, ISSN 0199-1388.

Henry, R.; Nogueira, M.G.; Pompeo, M.L.M. & Moschini-Carlos, V. (2006). Annual and short-term variability in primary productivity by phytoplankton and correlated abiotic factors in the Jurumirim reservoir (São Paulo, Brazil). *Brazilian Journal of Biology*, Vol.66, No.1B, (February 2006), pp. 239-261, ISSN 1519-6984

Karakassis, I.; Manolis, T.; Christopher, J. S.; & Heye, R. (2002). Fish farming impacts in the Mediterranean studied through sediment profiling imagery. *Marine Ecology*, Vol.27, No.4, (December 2006), pp. 310-319, ISSN 0173-9565

Karakassis, I.; Pitta, P. & Krom, M.D. (2005). Contribution of fish farming to nutrient loading of the Mediterranean. *Scientia Marina*, Vol.69, No.2, (November 2004), pp. 313-321, ISSN 0214-8358

Karakassis, I.; Tsapakis, M.; Hatzyanni, E.; Papadopoulou, K.N. & Plaiti, W. (2000). Impact of cage farming of fish on the seabed in three Mediterranean coastal áreas. *ICES J. Marine Science*, Vol.57, No.5, (October 2000), pp. 1462-1471, ISSN 1095-9289

Krebs, C.J. (1999). *Ecological methodology*. Benjamim/Cummings, Menlo Park, CA, United States, ISBN 0-321-02173-8

Kubitza, F.; Kubitza, L.M.M. (1999). *Principais Parasitoses e Doenças dos Peixes Cultivados* (3ª edition), F. Kubitza (1999), ISBN 85-98545-03-1 , Jundiaí, Brazil

Larsen, D.P. & Mercier, H.T. (1976). Phosphorus retention capacity of lakes. *Journal Fisheries Research Board of Canada*, Vol.33, No.8, pp. 1742-1750, doi: 10.1139/f76-221

Latini, A.O. & Petrere-Junior, M. (2004). Reduction of Native Fish Fauna by Alien Species: an Example from Brazilian Freshwater Tropical Lakes. *Fisheries Management and Ecology*, (April 2004), Vol.11, pp. 71-79, ISSN 1365-2400

Lester, R.J.G. & Adams, J.R. (1974). *Gyrodactylus alexanderi*: Reproduction, Mortality and Effect on it´s Host *Gasterosteus aculeatus*. *Canadian Journal of Zoology*, Vol.52, No.7, (July 1974), pp. 827-833, ISSN 1480-3283

Lin, S.D. (2001). *Water and wastewater calculations manual*, McGraw-Hill Professional, ISBN 0-07-137195-8, New York, United States

Lovshin, L.L. (1982). Tilapia Hybridization, In: *The Biology and Culture of Tilapias*, R.S.V. Pullin & R.H. Lowe-McConnel (Eds.), pp. 279-308, WorldFish Center/International Center for Living Aquatics resources Management , ISBN 9710400045/ 0009799710400041, Manila, Phillipines

Machias, A.; Giannoulaki, M.; Somarakis, S.; Maravelias, C.D.; Nofitou, C.; Koutsoubas, D.; Papadopoulou, K.N. & Karakassis, I. (2006). Fish Farming Effects on Local Fisheries Landings in Oligotrophic Seas. *Aquaculture*, (July 2006), Vol.261, pp .809-816, ISSN 0044-8486

Machias, A.; Karakassis, I.; Labropoulou, M.; Somarakis, S.; Papadopoulou, K.N. & Papaconstantinou, C. (2004). Changes in Wild Fish Assemblages After the Establishment of a Fish Farming Zone in an Oligotrophic Marine Ecosystem. *Estuarine, Coastal and Shelf Science*, Vol.60, (March 2004), pp. 771-779, ISSN 0272-7714

Machias, A.; Karakassis, I.; Somarakis, S.; Giannoulaki, M.; Papadopoulou, K.N. & Smith, C. (2005). The Response of Demersal Fish Communities to the Presence of Fish Farms. *Marine Ecology Progress Series,* Vol.288, (March 2005), pp. 241-250, ISSN 0171-8630

