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Dietary changes and histophysiological responses of a wild fish (*Geophagus* cf. *proximus*) under the influence of tilapia cage farm

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ABSTRACT

The influence of cage fish farm on the trophic, histopathological and metabolic aspects of a wild fish species (*Geophagus* cf. *proximus*) was evaluated considering diet, liver histopathology and the concentration of total proteins in the liver, gonads and muscles in fish from two sampling areas (cage farm and control). Diet composition and trophic niche breadth differed significantly between the sampling areas. Detritus, aquatic plants and Cladocera composed the diet in the control area, while mollusks and pelleted feed, followed by detritus, were highly representative of the diet of fish in the cage farm area. More severe histopathological alterations were found in the specimens collected in the cage farm area. These alterations include severe pancreatic hyperplasia and hepatic steatosis. Total protein concentrations in muscles showed no significant difference between the areas. For the liver, the highest concentration was found in fish from the cage farm area, whereas for gonads, higher values were detected in the fish from the control area. These results show that there were hepatic and gonadal metabolic changes in farm-associated specimens compared to specimens from the control area. The high protein and lipid contents of the diet promoted severe histopathological alterations in the liver, impairing hepatic function and possibly interfering in the mobilization of proteins to the gonads. Thus, the relationship between dietary changes and histophysiological alterations suggests an influence of cage fish farm on the ecology of farm-aggregated fish species.

1. Introduction

Brazil is one of the largest agricultural markets in the world and has an emphasis on zootechnical activities related to aquaculture, with estimates of growth of more than 100% by 2025 (Kubitza, 2015; FAO, 2016). The tropical climate and high availability of water resources, represented by more than 8500 km of coastline and 4.2 million hectares of water dammed in reservoirs, favor Brazilian aquaculture (Borges, 2014; Kubitza, 2015). These factors have led to the rapid growth of aquaculture and have raised questions about the potential environmental effects caused by this activity.

The most important type of aquaculture is cage fish farm, which in Brazil is usually carried out in the reservoirs of hydropower plants (Abrunhosa, 2011). Species successfully cultivated in these enterprises include tambaqui (*Colossoma macropomum*), tambacu (*Colossoma* sp. × *Piaractus* sp.), pacu (genus *Piaractus*), carp (*Cyprinus carpio*, *Aristichthys nobilis*, *Ctenopharyngodon idella*) (Abrunhosa, 2011) and tilapia (*Oreochromis niloticus* and its lineages) (Kirchner et al., 2016; Schulter and Vieira Filho, 2017). *Oreochromis niloticus* is the second most cultivated species worldwide, and it is the most abundantly produced fish species in Brazilian aquaculture (219,329 tons = 45.4% of fish production in 2015) (IBGE, 2015).

Cage fish farm in freshwater ecosystems is an intensive cultivation model in which fish are stored at high density, confined in floating structures in natural or semi-natural aquatic systems and provided with an intense pelleted feed supply, thus requiring continuous water renewal (Agostinho et al., 2007; Abrunhosa, 2011). This production model is known to cause changes in hydrological dynamics and the physical and chemical characteristics of the water, strongly interfering with habitat availability and quality and environmental trophic status (Agostinho et al., 2007; Tundisi, 2007). In this sense, cage fish farm in freshwater ecosystems represents additional influences in places that are already subject to changes in their environmental characteristics, fauna and flora (Ramos et al., 2008). This mode of production promotes several abiotic and biotic changes in the aquatic ecosystems used for this purpose and in adjacent areas.

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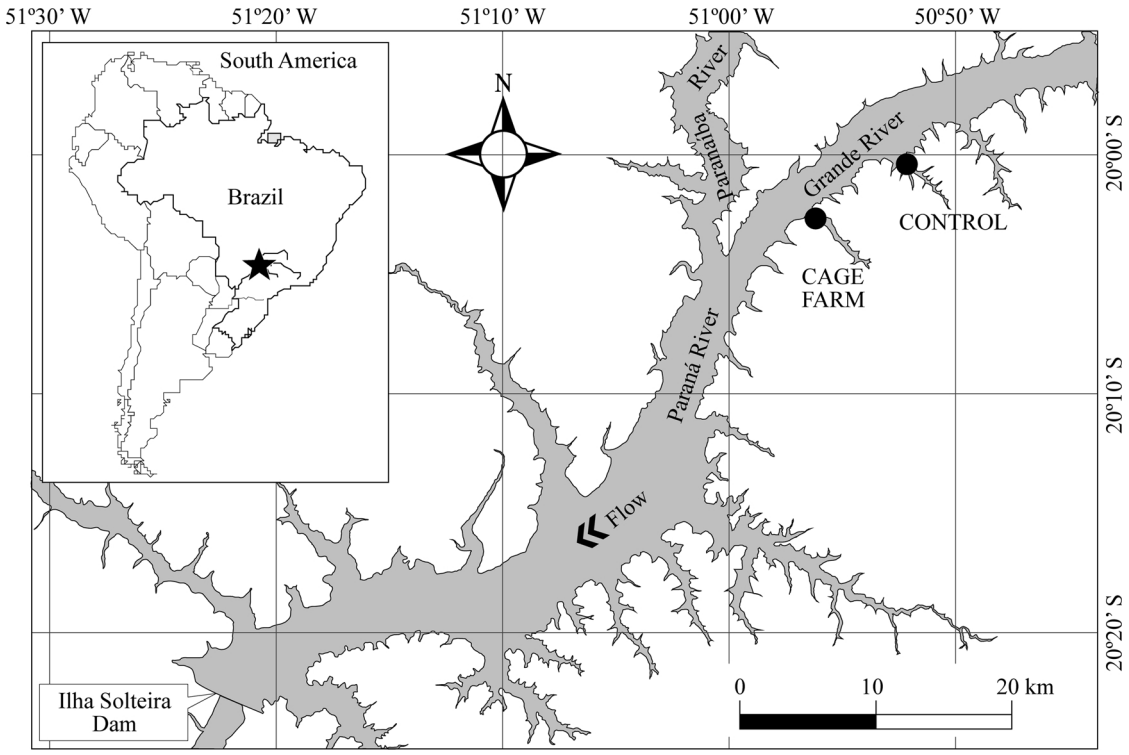