Mackenzie, K. (1970). *Gyrodactylus unicopola* Gluxhova, 1955, from Yong Plaice *Pleurinectes platessa* L., with Notes on the Ecology of the Parasite. *Journal Fish Biology*, Vol.2, No.1, (January 1970), pp. 23-34, ISSN 1095-8649

Martins, M.L. (1998). *Doenças Infecciosas e Parasitárias de Peixes* (2ª edition), Funep, Jaboticabal, Brazil

Martins, M.L.; Souza, V.N.; Moraes, J.R.E. & Moraes, F.R. (1999). Gill Infection of *Leporinus macrocephalus* Garavello & Britski, 1988 (Osteichthyes: Anostomidae) by *Henneguya leporinicola* n. sp. (Myxozoa: Myxobolidae). Description, Histopathology and Treatment. *Revista Brasileira de Biologia*, Vol.59, No.3, (August 1999), pp. 527-534, ISSN 034-7108

Medeiros, F.C. (2002). *Tanque-rede: mais tecnologia e lucro na piscicultura* (1ª. edition), F.C. Medeiros, Cuiabá, Brazil

Ministério da Pesca e Aquicultura – MPA (2010). Produção Pesqueira e Aquícola: Estatística – 2008 e 2009. In: MPA, Brasília, DF, Brasil. Available from (http://www.mpa.gov.br/mpa/seap/Jonathan/mpa3/dados/2010/Docs/Cadern o%20Consolida%C3%A7%C3%A3o%20dos%20dados%20estatiscos%20final%20cur vas%20-%20completo.pdf)

Ministério de Minas e Energia – MME (2006). Matriz energética brasileira. In: *MME, Brasília, DF, Brasil*. Available from (http:// www.mme.gov.br)

Moretto, E.M.; Marciano, F.T.; Velludo, M.R.; Fenerich-Verani, N.; Espíndola, E.L.G. & Rocha, O. (2008). The recent occurrence, establishment and potential impacto f *Geophagus proximus* (Cichlidae, Perciformes) in the Tietê River reservoirs: an Amazonian fish species introduced in the Paraná Basin (Brazil). Biodiversity Conservations, Vol.17, No.12, (November 2008), pp. 3013-3025, ISSN 0960-3115

Munday, B.W.; A. Eleftheriou, M. Kentouri; & P. Divanach. (1992). The interactions of aquaculture and the environment: a bibliographical review. In: Commission of the European Communities, Directorate General for Fisheries, Brussels

Nobile, A.B. (2010). A Ictiofauna Agregada a um Sistema de Piscicultura em Tanques-Rede na Represa Oligotrófica de Chavantes (Médio Rio Paranapanema, SP/PR): Composição de Espécies e Atributos Ecológicos. In: *Pesquisas de teses e dissertações - Instituto de Biociências, Universidade Estadual Paulista, Botucatu*. Available from (http://www.ibb.unesp.br/posgrad/teses/zoologia_me_2010_andre_nobile.pdf)

Noga, E.J. (1996). *Fish Disease* (1ª edition.), Mosby-Year Book, ISBN 0-8138-2558-X, Iowa University Press, United States

Nogueira, M.G.; Henry, R.; Jorcin, A. (2006). *Ecologia de reservatórios: impactos potenciais, ações de manejo e sistemas em cascata* (2ª. edition), RiMa, ISBN 85-7656-092-5, São Carlos, Brazil

Ono, E.A. (1998). *Cultivos de peixes em tanques-rede*. Fundação Biblioteca Nacional, Rio de Janeiro, Brazil

Orsi, M.L. & Agostinho, A.A. (1999). Introdução de Espécies de Peixes por Escapes Acidentais de Tanque de Cultivo em Rios da Bacia do Rio Paraná, Brasil. *Revista Brasileira de Zoologia*, (March 1999), Vol.6, No.2, pp. 557-560, ISSN 0101-8175

Paes, J.V.K. (2006). A Ictiofauna Associada e as Condições Limnológicas numa Área de Influência da Criação de Tilápias em Tanques-Rede no Reservatório de Nova Avanhandava. In: *Catalogo Athena - Universidade Estadual Paulista*. Available from

(http://www.athena.biblioteca.unesp.br/exlibris/bd/bbo/33004064012P8/2006/p aes_jvk_me_botib.pdf)

Pavanelli, G.C.; Eiras, J.C. & Takemoto, R.M. (1999). Doenças de Peixes: Profilaxia, Diagnóstico e Tratamento. EDUEM, ISBN 978-857-6281-17-7, Maringá, Brazil

Persson, G. (1988). Environmental impact band nutrient emissions from salmonid fish culture. In: French-Swedish Limnological Symposium, Thonon-les-Bains, Francia. Proceedings of French-Swedish Limnological Symposium, Thonon-les-Bains: INRA: 215-226

Persson, J.; Hakanson, L. & Pilesjo, P. (1994). Prediction of theoretical surface water turnover time in coastal waters using digital bathymetric information. *Environmetrics*, Vol.5, No.4, (December 1994), pp. 433 – 499, ISSN 1180-4009

Pillay, T.V.R. (2004). *Aquaculture and the Environment* (2ª edition). Blackwell Publishing, ISBN 978-140-5108-42-3, Oxford, United Kingdon

Pitta, P.; Apostolaki, E.T.; Giannoulaki, M. & Karakassis, I. (2005). Mesoscale Changes in the Water Column in Response to Fish Farming Zones in Three Coastal Areas in the Eastern Mediterranean Sea. *Estuarine, Coastal and Shelf Science*, (August 2005), Vol.65, pp. 501-512, ISSN 0272-7714

Queiroz, J.V. (2010). Mudança na composição bromatológica natural de *Pimelodus maculatus* (Siluriformes, Pimelodidae) sob influência de pisciculturas em tanques-rede. *Botucatu: Instituto de Biociências.* Universidade Estadual Paulista. Relatory (Scientific initiation)

Ramos, I.P. (2009). Aspectos da Biologia Populacional de *Pimelodus Maculatus* (Teleostei: Siluriformes), Sob Influência de Sistemas de Pisciculturas em Tanques-Rede. In: *Pesquisas de teses e dissertações - Instituto de Biociências, Universidade Estadual Paulista, Botucatu.* Available from (http://www.ibb.unesp.br/posgrad/teses/zoologia_me_2009_igor_ramos.pdf)

Ramos, I.P.; Vidotto-Magnoni, A.P. & Carvalho, E.D. (2008). Influence of Cage Fish Farming on the Diet of Dominant Fish Species of a Brazilian Reservoir (Tietê River, High Paraná River Basin). *Acta Limnolica Brasiliensia*, (October 2008), Vol.20, No.3, pp. 245-252, ISSN 0102-6712

Ranzani-Paiva, M. J. T; Felizardo, N. N.; Luque, J. L. (2005). Análise Parasitológica e Hematológica em Tilápia do Nilo, *Oreochromis niloticus* Linnaeus, 1757, da Represa de Guarapiranga, Estado de São Paulo, Brasil. *Acta Scientiarum - Biological Sciences*, Vol.27, No.3, (July 2005), pp. 231-237, ISSN 1807-863X

Rodgher, S.; Espíndola, E.L.G.; Fracácio, R.; Rodrigues, M.H.; Pereira, R.H.G. & ROCHA, O. (2002). Estudos ecotoxicológicos nos reservatórios em cascata do médio e baixo rio Tietê: uma avaliação dos impactos ambientais, In: *Recursos Hidroenergéticos*: usos, impactos e planejamento integrado, E.L.G. Espíndola; F.F. Mauad; V. Schalch; O. Rocha; N. Felicidade & A.C. Rietzler (Eds.), 131-144, RiMa, ISBN 8586552259, São Carlos, Brazil

Rojas, A. & Wadsworth, S. (2007). A review of cage aquaculture: Latin America and the Caribbean, In: *Cage aquaculture*: Regional reviews and global overview, M. Halwarth,; D. Soto & J.R. Arthur, pp. 73-104, FAO Fisheries technical paper Nº 498, ISBN 9251058016, 9789251058015, Rome