Fig. 1. Study area: Grande River, Ilha Solteira Reservoir, State of São Paulo, Brazil.

Studies on cage fish farm in freshwater systems have demonstrated changes in wild fish species on reproductive aspects of *Pimelodus maculatus* (Brandão et al., 2014) and influence parasitological factors in *Plagioscion squamosissimus* (Ramos et al., 2014). In addition, interference in settlement patterns has also been reported (Agostinho et al., 2007; Mallasen et al., 2012) due to the input of organic matter from cages and the introduction of non-native species (Zanatta et al., 2010), mainly through fish escaping from cultivation (Agostinho et al., 2007). As a consequence, there may be changes in the population dynamics of wild fish with the aggregation of fish in these areas (Ramos et al., 2013; Brandão et al., 2013; Ortega et al., 2015), as well as interference with the trophic ecology (Brandão et al., 2012; Ramos et al., 2013, Edwards, 2015) and the nutritional condition of fish (increased condition factor values) (Ramos et al., 2013; Ortega et al., 2015), when fish, mainly omnivores, feed on available food pellets.

Influences on the diet and fatty acid composition of wild fish due to feed on food pellets in the area around cage fish farm has also been reported for marine environments (Fernandez-Jover et al., 2007; Fernandez-Jover et al., 2011; Arechavala-Lopez et al., 2011). In addition, morphophysiological alterations in the organs of fish caused by the consumption of the food pellets have also been reported (Ségade et al., 2015; Zhang et al., 2017). Therefore, histophysiological studies conducted in conjunction with dietary assessments are efficient tools for detecting alterations in tissues and organs that result from changes in diet (Bernet et al., 1999; Baldisserotto, 2013). Moreover, they allow the visualization of biotic and abiotic effects on physiological functions such as nutrition, growth and reproduction (Saraiva et al., 2015, Yancheva et al., 2016). These tools can help build an understanding of the influence of freshwater cage fish farm on wild biota.

One of the ways to identify histophysiological effects is by quantifying cellular changes in organs, such as the liver, and changes in levels of metabolites, such as total protein contents. The liver plays a key role in the mobilization and metabolism of food molecules and is essential for organisms in detoxification (Bernet et al., 1999; Shiogiri et al., 2012; Yancheva et al., 2016). Morphofunctional alterations in the liver reflect the physiological responses of other organs, such as muscles and gonads. The function of the musculature is directly linked to the swimming performance and anaerobic condition of the fish (Mommsen, 2001), which his directly related to the ability to capture food and avoid predators. At the reproductive level, metabolic and histophysiological changes in the gonads can directly affect the success of vitellogenesis, the recruitment of oocytes and spawning, with consequences for the long-term maintenance of viable natural populations (Baldisserotto et al., 2014).

Studies related to the concomitant effects of dietary changes and histophysiological responses in wild populations of fish subjected to the effects of cage fish farm are lacking in the Neotropical region. Thus, omnivorous fishes with high trophic plasticity and a strong ability to adapt to anthropogenic environments, such as *Geophagus* cf. *proximus* (Castelnau, 1855), are good models to evaluate the effects of interference from cage fish farm on wild biota. This species was introduced through cage fish farm (Langeani et al., 2007) and is one of the most abundant species in the Ilha Solteira Reservoir.

In this context and considering that the pelleted feed supplied to fish in cage farms has high protein and lipid contents and that there is a surplus of this material in the surrounding aquatic environment, it was hypothesized that direct pelleted feed intake causes changes in the liver at the level of tissues and cells, as well as changes in metabolite concentrations. This study had the following objectives: i) to evaluate the diet of *G.* cf. *proximus* and determine if the species consumes surplus pelleted feed in the area surrounding cage fish farm; ii) to check if the consumption of surplus pelleted feed influences the condition of this species; iii) to analyze whether there are structural alterations in hepatic tissue in this species due the high concentration of proteins and lipids in artificial pelleted feed; and iv) to verify the physiological responses, as reflected by total protein concentrations in the muscles, gonads and liver, in specimens that consume pelleted feed.