Santos, G.B. & Formagio, P.S. (2000). Estrutura da Ictiofauna dos Reservatórios do Rio Grande, com Ênfase no Estabelecimento de Peixes Piscívoros Exóticos. *Informe Agropecuário*, (January 2000), Vol.21, No.203, pp. 98-106, ISSN 0100-3364

Shelton, W.L. & Popma, T.J. (2006). Biology, In: *Tilapia*: Biology, Culture and Nutrition, C.E. Lim & C.D. Webster (Eds.), 1-27, Haworth Press, ISBN 1560223189, 9781560223184, Birmington, NY, United States of America

Souto, A. C.; Vidotto-Magnoni, A.P.; Brandão, H.; Ramos, I.P. & Carvalho, E.D. (2011). Actinopterygii, Siluriformes, Loricariidae, Loricariichthys platymetopon Isbrücker and Nijssen, 1979: First record in Reservoir of Canoas II, Middle Paranapanema River, border of the states of São Paulo and Paraná, Brazil. *Check List, Vol.* (São Paulo, online edition). , Vol.7, pp. 279-281, ISBN 1809-127X

Stevaux, J.C. (1994). The upper Paraná River (Brazil): geomorphology, sedimentology and paleoclimatology. *Quaternary International*, Vol.22, pp. 143-161, ISSN 1040-6182

Stevens, R; Kerans, B.L.; Lemon, J.C. & Charlotte, R. (2001). The Effects of *Myxobolus cerebralis* Myxospore Dose on Triactinomyxon Production and Biology of *Tubifex tubifex* from Two Geographic Regions. *Journal of Parasitology*, Vol.87, No.2, (April 2001), pp. 315-321, ISSN 1937-2345

Strickland, D.D. & Parsons, T.R. (1968). *A practical manual of seawater analysis*. Bulletin of Fisheries and Resources Aquatics of Canada, pp.1-311.

Suresh, V. (2003). Tilapias, In: *Aquaculture: farming aquatic animals and plants*, J.S. Lucas & P.C. Southgate (Eds.), 321-345, Blackwell Publishing, ISBN 0-85238-222-7

Tavares-Dias, M.; Martins, M.L. & Moraes, F.R. (2001). Fauna Parasitária de Peixes Oriundos de "Pesque-Pague" do Município de Franca, São Paulo, Brasil. I - Protozoários. *Revista Brasileira de Zoologia*, Vol.18, No.1, (June 2001), pp. 67-79, ISSN 0101-8175

Teixeira, C.; Tundisi, J.G. & Kutner, M.B. (1978). Plankton studies in a mangrove environment. II. The standing stock ando some ecological factors. *Boletim do Instituto Oceanográfico*, Vol.24, pp. 23-41, ISSN 0373-5524

Thatcher, V.E. & Brites-Neto, J. (1994). Diagnóstico, Prevenção e Tratamento das Enfermidades de Peixes Neotropicais de Água Doce. *Revista Brasileira de Medicina Veterinária*, Vol.16, No.3, (September 1994), pp. 111-128, ISSN 0100-2430

Torloni, C.E.C.; Corrêa, A.R.A.; Carvalho Jr., A.A.; Santos, J.J.; Gonçalves, J.L.; Gereto, E.J.; Cruz, J.A.; Moreira, J.A.; Silva, D.C.; Deus, E.F. & Ferreira, A.S. (1993). Produção pesqueira e composição das capturas em reservatórios sob concessão da CESP nos rios Tietê, Paraná e Grande, no período de 1986 a 1991. *Pesquisa e Desenvolvimento*, CESP, São Paulo, Brazil

Tundisi, J.G. (2005). *Água no século XXI*: enfrentando a escassez. RiMa, ISBN 85-86552-51-8, São Carlos, Brazil

Tundisi, J.G. & Straškraba, M. (1999). *Theoretical reservoir ecology and its applications*. International Institute of Ecology, Brazilian Academy of Sciences and Backhuis Publishers, Netherlands. pp. 99-124, ISBN. 85-87418-02-5/90-5782-034X, São Carlos, Brazil

Valderrama, J.C. (1981). The simultaneous analysis of total nitrogen and total phosphorus in natural waters. *Marine Chemistry*, Vol.10, No.2 , (January 1981), pp. 109-122, ISSN 0304-4203

Valente, W.C. (2000). Aquaculture for sustainable development, In: Aqüicultura no Brasil: bases para um desenvolvimento sustentável, W.C. Valenti; C.R. Poli; J.A. Pereira &

Borghetti, J.R., pp. 17-24, CNPq/Ministério da Ciência e Tecnologia, ISBN 85-87632-09-4, Brasília, Brasil

Vita, R.; Marín, A.; Madrid, J.A.; Jiménez-Brinquis, B.; Cesar, A. & Marín-Guirao, L. (2004). Effects of Wild Fishes on Waste Exportation from a Mediterranean Fish Farm. *Marine Ecology Progress Series,* (August 2004), Vol.277, pp. 253-261, ISSN 1616-1599

Yucel-Gier, G.; Kucuksezgin, F. & Kocak, F. (2007). Effects of Fish Farming on Nutrients and Benthic Community Structure in the Eastern Aegean (Turkey). *Aquaculture Research,* (January 2008), Vol.38, pp. 256-267, ISSN 1355-557X

Zanatta, A.S. (2007). Tilapicultura em Ecossistemas Aquáticos: Desenvolvimento Sustentável ou Degradação Ambiental? Estudo de Caso em Represa Oligotrófica. In: *Pesquisas de teses e dissertações - Instituto de Biociências, Universidade Estadual Paulista, Botucatu.* Available from
(http://www.ibb.unesp.br/posgrad/teses/zoologia_me_2007_augusto_zanatta.pdf)

Zanatta, A.S. (2011). As Interferências das Pisciculturas em Tanques-Rede Sobre as Assembleias de Peixes em Grandes Reservatórios do Rio Paranapanema (Bacia do Alto Paraná). In: *Pesquisas de teses e dissertações - Instituto de Biociências, Universidade Estadual Paulista, Botucatu.* Available from
(http://www.ibb.unesp.br/posgrad/teses/zoologia_do_2011_augusto_zanatta.pdf)

Zanatta, A.S.; Ramos, I.P.; Silva, R.J.; Langeani, F. & Carvalho, E.D. (2010). Pisces, Siluriformes, Ictaluridae, *Ictalurus punctatus* (Rafinesque, 1818): First Record in Middle Paranapanema River Reservoir, Aquaculture and Exotic Species Dispersion. *Check List – Journal of Species List and Distribution*, (November 2010), Vol.6, No.4, pp. 589-591, ISSN 1809-127X

Zocchi, P. (2002). *Paranapanema: da nascente à foz.* Editora Horizonte Geográfico/ Audichromo, São Paulo, ISBN 85-88031-13-2
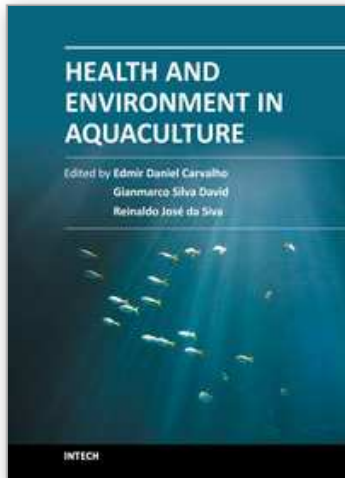
Health and Environment in Aquaculture

Edited by Dr. Edmir Carvalho

Aquaculture has been expanding in a fast rate, and further development should rely on the assimilation of scientific knowledge of diverse areas such as molecular and cellular biology, and ecology. Understanding the relation between farmed species and their pathogens and parasites, and this relation to environment is a great challenge. Scientific community is involved in building a model for aquaculture that does not harm ecosystems and provides a reliable source of healthy seafood. This book features contributions from renowned international authors, presenting high quality scientific chapters addressing key issues for effective health management of cultured aquatic animals. Available for open internet access, this book is an effort to reach the broadest diffusion of knowledge useful for both academic and productive sector.

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